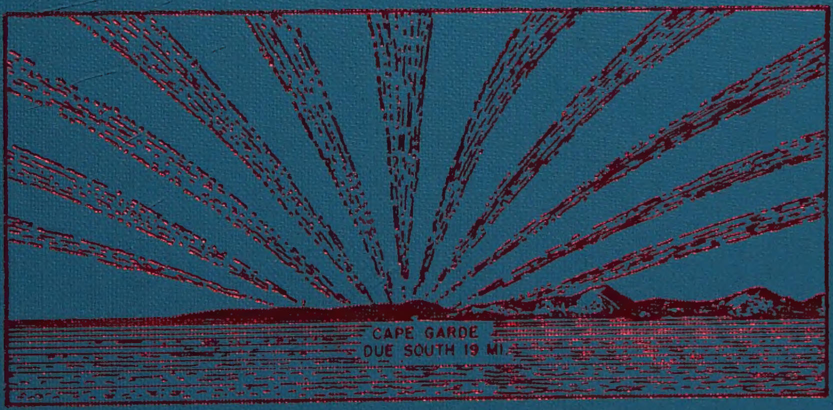
TORNADOS, DARK DAYS, ANOMALOUS PRECIPITATION, AND RELATED WEATHER PHENOMENA

Compiled by:

William R. Corliss



A CATALOG OF GEOPHYSICAL ANOMALIES

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LIST OF PROJECT PUBLICATIONS

CATALOGS: Lightning, Auroras, Nocturnal Lights, and Related Luminous Phenomena

Tornados, Dark Days, Anomalous Precipitation, and Related Weather Phenomena

HANDBOOKS: The Unfathomed Mind: A Handbook of Unusual Mental Phenomena

Incredible Life: A Handbook of Biological Mysteries

Unknown Earth: A Handbook of Geological Enigmas

Mysterious Universe: A Handbook of Astronomical Anomalies

Ancient Man: A Handbook of Puzzling Artifacts

Handbook of Unusual Natural Phenomena

SOURCEBOOKS: Strange Phenomena, vols. G1 and G2

Strange Artifacts, vols. M1 and M2

Strange Universe, vols. A1 and A2

Strange Planet, vols. E1 and E2

Strange Life, vol. B1

Strange Minds, vol. P1

NEWSLETTERS: Science Frontiers (current anomaly reports)

Anomaly Register (Catalog addenda)

For information on the availability, prices, and ordering procedures, write:

SOURCEBOOK PROJECT
P.O. Box 107
Glen Arm, MD 21057

PREFACE

After more than ten years of scouring the scientific and semiscientific literature for anomalies, my major conclusion is that this is an amazingly fruitful activity. In fact, organized science should have been doing the same searching for the past 200 years. It is simply astounding that a Catalog of Anomalies does not already exist to guide scientific thinking and research. It is at least as important to realize what is not known as it is to realize what is well-explained. Nevertheless, here begins the first publication of a Catalog of Anomalies; the product largely of one person's library research, carried forward without a single public or foundation dollar.

Under the aegis of the Sourcebook Project, I have already published 16 volumes, comprising well over 7,000 pages, of source material on scientific anomalies. (See page iv for a list of titles.) As of this moment these 16 volumes represent only about 20% of my collection of scientific anomalies. New material is being added at the rate of about 1,200 new articles and items per year, 300 of which are from the current literature. These rates could be easily multiplied several times over by spending more time in the libraries. After ten years only the scientific journals of the United States and England have received my serious attention. There remain the English-language journals of the rest of the world, those publications in other languages, university theses, government reports, bulletins of scientific research facilities, conference papers, and not the least, books and newspapers. The cataloging task is just beginning, for the anomalies in the world's scientific and semiscientific literature seem nearly infinite in number.

Given this rough assessment of the magnitude of the anomaly literature, one can understand why the planned Catalog of Anomalies will require at least 25 volumes of about the same size as the one you now hold. I visualize a shelf of 25 volumes, with master indexes, to be only the initial step in providing scientists with ready access to what is not, in my opinion, well-explained.

Will the Catalog of Anomalies revolutionize science? Probably not---at least not immediately. Quite often the initial reaction to the books of anomalies already published has been disbelief. The data must be in error; the data are mainly testimonial; the data are too old; the supposed anomaly was explained long ago. Germs of truth reside in all these complaints. But for every anomaly or example that can be legitimately demolished, ten more take its place. Nature is very anomalous or, equivalently, Nature is not yet well-understood by science. Much remains to be done.

William R. Corliss

P.O. Box 107
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March 1, 1983

"ROUND ABOUT THE ACCREDITED AND ORDERLY FACTS OF EVERY SCIENCE THERE EVER FLOATS A SORT OF DUST-CLOUD OF EXCEPTIONAL OBSERVATIONS, OF OCCURRENCES MINUTE AND IRREGULAR AND SELDOM MET WITH, WHICH IT ALWAYS PROVES MORE EASY TO IGNORE THAN TO ATTEND TO . . . . ANYONE WILL RENOVATE HIS SCIENCE WHO WILL STEADILY LOOK AFTER THE IRREGULAR PHENOMENA. AND WHEN THE SCIENCE IS RENEWED, ITS NEW FORMULAS OFTEN HAVE MORE OF THE VOICE OF THE EXCEPTIONS IN THEM THAN OF WHAT WERE SUPPOSED TO BE THE RULES." **William James**

HOW THE CATALOG IS ORGANIZED

Purpose of the Catalog

The Catalog of Anomalies is designed to collect and categorize all phenomena that cannot be explained readily by prevailing scientific theories. Following its definition, each recognized anomaly is rated in terms of: (1) its substantiating data; and (2) the challenge the anomaly poses to science. Next, all examples of the anomaly discovered so far are noted, some in detail. Finally, all examined references are listed. Thus, the Catalog is a descriptive guide as well as a compendium of examples and references. Scientific researchers therefore have a ready-made foundation for beginning further investigations into these intriguing phenomena. This is the basic purpose of the Catalog: the collection and consolidation of the unknown and poorly explained to facilitate future research and explanation.

General Plan of the Catalog

It was tempting to organize this Catalog alphabetically, making it an "encyclopedia of anomalies." But many of the phenomena have obscure names or, even worse, no names at all. Under these circumstances, access to the data base would be difficult. Therefore, a system of classification was designed based upon readily recognized classes of phenomena and the means by which the observer detects them. Subject matter is first divided into nine general classes of scientific endeavor, as illustrated in the diagram. Few persons would have difficulty classifying a phenomenon as biological, astronomical, etc. The second, third, and fourth levels of classification are also based upon generally recognized attributes, such as luminosity, sound, etc. The similarity of this method of categorization to those employed in natural history field guides is purely intentional. Like bird identification, phenomenon classification soon becomes second nature. In fact, almost all of the phenomena described in the Catalog are accessible to everyone with five normal senses and perhaps binoculars and telescope.

Most catalogs boast numbering systems and this one is no exception. Rather than employ a purely numerical system, the first three levels of classification are designated with letters. The triplets of letters chosen have some mnemonic value. Thus, a GWP anomaly is easily recognized as being in the geophysics class (G), weather-related (W), and involving some type of precipitation (P). The number added to the triplet of letters marks the fourth level of classification, so that GWP1 signifies cloudless rain. Every anomaly type has a unique alphanumeric code, like GWP1. All cross references and indexes are based upon this system. Catalog additions and revisions are made much easier with this scheme.

The Catalog codes may seem cumbersome at first but their mnemonic value to the compiler has been significant. Hopefully, they will help other users, too. The codes are simple, yet flexible enough to encompass the several thousand types of anomalies identified so far.

A glance through this volume of the Catalog will reveal that each example of a specific anomaly type bears an X-number, and each reference an R-number. GWP1-X12 therefore specifies the twelfth example of cloudless rain, and GWP1-R17 the seventeenth reference to cloudless rain. Indexes and cross references can consequently be made more precise then conventional page references.

How Data and Anomalies Are Evaluated

Each anomaly type is rated twice on four-level scales for data "validity" and "anomalousness," as defined below. These evaluations represent only the opinion of the compiler and are really only rough guides.

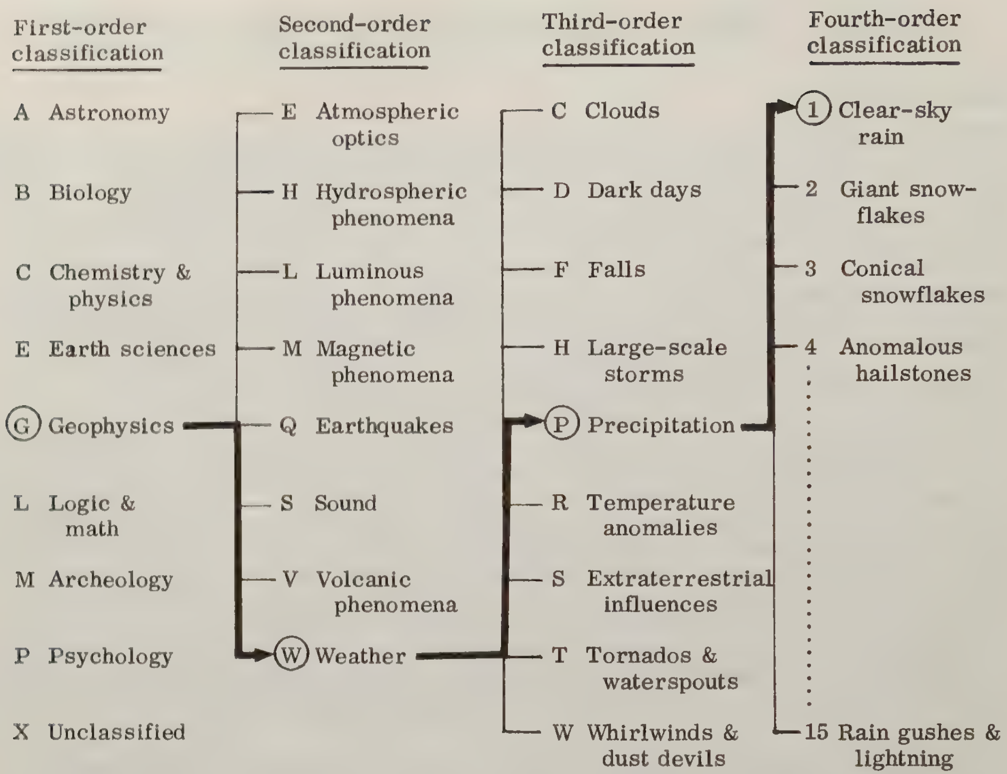
Data Evaluation Scale

1 Many high-quality observations. Almost certainly a real phenomenon.

2 Several good observations or one or two high quality observations. Probably real.

3 Only a few observations, some of doubtful quality. Pheonomena validity questionable.

4 Unacceptable, poor-quality data. Such phenomena are included only for purposes of comparison or amplification. Only two such items are registered in this volume.



Catalog Coding Scheme

Anomaly Evaluation Scale

1. Anomaly cannot be explained by modifications of present laws. Revolutionary.
2. Can probably be explained through relatively minor modifications of present laws.
3. Can probably be explained using current theories. Primarily of curiosity value.
4. Well-explained. Included only for purposes of comparison and amplification. Only one such item is registered in this volume.

Anomalies that rate "1" on both scales are very rare, with no entries at all in this volume of the Catalog, and only one in the first Catalog volume. Such anomalies, however, are the most important because of their potential for forcing scientific revolutions. As additional Catalog volumes are published, the relative proportion of "double-1s" will increase, especially in the fields of biology and psychology. The following matrix summarizes the ratings assigned in this volume.

		Anomaly Ratings			
		1	2	3	4
Data Ratings	1-	0	9	23	0
	2-	0	5	11	0
	3-	1	15	16	1
	4-	0	1	1	0

Total: 83 anomaly types

Anomaly Examples

Examples of anomaly types are designated by the letter X in the body of the Catalog. All examples discovered so far are listed. If the example is of the event type, time and place are specified if available. Some of the more significant geophysical events, such as the remarkable "Dark Day" of 1780, may appear in several references, all of which are provided in full and keyed to the X-number of the example. Dark days are represented by scores of examples (hundreds exist but have not yet been collected); but only a single example of dust spouts or "land spouts" is listed. When library research has made many examples of an anomaly type available, several of the most interesting and instructive are reported in some detail. Direct quotations from the eye-witness accounts are frequently employed to convey accurately the characteristics of the phenomenon to the reader. These selected examples are printed full-width in the Catalog columns. Examples of less import are indented to separate them visually.

The References and Sources

Each anomaly type and the examples of it are buttressed by all references that have been collected and examined. Since some references describe several examples, each reference includes the X-numbers of the examples mentioned. When a reference covers more than one type of anomaly, it is repeated in the bibliography following each anomaly type. Actually, there is little repetition of this sort in the Catalog.

Perusal of the Source Index will demonstrate that the great majority of references come from the scientific literature. Heavily represented in this volume of the Catalog are: Nature, Science, Monthly Weather Review, Meteorological Magazine, and the Quarterly Journal of the Royal Meteorological Society. Several less technical publications are also frequently mentioned: Marine Observer, Scientific American, and English Mechanic. The Marine Observer is a publication of the U.K. Meteorological Office. The English Mechanic was for many years an important English technical magazine, much like Scientific American. All of the serials mentioned so far are considered generally reliable, although one must always be wary. In addition to these often-referenced journals, there is a very wide selection of other publications. Some of these are more popular in character. In this context, it should be remembered that unusual phenomena do not seek out scientists, and the laymen who observe many anomalies have no knowledge of or access to scientific journals.

The time span covered by the sources ranges over 150 years. Many excellent reports of anomalies come from the latter half of the Nineteenth Century. Although many scientists frown on such old reports, the quality is often good, and they should not be discarded arbitrarily. Not only were the observers of a century ago competent, they were unbiased by knowledge of modern theories and lived in an environment unpolluted by modern vehicles, effluxes, and other contaminants. It should also be mentioned here that the modern meteorological literature tends heavily toward mathematical modelling and theory as opposed to eye-witness accounts of strange phenomena. Two journals that are exceptions to this rule are the Marine Observer and the U.K. Journal of Meteorology.

The Indexes

Each Catalog volume concludes with five separate indexes. At first glance this may seem to be too much of a good thing. But in the context of a science-wide catalog of anomalous events and unusual natural phenomena, each idex has its special utility.

The subject index is essential in any work of this type. It is placed last for easy access. The time-of-event and place-of-event indexes are analytical tools for the anomaly researcher. They help identify phenomena that are reported separately (perhaps in widely different journals) but are really different aspects of the same event. This integrating feature will become more apparent as additional Catalog volumes appear. To illustrate, the 1908 Tunguska Event produced luminous and barometric phenomena as well as atmospheric optical effects. It is possible that composite time-of-event and place-of-event indexes covering all scientific fields will reveal cause-and-effect relationships that have not been recognized before. It is the intent of the Catalog effort to generate a composite set of indexes when all four Catalog volumes in geophysics are published as well as a final master index covering all of science.

The source index shows immediately the dependence of this Catalog upon scientific literature rather than newspapers and other popular publications. Its real purpose, though, is the rapid checking to determine if a specific reference has or has not been caught already in the fishing nets of this Catalog project. The source index is doubly valuable because many footnotes and bibliographies in the scientific literature display sources only; that is, titles and authors are omitted entirely. The researcher also comes across many vague references to such-and-such an article by so-and-so back in 1950 in Nature. The exhaustive and rather ponderous source and first-author indexes can help pin down many references lacking specifics.

All five indexes use the catalog codes described above rather than page numbers. The codes are permanent whereas the page numbers will change as addenda and revised volumes are produced. The mnenonic value of the catalog codes is useful here, too, because the approximate nature of each index entry is readily apparent, while page numbers give only location.

Supporting Publications of the Sourcebook Project

The Catalog volumes are actually only distillations of huge quantities of source material. The Anomaly Data Research Center/Sourcebook Project has already published 16 volumes of source material, as detailed on page iv.

Catalog Addenda and Revisions

Over 1,000 new reports of anomalies are collected from current and older scientific journals each year. New anomaly types and additional examples of types already cataloged are accumulating rapidly. When new material assignable to a Catalog volume already in print is acquired, it appears first in the serial ANOMALY REGISTER, published frequently by the Anomaly Data Research Center. (Ordering information on page iv.) When sufficient new material has been assembled in a Catalog area, that volume of the Catalog will be revised and published with all additions and corrections incorporated.

Request for Additions and Corrections

The Anomaly Data Research Center welcomes reports of new anomalies and examples of unusual phenomena. If you discover a report of an anomaly not listed in the Catalog, send a xerox of the article to the Anomaly Data Research Center for evaluation. If the report is added to our data base, credit will be given to the submitter in the ANOMALY REGISTER and the revised edition of the Catalog. Reports from recognized scientific journals are preferred but everything is grist for the mill! The address of the Anomaly Data Research Center is: P.O. Box 107, Glen Arm, MD 21057.

INTRODUCTION TO WEATHER PHENOMENA

"Weather" is a composite experience of sight, sound, temperature, and other sensations of the elements. The phenomena of this Catalog volume are not primarily luminous or acoustic or confined to the sensory channels that form the bases for the other volumes in the field of geophysics. Here, we deal with rain, fog, wind, clouds, precipitation, and sunshine---but only when they are anomalous or at least curious enough to attract our attention.

Our weather experiences are so widely variable that a phenomenon has to be very strange indeed to gain access to this volume. The entrance criteria are not so much related to intensity or rarity as they are to unexpectedness and their deviations from meteorological theory. Thus, very heavy general rains, even with catastrophic flooding, are excluded, while rain from a cloudless sky and "point" rainfall are welcome additions.

Several themes that thread their ways through the geophysical volumes of the Catalog recur in this book:

1. The importance of electricity in geophysical phenomena
2. The possible influences of the sun, moon, planets, and inbound meteoric material on terrestrial weather
3. The occasional prankish, frivolous behavior of some weather phenomena. This judgment is, of course, highly subjective.

One interesting feature of weather phenomena taken as a whole is their rather low level of anomalousness; at least when compared to other geophysical phenomena in the Catalog of Anomalies. Weather, it seems, is not as strange as, say, luminous geophysical phenomena. There are more plausible theories available to explain weather phenomena than for ball lightning or long-delayed radio echoes. Of course, this does not mean that science understands all facets of the weather---this volume would not exist if it did.

GWC UNUSUAL CLOUDS

Key to Phenomena

GWC0	Introduction
GWC1	The White Sky Phenomenon
GWC2	Cloud Arches
GWC3	Polar Bands
GWC4	Miniature Thunderclouds
GWC5	Noisy Clouds
GWC6	Noctilucent Clouds
GWC7	Ring Clouds
GWC8	Thunderclouds Affecting the Ionosphere
GWC9	Circular Holes in Cloud Decks
GWC10	Anomalous Cloud Lines
GWC11	Dispersal of Clouds by the Moon
GWC12	The Morning Glory Phenomenon
GWC13	Long, Hollow, Cylindrical Clouds
GWC14	Cloud Spokes Radiating from Thunderclouds
GWC15	Great Excess of Ice Crystals in Cumulus Clouds
GWC16	Cloud Brightness Changes
GWC17	Anomalous High-Altitude Haze Layers

GWC0 Introduction

Clouds can be classified as unusual if they possess anomalous shape, motion, color, orientation, or emit unaccountable light or noise. Meteorologists recognize a variety of clouds as "usual" even though they are not fully understood. Lenticular clouds, for example, are lens-shaped and produce not a few UFO reports. Nevertheless, lenticular clouds are a recognized species and at least partially comprehended. They are, therefore, omitted here. Rotating, ring-shaped clouds and some spectacular roll clouds (i.e., the Morning Glory) do find places in this Catalog. Although these types of clouds are doubtless created by atmospheric vortices and solitary waves, they are neither common nor easy-to-explain. Cloud arches connecting two seemingly unrelated clouds pose some intriguing questions: Are the arches umbilical in character? Is a flow of electricity involved? Some clouds seem to interact in mysterious ways with the earth's magnetic field, as in the case of the so-called polar bands, which are evidently cirrus clouds aligned with the magnetic meridian. How can the earth's magnetic field twist lines of nonmagnetic ice crystals into neat bands oriented like compass needles? All in all, there are many imponderables in the character and behavior of the prosaic cloud.

GWC1 The White Sky Phenomenon

Description. Persistent veiling of the sky over wide areas by a high layer of haze of unknown origin. During periods of white sky, the dimmed sun appears white and can be viewed with the naked eye. Stars are seen only dimly at night.

Background. The most noted occurrence of white sky was during the summer of 1912, when much of the Northern Hemisphere was veiled.

Data Evaluation. The 1912 episode and the recurring Alaskan hazes are well-established phenomena. Rating: 1.

Anomaly Evaluation. Several explanations are possible. The chief mystery is simply one of proper identification. Rating: 3.

Possible Explanations. Dust raised by violent dust storms, volcanic eruptions, air pollution. Also suggested for the 1912 episode: debris from a comet's tail.

Similar and Related Phenomena. High-level "mystery" clouds (GWC17); high-level "auroral" hazes (GLA12); noctilucent clouds (GWC7); dry fogs and dust fogs (GWD4).

Examples of White Sky

X1. Summer 1912. Much of the Northern Hemisphere, especially Europe. "For weeks, when not clouded, it (the sky) has been white, and one could look at the white sun with the naked eye near the zenith in the unclouded sky---not a patch of blue to be seen, and frequently no clouds. (R1) Also seen in France and Germany.(R2) "It having been my good fortune to spend a few weeks in Ireland lately, I have been able to observe the strange condition of the upper atmosphere, which has been noted by several of our correspondents. At Ealing the sky has been of unusual whiteness, certainly, since the middle of June. This haze became more marked in August, and when I went to Western Ireland, on the 15th of that month, I found it much denser. During the daytime the sun never shone brilliantly, and towards sunset the upper atmosphere was filled with layers of fleecy mist. (R3). Extraordinary twilight colors seen in Europe. (R4) White sky also observed by a Greenland expedition, even when above 8,000 feet altitude. Dust from the eruption of Katmai in Alaska a possible cause. (R5)

X2. Frequent occurrence in March and April. Alaska and part of Arctic Ocean. "It's quite a high haze, around 10,000 feet. You can still see the mountains off in the distance. Yet the sky has a whitish, diffuse look to it... (from the air) the horizon almost becomes invisible...One of its puzzling features is its height;...haze usually hugs the ground...It no doubt also goes over at least part of the Arctic Ocean." Possibly due to dust from the Gobi and other Asia deserts. A layer of haze at lower levels seem to be air pollution from Japan. (R6)

References

R1. Moorhead, T. H.; "White Skies and a White Sun," English Mechanic, 96:133, 1912. (X1)

R2. "White Sky," English Mechanic, 96:199, 1912. (X1)

R3. Offord, J. Milton; "The White Sky," English Mechanic, 96:222, 1912. (X1)

R4. Hollis, H. P.; "A Sky Phenomenon in 1912," English Mechanic, 97:220, 1913. (X1)

R5. Scientific American, 108:171, 1913. (X1)

R6. "Alaska's Imported Haze," Mosaic, 9:41, September/October 1978. (X2)

GWC2 Cloud Arches

Description. Narrow bands of clouds crossing the sky in an arc that usually joins two widely separated cumulus clouds. While most arches seem formed from cloud, the arch sometimes seems to be simply a band of light. Most observations of cloud arches have been made from ships at sea.

Data Evaluation. A well-attested phenomenon. Rating: 1.

Anomaly Evaluation. The nature of the cloud arch is in question. Is it simply a cloud formed from a long, narrow vortex, or possibly of electrical origin similar to that suggested by some for tornados, or purely an optical phenomenon? No matter which, the formation and maintenance of these arches are very puzzling. Rating: 2.

Possible Explanations. Cloud arches may be long, narrow roll clouds that flare out into cumulus clouds at both ends---something like an intercloud tornado funnel.

Similar and Related Phenomena. Roll clouds (GWC12); anomalous cloud lines (GWC10); magnetically aligned cirrus clouds (GWC3); mirror-type cloud mirages (GEM); and, in geometry if not reality, cloud-like auroral arches (GLA2) and the banded sky phenomenon (GLA23); waterspouts between clouds (GWT10).

Examples of Cloud Arches

X1. February 8, 1933. South Atlantic Ocean. A well-defined arch of cirrostratus joins two rain squalls about 8 miles apart. (R1)

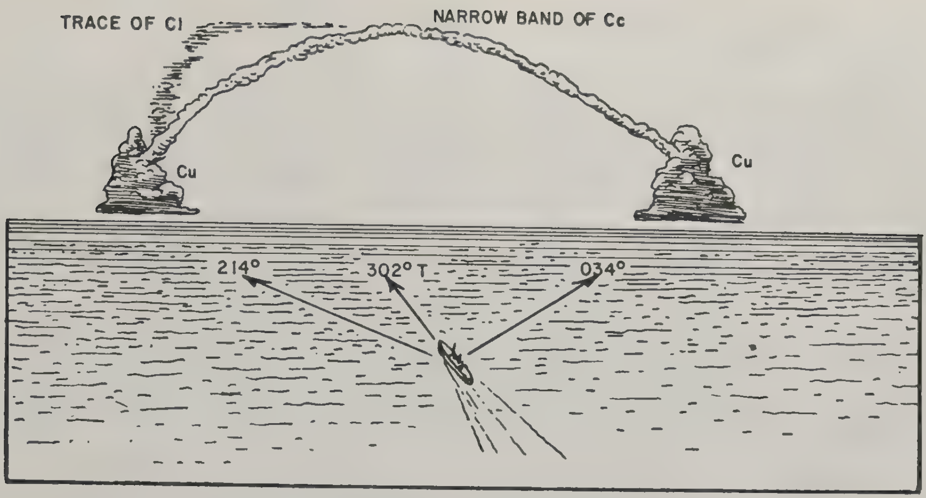
X2. November 24, 1933. South Atlantic Ocean. "From two points on the horizon bearing 138° and 304° respectively, an area of hard clear sky arched itself to an altitude of 9°. This maximum angular height was approximately above the sun, which set bearing 237 1/2°. Maintaining an almost equal distance with the rim of this arch was another smaller arch with an angular height of 2°. The space between these two arches was packed with Cirro-Cumulus globules which appeared to be closely stowed between well-defined layers of Cirro-Stratus clouds. Another patch of Cirro-Stratus cloud, low in the sky, temporarily dimmed the setting sun. From the two points on the horizon, bands of cloud radiated and passed obliquely into the sky, the Northerly band in both cases being composed of Cirro-Cumulus clouds. These bands became fainter with altitude and finally diffused into the upper sky." (R2) This example resembles in some ways the displays of aligned cirrus clouds (GWC3).

X3. May 31, 1952. Indian Ocean. "Two very dark towering Cu clouds bearing 034°, appeared to be joined to a single dark towering Cu cloud, bearing 214°, by a narrow band of Cc which stretched across the sky over the ship. This formation lasted about 2 hours before disintegrating. The moon was not visible at the time and the sky was cloudless except for the above formation." (R3)

X4. June 3, 1952. Indian Ocean. A cloud formation similar to that of X3. (R3)

X5. April 25, 1956. Arabian Sea. "A thin white band, not appeared to be cloud, joined

System of cloud arches in the South Atlantic (X2)



Cloud arch connecting two cumulus clouds (X3)

two tufts of towering Cu. The band remained as such until the clouds dispersed." (R4)

X6. July 12, 1980. Strait of Gibraltar. "At 1825 GMT whilst the vessel was transiting the Strait of Gibraltar, a line of low cloud was observed in an otherwise cloudless sky, see sketch. The cloud was in the form of an arch in an east-west line, reaching the surface approximately 2 n. mile ahead and astern of the vessel. Visibility under the cloud was about 10 n. mile in the north-south direction and 2 n. mile to the east and west. Once the vessel reached the point where the cloud touched the surface, the visibility was reduced to approximately 1.5 n. mile. Whilst the vessel was passing the cloud, the barograph trace fell almost vertically and both the air and sea temperatures dropped several degrees." (R5) Although there are no cumulus clouds at the terminations of the arch, this phenomenon is very similar to others in this category. (WRC)

References

R1. Harvey, H. B.; "Cloud Arch," Marine Observer, 11:6, 1934. (X1)
R2. Nelson, A. L.; "Cloud Formation," Marine Observer, 11:138, 1934. (X2)
R3. Townshend, C. R.; "Unusual Cloud Formations," Marine Observer, 23:76, 1953. (X3, X4)
R4. Mould, F. W.; "Unidentified Phenomenon," Marine Observer, 27:82, 1957. (X5)
R5. Shepherd, F.; "Cloud," Marine Observer, 51:107, 1981. (X6)

Curious cloud arch in the Strait of Gibraltar. The ends terminated in the ocean at points 4 miles apart. (X6)

GWC3 Polar Bands

Description. Long, parallel, sharply defined streaks of cirrus cloud aligned along the magnetic meridian. Taking perspective into account, a ground observer sees these parallel clouds as fans radiating from points on the northern and southern horizons. They spread out when overhead into evenly spaced bands, tenuous in nature, more like strips of haze in some cases, and sometimes faintly luminous at night.

Background. Von Humboldt applied the term "polar bands" to these geometrically aligned cirrus bands. English folklore dubs them "wind reels." Early observers believed that this phenomenon was surely associated with auroral activity. Indeed, many of the examples presented here possess auroral overtones. See GLA12 in this regard. The polar bands also bear a striking resemblance to the banded sky (GLA23), and in fact may be the same phenomenon, occurring in the daytime instead of at night.

Data Evaluation. Many observations of polar bands reside in the older literature, but they are recorded infrequently in recent times. Rating: 1.

Anomaly Evaluation. Two characteristics of the polar bands make them anomalous: (1) Their frequent alignment with the magnetic meridian; and (2) A less frequent association with auroral displays. Cirrus clouds would not seem to have intrinsic magnetic properties, nor do they occur anywhere close to the altitudes of normal auroras. Rating: 2.

Possible Explanations. The magnetic alignment may be just a coincidence, perhaps due to the creation of cirrus bands by high altitude winds with preferred directions of propagation. Less likely is the possibility that the auroras, which are usually magnetically oriented, and polar bands have a common cause, say, particles that cause high-altitude luminous phenomena and low-altitude nucleation of ice crystals.

Similar and Related Phenomena. Banded skies (GLA23), and the apparent close relationship between some auroras and some clouds (GLA12), cloud arches (GWC2).

Examples of Polar Bands

X1. October 30, 1870. England. "On that day the finest films of cirrus stratus cloud radiated in a most beautiful and symmetrical manner from a point below the northwest horizon, and their resemblance to the streamers of aurora was most perfect. Later, at about 1 o'clock on the same day, long ridges of cumuli were arranged in the same manner." (R1)

X2. April 8 and 9, 1871. England. Long streaks of cirrus stratus were polarized NW-SE. Auroral streamers on April 9 were parallel to the cloud display. (R2)

X3. April 10, 1872. Champion Hill, England. Cirrus clouds radiated from magnetic north. An aurora followed. (R3)

X4. June 18, 1872. England. Masses of cirrus cumulus clouds were polarized nearly along the magnetic meridian. (R4)

X5. October 23, 1872. England. Polarized streaks of haze and cirrus clouds. (R5)

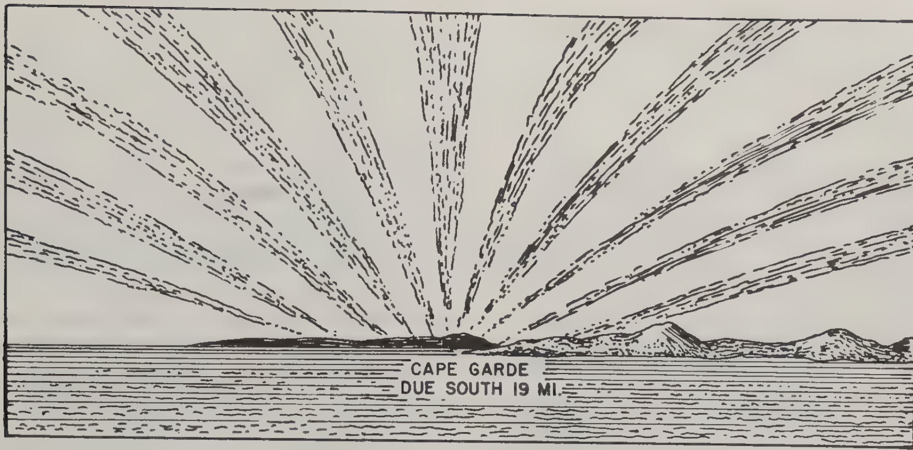
X6. September 11 and 12, 1873. England. Polarized streaks of haze and cirrus clouds. (R5)

X7. March 12, 1900. Harefield, England. "A number of gauze-like white clouds, in perfectly straight lines, radiated like a huge fan from a point due north, slightly below the visible horizon, where a clump of elm trees, about half a mile away, grew. The clouds were straight white streaks, of which the edges shaded off into the blue of the sky visible between them. The streaks were at regular distances apart, and about 24 in number above the horizon, those near it being but a few degrees from the horizontal, and stretching from the centre to about 40° of declination; but those near the horizon, apparently about 60°, and what struck me as most singular, they all ended almost abruptly." Later, the clouds extended and converged in the southwest. (R6)

X8. June 30, 1925. East London, South Africa. Cloud streamers radiated from the south. (R7)

X9. January 25, 1926. Indian Ocean. Cirrus streaks radiated from a point bearing 45°. (R8) A rare instance where the streaks do not radiate from magnetic north. (WRC)

X10. October 22, 1927. Mediterranean Sea.



Polar bands over the Mediterranean (X10)

"On 22nd October, 1927, off Cape Garde at about 5.30 a.m., observed remarkable cloud formation consisting of radiating streaks of Cirrus cloud forming complete evenly spaced arcs terminating in approximately the true north and south points of the horizon. It gave the sky a wonderful domed appearance and lasted until after sunrise (about 6.45 a.m.), the formation gradually broke up merging into Alto Stratus." (R9)

X11. General observation. A study of cirrus bands observed 1840-1847 indicated that their alignment was most frequently along the magnetic meridian. (R10) Contrast this with X12. (WRC)

X12. General observation. Polar bands are no longer believed to be preferentially aligned along the magnetic meridian. (R11)

X13. March 20, 1932. Oxford, England. Just before sunrise, a single band of cirrus 5° wide spanned the heavens north to south. It was a brilliant pink. (X12) If the observer had not identified this arch as composed of cirrus cloud, it might well be classified as auroral in category GLA2, auroral arches. (WRC)

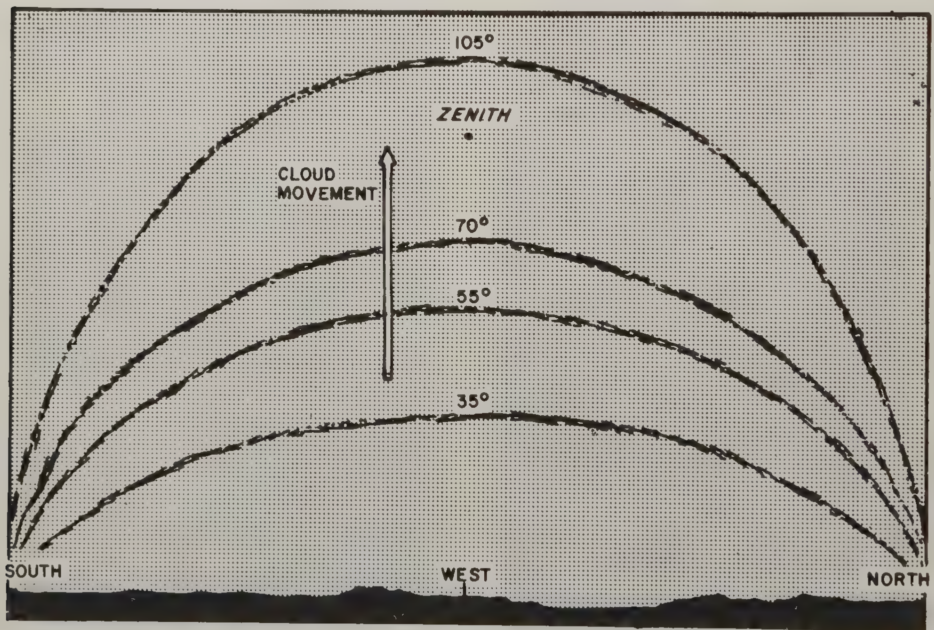
X14. July 24, 1933. Westcliff-on-Sea, England. "During the evening of July 24th, 1933, an unusual cloud formation of cirrus was seen at Westcliff-on-Sea, Essex. At 21 h. 20 m. G.M.T. a belt of cirrus cloud was observed stretching across the western sky at an elevation of 35°, from north to south, forming a bow, and moving in an easterly direction. This was rapidly followed by a second belt, and between 21 h. 20 m. to 21 h. 50 m. eight belts of cloud travelled across the sky from due west to east, the eighth belt disappearing at 21 h. 50 m. at an elevation of 105°. None of the belts appeared from the west until at an elevation of 35°, probably because the western sky was too bright at the time to allow any contrast at lower elevations, nor were any visible after reaching the elevation at 105°. At 21 h. 30 m. four belts were visible simultaneously at elevations of 35°, 55°, 70° and 105° from west. All the belts were approximately 1 1/2° in width, the width being even throughout their length. The belts of cloud were whitish in appearance, the three lower being very clear, whilst that which had passed overhead was considerably less clear. The brilliancy of the belts was similar to that of the Milky Way on a clear moonless night. As the belts of cloud travelled across the sky they presented a striking appearance. As each attained the 70° elevation and beyond, stars in the path of travel were plainly seen through the cloud, which clearly denotes that the cloud belts were very tenuous." (R13) Once again there is little to separate this observation and the banded sky phenomenon (GLA23). (WRC)

X15. General observation. Cirrus clouds often align in bands parallel to the magnetic meridian. This orientation may be due to ice crystals forming around meteoric dust particles which are frequently magnetic. (R14) See also X16.

X16. General observation. In reference to X15, meteoric dust has not been proven to be a nucleating agent for ice crystals. Furthermore, the alignment of individual ice crystals would not explain the macroscopic structure of the polar bands; i.e., parallel streaks aligned with magnetic north. (R15)

References

R1. Ingall, Herbert; "Aurora of 9th April and Polarisation of Clouds," English Mechanic, 13:155, 1871. (X1)
R2. Birt, W.R.; "Polarisation of Clouds and Magnetic Phenomena," English Mechanic, 13:131, 1871. (X2)
R3. Ingall, Herbert; "Aurora," English Mechanic, 15:147, 1872. (X3)
R4. Birt, W.R.; "Thunderstorm of June 18, 1872;" English Mechanic, 15:381, 1872. (X4)
R5. Ingall, Herbert; "Polarisation of Haze," English Mechanic, 18:262, 1873. (X5, X6)
R6. Sigma, Jemina; "Beautiful Atmospheric Display," English Mechanic, 71:127, 1900. (X7)
R7. Holcroft, A.V.; "Cloud Streamers," English Mechanic, 122:52, 1925. (X8)
R8. McCornish, A.B.; "Radiating Streaks of Cirrus," Marine Observer, 4:5, 1927. (X9)
R9. Bedwell, L.A.; "Radiating Cirrus Cloud," Marine Observer, 5:203, 1928. (X10)
R10. Stevenson, William; "Abstract of Observations on the Aurora....," Philosophical Magazine, 4:6:20, 1853. (X11)
R11. Talman, C. Fitzhugh; "Polar Bands," American Meteorological Society, Bulletin, 9:84, 1928. (X12)
R12. Jupp, C.A.; "A Remarkable Cirrus Band," Meteorological Magazine, 67:93, 1932. (X13)
R13. Horrex, E.J.; "Luminous Night Cloud," Meteorological Magazine, 68:186, 1933. (X14)
R14. Kellner, L.; "Alignment of Cirrus Clouds along the Magnetic Meridian," Nature, 199:900, 1963. (X15)
R15. McDonald, J.E., and Kellner, L.; "Meridional Alignment of Tropical Cirrus Clouds," Nature, 201:1316, 1964. (X16)



North-south cirrus streaks over England, 1933 (X14)

GWC4 Miniature Thunderclouds

Description. Electrically active thunderclouds with dimensions measured in feet rather than miles.

Data Evaluation. Only a single good observation, and this under special meteorological conditions. Rating: 3.

Anomaly Evaluation. Normal thunderstorm convection cells are measured in thousands of feet. It seems improbable that a cell a few feet across could form under natural conditions. Rating: 2.

Possible Explanation. Local conditions, as in X1, may result in the separation of enough electrical charge to cause local discharges similar to normal lightning, as in dust- and snowstorms.

Similar and Related Phenomena. Unusual electrical discharges in dust- and snowstorms (GLD5), whirlwinds of fire and smoke (GLD11), ground-level light flashes (GLD17).

Examples of Miniature Thunderclouds

X1. Circa 1919. Stockton Heath, England. "I was staying at Stockton Heath, in July, about 400 yards from the Manchester Ship Canal. The evening was somewhat oppressive, and the air had become strangely still. Gazing down the road, I saw a small black thundercloud gathering along the length of the canal, and about 30 or 40 feet above it. It was approximately 400 yards long and perhaps 6 feet thick. As I gazed at this strange formation, a dazzling lightning flash raced through the entire cloud, i.e. parallel to the water, and a bang like the discharge of field artillery followed immediately. About 40 seconds later, another flash and report occurred; then the cloud thinned and dispersed in about four minutes. I might add, that at least in those days an air current of varying intensity moved up that canal almost incessantly, i.e. inland towards Manchester, at the Stockton Heath section, one felt it on the neighboring bridge." (R1)

X2. No date or place given. Reference to a statement by Acamedician Marcolle that lightning from a cloudlet 1 1/2 feet in diameter killed a woman. (R2) Obviously this datum is too vague to be of much use, although the cloudlet might have been a form of ball lightning (GLB).

References

R1. Bailey, C. S.; "A Miniature Thunderstorm," Weather, 4:267, 1949. (X1)
R2. "Curiosities of Thunderstorms," Eclectic Magazine, 38:458, 1856. (X2)

GWC5 Noisy Clouds

Description. Rumbling, grating, hissing, crackling low-level clouds showing no evidence of lightning or other electrical discharge.

Data Evaluation. Data are sparse here. The situation is worsened by the great difficulty in eliminating obvious noise producers, such as internal electrical discharges. Rating: 3.

Anomaly Evaluation. Noisy clouds, although curious, almost certainly have prosaic explanations. Rating: 3.

Possible Explanations. Unseen electrical discharges are good noise-making candidates. The rattling of suspended hail is another possibility.

Similar and Related Phenomena. The hissing and crackling sounds associated with brush discharge and low-level electrified luminous patches (GLD4).

Examples of Noisy Clouds

X1. 1881. Haute-Garonne, France. "During a recent thunderstorm in Haute-Garonne, M. Larroque heard a dull continuous sound (like that of heavy carriages on pavement), which could not, apparently, be thunder, and which he accounts for thus: The storm was caused by meeting of two currents, one warm and charged with rain, the other cold and charged with hail. They met pretty high up, producing a gyratory storm centre, a cylindical vortex, in which the hail was liquified. The sound is attributed to the hail whirling in this cylinder." (R1)

X2. July 1932. Cache Lake, Ontario. "It was a chilly morning and the sky was completely overcast with clouds. My attention was attracted by a rumbling sound coming from the west, such as heralds the approach of a heavy thunderstorm. As I watched, a very long, low, narrow, tenuous cloud, resembling a squall cloud, appeared above the trees on the opposite shore, moving at right angles to its length. The continuous, rumbling noise, now grown remarkably loud, seemed to come unmistakably from this cloud, whose cross-sectional diameter was only about 200 feet. The cloud passed overhead eastward and was not followed by the expected rain storm. The cloud apparently marked the meeting place of two oppositely directed currents of air that differed in temperature. It seems almost incredible, however, that so much sound could have arisen from the agitated air alone, and yet this seems to be the only plausible explanation of its origin. I steadfastly looked for small lightning flashes in the cloud and saw none, although they would have had to come in rapid succession to produce the persistent sound which was heard. The noise could not have come from the rattle of hail because the cross-section of the cloud was too small to give time for hail formation; and in any case no hail fell." (R2)

X3. February 1969. Jacksonville Beach, Florida. Two clouds emitting sounds like "rattling cellophane" and "someone walking on pebbles." The clouds disappeared when they reached the Atlantic. (R3)

References

R1. English Mechanic, 34:11, 1881. (X1)
R2. Zeleny, John; "Rumbling Clouds and Luminous Clouds," Science, 75:80, 1932. (X2)
R3. Associated Press dispatch, reprinted in Pursuit, 2:32, April 1969. (X3)

GWC6 Noctilucent Clouds

Description. Very high, glowing clouds seen at high latitudes (45° to 70°) during the summer months. Noctilucent clouds, which often have band or wave structures occur at altitudes of about 50 miles and are illuminated by the sun, which may be well below the observer's horizon. These clouds are always white with perhaps a tinge of blue. The anomalous aspects of the phenomenon are intrinsic in the following questions: (1) Where do the nucleating particles and water vapor come from at such extreme altitudes; (2) Why the band and wave structures; (3) Why do the clouds form only at high latitudes during the summer; and (4) Why are they formed at such a narrow range of altitudes?

Background. Rockets probing the region of noctilucent cloud formation in the 1960s at first indicated that noctilucent clouds were composed of ice crystals formed around meteoric dust particles. (R1) Later experiments cast doubt on these results. (R2) Many unknowns still remain in this field; so many that noctilucent clouds are included in this catalog. The literature on the subject is extensive, and no attempt has been made to gather it all.(R3)

Data Evaluation. A common phenomenon in high latitudes. Rating: 1.

Anomaly Evaluation. The questions raised above about the origin and distribution of noctilucent clouds probably have simple answers. Rating: 3. However, if the time-space distribution of noctilucent clouds is due to the nonuniform distribution of meteoric dust, this rating would have to be revised.

Possible Explanations. The banded structure may be the result of high-altitude gravity waves, but no one yet understands their origin either. The concentration of these clouds at high latitudes during the summer could be the result of moisture being carried to high altitudes by turbulence during the warm months. Meteoric dust or ions and molecules released by meteors may be nucleating agents. Rocket launches may also contribute. (R4)

Similar and Related Phenomena. The same sort of banded structure is found in the banded sky (GLA23), magnetically aligned cirrus clouds (GWC3), and some air-glow events (GLA3).

References

R1. Soberman, Robert K.; "Noctilucent Clouds," Scientific American, 208:51, June 1963.
R2. Soberman, Robert K.; "Noctilucent Clouds," McGraw-Hill Encyclopedia of Science and Technology, 9:135, 1977.
R3. Ivengar, R.S.; "Origin of Noctilucent Clouds," Science, 145:767, 1964.
R4. Meinel, Aden B., and Meinel, Carolyn P.; "Low-Latitude Noctilucent Cloud of 2 November 1963," Science, 143:38, 1964.

GWC7 Ring Clouds

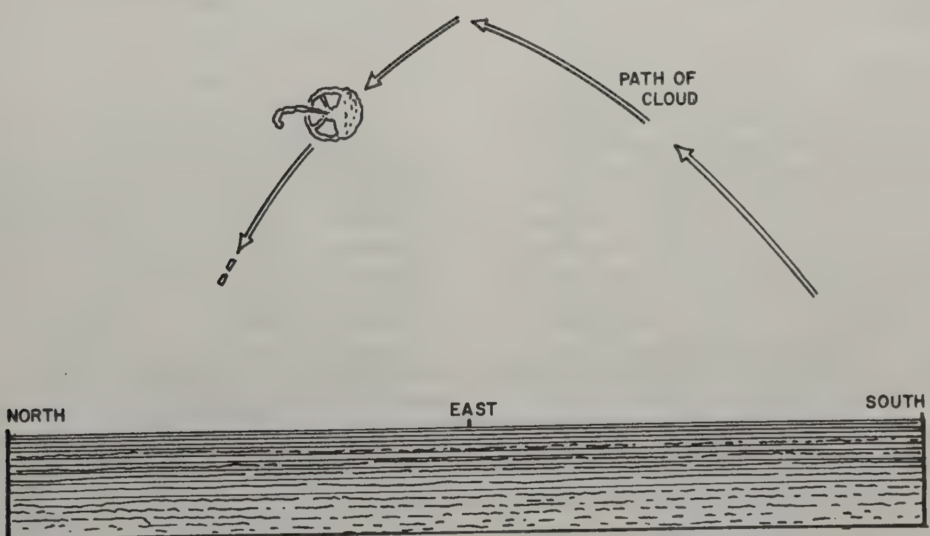
Description. Circular clouds with clear centers---like 'smoke rings'---which in many cases seem to rotate about the axis of the circle. Most ring clouds move at normal cloud levels, but examples at 30-miles-altitude have been reported.

Data Evaluation. Several good observations plus photographs. Rating: 1.

Anomaly Evaluation. Ring clouds are probably just the consequence of freak local meteorological conditions that generate small vortexes. No significant anomaly here. Rating: 3.

Possible Explanations. Pressure, temperature, and wind measurements made during the passage of a ring cloud confirm the presence of a small, local vortex. The precise origin of these small vortexes is not known. High-altitude ring clouds, which seem rare, may just be aberrant nacreous clouds; that is, accidentally distorted into rough circles.

Similar and Related Phenomena. Circular holes in cloud decks (GWC9).



Ring cloud with spokes and tail (X1)

Examples of Ring Clouds

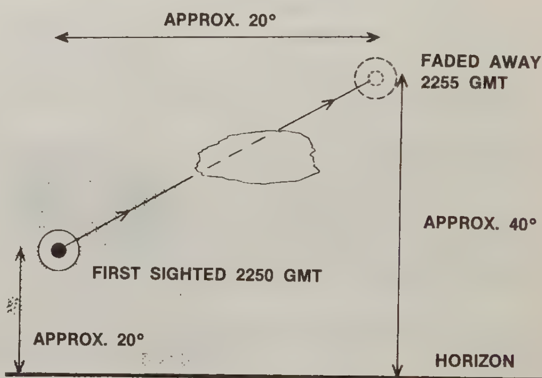
X1. March 22, 1870. North Atlantic Ocean. "At from 6.30 to 7 P.M. a curious-shaped cloud appeared in the S.S.E. quarter, first appearing distinct at about 25° from the horizon, from where it moved steadily forward, to about 80°, where it settled down bodily to the N.E. Its form was circular, with a semicircle to the northern face near the centre, and with four rays or arms extending from centre to edge of circle. From the centre to about 6° beyond the circle was a fifth ray broader and more distinct than the others, with a curved end:---diameter of circle 11°, and of semicircle 2 1/2°. The weather was fine, and the atmosphere remarkably clear, with the usual Trade sky. It was of a light grey colour, and, though distinctly defined in shape, the patches of cirro-cumulus at the back could be clearly seen through. It was very much lower than the other clouds; the shape was plainest seen when about 55° to 60° high. The wind at the time was N.N.E., so that it came up obliquely against the wind, and finally settled down right in the wind's eye; finally lost sight of it through darkness, about 30° from the horizon at about 7.20 P.M. Its tail was very similar to that of a comet." (R1) This observation is frequently referenced in the Fortean literature. (WRC)

X2. December 5, 1922. Biggin Hill Aerodrome, England. A cloud ring, 60° in diameter, moved across the sky, with stars occasionally visible in the center. "The phenomenon was like a great smoke ring." The ring broke up after passing through zenith. (R2)

X3. February 1, 1958. Gulf of Aden. "At 2300 S.M.T. a cloud, in the form of a circle about 1 mile in diameter, was observed lying above and ahead of the path of the ship. When the vessel came nearer, the cloud was clearly seen in the moonlight to be revolving in a clockwise direction. The centre of the circle was completely cloudless. While passing under the cloud there was a fall in barometric pressure of 3.5 mb and a 3° drop in temperature. The sea also was noticeably calmer under the clear sky. As the vessel left the area, both pressure and temperature reverted to their former values. The wind which had been NE., force 4, for a long time, veered completely round while the vessel was passing under the cloud, and finally settled again in the NE. quadrant, at force 3. When last seen, the cloud formation was thought to be breaking up. The phenomenon observed lasted for a little over 15 min." (R3)

X4. November 1, 1962. Red Sea. Cloud resembling a huge smoke ring moves northeast while rotating anticlockwise. (R4)

X5. November 27, 1980. North Atlantic Ocean. "At 2250 GMT a glowing 'smoke ring' phenomenon was observed on the starboard quarter at approximately 20° altitude and bearing approximately west. It moved towards the stern and climbed in the sky, disappearing behind a cloud and reappearing on the other side before finally fading away at approximately 40° altitude, bearing WNW, at 2255 GMT. The diameter was about 3-4° and the centre seemed to be darker than the surrounding sky when viewed through binoculars." (R5)



Smoke ring phenomenon in the North Atlantic (X5)

X6. February 28, 1963. Arizona. "Abstract. An unusual ring-shaped cloud was widely observed over northern Arizona near sunset on 28 February 1963. From a large number of observer's reports it is known to have appeared overhead near Flagstaff, Arizona. From initial computations based on four photos taken in Tucson, 190 miles south of the cloud, its altitude was approximately 35 kilometers. The most distant observation reported was made 280 miles from the cloud. The cloud remained sunlit for 28 minutes after local sunset. Iridescence was noted by many observers. Tentatively, the cloud may be regarded as similar to a nacreous cloud; but its unusually great height and unusually low altitude, plus its remarkable shape, suggest that it was a cloud of previously unrecorded type." (R6, R7) In the last sentence of the quotation, "altitude" evidently means "angular elevation, otherwise the sentence makes little sense.

References

R1. Banner, Frederick W.; "Extract from the Log of Barque 'Lady of the Lake'," Royal Meteorological Society, Quarterly Journal, 1:157, 1873. (X1)
R2. "An Unusual Sky Effect," Meteorological Magazine, 58:13, 1923. (X2)
R3. Jones, Digby; "Revolving Ring of Cloud," Marine Observer, 29:19, 1959. (X3)
R4. Dennis, T.S.; "Unidentified Phenomenon," Marine Observer, 33:190, 1963. (X4)
R5. McIntosh, H. H.; "Unidentified Phenomenon," Marine Observer, 51:185, 1981. (X5)
R6. McDonald, James E.; "Stratospheric Cloud over Northern Arizona," Science, 140:292, 1963. (X6)
R7. "The Mystery of the Flagstaff Cloud," New Scientist, 18:303, 1963. (X6)

GWC8 Thunderclouds Affecting the Ionosphere

Descriptions. Sharp increases in the level of sporadic E ionization in the ionosphere correlated with the passage of thunderstorms.

Data Evaluation. A single series of experiments in a single locality. Rating: 3.

Anomaly Evaluation. Thunderstorms occur in the lower atmosphere, whereas the E layer of the ionosphere exists between 50 and 85 miles altitude. How are the two phenomena connected physically? Rating: 2.

Possible Explanations. A channel of lower electrical conductivity may be established between the ionosphere and lower atmosphere by penetrating radiation.

Similar and Related Phenomena. Low-level auroras (GLA4), rocket lightning (GLL1), correlation of thunderstorms with cosmic rays (GLL16), correlation of auroras and thunderstorms (GLA9).

Examples of Thunderclouds Affecting the Ionosphere

X1. 1953 and 1954. Calcutta, India. The level of ionization in the sporadic E layer of the ionosphere was found to increase sharply with the passage of thunderclouds over Calcutta. The authors ventured that thunderstorms might be one of the causes of sporadic E ionization. (R1)

References

R1. Mitra, S.K., and Kundu, M.R.; "Thunderstorms and Sporadic E Ionization of the Ionosphere," Nature, 174:798, 1954. (X1)

GWC9 Circular Holes in Cloud Decks

Description. Circular holes several miles in diameter that form in otherwise dense, uniform cloud decks. Horn-shaped tails under the holes may infer precipitation.

Data Evaluation. Several modern observations complete with series of photographs. Rating: 1.

Anomaly Evaluation. Holes in cloud decks are symptomatic of natural or artificial seeding. In the observations recorded here, no artificial seeding was known to have occurred in the affected areas. The problem relates to what natural phenomenon seeded the cloud deck. Several candidate phenomena are available, so that circular holes in cloud decks are very likely only minor anomalies. Rating: 3.

Possible Explanations. Besides intentional cloud seeding for purposes of weather modification, rockets, aircraft, and even ground-based industries may contribute nucleating materials. Natural seeding may initiate from higher-level clouds.

Similar and Related Phenomena. None.

Examples of Circular Holes in Clouds

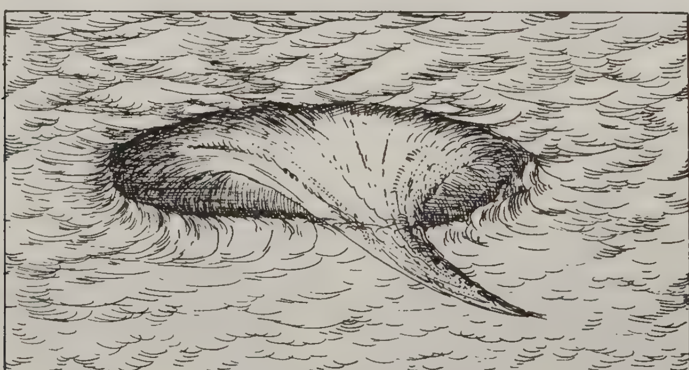
X1. December 1, 1967. Miami, Florida. 0830 EST. "At about this time one of us independently noted a distinct downward protrusion of what appeared to be middle cloud below the base of the otherwise uniform altocumulus layer. By 0900 EST the holes were conspicuous almost perfect circles. The sketch of the southern hole....depicts conditions observed at about 845 EST. A well-developed cirrus tail extended down from this hole, and trailed off approximately west-northwestward, thus indicating a downward decrease in wind speed." Some spectacular photographs attest to the nice circularity of the two holes, each of which measured about 4 miles in diameter. Some sort of natural cloud-seeding process was suspected. (R1)

X2. February 23, 1968. Vandenberg Air Force Base, California. A circular hole, about 6 miles in diameter, was observed in a cirro-cumulus cloud deck at 26,000 feet. (R2)

References

R1. Johnson, H. M., and Holle, Ronald L.; "Observations and Comments on Two Simultaneous Cloud Holes over Miami," American Meteorological Society, Bulletin, 50:157, 1969. (X1)

R2. Kinney, John R.; "Hole-in-Cloud," American Meteorological Society, Bulletin, 49:990, 1968. (X2)



Circular hole in cloud deck with a cirrus tail (X1)

GWC10 Anomalous Cloud Lines

Description. Lines of clouds, often hundreds of miles long and tens of miles wide, many without obvious causes. Anomalous cloud lines appear predominantly over the oceans.

Background. When high-resolution satellite photographs of the earth's surface became available in the 1960s, many showed anomalous cloud lines over ocean areas. At first, they were believed to be the contrails of ships. Later studies concluded that several other factors were also operating (see below) and that some had no obvious explanation.

Data Evaluation. Abundant, high quality satellite photographs. Rating: 1.

Anomaly Evaluation. Due to the multiplicity of reasonable explanations, anomalous cloud lines must be considered mainly as curiosities, although the precise method of formation of some remains unknown. Rating: 3.

Possible Explanations. Ship and aircraft contrails, meteor trails (rare), orographic clouds formed in the lees of oceanic islands, and clouds formed over linear perturbations in sea temperature arising from currents and internal waves.

Similar and Related Phenomena. Long roll clouds (GWC12); long, hollow, cylindrical clouds possibly formed by meteors (GWC13).

Examples of Anomalous Cloud Lines

X1. General observation. "Satellite cloud photography occasionally reveals anomalous cloud lines in the form of plumes often 500 km long and up to 25 km wide. These lines, found over the ocean, are composed of liquid particles. Hollow polygonal, convective or thin stratiform, cloud patterns in varying amounts are associated with these lines. Numerous lines within a 10-deg square have been observed which cover up to 4 per cent of the total area." In the author's opinion the cloud lines are exhaust plumes from ships. (R1)

X2. June 27, 1967. North Pacific Ocean. "On June 27, 1967, the ESSA 2, automatic picture transmission (APT) photograph, taken at 1720 GMT, showed anomalous cloud lines. B. J. Haley, pilot of United Airlines flight 185-27, flew over this area at 1945 GMT. He reported no clouds or vapor trails at his flight level of 31,000 ft. Below him, he observed a layer of low, thin stratus through which sunlight, reflected from the ocean, could be seen. He estimated the height of the stratus layer to be 1,000 ft above the surface. Haley also reported that a ship located near 35°N, 131°W and traveling due east was clearly visible through the stratus layer. The smoke from the ship's stack was forming a 'definite line of thicker clouds' in the layer of scattered and broken stratus. This condensation trail was estimated to be 2-4-mi wide at a point 10 mi behind the ship, and to extend 125-150 mi before fading out." (R2)

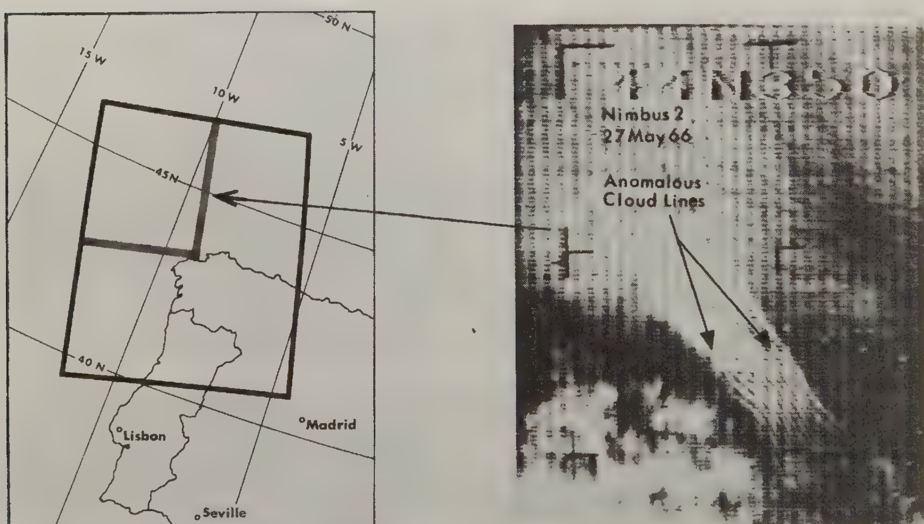
X3. General observation. After reviewing the problem, the authors concur with the ship exhaust theory. (R3)

X4. General observations on various satellite photos. "Anomalous cloud lines are depicted in Fig. 1, which was taken off the west coast of the United States (the date and time of the imagery are unknown). This is a DMSP product, daytime visual imagery with a 1/3 n mi resolution. An extended band of stratocumulus clouds, tops at 1200 m is shown. The upper left diagonal half of the picture contains a minimum of five anomalous cloud lines. Close examination revealed the majority of these lines to be connected to layers of clouds. Studies were performed by the First Weather Wing, Air Weather Service, using DMSP visual and infrared data in the early '70s. Hundreds of anomalous cloud lines similar to Fig. 1 were studied in an attempt to relate the lines to ship smoke trails. The following conclusions were derived: (1) All the lines consisted of stratocumulus type clouds with tops ranging from 1000 to 1400 m. (2) A U.S. Navy investigation at Pearl Harbor revealed that no ships were at the ends of any of the lines. In fact, most of the lines occurred above the ocean surface away from the major shipping lines. (3) It was concluded that the lines were random cloud activity oriented with ocean gradients." Several of the photographs examined showed cloud lines that could not be attributed to any artificial, meteorological, or oceanographic conditions. (R4)

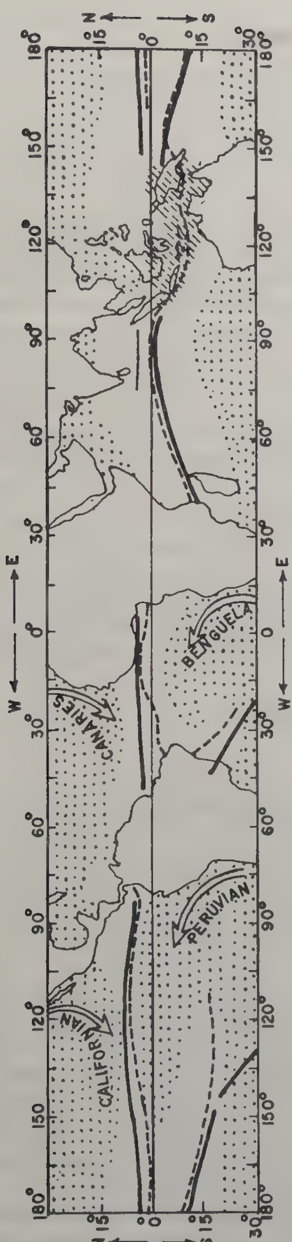
X5. Frequent occurrence. Tropical oceans. "Summary. Available observational evidence regarding occurrence of double cloud bands, one in each hemisphere, over tropical oceans is reviewed. An examination of their locations appears to suggest that these may be related to maxima in ocean surface temperature. Significant asymmetry and discontinuity are noticed over areas which are affected by cold ocean currents and monsoons.

"1. Observational Evidence. During the last quarter century or so, there have been occasional references in literature to the oc-

Satellite photo of anomalous cloud lines (Fig. 1 from R4) (X4) (Courtesy H. W. Brandli)



System of anomalous cloud lines taken from the satellite Nimbus 2 off the coast of Spain (X4) (Courtesy H. W. Brandli)



February double-cloud bands (solid lines) and lines of maximum ocean temperatures (dashed lines) (X5)

currence of double cloud bands in the tropical zone, although definitive information regarding their origin, nature and locations relative to the Equator in different regions has been rather scanty. The earliest reference appears to be that of Fletcher (1945) who cites aircraft reports of frequent occurrence of double cloud lines, one on each side of the Equator, in equatorial eastern Indian Ocean during autumn through spring. Recently, after the introduction of Meteorological satellites, double cloud bands have been observed in other parts of the Tropics as well."

The salient features of the double bands are: "(i) Double cloud bands are characteristic features of all tropical oceans; (ii) The cloud bands do not cross the Equator in any region; (iii) The intensity of the cloud bands generally varies with the seasons, the summer hemispheric band being the more intense. (iv) In some regions such as the equatorial western Pacific, the cloud bands in both the hemispheres lie close to and are more or less parallel with the Equator. In equatorial eastern Indian ocean, the cloud bands during February also lie close to and more or less parallel with the Equator. In the Atlantic and eastern Pacific, while the northern hemispheric cloud band lies close to and more or less parallel with the Equator, the southern hemispheric cloud band is displaced from the near-equatorial position and lies oblique to the Equator. (v) The continuity of the cloud bands in both the hemispheres is broken over some oceanic regions. Prominent among these regions are south-eastern Pacific, south-eastern Atlantic and western Indian ocean especially the western Arabian sea. (vi) In the monsoon regions, while the cloud band in the summer hemisphere is attracted to the continental landmass, that in the winter hemisphere shifts little from its near-equatorial position. The cloud bands are thus widely separated from each other. These effects are most prominently seen in the regions of the summer monsoon of Asia and Australia." (R5)

References

R1. Conover, John H.; "Anomalous Cloud Lines," Journal of the Atmospheric Sciences, 23:778, 1966. (X1)

R2. Parmenter, Frances C.; "Ship Trails or Anomalous Cloud Lines," Monthly Weather Review, 100:646, 1972. (X2)

R3. Pueschel, R. F., and Weickmann, H. K.; "Anomalous Cloud Lines....," Eos, 54: 285, 1973. (X3)

R4. Brandli, Henry W., and Orndorff, John W.; "Satellite-Viewed Cloud Lines, Anomalous or Others," Monthly Weather Review, 104:210, 1976. (X4)

R5. Saha, K.R.; "Global Distribution of Double Cloud Bands over Tropical Oceans," Royal Meteorological Society, Quarterly Journal, 99:551, 1973. (X5)

GWC11 Dispersal of Clouds by the Moon

Description. The tendency of clouds to disperse under the influence of the moon, particularly the full moon.

Background. Folklore has long stated that "the moon eats clouds." Scientific analyses have been both positive and negative in this matter---more negative than positive in the long run. Modern science looks with disfavor on the folklore assertion but nevertheless has found some evidence that supports the reality of a lunar influence on rainfall (GWS1), which in essence links the moon to cloudiness or the lack of it.

Data Evaluation. Several conflicting studies and many disagreeing opinions by observers of the night sky. Rating: 3.

Anomaly Evaluation. Moonlight should have no direct effect on clouds, but if it seems to there are at least two reasonable explanations (see below), a situation rendering this phenomenon "not very anomalous." Rating: 3.

Possible Explanations. Scientists agree that there is a tendency for clouds to disperse in the early evening (a solar effect?), which is precisely the time most people would notice a full moon if it were in the sky. Consequently, what is really coincidental might be labelled cause-and-effect. Some studies suggest that the moon's phase can be correlated with rainfall (GWS1) and suggest this effect may be due to the moon's gravitational field affecting the influx of meteoric nucleating debris, providing a cause-and-effect relationship between the moon and cloudiness.

Similar and Related Phenomena. The moon and the weather (GWS1).

Examples of the Dispersal of Clouds by the Moon

X1. General observation. Greenwich, England. Noting that Sir John Herschel had proclaimed that the full moon tended to disperse clouds, the author analyzed 7 years of cloud data recorded at Greenwich Observatory. Conclusion: the moon has no effect on general cloudiness. (R1)

X2. General observation. Greenwich, England. A study similar to X1, also using Greenwich cloud data. Same conclusion. Author noted, however, the tendency of the sky to clear in the early evening regardless of the moon's position. Since the full moon is always conspicuous at this time, the two unrelated phenomena might be assumed to have a cause-and-effect relationship. (R2, R6, R7)

X3. General observation. Batavia, Java. "In the appendices to the volumes of observations at Batavia, Dr. van der Stok publishes studies of the influence of the moon on the meteorological elements. He finds an appreciable effect on the cloudiness. The cloudiness there increases with the increase of the distance of the moon above the horizon, reaching its maximum at the superior meridian transit and its minimum at the inferior one. Thus the influence of the moon appears to be felt when she is below the horizon, which excludes the hypothesis of its being the result of direct radiation. There is also greater cloudiness at full than at new moon. In each case the extreme difference averages about 5 per cent." (R3)

X4. General observation. Several observers in mountainous regions have concluded that the full moon does indeed tend to disperse clouds. (R4) No further details given. (WRC)

X5. General observation. England. Analysis of 15 years of data showed no effect of the full moon on cloudiness. (R5)

X6. January 4, 1912. Dublin, Ireland. "This somewhat rare phenomenon could be observed here, Jan. 4d. 20h. 30m. to 21h. Two air-currents, the upper from S. S. W., and lower from W., carried their strata of clouds across the moon's disc. The lower clouds traveled at a very fast rate, while the lunar disc seemed to rise up to meet them as it advanced from E. The swiftly advancing clouds, on coming in contact with the moon's North Polar Region, instead of passing across the disc, coasted round it and drifted on their way. At times the scattering was directed in all directions, just as a piece of ice thrown on a frozen pond breaks and scatters broadcast." (R8) This may only have been a contrast effect, with bright moonlight seeming to make the thin clouds invisible. (WRC)

X7. 1908-1911. England. Of the 50 full moons during this period, 31 appeared to disperse clouds. (R9)
X8. General observation. Observations, such as those of X6, are merely matters of perspective; i.e., clouds seem to thin out when viewed directly overhead. (R10)
X9. General observation. England. An amateur astronomer avers that the full moon, in his experience, indeed does disperse clouds. (R11)
X10. General observation. The brightness of the full moon makes thin clouds seem to disappear; i.e., apparent dispersal is a matter of contrast. (R12)

X11. General observation. "The moon's changing faces, already linked to heavy rainfall, are also related to sunshine. There is more sunshine than usual when the moon is between first quarter and full moon, and between last quarter and new moon. Below average sunshine occurs between new moon and first quarter, and between full moon and last quarter. This relationship was reported to the American Meteorological Society meeting in Vancouver, Canada, by Iver A. Lund of the U.S. Air Force Cambridge Research Laboratories, Bedford, Mass. He studied weather records covering 58 years, from 1905 through 1962, for ten cities, a total of more than 211,000 observations." (R13)

X12. Frequent observation. Oxford, England. Re: the cloud-dispersing capability of the moon. "From repeated observations it appears that at Oxford the influence begins after the moon is four or five days old, and lasts till she approaches the sun again the same distance on the other side. So frequently has this been noticed by Mr. Johnson, that during a course of observations on which he was engaged a few years ago, he felt that his attendance at the observatory could not be dispensed with, however unpromising might be the appearance of the night, until the moon had fairly risen; and over and over again when this has occurred, the sky, before completely obscured, has become clear." (R14)

References

R1. Loomis, Elias; "Does the Moon Exert a Sensible Influence upon the Clouds?" American Association for the Advancement of Science, Proceedings, 7:80, 1853. (X1)
R2. Ellis, William; "Inquiry as to Whether the Tendency to Dispersion of Cloud under a Full Moon in Any Way Depends upon Lunar Influence," Philosophical Magazine, 4:34:61, 1867. (X2)
R3. "The Moon and the Weather at Batavia (Java)," Sidereal Messenger, 7:316, 1888. (X3)
R4. Merriman, Mansfield; "The Influence of the Moon on Rainfall," Science, 20:310, 1892. (X4)
R5. "The Moon and the Weather," Nature, 49:275, 1894. (X5)
R6. Ellis, William; "Supposed Dispersion of Cloud under the Full Moon," Observatory, 17:114, 1894. (X2)
R7. "The Moon and the Clouds," Scientific American, 105:341, 1911. (X2)
R8. MacDermott, Joseph; "The Full Moon Scatters Clouds," English Mechanic, 94:558, 1912. (X6)
R9. Munsergh, A. W.; "Full Moon Dispersing Clouds," English Mechanic, 95:59, 1912. (X7)
R10. Gardner, Edward; "Does the Full Moon Scatter Clouds?" English Mechanic, 95:86, 1912. (X8)
R11. Hill, R. J.; "Does the Full Moon Scatter Clouds?" English Mechanic, 95:106, 1912. (X9)
R12. Stephenson, G. E. B.; "Clouds and Moonlight," British Astronomical Association, Journal, 64:98, 1954. (X10)
R13. "Moon's Changing Faces Linked to Sunshine," Science News Letter, 86:8, 1964. (X11)
R14. Harrison, J. Park; "Evidences of Lunar Influence on Temperature," Report of the British Association, 1857, part 1, p. 248. (X12)
R15. "The Moon's Influence on the Weather," English Mechanic, 5:309, 1867. (X1)
R16. Broun, John Allan; "Cosmic Meteorology," Nature, 18:126, 1878. (X1)
R17. Oliver, John W.; "The Moon and the Weather," Popular Science Monthly, 32:473, 1888. (X1)
R18. Henkel, F. W.; "The Moon and the Wea-

ther," Symons's Meteorological Magazine, 48:72, 1913. (X10)

GWC12 The Morning Glory Phenomenon

Description. Long, spectacular roll clouds that advance rapidly in an otherwise nearly cloudless sky, bringing a sudden wind squall but little or no precipitation.

Background. This phenomenon is most impressive in the Bay of Carpentaria and southward into northern Australia. It probably occurs elsewhere, but no reports have been uncovered in the literature searched so far.

Data Evaluation. Of frequent occurrence in Australia. Rating: 1.

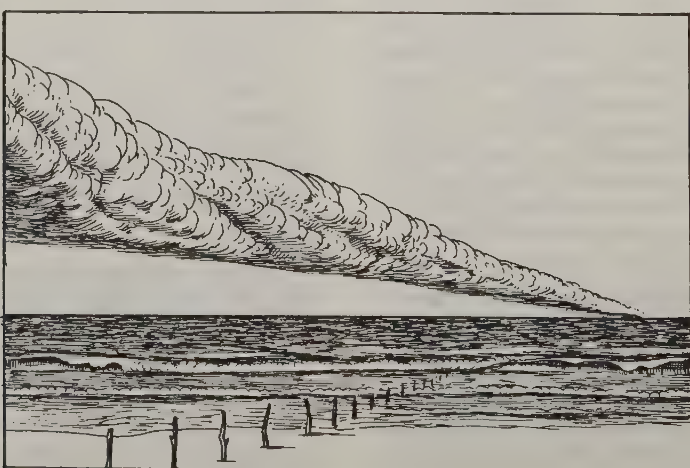
Anomaly Evaluation. In all likelihood the Morning Glory is a low-altitude solitary wave, but its details, especially the conditions that initiate it, are not well understood. Rating: 3.

Possible Explanations. Morning Glories are propagating cloud lines analogous to tidal bores and solitary waves on water surfaces. In scientific parlance they are atmospheric solitary waves or undular bores.

Similar and Related Phenomena. Anomalous cloud lines (GWC10) are similar in shape but do not propagate. Analagous are bores and solitary waves in rivers, estuaries, and some ocean basins (GH). Hollow cylindrical clouds (GWC13).

Examples of the Morning Glory Phenomenon

X1. Frequent occurrence. Gulf of Carpentaria, Australia. "The Morning Glory cloud assumes the form of an arch or bow stretching across the sky but its lateral dimensions are generally uniform along its entire length---the arched appearance to the ground observer being produced by perspective. The cloud is only 100-200 m thick and is very low (the highest base reported is 500 m but some as low as 50 m have been observed). Both the bases and the tops are quite regular and well defined but often the tops are inclined ahead of the bases. This gives a rolling effect but the cloud is not always observed to be actually rotating. One of the most re-



The Morning Glory, a spectacular roll cloud (X1) markable features of the Morning Glory is its great length. Ground observers frequently report it as extending from one horizon to the other, and an aircraft pilot once flew along one for 120 km without coming to the end.....double Morning Glories are commonly reported and as many as seven successive rolls have been observed. They are usually oriented north-north-west to south-south-east and move from east to west at speeds which range from 10 to 25 m s^{-1}. In cases of multiple rolls the whole entourage may take more than an hour to pass. The clouds do not usually produce precipitation but a fine mist sometimes occurs with multiple rolls." (R1-R3)

X2. October 5, 1979. Camooweal, Australia. Two closely spaced, propagating, cumulus cloud lines, extending from horizon to horizon. (R3)

X3. July 25, 1979. Julia Creek, Australia. Horizon-to-horizon cumulus line propagating over a featureless plain at 12 m s^{-1}. (R3)

References

R1. Neal, A. B., et al; "The Morning Glory," Weather, 32:176, 1977. (X1)

R2. Clarke, R. H., et al; "The Morning Glory of the Gulf of Carpentaria: An Atmospheric Undular Bore," Monthly Weather Review, 109:1726, 1981. (X1)

R3. Christie, D.R., et al; "Solitary Waves in the Lower Atmosphere," Nature, 293: 46, 1981. (X1-X3)

GWC13 Long, Hollow, Cylindrical Clouds

Description. Long, white clouds in the shape of hollow cylinders, 300 or so feet in diameter and on the order of 100 miles long.

Data Evaluation. Only a single observation. Rating: 3.

Anomaly Evaluation. Since several reasonable explanations exist, this phenomenon is included primarily for its curiosity value. Rating: 3.

Possible Explanations. A smoke and/or dust trail left by a large, low-altitude meteor; a roll cloud like the Morning Glory (GWC12) at unusual heights; an aircraft contrail (not especially likely in X1 due to date and location).

Similar and Related Phenomena. Anomalous cloud lines (GWC10), the Morning Glory Phenomenon (GWC12).

Examples of Long, Hollow, Cylindrical Clouds

X1. February 7, 1948. North Atlantic Ocean. Altitude: 10,000 feet; time: 1145 GMT. "At this time, an apparent condensation trail was seen overhead against a blue sky. (The pilot) added that he would hesitate to estimate the height to which the east end of the trail was visible, but that it was certainly higher than indicated on the sketch (40,000 feet). As the trail lay almost along the route, the aircraft, by a slight alteration in course, was flown underneath it for 25 minutes and then thru the lower end of the trail. The crew, by looking backwards and upwards from the top of the aircraft, could see into and along the trail. It appeared to be cylindrical, and about 300 to 400 feet in diameter at the level of flight. The diameter of the upper section must have been considerably larger, judging by the clarity with which it could be observed. The upper end of the trail was clearly defined, while the lower end was diffuse and disappeared at about 8,000 feet. The trail was white at all levels, altho the lower end was somewhat darker than the rest....it appeared in a straight line, disappearing into the eastern sky at great altitude, and in places appeared to be composed of spiral-shaped wisps." (R1) The trail length was estimated at 60 miles. Its downward trajectory made a meteoric explanation reasonable. (WRC)

Reference

R1. LaPaz, Lincoln; "A Possibly Meteoric Dust Cloud," Popular Astronomy, 58: 355, 1950. (X1)

GWC14 Cloud Spokes Radiating from Thunderclouds

Description. Cloud bands or ridges extending spoke-like from thunderclouds.

Data Evaluation. Very few observations, and these are rendered doubtful due to the problem of perspective. Rating: 3.

Anomaly Evaluation. Radial cloud structures are rare in meteorology and current theory offers no hints on why cloud spokes should radiate from thunderclouds. Rating: 2.

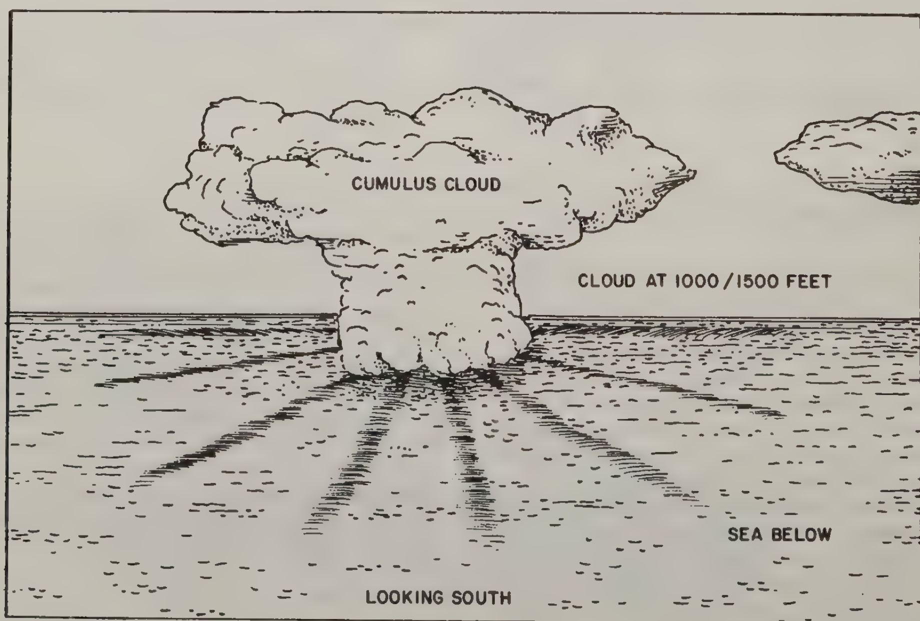
Possible Explanations. Conceivably, a strong central convection cell could set up a swirling pattern with spokes. More speculatively, electromagnetic forces might be involved.

Similar and Related Phenomena. Marine light wheels (GLW4); the banded sky (GLA23); magnetically aligned cirrus clouds (GWC3).

Examples of Cloud Spokes

X1. August 18, 1870. England. "A curious and I think important phenomenon to be investigated is the apparent radiation of luminous streamers or lines of haze from distant thunderstorms. My attention was first drawn to this on August 18th, 1870, when after a very hot day, (88° in shade), an exceedingly violent thunderstorm traversed the western and midland counties of England. The sky was very clear here, but from the distant storm, lines of faintly luminous haze of extreme tenuity appeared to radiate, and retained their position for a very considerable time." (R1)

X2. November 1, 1937. English Channel. A pilot observes a large cumulus near the center of a shallow weather depression. "The main body of the cloud with its anvil-like development is typical of a large cumulus cloud, but the radiating bands extending horizontally from the cloud base are remarkable. A continuous layer of low cloud was observed farther east and it is reasonable to suppose that the air at this level was almost saturated, and so required little upward motion to produce condensation. One is tempted to visualize a wave motion cir-



Bands radiating from a cumulus cloud over the English Channel (X2) culating round the cloud base although it is doubtful whether such an explanation would be dynamically acceptable. Judging from the diagram the bands might, however, be regarded as radiating from a point on the horizon rather than from the cloud base, in which case they would be parallel. The formation might therefore have to be explained as merely an illusion of perspective." (R2)

References

R1. Ingall, Herbert; "Polarization of Haze," English Mechanic, 18:262, 1873. (X1)
R2. "Curious Cloud Formation," Meteorological Magazine, 73:45, 1938. (X2)

GWC15 Great Excess of Ice Crystals in Cumulus Clouds

Description. Concentrations of ice crystals in the summits of slightly cooled cumulus clouds that are two to four magnitudes higher than the surrounding clear air.

Data Evaluation. Evidently a well-verified phenomenon. (R1) Rating: 1.

Anomaly Evaluation. The discrepancy in ice-crystal concentrations infers that some unknown cloud process can multiply crystal concentration. This process is not understood but is probably well within the capacity of today's cloud physics to explain. At least one promising process is at hand. See below. Rating: 3.

Possible Explanation. The author of R1 believes that rimed ice pellets may shed ice splinters as the first step in a rather complex process of crystal generation. See R1.

Similar and Related Phenomena. None.

Examples of Ice Crystal Excess in Cumulus Clouds

X1. General observation. "Perhaps the most puzzling observation in cloud physics reveals that some slightly supercooled cumulous clouds, with summit temperatures only a few degrees below 0^{o} C, contain high concentrations of ice crystals two to four orders of magnitude greater than the concentrations of ice nuclei measured in clear air at the same level. According to a series of careful and detailed aircraft observations and measurements by Mossop and his colleagues, such high concentrations of crystals occur only in aged cumulus that has been in existence for some time and acquired widths of several kilometres but are absent from newly rising cloud towers..... This large discrepancy between the concentrations of ice crystals and of ice nuclei suggests that some process of ice crystal multiplication must be active in the cloud." (R1)

References

R1. Mason, B. J.; "Production of Ice Crystals in Slightly Supercooled Cumulus," Nature, 245:451, 1973. (X1)

GWC16 Cloud Brightness Changes

Description. Certain clouds in aggregations of clouds exhibit marked changes in brightness.

Data Evaluation. A few observations of fair quality. Rating: 3.

Anomaly Evaluation. The nature of the anomaly is not clear because the source of the brightness changes is unknown---optical, electrical, or something else? However, since several possibilities exist (see below) this phenomenon is probably not especially mysterious. Rating: 3.

Possible Explanations. The most likely sources of brightness changes are altered reflecting and/or refracting characteristics of ice crystals within the clouds in question. For example, aerodynamic and electrical forces may change crystal orientation and, of course, the movement of the cloud itself changes the sun-cloud-observer angles. Then, too, the brightness changes may be due to internal electrical action.

Similar and Related Phenomena. Dazzling lights on clouds (GLD15), luminous patches moving on cloud surfaces (GLD16).

Examples of Cloud Brightness Changes

X1. September 27, 1880. Sweden. "A singular phenomenon of clouds was observed on Sept. 27, last year, by M. Hildebrandsson, of Upsala Observatory. About 6.34 p.m. bands of cirro-stratus extended N.E. to S.W.; they were moving slowly S.W. One of the bands, passing Auriga and Polaris, presented rapid changes of brightness. Sometimes it disappeared almost completely, then it would become very distinct again. The band next to it to the S.E. presented the same fluctuations, but in less degree. It was not a mere subjective phenomenon, for another observer perceived the variations. The luminous intensity sometimes remained constant a few minutes; then suddenly varied in a few seconds. The alternations lasted half an hour. The phenomena, it is suggested, may have been due to variations of the electric charge of the cloud; they cannot, apparently, be attributed to variations of illumination by the sun, for the twilight was already faint, and no other clouds than the cirro-stratus appeared in the sky." (R1) These may have been noctilucent clouds. There is also a strong similarity to those daytime clouds that seem to become luminous auroral streamers at night (GLA12). (WRC)

X2. February 25, 1942. Malmesbury, England. "A curious cloud phenomenon never previously seen by the present writer was observed near Malmesbury in Wiltshire on 1942 February 25 at 14 hours U.T., his attention at that time being directed to a patch of very high thin cloud about four degrees in diameter which appeared to shine with a radiance nearly, if not quite, as bright as that of the sun, at the same time exhibiting various prismatic colours, mainly yellow, pale orange and pale violet. The effect lasted at least four minutes and gradually faded away. The sun was shining brightly in a south-westerly direction at an altitude of approximately 25-30°...The curious thing about the luminous cloud...was that it did not appear in the same line of sight as the sun, but about 30° away in a westerly direction. Although there were other and similar clouds in the sky at the same time, none showed the same striking brilliance as the one here described, which was seen by at least four other persons..." (R2) The colors may have been due to iridescence. (WRC)

References

R1. English Mechanic, 32:493, 1881. (X1)
R2. Welsh, Henry; "A Cloud Phenomena," British Astronomical Association, Journal, 52:115, 1942. (X2)

GWC17 Anomalous High-Altitude Haze Layers

Description. Strata of haze, usually undetected from the ground, found by instruments at altitudes above 15 miles.

Data Evaluation. Although only two recent articles discussing the detection of high-level hazes by balloon-borne instruments have been found, it is claimed (R1) that 183 stratospheric clouds were recorded between 1870 and 1972, inferring that high-altitude hazes and clouds ~~and~~ are rather common. (Obviously these very early reports were ground observations and may have included noctilucent clouds.) Nevertheless, we are probably safe in assuming that high-altitude hazes are well-attested. Rating: 1.

Anomaly Evaluation. The presence of haze above 15 miles is classified as anomalous because the sources are not known with any certainty. Also problems are the evident stability and wide geographic dispersal of the haze layers. Rating: 2.

Possible Explanations. Particulate matter may be injected into high-levels of the stratosphere by volcanic eruptions, meteors, and the solar wind.

Similar and Related Phenomena. Noctilucent clouds (GWC6), low-level hazes, bright night skies (GLA13), the white sky phenomenon (GWC1).

Examples of High-Altitude Hazes

X1. June 20, 1974. New Mexico. Balloon-borne instruments reveal a large haze layer at 25 kilometers. (R1)
X2. February 5, 1982. Wyoming. Balloon experiments detected a 'mystery cloud' at 20 miles (32 kilometers). Author claims this is too high for volcanic ejecta (?). (R2)

References

R1. Gibson, Frank W.; "A Rare Event in the Stratosphere," Nature, 263:487, 1976. (X1)
R2. "2d, Higher 'Mystery Cloud' Found by Wyo. Scientists," Baltimore Sun, March 12, 1982, p. A3. (X2)

GWD DARK DAYS, FOGS, AND OTHER OBSCURATIONS

Key to Phenomena

GWD0 Introduction
GWD1 Dark Days and Obscurations of the Sun
GWD2 Pogonips and Other Ice Fogs
GWD3 Mists and Epidemics
GWD4 Dry Fogs and Dust Fogs

GWD0 Introduction

A dark day is not merely the veiling of the sun by ordinary clouds---they at least let through enough light to conduct the business of the world. On a dark day the pall of darkest night descends suddenly, chickens go to roost, and men and women pray and grope for candles, although not necessarily in this order. New England's famous Dark Day of 1780 is typical of the genre.

The standard explanation of the dark day is smoke from forest fires in the hinterlands or perhaps some unrecorded volcanic eruption. These are reasonable surmises because many dark days are accompanied by black rain that is thick with soot and ashes. Wind, goes the theory, carries these combustion products hundreds of miles from their origin and blots out the sun in the process. Sometimes, though, the darkness seems irrational, descending suddenly without the approach of ominous dark clouds. Not infrequently, forest fires commensurate in size with the dark day are never found. In America, they were "out west" somewhere---set by the Indians. This sufficed in the pioneer days when the forests of an entire state could be consumed without New Englanders ever hearing about it. While admitting that forest fires are very likely the cause of most dark days, we should not ignore the fact that some scientists have proposed that some forest-fire-less dark days might have been due to comet tails or cosmic matter obscuring the sun.

Superficially, fogs and mists would seem to present little grist for the anomaly mill. But diligent research among the older journals brings to light the supposedly deadly ice fogs, the pogonips, the curious association of "blue mists" and cholera outbreaks, and certainly not least the near-global, self-luminous dry fogs of 1783 and 1831, when one could read out-of-doors at midnight on the highest mountain and in the deepest valley.

GWD1 Dark Days and Obscurations of the Sun

Description. Periods when abnormal darkness descends upon a region. The sun may be obscured or weakened for anywhere from a few minutes to several days. In some instances, the stars may be visible; in most cases the entire sky is darkened. Many dark days are accompanied by yellowish clouds and black precipitation, signifying considerable particulate matter in the atmosphere. The areas afflicted may be just a few square miles or continent-sized.

Background. Dark days and solar obscurations are some of the oldest recorded anomalies of nature, beginning even before the strange darkness of the crucifixion. Many of the old tales are indeed mysterious, but only because of distortions and poor observation. Most modern dark days are found to have easily explained origins. Since there are several possible origins, this is a composite category lumping weather, incendiary, volcanic, and astronomical events into one class.

Data Evaluation. Dark days and solar obscurations have occurred throughout historical times. Old reports are vague but those of the last century are good. Rating: 1.

Anomaly Evaluation. The reduction of sunlight by smoke, volcanic ash, or menacing clouds can only be considered as curious. But if, during normal daylight hours, the sunlight fails and the stars are seen, common terrestrial obscuring agents can be ruled out, and a significant anomaly exists. An anomaly may also exist if the area afflicted by smoky and/or dust blankets is not commensurate with possible sources; viz., forest fires, volcanic eruptions, etc. Of course, one can always maintain, even today, that dark days are due to some distant, unrecognized source. A century ago, dark days, often as not, were blamed on Indians burning the prairies somewhere "out west." Generally, dark days will have prosaic explanations. Rating: 3.

Possible Explanations. Almost all of those dark days during which both the sun and stars are blotted out can be explained in terms of: (1) forest fires; (2) volcanic eruptions; (3) dust storms; and (4) intense storms, perhaps augmented by natural or artificial air pollution. When the stars appear during a dark day, one must search for extraterrestrial sources, such as cosmic material veiling the sun---a very unlikely situation.

Similar and Related Phenomena. Solar eclipses, unusual fogs (GWD4). Some major earthquakes have been accompanied by curious darknesses (GQE).

Examples of Dark Days and Other Obscurations

X1. 44 BC. Europe. The sun was pale for a whole year. (R12)

X2. 30. Middle East, Egypt. "The crucifixion of Christ was signalised by phenomena in nature the most extraordinary and terror-striking. The material creation seemed to have been moved into convulsive throes of sympathy with the last agonies of the Son of God. The sun refused to shine, and the earth robed herself in mourning. From the sixth hour there was darkness over all the land until the ninth---that is, from twelve o'clock, our mid-day, until three in the afternoon. All the region around Jerusalem was wrapped in a mysterious gloom. This darkness was not a natural event, and it was not a common eclipse of the sun, for it was at the time of the Passover, and that was set at full moon, when an eclipse is impossible. Besides a total eclipse can never last longer than a quarter of an hour. It is reported that Dionysius in Egypt observed this portentous gloom, and exclaimed, 'Either the God of Nature is suffering, or the machine of the world is tumbling into ruin.'" (R19)

X3. 96. Ephesus, Greece. Disc of sun obscured so that Philostratus observed the corona. No eclipse that year. (R39)

X4. August 22, 358. Two hours of darkness followed by an earthquake. Probably in Europe. (R12)

X5. 409. Europe. Stars visible during the day. (R12)

X6. 536. Europe. Stars visible during the day. (R12)

X7. 567. Europe. Stars visible during the day. (R12)

X8. 626. Europe. Stars visible during the day. (R12)

X9. August 19, 733. Europe. Sun was darkened. (R12)

X10. 934. Europe. Sun lost its light. (R12)

X11. September 29, 1091. Europe. The sun was darkened for three days. (R12) Many meteors.

X12. February 12, 1106. Europe and Brazil. Sun darkened. Many meteors seen. (R12, R8) An extraterrestrial event? (WRC)

X13. February 28, 1206. Europe. Six hours of complete darkness. (R12)

X14. 1208. Brazil. Solar obscuration. (R8)

X15. 1241. Europe. Stars seen during the day. (R12)

X16. April 23, 1547. Europe, Brazil. Sun the color of blood; many stars appeared during the daytime. (R7, R8, R10, R12, R39) Once again a date coincidence on opposite sides of the Atlantic. Some sort of astronomical event may be inferred here. (WRC)

X17. 1706. Brazil. Obscuration of the sun. (R7, R8)

X18. 1574. Europe. The sun was darkened for 18 days. (R11)

X19. May 12, 1706. New England. (R26)

X20. October 21, 1716. New England. Extraordinary darkness at midday. (R15, R26)

X21. August 9, 1732. New England. (R26)

X22. October 19, 1762. Detroit, Michigan. "A man in business seldom troubles himself about news; yet the following is so uncommon, I cannot neglect acquainting you therewith. Tuesday last, being the 19th instant, we had almost total darkness for most of the day. I got up at daybreak; about 10 minutes after I observed that it got no lighter than before; the same darkness continued until 9 o'clock, when it cleared up a little. We then, for the space of about a quarter of an hour, saw the body of the sun, which appeared as red as blood, and more than three times as large as usual. The air all this time, which was very dense, was of a dirty yellowish green color. I was obliged to light candles to see to dine, at 1 o'clock, notwithstanding the table was placed close by two large windows. About 3 o'clock, the darkness became more horrible, which augmented until half past three, when the wind breezed up from the S. W. and brought on some drops of rain, or rather sulphur and dirt, for it appeared more like the latter than the former, both in smell and quality. I took out a leaf of clean paper and held it out to the rain, which rendered it black whenever the drops fell upon it; but when held near the fire, turned to a yellow color, and when burned, it fizzed on the paper like wet powder. During this shower, the air was almost suffocating with a strong sulphur smell; it cleared up a little after the rain. There were various conjectures about the cause of this natural incident. The Indians and uneducated among the French, said that the English, which had lately arrived from Niagra in the vessel, had brought the plague with them; others imagined it might have been occasioned by the burning of the woods. But I think it most probable, that it might have been occasioned by the eruption of some volcano, or subterraneous fire, whereby the sulphurous matter may have been emitted in the air, and contained therein, until, meeting with some watery clouds, it has fallen down together with the rain." (R26, R40)

X23. May 19, 1780. New England. "This was the famous dark day of Friday, May 19, 1780, that extended over nearly all of New England. One of the many eyewitness reports still extant is a letter by Jeremy Belknap of Boston. He tells that the forenoon had been cloudy, and about 10 or 11 o'clock the clouds assumed a strange yellowish hue, which tinted all the landscape. An hour later the light began to fail, and by 1 o'clock the darkness was so great that candles were lighted and kept burning all afternoon. The atmosphere was not simply dark, said Dr. Belknap, but seemed full of 'the smell of a malt-house or a coal-kiln.'" (R32) The precipitation that fell was found to be thick, dark, and sooty. (R35) Many other articles mention this famous phenomenon. (R3, R14, R15, R26, R27)

X24. October 16, 1785. Quebec, Canada. Several periods of intense darkness. Yellowish clouds came from the northeast. Black rain. Standing water found with a yellow substance floating on the surface, which was thought to be sulfur. (R2, R26) See GWF3 for "sulphur" falls.

X25. July 3, 1814. New England and eastern Canada. Darkness due to clouds carrying dust and wood ashes. (R2, R26) But see X26.

X26. 1814. Borneo. It was pitch black for 3 days due to volcanic dust from Timboro Mountain 300 miles away. (R9) See X25.

X27. November 6-10, 1819. Eastern North America. "The darkness was so great (at Middlebury, Vermont), that a person, when sitting by a window, could not see to read a book, in small type, without serious inconvenience. Several of the students in the college studied the whole day by candle-light. A number of the mechanics in this village were unable to carry on their work without the assistance of lamps. The sky exhibited a pale yellowish-white aspect, which, in some degree, resembled the evening twilight a few moments before it disappears. Indeed we had little else but twilight through the day; and such, too, as takes place when the sun is five or six degrees below the horizon. The colour of objects was very remarkable. Every thing I beheld wore a dull, smoky, melancholy appearance. The paper, on which I was writing, had the same yellowish -white hue as the heavens. The fowls showed that peculiar restlessness that was remarked in them during the total eclipse of the sun 1n 1806. Some of them retired to roost. The cocks crowed several hours incessantly, as they do at the dawning of day." (R1) The phenomenon began on the 6th in New York State. On the 12th, residents of Georgia experienced a smoky atmosphere that irritated the eyes. (R1, R13, R26)

X28. July 8, 1836. New England. (R26)
X29. March 23, 1857. Europe. Gloom spread over the heavens, followed by 8 minutes of extreme darkness. (R5)
X30. May 20, 1857. Bagdad, Iraq. An extraordinary darkness. Much dust fell. (R4) Very likely a sandstorm. (WRC)
X31. April 11, 1860. Brazil. Several minutes of darkness. Venus visible. (R7, R8) R7 gives the date as April 18, but it is evidently derived from R8, which has April 11.
X32. October 16, 1863. Canada. (R26)
X33. September 15 through October 20, 1868. Western Oregon and Washington. (R26)
X34. September 6, 1881. New England. The Yellow Day. Clouds of smoke from forest fires in Michigan and Ontario made everything seem yellow. (R36) (R26)
X35. January 22, 1882. London, England. Not foggy but just like night at midday. (R16)
X36. April 26, 1884. Stonyhurst Observatory, England. Dense black clouds with yellowish tint. Black rain fell. (R17)

X37. March 19, 1886. La Crosse, Wisconsin. "A most remarkable atmospheric phenomenon occurred here at 3 p.m. The day was light, though cloudy, when suddenly darkness commenced settling down, and in five minutes it was as dark as midnight. General consternation prevailed; people on the streets rushed to and fro; teams dashed along, and women and children ran into cellars; all business operations ceased until lights could be lighted. Not a breath of air was stirring on the surface of the earth. The darkness lasted from eight to ten minutes, when it passed off, seemingly from west to east, and brightness followed. News from cities to the west say the same phenomenon was observed there is advance of its appearance here, showing that the wave of darkness passed from west to east. Nothing could be seen to indicate any air currents overhead. It seemed to be a wave of total darkness passing along without wind." (R18) Obviously, this was not the usual low-level concentration of smoke. (WRC)

X38. October 1886. Durkhamshire, England. (R20)
X39. November 19, 1887. Ohio River Valley. The Smoky Day. (R26)
X40. April 2, 1889. Aitken, Minnesota. Darkness accompanied by dirty snow. (R21)
X41. September 2, 1894. New England. (R26)
X42. July 1896. All of Siberia. Immense area covered with smoke for 11 days. No fires or volcanic sources found. (R22)
X43. September 12, 1902. Western Washington. Everything was reddish, and one could not read outdoors. No forest fires found to explain phenomenon. (R23, R26)
X44. June 5, 1903. Saratoga, New York. (R26)
X45. April 15, 1904. Wimbleton, England. Like a tunnel of darkness, with light at either end. Lasted 10 minutes. (R24)
X46. December 2, 1904. Memphis, Tennessee. 15 minutes of darkness. (R26)
X47. June 30, 1908. Caterham Valley, England. Sudden onset of darkness that lasted 1/2 hour. (R25) Note that this dark day coincided with the famous Tunguska Event or Siberian Meteor. (WRC)
X48. August 20-25, 1910. Northern United States from Idaho to St. Lawrence River. (R26)
X49. March 11, 1912. Sussex, England. Inky blackness with blood rain. (R29)
X50. February 28, 1923. New York, New York. So dark that all offices and vehicles had lights on. (R28)
X51. November 1924 or 1925. London, England. At 1145 it got darker and darker, by 1150 it was pitch black, but at 1159 the darkness disappeared in a flash. (R37)

X52. September 18, 1938. Northwestern Siberia, between 70 and 90° east longitude and 65 to 69° north latitude. "The records that Yemilianov has collected from documents and eyewitnesses tell of a darkness like deep twilight, with a yellow cast to the sky, lasting for several hours. This description recalls the New England 'dark day' of May 19, 1780 which is known to have been the result of smoke from forest fires. However the Siberian event cannot be so explained, according to Yemilianov. From a comparison of the times of onset of the darkening at different places, he calculates that it was traveling east north east at approximately 100 kilometers per hour. He believes it probable that the black cloud first appeared nearly simultaneously over an area about 300 kilometers in diameter. He points out further that all but one of the eyewitnesses he interviewed did not mention any odor, such as wood smoke occasion. Yemilianov therefore concludes that the Siberian darkening was probably caused by a dense compact cloud of cosmic dust that entered the earth's atmosphere." (R33, R34)

X53. January 16, 1955. London, England. Abnormal smoke belt 1 1/2 miles wide caused 6-10 minutes of extreme darkness. (R30)

X54. December 1, 1961. London, England. (R31)

X55. April 30, 1971. Jacksonville, Florida. "An ominous overcast lowered over downtown Jacksonville as the NWS issued a tornado warning in response to a suspicious radar cell 48 km to the west. By 1030 EST, the sky turned nearly black. Lights and street lamps came on and birds circled to roost. An eerie silence fell over the city. There was no thunder and no rain." (R38) A typical darkness due to extreme weather conditions. (WRC)

X56. Circa 1800. Amsterdam, Holland. On a bright summer day, total darkness descended about noon. It was so dark that many lost their lives when they fell into canals. (R6)

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GWD2 Pogonips and Other Ice Fogs

Description. A winter fog occurring in high elevations characterized by the rapid crystalization of ice on animals and objects. Inhalation of ice fog is reputed to cause death.

Background. Dangerous ice fogs are said to occur in many highly elevated areas, but the pogonip of Nevada is the only such fog treated in the literature examined so far.

Data Evaluation. The few reports found on ice fogs or pogonips have a sensational aspect and cannot be taken too seriously. Rating: 3.

Anomaly Evaluation. The reputed dire biological effects of ice fogs, if true, have not been explained to the compiler's knowledge. Near-instant death upon inhaling fog would certainly tax medical theory. Rating: 2.

Possible Explanations. For the extreme biological effects reported, none.

Similar and Related Phenomena. Mists and epidemics (GWD3), where once again unusual weather conditions are blamed for biological effects.

Examples of Ice Fogs

X1. General observation. Nevada. "A curious phenomenon is often witnessed in the mountainous districts of Nevada. Mountaineers call it 'pogonip,' and describe it as being a sort of frozen fog that appears sometimes in winter, even on the clearest and brightest of days. In an instant the air is filled with floating needles of ice. To breath the pogonip is death to the lungs. When it comes, people rush to cover. The Indians dread it as much as the whites. It appears to be caused by the sudden freezing in the air of the moisture which collects about the summits of the high peaks." (R1, R2) W. J. Humphreys denies that the pogonip can cause death. (R3)

References

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R3. "Expert Discusses Probable Causes of Fog Deaths," Science News Letter, 18: 383, 1930. (X1)

GWD3 Mists and Epidemics

Description. The correlation of epidemics, particularly cholera outbreaks, with persistent mists or fogs.

Data Evaluation. The evidence linking mists to cholera epidemics is purely circumstantial and unsupported by scientific observations. The tales about "blasting fogs" are extracted from popular histories and are also suspect. Rating: 3.

Anomaly Evaluation. Although swampy and poorly drained areas are often associated with malaria, cholera, and other diseases, fogs and mists in themselves should not be responsible for disease. If blue mists and blasting fogs, as described below, are truly involved in epidemics, we have an important anomaly. Rating: 2.

Possible Explanation. The association of mists and cholera is probably just coincidental. It is possible that extreme cold and dampness (blasting fogs) could weaken plants and encourage rusts and other plant diseases.

Similar and Related Phenomena. The theorized influx of viruses and bacteria from outer space via cosmic dust.

Examples of Fogs or Mists Correlated with Disease

X1. 1832. England. Correlation of a blue mist and cholera. (R1)

X2. 1848-1849. England. Correlation of a blue mist and cholera. (R1)

X3. 1854. England. Correlation of a blue mist and cholera. (R1)

X4. 1866. Greenwich, England. "According to Mr. Glaisher, there was a particular state of the atmosphere during the three epidemics of cholera in 1832, 1848-1849, and 1854, characterised by a prevalent mist, thin in high places, dense in low. On the 30th ult. this gentleman, while looking from the grounds of the Royal Observatory, Greenwich, under the trees towards the boundary walls of the park, saw a dense blue mist (similar to what he had observed in 1854), which continued without intermission to the 6th inst. Ordinary mists pass away with the wind blowing at a pressure of half a pound to the square foot; but this mist was immovable before a wind blowing at a pressure of nine pounds on the same area. It was apparent on all sides, and extended fully to the tops of the trees, though not there so easy to distinguish. It was most easily discernible through as much atmosphere as possible, viewed from under a tree and looking under other trees. Thus seen, the boundary walls of Greenwich park and all objects near them were coloured blue. When looked at through gaps in trees, if there were others at a sufficient distance to form a background, it resembled thin smoke from a wood fire. The intensity of the blue was increased when viewed through a telescope with a low power. The only other mist which Mr. Glaisher knows connected with the prevalence of an epidemic is a yellow mist perceptible when scarlatina is prevalent." (R1) Blue mist seen on the Isle of Wight during the cholera epidemic. (R2)

X5. Early December 1930. Belgium. A dense fog was followed by 40 human and many animal deaths. Mud rains in parts of Europe. The deaths, however, were probably due to a high concentration of industrial pollutants under a temperature inversion. (R3, R4) Much was made of this incident at the time, but it seems identical to modern smog deaths. (WRC)

X6. August 1694. Scotland. "During the night, a raw east wind from the North Sea blew over the county of Cromarty, to the north of Loch Ness, and was accompanied by a dense sulphur-smelling fog. The superstitious peasants opined that it was coming straight from the mouth of Hell. As dawn broke, this strange fog was already lifting in spots, but in many places it was heaped up in what was said to be like 'mountains of vapor', towering over valleys and dales. Soon, however, these too dissipated under the sun's rays---but a ghastly prospect was presented to the eye in the oatfields where the grain had been ripening with every indication of an early and bounteous harvest. A sort of mildew lay sprinkled on both blade and ear; as the sun shone on it, this mildew whitened and took on the appearance of flour, while the affected parts of the plants shrank and shriveled. In a few hours it was apparent that almost the entire crop had been destroyed---the worst devastation being in those fields over which the poisonous fog had lain the longest." (R5) There is some similarity between these "blasting fogs" and salt storms. See GWF4-X2. (WRC)

X7. August 1720. Scotland. A "blasting fog" similar to that in X6. (R5)

References

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GWD4 Dry Fogs and Dust Fogs

Description. Widespread hazes consisting of very fine, dry particles, usually dust, suspended in the air. Visibility in dust fogs is frequently severely limited, and the sun and moon are highly colored. Breathing may be impaired, and some experience a general malaise. Dust fogs may cover continent-sized areas and contribute to colored precipitation hundreds of miles from the dust's origin. Some dust fogs have seemed to be self-luminous at night.

Background. The Cape Verde dust fogs or red fogs have been recorded for centuries, not only far out into the Atlantic but far into Europe.

Data Evaluation. The true dust fogs have been described frequently. The more enigmatic dry fogs of 1783 and 1831, which afflicted much of the globe, are often mentioned in the older literature, but no scientific studies have yet been uncovered. Rating: 1.

Anomaly Evaluation. The frequent dust fogs radiating out from North Africa and the East Indies are included in this Catalog because, even though they are well-known and basically understood, they are remarkable in their geographical extent and meteorological effects. The following rating applies only to the great luminous dry fogs (as exemplified by the 1783 episode), which present serious problems in explanation. Rating: 2.

Possible Explanations. It is difficult to come to grips with the global dry fogs. One scientist proposed that the earth passed through a comet's tail in 1783. The luminosity of these dry fogs at night makes them resemble low-level auroras, which may mean they have an electrical origin.

Similar and Related Phenomena. Similar phenomena: low-level auroras (GLA4), auroral fogs and mists (GLA21). Phenomena that may be related: glowing night skies (GLA13), the white sky phenomenon (GWC1).

Examples of Dry Fogs

X1. Summer 1783. Much of the earth. A peculiar fog. "...it began on the 18th of June and at places very remote from each other. It extended from Africa to Sweden, and throughout North and South America. This Fog continued more than a month. It did not appear to be carried to different places by the atmosphere; because in some places it came on with a north wind and at others with a south or east wind, it prevailed in the highest summits of the Alps as well as in the lowest valleys. The rains which were very abundant in June and July did not appear to disperse it in the least. In Languedoc its density was so great that the Sun did not become visible in the morning till it was twelve degrees above the horizon; it appeared very red during the rest of the day and might be looked at with the naked eye. This Fog or Smoke had a diagreeable smell and was entirely destitute of any moisture, whereas most fogs are moist; besides all this there was one remarkable quality in the Fog or Smoke of 1783, it appeared to possess a phosphoric property, or a light of its own. We find by the accounts of some observers, that it afforded even at midnight a light equal to that of the full moon, and which was sufficient to enable a person to see objects distinctly at a distance of two hundred yards, and to remove all doubts as to the source of this light, it is recorded that at the time there was a New Moon." (R2) Also seen in Asia. Blamed on an eruption of Mount Hecla. (R1) First seen in Scandanavia on May 29, 1783. (R11) Also mentioned in many other articles. (R4, R12-R13)

X2. August 1821. Western Europe. This dry fog was similar to that of 1783 and lasted 12 days. (R4)

X3. May 1822. Europe. Another dry fog appeared suddenly. (R4)

X4. 1831. Almost worldwide. One could look directly at the sun. Nights were so bright that the smallest print could be read at midnight. (R4, R13, R14)

X5. Frequent occurrence. From Cape Verde hundreds of miles out into the Atlantic plus much of western Europe. The folowing account is from Teneriffe, in the Canary Islands. "From the first hours of the evening of February 15 (1898), there was observed a sensible but light fog; neither the strength of the wind (E. gentle breeze) nor any other phenomenon indicated that the supposed condensed vapours could be African dust transported by air. As the night advanced, the force of the wind increased, until it reached the value of a moderate gale. At about 5 a. m. on the 16th, some large drops of rain fell, but were inappreciable in the rain gauge. For a very short time the wind subsided, by and by again becoming a gentle breeze during the day and blowing due E. The fog became more dense, causing depression and a disagreeable feeling produced by its dryness. The sun, on account of its light being pale and feeble without the usual rays, was confounded with the moon; and it reminded one of the light of a voltaic arc seen through a frosted glass. The flame of a match appeared with a very marked violet hue. The drinking waters became salty and coloured as by oxide of iron. The dust was grey and extremely fine, and deposited itself on every object." (R6) (R3, R5, R7, R10)

X6. Frequent occurrence. East Indian Archipelago. The dry fog of 1914. "The fog had a grey colour, and was most intense in the month of September, and especially in October, and disappeared when the rains fell. In its most typical form it appeared in Sumatra, in the neighborhood of Ambon and the islands to the southeast. . . . In the morning the sun was not visible before eight o'clock, when it appeared as a dim red disc. Objects in general were barely visible at 500 metres' distance, and on the thickest days invisible within half this distance; the mountains had disappeared entirely from view." (R9) Another major recurrence in October 1902. (R8)

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R14. "Luminosity," Nature, 125:33, 1930. (X4)

GWF FALLS

Key to Phenomena

GWF0 Introduction
GWF1 Ice Falls or Hydrometeors
GWF2 Stone Falls
GWF3 Sulphur/Pollen Falls
GWF4 Falls of Miscellaneous Inorganic Substances
GWF5 The Fall of Manna
GWF6 Unusual Falls of Hay and Leaves
GWF7 Gelatinous Meteors or Pwdre Ser
GWF8 Prodigious Falls of Web-Like Material
GWF9 Falls of Miscellaneous Organic Substances
GWF10 Fish Falls
GWF11 Falls of Frogs and Toads
GWF12 Insect Falls
GWF13 Bird Falls
GWF14 Falls of Miscellaneous Living Animals

GWF0 Introduction

Anomalous rain, snow, and hail are treated in the next chapter. Beyond these "nearly normal" forms of precipitation are those falling materials that do not belong aloft at all: large chunks of ice, living animals, non-meteoric stones, and many other nominally terrestrial materials. Charles Fort made much of falling materials, even though most of them can be explained rationally by appealing to recognized meteorological mechanisms; i.e., whirlwinds, waterspouts, tornados, etc. Fort did have a point, however, that any small minority of falling material not succumbing to conventional explanations would require truly revolutionary explanations. Such is the claim of residual anomalies in all areas of science---and this claim is perfectly valid in this chapter.

The overwhelming majority of falls consist of terrestrially derived material and earth-dwelling animals. So-called sulphur falls almost invariably turn out to be wind-blown pollen. The sensationalized falls of fish and frogs, which are well-verified in the literature, are easily explained in terms of whirlwinds, waterspouts, and tornados. Immense falls of hay, leaves, and insects, though startling, are scarcely anomalous. Nature provides ready sources of such material as well as natural vacuum cleaners to snatch up light-weight objects and deposit them somewhere else. Even so, these types of falls present some enigmatic aspects: (1) The descent of some species of animals is so overwhelming in quantity that scientists are hard-pressed to explain where they could have all been collected; (2) The "purity" of the falls; that is, the absence of coexisting species and debris from the falling animals' habitat.

Falls of cobwebs and the so-called gelatinous meteors (or "pwdre ser") introduce a more unsettling factor. While admitting the reality of ballooning spiders, it seems that some of the great web falls involve a substance that may not be insect-produced---it is too strong and quickly evaporates away. It also falls in strands hundreds, even thousands of feet long. Some gelatinous meteors, too, seem to evaporate away strangely. If these properties can be verified, we have something more anomalous than a simple fish fall.

Another pair of phenomena with related characteristics will conclude this introduction: the large hydrometeors and the much-maligned thunderstone. Both phenomena typically occur during thunderstorms. A peal of thunder rings out and something strikes the ground nearby. If one finds a large chunk of ice, a passing plane can always be blamed; but if one finds a stone or even a meteor emotional disbelief takes charge. Yet, no physical reason bars the fall of meteorites during thunderstorms, nor can one deny the possibility of a strong whirlwind picking up a stone of several pounds weight and releasing it during a thunderstorm. After all some large hailstones reach several pounds, too. The point here is that the possibility of stonefalls should not be dismissed out-of-hand because of any innate distrust of legends carried over from ancient times.

The data presented below show rather conclusively that odd things do fall from the sky on occasion. Regardless of the sensationalism usually attached to these falls, most of them are not really very anomalous. A rain of frogs may be rare and certainly Fortean, but meteorology is well-equipped to deal with most aspects of this phenomenon.

GWF1 Ice Falls or Hydrometeors

Description. Chunks of ice that fall from the sky that are substantially larger than the largest recognized hailstones; that is, more than five inches in diameter or weighing more than 2 pounds. The ice pieces may fall from a clear sky or they may descend after a powerful stroke of lightning. The chunks may be clear ice, or layered structures, or aggregations of small hailstones. This diversity of structure and meteorological conditions suggests that ice falls may have several different origins.

Background. Today, the fall of large ice chunks is usually blamed on aircraft passing overhead. Certainly, aircraft constitute a likely source, but there are many pre-Wright examples of this phenomenon. Furthermore, aircraft can be ruled out in some modern cases. Nevertheless, it seems that most people are satisfied with the aircraft explanation---perhaps because other origins are difficult to imagine.

Data Evaluation. Some of the older data may seem apocryphal (viz., X1), but there are so many modern ice falls, some investigated by meteorologists, there no one can deny that large ice chunks do fall from the sky on occasion. Rating: 1.

Anomaly Evaluation. Given the fact of ice falls, it seems that large ice chunks weigh so much that the prevailing theory of hail formation in storm cells is inadequate to explain them. The vertical winds in hailstorms do not seem powerful enough to support the large pieces of ice under discussion here. In fact, some modern ice falls are so large that the customary "aircraft" explanation would seem to be wanting. Rating: 2.

Possible Explanations. (1) The vertical winds in storm cells are much stronger than generally recognized; (2) Some unappreciated mechanism in hailstorms permits the sudden aggregation of many hailstones; (3) Those hydrometeors that fall after severe lightning strokes may be formed in the lightning discharge channels, possibly as a result of electrostatic forces; (4) Some ice chunks may be true meteors, i.e., from outer space. This last explanation has been ridiculed in the past but some meteorologists are now seriously proposing it, noting in passing that Saturn's rings may be composed of ice chunks.

Similar and Related Phenomena. The fall of meteor-like objects during thunderstorms (GWF2); giant snowflakes (GWP2); giant hailstones (GWP5).

Examples of Ice Falls

X1. Late 1700s. Seringapatam, India. A block of ice as big as an elephant fell during the reign of Tippoo Sahib. It took three days to melt. (R1-R3) This purported event has always been a subject of derision. (WRC)

X2. May 8, 1802. Hungary. Mass of ice 3 feet long, 3 feet wide, and more than 2 feet thick fell during a storm. (R4, R5)

X3. May 12, 1811. Derbyshire, England. Lumps of ice a foot in circumference. (R4)

X4. July 24, 1818. Orkney Islands, Scotland. Jagged pieces of ice, some a foot long. When melted they emitted a sulphurous odor. (R4)

X5. 1826. Khandeish, India. A block of ice with a volume of a cubic yard. (R2, R4) (R3) The date is sometimes given as 1828.

X6. June 15, 1829. Cazorla, Spain. A block weighing 2 kilograms. (R5)

X7. April 1838. Dharwar, India. A mass of hailstones measuring 20 feet in its largest dimension. (R1, R2) (R3)

X8. May 22, 1838. Near Bangalore, India. Immense mass of hailstones cemented together found in a well. (R2, R3)

X9. October 1844. Cette, France. A block of ice weighing 5 kilograms fell. (R4, R5)

X10. August 1849. Scotland. "A curious phenomenon occurred at the farm of Balvullich, on the estate of Ord, occupied by Mr Moffat, on the evening of Monday last. Immediately after one of the loudest peals of thunder heard there, a large and irregular-shaped mass of ice, reckoned to be nearly 20 feet in circumference, and of a proportionate thickness, fell near the farmhouse. It had a beautiful crystalline appearance, being nearly all quite transparent, if we except a small portion of it which consisted of hailstones of uncommon size, fixed together. It was principally composed of small squares, diamond-shaped, of from 1 to 3 inches in size, all firmly congealed together. The weight of this large piece of ice could not be ascertained; but it is a most fortunate circumstance, that it did not fall on Mr Moffat's house, or it would have crushed it, and undoubtedly have caused the death of some of the inmates. No appearance whatever of either hail or snow was discernible in the surrounding district." (R4-R8)

X11. May 22, 1851. Bangalore, India. Ice masses as large as pumpkins. (R4)

X12. August 1857. Cricklewood, England. 25-pound mass of ice found on ground. Assumed to have fallen there. (R4)

X13. March 16, 1860. Upper Wasdale, England. Blocks of ice fell in a snowstorm. Looked like a flock of sheep on the ground. (R4)

X14. June 1881. Iowa. Mass of ice 21 inches in circumference falls with hail. (R4)

X15. August 1882. Salina, Kansas. An 80-pound hailstone. (R4, R9)

X16. December 6, 1893. Texas. A 4-pound lump of ice fell. (R4)

X17. August 1897. Scotland. "... a thunderstorm accompanied by heavy hail, although the hailstones were generally noted to be no larger than usual. However, shortly after the storm had passed away, at about 5 p.m., a shepherd saw what appeared to be a sheep lying prostrate on the ground. On closer inspection he found it to be a block of ice which he estimated to weigh about 50 kg. By the next morning this hadn't melted away but had broken up into smaller pieces."(R10)

X18. September 11, 1949. Stephens County, Texas. A 40-pound chunk of ice lands 15 feet from a Dr. Robert Botts. (R4)

X19. November 10, 1950. Bristol Channel, England. A chunk of ice weighing 14 pounds kills a sheep. Other large chunks found on ground. (R4)

X20. November 24, 1950. London, England. A piece of ice about a cubic foot in size smashes through a garage roof. (R4)

X21. November 30, 1950. Hampstead Norris, England. An ice block, 15 inches long, 7 inches wide, 4 inches thick, falls into a garden. (R4)

X22. December 26, 1950. Dunbarton, Scotland. Man sees a mass of ice fall on road and smash to pieces. 112 pounds of ice collected. (R4)

X23. 1951. Kempten, Germany. A carpenter working on a roof was killed by a piece of falling ice 6 feet long and 6 inches round. (R4)

X24. June 4, 1953. Long Beach, California. Fifty ice lumps, some weighing 75 kilograms each, fell. Total weight about 1 ton. (R5)

X25. January 1955. Los Angeles, California. Large chunks of ice fall, weighing between 6 and 26 pounds. (R4)

X26. July 30, 1957. Reading, Pennsylvania. Man and wife see a piece of ice 2 feet in diameter fall near them. (R4)

X27. January 26, 1958. San Rafael, California. Slab of ice, 2 feet square and several inches thick fell through the roof of a house. (R4)

X28. September 8, 1958. Chester, Pennsylvania. Large ice chunk crashes through the roof of a warehouse. (R4)

X29. 1959. Toccoa, Georgia. 30-pound ice chunk falls. (R4)

X30. September 11, 1959. Buffalo, New York. Ice chunk 1 foot long narrowly misses a child. (R4)

X31. December 1959. London, England. Basket-ball-sized ice mass damages a house. (R4)

X32. October 16, 1960. Melbourne, Australia. Two ice lumps the size of footballs just miss two golfers. (R4)

X33. February 1965. Woods Cross, Utah. 50-pound ice mass fell through the roof of the Phillips Petroleum Plant. (R4)

X34. February 1965. Aptos, California. A foot-long ice chunk falls on a house. (R4)

X35. February 5, 1968. Washington, D.C. A piece of ice 7-8 inches in diameter fell through an awning. (R4)

X36. February 22 or 23, 1969. Bracknell, England. Large ice mass crashes through the roof of a parked van. (R5)

X37. August 16, 1970. London, England. Large ice mass crashes through the roof of a house. (R5, R8)

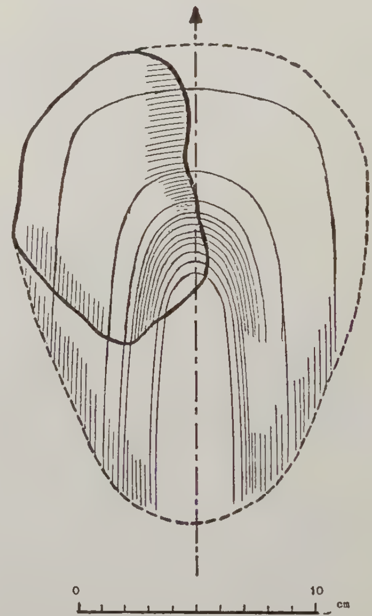
X38. August 19, 1971. Brive, France. A hailstone the size of a grapefruit injures a girl. Other hailstones weighing up to 3 pounds crashed through the roofs of houses. (R5)

X39. January 23, 1972. Surrey, England. A 4-foot, square block of ice fell. (R5)

X40. May 24, 1972. Riverside, California. "Building damaged by ice 'bomb': A chunk of ice weighing between 30 and 50 pounds fell from the sky and ripped through the roof of a downtown Riverside law office building and landed on a third floor hallway. No one was injured but damage to the building was estimated at several hundred dollars. Observing the evidence before it melted, authorities theorized it might have fallen from a passing plane, but a spokesman for the Federal Aviation Administration said he knew of no aircraft in the area at the time." (R12) Attributed to the Los Angeles Times.

X41. January 9, 1973. West Wickham, England. 10-pound block of ice shatters a front porch. (R5)

X42. April 2, 1973. Manchester, England. "A fragment of a very large hydrometeor was analysed in the laboratory where standard thin-section techniques were used to reveal its structure. The ice fell at the time of a severe lightning stroke which occurred in Manchester on 2 April 1973, a day when heavy rainfall was recorded in the area. Inquiries have revealed the pattern of nearby aircraft movements at the time, and it is suggested that the lightning was triggered off by an aeroplane which flew into the storm. No definite conclusion as to the origin of the sample has been arrived at, except that it was composed of cloud water." The ice chunk fell 3 meters from the observer and scattered pieces around. Weight estimate of the composite mass was about 1-2 kilograms. (R5, R8, R13) One theory proposed that such large hydrometeors may form in the lightning discharge channels with the help of the electrostatic acceleration of matter. (R14-R17)



Layered structure of a large hydrometeor (X42)

X43. September 22, 1973. Wombwell, England. A ball of ice crashes through a house roof. A fragment weighed 6 pounds. (R5, R8)

X44. December 13, 1973. Fort Pierce, Florida. An ice chunk roughly 10 inches in diameter fell through the roof of a house almost simultaneous with the launch of a Titan 3-C rocket from Cape Canaveral. Chemical analysis showed an unusual concentration of heavy metals. Since the rocket trajectory was out over the Atlantic rather than Fort Pierce, it was suggested that the chunk came from an airplane passing overhead. (R18)

X45. March 25, 1974. Pinner, England. A cuboidal mass of ice about 18 inches in diameter crashed into a car. A bucket of yellowish-brown ice was collected. May have fallen from an aircraft. (R5)

X46. January 24, 1975. London, England. A block of ice weighing about 50 pounds fell on an apartment roof. (R5, R19)

X47. March 7, 1976. Timberville, Virginia. Two blocks of ice fall. One was about the size of a basketball. It smashed through a tin roof. Chemical tests showed the pieces to be similar to local tapwater. (R20)

X48. January 2, 1977. Middlesex, England. A large ice chunk crashes through a bedroom ceiling. Size estimate: 3 feet long, 12-15 inches wide, 6-8 inches thick, weight more than 100 pounds. (R5, R21)

X49. May 1979. Forked River, New Jersey. "Robert Cloupe and his son Robbie were out in their garden in Forked River, Ocean County, New Jersey planting some vegetables on an overcast Memorial Day, 1979, when they were startled by a whistling sound in the sky. The sound, 'like a firecracker makes before it explodes,' Mr. Cloupe said, occurred around 3:45 p.m. Robbie told his father to look above them and together they observed 'something' falling several hundred feet to land in a field next to their neighbor's house a short distance away.... The object, they discovered, was apparently an ice ball. Having left a six-inch deep depression in the ground where it landed, the main mass had then broken up into 'grapefruit-sized chunks' six to eight inches in diameter which were spread over an area some 25 feet across." The object consisted of semihard ice and compacted snow. (R22)

X50. March 1982. Tecumseh, Oklahoma. An ice mass estimated at 30 pounds fell on the land of A. C. Hinson. Investigating meteorologists said that it was not a hailstone but might have fallen from an airplane or even come from outer space. (R23)

X51. September 1964. Transvaal, South Africa. "A large lump of ice fell from a cloudless sky one morning in September 1964 and landed only ten yards from a farmer in the Brits district of the Transvaal, South Africa. A whirring sound shortly before the impact alerted the farmer so that he saw the ice as it struck the ground. The lump was flattish-shaped and irregular, estimated at 11 x 9 x 6 inches, and gave off a peculiar odor, The farmer also observed that the ice was composed of numerous layers and that parts of its interior were brownish-coloured. He did not recall noticing aircraft in the vicinity at the time of the incident." This ice fall was later correlated with the passage overhead of an aircraft descending for landing. (R11)

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R23. "Sky Ice: 30-Lb. Close Encounter," Boston Herald American, March 16, 1982, p. 2. (X50)

GWF2 Stone Falls

Description. The fall of stones, singly or en masse, larger than the coarsest sand carried by strong winds, say, more than 1/4 inch in diameter. Most stone falls are recorded during powerful thunderstorms, usually in conjunction with loud peals of thunder. Some stone falls are meteoric in character; that is, a luminous streak is observed. The stones recovered, however, are almost always of terrestrial origin.

Background. Such observations are the basis of the discredited thunderstone belief. Many ancient peoples believed that lightning and thunder were accompanied by a missile, often shaped like an ax head, that was hurled by some supernatural agency. So strong is scientific antipathy towards these supernatural overtones that stone-fall reports are usually rejected with contempt regardless of their merits.

Data Evaluation. Stone-fall data are weak. Almost all testimonial. These data are gathered under stressful conditions that encourage distortion and exaggeration. Other phenomena, such as ball lightning and ordinary meteors, have similar characteristics, thus confusing the situation. Finally, it is always difficult to be sure that recovered stones are not just indigenous rocks that happened to be in the area where the phenomenon occurred. Rating: 3.

Anomaly Evaluation. Two kinds of anomaly may be present here: (1) If the fallen stones are terrestrial in origin and have been picked up by small whirlwinds, the weights of the stones infer higher vertical wind velocity components than generally allowed in thunderstorms; and (2) If the stones are meteoric and fall preferentially during thunderstorms, a cause-and-effect relationship is inferred. Rating: 2.

Possible Explanations. (1) The stones are simply wind-levitated terrestrial objects dropped during thunderstorms; (2) They are meteorites that just happen to fall during thunderstorms; (3) The supposed fallen stones never actually fell and are indigenous to the area.

Similar and Related Phenomena. The similarity of stone-fall and ice-fall characteristics cannot be ignored; both are often accompanied by loud claps of thunder and are frequently much larger than current meteorological theories permit. Ball lightning may closely emulate stone-fall phenomena. See also "terrestrial" meteorites (AY).

Examples of Stone Falls

X1. July 1681. North Atlantic Ocean. The reknowned Arago stated: "Without having the slightest wish to revive antiquated ideas regarding thunder-stones, I shall simply remark here, that it is not proved that we should absolutely regard as false the whole of the narratives, in which the fall of various matters is related to have accompanied thunder storms. What pretext, for example, is there for considering as untrue the following fact, which I extract from the works of Boyle. 'In July 1681, a thunderstorm produced a great deal of damage near to Cape Cod, upon the English ship the Albemarle. A flash of lightning was followed by the fall of a burning bituminous matter into the boat hanging at the stern, which gave out an odour similar to that of gunpowder. This substance was consumed on the spot, and it was in vain that they attempted to extinguish it with water, and to sweep it overboard with a broom.'" (R1, R29, R30)

X2. Summer 1846. Richland, South Carolina. A 6 1/2 ounce stone, almost perfectly round, fell during a violent thunderstorm. The exterior was coated with a reddish brown glaze; the interior was like firebrick. (R2)

X3. September 1850. Barcelona, Spain. Conical stone. Specific gravity: 8.12. Fell during thunderstorm. (R3)

X4. September 25, 1851. Bombay, India. "On the 25th of September a violent explosion occurred in the air at Bombay, followed by a wild rushing sound overhead, heard at various points over an area of thirty miles in length and eight in breadth, followed by a severe concussion, as if a heavy body had fallen, just before the occurrence of which a large fire-ball was seen plunging into the sea." A thunderstorm was in progress. (R4) This account sounds as if a true meteor had fallen during a thunderstorm, either through coincidence or some unappreciated connection between thunderstorms and meteoric activity. Note also that India is also famous for remarkable ice falls (GWF1) and fish falls (GWF9).(WRC) A much more detailed account of the X4 fall may be found in R5.

X5. March 18, 1851. Dhatmah, India. During a heavy thunderstorm, a meteor-like object was seen to fall and hit the ground, with considerable noise. (R4)

X6. April 30, 1851. Kurrachee (sic), India. A violent explosion was heard during a thunderstorm and, about half a minute later, a meteor was seen falling into the sea. (R4)

X7. May 13, 1856. Bremervorde, Germany. "A fall of meteoric stones took place near Bremervorde a short distance from Hamburg, on the 13th of May last, at 5 o'clock, P. M. It took place during a storm accompanied by thunder and lightning. A number of stones have been found. One of them weighed nearly 7 lbs., another 3 1/3 lbs., a third two-thirds of a pound. They were covered with a black crust apparently the effect of fusion. In the fracture, the stone has a gray color, and shows several minerals, among which there is a large quantity of native iron and pyrites." (R6)

X8. April 29, 1868. Birmingham, England. A violent thunderstorm. "There was an extraordinary phenomenon during the deluge of rain. From nine to ten, meteoric stones fell in immense quantities in various parts of the town. The size of these stones varied from about one-eighth of an inch to about three-eighths of an inch in length, and about half those dimensions in thickness. They resembled in shape broken pieces of Rowley ragstone. A similar phenomenon visited Birmingham ten years ago." (R7) Subsequent analysis of the stones confirmed that they were similar to the Rowley ragstone, a common local formation. (R8) The date of this event is given as May 30, 1869, conflicting with R7 and R8. (R10) The Birmingham fall is a possible case of levitation by a whirlwind or tornado. (WRC)

X9. May 25, 1869. Wolverhampton, England. Many pebbles, about 3/4 of an inch in diameter, fell during a powerful thunderstorm. (R9) Meteoric origin of the stones doubted. (R10)

X10. June 12, 1858. Birmingham, England. Shower of stones during a violent thunderstorm. (R7, R10)

X11. June 26, 1880. Chelsea, England. About 3 p.m., in the midst of many peals of thunder, one clap was heard which sounded far louder and sharper than the others, and gave one the idea of a conservatory being shattered. At this time, what appeared like a ball of fire fell on the chimney stack of 180 Oakley street. The servants sitting in the kitchen were suddenly alarmed by the room being filled with smoke and a heavy black mass falling down the chimney into the grate, where it appeared to break and scatter fragments over the room. They naturally rushed from the room, but as soon as they recovered from their fright, and the smoke had somewhat dispersed, they returned to the kitchen to ascertain what had really happened. Among the debris in the grate a piece, apparently of a ball about 8 or 9 inches in diameter was found, like a cinder with here and there fragments of metal in it." Investigators thought that lightning had perhaps fused material in the grate. (R11-R12)

X12. Circa 1883. Guildford, England. An iron sphere was found at the bottom of a ten-inch-deep hole where lightning had been seen to strike. The hole had charred sides. (R13) Like so many old tales, this one is impossible to evaluate. (WRC)

X13. No date given. Canton de Vaud, Switzerland. Stones up to 1 1/2 centimeters in diameter fell. No storm mentioned. (R14)

X14. No date given. Chateau Landon, Switzerland (?). Small calcareous stones 3 centimeters in diameter carried 150 kilometers by the wind. No storm mentioned. (R14)

X15. 1883. Sweden. Stones the size of filberts enveloped in large ovoid hailstones. The stones were apparently carried 60 kilometers. (R14)

X16. August 1887. Harrowgate, England. Simultaneous with a sharp crack of thunder, a white light fell to earth. A small dense stone was found where the earth had been disturbed. (R15)

X17. October 15, 1890. South Pacific Ocean. A bulky mass was seen falling into the sea during a violent thunderstorm. (R16)

X18. 1892. Hereford, England. A bolt of lightning fell into a yard, leaving a sulphurous smell and fragments of a metal-bearing material. (R17)

X19. No date given. Casterton, England. "I have frequently been struck by the fact of thunderbolts falling during violent storms, and of their simultaneous appearance with flashes of lightning. That masses of matter occasionally accompany the electric fluid when it reaches the earth there is no question; they have been seen and described as 'balls of fire,' and I have in my possession one that fell some time ago at Casterton, in Westmoreland. It was seen to fall during a violent thunderstorm, and, killing a sheep en route, buried itself about six feet below the surface, and when dug out shortly after it was still hot. It appearance it much resembles a volcanic bomb; it is about the size of a large cocoa-nut, weighs over 12 lbs., and seems to be composed of a hard ferruginous quartzite. I have not yet submitted it to a technical analysis, but hope to do so shortly. There is an external shell of about an inch in thickness, and this contains a nucleus of the same shape and material as the shell, but is quite independent of it, so that the one is easily separated from the other; I attribute this separation of the parts to an unequal cooling of the mass." (R18)

X20. July 13, 1909. Ongar, England. "During the severe thunderstorm on the 13th inst. a meteoric stone fell in the stable yard here with a terrific explosion when within a few feet of the ground, embedding itself in the gravel about 8 inches, the ground around for several feet being perforated with small holes caused by the fragments. The main part and fragments which we could collect weighed 1 lb. 13 oz. The fall was witnessed by my daughters, who were sheltering about eight yards away." (R19)

X21. March 4, 1912. St. Albans, England. During a heavy thunderstorm which ensued on March 4 between 2.30 p.m. and 4.15 p.m., an aerolite was observed to fall at Colney Heath, near St. Albans. The observer, who has placed the specimen in the hands of Mr. G.E. Bullen, of the Hertfordshire Museum, for examination, stated that the stone fell within a few feet from where he was standing, and that it entered the ground for a distance of about 3 ft. Its fall was accompanied by an unusually heavy clap of thunder. The example, according to Mr. Bullen, who describes it in Nature, weighs 5 lb. 14 1/2 oz., and measures 6 3/4 in. by 5 5/8 in. at its greatest length and breadth respectively. The mass is irregularly ovate on the one side, and broken in outline on the other. The actual surface throughout is fairly deeply pitted, and under magnification exhibits the usual chondritic structure of the crystalline matter, with interspersed particles of what appears to be nickeliferous iron. Mr. Bullen has since written to Nature to say that he has since submitted the stone for examination to Dr. George T. Prior, of the British Museum (Natural History), who informs him that it is not of meteoric origin." (R20, R21)

X22. March 27, 1921. Rome, Italy. (R22)

X23. General observations. A review of the thunderbolt theme in literature. No specific examples. (R23)

X24. General observation. The concept of the thunderbolt is only the childish belief of unenlightened peoples. (R24, R25)

X25. General observation. Review of the thunderbolt theme in Maori folklore. (R26)

X26. General observation. A general history of the thunderbolt belief. (R27, R28)

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GWF3 Sulphur/Pollen Falls

Description. The fall of a yellowish substance in chunks, in the form of dust, or in yellow rain. On rare and questionable occasions, the substance has been said to be burning as it fell. In other circumstances, the collected matter can be burnt and seems to have some of the properties of sulphur. Most often, though, the fallen material is quickly identified as pollen, particularly pine pollen.

Background. Sulphur/pollen falls bring to mind the Biblical falls of fire and brimstone. Indeed some sulphur/pollen falls have been linked with the imminent end of the world. As in the case of thunderstones, scientists have gone out of their way to deny the possibility of sulphur falls, blaming all such phenomena on pollen falls. A few cases do not yield to this explanation so easily. We present these here along with a few run-of-the-mill cases of misidentified pollen falls.

Data Evaluation. The data supporting the reality of true sulphur falls are old and very weak. The eye-witness accounts are old and shaky; the purported chemical analyses are presented without adequate detail. Rating: 3.

Anomaly Evaluation. The fall of free sulphur, which is rarely found in surface deposits where winds could pick it up, would seem to be very unlikely although not impossible. Volcanic eruptions might also contribute sulphur. A significant anomaly would be posed only if the remarkable tales of falls of burning sulphur were true. Overall rating: 3.

Possible Explanations. It cannot be denied that almost all so-called sulphur falls are really pollen falls. Yet, as mentioned above, real falls of free sulphur are definitely not impossible---just improbable. Falling, burning matter might conceivably be meteoric. (See X8, for example.)

Similar and Related Phenomena. Rain colored other than yellow (GWP10). Dust falls with various hues are so common and well-understood that they are not included in this Catalog. Exceedingly rare are reports of falls of other types of burning materials (GWF2-X1). Ball and bead lightning on occasion seem to leave behind residues of burning material (GLB and GLL23).

Examples of Sulphur/Pollen Falls

X1. June 1642. Magdeburg, Germany. Burning lump of sulphur the size of a man's fist. (R7) Too large to be pollen? (WRC)

X2. May 16, 1646. Hasnia, Italy. Heavy rain leaves sulphurous powder. (R17) This is a more typical observation. Pine pollen is the usual verdict. (WRC)

X3. March 1832. Kourianof, Russia. "In March last, there fell in the fields of the village of Kourianof, thirteen versts from Wolokolamsk, a combustible substance of a yellowish color, at least two inches thick, and covering a superficies of between six and seven hundred square feet. The inhabitants, at first, thought it was snow, but on examination, it appeared to have the properties of cotton, having, on being torn, the same tenacity; but, on being put into a vessel full of water, it assumed the consistency of rosin. On being put into the first, in its primitive state, it burnt and sent forth a flame like spirits of wine; but in its resinous state, it boiled on the fire, without becoming inflamed, probably because it was mixed with some portion of snow, from which it had been taken. After a more minute examination, the rosin had the color of amber, was elastic like indian (sic) rubber, and smelt like prepared oil, mixed with wax." (R2) Obviously, one cannot do much with a datum such as this, but the time of year and reported properties militate against the pollen theory. (WRC) Item first published in R1.

X4. June 1841. Pictou, Nova Scotia, Canada. Yellow matter fell on a vessel in Pictou harbor. Swept up by the bucketsfull. Examination proved it to be pollen. (R3)

X5. 1850. Napoleon, Arkansas. Rain had the appearance of liquid sulphur and left a thick scum on surfaces. Pollen suspected. (R4)

X6. October 18, 1867. Thames Ditton, England. "The inhabitants of the village of Thames Ditton, Surrey, were, on Friday night, October 18th, 1867, a good deal startled at witnessing a very strange phenomenon, which had the appearance of a shower of fire. The shower lasted about ten minutes, and during its continuance afforded a brilliant light. Next morning it was found that the waterbutts and puddles in the upper part of the village were thickly covered with a deposit of sulphur." (R5) Pollen would hardly burn while falling, but neither would particles of free sulphur. (WRC) See also X8.

X7. February 14, 1870. Genoa, Italy. A remarkable rain of yellowish matter that proved to be pollen. (R6)

X8. June 17, 1873. Proschwitz, Austria. "It is remarkable that perfectly authentic statements were received of the deposition, soon after, or about the time of, the meteor's explosion over Zittau and its neighborhood, of a mass of melted and burning sulphur the size of a man's fist, on the roadway of a village, Proschwitz, about 4 miles south of Reichenberg, where the meteor exploded nearly in the zenith. It was stamped out by a crowd of the villagers, who could give no other explanation of its appearance on the spot other than that it had proceeded from the meteor; on examination at Breslau some remnants of the substance proved to be pure sulphur." (R7)

X9. April 18, 1883. Iowa. An abundance of pine pollen was found floating on a pond. Pines in nearby forests not in bloom, so the pollen must have travelled at least 300-400 miles. (R8)

X10. May 12, 1886. Munich, Germany. Heavy rains cover pools and streams with a yellow matter. Local populace thought it was sulphur and betokened the end of the world. Scientists identified it as fir pollen. (R10)

X11. March 4, 1892. Balearic Isles. A violent north wind brought a rain that covered the ground with a yellow coating that proved to be sulphur. (R11)

X12. April 13, 1894. Adissan, France. (R12)

X13. March 21, 1898. Mount Vernon, Kentucky. A supposed sulphur fall. The fallen substance burned and gave off sulphur-like fumes. Editor of journal insists it must have been pine pollen. (R13)
X14. June 1, 1902. England. (R15)
X15. May 4 and 21, 1908. Orleans. France. (R16)
X16. General observations. The so-called "sulphur rains" are nothing more than pollens falls. (R9) Except where real sulphur may be blown from volcanos. (R14)

X17. General observations. "Pollen of various plants, as previously noted, is one of the most common constituents of atmospheric dust; for instance, Miquel found that there are often a thousand pollen grains to each cubic meter of air. But pollen deserves more extended notice because it is really showers of pollen that have been so often reported as showers of sulphur. The yellow color suggested sulphur; pollen, especially of pine, is highly inflammable, the imagination supplied the smell of brimstone, and superstition jumped at the conclusion that the devil had been busy. The occasional phosphorescent appearance of pollen falls at night also has encouraged preternatural speculations." (R18)

X18. April 11, 1832. Europe. 'This substance fell from the sky on the 11th April, 1832, 13 werstes from the town of Wolokalamsk, and covered to the thickness of 1 to 2 inches a space of 8 to 10 square rultres. It was of a wine yellow, transparent, soft, and smelling like rancid oil. Its sp. gr. was 1.1. It melted in a close (sic) vessel, and yielded the common products of vegetable substances, leaving a brilliant charcoal. It burnt with a blue flame, without smoke. It is insoluble in cold water, but melts in boiling water, and then swims on the fluid. Boiling alcohol dissolves it. It dissolves also in carbonate of soda, and the acids separate from the solution a yellow viscous substance, soluble in cold alcohol, and which contains a peculiar acid." (R19)

X19. June 18, 1860. Amesbury, Massachusetts, and Prospect, New York. After a thunderstorm, the ground was covered with "sulphur." It burned with a blue flame and smelled like common sulphur. The writer noted that such observations are usually due to pine pollen. (R20)
X20. March 12, 1867. South Union, Kentucky. A yellow substance falls with rain. (R21)
X21. February 14, 1870. Genes, France. A remarkable yellow rain. Analysis yielded mostly sand, clay, iron oxide, and some organic debris. (R22) See also X7.
X22. April 25, 1880. Bonneville, Switzerland. A rain made yellow by vegetable debris, which included spores but no pollen. (R23)
X23. April 8, 1906. Central China. The air was filled with dust. A subsequent rain left puddles ringed with a yellow substance that the local doctor identified as sulphur. (R24)

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R17. "Rain of Brimstone," Nature, 125:729, 1930. (X2)
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R23. "A Yellow Rain," English Mechanic, 31:466, 1880. (X22)
R24. Deans, Wm.; "Sand Mist in China," Knowledge, 3:511, 1906. (X23)

GWF4 Falls of Miscellaneous Inorganic Substances

Description. The fall from a clear sky or with normal precipitation of inorganic substances, such as crystalline material and cinders, but excluding sulphur-like substances (GWF3), stones (GWF2), dust, and ashes. The criteria employed in choosing examples here are: (1) Unusual chemicals not expected in precipitation; (2) Materials that do not seem to exist in the immediate vicinity of the fall; and (3) Anomalous meteoric material. Coal is considered "inorganic" here.

Background. Dust and ash falls are common and generally well-explained. They are omitted.

Data Evaluation. The data are rather convincing and minus the sensationalism associated with sulphur falls and thunderstones. Rating: 2.

Anomaly Evaluation. Most of the substances mentioned here are common in nature. The anomaly consists primarily of finding reasonable sources and transporting mechanisms. Since winds fit the bill quite well, the only mystery remaining is locating nearby sources or explaining transportation over long distances. Rating: 3.

Possible Explanations. Salt storms are easily attributed to the evaporation of wind-blown seawater. The other falls are likely wind-blown debris or incoming meteoric particles.

Similar and Related Phenomena. All falls, especially stone falls (GWF2).

Examples of Falls of Miscellaneous Inorganic Substances

X1. Date of fall indeterminate. Arctic. From the log of the Vega expedition. "Lieutenant Nordquist observed small yellow specks in the snow, which I asked him to collect and hand over for investigation to Dr. Kjellman. For I supposed that the specks consisted of diatom ooze. After examining them Dr. Kjellman however declared that they did not consist of any organic substance, but of crystallized grains of sand. I too now examined them more closely, but unfortunately not until the morning after we had left the ice-field, and then found that the supposed ooze consisted of pale yellow crystals (not fragments of crystals) without mixture or foreign matter. The quantity of crystals, which were obtained from about three litres of snow, skimmed from the surface of the snow on an area of at most 10 square metres, amounted to nearly 0.2 gram. The crystals were found only near the surface of the snow, not in the deeper layers. They were up to 1 mm. in diameter,.... and appeared to belong to the rhombic system, as they had one perfect cleavage and formed striated prisms terminated at either end by truncated pyramids. Unfortunately, I could not make any actual measurements of them, because after being kept for some time in the air they weathered to a white noncrystalline powder. They lay, without being sensibly dissolved, for a whole night in the water formed by the melting of the snow. On being heated, too, they fell asunder into a tasteless white powder. The white powder, that was being formed by the weathering of the crystals, was analysed after our return---21 months after the discovery of the crystals---and was found to contain only carbonate of lime." (R1) It is assumed that these crystals fell onto the Arctic snow. (WRC)

X2. 1916. Northern Ireland. "The great barometric depression that developed from the 16th to 18th with its prolonged south-easterly blast, has brought a great shower of salt that I have traced as far inland as the Lough Neagh district. It was first detected on 18th, dimming the windows facing eastward, but some of the more succulent and absorbent forms of vegetation have also revealed its presence by wilting under the poisonous blast." (R2) See also X3. Obviously this phenomenon is caused by wind-blown seawater that is evaporated, leaving salt behind. See also the effects of the so-called "blasting fogs" (GWD3-X6).

X3. Circa 1815. Massachusetts. After a high wind and heavy rain, all homes and objects within a mile of the water were coated with salt. (R3)

X4. August 20, 1872. Zurich, Switzerland. "Prof. Kenngott, of Zurich, states that in a hailstorm, on the 20th of last August, the stones, some of which weighed twelve grains, consisted essentially of common salt, mainly in imperfect cubical crystals. He supposes that the salt had been taken up from the salt plains of Africa, and brought over the Mediterranean." (R4)

X5. June 1893. Daduzai, India. "A few days ago in a village named Daduzai (a tehsil in the Peshawar district) rain fell, preceeded by a wind storm, and with the rain came a shower of hailstones; which lasted a few minutes. The most curious part of this occurrence is that the hailstones when touched were not at all cold, and when put in the mouth (as is the custom in this hot country) tasted like sugar. I am further told that the hailstones were extremely fragile, and as soon as they reached the ground they broke into pieces. These pieces when examined looked like broken sticks of crystallised nitre. My informant tasted them, and was struck with their purity and sweetness." (R5)

X6. March 2, 1940. Springfield, Missouri. "Immediately after the hail storm Mr. R. F. Buchanan of #808 S. Douglas Street in this city called the office and advised me that it had 'hailed coal in his part of town' and that he was bringing some of the hail stones to my office. He arrived shortly but the hail had melted before he got here. He showed me his car which he had just finished washing previous to the storm. It was literally covered with small pieces of coal, varying from one sixteenth to one eighth of an inch cube size. Each little piece of coal was encased in a small muddy circle on his car where the hail had melted. There were thousands of them on the car top and surface. He said that each hail stone was black in the center before it melted. His lawn, sidewalk and the street in his section of the city were covered with the bits of 'coal' while several blocks away others advised me that they had noticed the same thing only it was mostly a black dust deposit after the rain. In all other sections of the city the deposit was a yellow dust." Author surmised that a small tornado might have carried the coal from strip mines a hundred miles away. (R6)

X7. November 14, 1856. South Pacific Ocean. Spherules of magnetic material the size of birdshot fell on a ship. It was supposed that this was meteoric dust. (R7)

X8. Circa 1885. Pelham, New Hampshire. Metallic dust and granules, identified as meteoric dust, found on a sidewalk after a thundershower. (R8)

X9. November 14, 1968. Jurmenha, Portugal. A rain of 'sand' accompanied the fall of the so-called Alandroal meteor. (R9)

X10. June 17, 1857. Ottawa, Illinois. "The cinders fell in a northeasterly direction in the shape of the letter V. The weather had been showery, but I heard no thunder and saw no lightning. There appeared to be a small, dense black cloud hanging over the garden in a westerly direction, or a little to the south of west. The cinders fell upon a slight angle within about three rods of where I was at work; there was no wind at the moment, or none perceptible. My attention was called first to the freak the wind had in the grass, the next moment to a hissing noise caused by the cinders passing through the air. The larger ones were considerably imbedded in the earth, so much as only to show a small part of it, while the smaller ones were about half buried. I noticed at the time that the ground where I afterwards picked up the cinders showed signs of warmth, as there was quite a steam or fog at that particular point." The cinders were glassy with a cellular interior. They were a little over an inch long. Color: black. (R10, R11) The "cinders" do not appear to be meteoric because of their cellular structure, although in 1857 there were probably few sources of real cinders in this region. The black cloud, however, resembles those frequently seen in the vicinity of descending meteors. (WRC)

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GWF5 The Fall of Manna

Description. The fall from the sky of large quantities of edible substance. Manna is generally granular in form and may appear in various colors, consistencies, and flavors. Almost all reported falls of manna come from Asia Minor.

Background. Discussion of the possible fall of manna is inescapable due to its prominence in Biblical history and folklore.

Data Evaluation. The actual fall of manna from the skies is claimed only in a few old and questionable sources. More sober observers tell of: (1) The collection or fall of edible substances from trees and bushes; (2) The sudden appearance of edible plants and lichens due to natural population explosions; and (3) Wind-blown lichens. In sum, the data supporting actual falls of manna from the skies is very shaky. Rating: 4.

Anomaly Evaluation. Even if manna did fall from the sky or arrived with normal precipitation, it is light enough to be carried long distances by meteorological agencies. The large, localized falls, however, are curious. Rating: 3.

Possible Explanations. Two varieties of manna seem to exist: (1) Lichens, wind-blown and indigenous; and (2) Sugary granules produced by insects and/or vegetation.

Similar and Related Phenomena. All other falls, particularly the rare prodigious falls of leaves and hay (GWF7).

Examples of Falls of Manna

X1. 1824. Persia. Ground covered in some regions by edible lichens, called manna. (R1)

X2. 1828. Persia. Edible substance said to fall from the sky. "It occurred in such abundance that the ground was of a sudden entirely covered by it over a great extent. In some spots it was five or six inches deep. It was eaten by cattle, and particularly sheep; and bread was made of it, which afforded nourishment to man. Such were the accounts furnished to the French Consul in Persia, by a Russian general, who was an eye-witness." (R1) The fallen substance was later identified as the plant Parmella esculenta. (R2, R10) This classic example said to occur in 1829. (R3)

X3. Spring 1841. Lake Van, Turkey. The ground was covered to depths of 3 or 4 inches by a gray, granular substance that was pleasant to the taste. Bread was made from it. (R10)

X4. January 1846. Jenischehir, Turkey. Edible substance falls during a time of famine. "It lasted some days, and the pieces of lichen were of the size of hazel-nuts. They were ground into flour, the bread from which was pronounced little inferior to wheat bread. Another account says that the manna was of greyish-white colour, rather hard and irregular in form, inodorous and insipid." (R10, R17) Another report puts this fall in April 1846. (R3)

X5. April 18, 1848. Byazid, Turkey. Edible lichens said to have fallen from the skies. (R4)

X6. July 1864. Diarberker, Turkey. Manna appeared. Said to be lichen. (R5, R6)

X7. Circa 1887. Turkey. The following description was provided by a Mr. Cole, an American missionary. "We travelled for four days through a region where had newly fallen a remarkable deposit of heavenly bread, as the natives sometimes call it---manna. There were extensive forests of scrubby oaks, and most of the deposit was on the leaves. Thousands of the poor peasants, men, women, and children, were out upon the plains gathering the sweet substance. Some of them plunge into kettles of boiling water the newly cut branches of the oaks, which washes off the deposit until the water becomes so sweet as to remind the Yankee of a veritable sugaring off in the old Granite State as he takes sips of it. Other companies of natives may be seen vigorously beating with sticks the branches, that, having been spread on the ground, have so dried that the glistening crystals fall readily upon the carpet spread to receive them. The crystals are separated from the pieces of leaves by a sieve, and then the manna is pressed into cakes for use." (R8)

X8. August 1890. Diarbekir(sic), Turkey. "The director of the central dispensary at Bagdad has sent to La Nature a specimen of an edible substance which fell during an abundant shower in the neighbourhood of Merdin and Diarbekir (Turkey in Asia) in August 1890. The rain which accompanied the substance fell over a surface of about ten kilometres in circumference. The inhabitants collected the 'manna,' and made it into bread, which is said to have been very good and to have been easily digested. The specimen sent to La Nature is composed of small spherules; yellowish on the outside, it is white within. Botanists who have examined it say that it belongs to the family of lichens known as Lecanora esculenta." (R9)

X9. General observations. Sinai, Egypt. An expedition from the Hebrew University was sent out to determine the true nature of the Biblical manna. It found that two scale insects in the region excreted a clear, sweet fluid that crystallized into grains and fell to the ground from the trees. (R16)

X10. March 1900. Chanda, India. During a great famine, bamboo trees exuded a type of edible manna. (R13)

X11. General observation. "Our Consul in Jerusalem states that manna is found now in the regions of upper Mespotamia and Kurdistan and along the Persian frontier. It falls, he says, in the form of dew during September, October, and November, and lodges upon the leaves of oak trees. It immediately hardens and assumes the form of a grain. Early in the morning before the heat of the day it is gathered by spreading sheets beneath the trees, which are shaken, and the manna is then collected and stored for winter to be used as a food or shipped to Bagdad for sale in the bazaar. The manna falls on other vegetation, including the grass, but all of it is lost except that which is gathered from the oak leaves. The manna is sweet and is eaten by the natives as a substitute for sugar or honey." (R15) Such widespread occurrences would seem to indicate that the manna is not the product of a specific tree. See X12 and X13.

X12. General observation. A kind of manna is produced by the linden in Europe. (R7)

X13. General observations and controversy. No agreement reached on whether the manna of the Israelites was lichens or a product of the tamarisk tree. (R10, R11, R12, R14)

X14. General observations. "An account of manna 'rains' certainly pertains to the discussion of showers of vegetable matter, for the substance manna consists of lichens of the genus Lecanora, but in none of the numerous recorded instances of manna 'rains' is there any direct evidence that the substance really fell from the sky. These lichens form, small, round bodies that are easily blown over the surface of the ground and accumulate in depressions; they are very buoyant also and hence easily drifted into masses during the run-off of rain water. Manna 'rains' have not occurred except in countries where these lichens are common, and as for statements of their falling down upon roofs or upon people, or for any other proofs that they really rained down, I have seen none." (R18)

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GWF6 Unusual Falls of Hay and Leaves

Description. The fall from a clear sky or with normal precipitation of large quantities of hay or dead leaves. Many of these falls begin at great heights and may continue for hours. The sources of these materials may be miles from the place-of-fall. A curious feature of this type of fall is the apparent lack of debris among the hay or leaves and, in the latter case, the presence of only one type of leaf.

Background. Virtually every country lad has seen cut hay suddenly whipped aloft by whirlwinds and deposited on roofs and telephone wires. The falls meriting mention here are notable for the heights involved, great quantities of materials, long distance of travel, and long duration of fall.

Data Evaluation. This phenomenon is well-documented in the older literature. Rating: 1.

Anomaly Evaluation. This phenomenon, as defined above, is merely an extreme case of well-known pranks of whirlwinds. The only possible mystery is the high selectivity of the transporting agency; i.e., the lack of debris and more than one species of leaf. Rating: 3.

Possible Explanation. Whirlwinds and tornados.

Similar and Related Phenomena. Other falls in this section of the Catalog.

Examples of Unusual Falls of Hay and Leaves

X1. Circa 1845. England. Quoting a letter from Sir John F. W. Herschel. "In the hay season, some three or four years ago, the day being clear and hot and calm (at least in the immediate neighbourhood of our house), our attention was excited by what first seemed to be strange-looking birds flying; but though presently assured they were not birds, it was by no means clear what they were. They were irregular wispy masses sailing leisurely up and settling down again, apparently over a hay field on the east of our grounds, and about a quarter or three-eighths of a mile from our house. Some of these were of considerable size, and their general appearance was convex downwards and taily upwards. After wondering awhile, I got a telescope and directed it to the flying phaenomenon when it became evident that they were masses of hay---some of very considerable size, certainly not less (allowing for the distance) than a yard or two in diameter. They sailed above leisurely, and were very numerous. No doubt wind prevailed at the spot, but there was no roaring noise, nor any sign of a whirlwind, and all about us was quite calm." (R1)

X2. September 1861. Putney, England.

Clumps of hay fell from great heights. (R2)

X3. July 27, 1875. Monkstown, Ireland. "About half-past nine o'clock this morning, as I was standing at a window facing east, in Monkstown, my attention was called by the Rev. T. Power to a number of dark flocculent bodies floating slowly down through the air from a great height, appearing as if falling from a very heavy, dark cloud, which hung over the house. On going to the hall door, a vast number of these bodies were discerned falling on all sides, near and far, to as great a distance as their size permitted them to be seen--- over an area whose radius was probably between a quarter and half a mile. Presently, several of these flocks fell close to my feet. On picking up one, it was found to be a small portion of new hay, of which I enclose a sample. When it fell it was as wet as if a very heavy dew had been deposited on it. The duration of this phenomenon, from the time my attention was first called to it till it had entirely ceased, was about five minutes, but how long it may have been proceeding before this I cannot tell. The flocks of hay, from their loose, open structure, made a large appearance for their weight, but the average weight of the larger flocks was probably not more than one or two ounces, and, from that, all sizes were perceptible down to a single blade. There was no rain from the dark cloud overhead, though it had a particularly threatening appearance at the moment of observation. The air was very calm, with a gentle undercurrent from S. E. The clouds were moving in an upper-current from S. S. W." (R3, R4, R5, R10, R12)

X4. June 17, 1884. England. During fine weather, considerable hay passed overhead. Some fell, but some armful-sized bunches sailed along until out of sight. (R6)

X5. July 26, 1891. Boraston, England. "We had a curious sight from this house yesterday. It was a dead calm, but in a field just below the garden, with only one hedge between us and it, the hay was whirled up high into the sky, a column connecting above and below, and in the course of the evening we found great patches of hay raining down all over the surrounding meadows and our garden. It kept falling quite four hours after the affair. There was not a breath of air stirring as far as we could see, except in that one spot." (R7)

X6. June 30, 1897. Belchamp St. Paul, England. A whirlwind carries hay out of sight at Halstead. It falls (apparently) at Belchamp St. Paul, 3 miles distant. Some of it was in large bunches. (R8)

X7. June 7, 1906. Sprimont, France. A cloud of hay obscures the sun. (R9)

X8. July 31, 1920. Stone, England. Wisps of wet hay, larger than dinner plates, fall. (R11)

X9. June 28, 1931. Spa, France. (R13)

X10. October 1889. Dumfriesshire, England. "I was struck by a strange appearance in the atmosphere, which I at first mistook for a flock of birds, but as I saw them falling to the earth my curiosity quickened. Fixing my eyes on one of the larger of them, and running about 100 yards up the hill until directly underneath, I awaited its arrival, when I found it to be an oak leaf. Looking upwards the air was thick with them, and as they descended in an almost vertical direction, oscillating, and glittering in the sunshine, the spectacle was as beautiful as rare. The wind was from the north, blowing a very gentle breeze, and there were occasional showers of rain. On examination of the hills after the leaves had fallen, it was found that they covered a tract of about a mile wide and two miles long. The leaves were wholly those of the oak. No oak trees grow in clumps together nearer than eight miles." (R14) Same incident placed in 1890. (R10)

X11. April 7, 1894. Clairvaux, France. It rained dead leaves for half an hour. (R15)

X12. April 1, 1900. Wallingford, England. "At about four o'clock on the afternoon of Sunday last (April 1st), my attention was arrested by the fall of numbers of dried beech leaves. On looking up I found that the leaves were passing in large numbers from east to west, and as high as the limit of vision. Many appeared to be mere specks, whose height and motion promised them a journey of some miles at least. The shower continued for perhaps twenty minutes. The fall was noticed by many persons here, who were unable to account for it, as there are no beech trees within two miles at nearest. Probably the leaves had been raised by a whirlwind, and at a very considerable distance east of this neighborhood." (R16)

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GWF7 Gelatinous Meteors or Pwdre Ser

Description. The fall of gelatinous masses, usually accompanied by luminous phenomena. The substance is soft and jelly-like, odiferous, and has a tendency to evaporate away rapidly. Gelatinous meteors range from a few inches to four feet in diameter according to reports.

Background. The idea that offensive masses of jelly-like substance can fall from the sky is firmly entrenched in folklore, as confirmed by many colorful names, such as pwdre ser (a Welsh term, more correctly spelled pwdr ser), star shot, rot of the stars, etc. In the examples that follow, the reader will find two different phenomena confused: (1) The observed fall of something from the heavens; and (2) The discovery in fields of gelatinous masses. The latter phenomenon possesses a simple biological explanation---assuming the mass did not fall. The actual fall of jelly-like substances admits to no easy solution, assuming its reality.

Data Evaluation. With few exceptions, the observations of gelatinous meteors in flight are old and rather shaky. Many examples profferred as cases of gelatinous meteors are weakened by the strong possibility of misidentification and coincidence; that is, one sees a luminous body descend nearby, searches the next morning, discovers a gelatinous mass in the general direction of the visual phenomenon, and calls it a gelatinous meteor. Meteor impact points are easily misjudged, and natural gelatinous masses seem rather common in fields. Nevertheless, many cases cannot be eliminated easily, and there is much internal consistency. Rating: 3.

Anomaly Evaluation. The confirmed descent of gelatinous masses from outer space would constitute a significant anomaly, for (quite obviously) they do not fall into any recognized class of meteorites. Rating: 2.

Possible Explanations. Most so-called gelatinous meteors (really meteorites) are likely terrestrially produced substances, such as plasmodia, decaying fungi, water-swollen and distorted animal remains, and even man-made substances. True gelatinous meteors can not be explained.

Similar and Related Phenomena. Animal falls (GWF10-14), biological matter in meteorites (ER).

Examples of Gelatinous Meteors

X1. October 21, 1638. Dartmoor, England. A thunderstorm of great extent and fury. A church was struck and wrecked by lightning. A loathsome odor accompanied the phenomenon. "It seems that some person who ventured to go up into the wrecked tower, there discovered 'a round patch as broad as a bushel, which looked thick, slimy, and black, to which he put his hand, and found it soft, and bringing some from the wall, came down and showed that strange compound. It was like a slimy powder, tempered with water; he smelling thereto, it was odious beyond expression, and in a far higher degree of loathsomeness than the scent which was in the church when they first smelt it, being of the same kind,' and the discoverer was shortly after attacked with severe colic." (R20)

X2. March 24, 1718. Isle of Lethy, India. Gelatinous matter fell along with a ball of fire. (R3, R5)

X3. March 8, 1796. Lusatia, Europe. A viscous matter fell with a meteor. It had the color and odor of varnish. (R3, R5)

X4. January 21, 1803. Silesia, Germany. A meteor fell with a whizzing sound and seemed to lie burning on ground. On the next day a jelly-like mass was found on the snow.

X5. August 13, 1819. Amherst, Massachusetts. "On the 13th of August, 1819, between eight and nine o'clock in the evening, a fireball, of the size of a large blown bladder, and of a brilliant white light, was seen in the atmosphere. It fell near a house, and was examined by Rufus Graves, esq. former lecturer of chemistry at Dartmouth College. It was of a circular form, resembling a solid dish, bottom upwards, about eight inches in diameter, and about one in thickness, of a bright buff colour, with a fine nap upon it, similar to that of milled cloth. On removing this nap, a buff-coloured pulpy substance, of the consistence of soft soap, appeared, having an offensive suffocating smell, producing nausea and giddiness. After a few minutes exposure to the air, the buff-colour was changed to a livid colour, resembling venous blood. It attracted moisture readily from the air." (R1, R2, R13) Comment that observers just thought they saw the meteor land where the jelly was found, and that the substance was likely a plasmodium. (R19)

X6. November 13, 1833. Rahway, New Jersey. During the incredible meteor shower seen over much of the eastern United States. People saw a fiery rain and upon examination discovered lumps of jelly. (R6)

X7. November 13, 1833. Newark, New Jersey. A mass of gelatinous matter, like soft soap, was found after the great meteor shower. Force of impact disturbed the ground. Substance evaporated readily when heat was applied. (R6)

X8. November 13, 1833. West Point, New York. Woman sees a round, flattened mass, the size of a coffeecup, fall. It was transparent and quickly evaporated. (R6)

X9. 1830s. Lincoln, England. Man sees a meteor fall in a field, found nothing but a lump of jelly. (R14)

X10. October 8, 1844. Coblentz, Germany. "...a German gentleman (a friend of Mr. Greg's), accompanied by another person, late in the evening, walking in a dry ploughed field, saw a luminous body descend straight down close to them (not 20 yards off), and heard it distinctly strike the ground with a noise; they marked the spot, and returning early the next morning as nearly as possible where it seemed to fall, they found a gelatinous mass of a greyish colour so viscid as 'to tremble all over' when poked with a stick. It had no appearance of being organic." (R9)

X11. November 11, 1846. Loweville, New York. "...the most remarkable meteor ever seen in that section made its appearance from the west. It appeared larger than the sun, illumined the hemisphere nearly as light as day. It was in sight nearly five minutes and was witnessed by a great number of the inhabitants of the village, and finally fell in a field in the vicinity, and a large company of the citizens immediately repaired to the spot and found a body of fetid jelly, four feet in diameter." (R7)

X12. 1914. Russia. A brilliant cigar-shaped object crossed the sky. An unpleasant jelly-like substance fell near the house of a peasant. It evaporated in several hours. (R22) (Attributed to Znannya ta Pratza, no. 1, 1967.)

X13. February 3, 1980. Hemel Hempstead, England. "Mr. Philip Buller found lumps of a colourless gel lying close together on his lawn. The lumps lay so near to one another that their common origin was not in doubt. The total volume was considered to be approximately sufficient to fill a yoghurt carton, say 75 ml." A sample submitted for analysis was thought to be of amphibian origin and perhaps regurgitated by some predator. (R26)

X14. No date given. Wales. A mass of jelly fell on a man working in a field. No storm or luminous phenomena reported. (R13)

X15. No date given. Lowell, Massachusetts. A man sees a brilliant shooting star fall to earth near him. Upon investigation he found a jelly-like mass with an offensive smell. (R16)

X16. Table of "doubtful" meteorites. Falls of viscid matter with luminous meteors reported in the years 850, 1110, 1548, 1557, 1652, 1686, 1718, 1796, 1811, 1819, 1844. (Since no details are given, and the observations are said to be questionable, no separate entries are provided. WRC) (R8)

X17. General observations. The analysis of substances found in a field and thought to be gelatinous meteors were found to be of animal origin and similar to snail jelly. (R4) The source of pwdre ser observations is probably the Tremella Nostoc, a jelly-like substance seen in wet places. (R10)Jelly-like masses, called 'pwdre ser' in Welsh, are frequently mentioned in literature and often associated with luminous phenomena. (R12) The jelly-like masses found in the fields are undoubtedly plasmodia of a myxocete. (R15, R18)

X18. General observations. Gelatinous masses found in fields may be food disgorged by herons. Such matter may sometimes be luminous. (R18) These masses are probably the viscera of toads and frogs that have become swollen with moisture. Herons may disgorge such matter and other predators may disembowel frogs and toads before consuming them. (R21)

X19. 860. Balch. Germany. (R27) See discussion under X22.

X20. 1406. Lucerne, Switzerland. See discussion under X22. (R27)

X21. 1548. Mannsfeld, Germany. (R27) See discussion under X22.

X22 1557. Schlage, Germany. "These cases were first observed some time after they were believed to have fallen from the atmosphere upon the earth; and it hence remains doubtful whether they were ever in the atmosphere. Meteoric stones, indeed, suggest indications of atmospherical formation, but these gelatinous masses point out no indications of the kind. Indeed botanists themselves are at variance with philosophers about the matter of shot-stars, which is commonly colourless, and the Tremella meteorica, which Meyen recently described as Actinomyce, may be readily taken for a shot-star, if both are generally capable of being discriminated. It may be conceived that this is not necessary, and that the meteoric mass might assume the organic and vegetable structure. To this it may be objected, that the specimens of Tremella meteorica, are frequently found of different sizes, without it being probable that they are remains of a shot-star, especially where they are small, and, as is commonly the case, occur attached to animal bodies, and even incorporated with them. It is therefore improbable that it is sometimes formed terrestrially and sometimes meteorically, because the body exhibits too little characteristic peculiarity to owe its origin to circumstances so very dissimilar. Besides, this supposes that the sudden origin of organic bodies from unorganized materials may be proved. As to the two cases of Lucerne and Mannsfeld, it is to be remembered, that, in the latter case, the blood-spots found on the soil, on the morning after the appearance and explosion of a fire-ball, admit of a very simple explanation, that, in searching for something extraordinary, as the sign of a mass that had fallen, another fungus was found, the Telephora sanguinea, which Agardh calls Palmella cruenta; and which, on account of its entirely superficial extension on moist ground, and from its striking colour, exhibited completely the appearance of spots of blood. The thick gelaninous masses of both the other cases is distinguished from the usual matter of shot-stars, the Tremella meteorica, by their red colour. It would therefore be of importance to examine whether similar appearances are any thing else than this, with a particular difference of colour; whether they are definitely marked by a peculiar structure; or whether, in the absence of any structure, it can be perceived to be an inorganic meteoric concrement,---a matter hitherto undecided." (R27)

X23. June 23, 1978. Cambridge, England. "I wonder if you could tell me what the substance was that alighted on my lawn during a very heavy rainstorm last Friday evening (23 June). It glided down about the size of a football and settled like a jelly. It was white and gloy-like, but cellular. It did not appear to disintegrate, but had completely disappeared by the morning. I came down north-south." This observation was subsequently confirmed in writing by a neighbor. (R23)

X24. August 11, 1979. Frisco, Texas. "Two purple blobs that Sibyl Christian found on her front lawn have defied analysis by space scientists, who say they haven't ruled out the possibility they could be a rare form of meteorite. 'It's kind of like a plum pudding,' according to Doug Blanchard, a geochemist at the National Aeronautics and Space Administration near Houston. 'It has round, solid chunks in it that remain after the goo goes away. We don't know what it is,' he said yesterday." (R24) "The mysterious purple blobs found in a yard in this North Texas town and turned over to the nation's top space scientists for study are the chemical leftovers of a battery reprocessing plant, a Texas museum official says. And officials at the National Aeronautics and Space Administration say it looks like the museum official is right." (R25)

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GWF8 Prodigious Falls of Web-Like Material

Description. The fall from great heights of large quantities of cobweb-like material in long strands, tangled sheets, and balls. Hundreds of square miles may be covered as if by snow by fallen gossamer. Strands thousands of feet long have been reported. Some observers say the strands are tough, hard-to-break, and sometimes seem to evaporate away. Web falls occur mainly in the fall. Rarely are spiders reported attached to the webs.

Background. Gossamer falls are nothing new; but the association of UFO sightings with the fall of 'angel hair' is a modern development.

Data Evaluation. Ordinary gossamer falls are rather common, but the observation of 1000-foot strands, ephemeral material, toughness of strands, and falls of immense areal extent are curious and rare. The rating applies only to such falls. Rating: 3.

Anomaly Evaluation. If all falls of web-like material can be attributed to spiders, no anomaly exists. The immense falls would simply follow from population explosions of spiders. If, however, the strands are not of animal origin, a serious anomaly emerges. Rating: 2.

Possible Explanations. The great majority of falls of web-like material can probably be blamed on ballooning spiders. Reports of unusual web properties may be erroneous, although they are internally consistent. Mats and very long strands of cobweb may be due to the clumping and sticking of smaller webs.

Similar and Related Phenomena. Gelatinous meteors, which also have the puzzling property of evaporating away (GWF7); animal population explosions (BI); the other falls in the section.

Examples of Prodigious Falls of Web-Like Material

X1. September 21, 1741. Selbourne, England. "Thunder, ebb and flood, and mist, are now pretty well understood, and even the mystery of gossamer is no longer referred to the superstitious imaginations of our forefathers. Yet the whole cause is not wist. We wot not how the spiders cast off their holdfasts and scud away, nor how they adjust themselves for flight, and regulate their movements; we only know that they do it. No one knows at present why, on particular days, flakes of gossamer should fall so fast upon the trees and hedges, that a diligent collector might gather basketfuls. Gilbert White, being on a visit to a friend and intent on field-sports, rose before daybreak on the morning of the 21st September, 1741, and, on coming into the enclosures, found the stubbles and clover-grounds matted all over with a thick coat of cobweb, in the meshes thereof a copious and heavy dew, so plentiful that the whole face of the country seemed as it were covered with two or three setting-nets drawn one over the other. When the dogs attempted to hunt, they, blinded and hoodwinked, were obliged to lie down and scrape the cobwebs from their faces with their fore-feet. As the morning advanced, the day became bright, calm, cloudless, warm, one of the loveliest of autumn days, until about nine o'clock, when a shower of cobwebs began to fall from the skies, which continued without interruption until the close of the day. These cobwebs were not single threads, but flakes or rags, which, as they fell, twinkled as they turned their sides to the sun. They were about an inch broad by five or six long, and considerably heavier than the air, as they fell with some velocity. This shower was of a surprising extent, reaching Bradley, Selbourne, and Airesford, three places lying in a sort of triangle, the shortest side being about eight miles in length. At Selbourne, a gentleman, thinking he could get above the shower, rode three hundred feet above his fields to the highest point he could reach; but the cobwebs seemed still as much above him as before, still descending into sight successively, and always twinkling in the sun." (R3, R6)

X2. October 1, 1820. Wigan, England. The countryside was covered by a substance that was taken for cotton. It came down like a sheet on Wigan. It contained flies so small that a magnifying glass was required to make them perceptible. (R7) Attributed to the London Times of October 9, 1820. See GWF8-X3 for a time-correlated fall in Brazil.

X3. Early October 1820. Pernambuco, Brazil. "...at the beginning of the preceding month there was a shower from the sky, consisting of a substance resembling silk, of which many persons preserved specimens. This phenomenon extended to the distance of 30 leagues inland, and nearly as many off to sea. A French vessel was covered with the silky material." (R1) See GWF8-X2 for a time-correlated fall in England.

X4. October 1881. Milwaukee, Wisconsin. "In the latter part of October the good people of Milwaukee (Wis.) and the neighboring towns were astonished by a general fall of spider webs. The webs seemed to come from a great height. The strands were from two feet to several rods in length. At Green Bay the fall was the same, coming from the direction of the bay, only the webs varied from sixty feet in length to mere specks, and were seen as far up in the air as the power of the eye could reach. At Vesburg and Fort Howard, Sheboygan, and Ozaukee, the fall was similarly observed, in some places being so thick as to annoy the eye. In all instances the webs were strong in texture and very white. Curiously there is no mention, in any of the reports we have seen, of the presence of spiders in this general shower of webs." (R4)

X5. September 20, 1892. Southeastern United States. "The postmaster of Gainesville, Florida, writes as follows: 'I enclose you something which has created a great deal of curiosity in our community; it was first discovered late this afternoon floating in the air or falling from the clouds. I have seen people, who live at least ten miles apart, who tell the same story---that it sometimes falls in long strands like spider webs, two and three thousand yards long, then doubled up into strands and wads.' The following letter, written by a correspondent from Gainesville, Fla., to our fellow-member Judge L. C. Johnson, or Meridian, Miss., refers to the same phenomenon; this letter is dated September 21, 1892: 'Of all the curious things in nature the inclosed webs are among the strangest. Yesterday great white sheets were seen floating with the daily showers, resembling large, pure white spider-webs, some of them fifty yards or more in length. The trees in many cases are covered. Near the small stream, about 100 yards from the house, some of it extended as an immense web; in other places it rolled up into a ball.'" (R5)

X6. September 26, 1948. Port Hope, Ontario, Canada. "'This day was warm and the sky cloudless. We had had dinner in the garden and I was lying on my back on the lawn, my head just in the shade of the house, when I was startled to see an object resembling a star moving rapidly across the sky. The time was 2 o'clock, Eastern Standard Time. At first it was easy to imagine that recent reports of 'Flying Saucers' had not been exaggerated. More of these objects came sailing into view over the ridge of the house, only to disappear when nearly overhead. With field glasses I was able to see that each was approximately spherical, the center being rather brighter than the edges. The glasses also showed quite a number at such heights that they were invisible to the naked eye. With only a gull flying in the sky for comparison, I should estimate the elevation of the lower objects to be about 300 ft. and the higher ones 2,000 ft.; the size was about one foot in diameter and the speed about 30 m.p.h., in a direction SW. to NE. Also visible now and then were long threads, apparently from spiders. Some of these were seen to reflect the light over a length of three or four yards, but any one piece may of course been longer. Each was more or less horizontal, moving at right angles to its length. In one case an elongated tangled mass of these gave the appearance of a frayed silken cord. These threads appeared only in the lower levels." (R8)

X7. October 11, 1950. Butte County, California. The sky was filled with hundreds of silvery white balls speeding north. They seemed to divide, unite, and disappear. Size: about that of a dinner plate. The next day a mass of gossamer was found caught in a tree. (R9)

X8. October 10, 1962. Montreal, Quebec, Canada. "At 2000GMT while the Roxburgh Castle was moored to her berth (Section 24) in Montreal, I was walking around outside my accommodation and noticed fine white filaments of unknown kind hanging around stanchions and topping lift wires of derricks. Calling the attention of the Chief Officer, I pulled one of these strands from a stanchion and found it to be quite tough and resilient. I stretched it but it would not break easily (as, for instance, a cobweb would have done) and after keeping it in my hand for 3 or 4 minutes it disappeared completely; in other words it just vanished into nothing. Looking up we could see small cocoons of the material floating down from the sky but as far as we could ascertain there was nothing either above or at street level to account for this extraordinary occurrence." (R10) High strength and disappearance are not among the usual properties of spider's webs. This account resembles those of "angel hair" in the UFO literature. (WRC)

X9. October 1969. St. Louis, Missouri. "Great globs of spider-web-like material descended from the sky, alarming numerous citizens. As Donald Pecsok, director of the county's air pollution control division, remembers hundreds of calls poured into the newspapers and his office. People thought the material was from an exploded test airplane from nearby McDonnell Douglas plant; thought it was from a flying saucer; or thought it was a divine sign, etc. According to nearby rural residents, says Pecsok, the globs contained a few eggs of 'balloon spiders,' which spun the material at the tops of trees and left it there for the wind to catch. Unfortunately, most of the material dissolved as it hit the ground. Some that was retained and put under a microscope resembled a spiderweb, but Pecsok is reluctant to make any great claims because he could not get any local scientists to investigate.... Although the event is listed as a 'spider invasion', Pecsok notes that he found only one spider, a small browish creature, about an eighth of an inch in diameter and about the size of a quarter with its legs stretched out." Attributed to the Washington Post, March 28, 1970. Later tests made on the strands indicated that it was not of biological origin.(R11)

X10. Circa May 1971. Near Melbourne, Australia. "A mysterious rain of fine thread fell over the Kilmore area on Saturday. (Kilmore is 35 miles north of Melbourne.) Farmers said it looked like snow as the thread, up to 20 feet long, floated to earth, carpeting paddocks and hanging from trees, telegraph lines and fences. The elastic, synthetic-type thread stuck to objects and rolled up into balls when gathered. Sheep and cattle were covered by the mystery thread." One report mentioned the presence of spiders. Attributed to the Melbourne Sun, May 10, 1971. (R12)

X11. No date or place given. Curious statement that auroras are sometimes accompanied by the fall of silken threads. (R2) See also GLA17.

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GWF9 Falls of Miscellaneous Organic Substances

Description. The fall of seeds, berries, feathers, butter-like substances, and various other organic materials. Such falls, like most others in this section, are usually observed during or just after heavy rain or hail.

Background. So great is the variety of organic substances reported to fall from the sky that this catch-all section must be provided to record the less-common types.

Data Evaluation. Much of the data are old and circumstantial; and most falls listed here are one-of-a-kind. Yet, there are basic similarities, such as material selectivity and the common association with stormy weather. Rating: 3.

Anomaly Evaluation. While some of the substances mentioned below are peculiar, they all seem terrestrial in origin and probably accessible to levitating whirlwinds and tornados.

The selectivity of the transporting mechanism and the magnitude of some falls are mildly anomalous. Rating: 3.

Possible Explanations. Whirlwinds and tornados pick up surface material and deposit it at a distance, usually along with normal precipitation. (This is the inevitable scientific answer.) It also seems reasonable that the winds inside a storm might somehow segregate materials by size and/or density.

Similar and Related Phenomena. Colored precipitation (GWP), all other falls in this section (GWF).

Examples of Falls of Miscellaneous Organic Materials

X1. Circa 1879. Fifeshire, Scotland. After a heavy hailstorm, the hills were covered with a substance resembling seaweed. It hung from trees and shrubbery. (R1, R2)

X2. January 31, 1686. Rauden, Germany. A substance called "mourning paper" (trauer papier) fell in great quantities. "It consisted of a mass of black leaves, having the appearance of burnt paper, but it is harder, coheres together, is somewhat brittle; and when examined by chemical reagents is found to be a mineral mass, composed of the same ingredients as meteoric stones; for it consists of silica, magnesia, iron, and some nickel, and exhibits also traces of chromium. It may be compared to the black crust which covers the surface of the meteoric stones. Black substances, like beans, are described as having fallen along with this matter, but these bodies have not yet been recognized." (R3)

X3. August 17, 1841. Lebanon, Tennessee. A shower of flesh and blood reported in a tobacco field. (R4) A hoax was later admitted. (R5)

X4. No date given. Kentucky. A shower of flesh (no details given) was considered to have been nostoc. (See GWF7) (R6) But a microscopic examination of the substance proved it to be of animal origin. (R7)

X5. No date given. Cumberland, Kentucky. "While we were in that land of water-fowl below Cumberland, I witnessed a shower of feathers; as we sailed up a reach of the river with a fresh breeze, without the knowledge of a human being within many miles of us, it appeared to be snowing; this was nothing more than small feathers, and we supposed that at some Indian camp in the swamps to windward the operation of goose-plucking must be going on; these feathers had likely travelled many miles, and would continue while the breeze lasted." (R8, R9) The state of Kentucky is assumed here, but the original article does not specify which of the several Cumberlands in the United States is meant. (WRC)

X6. September 24, 1848. Lyon, France. "On a calm evening, about sunset, Lortet observed, near Lyon, a thick and rapid shower of fossil Ostracods (Cypridinia), and heard the minute shells rustle the withered leaves. They had no doubt been caught in an ascending air-current from some of the regions in North Africa, where they are found." (R10, R11) Once again, the selectivity of the meteorological mechanism is intriguing. (WRC)

X7. May 9, 1867. Dublin, Ireland. "On the night of May 9, during a violent rainstorm, a remarkable shower of 'berries' fell in Dublin, on both sides of the river. They were described as having the form of a very small orange, about half an inch in diameter, black in colour, and when cut across seeming as if made of some hard dark brown wood. They fell with such force that even the police were forced to seek shelter. The 'berries' were afterwards identified as hazel nuts which had been partially fossilized in a peat bog. How they came into the air is not known." (R12, R13)

X8. No date given. Warminster, England. Fierce wind and hailstorms deposited ivy berries around Westminster and areas within 6 or 8 miles of it. (R14)

X9. No date given. Macerata, Italy. A heavy fall of seeds occurred during a heavy storm, covering the ground up to a depth of about half an inch. One naturalist stated they were the seeds of the Judas Tree, found in Central Africa and the Antilles. Some of the seeds had begun to germinate. (R15)

X10. April 28, 1893. Jafferabad, India. A fall of seeds simultaneous with the descent of a meteorite. (R16)

X11. No date given. Spain. Wheat fell like rain. Author suggests it was blown over from North Africa. (R17)

X12. March 24, 1840. Rajket, India. A shower of an unknown type of grain during a thunderstorm. (R18)

X13. June 24, 1911. Eton, England. "On the morning of Saturday, June 24, the ground here was found to be covered with small masses of jelly about as large as a pea. There had been a heavy rain on Friday night, and it was raining at 7 a.m., when, so far as I could ascertain, the phenomenon was first seen. On being examined microscopically the lumps of jelly turned out to contain numerous ova of some insect, with an advanced embryo in each. The egg itself is very minute---an elongated oval 0.04 mm. in length. Yesterday and the day before many larvae emerged, and were obviously those of some species of Chironomus, though colorless, having no hemoglobin, as is the case with the larvae of C. plumosus. Not being an entomologist, I am at a loss to understand how these egg-masses could have appeared where they did unless they were conveyed by the rain, as it does not seem likely that the midges would have laid their eggs on pavements, gravel paths, tombstones &c." (R19)

X14. Fall and winter 1695. Cos. Limerick and Tipperary, Ireland. "We have had of late, in the County of Limerick, and Tipperary, showers of a sort of matter like butter or grease. If one rubs it upon one's hand it will melt, but lay it by the fire and it dries and grows hard, having a very stinking smell. And this last night some fell at this place, which I did see myself this morning. It is gathered into pots and other vessels by some of the inhabitants of this place." The preceding account was amplified by the Bishop of Cloyne, who described a similar phenomenon occurring in Munster and Leinster, Ireland. "For a good part of last winter and spring, there fell in several places, a kind of thick dew, which the country people called butter, from the consistency and colour of it, being soft, clammy, and of a dark yellow. It fell always in the night, and chiefly in moorish low grounds on top of the grass, and often on the thatch of cabins. 'Twas seldom observed in the same places twice. It commonly lay on the earth for near a fortnight without changing its colour, but then dried and turned black.....It fell in lumps, often as big as the end of one's finger, very thin and scatteringly. It had a strong, ill scent, somewhat like the smell of churchyards or graves; and indeed we had during most of that season very stinking fogs, some sediment of which might possibly occasion this stinking dew, though I will by no means pretend to offer that a reason of it." (R20) The spelling and punctuation have been modernized to some extent. See also the blasting fogs (GWD3) and gelatinous meteors (GWF7). (WRC)

X15. September 5 and 6, 1978. Washington, D.C. "An unexplained green slime fell on Washington, D.C., 5 and 6 September 1978. The affected area is generally bounded by Rock Creek Parkway on the west, Pennsylvania Avenue on the north, G Street on the south and 23rd Street on the east. The slime was discovered injuring plants and animals, soiling automobile windshields, angering residents and baffling city health officials. About half the flowers in one resident's back-yard garden simply wilted and died in the two-day period during which the substance fell." The substance was a green liquid that apparently fell from quite a height because the roof of a 12-storey building was coated with the substance. (R21)

X16. November 11, 1953. North Atlantic Ocean. The wind coated the lookouts of S.S. Caxton with a phosphorescent substance that gave off a greenish glow. It was readily brushed off and could be transferred to other objects. It might have been wind-blown bioluminescent organisms. (R22)

X17. December 1870. Venezuela. After a heavy rain, plant leaves were covered with a great many yellow specks, which microscopic examination proved to be fresh-water plant cells; species Triceratium and Cosmarium. (R23)

X18. Frequent occurrence. Bath, England. "I should be very glad if I could obtain information as to the cause and nature of certain 'purple patches' which I have noticed from time to time for many years past, but have been unable to get explained. The patches in question occur during, or immediately after, rain, on the pavement or roadway; dashes of vivid purple, or rather violet, varying in size from small splashes or drops to patches as large as the palm of one's hand, but most commonly they are about the size of a shilling. When quite fresh, sometimes a little clot is observable in the centre of the splash. Sometimes I find one patch completely isolated, sometimes two or three in close proximity; sometimes, again, numerous little drops scattered over a certain space; once I counted twenty or thirty tiny dashes in about ten yards of pavement. When quite wet the violet colour can be rubbed up with a handkerchief or paper, which it stains as with 'aniline purple' dye, as it does the pavement, and when once dry it is quite inerasible, and lasts till it is worn away by exposure, or the feet of passers-by. I observe it to occur chiefly during warm rain after a dry or cold spell; never during dry weather, whether in summer or winter. During the past hot summer there was none to be found, but directly the weather changed in July, I saw it in various localities. This was also the case in the long cold winter of 1895, when on the breaking up of the frost there were plentiful patches to be seen up and down the streets; there was also a complete absence during the following summer, till the drought gave, and then again I found this appearance recur." (R24) One letter to Nature suggested the patches were droppings from berry-eating birds. (R25) The purple patches, however, seem to be found all seasons of the year in many localities. But there is probably some similar prosaic explanation. (WRC)

X19. 1876. Bath Co., Kentucky. An extensive shower of jelly-like substance. Thought to be the dried spawn of fishes or frogs. (R26) See X4, which may be the same incident.

X20. May 5, 1786. San Domingo. "Manna is the bread of organic showers; but what is the meat? Showers of flesh have often been recorded and they have proved to be precipitations of a glairy substance, which upon partial drying formed enough of a skin on the outside to induce people to call it flesh. When found fresh, this material has been compared to butter. Probably most if not all of it is the material known as zooglea formed on the surface of water where bacteria are actively multiplying. The substance known as zoogen or xoiodin is probably the same." (X19 described here) "Such spawn really has rained down also, if we may believe the account of M. Moreau de St. Mery, relating to an observation in San Domingo. 'From November, 1785, to the 5th day of May, 1786, there was experienced a terrible drought. The last day, viz, May 5, 1786, there fell during a strong east wind, in several parts of the city of Port au Prince....a great quantity of black eggs, which hatched the following day. M. Mozard preserved about 50 of these small animals in a flask half full of water, where they shed their skins several times. They resembled tadpoles.'" (R26)

X21. No date given. Lake Providence, Louisiana. "It is stated that during a heavy thunder-storm near Lake Providence, Louisiana, a number of small bodies were found on the ground, immediately after the shower, scattered along the shore of the Mississippi River for a distance of forty miles above the lake; as many as half a bushel being collected around one house. These, on being submitted to critical examination, proved to be the scales of the common gar-fish of the South (Lepidosteus). The species inhabits the shallow, muddy waters of the South and sometimes attains a length of five or six feet, and is especially characterized by being enclosed in an almost impenetrable coat of mail (the scales in question), so compact as almost to resist the penetration of a bullet. It is very difficult to give credence to this story; as the gar-fish are not particularly abundant, and the method of aggregation of so large a number of detached scales would be a problem extremely difficult of solution. Perfectly authentic instances are on record of small fish, shells, etc., being taken up in storms and scattered over the earth; but when it comes to special portions of fishes which weight from 5 to 50 lbs. each, the draft upon one's faith is rather too severe." (R27)

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R5. "Correction of the Statement Concerning an Alleged 'Shower of Red Matter Like Blood and Muscle'," American Journal of Science, 1:44:216, 1843. (X3)

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R8. Greene, T. W.; "Showers of Feathers," Zoologist, 17:6442, 1859. (X5)

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R26. McAtee, Waldo L.; "Showers of Organic Matter," Monthly Weather Review, 45:217, 1917. (X19, X20)
R27. Gudger, E. W.; "Rains of Fishes," Natural History, 21:607, 1921. (X21)

GWF10 Fish Falls

Description. The fall of fish from the sky, often by the thousands, and usually along with heavy downpours. With rare exceptions, the fish are native to the area and alive when they hit the ground, roofs, and other structures. However, falls of dead, decaying, and dry fish have been reported. Fallen fish average 2-4 inches in length, although specimens up to a foot are on record. The area of a fish fall is typically long and narrow---a hundred feet to several miles in length.

Background. Fish falls have long been ridiculed by the scientific world and debunkers of strange phenomena, even though perfectly reasonable meteorological mechanisms exist for levitating fish and transporting them long distances.

Data Evaluation. Most reports of fish "falls" are really announcements that fish have been found out of their element; viz. on dry land or isolated pools of water. Observations of fish in free fall are rare. Nevertheless, the circumstantial evidence is very strong in many instances and when combined with the high-quality accounts of people seeing fish in the air and even being hit by them makes a strong case for the reality of the phenomenon. Rating: 1.

Anomaly Evaluation. Whirlwinds, waterspouts, and tornados can all pick up surface-swimming fish and deposit them at a distance. The anomalous features of fish falls are: (1) the falls of dead, decaying, frozen, and dry fish; and (2) the selectivity of most falls; i.e., one species only and no debris. These are not serious anomalies. Rating: 3.

Possible Explanations. Whirlwinds, waterspouts, and tornados probably account for most fish falls. Even dead and decaying fish along a shore may be picked up and transported. Some instances of supposed fish falls may result from the temporary overflowing of fish-containing bodies of water and the release of fish buried in the mud.

Similar and Related Phenomena. All other falls of living animals, especially frogs and toads (GWF11).

Examples of Fish Falls

X1. 689. Saxony, Germany. A rain of fish during a storm. (R34, R35)

X2. Spring 1666. Kent, England. "About Easter, in the year 1666, a pasture field in this parish, which is a considerable distance from the sea or any branch of it, and a place where there are no fish ponds but a scarcity of water, was scattered over with small fish, in quantity about a bushel, supposed to have been rained down from a cloud, there having been at that time a great tempest of thunder, hail, wind, etc. These fish were about the size of a man's little finger; some were like small whitings, others like sprats, and some smaller like smelts. Several of these fish were shown publically at Maidstone and Dartford." (R10, R26, R31, R44, R47) One of the classic accounts. It is typically vague in that it does not say positively that fish were seen to fall---they were simply found on the ground. (WRC)

X3. 1673. Island of Kolter, Great Britain. Many herring found on mountain top. Whirlwind postulated. (R34)

X4. 1691. Ecuador. Mud and fish erupt from volcano. (R1)

X5. June 19 and 20, 1698. Ecuador. "When the summit of the mountain Carguairazo, to the north of Chimborazo, and 18,000 feet high, fell, in the night between the 19th and 20th of June, 1698, the surrounding fields, to the extent of about 43 English square miles, were covered with mud and fishes... I recur to these facts, because they throw some light on the difference between the eruption of ashes, and that of mud-like masses of tufa and trass, which contain wood, coal, and shells." (R1, R10, R26, R31) This is not an example of a true fish rain, being geological rather than meteorological, but it does underscore the fact that fish can be deposited on the ground in many ways. (WRC)

X6. September 2-3, 1771. Cotbus, Germany. Fish 5-6 inches long reported to have fallen during a heavy thunderstorm. (R31)

X7. 1795. Lake Muritz, Germany. Heavy shower passed over lake, scattering fish over surrounding fields. (R31)

X8. July 25, 1795. Steuer, Germany. (R31)

X9. 1796. Lorn, Great Britain. Herring fry. (R2, R31)

X10. Circa 1809. Pondicherry, India. "In a heavy shower of rain, while our army was on the march, a short distance from Pondicherry, a quantity of small fish fell with the rain, to the astonishment of all. Many of them lodged on the men's hats; when General Smith, who commanded, desired them to be collected, and afterwards, when we came to our (camping) ground, they were dressed, making a small dish that was served up and eaten at the general's table. They were not flying fish, they were dead, and falling from the common well-known effect of gravity; but how they ascended, or where they existed, I do not pretend to account." (R31)

X11. March 1817. Appin, Scotland. After abundant rain, herring fry 1 1/2 to 3 inches in length found scattered over the ground. About 3 barrels full. (R2, R31)

X12. 1821. Melford House, Scotland. Shower of large herring fell during boisterous weather. (R2, R31)

X13. July 1824. Meerut, India. Fish fell on soldiers at drill. (R10, R17)

X14. Summer 1824. New York, New York. Fish found in the streets. (R47)

X15. 1825. Kinross-shire, Scotland. (R2, R10, R26, R31)

X16. July 1826. Moradabad, India. Live fish were seen to fall on the grass. (R10, R17)

X17. May 28, 1828. Kratzburg, Germany. (R31)

X18. April 21, 1828. Strathpeffer, Ireland. Ground covered with herring 3-4 inches long. (R3, R10, R21, R31, R29)

X19. Summer 1828. Cambridge, Maryland. Large fish were found in rain-filled ditches 1 mile from a river. (R4, R31)

X20. July 20, 1829. Moradabad, India. Fish were seen flipping about on the grass after a shower; one was 2 1/4 inches long. (R20, R31)

X21. February 19, 1830. Nokulhatty Factory, India. "On the 19th of February, 1830, at noon, a heavy fall of fish occurred at Nokulhatty Factory, in the Dacca zillah; depositions on the subject were obtained by nine different parties. The fish were all dead; most of them were large; some were fresh, others rotten and mutilated. They were seen at first in the sky like a flock of birds descending rapidly to the ground. There was rain drizzling at the time, but no storm." Some of the fish were headless. Some witnesses were hit by falling fish; others found them on their roofs. (R6, R10, R17, R26, R31, R40)

X22. 1830. Dunkeld, Great Britain. (R10)

X23. March 9, 1830. Argyleshire, Great Britain. Small herring scattered over the fields. (R10, R26, R44)

X24. May 16 or 17, 1831. Futtehpur, India. After a storm several thousand fish were found strewn over a wide area. They were all dead and dry. (R31) Date for this fall said to be 1833. Some of the fish weighed 3 pounds. (R10, R17, R26)

X25. 1833. Lake Gwynant, Wales. (R44)

X26. May 1835. Allahabad, India. Dead and dry fish found after storm. (R10, R17)

X27. 1835. Louisville, Kentucky. After a heavy rain, a great number of sun-perch, 2-3 inches long, found swimming in the gutters. (R44) Date given as 1837. (R7)

X28. 1838. Calcutta, India. Fish taken out of a pluviometer. (R17)

X29. September 1839. Calcutta, India. Fish, about 3 inches long, fell in a long straight line. (R10, R31) Event occurred on September 20, according to R50.

X30. June 30, 1841. Boston, Massachusetts (?). One fish 10 inches long with smaller specimens. (R10, R31, R47)

X31. July 8, 1841. Derby, England. Fish and ice fall. (R10, R31) Frogs also reported to have fallen. (R8)

X32. October 1841. Dunfermline, Great Britain. Many small fish during a heavy thunderstorm. (R9, R34)

X33. July 25, 1850. Kattywar, India. After 35 inches of rain in 26 hours, the ground was literally covered with fish; some on the tops of haystacks. (R10, R17, R31)

X34. August 3, 1852. Poonah, India. Multitudes of fish on ground after heavy rain. (R10, R17)

X35. February 9, 1859. Aberdare, Great Britain. "On Wednesday, February 9, I was getting out a piece of timber for the purpose of setting it for the saw, when I was startled by something falling all over me---down my neck, on my head, and on my back. On putting my hand down my neck I was surprised to find they were little fish. By this time I saw the whole ground covered with them. I took off my hat, the brim of which was full of them. They were jumping all about. They covered the ground in a long strip about 80 yards by 12, as we measured afterwards. That shed (pointing to a very large workshop) was covered with them, and the shoots were quite full of them. My mates and I might have gathered bucketsful of them, scraping with our hands." (R11, R12, R13, R17, R29, R31, R34, R48) J. E. Gray, of the British Museum, thinks it was all a practical joke. (R14) R. Drane, who investigated the fall carefully asserts that it could not have been a practical joke because the fall occurred over a considerable tract of country, with testimony from widely separated areas. (R15)

X36. February 20, 21, and 26, 1861. Singapore. "When the sun came out again I saw numbers of Malays and Chinese filling their baskets with fish contained in the pools formed by the rain. They told me the fish had 'fallen from heaven,' and three days later, when the pools were all dried up, there were still many dead fish lying about. I found them to belong to the Clarias batrachus, which can live a considerable time out of water, and even move to some distance on dry land. As they lay in my courtyard, which is surrounded by a wall, they could not have been brought in by the overflowing of a torrent, nor is there any considerable one in the neighborhood. The space covered by these fishes might be about fifty acres. They were very lively and seemed to be in good health." (R16, R26, R31, R34, R47)

X37. June 9, 1868. Dolitz, Germany. (R31)

X38. May 24, 1873. Bremen, Germany. Great number of whitefish. A waterspout was seen in the area. (R31)

X39. Circa 1875. Woodbury, New Jersey. Small fish found flapping about after a heavy rain. (R34)

X40. 1879. Berrybank, Australia. Thousands of minnows found swimming in pools left by a rainstorm. The track of the storm was only 100 yards wide by half a mile long. (R34)

X41. December 15, 1883. Airdric, Scotland. A shower of live perch, which are usually deep-water swimmers. (R19)

X42. Circa 1886. Aberdeen, South Dakota. Small fish found on the roofs of office buildings after hard rain. (R34)

X43. January 24, 1887. Walgett, Australia. Many fish about 3 inches long found in standing water on a road after heavy storms. After the water dried up there were thousands of dead fish counted. (R20)

X44. 1888. Near Little Rock, Arkansas. Fish found in ponds that were dry before a heavy rain. (R34)

X45. 1889. Steyl-Teegelen, Holland. A waterspout formed and then retracted itself into a cloud, disintegrating with a couple loud detonations. A huge quantity of water and many fish fell immediately after. (R34)

X46. Summer 1890. Grape Creek, Illinois. Small sunfish and small frogs covered a field after a heavy rain. (R25)

X47. May 29, 1892. Coalburg, Alabama. So many eels fell in a shower that farmers came with carts to take them away for fertilizer. (R47) Why only eels?

X48. 1893. Winter Park, Florida. Sunfish 2-4 inches long fell with rain. (R22)

X49. June 15, 1895. Co. Clare, Ireland. Many fish 1 1/2-2 inches long fell with a few drops of rain. (R23)

X50. July 26, 1896. Essen on the Ruhr, Germany. A hailstone the size of a hen's egg contained a crucian carp 40 mm long. (R31, R44)

X51. May 15, 1900. Providence, Rhode Island. During a severe thunderstorm, perch and bullpouts 2-4 inches long fell on yards and streets. (R35. R47)

X52. Summer 1900. Buffalo, New York. Street puddles filled with small fish. (R34)

X53. June 27, 1901. Tillers Ferry, South Carolina. Hundreds of little catfish, perch, trout, etc., fell during a heavy rain and were found swimming in the pools between cotton rows. (R24, R26, R31, R47)

X54. April 14, 1909. Newcastle, Natal. "The locality of this rain was near the borough of Newcastle, Natal, and the area covered was about 400 yards long by 100 wide. This area lies between two running streams ---Osborne Spruit, 400 yards away and at about 50 feet lower level, and Indanda River, a mile away and about 80 feet below the level of the region where the fishes fell. Thus there was no possible chance that the fishes had been brought on the land by an inundation. Mr. Nesbit did not actually witness the fall, since it took place some time between midnight and 6 o'clock of the morning of April 14, 1909, but he did see and pick up some of the fishes alive at 7:30 A. M. on this day. He reported that there were literally hundreds of fishes, some alive and comparatively unhurt, some dead, and some smashed almost to a pulp. The largest fishes were 3 inches long, the average length about 1.5 inches. There were several kinds of fishes, and Dr. Warren notes that the largest were Barbus gurneyi." (R34, R36) The varying amounts of damage done to the fishes is curious. Why are some unhurt while others are smashed to a pulp? (WRC)

X55. 1915. Kelantan, Malaya. A terrific thunderstorm; water was ankle-deep in 10 minutes. Many small fish about 1 1/2 inches long seen in water covering hard-baked fields. They were not mudfish because the water ran off before mud was formed. (R34)

X56. August 24, 1918. Hendon, England. "About 3 o'clock on the afternoon of Saturday, August 24 last, the allotment-holders of a small area in Hendon, a southern suburb of Sunderland, were sheltering in their sheds during a heavy thundershower, when they observed that small fish were being rained to the ground. The fish were precipitated on three adjoining roads and on the allotment-gardens enclosed by the roads; the rain swept them from the roads into the gutters and from the roofs of the sheds into the spouts.... The precipitation of the fish, we were told, lasted about ten minutes, and the area involved Commercial Road, Canon Cocker Street the portion of Ashley Street lying between these streets, and the adjoining gardens. The area measured approximately 60 yards by 30 yards, and was thus about one-third of an acre. It is not easy to say how many fish fell, but from the accounts it may be gathered they were numerous; there were apparently several hundreds." The fish were identified as sand-eels. All were dead when they fell. They were, in fact stiff and hard; and some broke when they hit the ground. (R27, R28, R34, R45, R47) If the sand-eels were dead and stiff they must have been aloft for many minutes, perhaps hours. (WRC)

X57. 1919. Argylshire, Great Britain. A waterspout burst, precipitating herrings in heaps on pavements and roofs. (R30)

X58. June 11, 1921. Gulf of Mexico. A cloud to which a waterspout had been attached dumped a torrent of water upon a fishing boat. Between 30 and 50 menhaden 2-3 inches long came down with the deluge. (R34)

X59. 1924. Gulargambone, Australia. Hundreds of small gudgeons found in the gutters after heavy rain. (R33)

X60. May 29, 1928. Drumhirk, Ireland. After an exceptionally violent thunderstorm, dozens of tiny red fish were discovered on the roof of a house. (R38)

X61. May 18, 1928. Tarboro, North Carolina. Hundreds of small fish were found swimming in puddles in the fields after a heavy downpour. (R35)

X62. July 10, 1933. Muzaffapur District, India. (R39)

X63. September 1936. Guam. "While stationed on the island of Guam in September, 1936, I witnessed a brief rainfall of fish, one of the specimens of which was identified as the tench (Tinca tinca) which, to my knowledge, is common only to the fresh waters of Europe. The presence of this species at a locale so remote from its normal habitat is worthy of note." (R43)

X64. October 23, 1947. Marksville, Louisiana. "A rainfall of fish occurred on October 23, 1947, in Marksville, Louisiana, while I was conducting biological investigations for the Department of Wild Life and Fisheries. In the morning of that day, between seven and eight o'clock, fish ranging from two to nine inches in length fell on the streets and in yards, mystifying the citizens of that southern town. I was in the restaurant with my wife having breakfast, when the waitress informed us that fish were falling from the sky. We went immediately to collect some of the fish. The people in town were excited. The director of the Marksville Bank, J. M. Barham, said he had discovered upon arising from bed that fish had fallen by hundreds in his yard, and in the adjacent yard of Mrs. J. W. Joffrion. The cashier of the same bank, J. E. Gremillion, and two merchants, E. A. Blanchard and J. M. Brouillette, were struck by falling fish as they walked toward their places of business about 7:45 a.m. There were spots on Main Street, in the vicinity of the bank (a half block from the restaurant) averaging one fish per square yard. Automobiles and trucks were running over them. Fish also fell on the roofs of houses." The several species that fell were native to local waters. They were cold when picked up; one person claimed they were frozen. The fish fell in a strip 75-80 feet wide and about 1,000 feet long. The weather was foggy but comparatively calm. (R42) The calm weather is an unusual aspect of this report. (WRC)

X65. July 13, 1949. Wellington, New Zealand. (R45)

X66. 1824. Fifeshire, Great Britain. (R34)

X67. No date given. Gulargambone, Australia. Many fish found in gutters after a heavy rain. (R34) Same as X59?

X68. No date given. Argentina. It is not unusual for heavy rains in the Chaco region to include fish falls. (R34)

X69. No date given. Shaw, Mississippi. Minnows found swimming between cotton rows after a heavy rain. (R34)

X70. No date given. Galloway, Scotland. A shower of herrings. (R2)

X71. No date given. Near Paris, France. Streets covered with fish up to 6 inches long. (R31)

X72. General observation. In the arctic live fish are occasionally found in dry places. They may get there during migration, when they often leap (like salmon) over obstructions. (R32)

X73. General comment. Fish found alive in fields did not fall there but were stranded after heavy rains inundated the areas. (R18)

X74. General comment. Evidence for fish falls is all hearsay. They never occur in fact. (R41) The author of this letter to Science, Bergen Evans, was a well-known debunker of unusual phenomena. (WRC)

X75. Superficial descriptions of the fish-fall phenomenon. (R37, R46)

X76. No date given. Bullia, India. A waterspout broke and produced heavy rain along with a shower of fish and turtles. (R21)

X77. July 5, 1825. Kingwood, New Jersey. A four-inch sunfish, still alive, during a violent rainstorm. (R49)

X78. November 1931. Bordeaux, France. (R51)

X79. January 20, 1936. Florence, Italy. Fish seen spinning in the air in violent whirlwinds. (R52)

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GWF11 Falls of Frogs and Toads

Description. The descent of frogs or toads from the sky, usually by the hundreds or thousands. Frog and toad falls are inevitably associated with heavy summer rainstorms. The falling animals are usually alive, although some die upon impact, and average about a half inch in length. These falls are generally "pure"; that is, not accompanied by other aquatic species or plant debris.

Data Evaluation. Rather surprisingly, many very good cases of frog/toad falls are on record, although they tend to be concentrated in the Nineteenth Century, when science openly discussed such events without fear of ridicule. While the bulk of the cases involve animals actually seen in flight, some reports may be due to population explosions and mass migrations, with no actual levitation involved. Rating: 1.

Anomaly Evaluation. As in the case of fish falls (GWF10), whirlwinds, waterspouts, and tornados are believable meteorological mechanisms for collecting and transporting small frogs and toads. The anomalous features of this phenomenon are: (1) The very large number of individuals involved, which infers that the levitating mechanism must strip very large areas of toad/frog habitat and then concentrate its cargo; (2) The selectivity of the phenomenon; i.e., the general lack of debris and other species typical of the animals' habitat. Rating: 3.

Possible Explanations. The conventional explanation---whirlwinds, waterspouts, tornados ---seems the only reasonable one at this time.

Similar and Related Phenomena. The other animals falls in this section, particularly fish falls (GWF10).

Examples of Falls of Frogs and Toads

X1. Summer 1794. Lalain, France. "It was very hot. Suddenly, at about 3 o'clock in the afternoon, there fell such an abundance of rain that 150 men of the grand guard, in order not to be submerged, were obliged to leave a large depression in which they were hidden. But what was their surprise when there began to fall on the ground all about a considerable number of toads, the size of hazelnuts, which began to jump about in every direction. M. Gayet, who could not believe that these myriads of reptiles fell with the rain, stretched out his handkerchief at the height of a man, his comrades holding the corners; they caught a considerable number of toads, most of which had the posterior part elongated into a tail, that is to say, in the tadpole state. During this rain storm, which lasted about half an hour, the men of the grand guard felt very distinctly on their hats and on their clothing the blows struck by the falling toads. As a final proof of the reality of this phenomenon, M. Gayet reports that after the storm the three-cornered hats of the men of the guard held in their folds some of the reptiles." (R18)

X2. August 1804. Near Toulouse, France. "Many accounts of showers of frogs have been reported to the French Academy. In August, 1804, two gentlemen, returning from Toulouse, noticed a black cloud, which burst upon them, and they were surprised to see an immense shower of frogs, which fell on their cloaks and covered the road and the fields, so that a diligence passing along killed a large number." (R11)

X3. 1804. Windham, Connecticut. (R21)

X4. June 23, 1809. France. Little toads, the size of hazelnuts, fell during a rain storm. (R18)

X5. August 1814. Fremon, France. During a storm with strong winds. Small frogs fell upon people. (R18)

X6. August 1822. France. A heavy shower of large raindrops also brought toads the size of walnuts. Some of the toads fell upon the hat of the observer. (R18)

X7. Circa 1830. Bushmills, England. A shower of half-formed frogs. No rain mentioned. (R1)

X8. Circa 1830. Rouen, France. Innumerable small, perfectly formed, frogs fell on roofs, window sills, and walks. (R1)

X9. June 1833. Jouy, France. "I saw toads falling from the sky; they struck my umbrella; I saw them hopping on the pavement, during about 10 minutes in which time the drops of water were not more numerous than the toads. The space upon which I saw the multitude of these animals was about 200 fathoms." (R18)

X10. July 30, 1838. London, England. After a heavy shower dozens of young frogs were discovered hopping on the pavement. (R12)

X11. June 1841. Tutbury, England. A shower of frogs fell during a severe thunderstorm. They fell in countless numbers from the housetops. (R11)

X12. 1841. Derby, England. A heavy thunderstorm deposits hundreds of fish and frogs along with half-melted ice. Many of the frogs were killed by the impact. (R2)

X13. 1844. Selby, England. "In the course of the afternoon of Monday last, during the prevalence of rather heavy rain, the good people of Selby were astonished at a remarkable phenomenon. It was rendered forcibly apparent, that with the descent of the rain, there was a shower of another description, viz., a shower of frogs. The truth of this was rendered more manifest by the circumstance that several of the frogs were caught in their descent by holding out hats for that purpose. They were about the size of a horse-bean, and remarkably lively after their aerial but wingless flight. The same phenomenon was observed in the immediate neighborhood." (R3, R10)

X14. Summer 1846. Humber River, England. Frogs fell on vessels in the river and the coast near Killinghome lights. (R18)

X15. 1847. Venton, France. A shower of toads. (R4)

X16. 1859. Waveney River, England. "I was out insect-catching by the side of the river Waveney, about a quarter-past 9 on Friday night, when a thunderstorm came on. I ran for shelter to the buildings at Aldeby Hall. The rain came down in torrents. Just before I was clear of the fens I observed some small toads on my arms, and several fell in my net, and on the ground and paths there were thousands. I am quite sure there were none in my net before I started, as I took out a Leucania pudorina out of it. I believe they fell with the rain out of the clouds." (R5)

X17. 1860s. Briton Ferry, Great Britain. Shower of frogs. (R15)

X18. 1864. Pontiac, Michigan. A small green frog found in a hailstone. (R6)

X19. August 12, 1871. No place given. A shower of small green frogs. (R7)

X20. July 1873. Kansas City, Missouri. A shower of frogs darkened the air and covered the ground for a long distance. (R9)

X21. June 16, 1882. Dubuque, Iowa. Small, still-living frogs found in hailstones. (R8)

X22. Summer 1890. Grape Creek, Illinois. After a heavy rain, the ground was covered with small perch and frogs 3/4 to 1 inch long. (R17)

X23. Circa 1891. Bournemouth, England. "One day we had a violent thunderstorm. Having no shelter, I was wet to the skin in a few minutes, and saw small yellow frogs, about the size of a florin or half-crown, dashed on the ground all around me. I ran to shelter under a large mortar-pan, and, after the storm was over, found in this pan hundreds of these small frogs... Thousands were impaled on the furze bushes on the common close by, and days afterwards the stench from the decomposing bodies was very noticable." (R14)

X24. June 30, 1892. Moseley, England. A furious storm brought a shower of nearly white frogs. (R18)

X25. Circa 1894. Dunfermline, Great Britain. (R10)

X26. August 1894. Thatto Heath, England. Great numbers of frogs or toads found on the ground after a rain. (R11, R24)

X27. 1901. New York City. Tadpoles. (R21)

X28. 1911. Twickenham, England. Tadpoles found in a rain barrel. (R13) A weak bit of evidence. (WRC)

X29. May 25, 1915. Gibraltar. "During a thunderstorm near Gibraltar on May 25, a cloud is said to have belched forth millions of small frogs which had apparently been drawn up from a lake twenty miles away." (R16)

X30. July 21, 1933. North Chelmsford, Massachusetts. Shower of small toads. (R21)

X31. June 16, 1939. Trowbridge, England. "Mr. E. Ettles, superintendent of the municipal swimming pool stated that about 4.30 p.m. he was caught in a heavy shower of rain and, while hurrying to shelter, heard behind him a sound as of the falling of lumps of mud. Turning, he was amazed to see hundreds of tiny frogs falling on the concrete path around the bath. Later, many more were found to have fallen on the grass nearby." (R19-R21, R25)

X32. July 26, 1947. Towyn, Great Britain. Frog fall. (R20)

X33. August 28, 1977. Canet-Plage, France. Thousands of frogs, the size of peas, fell just prior to a heavy rain shower. (R22)

X34. No date given. Ham, France. A statement by M. Peltier. "I cite an incident I observed in my youth; a storm advanced on the little village of Ham, Department of the Somme, where I lived, and I observed its menacing march, when suddenly rain fell in torrents. I saw the village square covered everywhere with little toads. Astonished by this sight, I held out my hand and was struck by several of the reptiles. The dooryard was also covered; I saw them fall upon the slate roof and rebound to the pavement.... Whatever the difficulty of explaining the transport of the reptiles, I affirm, without doubt the fact which made such a profound impression upon my memory." (R18) The observer may have been the scientist Peltier, but this has not yet been established definitely. (WRC)

X35. No date given. Godalming, Great Britain. The town was swarming with small black frogs. Inhabitants said that they had come with the rain. (R11) Population explosions can often account for the sudden appearance of large numbers of animals. Some species mature and migrate in incredible numbers. (WRC)

X36. 1834. France. (R23) Same as X4?

X37. 1922. Chalon-sur-Saone, France. Frog fall disproved. Due to migrating swarms of frogs. (R24)

X38. June 24, 1979. Bedford, England. Fall of small frogs. Tornados reported in area. (R24)

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GWF12 Insect Falls

Description. The fall of flightless insects from the sky. Worms and caterpillars are the most common occupants of this category.

Data Evaluation. Only a few accounts of rather poor quality exist. Some cases are suspect because some insect species migrate in immense numbers and shed their wings immediately upon landing. There are as a consequence many opportunities for labelling natural insect movements as "falls." Rating: 3.

Anomaly Evaluation. Since insects may appear in great profusion and are very light in weight, wind transport is a reasonable explanation in almost all cases; and insect falls are really more curiosities than anomalies. Rating: 3.

Possible Explanations. Whirlwinds, waterspouts, tornados, and even strong, non-rotating winds seem adequate here.

Similar and Related Phenomena. Other animal falls in this section (GWF). Insect population explosions (BI).

Examples of Insect Falls

X1. June 1819. Riga, Latvia. "During a strong north west wind, an immense quantity of young caterpillars fell upon the great meadows on the south bank of the Duna, and devoured the grass, with the roots, upon a very extensive tract." (R1) A classic case, but one in which the word "fell" might only mean "appeared." (WRC)

X2. November 1854. Turin, Italy. Several thousand insects, both larvae and adults, fell during a violent wind. There were a species of hemiptera known only on Sardinia. (R7)

X3. May 1871. Bath, England. "A most violent storm of rain, hail, and lightning visited Bath on Saturday night. The rain descended in torrents, causing the Avon to overflow its banks in the lower districts, especially at Salford, where whole tracts of land were laid under water. The storm was accompanied by a similar phenomenon to that of the previous Sunday; myriads of small annelidae enclosed in patches of gelatinous substance, falling with the rain and covering the ground. These have been microscopically examined, and show, under a powerful lens, animals with barrel-formed bodies, the motion of the viscera in which is perfectly visible, with locust-shaped heads bearing long antennae, and with pectoral and caudal fin like feet. They are each and inch and a half long, and may be seen by the curious at Mr. R. Butler's, The Derby and Midland Tavern, where scientific men, on inspecting them, pronounce them to be marine insects, probably caught up into the clouds by a waterspout in the Bristol Channel." (R2)

X4. July 25, 1872. Bucharest, Romania. "A letter from Bucharest, given in the Levant Times, reports a curious atmospheric phenomenon which occurred there on the 25th of July, at a quarter past nine in the evening. During the day the heat was stifling, and the sky cloudless. Towards nine o'clock a small cloud appeared on the horizon, and a quarter of an hour afterwards rain began to fall, when, to the horror of everybody, it was found to consist of black worms of the size of an ordinary fly. All the streets were strewn with these curious animals." (R3)

X5. Circa 1897. Hutchinson, Minnesota. A luminous cloud "rose majestically from the eastern horizon, shown with a uniform, vivid whitish light and passed directly over the town. When the cloud was overhead a great shower of insects descended to earth covering the ground all around to the number of about 50 to 100 per square foot. These insects proved to be a species of hemiptera and were nonluminous. They had apparently been induced to take wing by the bright object in the sky." (R5) Since these insects were winged, it is the possible association with the cloud that is of interest here. (WRC)

X6. No dates given. Galatz and Bucharest, Romania. (R4)

X7. October 14, 1934. Rock Creek, British Columbia, Canada. "It rained beetles at Rock Creek, B. C., Oct. 14. The downpour of tiny brown insects lasted intermittently for three hours. The beetles had wings, but seemed unable to use them." (R6) Another weak example, obviously. (WRC)

References

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R5. Zeleny, John; "Rumbling Clouds and Luminous Clouds," Science, 75:80, 1932. (X5)
R6. American Meteorological Society, Bulletin, 15:113, 1934. (X7)
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GWF13 Bird Falls

Description. The fall of live or dead birds from the sky. Bird falls are usually associated with severe weather conditions. During spring and fall migrations, many birds are killed by impact with tall buildings, TV antennas, and other obstructions. Except for a couple extreme cases, which may involve anomalous factors, such normal bird mortality is excluded here.

Background. We consider birds to be masters of the air, but it is obvious that they are sometimes overwhelmed by the elements and have their navigational senses confused, resulting in immense numbers being killed.

Data Evaluation. Excluding the common reports of dead birds found around tall obstructions during migration leaves only a few difficult-to-explain cases, many of which come from suspect sources. Rating: 2.

Anomaly Evaluation. Most of the bird falls or kills described below seem understandable in the context of severe weather and, though huge numbers of birds are involved, they are more curious than anomalous. Examples X1, X3, and X6, however, have puzzling characteristics that make the "weather" explanation seem simplistic. Rating: 3.

Possible Explanations. Dead birds found around tall obstructions typify "impact kills" and need no further explanation. Dead birds falling from an unobstructed sky are frequently found to have suffered decompression effects and were probably carried to great heights by storms. Lightning has also been advanced as a factor in some bird falls.

Similar and Related Phenomena. None.

Examples of Bird Falls

X1. 1896. Baton Rouge Louisiana. "On Friday morning last early risers in the little capital witnessed a peculiar sight in the shape of a shower of birds that fell from a clear sky, literally cluttering the streets of the city. There were wild ducks, catbirds, woodpeckers, and many birds of strange plumage, some of them resembling canaries, but all dead, falling in heaps along the thoroughfares, the singular phenomenon attracting many spectators and causing much comment." In the neighborhood of National Avenue, children collected 200 birds. (R1)

X2. March 20, 1941. Shreveport, Louisiana. "Blackbirds by the hundreds dropped dead from the sky at Barksdale Field. They cluttered the army airbase so thickly that its police were called out to clear the ground. A soldier said large flocks of the birds broke flight suddenly and plopped to the ground." (R2)

X3. March 13-14, 1904. Minnesota. "Roberts tells the fate of migrating Lapland Longspurs on the night of March 13-14, 1904, which 'was very dark but not cold, and a heavy, wet snow was falling with but little wind stirring. Migrating Longspurs came from the Iowa praries in a vast horde, and from 11 P. M. until morning, incredible numbers met their deaths in and about villages by flying against buildings, electric light poles and wires, and by dashing themselves forcibly onto the frozen ground and ice.' In Worthington, Minnesota, an attempt was made to compute the numbers lying dead on two lakes with an aggregate area of about two square miles. 'A conservative estimate showed that there were at least 750,000 dead Longspurs lying on the two lakes alone!' The total area on which dead migrants were found covered approximately 1,500 square miles." (R3) Although some of the birds apparently flew into obstructions, the great majority seems to have been found on relatively featureless terrain. (WRC)

X4. December 13, 1928. Caliente, Nevada. "During an early morning hour (about 2 A. M.) of December 13, 1928, residents of Caliente, Nevada, were awakened by a heavy thumping of something falling on the roofs of their houses. Those who were curious enough to step outside and investigate the unusual occurence found scores of water birds in the new fallen snow. The next morning, several thousand Eared Grebes were found on the ground and on flat roofs of business houses throughout the city....literally thousands of these birds were found in every portion of the town and outskirts....they were forced out of the air by the heavy density of the snow.... Caliente had the main bunch, but they were scattered for twenty miles every way." Hundreds more were discovered in various spots in Utah. (R3)

X5. October 7-8, 1954. Warner Robins Air Force Base, Georgia. "On the night of October 7-8, 1954, the largest recorded ceilometer kill in history occurred at Warner Robbins Air Force Base, a few miles south of Macon, Georgia. It involved 53 species and an estimated 50,000 birds, 2552 of which were examined.... An advancing cold front in the autumn is believed to have precipitated these mass mortalities by bringing together adverse weather conditions (especially a lowered cloud ceiling), nocturnal migrants, ceilometers and/or tall obstructions." (R4) These is an extreme example of bird kills that take place around obstructions during every migration period. (WRC)

X6. January 25, 1969. St. Mary's City, Maryland. "On Jan. 25, 1969, something smashed up flocks of ducks flying over Maryland so that their dead and dying bodies rained down around the southern Maryland community of St. Mary's City (about 50 miles SE of Washington, D. C.) Canvasbacks, redheads and scaups were found scattered around St. Mary's City, on the local college campus, in the St. Mary's River and even in the downtown business section. The ducks had sustained widespread hemorrhages and multiple rib fractures." Attributed to the Washington Post of January 26, 1969. (R5)

X7. January 3, 1978. County of Norfolk, England. "136 pink-footed geese were killed in flight in the county of Norfolk. They dropped dead out of the clouds along a track 45 km in length, orientated WNW to ESE between Castleacre and Swardeston. Their deaths occurred at the same time as a tornado-bearing cold front was sweeping southeastwards across East Anglia." Autopsies showed extensive hemorrhaging of the lungs, ruptured livers, and massive internal fracures and bone damage. It was postulated that the decompression effects experienced in a tornado and falls from a great height could account for all the damage noted. (R6)

X8. November 1973. Stuttgart, Arkansas. "On the day after Thanksgiving, hefty, mature mallards came crashing out of the sky. Many of them were frozen stiff.... The day the ducks came tumbling down was a wild and turbulent one in Arkansas. Several twisters were sighted over the state and several touched down amid violent springlike thunderstorms, wind flurries and hail storms. ....'It was about 4 PM,' said Lloyd McCollum, chairman of the State Game & Fish Commission, who lives here. 'Within 10 to 15 minutes all of them had come down, all mature, fairly heavy ducks.' The ducks came down with a lot of hail and several were completely ice-encrusted, according to witnesses. Possibly they may have been pitched up higher than normal and frozen along with the hail. 'They goy up there in colder atmosphere and, just like an airplane, got iced over,' Mr. McCollum said. 'They got ice on their wings and couldn't fly. In short, they just froze to death.'" (R7)

References

R1. McAtee, Waldo L.; "Showers of Organic Matter," Monthly Weather Review, 45:217, 1917. (X1)

R2. "Rain of Dead Blackbirds," Fortean Society Magazine, 1:4, October 1941. (X2)

R3. Hochbaum, H. Albert; Migrations of Waterfowl, 1955, p. 168. (X3, X4) (Cr. L. Gearhart)

R4. Johnston, David W., and Haines, T. P.; "Analysis of Mass Bird Mortality in October, 1954," The Auk, 74:447, 1957. (X5) (Cr. L. Gearhart)

R5. "Fall of Ducks," INFO Journal, 1:43,

Spring 1969. (X6)
R6. Meaden, G.T.; "Tornado on a Wild Goose Chase," Journal of Meteorology, U.K., 4:77, 1979. (X7)
R7. "Frozen Ducks Fall from the Sky onto Town," Buffalo Evening News, December 5, 1973, p. III-60. (X8) (Cr. L. Gearhart)

GWF14 Falls of Miscellaneous Living Animals

Description. Falls of living animals other than those described in earlier sections. Included here are purported falls of shellfish, snails, snakes, lizards, and similar reptiles and amphibians. As with the other reported animal falls, the miscellaneous falls are generally concurrent with heavy rainfall. Very large numbers of individuals may be involved. These falls usually consist of one species only, with no accompanying debris.

Background. Heavy precipitation may drive terrestrial animals out of their hiding places and, in other instances, stimulate population explosions or mass movements. Most humans have little appreciation for the immense numbers of animals living hidden around them. Thus, when a storm drives these creatures abroad in great numbers, anomalous falls from the sky are claimed erroneously.

Data Evaluation. Most reports of animal falls recorded below are suspect because the animals were not actually seen in flight. The evidence for a "fall" is therefore circumstantial. A few cases are rather convincing (X1, X2, X6, X7); and these generally involve water-dwelling species. Composite rating: 2.

Anomaly Evaluation. The best cases, which include water-dwelling animals, yield readily to the usual whirlwind-waterspout-tornado explanation. It is curious though how shellfish, for example, are separated so cleanly from the sand in which they live. The weakest cases concern rather large animals, snakes, turtles, etc., and would require very strong winds to whisk them aloft. The puzzling aspects here are minor, and a composite rating of 3 is all that is justified. Rating: 3.

Possible Explanations. The familiar trio: whirlwinds, waterspouts, and tornados.

Similar and Related Phenomena. All other animal falls in GWF. See also "population explosions" in BI, BR, etc.

Examples of Falls of Miscellaneous Living Animals

X1. June 8, 1881. Salem, Iowa."'On the night of June 8, 1881, there was a heavy rain-fall, and on the morning of the 9th, the ground was covered, in places, with something that looked like blood. I found that they were living creatures, and with a spoon took up a pint of the muddy water containing them.' Upon examining the sample received, I found it to be swarming with Cyclops quadricornis, or what I take to be that species. The only thing peculiar about them, is, that the body is full of bright red corpuscles, which accounts for their imparting a red appearance to the water containing them.... While it might not be considered remarkable that a few of these animals should be found in pools of rain-water, I am puzzled to understand how they came here in such immense numbers, unless we suppose that they were distributed through the whole body of rain that fell, and were afterwards concentrated by the draining away of surplus water. There were not less than five hundred in the sample of water sent me, of which about one-third were alive when received, after having been tightly corked for several days." (R8) Cyclops quadricornis is a small crustacean.

X2. August 1894. Bath, England. "During a recent thunderstorm at Bath there fell many thousands of small jelly fish, and the pavements and roads were splattered with them. They were of about the size of a shilling." (R16)

X3. No date given. Monastereen, Ireland. A shower of shells. (R1)

X4. August 9, 1834. United States. A fall of molluscs. (R18)

X5. 1835. Montpellier, France. A fall of Bulimus truncatus, a type of mollusc. (R18)

X6. June 6, 1869, Chester, Pennsylvania. "Mr. John Ford exhibited to the Conchological Section, Academy of Natural Sciences, Philadelphia, specimens of Gemma gemma, remarkable as having fallen, accompanied by rain, in a storm which occurred at Chester, Pennsylvania, on the afternoon of June 6, 1869. The specimens were perfect, but very minute, measuring one-eighth inch in length by three-sixteenths of an inch in breadth. Though most of the specimens which fell were broken, yet many perfect ones were collected in various places, sheltered from the heavy rain which followed their descent. A witness of the storm, Mr. Y. S. Walter, editor of the Delaware County Republican, assured Mr. F. that he noticed the singular character of the storm at its very commencement, and, to use his own words, "it seemed like a storm within a storm." A very fine rain fell rapidly, veiled by the shells, which fell slower and with a whirling motion. Judging from the remains of animal matter attached to some of the specimens, together with the fresh appearance of the epidermis, it is highly probable that many of them were living at the moment of transition. This minute species resembles a quahaug shell, and is common on the seashore between tide marks." (R5)

X7. August 9, 1892. Paderhorn, Germany. "A yellowish cloud attracted the attention of several people, both from its colour and the rapidity of its motion, when suddenly it burst, a torrential rain fell with a rattling sound, and immediately afterwards the pavement was found to be covered with hundreds of mussels." The mussels were still alive and were identified as Anodonta anatina L. (R13, R19)

X8. Summer 1821. Bristol, England. A supposed shower of periwinkles. A resident of the area thought it was just the annual pilgrimage of Helix virgata looking for a mate. (R3)

X9. May 1851. Bradford, England. A heavy shower of snails, which might have been gathered by the bushel. (R2)

X10. 1885. Pembroke Dockyard, England. A thick shower of small snails fell during a downpour of rain over a space about 100 yards in diameter. (R9) Another observer believed the snails were there all the time and emerged from hiding after the rain. (R10)

X11. 1886. England. "Having heard that a fall of shell snails had taken place a few miles from here, I visited the place and found from a man who lived on the spot, that about 9 p. m. just as it was nearly dark, what appeared to be a very black thunder cloud rose from the west, and he went in for shelter. Next morning, on going to work, the roads, fields and stone hedges were plentifully strewn with small living shell snails, the fall extending over about three acres of land, but beyond these limits no shells were to be found." (R11) Once again, the snails were not seen to fall, and sudden emergence after a rain remains a viable explanation. (WRC)

X12. July 8, 1886. Redruth, England. "After a rather prolonged period of dry hot weather, a heavy thunder-shower fell on the north side of the parish of Illogan, about three miles from Redruth, Cornwall, about 9 P. M. on Thursday, July 8th, the wind being N. N. W. On the following morning, a farmer resident in the district, going to his work about 6 A. M., noticed that the roads and fields in the track over which the shower extended were strewed with small snails of a kind quite different to any previously observed in the district. They were then, he states, lying about in such numbers, that he could gather them together in handfuls." (R12) Actual fall of snails not observed, as usual with this class of animal. (WRC)

X13. January 20, 1894. Nashville, Tennessee. During unusually heavy rain, seven young men sheltering under an awning heard a splash and saw a living creature 5 feet from the pavement. They captured a full-grown salamander (Amblystoma xiphias) 10 3/4 inches long. The animal was not actually seen to fall. (R17)

X14. December 1857. Montreal, Quebec, Canada. A shower of live lizards fell upon the sidewalks and streets. (R14, R21)

X15. July 3, 1860. South Granville, New York. During a very heavy shower, observer hears sound at his feet, looks down and finds a stunned snake. He assumed it fell there during the rain. (R4)

X16. January 15, 1877. Memphis, Tennessee. "Morning opened with light rain; 10:20 a. m. began to pour down in torrents, lasting fifteen minutes, wind SW; immediately after the reptiles were discovered crawling on the sidewalks, in the road, gutters and yards at Vance street, between Lauderdale and Goslee streets, two blocks; careful inquiry was made to ascertain if anyone had seen them descend, but without success; neither were they to be found in the cisterns, on roofs, or any elevations above the ground;

Vance street is comparatively new, has no pavements, gutters merely trenches; I heard of none being found elsewhere; when first they were a very dark brown, almost black; were very thick in some places, being tangled together like a mass of thread or yarn." (R6) The foregoing is an on-the-spot report by a weather observer. The famous Memphis snake shower seems best explained in terms of emergence after heavy rain. But a later report in Scientific American (R7) claims that thousands of snakes 12-18 inches long fell after being "carried aloft by a hurricane."

X17. 1873. Minnesota. Shower of unidentified reptiles. (R18)

X18. May 11, 1894. Bovina, Mississippi. A gopher turtle, 6 by 8 inches, entirely encased in ice, fell with the hail. (R15, R20, R22, R23, R18)

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R2. Douglas, J. W.; "Shower of Snails," Zoologist, 9:3176, 1851. (X9)
R3. Baker, Wm.; "Shower of Snails," Zoologist, 10:3187, 1851. (X8)
R4. Ruggles, Wm.; "Raining Snakes," Scientific American, 3:112, 1860. (X15)
R5. "A Shower of Shell-Fish," Scientific American, 22:386, 1870. (X6)
R6. "Reptiles," Monthly Weather Review, 5:8, 1877. (X16)
R7. "A Snake Rain," Scientific American, 36:86, 1877. (X16)
R8. Beal, F. E. L.; "A Shower of Cyclops Quadricornis," American Naturalist, 15:736, 1881. (X1)
R9. Reynolds, B.; "A Shower of Snails," Knowledge, 8:253, 1885. (X10)
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R13. Nature, 47:278, 1893. (X7)
R14. Baxter, Charles R.; "A Shower of Frogs," Notes and Queries, 8:6:104, 1894. (X14)
R15. Nature, 50:430, 1894. (X18)
R16. Penny, C. W.; "A Shower of Frogs," Notes and Queries, 8:6:190, 1894. (X2)
R17. Osburn, Wm.; "Do Earth Worms Rain Down?" Science, 23:66, 1894. (X13)
R18. McAtee, Waldo L.; "Showers of Organic Matter," Monthly Weather Review, 45:217, 1917. (X4, X5, X18)
R19. "Showers of Fishes and Other Things," English Mechanic, 108:118, 1918. (X7)
R20. Nature, 125:728, 1930. (X18)
R21. Martin, M. W.; "Crazy Rains or Animals That Fall from the Sky," Science Digest, 67:32, January 1970. (X14)
R22. Meaden, G. T.; "The Giant Ice-Meteor or Superhailstone," Journal of Meteorology, U.K., 2:201, 1977. (X18)
R23. "Remarkable Hail," Monthly Weather Review, 22:215, 1894. (X18)

GWH LARGE STORM SYSTEMS

Key to Phenomena

GWH0 Introduction
GWH1 Ozone in Hurricanes
GWH2 Hurricane Geographical Anomalies
GWH3 Thunderstorm Systems

GWH0 Introduction

The sourcebooks and handbooks that preceded this Catalog did not include material on large-scale storm phenomena because nothing had yet been discovered in the literature. Recently, however, a few hitherto unappreciated phenomena have forced themselves upon our attention.

Hurricanes contribute two varieties of anomalies in this category. (More will certainly be found in the future.) The presence of strong ozone odors in hurricanes is, at the very least, perplexing because there is generally little obvious electrical activity about. A more central conundrum associated with hurricanes is why they form so seldom when conditions seem so ideal. Hurricanes do not form at all in the South Atlantic and rarely, even when they are expected to, elsewhere. Do hurricanes require some special stimulus?

The large-scale organization of thunderstorms has surprised meteorologists, who had thought that general weather patterns were controlled more or less exclusively by upper atmospheric winds. Further complicating this unexpected picture is the possible cause-and-effect relation between thunderstorm incidence and solar activity (GWS3) and lunar phase (GWS2).

GWH1 Ozone in Hurricanes

Description. The smell of ozone or its instrumental detection at abnormally high levels during powerful hurricanes.

Data Evaluation. A single report of good quality has been uncovered. Rating: 3.

Anomaly Evaluation. Hurricanes are usually not accompanied by significant electrical activity, so the existence of a strong odor of ozone is perplexing. If not electrically generated, where could the ozone originate? Rating: 2.

Possible Explanations. Hurricanes are powerful storms, and it is possible that some diffuse electrical discharge occurs. Such discharges need not be detectable by eye and ear.

Similar and Related Phenomena. The smell of ozone and sulphur frequently attend some of the more concentrated storms, such as tornados and thunderstorms.

Examples of Hurricane Ozone

X1. September 21, 1938. Amherst, Massachusetts. "During the hurricane on September 21, 1938, the smell of ozone was strong during the latter part of the storm. The peak of the storm was shortly after 6 P.M. (D.S.T.); the lowest barometer 28.41 (corrected) at Amherst, Mass., being at 6:05, and the highest wind velocity, 80 miles, at 6:17. During the heavy rain, about 6 to 6:30, the ozone was strong, and later, when the rain stopped, the ozone was so strong I was uncomfortable. At this time my watch said 7 o'clock. No odor of ozone was noticed in the first part of the storm nor was any noticeable in the house. My colleague in chemistry, in the Massachusetts State College, Dr. Walter S. Ritchie, independently reports similar observations." (R1)

References

R1. Peters, Charles A.; "Ozone in the '38 Hurricane," Science, 90:491, 1939. (X1)

GWH2 Hurricane Geographical Anomalies

Description. The absence of any historical record of hurricanes in the South Atlantic.

Data Evaluation. A mention of this fact in a popular book on hurricanes (R1) has been confirmed in the McGraw-Hill Encyclopedia of Science and Technology. Rating: 1.

Anomaly Evaluation. All other tropical ocean areas spawn hurricanes or typhoons. From the standpoint of equatorial symmetry, one would expect at least one South Atlantic hurricane in recorded history. Obviously, this cannot in itself be a serious anomaly because local conditions may easily preclude hurricanes. (See below.) The situation, however, is complicated by the observation that situations thought to be highly conducive to hurricane formation result in hurricanes less than 10% of the time. The South Atlantic anomaly may therefore be symptomatic of a larger problem. Rating: 3.

Possible Explanations. The "official" explanation for the absence of hurricanes in the South Atlantic is that the waters are too cold and the wind distribution with altitude is not right. One wonders, though, whether extraterrestrial triggering forces may not be at work in cases where hurricanes do erupt and absent where they do not, including the South Atlantic. This is, of course, radical thinking, but see GWS5.

Similar and Related Phenomena. Hurricanes are also notably absent from the eastern South Pacific.

Examples of Hurricane Geographical Anomalies

X1. General observations. "There is no record of a tropical cyclone of hurricane intensity ever having occurred in the South Atlantic Ocean." (R1)

References

R1. Helm, Thomas; "Anatomy of Hurricanes," Hurricanes: Weather at Its Worst, New York, 1967, p. 16. (X1) (Cr. L. Gearhart)

GWH3 Thunderstorm Systems

Description. Large complexes of thunderstorms, organized into rings hundreds of miles in diameter.

Data Evaluation. Satellite photos unequivocally reveal these huge circular systems. Rating: 1.

Anomaly Evaluation. Thunderstorms are normally considered small-scale storm systems (50-100 miles in extent) which are controlled by upper-air winds. The discovery of thunderstorm ring systems has overturned this conventional wisdom, as elaborated in X1. Rating: 2.

Possible Explanations. The ring structure suggests an outwardly propagating triggering phenomenon, but the workings of this mechanism are obscure.

Similar and Related Phenomena. None.

Examples of Thunderstorm Systems

X1. General observations. "The conventional wisdom about storm formation begins with the assumption that storms are small-scale (50 to 100 miles), localized phenomena whose overall dynamics are determined by high velocity upper air winds. This theory of thunderstorm formation has made the prediction of storms difficult. It has also greatly impeded the development of computer models that are able to predict storm formation and evolution, because the theory required such fine detail to describe the weather.

The new data taken from the satellite photographs, as interpreted by Fritsch and Maddox, show a dramatically different picture: The most violent and widespread storms are not local phenomena; instead they are frequently organized into large-scale, roughly circular complexes of storms.

These complexes form as the energy transfer from the release of latent heat from an initiating storm causes a chain reaction of storm formation in a wide area around the first storm. The resulting intense atmospheric activity, called a 'mesohigh,' can change the usually dominant high velocity jet stream. As Maddox describes it, 'This interaction is an important finding since the traditional viewpoint has been the other way around---that convective storms are regulated by the upper air patterns." (R1)

References

R1. Bardwell, Steven; "Satellite Data Show New Class of Thunderstorms," Fusion Magazine, p. 50, September 1981. (X1) (Cr. P. Gunkel)

GWP ANOMALOUS PRECIPITATION

Key to Phenomena

GWP0 Introduction
GWP1 Precipitation from a Clear Sky
GWP2 Giant Snowflakes
GWP3 Conical Snowflakes
GWP4 Hailstones with Anomalous Shapes
GWP5 Giant Hailstones
GWP6 Hail Strew Patterns
GWP7 Slowly Falling Hail
GWP8 Unusual Inclusions in Hail
GWP9 Explosive Hail
GWP10 Colored Precipitation
GWP11 Luminous Precipitation
GWP12 Point Precipitation
GWP13 Surplus Ice Crystals in Clouds
GWP14 Decrease of Rainfall with Increasing Altitude
GWP15 Rain Gushes Associated with Lightning

GWP0 Introduction

What makes precipitation anomalous? The major variables involved are color, shape, size, intensity, and distribution. Huge hailstones, red rain, and prodigious concentrations of rainfall are obvious candidates for this chapter. But any form of precipitation without clouds visible in the sky must also be considered anomalous. True, very fine ice crystals can be frozen out of clear air when the cold is intense, but where does cloudless rain originate? Evidently, the atmosphere can carry considerable moisture without the formation of telltale clouds.

Colored rain, snow, and hail are rather common---so frequent, in fact, and so well-explained that they receive only passing notice here. The European "rains of blood," described since history began to be written down, and made much of in Fortean circles, can usually be blamed on dust blown north from Africa. Black rain is even more common and can be ascribed to forest fires, volcanos, and urban pollution, just as the closely related dark days (GWD) are.

Uncolored rain can, on occasion, be very intriguing. Fantastic examples of "point rainfall" and supposedly collapsing waterspouts have been noted often in meteorological magazines. The naming of the phenomenon does not, of course, explain the unbelievable quantities of water that is sometimes dumped in very small areas. Some sort of meteorological-topographical focussing effect seems to be at work here.

Hail is notable if it is unusually large, if it comes in odd shapes, and if it contains inclusions that should not be present inside ice particles falling from the sky. (Note that isolated ice falls and "hydrometeors" are dealt with in GWF1.) The fantastic variety of hailstone shapes: crystals, discs, large flat plates, spiked spheres, etc., may indicate the work of unappreciated forces in hail formation. Some of these formative forces may be electrical in nature. On a larger scale, the peculiar mesh and parallel-line patterns of some hail falls call for explanation in terms of hailstorm dynamics. Finally, the phenomenon of slowly falling hail is not easy to explain.

As in many other weather phenomena, electricity seems to play a subtle role. Electrically charged precipitation that sparks and snaps upon hitting the ground has been observed on many occasions. Given the powerful electrical-charge-separating mechanism of the active thunderstorm, electrically charged rain is perhaps not too surprising. But can these same electrical forces also initiate the curious gushes of rain correlated with lightning flashes? The possibility of lightning-induced rain gushes has long been debated and may be related to those hydrometeors that fall just after lightning flashes (GWF1) and hot air blasts experienced in thunderstorms (GLL12).

A significant general observation concerning precipitation anomalies will be obvious after perusing this chapter: Precipitation phenomena as a class are not especially anomalous. They are interesting, sometimes startling, but do not really shake the foundations of meteorological theory.

GWP1 Precipitation from a Clear Sky

Description. The fall of rain, snow, or hail from a cloudless or nearly cloudless sky.

Background. The descent of tiny ice needles in the arctic regions and on high mountain ranges is fairly common. In these regions, the extremely low temperatures cause water vapor to crystallize and fall without the formation of visible clouds.

Data Evaluation. Many sound observations of precipitation from cloudless skies are on file. Rating: 1.

Anomaly Evaluation. The thermodynamic conditions for the condensation of water vapor in the atmosphere are well known. What is lacking, except in the fall of ice needles, is a suitable, possibly short-lived, meteorological mechanism that causes precipitation without creating visible clouds. Since several possibilities exist (see below), precipitation from a clear sky is more curious than anomalous. Rating: 3.

Possible Explanations. Transient atmospheric disturbances, such as gravity waves and the sudden expansion and cooling of wind blowing across mountain ranges. Large influxes of meteoric dust may also stimulate precipitation. Some spurious instances of precipitation from a clear sky may derive from wind-blown precipitation from distant, unseen clouds, from ocean breakers, and even from waterfalls. Occasional pseudoprecipitation occurs on warm fall days in wooded areas when sap exudes from leaf scars.

Similar and Related Phenomena. None.

Examples of Precipitation from a Clear Sky

X1. April 23, 1800. Philadelphia, Pennsylvania. "A shower of rain of at least twenty minutes' continuance, and sufficiently plentiful to wet the clothes of those exposed to it, fell when the heavens immediately over head were in a state of the most perfect serenity. Throughout the whole of it, the stars shown with undimished lustre. Not a cloud appeared, except one to the east and another to the west of the city, each about fifteen degrees distant from the zenith." (R3) In this instance wind could have blown the rain horizontally from the extant clouds. (WRC)

X2. November 13, 1833. Harvard, Massachusetts. "At Harvard, in this state, at about 8 o'clock on the morning of the 13th, there was a slight shower of rain, when not a cloud was to be seen, the weather being what is called perfectly fair." (R1, R3) This observation is significant because it occurred immediately after one of the greatest meteor showers in historical times. (WRC)

X3. August 9, 1837. Geneva, Switzerland. Several short showers of tepid drops of large size. (R3)

X4. May 31, 1838. Geneva, Switzerland. A lukewarm rain lasting 6 minutes. (R2)

X5. April 21, 1842. Flanders, France. (R4)

X6. July 26, 1855. Ostend, Belgium. (R5)

X7. April 17, 1857. Paris, France. (R6)

X8. July 22, 1888. Stevenage, England. Rain from a cloudless sky preceded a violent thunderstorm by 1 1/2 hours. "The appearance was first seen about 7 p.m., and it looked like a shower of luminous particles of a somewhat skim-milky appearance. As soon as I realized the fact of its electrical nature I endeavoured to ascertain if the movement of the particles was upwards or downwards, but without effect. But what I did more successfully observe was that the particles were of the size of tare-seed, and that they moved in remarkably straight lines, so much so that they resembled the warp in a weavers frame. My view extended over about two-fifths of the circle of the heavens, and the appearance within that area was precisely the same." (R7) The luminous nature of the phenomenon is unusual and somewhat resembles low-level auroras and auroral fogs (GLA4 and GLA21). (WRC)

X9. 1892. England. (R8)

X10. February 6, 1895. Surrey, England. "On the 6th February, at 9 a.m., light snow began to fall, sparkling in sunshine from a cloudless sky. Thinking that the snow might be blown off a roof, I went out on the common, clear of houses, and made no doubt that the fall was from the sky. Gradually it clouded over, and at 10 a.m. was quite overcast, the snow continuing as a natural shower for a short time longer. (R9) In Sussex it was a brilliant day, with snow crystals and minute spiculae of ice falling at intervals. (R10)

X11. 1902. Tarbes, France. "...after a day of mist and rain, with low temperature, the sky cleared and the night became fine. This lasted till midnight, when the town was suddenly deluged with hail, the streets being thick with stones of large size. The most singular feature of this meteorological freak was at the time the hail fell there was an absolutely clear star-lit sky."(R11)

X12. July 18, 1925. Boveysand, England. A very short, localized shower from a blue sky. (R13)

X13. December 29, 1929. Grayshott, England. A few minutes of drizzle from a clear sky with bright stars. (R15)

X14. January 3, 1933. Grayshott, England. (R15)

X15. January 20, 1935. Benson, England. Drizzle from a pale, watery-blue sky. (R14)

X16. February 5, 1955. Wrexham, England. "On February 5 there was a period of light rain from 2130 to 2230 G.M.T. The cloud then suffered a complete and rapid dispersal, and from 2235 to 2255 light rain continued to fall from the cloudless sky. Not a trace of cloud could be seen and the stars were as bright as they can be with a nearly full moon, and it was calm at the surface. The rain was not heavy enough to be registered on the autographic rain-gauge, but was sufficient to wet clothing." (R16)

X17. February 15, 1955. Wrexham, England. Snow fell in the absence of low clouds, although high cirrus were present. (R16)

X18. January 1, 1979. Houwaart, Belgium. After an extremely cold night, ice needles fell from a clear sky. (R17)

X19. General observation. The slow fall of ice needles (so-called "diamond dust") from a cloudless sky is rather common in polar regions and on high mountains. (R12)

References

R1. Olmsted, Denison; "Observations on the Meteors of November 13th, 1833," American Journal of Science, 1:25:363, 1834. (X2)

R2. "Fall of Rain from a Serene Sky," Edinburgh New Philosophical Journal, 25:423, 1838. (X4)

R3. "Rain from a Clear Sky," American Journal of Science, 2:1:178, 1839. (X1, X2, X3)

R4. de Noirfontaine, Bodson; "Note sur de la Pluie Observee par un Ciel Completement Serein," Comptes Rendus, 14:663, 1842. (X5)

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R6. Phipson, T. -L.; "Sur une Pluie sans Nuages Observee a Paris," Comptes Rendus, 45:906, 1857. (X7) (Cr. L. Gearhart)

R7. Jones, Samuel; "Rain from a Cloudless

Sky ("Serein") at Stevenage, July 22nd, 1888," Royal Meteorological Society, Quarterly Journal, 15:123, 1889. (X8)
R8. Godden, William; "Rain without Clouds," English Mechanic, 54:506, 1892. (X9)
R9. Maclear, J. P.; "Snow from a Cloudless Sky," Symons's Monthly Meteorological Magazine, 30:27, 1895. (X10)
R10. Prince, C. Leeson; "Snow from a Cloudless Sky," Symons's Monthly Meteorological Magazine, 30:44, 1895. (X10)
R11. English Mechanic, 76:12, 1902. (X11)
R12. "Snow without Clouds," Monthly Weather Review, 45:13, 1917. (X18)
R13. Applegate, T. H.; "Rain from a Blue Sky," Meteorological Magazine, 60:193, 1925. (X12)
R14. Dines, J. S.; "Drizzle Falling from a Clear Sky," Meteorological Magazine, 70:16, 1935. (X15)
R15. Ashmore, S. E.; "Drizzle Falling from a Clear Sky," Meteorological Magazine, 70:116, 1935. (X13, X14)
R16. Ashmore, S. E.; "Precipitation with a Clear Sky," Meteorological Magazine, 84:156, 1955. (X16, X17)
R17. Goethuys, J. P.; "A Fall of Ice-Prism Dust in Belgium," Journal of Meteorology, U.K., 4:191, 1979. (X18)

GWP2 Giant Snowflakes

Description. Large agglomerations of smaller flakes in the form of plate-like masses measuring up to 38 centimeters in diameter.

Data Evaluation. Aggregations of flakes 2-4 inches in diameter are common; those 4-6 inches in diameter are rare but well-verified. The record flake, 38-centimeters across (X2), may be an exaggeration, but no one contests the fact that immense snowflakes do fall under some conditions. Rating: 1.

Anomaly Evaluation. The aggregation of snowflakes by collision poses no problems for geophysicists; large flakes fall faster than small ones and, in so doing, pick up more and more smaller flakes. One observation suggests that electrostatic attraction may play a role, but even here there are no theoretical problems, because it has long been accepted that snowflakes may carry substantial electrical charges. Rating: 3.

Possible Explanations. Large flakes are probably aggregations of smaller flakes created by collision and/or electrostatic attraction.

Similar and Related Phenomena. Electrical discharges observed during snowstorms (GLD5).

Examples of Giant Snowflakes

X1. January 7, 1887. Chepston, England. Some flakes measured 9 centimeters in diameter, larger ones seen. One flake yielded 16 drops of water. The flakes consisted of hundreds of undamaged crystals set together at all angles. The observer thought he saw the large flakes exerting an attractive force on smaller ones. In part, though, the giant flakes could be explained in terms of the huge flakes overtaking and combining with the smaller ones. (R2)

X2. January 28, 1887. Fort Keogh, Montana. Huge flakes "larger than milk pans" and measuring 38 centimeters across by 20 centimeters thick. (R2)

X3. January 24, 1894. Nashville, Tennessee. Some flakes almost 14 centimeters in diameter. (R2)

X4. March 25, 1900. Richmond, Virginia. "There was nothing unusual about the first falls of flakes, but the sleet immediately diminished in volume and as this occurred the flakes increased in size until they attained unusually large dimensions. They were of irregular shape, usually oblong; several were observed whose greatest diameters could hardly be covered by a teacup (perhaps about 7.6 centimeters). Some of these flakes were caught upon a piece of dry wood and examined: in every instance they showed the center to consist of a soft mass of snow about one-half inch (1.3 centimeters) in diameter, while the outer edges were thin, as though they were separate flakes that had attached

Snowflakes 38-cm in diameter fall in Montana (X2)

themselves to the central mass while it was falling. The greater weight of the center caused the larger flakes to assume the form of an inverted cone as they fell, the outer, thinner edges being bent upward by the resistance of the air." (R2)

X5. January 17, 1912. Bristol, England. Some flakes were 3 1/2 inches in diameter. (R1)

X6. January 10, 1915. Berlin, Germany. "On this occasion a large number of snowflakes had diameters of 8 to 10 centimeters, and these giant flakes fell with both a greater speed and more definite paths than did the smaller flakes. They did not have the complicated, fluttering flight of the latter. In form the great flakes resembled a round or oval dish with its edges bent upward. During flight they rocked to this side or that, but none were observed to turn quite over so that the concave side became directed downward." (R2)

X7. April 13, 1951. Berkhamsted, England. Enormous flakes about 5 inches across. (R3)

References

R1. Denning, W. F.; "Large Snow Flakes," Symons's Meteorological Magazine, 47: 22, 1912. (X5)

R2. "Gigantic Snowflakes," Monthly Weather Review, 43:73, 1915. (X1-X4, X6)

R3. Hawke, E. L.; "Outsize Snowflakes," Weather, 6:254, 1951. (X7)

GWP3 Conical Snowflakes

Description. Dense snow pellets in the shape of cones with spherical bases. Conical snowflakes seem composed of small conical needles of ice welded into larger cones.

Data Evaluation. Although only three reports of conical snow have been uncovered so far, one observer states (X3) that such falls are not rare, occurring several times a year in northern Vermont. Apparently, this is a rather common phenomenon that no one bothers to write about. Rating: 1.

Anomaly Evaluation. No one has explained how conical snow pellets, with their needle-like conical substructure, are formed in the atmosphere. Such a process, while interesting to meteorologists, does not seem to depend upon any radical new theories, being merely an unexplored byway of geophysics. Rating: 3.

Possible Explanations. None.

Similar and Related Phenomena. Conical graupel and hail (GWP4).

Examples of Conical Snowflakes

X1. April 26, 1931. Ann Arbor, Michigan. Three short falls of conical snow. "The crystal formation was that of a solid cone with a round base. The side of the cone made an angle of about 30 degrees with the axis. The round base was part of a spherical surface. The shape was exactly like that of a conical section of a sphere. As nearly as the eye could see into the formation of a snowdrop, the whole structure seemed to be made up of conical needles, packed together, with the upper ends forming the pointed tip of the cone, and the larger lower ends forming the rounded base. The density was very high; a handful of snow, slightly compressed, immediately formed soft ice. The ratio of snow volume to volume when compressed to ice without air included would hardly have been higher than four to one. Hundreds if not thousands of individual snowdrops came under observation on a window sill; irrespective of size, from tiniest to largest, the crystals were of the same form.... Many large crystals fell; one of the largest, by actual measurement, was three eighths of an inch across the base." (R1)

X2. September 1920. Ephraim, Utah. Cones of hard, compacted snow with hemispherical bases---like inverted parachutes. All measured more than 1/4 inch across the base, with many reaching 1/2 inch. They were definitely snow and not ice. (R2)

X3. Regular occurrence. Northern Vermont. Several falls of conical snowflakes recorded each year. They come only from cumulo-nimbus clouds, have a granular texture, and are built up from undercooled cloud droplets that have frozen together. The nuclei are almost always branching tabular crystals. (R3) This description does not seem like that of X1 as far as internal structure in concerned.

References

R1. Moore, A. D.; "Conical Snowflakes," Science, 73:642, 1931. (X1)

R2. Wagener, Willis W.; "Conical Snowflakes," Science, 74:414, 1931. (X2)

R3. Bentley, Wilson A.; "Conical Snow," Science, 75:383, 1932. (X3)

GWP4 Hailstones with Anomalous Shapes

Description. Hailstones that depart from the usual spherical shape. The variety of oddly shaped hail is astounding, ranging from geometrically satisfying hexagonal crystals to bizarre Dali-like shapes. The accompanying illustrations only begin to do justice to this phenomenon. Some of the more common shapes are cones, pyramids with rounded bases, flat plates, and spheroids with spikes or protuberances.

Background. Hail is generally described as forming when water droplets freeze in the atmosphere. Motion of the air in a storm may carry hail repeatedly through regions where additional ice is added layer by layer.

Data Evaluation. Most of the bizarre species of hail described here have been carefully observed and often measured accurately. Because hail melts quickly, some testimony may underestimate size and describe partially distorted geometries. Rating: 1.

Anomaly Evaluation. The prevailing theories of hail formation usually cannot account for hail geometries that deviate significantly from the sphere. Some attempts have been made to account for conical hail (R60), but there seems to be no general theory that explains the tremendous variety of shapes that have been observed. One cannot dismiss anomalous hail shapes as freaks; they are repeated again and again all over the world; each storm produces the same freaks by the millions. Even grotesque shapes, which one would think unique, come down from the sky by the thousands. Over a century ago, naturalists wondered how crystalline hail, which should require slow, quiet growth, could form in the tumult of a hailstorm. The hail-forming mechanism, it is clear, is prolific and imaginative. Nevertheless, the laws of atmospheric physics, possibly with slight modifications, can probably account for all of the geometries, if we only knew how to apply them. Rating: 2.

Possible Explanations. No good explanations are forthcoming, but among the contributing variables are: different ice nuclei, the crystalline forms of water, aerodynamic forces, the motion of the forming hailstone, and possibly electrical forces.

Similar and Related Phenomena. Snowflake geometries, conical snow (GWP3).

Examples of Anomalous Hailstones

X1. 1769. Paris, France. Crystalline hail falls. (R21)

X2. August 26, 1834. Padua, Italy. Crystals about 1 1/2 inches long in the shape of four-sided prisms, one side of which was very narrow in comparison with the other three sides. Each prism terminated in a four-sided pyramid. (R4)

X3. 1819. Southern France. Crystalline hail. (R21)

X4. 1863. Tiflis, Russia. Crystalline hail. (R21)

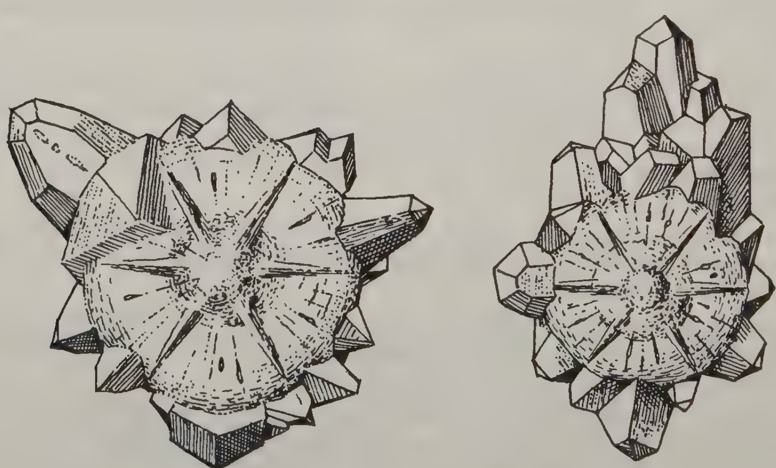
X5. June 9, 1869. Tiflis, Russia. "...a complete 'shower of ice crystals'---not of fragments of ice of indistinctly crystalline outlines, but of spheroidal crystalloid solids, densely but irregularly set, on the surfaces corresponding to their longitudinal diameter, with limpid regular crystals showing various combinations of forms belonging to the tri- and monoaxial systems---a peculiarity which it seems, has not yet been observed, or at least published. The forms characteristic of calcareous spar and of specular oxide of iron prevailed, especially the scalenohedron, combined with rhombic planes, in crystals 15 to 20 millims. in length. Other crystals exhibit the prism, combined with obtuse rhombohedra, and with the terminal plane perpendicular to the principal axis.... How could indeed the formation of such crystalline aggregations, as regular as those of the calcareous spars of Andreasberg, be possible in the midst of the tumult generally supposed to be necessarily connected with the formation of hail?" (R10, R12, R21, R28)

X6. June 21, 1869. Bely-Klutch, Russia. (R21)

X7. 1876. Italy. (R21)

X8. June 29, 1879. Bale, Russia. Lenticular central mass with pyramidal crystals set around the circumference. (R17, R21)

X9. October 1, 1889. Philadelphia, Pennsylvania. "On some of the stones, though not on the majority of them, well marked crystals of clear transparent ice projected from their outer surfaces for distances ranging

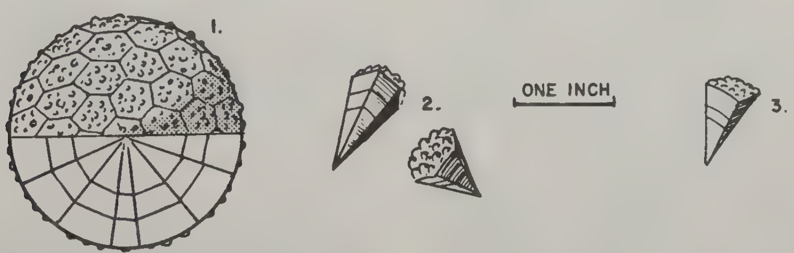


Hailstones formed of crystalline masses (X5) from one eighth to a quarter of an inch. These crystals, as well as I could observe from the evanescent nature of the material, were hexagonal prisms with clearly cut terminal facets. They resembled the projecting crystals that form so common a lining in geodic masses, in which they have formed by gradual crystalization from the mother-liquor. They differed, however, of course, in being on the outer surface of the spherules."(R29)

X10. January 26, 1940. Sheffield, England. "...a sudden 'deluge' of sharply edged hard transparent crystals of clear ice. Unaccompanied by any other form of precipitation they fell profusely from a sky generally overcast to form on the ground a thick layer of dry ice grains that were remarkable for the size---some 3-4 mm. in length---to which each had grown as well-developed single hexagonal prisms with basal planes and showing sharply cut crystal faces." (R51)

tice. They were included, almost universally, each by five sides or surfaces, four plane, constituting the sides of an irregular pyramid, and one spherical in place of a base. The length of the longest line did not exceed 1/2 inch in any instance that I observed; but as the hail-stones dissolved very fast, and as they were indeed, for the most part, rounded in the angles before I found them, it is probable they had been larger at first. I however examined them the moment they fell. The spherical surface appeared, to the depth of 1/20 to 1/30th of an inch, to be solid, as it was transparent. The rest of the hailstone was opaque, consisting of crystals or minute columnar forms, perpendicular to the spherical surface." (R3)

X14. August 26, 1834. Padua, Italy. Tetrahedrons. (R4) Same as X2?



Tetrahedral hailstones and postulated parent sphere (X15)

X11. No date given. Clermont, France. Hexagonal prisms terminating in six-sided pyramids. (R5)

X12. July 4, 1819. Baconniere, France. "During ten years, M. Delcross had observed that hail consisted of spherical pyramids or fragments of spheres, which had been broken by some explosion, and the cleavages of which always passed through the centre of the sphere. He frequently looked in vain for the original sphere, but never observed it until the 4th July 1819, during the dreadful hailstorm at Baconniere. Some of the spheres were fifteen inches in circumference." (R2)

X13. June 27, 1823. Aberdeen, Scotland. "The regularity in the shape of the hailstones, and their hard and peculiar consistence, seemed to entitle them to some no-

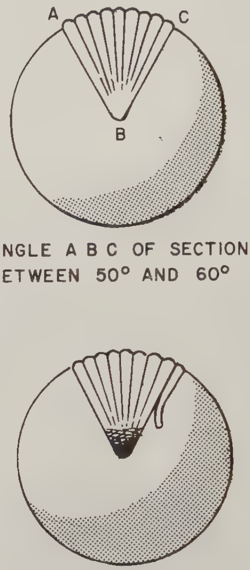
X15. March 31, 1876. Leamington, England. "The hail fell from a thick heavy nimbus, coming from the S. E., while the sun in the W. was not obscured. It fell thickly for about 20 minutes, with much noise, both in the air, and from the roofs and trees, and splashed the river considerably on the surface. Everybody ran into shelter, as well they might, considering the size of the stones, which were as big as pebbles, angular, and pointed. They appeared to be shaped like pyramids, with points, and convex bases, studded with tubercules, and had plain sides, either square, pentagonal, or hexagonal. They would have probably belonged to complete spheres, when their sides were adjusted together, and which would have been about 1 1/4 in. in diameter, and these segments were, therefore, about 1/2 in. long. They were of crystalline ice, with concentric bands, and probably the perfect pyramids weighed from 10 to 20 grains, and, as 24 might be estimated to make up a sphere, this, at the least, might have been half an ounce in weight, and at the most about one ounce. As they were tuberculated on the convex bases, the whole sphere would have looked very much like a raspberry, or an oxalate of lime calculus. These spheres of ice must have burst, or become split up into segments somewhere in the fall through the air, as none were actually found perfect on the grass in the gardens." (R15)

X16. November 28, 1888. Edinburgh, Scotland. Pyramids with four flat sides and a convex base. The ice was transparent with numerous liquid-filled cavities. (R26)

X17. October 13, 1919. Chiltern, England. "... a dense mass of hail literally swooped out of the squall cloud. I was out at the time and avoided immediately seeking shelter in order to examine the shape and texture of the hailstones. I found that all those which I caught on the sleeve of my overcoat were white and opaque, and in shape tetrahedral, showing four triangular faces roughly between 1/8 and 1/4 of an inch in length from base to vertex." (R45) Note that these are true tetrahedrons as opposed to the pyramids with rounded bases typified by X15. (WRC)

X18. June 1958. Fort Collins, Colorado. "In a recent hailstorm on the campus of Colorado State University at Fort Collins, the writer observed a number of hailstones having the shape of a triangular pyramid. The stones were formed from layers of ice of varying opacity in concentric layers about the tip of the pyramid. The measured dimensions of the largest stones are given on the accompanying sketch. (See illustration of X15 for configuration.) The shape of the stone indicated that about 1/4 inch had melted from the tip of the pyramid before measurements were made. The smooth sides of the pyramid indicated that the stone probably was fractured from a sphere that initially was about 3 1/2 inches in diameter." (R57)

X19. April 24, 1887. Marlborough College, England. "On April 24, about 12.30, while walking between Melrose and Kelso, a friend and myself were overtaken by a sudden and very violent hailstorm, accompanied by thunder. The violent burst lasted about two minutes, in which time the ground was completely covered with large hailstones rather more than half an inch long. I say 'long' advisedly, for all the specimens I examined were conical, and were all of them formed the same way. The points had all the appearance of snow, being softer than the main bulk of the 'stones.' These snow portions occupied about one-third of the whole length, being white and non-transparent. The main portions of the hailstones



Conical hailstones made of ice fibers (X19)

were hard and ice-like, stranded lengthwise with from forty to fifty fibres of ice---each fibre curved separately at the top---and together forming a curved surface, as of a sphere having the snow point for its centre. On melting, the pointed part became translucent, while the other part became more opaque than at first, strands often remaining for a time, partly separated and curving outwards, as though they had been freed from compression in their lower extremities. The above appearances might admit of the hypothesis that these hailstones were fragments of radiated crystalline spheres, but one would expect in that case to find pyramidal rather than conical shapes, or at least to find some shaped so as to complement the cones." (R23)

X20. June 7, 1902. Cheltenham, England. "At first the hailstones were more or less round and like small crystallised raspberries; but during the latter and main part of the shower they were in the form of wedges or small cones, somewhat varied in shape. Many of these hailstones were about three-quarters of an inch in height and measured about half an inch across. Mr. Swordy suggests that these were only conic sectional parts of what had been much larger hailstones. To test this view he put some selected ice cones in a circle and added two more layers upon the first circle and a key wedge or cone at the top. By this arrangement he obtained half an iceball, consisting of fifteen sections. The hailstones when first formed may therefore have been about the size of 'ping-pong' balls, about an inch and a half or two inches in diameter." (R41)

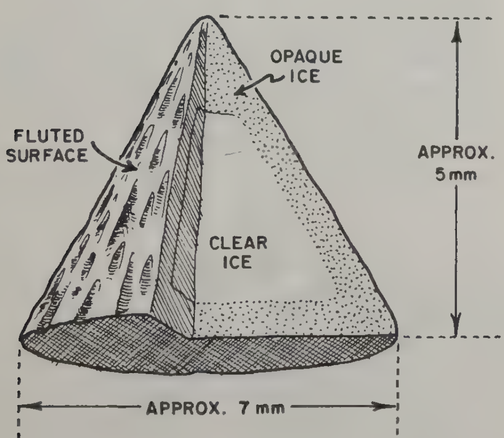
X21. May 1907. Northern Ireland. Conical hail with rounded bases. (R42) The possibility exists that conical hailstones may be pyramids with the edges melted down. (WRC)

X22. May 8, 1910. Epsom, England. Conical hail. (R43)

X23. January 17, 1933. Hastings, England. Cones with round bases about 1/4 inch long. (R50)

X24. February 10, 1945. Uxbridge, England. Conical hail 25-30 mm in height; base, 25 mm in diameter. (R54)

X25. April 3, 1968. England. "Among the hailstones of normal character (i.e. roughly spherical) there occurred a fairly large proportion of stones which had the conical appearance shown in the diagram below. These



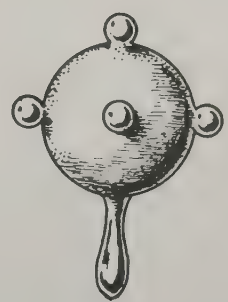
Conical hailstones with fluted sides (X25)

stones had a distinctly fluted outer surface with edges running from base to apex. The stones were soft and easily sliced with a sharp penknife. The central core, shaped like a truncated cone, was of clear ice, the outer layer was opaque. The largest of the stones observed had the dimensions shown in the diagram but the shape was retained down to sizes of 2-3 mm." (R59)

X26. April 11, 1878. Canton, China. Hailstones shaped like starfish. As large as pigeon eggs. (R16)

X27. December 1, 1878. Plains of Troy, Turkey. Roundish hailstones with many sharp projections. (R18)

X28. August 21, 1880. Partenkirschen, Germany. "There had been little or no rain and no visible lightning, and the hailstones fell at intervals and about six feet apart. There were very few of them, my family picking up twenty in a space occupied by a full-sized lawn tennis court. My son made a sketch of their shape and size, which I enclose. The greater part were of the 'tadpole' shape and were clear as glass, perfectly round, the five knobs being at equal distance from one another. The flat stones had more or less a



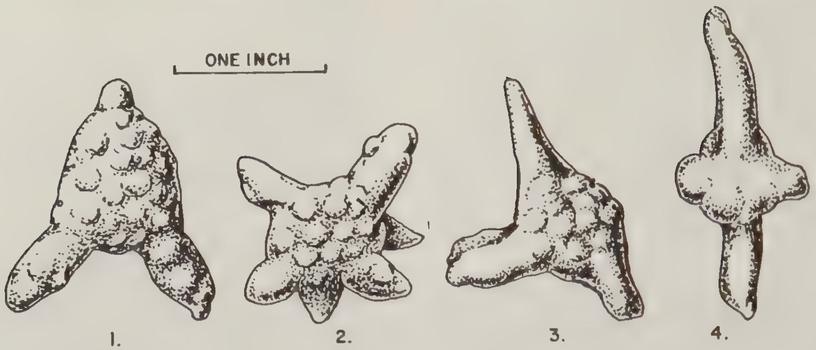
Hailstones with knob-like appendages (X28)

slight nucleus of snow in the convex portion of the stone. My wife and three daughters, and two ladies staying with us, say that the stones looked just like a lady's hand looking glass, with a knob at the top and on either side for ornament. More than twenty, perhaps thirty, were picked up of this shape." (R19)

X29. July 1881. Partenkirchen, Germany. Hailstones like those of X28 again fell in this location, but with a greater variety of odd shapes, including mushroom-like stones. (R20)

X30. August 22, 1893. Welton-le-Wold, England. A violent hailstorm with large stones bearing irregular projections, as shown in the illustration. (R34)

X31. May 17, 1894. Cleveland, Ohio. Large hailstones, some the size of goose eggs. Shapes varied from spheroidal, to discoidal, to exceedingly irregular. Some



Irregular hailstones that fell in England in 1893 (X30)

of the stones with a knobby or berry-like surface were sectioned and found to be formed about a single nucleus rather then being aggregations of smaller stones. (R31)

X32. February 25, 1900. Harbertsdale, Cape Colony, South Africa. Round hail with spikes, like a hedgehog rolled up in a ball. (R38)

X33. June 21, 1918. King Island, Tasmania, Australia. "The hailstones were like star-fish, i.e. with a roughly spherical core and fingers out in all directions, not only on one plane; more like one of those most useful-looking old-time war weapons, spikes protruding from a sphere of iron in all directions mounted on a handle by a short chain! But in the case of the hailstones the spike was much longer, the largest part of the whole. One or two I measured were more than three inches across from point to point, and several were above two inches in two directions; the centre was comparatively small, from 1/2 in. to 3/4 in. in diameter, roughly. They were not heavy, and were clear ice, not opaque as hail usually is, and at the same time each 'stone' appeared to be an agglomeration of ordinary small hailstones." (R44)

X34. July 22, 1925. Plumstead, England. After a hailstorm of great violence. "I went into the garden and collected a few specimens, examined them, and measured the largest. Its length was 3 1/4 inches and in width it was 2 inches. Each hailstone had a central nucleus of white and opaque ice about the size of a marble. Round this was a ring of splintery particles embedded in translucent ice. Outside this was a petal-like structure of transparent ice. One side of the stone was concave, the other convex. Some resembled cracknell bisquits in size and curvature." (R46)

X35. June 15, 1929. Urbana, Illinois. Grotesquely shaped hailstones that seemed to be agglomerations of smaller stones. One measured 6.5 x 2 x 3.5 cm. (R47)

X36. August 6, 1949. Eldoret, Kenya. "The sky became very dark and large hailstones fell, but in the shape of stars similar to those of snow crystals in shape (when seen under the microscope). They nearly all measured 1 1/2 in. in width. They consisted of large ice balls the size of a very large pea with fine radiating arms of ice. Some of these landed on their sides and stuck sideways on in the grass." (R55)

Iceballs with radiating arms (X36)

X37. August 21, 1963. Indian Ocean. Spherical hailstones with irregular horn-shaped protuberances 1 1/4 inchs long. (R58)

X38. June 15, 1829. Cazorla, Spain. "... hailstones fell in the form of blocks of ice, some of which had a circumference of 20 in. and weighed as much as 4 1/2 lb. Great damage was done, houses being literally crushed beneath the bombardment of ice. (R48) It is the block-like form of the hail that it significant here and in several of the following examples. (WRC) See GWP5-X4.

X39. January 14, 1860. Indian Ocean. Dur- a squall there was a shower of ice consisting of large, irregular chunks of solid ice---some as large as a brick. (R7, R62)

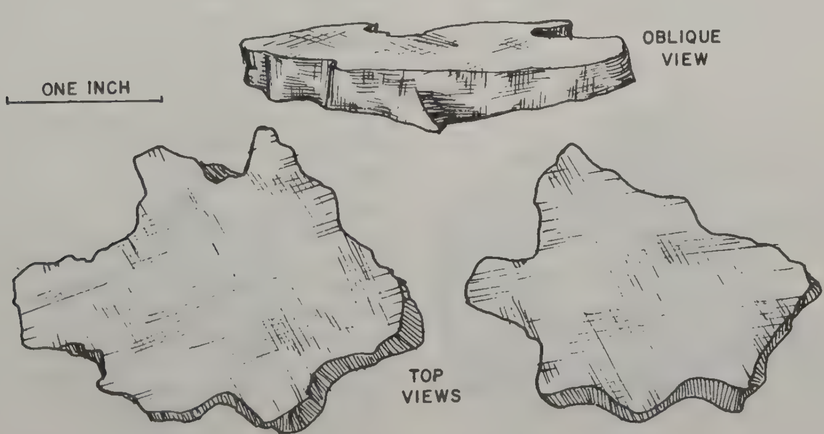
X40. November 15, 1863. South Atlantic Ocean. "At 6.30 p.m. an immense waterspout formed suddenly in the west, about two miles distant, and bore rapidly down upon the ship. She was steered to the south in the hope of clearing it, but it approached within three ships' lengths and discharged pieces of ice upon our decks, about 2 inches square (not in balls, but flat). This was immediately followed by a terrible flash of lightning and sharp rattling thunder, a deluge of rain, and a furious squall." (R35)

X41. June 3, 1894. Eastern Oregon. A tornado was accompanied by unusual hail. "One correspondent states that the formation was more in the nature of sheets of ice than simple hailstones. The sheets of ice averaged 3 to 4 inches square and from three-fourths of an inch to 1 1/2 inches in thickness. They had a smooth surface and in falling gave the impression of a vast field or sheet of ice suspended in the atmosphere and suddenly broken into fragments about the size of the palm of the hand." (R32, R33)

X42. August 10, 1897. Manassas Depot, Virginia. "There was some pretty severe thunder and lightning for a half hour or so, and then came a heavy shower of rain, during which there was the most remarkable fall of hail I have ever witnessed. I hurried out in the rain to examine the stones and picked up several. These were nearly square flattish blocks, say from 3/4 to 1 inch in length and breadth, and from 1/4 to 1/2 an inch in thickness. They suggested, by both shape and size, the ordinary 'chocolate caramels,' of the confectioner." (R36, R37)

X43. July 28, 1979. Hellesdon, England. An unusual fall of large ice flakes measuring 50 x 100 x 3 mm. "Looking out of the front window, we noticed that glistening hail, about the size of large peas to approximately halfpenny round, were falling at about 5 to 7 to the square foot. Then we thought it was 'snowing', so we looked more closely from the open front door and said it must be white rose petals, about two inches by four inches and about an eighth of an inch thick...and about one per square yard. Then they increased in number to about one per square foot, and one landed on the doorstep, and they reached about a palm in size, i.e. four inches round. This size lasted just over a timed minute; then they slowly drifted back to one per square yard, and after a full five minutes or slightly longer there were none." (R61)

X44. 1806. Morris County, New Jersey. "The hail stones were generally about one fourth or three eighths of an inch thick and of sufficient dimension in length and breadth to hide a shilling, and in many cases a cent, and almost every one perforated in the middle as if they had been held between the fin-



Flattish blocks of hail (X42)

gers, till the fingers by their warmth had melted away the middle and had met. When the perforation was not complete, there was in every case an inclination to perforation." (R1)

X45. June 14, 1880. Russia. Hailstones pierced with hole from side to side. (R21)

X46. July 12, 1902. Canada. "Many of the pellets, both small and large, were almost perfect spheres, but not infrequently the large ones took the form of disks, thin and transparent in the middle, with thicker edges of snow, reminding one of the shape of the red blood corpuscles or the fly-wheel of a sewing machine. One large pellet of this kind measured 1.75 inches in diameter and the circular rim was one inch thick, the middle portion of the disk being transparent." (R40)

X47. August 8, 1901. On the St. Lawrence River. Cylindrical hail, like pieces of round lead pencils, 3/8 inch long.(R39)

X48. May 29, 1944. London, England. Hail was initially spherical but changed to double convex lenses. "The climax was, however, reached by the sudden appearance of a slab of ice which luckily fell a few yards from where I was standing. This formed one half of a cylindrical mass slpit along its diameter, which measured 1 3/4 in. Its thickness lay between 1/4 and 3/8 in. The central core, of diameter 5/8 in. was of clear transparent ice, the outer annulus being of the opaque variety." (R53)

X49. September 12, 1930. Cyprus. Button-like hailstones the size of an English penny. (R49)

X50. June 25, 1888. Guildford, England. Spherical hail with raised rims, looking like the planet Saturn. (R27)

X51. May 29, 1859. Beeston, England. "The principal forms were round, acid-drop shaped, and a small circular stone attached to a larger one, the general proportional size being as 3 to 1. There were, however, very many closely resembling an appearance of Saturn with his ring, and another prevalent form very like a frying pan with a short handle. Among the more remarkable shapes, one represented a section of an orange; another a close representation of a leg of mutton; another a comma; another a sheet of glass; while others were too grotesque for any pictorial description." (R6)

X52. June 20, 1870. Northampton, Massachusetts. A variety of hailstone shapes, including starfish types, symmetrical ovoids with rough crowns, and one with spiral layers of white and clear ice alternating. (R11, R13)

X53. No date or place. Hail in the shape of exact cubes 7 mm in size. (R22)

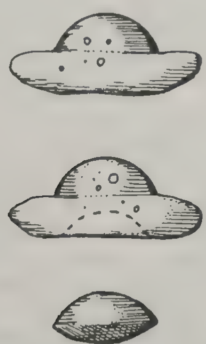
X54. May 20, 1887. Penmaenmawr, Great Britain. Pear-shaped hailstones. (R24)

X55. April 8, 1890. Hampstead Heath, England. "A remarkable shower of soft hail occurred here shortly before 1 p.m. on Tuesday last (April 8th). The masses of hail (they were neither 'stones' nor 'balls') were of irregular shape, in some cases half an inch in diameter, and appeared to be made up of small plates of ice adhering like the petals of a double marigold. The last form, on melting, was an irregular disc of ice. A noticeable point was the facility with which the masses adhered on being brought into contact, so that merely by putting them together on a sheet of paper you could get a layer three inches or more in diameter." (R30)

X56. June 28, 1942. Silver Lake, New Hampshire. "...some of the hail consisted of only a hollow shell 1/16 to 1/8 in. thick, but 3/4 in. across and 1/4 in. thick, evidently a hailstone which was still partly liquid when it struck, but which had cracked open and let the water out. I found one stone that had the unfrozen water still in it, for the bubbles moved about as it was tilted. As the hail melted some of the stones became complete rings of ice. The outer edge of the hail had frozen more than the inner portions, presumably because of the greater flow of air." (R52)

X57. February 8, 1954. Persian Gulf. "The stones fell with sufficient force that the brass binnacle cover of the standard compass was badly dented. The stones averaged about 1 1/2 in. diameter, and it was observed that many were perfectly hemispherical in shape, as though split in half, and showing ringed layers of ice on the flat surface." (R56)

X58. May 2, 1887. Kingston, Jamaica. "The hailstones were of clear ice, inclosing a few bubbles of air, varying from mere points to bubbles of the size of a split pea. The shape of the stones was singular. Suppose a shallow and very thick saucer to have a shallow cup, without a handle, inserted in it, and you will have a good idea of the form of the hailstones when unbroken. Many had more or less lost the 'saucer' by violence, while some were entirely without it, presenting the appearance of a double convex lens with faces of different curvature." (R25)



Saucer and lens-shaped hailstones (X58)

X59. May 7, 1862. Headingley, England. A hailstorm of great violence and remarkable for the wide variety of hailstone shapes. Two of the more startling forms are illustrated here. (R8, R9)

X60. General observation. The mechanism for the formation of conical hail or graupel is not well understood, the theories offered having defects. A new theory is presented. (R60)

X61. June 3, 1873. Nottingham, England. Conical hail the size of peas. (R14)

X62. July 2, 1873. Germany. During a journey up the Rhine. "Heavy hailstorms closed just before reaching Strasburg Station, where the paths appeared strewn with cubes of ice like lump-sugar, which I got out and sampled, perfect 'squares.'" (R63)

X63. July 16, 1918. Surrey, England. "The lumps were not aggregated separate stones. Knobs nearly an inch long were often a bare quarter inch across at the base. Several had three such round their equator at even distances, with numerous shorter ones all over. In many cases there must have been fifteen to twenty knobs in all, or even more. Further, even the largest lumps had but one nucleus of opaque ice." (R64)

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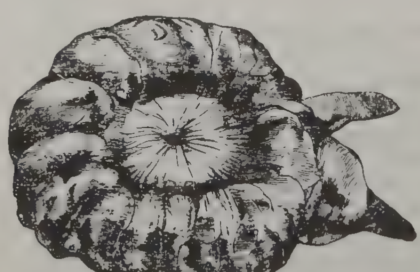

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GWP5 Giant Hailstones

Description. Hailstones weighing more than 1 pound and/or exceeding 4 inches in diameter, these being the approximate limits set by meteorological theories of hail formation. Giant hailstones fall along with smaller hailstones during storms and thus differ from the ice falls and hydrometeors (GWF1), which are usually solitary phenomena and often occur in the absence of storms.

Background. Reports of hailstones the size of marbles, hens' eggs, etc. are numerous. Hail of these dimensions pose no problems in explanation, at least in the matter of size.

Data Evaluation. Several believable reports of hailstones larger than 4 inches and weighing more than a pound have been found in the literature. Such reports are few in number, and in no instance do the dimensions greatly exceed the meteorologists' upper limits for hail. As in the case of hydrometeors, however, one finds reports of colossal hailstones, which, like fish stories, must be discounted according to age and locale. Rating for hailstones modestly larger than 4 inches and/or 1 pound: 1.

Anomaly Evaluation. Since the high-quality reports of giant hailstones claim dimensions not significantly greater than theoretical considerations permit, it seems that slight modifications of theory can explain most believable observations. Rating: 3.

Similar and Related Phenomena. Ice falls and hydrometeors (GWF1); hailstones with anomalous shapes (GWP4), some of which approach the acceptable dimensional limits.

Examples of Giant Hailstones

X1. March 1295. Yemen. A great hailstorm that killed many animals. One hailstone, which partly buried itself in the ground, was supposedly so large that men could not see over it. This account was reprinted from the Annals of the Resuli Dynasty of Yemen. (R4) Obviously such a story must be placed in the same class as the Indian hydrometeor that was as big as an elephant. (GWF1-X1)

X2. August 31, 1820. London to the English south coast. Pieces of solid ice 6 x 18 inches fell during a hailstorm. (R6)

X3. April 10, 1822. Bangalore, India. Angular and oval hailstones, as large as pumpkins. Many cattle killed. (R7)

X4. June 15, 1829. Cazorla, Spain. Houses literally crushed under blocks of ice weighing up to 4 1/2 pounds. (R8, R10, R11) See GWP4-X38.

X5. August 13, 1851. New Hampshire. Masses of ice fell weighing 1 1/2 pounds. (R15)

X6. May 22, 1851. Bangalore, India. More hailstones the size of pumpkins! (R15)

X7. March 28, 1867. Adoni, India. "In Adoni to the north of the talook, at Nukkulmittah and other villages, the hail is described as being of the size of cocoa nuts to woodapples, and lying to one foot in depth; in some places destroying the wet and dry crops. In Gooty, at eight p.m. on the 28th, the hail was described as ranging from the size of bullets to limes; some sheep were killed and crops destroyed.....In Anantapur talook the size of the hailstones is apparently incredible. I give, however, the local report, that in a field of the village of Bondalavada some of the stones were two-thirds of a cubic yard in size. In the village of Chadula a cubic span, and in other villages of six seers, or three pounds in weight; this last was verified by the Tahsildar. Two men, 2,470 sheep, and eight cattle were killed, and some thatched houses were destroyed." (R1)

X8. Autumn 1875. Potter, Nebraska. On a Union Pacific train. "The hailstones were simply great chunks of ice, many of them three and four inches in diameter, and of all shapes---squares, cones, cubes, etc. The first stone that struck the train broke a window, and the flying glass severely injured a lady on the face, making a deep cut. Five minutes afterward there was not a whole light of glass on the south side of the train, the whole length of it. The windows in the Pullman cars were of French plate, three eighths of an inch thick, and double. The hail broke both thicknesses, and tore the curtains to shreds." (R2, R16) The same area was visited by another phenomenal hailstorm in 1928. See below. (X17)

X9. May 3, 1877. Texas. Pieces of ice as large as a man's hand killed thousands of sheep. (R15)

X10. June 1881. Iowa. During a hailstorm a mass of ice 21 inches in circumference fell. (R15)

X11. July 12, 1883. Lake Michigan. Ships on the lake northeast of Chicago reported hail the size of goose eggs. One piece, the size of a brick, weighed 2 pounds. (R3)

X12. July 16, 1883. Urbana, Illinois. Many hailstones measuring 12 inches in circumference. (R3)

X13. May 1888. India. Hailstones weighing 1 1/2 pounds. (R15)

X14. December 6, 1892. Gray Hill, Texas. "This remarkable hail fell in large lumps, ranging from three to six inches in diameter. I heard of one piece eight inches in diameter, which weighed four pounds. They were, as a rule, spherical in form, but some were somewhat flat, and nearly all were covered with oval knobs. They fell in small areas, about two feet apart, while in other places only one would fall in a space twenty feet square. The average under my observation was about one hailstone to every three feet square. A most remarkable fact in connection with these large hailstones is that some of them have particles of dirt in the center." (R5)

X15. Summer 1902. Yuwu, China. An English missionary reported a hailstone of ten pounds weight. (R8, R11)

X16. August 10, 1925. Heidgraben, Germany. A 4 1/2 pound hailstone, 10 inches long, fell through a house roof. (R8)

X17. July 6, 1928. Potter, Nebraska. One hailstone weighed 1 1/2 pounds and was 17 inches in circumference. Fragments of another, when pieced together, made a stone as large as a man's head. (R9, R16)

X18. January 24, 1957. Northwood, England. A hailstone 4 x 5 1/2 inches, weighing 13 1/2 ounces fell during a shower of hail. (R17)

X19. April 7, 1961. Persian Gulf. Hailstones estimated to be at least 5 inches in diameter. (R13)

X20. April 20, 1962. Persian Gulf. Hailstones 4 inches in diameter fell on the decks of the s.s. City of Durban. (R14)

X21. General observation. Based upon aerodynamic considerations, the upper limit on the size of spherical hailstones is 1 1/2 pounds. (R12)

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GWP6 Hail Strew Patterns

Description. The fall of hail in long, parallel strips or geometrical arrays of patches.

Background. After severe hailstorms, farmers surveying their fields often find long strips where the damage is almost total. These linear patterns are called "hailstripes." Hailstreaks are larger-scale patterns of damage, while hailswaths are larger still, being the result of overlapping hailstreaks. A more general term is "hail strewn" or "hail strew" pattern.

Data Evaluation. Hailstripes are rarely mentioned in the meteorological literature. Yet, recent aerial surveys and closely spaced arrays of hail-monitoring instruments leave no doubt as to their existence. Rating: 1.

Anomaly Evaulation. Hailstripes are thought to originate in long, linear storms features termed "hailstrands." The genesis and precise nature of these hailstrands are unknown, although it seems reasonable that such fine structures of hailstorms will ultimately be encompassed by current meteorological theory. In other words, hailstripes are poorly understood details of hailstorms rather than strong anomalies. Rating: 3.

Possible Explanations. Linear hailstorm structures of obscure origin.

Similar and Related Phenomena. Point rainfall (GWP12); whirlwind and tornado tracks.

Examples of Hail Strew Patterns

X1. June 9, 1856. Guilford County, North Carolina. A hailstorm of unusual violence. "The hail fell in lines, a field here and a garden there being destroyed, while intermediate ones were left uninjured. The hail had a strong flavor of turpentine. This is the testimony of persons testing it at different and distant localities." (R1)

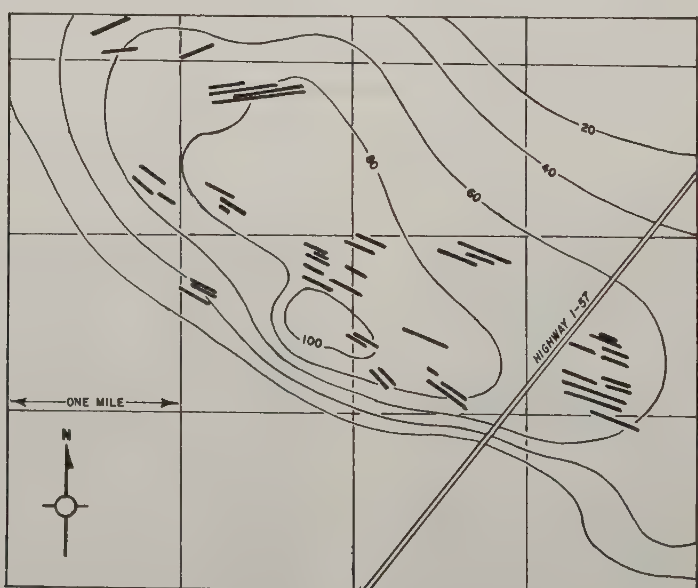
X2. July 3, 1863. Clermont-Ferrand, France. About 6 P.M. a cloud approached rapidly from the west, at a height estimated as 5000 feet. It resembled a huge net in form, the portion represented by the netting showed violent agitation, and soon after the arrival of the cloud there was a heavy hailstorm lasting about five minutes, the hailstones being as large as nuts. During the fall of the hail there was no wind. The hail caused considerable damage whereever it fell, and M. Lecoq, who saw the storm and described it in the Comptes Rendus, stated that the damage was limited to small patches, which were surrounded by undamaged zones, forming a network the meshes of which were irregular but roughly 60-100 metres apart. The distribution of the hail corresponded with the form of the cloud." (R2, R3)

X3. General observations. Quoting from the Abstract: "A hailstreak is an area of continuous hail with temporal coherence and is considered an entity of hail generated within a thunderstorm. The average hailstreak represents a fast-moving, short-lived, and relatively small phenomenon. Eighty five per cent of all hailstreaks had areas < 16 mi^2 and hail impact energy values < 0.1 ft-lb ft^{-2}, but areal extremes were 0.9–788 mi^2 and energy extremes sampled were 0.0001–12.6 ft-lb ft^{-2}. A hail-producing system in a 1600 mi^2 area normally produced five hailstreaks with an average separation distance of 15 mi. Cold fronts and unstable air mass conditions led in the production of hail systems and hailstreaks, respectively. Hailstreaks produced by different synoptic weather conditions differed considerably. Point durations of hailstreaks averaged 3 min, 43% occurring in the 1500–1900 CDT period. Eighty-five per cent of all hailstones had diameters $\leq 1/4$ inch and only 1% were ≥ 1 inch. A 1-ft^2 area in a hailstreak normally experienced 24 hailstones. Hailstreaks occurred in all locations and stages of age of their associated rain cells, but their preferred location was along the major axis and in the mature stage. Normally, a rain cell produced only one hailstreak, although 20% produced four or more." (R4)

X4. General observations. Hailstripes are microscale hail phenomena that occur on a smaller scale than hailstreaks. "Abstract. Aerial photographs of crop-hail damage areas have revealed a smaller-scale feature of damage patterns than has previously been reported. These features, called 'hail stripes', are long, narrow (15–30 m width) stripes of alternating light and heavy damage. These are believed to be caused by a combination of strong wind and 'hailstrands', long string-like substructures of the hailshaft." (R5)

X5. No date given. France. "The space ravaged by hailstorms, often indicates the presence of aerial currents, the devastations being frequently confined to a long and narrow strip of country. Sometimes the storm proceeds in two parallel tracks, leaving the intervening region entirely uninjured. Thus a hailstorm once commenced in the south of France in the morning, and in a few hours reached Holland. The places desolated formed two parallel paths from S. W. to N. E.; the length of one was 435 miles; and that of the other 497 miles. The average width of the eastern track was five miles, and that of the western ten; and upon the space comprised between them, which was twelve miles and a half in breadth, no hail fell, but only a heavy rain." (R6)

X6. July 16, 1918. Surrey, England. "Greenhouses were riddled, window panes smashed, trees stripped; vegetables of all kinds destroyed. The stones were like walnuts in size, many 1 1/2 inches across. Cereal crops were beaten down, the straw broken in three or more pieces, the green grain beaten out of the ears. The storm passed from south-west to north-east, the damage being confined to a



Strips heavily damaged by hail in Illinois fields (X4) strip of 800 yards, 'inside which 'everything growing has been destroyed, whereas the adjoining land remains unscathed.''' (R7)

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GWP7 Slowly Falling Hail

Description. Hailstones that seem to float gently to the ground. The terminal velocities of some hailstones have been measured as several times less than one would predict from air resistance and hailstone diameter. All examples of slowly falling hail involve large stones; i.e., an inch or more in average diameter.

Data Evaluation. Several qualitative observations plus one estimate of terminal velocity by a trained weather observer. Rating: 2.

Anomaly Evaluation. Slowly falling hail can be explained by appealing to low-altitude updrafts. This phenomenon is therefore primarily a curiosity, although the genesis of low-altitude vertical winds is not well-understood. Rating: 3.

Possible Explanation. Low-altitude updrafts slow the falling hailstones.

Similar and Related Phenomena. None.

Examples of Slowly Falling Hail

X1. May 29, 1859. Beeston, England. Grotesquely shaped hailstones more than an inch in diameter fell very gently. (R1)
X2. June 27, 1866. Cricklewood, England. A puzzling aspect of this violent hailstorm was the gentle fall of the larger stones. The big hailstones did less damage than the smaller ones. (R2)
X3. Circa 1908. Remiremont, France. The velocities of the hailstones were so slight that they seemed to fall from heights of just a few yards. (R3)

X4. April 24, 1930. Bagdad, Iraq. "The most remarkable features of the hailstorm were the large size and slow terminal velocity of the hailstones and the absence of dust in their composition..... The total diameter (of an average stone) was one and five eighths inch, and in calm air the terminal velocity of hailstones of this size would be nearly 30 miles per hour. The descent of several specimens was actually timed against the wall of a building, and it was found that they fell 40 feet in about three seconds, giving a velocity of only 9 miles per hour. The observer is to be congratulated on his enterprise in obtaining this measurement, which appears to indicate an upward current of air of at least 30 m.p.h. at a comparatively low elevation." (R4)

References

R1. "Extraordinary Hailstorm," Annual Register, 101:70, 1859. (X1)
R2. "The Storms of June 27th, 1866," Symons's Monthly Meteorological Magazine, 1:43, 1866. (X2)
R3. "More about the Hailstones of Remiremont," English Mechanic, 87:436, 1908. (X3)
R4. "Remarkable Hailstorm in Iraq," Meteorological Magazine, 65:143, 1930. (X4)

GWP8 Unusual Inclusions in Hail

Description. Anomalous substances found in hailstones. Inclusions of dirt and sand are so common and so easily accounted for by appealing to windblown dust and sandstorms that they are not treated in this catalog. Somewhat more curious are inclusions of salt, iron sulfide, radioactivity, and small insects. Ice-encased birds, turtles, etc. must definitely be considered anomalous.

Data Evaluation. Excluding inclusions of terrestrial dust and sand, reports of other sorts of inclusions are generally one-of-a-kind. Age and lack of detail also weaken the case for the more fabulous inclusions. Rating: 3.

Anomaly Evaluation. The chapter on falls (GWF) demonstrated the power of whirlwinds and waterspouts to lift a great variety of lightweight objects into the atmosphere. This levitating power combined with hail-forming conditions would seem to make all manner of inclusions possible and, in fact, not very anomalous. Rating: 3.

Possible Explanation. Windblown materials serve as hailstone nuclei.

Similar and Related Phenomena. All falls (GWF).

Examples of Unusual Inclusions in Hail

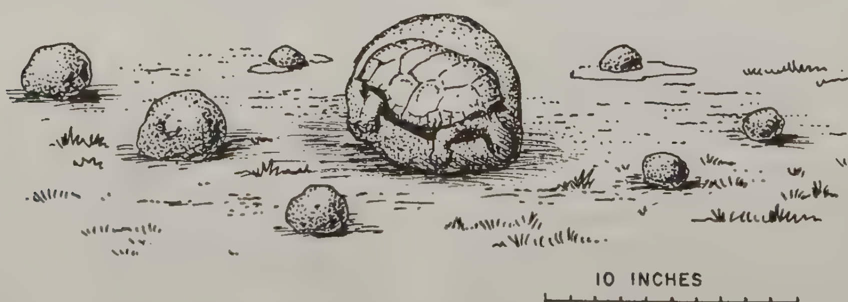
X1. August 26, 1834. Padua, Italy. "...hailstones with nuclei of a dark grey colour. These nuclei, examined by Cozari, consisted of grains of different sizes, the largest of which could be attracted by the magnet, and were found to be composed of iron and nickel. The identity of this matter with that of aerolites can scarcely be open to doubt. An analogous observation has been made at Stockholm by Nordenskiold, who proved the presence of little dark grains of metallic iron in some hailstones." (R4)

X2. June 1842. Nismes, France. The peculiar taste of some hail led to an analysis that revealed the presence of nitric acid. (R1)

X3. 1871. Zurich, Switzerland. Hailstones with salty taste fell. Crystals of salt found inside. (R2,R3)

X4. May 11, 1894. Vicksburg, Mississippi. "During a severe hailstorm at Vicksburg on the afternoon of Friday, May 11, a remarkably large hailstone was found to have a solid nucleus, consisting of a piece of alabaster from one-half to three-quarters of an inch. During the same storm at Bovina, 8 miles east of Vicksburg, a gopher turtle, 6 by 8 inches, and entirely encased in ice, fell with the hail." (R5, R6)

X5. May 26, 1953. Washington, D.C. Following a report of radioactive hailstones in the Washington area. "During the subsequent few days, we obtained a number of the hailstones, which because of their unusual size many people had collected and stored. The average beta activity of eleven of the melted hailstones was 1.4×10^{-10} curie per milliliter. Radiochemical analysis of 41 hailstones gave the characteristic isotopic distribution of a young fission product conglomeration. All hailstones showed the familiar concentric layer formation and most were



Gopher turtle encased in ice falls in Mississippi hailstorm (X4) roughly spherical in shape.....It is clear from our measurements, that the centers of the hailstones contained significantly more radioactivity than the outside layers. Therefore it seems probable that these hailstones were formed in a region of relatively high fission product concentration." (R7) Atmospheric nuclear tests are to be suspected here. (WRC)

X6. June 14, 1975. Norman, Oklahoma. A small insect (a chalcid) was found in the center of a 3-centimeter hailstones. The authors also refer to birds encased in ice being observed in the past, but no specific reference was given. (R8)

X7. No date or place given. Hailstones reported containing small crystals of "sulphuret of iron." (R2, R3)

References

R1. Ducres, M.; "Observations on an Acid Rain," American Journal of Science, 2:1:112, 1846. (X2)

R2. "Salt and Iron Hail," Scientific American, 26:128, 1872. (X3, X7)

R3. Nature, 5:211, 1872. (X3, X7)

R4. Schwedoff, Theodore; "On the Origin of Hail," Symons's Monthly Meteorological Magazine, 17:146, 1882. (X1)

R5. "Remarkable Hail," Monthly Weather Review, 22:215, 1894. (X4)

R6. "Enormous Hailstones," Symons's Monthly Meteorological Magazine, 29:151, 1894. (X4)

R7. Blifford, I. H., Jr., et al; "On Radioactive Hailstones," American Meteorological Society, Bulletin, 38:139, 1957. (X5)

R8. Knight, Nancy C., and Knight, Charles A.; "Some Observations on Foreign Material in Hailstones," American Meteorological Society, Bulletin, 59:282, 1978. (X6)

GWP9 Explosive Hail

Description. Hail that fragments with pistol-like reports when impacting a hard surface. The fragments fly energetically in all directions.

Data Evaluation. Only two descriptions from the same observer, one of which is presented in good detail. Rating: 2.

Anomaly Evaluation. Explosive hail probably derives its energy from internal stresses accumulated inside the hailstone. The existence of a reasonable explanation for this phenomenon relegates it to the curiosity category. Rating: 3.

Possible Explanation. Internal stresses due to phase and temperature changes.

Similar and Related Phenomena. The shattering of ice cubes when dropped in warm fluids.

Examples of Exploding Hail

X1. Circa 1894. Lexington, Virginia. Hailstones fragmented upon impact with the ground and rebounded. (R1)

X2. November 11, 1911. Columbia, Missouri. "The morning had been unseasonably warm; about noon there were the usual sounds of a coming thunderstorm---heavy cumulo-nimbus clouds with a gusty wind---which began about 2.30 p.m. with a slight shower of heavy raindrops; shortly afterwards there were two or three flashes of lightning and thunder, followed by a fall of large hailstones, which on coming in contact with the windows or walls or pavement in many instances exploded with a sharp report, so loud as to be mistaken for breaking window panes or a pistol shot. As the hail fell, the fragments sprang up from the ground and flew in all directions, looking like a mass of 'popping corn' on a large scale. The fall lasted two or three minutes, about half the hailstones being shattered, the ground in some places being nearly covered white with stones and fragments. Of the unbroken stones, seventy were gathered. They weighed roughly 225 grams. A few were ellipsoidal, the longest axis about 25 mm. in length; most of them, however, were nearly spherical, and somewhat smaller, from 15 to 20 mm. in diameter. Practically all of them contained a nucleus. In a few of the stones the nucleus was porcelain-like, raspberry-shaped, surrounded by almost colourless spherical layers of ice, for about five-sevenths of the diameter, and then a shell of porcelain-like, snowy ice. A fair proportion of the stones showed, in addition to the spherical, a radiate structure, which was very apparent as the stones melted in a flat dish, showing the cross section with great distinctness." (R1)

References

R1. Brown, W. G.; "Explosive Hail," Nature, 88:350, 1912. (X1, X2)

Explosive hail (X2)

GWP10 Colored Precipitation

Description. Rain, snow, or hail colored blue, green, and any other color except red, black, yellow, brown, and gray. The excepted colors are so common and so well-explained that they cannot even be considered as curiosities.

Background. Yellow precipitation is classified with the so-called "sulphur falls" (GWF3), which almost always turn out to be pollen falls. It should be recognized, however, that some yellow rain and hail may be the result of yellowish dust and sand being mixed with the precipitation. Black, brown, and gray precipitation is very common. The contaminating substances are usually industrial pollutants and ash and soot from distant forest fires. (R2) Many of the "dark days" (GWD), particularly those in North America, have been accompanied by black rain. Throughout history, red or "blood" rains have been viewed with utmost concern by the superstitious. The coloring matter in blood rains inevitably turns out to be reddish dust and organic matter. (R1) The red precipitation of Europe seems to originate mostly in African dust blown north and is probably linked to the Cape Verde dust fogs (GWD4).

Deposits of red snow have often been observed in the polar regions; for example, the famed Crimson Cliffs of Greenland, described by Captain John Scott early in the Nineteenth Century. Such curious sights are due not to colored precipitation but rather infestation by organic matter. (R4)

Data Evaluation. The accounts of blue and green precipitation are sparse and lack detail. Rating: 3.

Anomaly Evaluation. Like the polar red snows, blue and green snow probably owe their hues to organic matter, although no scientific analyses are at hand. It seems that there is little that is anomalous here. Rating: 3.

Possible Explanations. Contamination by organic matter or, possibly industrial pollutants. In the case of blue snow deposits, one cannot rule out an optical origin, say, scattering of sunlight by the snow particles.

Similar and Related Phenomena. Dark days and their attendant sooty rains (GWD1); colored icebergs, which may be blue, black, striped with colors, etc. (ES)

Examples of Colored Precipitation

X1. Permanent feature. Spitzbergen. "When the French meteorologists, Martin and Bravais, traversed a field of snow at Spitzbergen, in 1838, it appeared of a green hue, wherever it was pressed by the foot. The coloring matter seemed to reside just below the surface, which was brilliantly white. Upon another excursion, the first observer beheld green particles spread like dust over the snow, and upon the sides of the field." (R3) Green snow in Arctic said to derive from minute organisms."(R4)

X2. March 1, 1934. Mount Washington, New Hampshire. Holes dug in newly fallen snow were promptly filled with deep blue light. Sky obscured by dense fog, precluding reflection from blue sky. (R5)

X3. April 12, 1934. New Hampshire. Same effect as in X2. (R5)

X4. January 1955. Western New York state. Bluish snow reported in many towns. (R6)

References

R1. Judd, J. W.; "The Recent 'Blood Rains,'" Nature, 63:514, 1901.

R2. Baskerville, Chas., and Welles, H. R.; "Black Rain in North Carolina," Science, 15:1034, 1902.

R3. Brocklesby, John; Elements of Meteorology, New York, 1855, p. 119. (Cr. L. Gearhart) (X1)

R4. "Colored Snow," Monthly Weather Review, 29:465, 1901. (X1)

R5. Pagliuca, S., and McKenzie, A. A.; "Blue Snow," American Meteorological Society, Bulletin, 15:114, 1934. (X2)

R6. "AEC Checking Blue Snow That Fell in Parts of WNY," Buffalo Evening News, January 27, 1955. (Cr. L. Gearhart) (X3)

GWP11 Luminous Precipitation

Description. Raindrops, hailstones, and sleet particles that emit flashes of light and cracklings sounds when they hit terrestrial surfaces. Some reports refer to electrical "sparks," others to phosphorescent "flashes;" so two different light-emitting mechanisms may be at work.

Data Evaluation. Several good reports by experienced observers from the older literature; but, strangely, none from the past 60 years. Rating: 2.

Anomaly Evaluation. At least three light-emitting mechanisms are possible (see below). Even though no one has investigated this phenomenon, satisfactory explanations seem to be at hand. Rating: 3.

Possible Explanations. Electrical discharges when electrically charged precipitation hits terrestrial objects; triboluminescence (as in crushing sugar cubes); sonoluminescence, in which trapped gasses become incandescent due to sudden, violent pressure changes.

Similar and Related Phenomena. Electrical discharges during snowstorms (GLD5); flashes of light at the bases of waterfalls (GLD14); phosphorescence and sparks when sea ice is broken up by ships. (GLD14)

Examples of Luminous Precipitation

X1. October 28, 1772. France. "...as the Abbe Bertholon was traveling between Brignai and Lyons, in the midst of a heavy storm, he was surprised at seeing the raindrops and hail-stones emitting jets of light, as they fell upon the metallic parts of his horse's trappings." (R2)

X2. September 22, 1773. Skara Sweden. drops of rain struck fire and sparkled as they touched the ground. (R2)

X3. January 25, 1822. Freyberg, Germany.

Sleet struck the earth with flashes of light. (R2)

X4. November 1, 1844. Paris, France. "It was stated to the French Academy of Sciences, that, on the 1st November 1844, at half-past eight in the evening, during a heavy fall of rain, Dr. Morel-Deville remarked, as he was crossing the court of the College Louis-le-Grand, in Paris, that the drops, on coming in contact with the ground, emitted sparks and tufts (aigrettes) of light, accompanied by a rustling and crackling noise; a smell of phosphorus having been immediately afterwards perceptible. The phenomenon was seen three times. M. Duplessy saw at the same hour a remarkable brightness in the northern sky." (R1)

X5. 1892. Cordova, Spain. "Rain which on touching the ground crackles and emits electric sparks is a very uncommon but not unknown phenomenon. An instance of the kind was recently reported from Cordova, in Spain, by an electrical engineer who witnessed the occurrence. The weather had been warm and undisturbed by wind, and soon after dark the sky became overcast by clouds. At about 8 o'clock there came a flash of lightning, followed by great drops of electrical rain, each one of which, on touching the ground, walls, or trees, gave a faint crack, and emitted a spark of light. The phenomenon continued for several seconds, and apparently ceased as soon as the atmosphere was saturated with moisture." (R3)

X6. July 16, 1918. Surrey, England. "When the hailstones struck the windows there was a phosphorescent flash of light." (R4)

References

R1. "Phosphorescent Rain," Edinburgh New Philosophical Journal, 39:180, 1845. (X4)

R2. Brocklesby, John; "Electric Rain, Hail, and Snow," Elements of Meteorology, New York, 1855, p. 157. (Cr. L. Gearhart) (X1-X3)

R3. "Sparkling Rain," Symons's Monthly Meteorological Magazine, 27:171, 1892. (X5)

R4. Clark, J. Edmund; "The Surrey Hailstorm of July 16, 1918," Royal Meteorological Society, Quarterly Journal, 46: 271, 1920. (X6)

GWP12 Point Precipitation

Description. The concentration of rain, snow, or hail in very small geographical areas. Many inches of rain may fall on just a few acres to the near exclusion of surrounding territory.

Background. The older meteorological literature describes a number of cloudbursts and "waterspouts" that burst against hillsides, carving deep holes and channels, sometimes in solid rock. Probably these concentrated storms are not really waterspouts because they frequently occur far inland and even in desert-dry conditions.

Data Evaluation. Actual measurements of point rainfall are rare, but subsequent surveys of the physical damage wrought are conclusive that precipitation can indeed be highly concentrated. The excavation of great holes and gullies in resistant terrain has been reported often and is taken as proof of point precipitation. In addition, eyewitnesses tell of funnel-like storm structures over the afflicted areas. Rating: 1.

Anomaly Evaluation. No meteorological explanation has yet been discovered for the formation of intensely concentrated storms in hilly terrain and the subsequent rapid release of huge quantities of precipitation. Point precipitation may be the result of an unrecognized type of storm structure or some unappreciated ability of certain terrain to focus or capture storms. Rating: 2.

Possible Explanations. Speaking in vague generalities, certain types of topography may "capture" and concentrate passing storm systems, possibly by augmenting rotary motion much like quasipermanent eddies along a rocky stream bed.

Similar and Related Phenomena. Orographic clouds; the so-called "lake effect" which leads to large snowfalls in the Buffalo area and elsewhere.

Examples of Point Rainfall

X1. May 31, 1682. Oxford, England. Nearly two feet of rain fell in less than a quarter of an hour in a limited area. (R20)

X2. June 9, 1809. London, England. A cascade of water and hail poured in a torrent on an area of 200 acres. (R17)

X3. October 25, 1822. Genoa, Italy. About 32 inches of rain fell on a small area (size not specified) within 24 hours. (R1)

X4. July 8, 1847. Tusquitta Mountain, United States. After the fall of a great waterspout. "An intelligent professional gentleman, who visited the locality soon after the storm, described to me the effects produced. The chasm excavated in the earth, he said, had a depth of several feet, with its sides cut out as vertical as if dug with a spade. The roots of the trees and plants beneath the surface, were cut off as squarely as if done with the knife. At the surface, close up to the sides of the chasm, nothing seemed to be disturbed. The shrubs and grass, and even the fallen leaves upon the soil, remained unmoved, as though no running water had come into contact with them. This was the condition of things where the waterspout first struck the ground; and as the excavation, at the point of origin, had a width of but a few yards, the whole volume of the descending water, he concluded, must have been concentrated within that space, and continued thus contracted till the contents of the cloud were exhausted. In descending the mountain, along the line of the widening chasm, evidences existed that the torrent produced had attained, in places, a depth of sixty feet, uprooting in its course the largest trees, and removing immense rocks from the gulch created in its descent to the valley below." (R3)

X5. 1849. Alpine, Georgia. "A Water Spout, of immense size, the 2d inst., near Alpine, Chattanooga county, Ga. It is said to have made an impression in the earth thirty feet deep, and forty or fifty feet wide, and that it eradicated the largest forest trees, and removed rocks weighing several thousand lbs." (R2)

X6. May 3, 1849. Bredon Hill, England. An enormous body of water rushed down a gully doing considerable damage. "The course of the torrent could easily be traced up the hill for more than a mile, to a barley field of five acres, the greater part of which was beaten down flat and hard, as if an enormous body of water had been suddenly poured out upon it. Beyond this there were no signs of the fall of water to any great amount." (R11)

X7. August 1864. Nevada. "I was travelling from Humboldt mines to Reese river. The whole country was dry and parched, as is usual at that season of the year, and the weather was even warmer than common. About 2 o'clock p. m. I saw what appeared to be a whirlwind. It appeared to be about 25 miles distant, and the spiral column extended from the earth to a very dense cloud, which was nearly as high as the scattered mountains in that vicinity. Soon this column seemed to break, the upper third of it being detached from the rest and bent over to the eastward. I then perceived that this spiral column was not of dust, as I had first supposed, but was water. The next day I crossed a canon leading from the place where the phenomenon had occurred. Water was still running in it, and there was evidence of a recent flood. Inquiring further, I consulted the Hon. William R. Harrison, a gentleman of scientific attainments who had spent several years in the Humboldt mountains. He told me that such phenomena were not of infrequent occurrence in the Humboldt mountains, and were called 'cloud-bursts.' He had witnessed several of them---had once been in the edge of one, and had once stood on the top of a mountain and witnessed the terrific scene in the canon beneath him. He says: 'The first sign of them is the sudden gathering of a small, dense, black cloud on the mountain side, about one-third of the way from the top, and generally at the head of a canon. Soon this cloud seems to dash itself to the earth, taking a circular motion. It appeared as if an inverted whirlwind was drawing from the cloud immense quantities of water, which is dashed in floods against the mountain side.'" (R4)

X8. June 14, 1878. Bath, England. "Shortly after five o'clock in the evening the inhabitants of the village of Weston, which lies between Kelston Hill and Bath, were startled by a volume of water advancing like a tidal wave along the Kelston Road; in a minute the water was upon them, flooding the houses and laying the main street four feet deep under water; with such force did it come that a stone weighing five hundred-weight was carried several yards, while smaller ones were taken a much greater distance. It was not known in the village from where the water had come, but it so happened that about five o'clock I was proceeding to Weston Station by the Midland Railway from Bristol to Bath, and when in sight of the Round Hill I was struck by the blackness and lowness of the clouds in its vicinity. Suddenly there was a flash of lightning, and immediately after the Hill was enveloped in what appeared to be a storm of rain of unusual density. On arriving home I was not altogether surprised to find the commotion in the village, and I at once attributed the source of the water to the cloud which I had seen; I therefore made my way in the direction of Kelston Hill. On arriving under the brow of the Hill it was very clear that something more than an ordinary storm had occurred. Near the end of a lane (Northbrook) leading to some fields, the hedge on the right for some yards was lying in the road, but the field beyond this point presented only the appearance of an ordinary storm, while the lane itself was like the bed of a river. To the left was a field of standing grass; for about twelve feet from the hedge the grass remained intact, then for about the same distance it was as though it had been mown down. This torrent, for such it might have been compared to, came to almost a sudden termination a little above the end of the lane, but it extended down the Hill till it was joined by two others, one of which had carried a hedge away bodily....I gather from spectators at Kelston Hill that it began to be cloudy at half-past four in the afternoon; at five there was a rattling clap of thunder, followed by a downpour of rain---in 'bucket-fulls,' as one expressed it; but all seemed to agree that the greater portion of the water fell under the brow of the hill, where it came down in several columns." (R5)

X9. October 21, 1881. Little Haldon, England. A fall of water in the shape of a waterspout. Intense rain in a localized area. (R6)

X10. August 2, 1883. The Ochils, Scotland. A waterspout burst against the Ochils. Much property damage. (R7)

X11. June 9, 1888. Langtoft, England. See description in X12. (R8, R12)

X12. July 3, 1892. Langtoft, England. "At a place named 'Round Hill,' on Saturday, June 9th, 1888, about noon, a waterspout had torn its way into a slight hollow or combe on the hillside taking a northeasterly course, and formed three large holes in the chalky rubble scattering the stones all around, producing a flood which inundated the village lower down the valley. These holes, which are roughly circular and connected by a deep trench....measured from one end to the other about 70 yards, and were from 8 to 9 feet deep in their deepest portions. Several tons of soil, boulders, and gravel were thrown out and carried down the valley by the flood, and the village streets were covered with a mixture of these substances. The damage done by that flood of 1888 was, however, insignificant when compared with the one now under discussion. Not more than 20 yards from the site of the former cloudburst, or waterspout, and a little further to the south, three gutters or trenches have been scooped out of the solid rock, nearly parallel to each other and at right angles to the valley bottom; the direction taken being slightly more easterly than that on the former occasion. From the appearance of the trenches it is highly probable that there were three waterspouts moving abreast simultaneously. Two of the trenches or ravines are 68 yards in length and of great size and depth, and as the hillside here somewhat differs from the adjoining portion, where it consists of loose chalk mixed with soil and is composed of strata of solid rock slightly inclined to the vertical, beneath a thin layer of earth, the force exerted in removing the ponderous mass of material, about 180 yards in circumference, must have been very great indeed. The smaller trench, 15 yards to the left and much shallower, is rather over 50 yards long, but this is discontinued before the summit of the hill is reached, as the gyratory power of the tornado had evidently become weaker and the spout was presumably drawn up again into the cloud....The probable causes that bring about the formation of these waterspouts or cloudbursts in this particular spot may lie in the peculiar character and configuration of the surrounding valleys, which all converge to a point south of this place, and have only one outlet to the east, while the north-easterly side upon which the waterspouts impinge is strongly fortified by steep declivities which appear to impede the storms in their path. Here, possibly, the overcharged undercurrent of warm air, supplemented by the warm air of the valley (for the afternoon sun had been bright and hot), was suddenly broken into and disturbed by the cool rain and air descending from above, and a series of whirls were formed, which, after developing into waterspouts and conforming to the laws of tornado motion, moved away in a northeasterly track, and hence came in contact with the steep hillside, where, finding their paths impeded, they tore huge holes in the hillside." (R8, R18)

X13. July 2, 1893. Cheviots, England. "A hill in the Cheviots, known as Bloody Bush Edge, was visited by a waterspout or cloudburst. The day was oppressive and about 10 A.M. heavy clouds gathered. These broke about 1 P.M. and 'the whole hill and parts of the adjoining hills were covered with a sheet of water'. The peat which forms the surface of the hill was ploughed up to a depth of about five feet, and the rocks beneath laid bare over a space of 30-40 acres. The River Breamish rose forty feet in sudden flood, swept away its bridges and destroyed long stretches of roadway." (R14)

X14. 1898. No place given. "As a boy I saw a small hailfall of about ten to fifteen meters width across a road. We boys ran from the dry side through the hail to the other dry side and back." (R10)

X15. June 18, 1907. Blanchland, England. A waterspout burst, flooding the countryside, breaking up stone walls, and doing much damage. (R13)

X16. April 26, 1922. Semur, France. A couple driving along a road encountered two "walls" of intense precipitation. (R9)

X17. August 1, 1932. London, England. "It began to rain---heavily at first and then softly. Suddenly torrential rain fell only one hundred yards from where I was standing. The nearest trees in Kensington Gardens were almost hidden behind a milky mist of heavy rain. The rain-drops rebounding off the street created a layer of spray as high as the tops of the wheels of the taxis standing in the street. Where I was sheltering, hardly a drop of rain was falling. The contrast was so striking that I called the attention of an unknown bystander (as though I could not believe my eyes). Then the spray on the ground came nearer like a wave, and receded. Suddenly it vanished completely, and the trees behind in Kensington Gardens stood out black against the sky. It was over." (R15)

X18. August 2, 1966. Greenfield, New Hampshire. "Rain began to fall about 1900 EST, or about an hour before the outbreak of more generalized showers in the region. It soon became a downpour, continuing until about 2300 EST, at which time Mr. Stanley went to bed. It was then still raining, but had slackened noticeably. The rain may have stopped by midnight. A remarkable nonvariability of the intense rain was noted by Mr. Stanley. There was very little slackening, even for brief intervals, during the period of heaviest fall, which was from about 1945 to 2215 EST. There was practically no wind. Neither thunder nor lightning was observed. The noise on the roof was terrific, like that of a continuous waterfall. A plastic bird feeder mounted on the side of the house was broken by the impact of sheets of water from the eaves. Looking out the window, Mr. Stanley could see stones and gravel from the roadway, south of the house, being washed away by torrents of water. Upon rising in the morning, Mr. Stanley noted that the weather had cleared, with a brisk westerly wind. After finding the 5.75 in. of rain in the gage, he inquired from a neighbor 0.3 mi to the east. He found that the neighbor had but 0.50 in. in his gage. He thereupon examined the countryside for visible effects. The road washout extended only a few hundred feet. Upon going one-half mile in either direction, no evidence of rain erosion of sand or gravel could be found. South of the house, beginning at the gage which was mounted on a pole, well distant from structures or trees, there stretches a 10-acre field. The knee-high grass therein was beaten down flat. By afternoon it began to revive. By the following noon it was erect. To the west of the house, a dry-wash brook running bankful at dawn was empty by 0800 EST. Drawing a line around the traces of erosion, one obtains an oval area about a mile north-south and about three fourths of a mile east-west. Within this area, rain varied from the order of 1 in. on the limits to almost 6 in. in the center. Outside this limit, rain is believed to have fallen off sharply to less than one-fourth of an inch, generally within a few thousand feet." (R19)

X19. No date given. Chatham, England. Heavy rain fell in a strip 30 feet wide and three miles long. (R16)

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R2. "A Great Waterspout," Scientific American, 4:414, 1849. (X5)

R3. "Water-Spouts in the Mountains," Scientific American, 14:349, 1866. (X4)

R4. Young, William J.; "Cloud-Bursts," Smithsonian Institution Annual Report, 1867, p. 471. (X7)

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R10. Kassner, C.; "Sharply Defined Showers," American Meteorological Society, Bulletin, 10:196, 1929. (X14)
R11. "Cloudburst," Nature, 125:657, 1930. (X6)
R12. "Waterspout," Nature, 125:877, 1930. (X11)
R13. "Waterspout," Nature, 125:913, 1930. (X15)
R14. "Cloudburst in Chevıots," Nature, 125:994, 1930. (X13)
R15. Hinkson, G. A.; "Well-defined Rain Area," Meteorological Magazine, 67:159, 1932. (X17)
R16. American Meteorological Society, Bulletin, 14:302, 1933. (X19)
R17. Fort, Charles; "The Notes of Charles Fort," Fortean Society Magazine, 1:14, September 1937. (X2)
R18. Hawke, E. L.; "Rainfall in a 'Cloudburst,'" Nature, 169:204, 1952. (X12)
R19. Lautzenheiser, R. E., et al; "Remarkable Point Rainfall at Greenfield, N. H., Evening of August 2, 1966," Monthly Weather Review, 98:164, 1970. (X18)
R20. Meaden, G. T.; "Point Deluge and Tornado at Oxford, May 1682," Weather, 34:358, 1979. (X1)

GWP13 Surplus Ice Crystals in Clouds

Description. The presence in clouds of from 1,000 to 10,000 times more ice crystals than can be accounted for by the number of active ice nuclei. The ice nuclei are needed to initiate the crystallization of supercooled cloud water.

Data Evaluation. The great discrepancy between ice crystals and ice nuclei is confirmed by actual counts at high altitudes, according to the single discussion of the subject found so far in the literature. Rating: 2.

Anomaly Evaluation. Modern cloud physics requires that each ice crystal form on an ice nucleus. At present, there seems to be no acceptable theory explaining how all the ice crystals form without corresponding numbers of ice nuclei. Rating: 2.

Possible Explanation. Supercooled water droplets may be carried to high altitudes where adequate populations of nuclei exist by convection. Existing ice crystals may splinter and multiply the number of ice nuclei present.

Similar and Related Phenomena. None.

Examples of Surplus Ice Crystals in Clouds

X1. General observations. Counts of ice crystals in clouds are from 1,000 to 10,000 times greater than ice nuclei. (R1)

References

R1. "Where Do All the Extra Ice Crystals Come From?" New Scientist, 64:316, 1974. (X1)

GWP14 Decrease of Rainfall with Increasing Altitude

Description. The observation that the quantity of rain collected in rain gauges usually diminishes markedly as the height of the gauge above the ground is increased. Apparently, additional rain condenses rather close to the ground.

Background. This intriguing observation comes from a very old report, but nothing further has been discovered on the subject in later journals and texts. Quite possibly, this phenomenon is well recognized and explained but has not yet been encountered in our literature searches.

Data Evaluation. Only a single report from 1868 wherein the phenomenon is represented as well-accepted. Rating: 3.

Anomaly Evaluation. According to R1, the condensation of water vapor on cold, falling raindrops cannot explain the facts, but small droplets, invisible to the eye, may be present in sufficient quantity to account for the increased rainfall closer to the ground. If this is true, no anomaly exists. Until such confirmation is found, this phenomenon will be recorded and given a low anomaly rating. Rating: 4.

Possible Explanation. The "sweeping out" of small, invisible droplets of water by falling raindrops.

Similar and Related Phenomena. Precipitation from a cloudless sky (GWP1) may originate in the same population of water droplets that is substantial but nevertheless not visible in cloud form.

Examples of Decrease of Rain with Increasing Altitude

X1. General observations. "One of the most remarkable results of observations made upon rain, has been the discovery that the amount of fall at any place diminishes largely as the rain gauge is raised above the level of the ground. It is not very easy to explain this remarkable fact. The explanation offered by Kamtz is, that a falling drop carries with it the temperature of the upper regions of air, and condenses on its surface the aqueous vapour present throughout the lower strata of the atmosphere, as a decanter of cold water does when brought into a room. And of this explanation Professor Nichol remarks, that 'it is not an hypothesis but a rigorous deduction, giving an account of all the facts as yet ascertained in connection with this subject.' But unfortunately, the explanation, though it undoubtedly presents a vera causa, will not bear the test of 'quantitative analysis.' Sir John Herschel has gone through the simple calculation required to overthrow the theory, and points out, that if we allow the cause the full value it can possibly have (a value far exceeding that which can probably be attributed to it) we obtain an effect only one-seventeenth part of what is wanted to account for the phenomenon," The author next suggests a connection between the phenomenon and the well-known fact of precipitation from a clear sky. There are, he says, considerable numbers of small water droplets in the atmosphere, even when the sky seems clear. (R1)

References

R1. Proctor, R. A.; "Rain," English Mechanic, 6:357, 1868. (X1)

GWP15 Rain Gushes Associated with Lightning

Description. Sudden gushes of rain or hail that are closely associated in time and space with lightning flashes.

Data Evaluation. Rain gushes have been linked to lightning flashes for over a century. Radar observations of thunderstorms suggest that lightning flashes are followed by the intensification of radar echoes and ground observation of gushes of precipitation. Some older observations, however, insist that the rain gushes precede the lightning. Rating: 2.

Anomaly Evaluation. There is currently considerable debate as to whether the strong electric fields existing within thunderstorms have any effect on precipitation. Theory seems to say that no connection exists, which is contrary to observation. Rating: 3.

Possible Explanations. Electrostatic fields may help stimulate the condensation of water vapor in the storm clouds. The thunder, too, may affect condensation of raindrops.

Similar and Related Phenomena. Large hydrometeors (GWF1) and the so-called "thunderstones" (GWF2), both of which are linked to lightning. Hot-air blasts after lightning (GLL12).

Examples of Rain Gushes Associated with Lightning

X1. July 25-26, 1849. England. Observations made during severe thunderstorms. "On this occasion his attention was more particularly directed to the connexion between the electric discharge and the sudden gush of rain that more or less accompanies it, with a view to illustrate the question occurring in the Report of the Committee of Physics approved by the President and Council of the Royal Society, p. 46, 'Is this rain a cause or consequence of the electric discharge?' On the previous day, the 25th, about 3h 50m P. M., during a thunderstorm a sudden gush of heavy rain occurred, which within two seconds, by estimation, was succeeded by a vivid flash of lightning: the thunder occurred at a further interval of some seconds. From this it would appear, provided the heavy rain fell over the entire space between the place of observation and that of the electric discharge, that it was not a consequence of that discharge, the gush occurring at a sensible interval previous thereto. The setting in of the storm of the 26th, about 1h 45m P. M., again called the attention of the writer to this point; and several flashes occurred between 1h 45m P. M. and 2h 3m P. M. without being preceded by a gush, although heavy rain more or less accompanied the discharges, in one or two instances alsimultaneously or immediately afterwards. At length, about 2h 4m P. M., a most violent and very remarkable gush of rain occurred, which was followed within one minute by a most vivid flash of lightning, the thunder succeeding almost instantaneously..... Within a minute or two after this discharge a partial cessation of the heavy rain took place, but sudden gushes occurred at short intervals within the next six or seven minutes; they were, however, unaccompanied by lightning. ....Within ten minutes, however, the storm again burst forth; the lightnings played, the thunder roared, and heavy rain, mingled with hail so thickly that comparatively near objects could scarcely be distinguished, fell in torrents, and the writer observed during the remainder of the storm four or five sudden gushes that were quickly succeeded by lightning. On all these occasions he is quite certain that the sudden gush of rain preceded the electric discharge." (R1) The order of events here is the reverse of those in the following reports. (WRC)

X2. General observations. "Abstract. Observations of thunderstorms in New Mexico were made with a vertically-scanning, 3-cm radar on a mountain top. Prior to a cloud-to-ground lightning discharge nearby, the radar echo overhead was usually quite weak, indicating low intensities of precipitation there. Following the lightning it was observed sometimes that in the region of the cloud where the discharge occurred the radar echo intensity rapidly increased, and shortly thereafter a gush of rain or hail fell nearby. These studies confirm earlier radar observations, made by the authors at Grand Bahama Island, B. W. I., in which it was found that lightning is often followed by a rapidly intensifying echo and then by a gush of rain at the ground. The increases in radar reflectivity in small of the cloud following lightning suggest that the electric discharge is influencing the size of the particles in the cloud. An analysis indicates that within 30 seconds after a lightning discharge, the mass of some droplets may increase as much as 100-fold as a result of an electrostatic precipitation effect." (R2) However, see the following item.

X3. General observation. Calculations suggest that electrostatic forces, such as those in thunderstorms, are not necessary to explain rainfall. (R4)

X4. General observations. "In his book, The Flight of Thunderbolts, Dr. Schonland states, 'It is a familiar experience to all who live in thundery regions that rain does not usually fall from a thundercloud until at least one lightning flash has taken place.' From observations of many isolated, air-mass thunderstorms over the mountains of New Mexico, we support Dr. Schonland's conclusion." (R3)

References

R1. Birt, William Radcliff; "On the Production of Lightning by Rain," Philosophical Magazine, 3:35:161, 1849. (X1)
R2. Moore, C. B., et al; "Gushes of Rain and Hail after Lightning," Journal of the Atmospheric Sciences, 21:646, 1964. (X2)
R3. Moore, C. B.; "Lightning Discharge and Precipitation," Royal Meteorological Society, Quarterly Journal, 91:368, 1965.(X4)
R4. Brazier-Smith, P. R., et al; "Increased Rates of Rainfall Production in Electrified Clouds," Royal Meteorological Society, Quarterly Journal, 99:776, 1973. (X3)

GWR TEMPERATURE ANOMALIES

Key to Phenomena

GWR0 Introduction
GWR1 Temperature Flashes
GWR2 Incendiary Phenomena

GWR0 Introduction

Meteorological records often quote high and low temperature extremes but say little about rapid rates of temperature change, which some term "temperature flashes." To the anomalist these temperature flashes are much more interesting than mere highs and lows, for they signify violent weather. Although the familiar Chinook winds and thunderstorm activity seem to accompany most temperature flashes, there are some that have no ready explanation.

Incendiary phenomena comprise the second category of temperature anomalies. This classification is perhaps a bit misleading, because the anomalous aspects of incendiary phenomena are primarily the great speeds of propagation, the strange quirks in fire distribution, and the curious "pranks" discovered in the trail of firestorms, some of which are not very amusing.

GWR1 Temperature Flashes

Description. Large, rapid temperature fluctuations, often amounting to tens of degrees in a few minutes. Temperature flashes are often associated with Chinook-type winds in the United States and with their analogs elsewhere. Other temperature flashes sometimes accompany thunderstorms.

Data Evaluation. Several excellent instrumented observations. Rating: 1.

Anomaly Evaluation. The hot, dry Chinook winds are fairly well understood, but the temperature flashes associated with nighttime thunderstorms remain to be elucidated. Other temperature flashes, viz. X2, have no known causatative agent. Rating: 3.

Possible Explanations. Passing over the well-known Chinook winds, one can surmise that thunderstorms are the products of instability and must therefore consist of regions with strong temperature variations; in other words, the temperature flashes are the consequence of unmixed volumes of hot daytime air. Electrical heating of air by thunderstorm activity is also a possibility, but no evidence has been discovered for this.

Similar and Related Phenomena. Hot air blasts subsequent to lightning strokes. (GLL12)

Examples of Temperature Flashes

X1. September 20, 1911. Kimberley, South Africa. "It may interest you to know that at 9 p.m., on the 20th September, a thunder cloud approached from the west, bringing with it a squall of wind that caused the temperature to rise in a few minutes to 110°F. By 9.45 p.m. it had fallen again to 67°, which I expect was about the temperature before the squall. I do not think my thermometer responded quick enough to register the highest point, but it is safe to say it rose 40° in five minutes." (R3)

X2. November 4, 1911. Teneriffe, Canary Islands, Spain. A curious heat wave. "At 12:45 A.M. the thermometer at the municipal meteorological observatory registered 63 deg. F.; it then suddenly rose within two minutes to 79 deg. F., and after remaining at the latter temperature for a few minutes fell back suddenly to 63 deg. F. During this time the barograph showed marked oscillations of pressure. No satisfactory explanation of this occurrence has been offered." (R2)

X3. January 13, 1913. Rapid City, South Dakota. During the onset of a Chinook wind. The 8 A.M. temperature was -17° F; at 10 P.M., it was 47° F; an increase of 64° in 14 hours. (R4)

X4. June 30, 1921. Killarney, Manitoba, Canada. During a thunderstorm, at midnight, the temperature rose to 93° F. (R5)

X5. January 22, 1943. Rapid City, South Dakota. Chinook wind. Beginning at 7:32 A.M. the temperature rose 49° in two minutes---from -4° to 45° F. Frost appeared almost instantaneously on car windshields. (R4)

X6. June 20-21, 1960. Gretna, Manitoba, Canada. Thunderstorms along an advancing squall line. "After midnight had passed there occurred two sudden and most pronounced temperature rises at Gretna. The situation was described thus by the observer on duty:'We had two blasts of hot air from the south of approximately 15 minutes duration each; the first from 0025 to 0040 and the second from 0200 to 0215. The first reached a high of 96° and the second 97°. The wind changed direction several times before and after these periods and at times was calm.' There is no thermograph at Gretna station hence a pictorial record of the temperature variations is not available. The first temperature flash was a rise of 16 degrees---the temperature equalling the previous afternoon's maximum. The extent to which the temperature dropped between flashes is not known. The second flash exceeded the previous afternoon's maximum by one degree. The temperature then dropped sharply although again the amount of the sudden drop is unknown. " (R5)

X7. No dates given. Georgia and Kansas. "Several currents of intensely hot air have been experienced which appear to be similar to those which are common in Egypt, Persia, and some portions of India. A hot wind extending about 100 yards in width, lately passed through middle Georgia, and scorched up the cotton crops on a number of plantations. A hot wind also passed through a section of Kansas; it burned up the vegetation in its track and several persons fell victims to its poisonous blast. It lasted for a very short period, during which the thermometer stood at 120°---far above blood heat." (R1)

References

R1. "Hot Weather and Burning Winds," Scientific American, 3:106, 1860. (X7)
R2. "A Strange Heat Wave," Scientific American, 104:54, 1911. (X2)
R3. Parkinson, F. B.; "Great Heat in a Thunder Squall," Symons's Meteorological Magazine, 46:201, 1911. (X1)
R4. Hamenn, Roland R.; "The Remarkable Temperature Fluctuations in the Black Hills Region, January 1943," Monthly Weather Review, 71:29, 1943. (X3, X5)
R5. Lowe, A. B.; "Temperature Flashes at Gretna, Manitoba," Weatherwise, 16: 172, 1963. (X4, X5)

GWR2 Incendiary Phenomena

Description. Extensive firestorms that propagate at great speeds and leap wide natural barriers. Millions of square miles may be involved. As with lightning, earthquakes, and other powerful natural phenomena, many strange by-product anomalies may be generated.

Background. Here, we exclude fire whirlwinds and the milder firestorms common in the more severe forest fires, as well as human-induced conflagrations, such as the infamous Hamburg firestorm of World War II vintage. The defining example is the series of firestorms that raged through the North Central states in 1871.

Data Evaluation. Several books have been written on the 1871 Great Chicago Fire and the "Pestigo Horror" in Wisconsin, but we have found little on this great conflagration in the scientific literature examined so far. Rating: 2.

Anomaly Evaluation. Severe forest fires sometimes advance rapidly and leap wide natural barriers. The incendiary phenomena reported here are extreme and spectacular examples of ordinary firestorms, with attending "pranks" much like those associated with lightning, ball lightning, and earthquakes. The factor that might elevate this phenomenon from the curiosity level would be the definite involvement of electricity, as suggested in X1. Without this, the anomaly content of incendiary phenomena is low. Rating: 3.

Possible Explanations. Although the speed and barrier-leaping characteristics of vigorous firestorms are awe-inspiring, they can be reasonably well-understood by appealing to the strong winds induced by the conflagrations.

Similar and Related Phenomena. Whirlwinds of fire and smoke (GLD11).

Examples of Remarkable Incendiary Phenomena

X1. October 1871. North Central United States. "During the great fire that raged over northern Wisconsin in 1871, and which wiped out not only the prosperous village of Pestigo, but, in the aggregate of farmhouses, half a dozen villages like Pestigo, there were many evidences of electrical phenomena present. The flames were seen to possess that sudden rapidity of action which only electricity can impart. They would leap over wide spaces with the greatest rapidity, leaving many objects in the rear that one would suppose could not escape, and striking others beyond, and least exposed, in the most unaccountable manner. The details of that great disaster would disclose many curious and instructive facts. People were found dead without any apparent injury, though lying out in the open fields, and far from the burnt woods. Of course, it is popularly supposed that these suffocated in the superheated atmosphere. However that may be, one circumstance coming under my own observation proves conclusively the presence of electricity, and a very curious action of the subtle fluid, too. Shortly after the fire, the editor of the Green Bay Advocate exhibited a copper coin taken from the pocket of one of the victims found dead in the middle of a large clearing. The coin was fused, but no sign of injury whatever was discovered on the man's person." (R1) Describing "...the most disasterous fire period in our nation's history." "In Michigan, 2.5 million acres of timber lay charred, and perhaps 200 people died there. A complete tabulation was never made. In northeast Wisconsin, 1.25 million acres of timber was destroyed, and about 1,300 people died. In Chicago, where a detailed survey was made, 17,450 buildings were destroyed and over 200 people were killed. The major question is: With relatively light winds reported in much of the fire area the evening of the 8th, what caused the rapid, high-burning phenomena in most places? In northeast Wisconsin, the major fire run was finished by 0200, 9 October leaving a virgin forest in smoldering ruin. In some sections of Chicago, the rate of fire advance was clocked at 100 yards per minute, and there were reports that the whole horizon was one line of fire." (R2)

References

R1. Gibson, Geo.; "Electric Eccentricities," Science, 14:305, 1889. (X1)

R2. Haines, Donald A., and Kuehnast, Earl L.; "When the Midwest Burned," Weatherwise, 23:113, 1970. (X1)

GWS WEATHER AND ASTRONOMY

Key to Phenomena

GWS0 Introduction
GWS1 The Correlation of Lunar Phase and Terrestrial Weather
GWS2 The Correlation of Thunderstorms with Lunar Phase
GWS3 Thunderstorms Correlated with Solar Activity
GWS4 The Effects of Meteors on the Weather
GWS5 Correlations between Solar Activity and Weather
GWS6 The Influence of Lunar Phase on Atmospheric Ozone
GWS7 The Lunar Temperature Effect
GWS8 The Purported Effects of the Planets on the Weather
GWS9 Comets and the Weather

GWS0 Introduction

Folklore is emphatic that the moon affects rainfall, and a few scientists have long suspected a solar influence on terrestrial weather. Neither effect is overwhelming, whatever the mechanisms may be, assuming the phenomena really do exist. In fact, the effects are so small that most scientists have pooh-poohed both solar and lunar weather influences for many years. Nevertheless, an immense literature (merely sampled here) definitely favors some statistical relationship between weather and astronomy.

Recently, with spacecraft and rocket measurements, it has become apparent that solar activity can indeed affect the earth's atmosphere through sun-emitted streams of plasma. It is possible that these atmospheric changes may manifest themselves as weather modifications. This new creditability of sun-weather relationships removes some of them from the category of anomalies and thus outside the purview of this Catalog.

The moon's influence on weather, however, is still highly controversial. Favorable and unfavorable data abound. Two kinds of effects are recognized, each with a proposed physical mechanism: (1) Lunar modulation of rainfall through the gravitational or electrostatic modification of the influx of meteoric dust that serves as a source of precipitation nuclei; and (2) Lunar influence on thunderstorm and lightning incidence through the moon's interaction with the earth's magnetic tail that, in turn, modifies the number of electrically charged particles entering the atmosphere and the planet's electrical balance.

Solar and lunar effects on the weather are so muted that other astronomical bodies would be expected to be completely ineffectual. But to be thorough in the search for anomalies, we must ask whether the planets may not modify the weather, too. This effect may be indirect, for planetary position has frequently (and controversially) been correlated with solar activity, which itself may influence the earth's weather. Meteors and even comets must also come under scrutiny, for it is conceivable that sudden influxes of meteoric dust could trigger storms that would otherwise have never formed. In short, whatever orthodox science may say today, we should not close our minds to potential extraterrestrial modulation of our weather. Only a century ago, the foremost scientists declared with great certainty that the influence of the sun on terrestrial weather was nil and that all who thought otherwise were fools!

It would also be incorrect to be too generous with respect to those statistical correlations of phenomena that seem to have no obvious cause-and-effect relationships. As ESP proponents have found to their dismay, poor statistical techniques may suggest influences that simply do not exist. Similarly, improper statistical methods have long dogged the correlation of astronomy and terrestrial weather. So often the data employed are insufficient in quantity and quality. The mere comparison of graphs may be misleading if the data are not handled properly. Before science accepts astronomical influences on weather, the correlations must have high statistical significance. The existence of a recognized physical mechanism also makes scientific acceptance easier, although mechanisms and theories should not veto good data.

GWS1 The Correlation of Lunar Phase and Terrestrial Weather

Description. The statistical correlation of lunar phase with various terrestrial weather phenomena, such as precipitation, temperature, barometric pressure, wind, amount of sunshine, etc. The relationship between phases of the moon and precipitation has received considerable attention from folklore and science down the centuries.

Background. Weather lore has long insisted that rainfall is heavier around the time of the new moon. Scientists have both ridiculed and embraced this contention, presenting data both pro and con. Generally, in the past, scientists rejected the lunar connection because they perceived no physical mechanism whereby the moon could affect the earth's weather. In more recent times, some analyses of rainfall and the formation of tropical depressions have strongly supported a dependence upon lunar phase, at least in some areas of the globe. In addition, some possible physical mechanisms have been suggested, such as the moon's gravitational modulation of micrometeoroids entering the terrestrial atmosphere and therefore the number of nuclei reaching the lower atmosphere. The statistical picture, however, is far from clear; some analysts find a lunar effect and others do not. Possibly the situation is more complex than currently imagined, with erratic temporal and geographical factors involved. In passing, it should be recognized that scientists seem to have a natural antipathy for any modulation of terrestrial phenomena by celestial bodies---doubtless an attitude derived from an abhorence of astrology. The items selected for inclusion here, although a bit ancient and confused at first glance, follow the historical ups and downs and the emotional tides associated with this subject.

Data Evaluation. Numerous, seemingly sound, statistical analyses, which do not always come to the same conclusions. Therefore, the reality of the lunar effect on weather, if it exists at all, is not yet on firm scientific grounds. Rating: 2.

Anomaly Evaluation. If only gravitational forces and the moon's radiant energy are assumed to act on terrestrial weather, an acute anomaly exists, because these forces seem far too tiny to have any detectable effect. If, however, lunar modulation of incoming meteoric debris by gravitational or (possibly) electrostatic forces is allowed, the anomaly is not as serious, since a rational explanation using current concepts is within reach. Rating: 2.

Possible Explanations. A lunar effect on terrestrial weather may arise from the gravitational (or electrostatic) deflection of meteoric material away from the earth, reducing the number of nucleating particles in the terrestrial atmosphere. This mechanism may be erratic in time and terrestrial effects may vary geographically. Another possibility is that lunar tidal action upon the earth's atmosphere, although small, may trigger the formation of rain-making systems, especially tropical storms.

Similar and Related Phenomena. The list of suspected lunar influences on terrestrial phenomena is too long to reproduce here. A few of the more pertinent are: the moon's alleged dispersal of clouds (GWC11); thunderstorm frequency (GWP2); auroras (GLA18); and the possible correlation of planetary position with weather (GWP8). See Catalog indexes.

Examples of the Relation of the Moon to the Weather

X1. Statistical analysis. London and vicinity. The analysis of 100 lunar cycles showed that 47.60 inches of rain fell during days 3-7, but only 26.42 during days 17-22. These periods include the times during which the moon ascends and descends through the plane of the earth's orbit respectively. (R1)

X2. Statistical analysis. English wind data from 1840 to 1847. "...it seems that when the sun and the moon were in and near conjunction, the air was less frequently calm; the duration of the north wind with its east compounds was less frequent; the south wind with its west compounds was more frequent than when the sun and moon were in and near opposition. From this it would seem that the position of the moon in respect to the sun has exercised an influence on the direction of the wind in these years.... The influence of the moon on the temperature, and therefore density, of our local atmosphere, seems to be exercised chiefly through the medium of the winds. It is a secondary effect of her varied attraction, which continually tends to change the bearings of the different currents in the great body of the atmosphere, and we are successively involved in all their modifications. Not but that there are seasons, such as dry years after wet, or vice versa, in which the predominant solar influence is exerted to a degree which renders these lunar changes of small consequence, and when, in spite of the various aspects of our attendant planet, we are drenched with rain or parched with drought for months together." (R2) This obviously primitive and simplistic view of the weather and its possible relationship to astronomy is included here as a period piece. (WRC)

X3. Statistical analyses. Two quotes from a cogent survey of several studies of the possible influence of the moon upon weather. "In examining a question of this kind, preconceived opinions are very liable to influence the results obtained, except where absolute measurements (such as height of barometer, depth of rain, &c.,)are employed; therefore, though we have lunar maxims and theories more than 2000 years old, we leave them unnoticed, for the present at any rate, and with them all but instrumented records, for an observer predisposed to a belief in the influence of lunar phases will consider himself warranted in classing as a change in weather a variation which one holding opposite views would consider far too trivial to constitute a 'change.'..... Thomas Forster, in his Atmospheric Phenomena, says, 'It is certain that the place of the moon has much influence on the weather. That changes of weather oftener take place about the full and new of the moon and about the quadratures than at other times, is really a fact founded on long observation, and is quite conformable to what we actually know, respecting the moon's influence on the tides.'" (R3) The latter statement is by a 'believer' in lunar influence and, in the literature of this period (1868) is literally overwhelmed by condescending comments by 'unbelievers.' (WRC)

X4. Statistical analysis. "Although it seems certain that the meteorological influence of the moon's phases is very slight, I am prepared to prove---as the result of a long series of investigations---that the declination influence of our satellite is very great. One extremely important secret of lunar influence on the weather is in the principle of uniformity---uniform movements of the moon causing fine weather, and extremes of temperature both in summer and winter; while irregularity of lunar movements (a condition far more common than uniformity) appears to cause the unsettled weather that usually prevails in this climate. Another extremely important secret of lunar influence on the weather is the distance of the sun from our meridian, or the meridian of the antipodes at the time the moon crosses the equator; for the nearer the sun is to noon or midnight at the time of this lunar phenomenon, the greater the influence of the moon in raising or depressing our temperature according to the season of the year..... In conclusion, I may observe that until the year 1860 I entirely disbelieved in the moon's influence on the weather, and invariably ridiculed the theories of lunar meteorologists; but certain phenomena that occurred in that year induced me to examine the subject with some care, and a seven year's investigation of this branch of predictive meteorology has so far converted me, that I have become a lunarist in spite of my prejudices, and almost against my will." (R4) Such reluctant conversions are very common in anomaly research. (WRC)

X5. Review of statistical studies. The lunar effect on weather is essentially nil. The "influence of the planets" is the sole cause of the weather and its variations. See GWS8 for more on this theory, which smacks even more of astrology. (R5)

X6. General observation. Lunar radiation and tidal pull are too small to affect terrestrial weather. (R6)

X7. A review of weather lore involving lunar phases. The author generally ridicules any suggestions that the moon has an effect on terrestrial weather because no known physical force is powerful enough to have an effect. It is akin to astrology and superstition. One example of lunar weather lore is the so-called "Saturday moon," which insists that when a new moon falls on a Saturday wet and unsettled weather invariably follows. (R7)

X8. Statistical analysis. Bethlehem, Pennsylvania. "The observations of rainfall, taken at Bethlehem, Pa., by Mr. F.E. Luckenbach, during 1881-1890, are selected as as the basis of a brief discussion, and they are believed to be free from the objections above noted. The amount of rainfall in each year was obtained for the day of new moon and for each of the three days preceding and following, and also for the other quarters. For each year a curve of rainfall throughout a lunar month of 28 days could then be drawn, and these curves were combined in various ways to endeavor to ascertain the features common to all of them. The following conclusions were derived: First, the new moon is liable to be followed by an increase in rainfall; second, the full moon is liable to be followed by a decrease in rainfall; third, the wettest period is generally at and preceding the full moon; and, fourth, the driest period is generally at and preceding the first quarter. These conclusions are, in general, most plainly marked in the years of least rainfall." This study was followed by one by Hazen, using Philadelphia data (not far from Bethlehem), in which it was concluded that there is little if any lunar effect on rainfall. (R8)

X9. Statistical analysis. East coast rainfall data. "While both New York and New Haven show an increase at the time of new moon, yet the figures at Boston show a very remarkable maximum at the day of new moon, and an equally remarkable minimum on the seventeenth day of the lunation, or two days after full moon. I do not set forth these figures as an absolute proof that the moon does influence rainfall in the neighborhood of Boston, but it looks as though there must be something in it." (R9) This study is by the same H. A. Hazen mentioned in X8, where he concluded no effect existed. (WRC)

X10. Statistical analysis. Greenwich, England. Data on rainfall from 1889-1900 show maximum wetness near the time of the new moon with a minimum shortly before the last quarter. (R10, R11)

X11. General observation. Scientific men of the present day (1902) see no reason whatsoever for imputing to our satellite even the slightest change in the weather. It is all superstition. (R12)

X12. Statistical analysis. Barometer data from Greenwich (1889-1904) and Ben Nevis (1884-1892) tend to substantiate the notion from folklore that the full moon brings fine weather. Referring to his graphs of average values, "These two curves seem to tell much the same tale; <u>few</u> days of low barometer about (just after) full and new moon, <u>many</u> such days about (just after) the quarters. Thus, so far as the summer half in those twenty-one years is concerned, the popular belief would appear to be vindicated." (R13)

X13. Review of weather folklore. A typical condescending discussion of popular weather lore, which emphasizes the fact that the moon's heat and gravitational force cannot possibly affect terrestrial weather. All lunar weather lore is thus merely superstition. (R14)

X14. Statistical analysis. Glasgow Observatory's hourly barometric pressure reading from 1868-1912. A strong diurnal variation was shown to exist at Glasgow in contrast to other sites where the variation is semidiurnal. No satisfactory explanation exists for this anomaly. (R15)

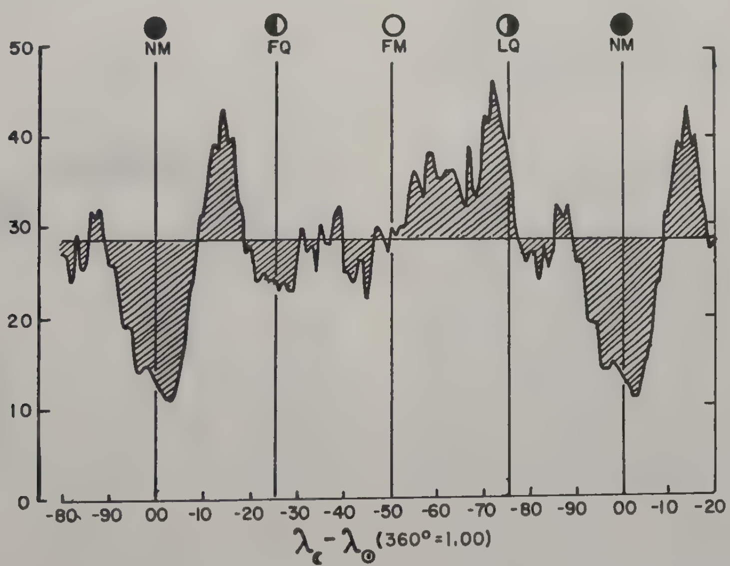
X15. Statistical analysis. 41 lunar cycles from Shangugu, Ruanda. A 27-day cycle in precipitation was confirmed. (R16)

X16. Statistical analysis. United States. "<u>Abstract</u>. Precipitation activity over broad areas appears to be closely associated with the monthly lunisolar cycle. Indexes of precipitation in the continental United States over a continuous 50-year period, and 91-year daily histories of individual stations, reveal that heavy rains occur most frequently in the first and third weeks of the synodical month." (R17, R18, R20)

X17. Statistical analysis. New Zealand. "The influence of the moon in producing tides in the upper atmosphere and the appearance of a lunar component in daily temperature in certain parts of the world are comparatively well known, but the effects are extremely small and difficult to detect. The possibility of a large effect on rainfall first came to our notice in 1960 with the chance reading of a paper by Rodes. Rodes showed what appeared to be a connection between rainfall in the Spanish peninsula and both the declination and the position of apogee and perigee of lunar motion. An investigation was therefore made of the rainfall data in our possession, and it was apparent that it contained a strong lunar component. However, it was also clear that this was connected with the phase of the moon rather than with the parameters used by Rodes. At this point a decision was taken not to publish the data immediately, but to reserve it for a later date. The reason for doing so was that our work on singularities in rainfall was still being treated with disbelief in meteorological circles, and to suggest a lunar effect on rainfall would simply not have met with the right response. We were not surprised therefore when we received a communication from Bradley, Woodbury, and Brier indicating a pronounced lunar effect in U.S. rainfall. The effect is matched by similar effects in the southern hemisphere. A curve showing the heaviest falls of the month for 50 stations in New Zealand, plotted in the same way as the U.S. data are plotted, is given in Fig. 1. It shows variations of a magnitude comparable with those in the U.S. and closely related in phase." (R18, R20)

X18. General observation. In response to X16 and X17, widespread precipitation is frequently associated with hurricanes, which are in turn probably influenced by the moon's tidal action during their formative period. (R19)

X19. Statistical analysis. Indiana. "About 10 years ago I was working on weekly rainfall totals and their effect on corn yields for 15 counties in central Indiana. From folklore I had learned that precipitation was more likely to occur during the week following a new moon and the week following a full moon than at other times, so I proceeded to test this idea. To my amazement I found some agreement. After applying several statistical treatments to the data I produced a short manuscript as well as an outline suggesting some further investigations along



Ten-unit moving totals of the heaviest falls of the month, for fifty New Zealand stations, 1901–1925 (X17) this line. I need not relate here the review comments or the outcome of the proposed investigations. In short, the whole matter was dropped." (R21)

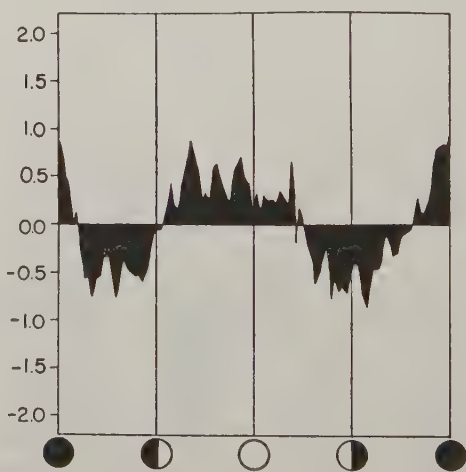
X20. Statistical analysis. After presenting a series of graphs showing ice nucleus concentrations in the southern hemisphere, E.K. Bigg observed: "The result is as surprising as the rainfall discoveries. In every case, there are two distinct maxima in the lunar month, about the first and third quarters of the Moon, and the total range is three or four to one, even with the smoothing used. There appears to be a slight shift with latitude, the peaks occurring later nearer the equator.... It is apparent, therefore, that, in addition to the effect on rainfall, the Moon has a large effect on the freezing nucleus count. It is well known that the effect of the Moon on other meteorological variables like barometric pressure, surface temperature, is extremely small; the implication is strong, therefore, that the effect on the freezing nucleus count does not originate in the lower atmosphere. However, a possible mechanism is that the Moon in some way controls the incoming meteor rate and so affects the number of freezing nuclei falling into the lower atmosphere." (R22, R23)

X21. Survey paper. A review of the data presented in R18, R19, and R22, plus a discussion of the theory that the moon and meteoric particles are electrically charged. The moon would thus deflect like-charged meteoric particles away from the earth during part of the lunar cycle, consequently affecting rainfall. (R23)

X22. Statistical analysis. United States. "A cycle of 14.765 days, one-half of the lunar synodic month, can be demonstrated in the precipitation data for the United States for the period 1871-1961. Numerous rigorous statistical tests show that the association is real and an estimate is obtained of the magnitude of the lunar effect. Geographical, seasonal and other sources of variation in the effect are suggested by the data. No other periodicity with comparable amplitude was found by the statistical analysis, but there is evidence that the lunar synodic cycle interacts with the nodical cycle." (R24)

X23. Statistical analysis. Atlantic hurricanes. "An American research worker reports an apparent connection between the phases of the Moon and the genesis of hurricanes. Donald A. Bradley, of the College of Engineering, New York University, took the records of 269 Atlantic hurricanes between 1899 and 1958. He noted the positions of the Moon on dates when they 'matured', in other words, when they first developed winds of force 12 on the meteorologist's Beaufort scale. His figures show that 90 of the hurricanes matured within 46 hours of either New Moon or Full Moon. That is 20 or more than one would expect if there was no connection between the weather and the lunar cycle and is, in statisticians' terms, highly significant." (R25)

X24. Statistical analysis. United States. "Abstract. An analysis of daily observations of sunshine taken in the central and northeastern United States during the spring and summer indicates the presence of a lunar synodical period. Less than average sunshine is observed during the first and third weeks of the lunar month and more than average sunshine is observed during the second and fourth weeks. Although this lunar period is significant by most statistical tests, the possibility that its appearance is due to a combination of the smoothing procedure and the temporal and spatial correlation among the observations cannot be completely ignored." (R26) See GWC11 for data on the possible dispersal of clouds by the moon. (WRC)



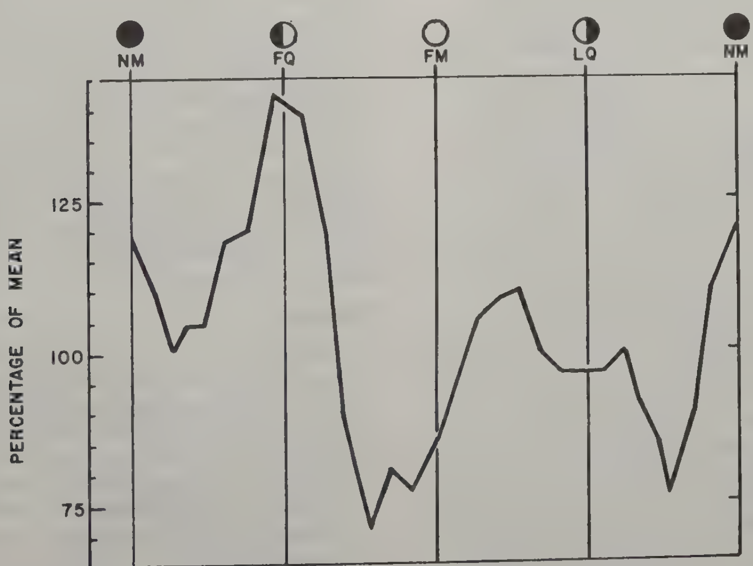
Sunshine trends versus lunar phase (X24)

X25. Statistical analysis. Sydney, Australia. "Summary. Daily rainfalls of an inch or more for 100 years at one station have been classified according to the phase of the moon with which they occurred. An apparent significant correlation between two 50-year smoothed sub-series is found to have been induced by the filtering process of taking sums. When the effects of the ensuing serial dependence are eliminated, the results are not indicative of a significant overall relationship between the series of rainfall and moon phase." (R27) This seems to contradict other data from the southern hemisphere; viz., X17. (WRC)

X26. Statistical analysis. South Africa. Abstract. "Rain and hail data from five meteorological stations on the plateau of South Africa have been examined for a dependence on lunar phase. Different distributions with respect to lunar phase were found for summer and winter data. Statistical analyses of the winter descriptions, which appeared to be more significant than those for the summer, suggested that winter rain is modulated by the moon in such a manner that there is one component with the same period as the luni-solar cycle which depends on station latitude and another having three peaks which is latitude independent. This three-peak component seems to operate throughout the year." (R28)

X27. Statistical analysis. Indian Ocean. "The data for this investigation were taken from a publication issued by the Indian Meteorological Department which catalogues depressions formed in the Indian Seas, and gives the date on which the depression stage was reached and its corresponding position. The phase of the Moon for each day is given in terms of synodic decimals (hundredths of a synodic month) in the ephemeris by Carpenter. The synodic decimal corresponding to each date was taken from that source and the frequency of formation of depressions corresponding to each synodic decimal was found. Successive ten-unit moving totals of the frequencies were then made, and of the hundred such totals thirty were chosen to correspond to the thirty days of the lunar month. For purposes of comparison the frequencies were expressed as percentages of the mean. Fig. 1 shows the curve, prepared in this manner, of depressions which formed in the latitude band 19°N - 22°N in the Bay of Bengal and Arabian Sea during the period 1877-1960.... There is a strong indication that the heavy falls (of rain) were associated with the depressions. The tidal influence on the formation of depressions is also indicated, as in both curves the 14.765 day wave accounts for 48.1 of the total variance and is the largest component." (R29)

X28. Statistical analysis. Worldwide study. "Abstract. To examine the hypothesis of a worldwide relation between some lunar periods and tropical disturbances, we collected first-formation dates for 1,013 hurricanes



Frequency of atmospheric depressions, 1877-1960, in the Bay of Bengal and Arabian Sea (X27) and typhoons and 2,418 tropical storms in both hemispheres. Using the superposed epoch method, we found a lunar synodic cycle (29.53 days) in North Atlantic hurricane and northwest Pacific typhoon formation dates. About 20 percent more hurricanes and typhoons formed near new and full moon than near the quarters during a 78-yr period, showing a stronger peak at new moon than at full moon. Statistically, the existence of an effect dependent on the lunar synodic cycle is supported by a significance level of 7 percent on unsmoothed data from an analysis of variance for categorical data. During the same 78 yr, North Atlantic tropical storms that did not later become hurricanes tended to form near the lunar quarters. Several other categories of tropical storms were not clearly related to the synodical month. Severe tropical storms in two portions of the Indian Ocean over 75 yr formed more often several days after syzygy and quadrature, but this and other severe tropical storm results lack definition, probably due to poor data. Theoretical calculations of the lunar-solar gravitational tide showed that the anomalistic lunar cycle affects only the amplitude and not the timing of extrema. No marked anomalistic or latitude components in hurricane formation were found." (R30)

X29. Statistical analysis. New South Wales, Australia. "An examination of the weather of one hundred years of New South Wales has shown that certain features recur every nineteen years; we have seen that the droughts of history---the great and conspicuous droughts I mean---all drop into this same cycle; both those that happened before the birth of Christ, and those that have occurred in our era; for instance, Elija's drought happened in B. C. 908, that is, 2736 before our great drought in 1828, and the interval is 19 x 144. Great hurricanes, the great frosts of history, all the red rains, and all the droughts that history records, with a very few exceptions, likewise are included in this cycle, and the level of great lakes in Palestine, South America, and New South Wales are subject to the same mysterious influence that controls our weather.

As my investigation proceeded, the weight of evidence gradually converged upon the moon as the exciting cause. I have never had any sympathy with the theory of lunar influence upon weather, and received, rather against my will, the evidence that presented itself; still the logic of facts left no alternative but to accept the moon as prime motor. There has not been time to complete this investigation, and when finished it must form another paper. Meantime I may say that, so far, the comparison of the moon's position in relation to the sun and earth and droughts shows that when the eclipses congregate about the equinoxes, that is, in March and September, they do so in the years which give us great droughts. Further, that when the eclipses accumulate in February and March, that is, at the vernal equinox and the month before it, and September, the autumnal equinox, and the month before it, August, we have the more intense and relatively shorter droughts of the second series, with heat, gales, and hurricanes; on the other hand, when they accumulate about March and April, that is, the month of equinox, and the one following, and about September, the month of equinox, and October following it, we have droughts of the first series that are less severe, but much longer than the droughts of the second series. I have spoken chiefly of droughts; though, so far as our own history is concerned, it would have served the purpose just as well if I had taken up the periodicity of wet years, but outside Australia it would have been very difficult to get the necessary data, for history has much more to say about the horrors of drought than the abundance of wet seasons." (R31)

X30. General observations. The "20-year" droughts of the American Midwest may actually be controlled by the lunar 18-year cycle, for the data fit the 18-19 year cycle just as well as they do the 21-22 year double sunspot cycle. (R32) "It now looks very much as if western US droughts over the past four centuries have been modulated at periods of 22 and 18.6 years---corresponding to dominant solar and lunar cycles. This explanation of why the solar and drought cycles do not always march in step greatly strengthens the case for some solar variability influences on western US droughts." (R33)

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GWS2 The Correlation of Thunderstorms with Lunar Phase

Description. The supposed tendency of thunderstorms to be more frequent around the time of the new moon. This phenomenon is not clear-cut and is, of course, embedded in the lunar rainfall effect (GWS1).

Data Evaluation. As with GWS1, the statistical analyses of available data are in conflict, even though based upon many years of observations. Different geographical areas seem to encounter different moon-thunderstorm relationships, suggesting a complex relationship or perhaps none at all. Rating: 3.

Anomaly Evaluation. The magnitude of the anomaly here depends upon whether current scientific theories of thunderstorm development can countenance a lunar effect. Since thunderstorm frequency seems to be related to solar activity (GWS3) and the state of the terrestrial-atmospheric electrical circuit, any lunar disturbance of these relationships might carry through and affect thunderstorm frequency. The moon does, in fact, pass through the earth's magnetic tail and neutral sheet, providing a mechanism that could explain any positive correlation between lunar phase and thunderstorm frequency. Rating: 3.

Possible Explanations. The moon's passage through the terrestrial magnetosphere may modulate the number of charged particles reaching the earth from the sun, thus disturbing the terrestrial-atmospheric electrical current and thunderstorm formation.

Similar and Related Phenomena. The correlation of thunderstorm frequency with solar activity (GWS3); the relationship between thunderstorms and cosmic rays (GLL16).

Examples of Thunderstorms Correlated with Lunar Phase

X1. Statistical analysis. Greenwich, England. Thunderstorm frequency is maximum near the new moon and minimum between the full moon and the last quarter. (R1)

X2. Statistical analysis. Providence, Rhode Island. Comparing American data with that of X1, thunderstorm frequency is maximum between new moon and the first quarter, minimum from the first quarter to full moon. The Providence data were so different from those from Greenwich that the author ventured that the effect must be quite different at Greenwich or that the moon really has nothing to do with thunderstorm frequency. (R2)

X3. Statistical analysis. Bridport, England. More thunderstorms were recorded near the full moon than the new moon, in contradiction of X1 (Greenwich) observations. (R3)

X4. Statistical analysis. Germany. "To most of us who have been brought up to consider that it is rank heresy to suggest that the Moon has any influence on the weather, it is a little startling to look up the amount and quality of the data that have been collected upon this subject, especially in Germany. The point which seems to have been particularly investigated is the relation of the phases of the Moon to thunderstorms." A large table of German data is omitted here. "The number of observations here collected seems to be large enough to enable us to draw definite conclusions, without fear that further records will revise or neutralize them. From these observations we conclude that there really is a greater number of thunderstorms during the first half of the lunar month than during the last half, also that the liability to storms is greatest between new moon and the first quarter, and least between full moon and last quarter. Also we may add that while theoretically very interesting, the difference is not large enough to be of any practical consequence. Thus it would seem that besides the tides and certain magnetic disturbances, there is a third influence that we must in future attribute to the Moon." (R4, R5) Note that W. H. Pickering, the author of this article, held many unconventional views with regard to the moon. (WRC)

X5. Statistical analysis. Northern Italy. A review of the studies of Schiaparelli, using 1827-1864 data, arrives at a conclusion exactly the reverse of Pickering (X4). (R6)

X6. Statistical analysis. United States. "Abstract. Using the superposed-epoch method, we statistically analyzed thunderstorm frequencies for 108 stations in eastern and central United States in relation to lunar positions for the years 1930-1933 and 1942-1965. The results are as follows. With full moon as key day, a peak in thunderstorm frequency occurs for 1953-1963 two days after full moon, the mean being 2.7σ above average level. This mean frequency is 4.8σ above the mean when computed only for the full moons as key days that have a declination of 17° north or more. We suggest that these increases near full moon may be related to the earth's magnetic tail and the neutral sheet." (R7)

X7. General observation. "Many facts relative to the cause of storms are still unknown; no reason can be given for the fact that on the shores of the North Sea, of the Gulf of Bengal, and many other regions bordering the ocean, thunder-storms almost always commence at the hour of high tide." (R8) This is the only allusion we have found to this remarkable phenomenon. (WRC)

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GWS3 Thunderstorms Correlated with Solar Activity

Description. The increase of thunderstorm frequency and/or lightning incidence during short-term solar flares and long-term, more general increases of solar activity. This relationship can be seen in the historical analysis of thunderstorm and lightning incidence and also in direct measurements of the electrical properties of the atmosphere, such as electrical conductivity.

Background. It is well-established that aurora frequency increases with solar activity. A few investigators have maintained that a reciprocal relation holds between auroras and thunderstorms, both being in effect competing mechanisms for carrying electrical currents in the upper atmosphere. In other words, when auroras wax, thunderstorms wane.

Data Evaluation. Modern measurements of atmospheric electrical properties via balloon and rocket are quite convincing. However, the statistical analyses of thunderstorm/lightning incidence versus solar activity are sometimes conflicting and may include a confusing latitude effect. Rating: 3.

Anomaly Evaluation. A reasonable physical mechanism explains how the sun can modulate thunderstorm/lightning activity, although many details remain to be elucidated. Rating: 3.

Possible Explanations. Charged particles and ionizing radiation emitted by the sun change the electrical properties of the terrestrial atmosphere such that lightning incidence is enhanced.

Similar and Related Phenomena. Solar activity and terrestrial weather (GWS5); lunar phase correlated with thunderstorms (GWS2); lightning and cosmic-ray coincidence (GLL16); the possible reciprocal relation between auroras and lightning (GLA9).

Examples of Thunderstorms Correlated with Solar Activity

X1. Statistical analysis. Kremsmunster, Germany. Thunderstorm observations made between 1764 and 1869. "In years when the temperature is high and the sun's surface relatively free from spots, thunderstorms are abundant. Since, moreover, the maxima of the sun-spots coincide with the greatest intensity of auroral displays, it follows that both groups of phenomena, thunderstorms and auroras, to a certain extent supplement each other so that years of frequent storms correspond to those auroras, and vice versa. He (W. von Bezold) observes that such a connection between sun-spots and storms does not by any means sanction the supposition of a direct electrical interaction between the earth and sun, but may be simply a consequence of a degree of insolation dependent upon the sun-spots." (R1, R2) Today, space experiments do find a direct electrical connection between earth and sun---the solar wind. (WRC)

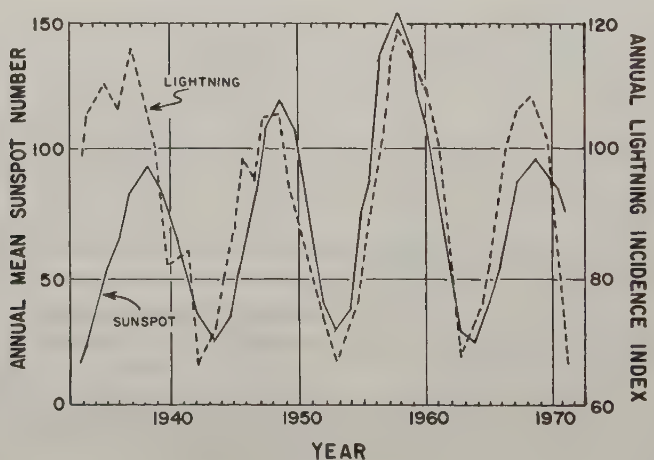
X2. General observations. Conclusions from a long study. "As a result of the extended series of observations described, it has been found in general that whenever groups of faculae, with or without dark spots, are appearing by rotation or are bursting forth upon the eastward side of the sun there is an immediate increase in thunderstorms in the lower latitudes, and probably of auroras in the higher latitudes. If, however, the aurora becomes visible nearer the equator at such times, there is an immediate, though perhaps temporary, decrease in thunder-storms, as though the aurora had taken their place. In short, the aurora and thunder-storms appear to have a common origin, and in certain localities, at least, a reciprocal relation to each other. Instances have been noted also in which an aurora in the United States has been coincident with unusual electrical storms in Europe, and vice versa." (R3, R16)

X3. Statistical analysis. Geneva, Switzerland, and Berlin, Germany. Data from 1850-1891. The maximum in thunderstorm frequency occurs when sunspots are fewest. (R4)

X4. Statistical analysis. Siberia, Russia. Data from 1888-1924. Thunderstorm frequency peaks when sunspot number peaks. (R5) This is, of course, just the opposite of X3. Does it indicate that the correlation is dependent upon geography? (WRC)

X5. Statistical analysis. England. Lightning incidence records from 1930-1973. "There is a clear-cut cyclic variation in the thunderstorm incidence which varies with an 11-year cycle, in phase with the solar activity, and with an amplitude of ±30 per cent of the mean---a real enough effect indeed!" (R6, R7)

X6. General observations. Correlative evidence accumulating since 1926 suggests that there must be some physical coupling mechanism between solar activity and thunderstorm occurrence in middle to high latitudes. Such a link can be provided by alteration of



Lightning incidence compared with the sunspot number (X5) atmospheric electric parameters through the combined influence of high-energy solar protons and decreased cosmic ray intensities, both of which are associated with active solar events. The protons produce excess ionization near and above 20 km, while the Forbush decrease causes a lowered conductivity and enhanced fair-weather atmospheric electric field below that altitude. Consequent effects ultimately lead to a charge distribution similar to that found in thunderclouds, and then other cloud physics processes take over to generate the intense electric fields required for lightning discharge." (R8, R9)

X7. General observations. Thunderstorm frequency in some regions is positively correlated with sunspot number. The triggering mechanisms proposed are essentially those of X6. (R10)

X8. General observations. A detailed scenario in which cosmic rays initiate and control the development of lightning. (R11)

X9, August 1972. Worldwide phenomenon. "A direct observation of solar flare modification of thunderstorm driven electric fields is presented. During the August 1972 solar flares the vertical atmospheric electric field in the stratosphere decreased by at least an order of magnitude. The electric field decrease can be explained by a model in which the electrical conductivity is enhanced by ionization due to the solar protons. A global index of VLF whistlers shows a large increase at the time of the solar proton maximum, thereby indicating a possible worldwide high latitude enhancement in thunderstorm activity. Models of thunderstorm triggering mechanisms which are supported by these data will be discussed." (R12, R13)

X10. November 1979. Antarctica. "Last November, a sequence of balloons was launched at the same time as a major solar flare. At first, no changes in the weak air-to-ground currents were recorded but subsequent balloons showed a major rise over a period of two days, eventually saturating the electrosondes between 25 and 30 km height. This implies an increase in current of more than 70 per cent. The surge was followed by a gradual return to a normal weak current---clearly bursts of energetic particles from the flare enhanced the weak current. This could raise the frequency of lightning flashes in thunderstorms and increase their rain-producing activity. The Sun could be an external driving force on the severity of the 1500 or so thunderstorms which are active on Earth at any one time. The global circuit theory must now be modified to accommodate solar as well as thunderstorm effects." (R14)

X11. General observation. Electrification of the terrestrial atmosphere is strongly affected by cosmic rays. There also seems to be a thundercloud electrical mechanism that is sensitive to atmospheric electrification, so that thunderstorms (and lightning) are influenced by cosmic rays. (R15) Solar activity produces some of the cosmic rays incident upon the earth. (WRC)

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GWS4 The Effects of Meteors on the Weather

Description. The correlation of weather phenomena with meteor showers, especially the apparent peaking of rainfall approximately 30 days after prominent meteor showers.

Data Evaluation. Several analyses of rainfall data indicate strong positive correlations with well-known meteor showers, but the correlation of rainfall with visual meteor rates is weak. Rating: 2.

Anomaly Evaluation. Although meteoric particles are acceptable nucleating agents and could enhance rainfall, the rainfall peaks should theoretically be spread out in time, but instead they are sharp. This puzzling detail is probably well within the explanatory capabilities of current theories. Rating: 3.

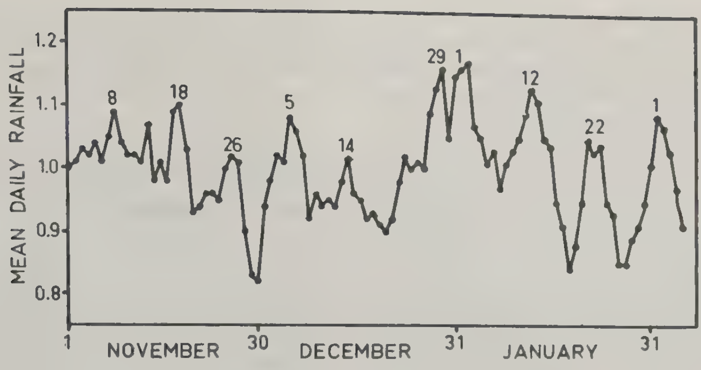
Possible Explanations. Meteoric particles serve as precipitation nuclei.

Similar and Related Phenomena. The correlation of lunar phase with terrestrial weather (GWS1), which may depend upon lunar modulation of meteor flux.

Examples of the Effects of Meteors on the Weather

X1. General observations. After a discussion of Erman's theory that the so-called "cold days" occurring in February, April, and May are due to the partial screens of the earth by meteor streams. "I have been in the habit of regarding Erman's theory as probably erroneous altogether, though noting that it would have to be accepted if any evidence were obtained showing the whole Earth, and not Europe only, to undergo these periodical refrigerations. Mr. Russell, Government Observer at Sydney, has recently published evidence which seems to go a great way towards proving that this really is the case. In Australia and in America, it would seem, the average temperature of the cold days is lower than it should be if the seasonal rise from January to July were steadily maintained. He also quotes evidence obtained in Galileo's time, which shows that the same peculiarity was recognized in Europe more than two centuries and a half ago. That sometimes the fall of temperature must have been very marked is shown by the existence of popular proverbial expressions, doggerel verses, and so forth, in reference to these cold spells." (R1) Little credence is given to this theory today. (WRC)

X2. Statistical analysis. "Examination of rainfall figures for a large number of stations shows that there is a tendency for more rain to fall on certain calendar dates than on others. There is a close correspondence between the dates of the rainfall maxima in both the northern and southern hemispheres, and this is difficult to explain on a climatological basis. The effect might, however, be due to an extraterrestrial influence. The rainfall peaks occur approximately 30 days after prominent meteor showers, and it is suggested that they are due to the nucleating effect of meteoric dust falling into cloud systems in the lower atmosphere, the time difference being accounted for by the rate of fall of the material through the atmosphere. The hypothesis is tested for a particular meteor stream, the Bielids, which is known to have a 6.5-year period. The rainfall 30 days after the meteor shower is found to have a similar period. Furthermore, the phase of the rainfall periodicity is almost identical with that of the meteor shower. The data examined are confined to the month of January, and it



World rainfall as affected by meteor showers (the numbers above the peaks indicate specific meteor showers) (X2)

is proposed to extend the investigation to other months in future papers." (R2)

X3. General review of the meteor hypothesis put forward in X2. Studies subsequent to X2 have established fairly firmly the reality of world-wide, annually recurring singularities in rainfall, which seem to require an extraterrestrial mechanism. The striking feature of the meteor hypothesis is the 30-day delay between the meteor shower and the rainfall peak. The peak is explained in terms of the time of fall of the meteoric particles; but the different rates of fall of the different sized particles should smear out the rainfall peak. On the contrary, the rainfall peaks remain sharp. (R3)

X4. Statistical analysis. "Abstract. Recently published data on the average hourly rates of visual meteors for each night of the year have been compared with the average daily precipitation of a number of stations for a 50-year period. No significant relation was found between meteor showers and precipitation although there was a very slight suggestion of a maximum in precipitation around 30 days after peak meteor activity.: (R4)

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R1. Proctor, Richard A.; "Meteors and Meteorology," Royal Astronomical Society, Monthly Notices, 43:110, 1883. (X1)
R2. Bowen, E.G.; "The Relation between Rainfall and Meteor Showers," Journal of Meteorology, 13:142, 1956. (X2)
R3. Fletcher, N.H.; "Freezing Nuclei, Meteors, and Rainfall," Science, 134:361, 1961. (X3)
R4. Brier, Glenn W.; "Visual Meteoric Activity and Rainfall Singularities," Journal of the Atmospheric Sciences, 19:56, 1962. (X4)

GWS5 Correlations between Solar Activity and Weather

Description. The correlation in time of various weather-related parameters (rainfall, temperature, droughts, etc.) with solar activity. In addition to the possible short-term, direct influence of solar flares on weather, the literature abounds with a wide variety of longer-term statistical correlations of terrestrial weather and the single- and double-sunspot cycles. The main cyclic periods claimed are about 27 days, 11 years, 18.6 years, and 22 years, but there are many more. Most of the correlations are weak and have been hotly debated. Furthermore, the physical mechanisms underpinning the proposed correlations are not well understood. To make things worse, the statistical methods employed sometimes introduce false periodicities.

Background. Ever since the sunspot cycle was discovered, it has been correlated with various natural phenomena as well as human activities. Great are the extremes of opinion expressed, from almost blind faith in the sun-weather connection (disdainfully termed "sunspottery" a century ago) to outright ridicule and the strongest declarations that no physical mechanism is possible. With such heated controversy, it is not surprising that an extensive literature exists---one that is merely sampled here.

Data Evaluation. The data are often very convincing for specific time periods and limited geographical areas, but students of the subject have often erred in their selection and statistical treatment of observations. The situation is further clouded by high noise levels in the data and the superposition of several periodicities, including lunar modulation. Rating: 2.

Anomaly Evaluation. Scientists have proposed many different physical mechanisms that might link solar activity with terrestrial weather (see below). The abundance of potential explanations infers that we have only a weak anomaly here. It seems to be more a matter of selecting the correct mechanism(s) from among several reasonable possibilities. Rating: 3.

Possible Explanations. Variations in direct insolation; the passages of solar sector boundaries, solar wind periodicities; electrical disturbances of the upper atmosphere by solar cosmic rays.

Similar and Related Phenomena. Possible effects of solar activity are pervasive throughout the entire Catalog of Anomalies; consult the indexes of the various volumes. In this volume; the correlation of weather with lunar phase (GWS1), planetary position (GWS8), and the possible effect of solar activity on thunderstorm frequency (GWS3).

Examples of Correlations between Solar Activity and Weather

X1. 1859. Worldwide phenomenon. "M. Rudolph Wolf of Berne has shown that those years remarkable for abundance of solar spots have also been more than commonly rich in aurorae boreales. The greal auroral display at the commencement of September 1859, occurring about the time for the return of sun-spot maximum, and which seems to have been visible over the greater portion of both hemispheres, appears to have been the precursor of a great meteorological disturbance: in England and Northern Europe more than an average amount of cold, wind, and rain have prevailed ever since; in North America and India more than an average amount of drought and heat. The opinions of philosophers differ respecting the influence of a paucity or an abundance of solar spots upon the temperature and seasons of the earth; the probability is, there is simply a general disturbance, arising from increase of (solar) magnetic influence, which may produce greater heat and dryness in one part of the globe, and more cold and rain in other parts." (R1) These general thoughts about the sun-weather effect can hardly be made much more specific today, even after well over a century of correlations and more sophisticated research. See the recent skeptical opinions expressed in later entries. (WRC)

X2. Statistical analysis. A presentation of tables of rainfall data from 18 stations at various localities around the world for different spans of time. "The above Table comprises the results of all the rainfall-tables I can find containing a maximum- and a minimum-period. Now we see that, in the maximum-sunspot periods of three years each, the rainfall at the eighteen stations was 395.85 inches greater than in the minimum-sunspot periods of three years each, and, which is still more striking, that the excess is on the side of the maximum-periods at fifteen out of the eighteen stations." (R2) At this point in history worldwide weather data were almost nonexistent, and the studies were necessarily crude by modern standards. (WRC)

X3. General observation. Comments on an article in the London Times linking the Indian famines (droughts) with the sunspot cycle. In essence, the whole idea is "absurd and ridiculous." (R3) Similar disdain is still expressed today.

X4. Statistical analysis. Worldwide data. "The idea that years of maximum sunspots are also years of abundant harvests, originally suggested by Sir William Herschel, has lately been brought into prominence through the labours of Mr. Meldrum, of the Mauritius, whose latest paper on the subject, published in the monthly notices of the Mauritius Meteorological Society, gives figures based on the rainfall statistics of a large number of stations in different parts of the world. These seem to show that the average rainfall of the globe is subject to a regular fluctuation through periods of about 11 years, and that at its maximum, which occurs about a year later than the epoch of maximum sunspots, the mean fall is about 15 per cent. greater than at its minimum, which precedes that of minimum sunspots by one or two years." (R4, R5) Meldrum's careful analysis was an early benchmark in sun-weather analysis. (WRC)

X5. Historical review. Sir William Herschel's 1801 papers on a possible connection between the solar cycle and our weather are resurrected. Long quotations from Herschel's papers reveal that he proposed that variations in the quantity of solar heat reaching the earth might contribute to the cyclic variations in weather. (R5)

X6. General observations. A rambling dissertation on how the sunspot cycle might affect both terrestrial weather and human activities. Written in memory of Stanley Jevons, an early and prolific proponent of "sunspottery." The only pertinent data are the following observations, which are fairly typical of 1883: "Of late years the rainfall of the British Islands has become an object of special study and investigation, with amateurs as well as paid officials. Mr. J. J. Symons, of the Meteorological Society, who has recently published statistics gathered from numerous quarters, takes occasion to refer to the existing caprice of heaping ridicule on the astronomical precedent of referring the phenomena of Nature to fixed and pre-determinate laws. He calls attention to the circumstance that the wettest years in England of late prove to have been 1836, 1841, 1848, 1852, and 1860, and that the first, third, and fifth of these years fall into a twelve-year period. He further calls attention to the circumstance that the driest years in England of late prove to have been 1826, 1834, 1844, 1854-5, 1858, and 1864, and that the second, third, fourth, and seventh of these fall into a ten-year period. Now it is at once manifest that the twelve-year period of wet years he here indicates coincides with the solar cycles, and that the dates only differ by two years on the whole from the epochs of most sun-spots assigned by Prof. Wolf. The ten-year period of dry years, which alternates with these wet years, which then consequently correspond to the minima years of solar spots, from which in three of the instances they differ but one year." (R6)

X7. Statistical analyses. Following a short history of sunspot-weather correlations, a statement by Arthur Schuster, "There can be no longer any doubt that during about four sun-spot periods (1810 to 1860) a most remarkable similarity (existed) between the curves representing sun-spot frequency and the curves of nearly every meteorological element which is related to temperature. This is not, in my opinion, a matter open to discussion: it is a fact. But it is equally certain that during the thirty or forty years previously to that time so such relationship existed, and that since 1860 the connection has again in some instances become less distinct." "In so far as regards the temperature of the globe, these conclusions are almost identical with those enunciated by Prof. Koppen, in a paper published in the April-May Heft of the Austrian Meteorological Zeitschrift for 1881, and indeed the apparent discrepancy of the temperature and sun-spot curves after 1858 had been indicated by him in his former paper, published eight years earlier. But this discrepancy did not set in simultaneously in different parts of the globe, nor has it been such as to obliterate all trace of the sun-spot cycle in the temperature curves. During about four cycles previous to 1858, the temperature of the tropical zone rose and fell with somewhat striking regularity inversely as the spotted surface increased or diminished, so that the highest temperatures approximately coincided with the sun-spot minima, and the lowest with their maxima." (R7) Almost a century ago the complexity of the sun-weather relationship was appreciated, as correlations waxed and waned. (WRC)

X8. Statistical analysis. Scotland. An unbroken series of rainfall data from 1800 shows good correlation with the sunspot cycle. (R8)

X9. Statistical analysis. Jamaican rainfall data from 1870-1910. "Excepting the rainfall minimum in 1875 the minima for rainfall follow solar maximum and minimum by one and a half or two years. The rainfall maximum between the minimum are more irregular." (R9) Spelling is as in the original article.

X10. Statistical analyses. Christiania, Norway, and Greenwich, England. Mean temperatures for both locations show strong correlation with the sunspot cycle. (R10)

X11. 1911. Opinion ventured that the unusual diminution of ultraviolet radiation from the sun caused an extremely dry summer in Europe and a very wet winter in South America. Fewer condensation nuclei thought to be the underlying reason. (R11)

X12. Statistical analysis. Montezuma, Chile, and Washington, DC. "Regular observations of the sun's radiation are made from a station at Mount Montezume, Chile, a mountain 9,000 feet high in the Atacama desert, and these show that the sun does not always radiate the same amount of heat. Instead, it varies from day to day, even after allowances are made for the effect of the earth's atmosphere. In a study of these variations since January, 1924, Dr. (C. G.) Abbot has found 98 cases of rapid increase of the radiation of heat and 91 of decrease, in each case the change taking about four or five days. Dr. Abbot has studied the temperature variations at Washington at the times of each of these increases and decreases. Taking the temperature just before the beginning of the solar change as normal, he finds that as the solar radiation varies, the temperature also changes, and that the change in temperature continues until at least four days after the maximum or minimum of radiation. A change in the radiation of eight-tenths of a per cent is accompanied by a temperature change of about five degrees. At times when increase of radiation is accompanied by an increase in temperature, a decrease of radiation is generally accompanied by a decrease in temperature. This is taken by Dr. Abbot as rather conclusive proof that the changes are not mere coincidences. A curious feature of the results is that an increase of radiation is not always accompanied by an increase in temperature, or vice versa." (R12)

X13. Statistical analysis. Egypt. Flood and low stages of the Nile. "A remarkable series of yearly records of high and low levels of the Nile at the Roda gage, Cairo, from 622 A. D. to 1470 has been published by Prince Omar Toussoun. The original records are in cubits and dated in Mohammedan years. One list from 640 to 1451 was published in 1923. Another list from 622 to 1470 in metric equivalents and corrected to the modern calendar was published in 1925. These two lists differ slightly and after careful examination of the graphs of both lists it was decided to use the first one, making a few corrections to readings, evidently misprints, by comparison with the later list and supplying a number of missing years. Five-year means have been computed for both flood and low stages. The 11-year period. The influence of the 11-year solar period on the flood stages is shown by an excessive predominance in the 5-year means of the two intervals. over the normal frequency for random numbers, 50 percent vs. 40 percent. As for the minima there is a relative excess of the four- and five-intervals, indicating a 20- to 25-year period." Longer periods evident in the analysis are 37, 83, and 300 years. (R13)

X14. Statistical analysis. Severe winters in Europe. "Records of unusual meteorological events are abundant in European literature. The occurrence of severe winters has been very consistently recorded, and Bruckner, by means of this material, was enabled to extend his 35-year cycle, deduced from modern instrumental records, back to the year 1000..... To extend the series backward, I have used Hennig's catalog which is very complete. Easton's list was also consulted. Employing the method used by Bruckner, the total number of severe winters in the 20-year interval centered on every fifth year were counted and the numbers from 340 to 1030 together with his numbers from 1030 to 1775 are shown graphically.... The 37-year period. Maxima and minima are quite definitely apparent except in a few instances where data are lacking." There are indications of 83- and 300-year periods, too. (R13)

X15. Statistical analysis. Wheat prices in England. "In a paper published after his "Klimaschwankungen", Bruckner concluded from an examination of wheat prices in western Europe for 200 years that high prices occur during or shortly after periods of maximum rainfall. Beveridge computed yearly index numbers of wheat prices in England from 1500 to 1870 by expressing them as a percentage of 35-year moving averages. His periodogram of wheat prices shows a period of considerable amplitude at 35.5 years." (R13)

X16. Statistical analysis. Tree growth in Arizona and California. Measurements of tree growth rings in California (sequoias) and Arizona (yellow pine) demonstrated the existence of climatic periods of 37, 83, and 300 years. (R13)

X17. Statistical analysis. Levels of the Great African Lakes, 1900-1930. "In 'The Hydrology of Lake Tanganyika'.... C. Gillman gives us for the first time a picture of the fluctuations in level of Lake Tanganyika. To it he adds C. E. P. Brooks's curves of Victoria and Albert and F. Dixey's of Nyasa, brought up to date, and the curve of sunspot numbers. Excepting the abnormality in Nyasa dating from the closing of the Shire outlet (1924), the trends of the lake fluctuations are similar and the correlation with the sunspot curve close. Mr. Gillman, however, cautions against too facile an interpretation. He points out that in 1929 when Victoria, Albert, and Tanganyika were at a distinct low, sunspot numbers soared, and when in 1930-1931 the numbers declined, there was a rise in lake level. Before 1902 also Victoria seems to have 'reacted incorrectly.' While we are still far from a solution of the problem, much is to be hoped from simultaneous study of all four lakes, with their broad regional similarity and their individual differences." (R14)

X18. Statistical analysis. Greenwich, England. The sunspot cycle is barely seen in 100 years (1764-1863) of mean temperature data from Greenwich. (R15)

X19. Study of post-Pleistocene climates. Abstract. "The most conspicuous climatic aberration of the past two millennia was the temperature decline and glacial advance of the A.D. 1550 to 1900 period. This temperature decline has been correlated with an interval of lower solar activity and there is evidence from both the post-Pleistocene glacial record and from oxygen-18 analysis that such an interval has recurred at cyclic periods of around 2400 to 2600 years." (R16)

X20. Statistical analysis. "...two investigators, Walter Orr Roberts, president of the University Corporation for Atmospheric Research, and Roger H. Olson, an Environmental Data Service research meteorologist with NOAA, appear to have confirmed a statistical relationship between the behavior of certain atmospheric features over the Gulf of Alaska and geomagnetic storms. Apparently, low-pressure troughs found at the 300-millibar level tend to intensify or deepen, in response to storms in the geomagnetic field, which are marked by displays of auroras. Trough development in that geographic area has an important influence on North America's weather. About one-third of the Gulf of Alaska'a low pressure systems eventually move into the central United States. Those preceded by northern lights penetrate about 200 miles farther south, and bring cooler weather with them. Although not all large troughs are triggered by northern lights and not all auroras are followed by trough development, the probability of the trough's intensifying seems to be approximately doubled by the occurrence of a magnetic storm.....Still, the results of the entire study are perplexing to the scientists because there is no proven physical explanation for them. Regarding mechanisms to explain the findings, they speculate that the geomagnetic control may come about through trapping of the black-body radiation normally lost to space over the relatively warm Pacific during these winter months. This could be the result of cirrus cloud formation by phenomena associated with the geomagnetic disturbance. Other alternative explanations may involve changes in ozone content, and possibly increased thunderstorm activity." (R17)

X21. Statistical analysis. Tree ring data from the western United States from 1700 to date. "No evidence was found for any influence of the 11-year cycle, but there is a very strong match between periods of drought and the 22-year double sunspot cycle (the Hale magnetic cycle). The area covered by drought tended to reach a maximum about 3 years after every other minimum in the 11-year cycle, with the most recent well-documented drought being that of the mid-1950s, correlating with the sunspot minimum of 1954. (The drought of the 1970s seems to be correlating with the sunspot minimum of 1976.) The time between droughts averaged 20.4 years, whereas the average double sunspot cycle is 22 years. The reason for this apparent discrepancy is that the best coherence between drought area and sunspots comes during times when the sunspot maxima are high. It is during such periods that the time between successive maxima and minima tends to be smaller. When the sunspot numbers are small, the period of the cycle increases, and the correlation with drought area becomes weak." (R18) These data hardly support those of X16. (WRC)

X22. Review paper. Several studies now confirm a solar influence on atmospheric circulation at the 300 millibar level and below. The passage of solar-sector boundaries seem to affect the vorticity of the atmosphere. (R19)

X23. Review of a lecture by J.W. King of the Appleton Laboratory. "...the new work from the Appleton Laboratory concentrates instead on much shorter term influences, associated with the roughly 27.5 d rotation period of the Sun. The 'signature' of this rotation shows up clearly in such meteorological parameters as the height of the 500 mbar pressure level in the atmosphere, as well as influencing ionospheric properties. In some danger of numbing his audience with overkill at times, King hammered home the reality of these links with a wealth of data, the most intriguing of which showed clear geographical variations of the magnitude and even sign of the atmospheric changes produced by the Sun. Small wonder, then, that global averages over long periods show much less indication of any solar influence on weather!....The Appleton team have now found that not only does a solar flare produce a disturbance of the atmosphere, commencing some four days after the flare, as shown by the work of Olson and others, but that the atmospheric disturbance is repeated at 32 and 60 days as well, one and two solar rotations later. In at least one case, an effect on the atmosphere is also found at -24 d, that is one solar rotation before the flare became apparent. So a specific region of the Sun which is involved in some disturbance can affect specific regions of the Earth's atmosphere over a period of 2-3 months---and, equally, the effects of solar activity which are disturbing the atmosphere today must be the integrated effects of several such past disturbances, which suggests that we should not find any simple relation between what the Sun is doing today and what the atmosphere does tomorrow." (R20) But see the following entry. (WRC)

X24. Summary of the Ohio State University Sun-Weather Conference, July 24-28, 1978. Many of the presentations were skeptical of the reality of any sun-weather effects, as typified by the following: "The chief skeptic by far, was A. B. Pittock, temporarily of the University of Arizona. He cast strong doubts on many published reports of correlations between weather and the various solar cycles (such as 27 days, 11 years and 27 years). The 27-day cycle was also attacked by others, who pointed out that it is difficult to distinguish between 27-day solar and lunar effects." (R21)

X25. Review paper. Abstract. "During the past century over 1,000 articles have been published claiming or refuting a correlation between some aspect of solar activity and some feature of terrestrial weather or climate. Nevertheless, the sense of progress that should attend such an outpouring of 'results' has been absent for most of this period. The problem all along has been to separate a suspected Sun-weather signal from the characteristically noisy background of both systems. The present decade may be witnessing the first evidence of progress in this field. Three independent investigations have revealed what seem to be well resolved Sun-weather signals, although it is still too early to have unreserved confidence in all cases. The three correlations are between terrestrial climate and Maunder Minimum-type solar activity variations, a regional drought cycle and the 22-yr solar magnetic cycle, and winter hemisphere atmospheric circulation and passages by the Earth of solar sector boundaries in the solar wind. The apparent emergence of clear Sun-weather signals stimulated numerous searches for underlying causal links." (R22)

X26. General observations. "There is a general consensus among meteorologists and climatologists that for reasons unknown to them, quiet Sun produces severe winters whereas the appearance of colder sunspots on the solar disk produces warmer winters on Earth. Severe winters appear to correlate well with the solar cycle. There is also evidence of enhanced cloud cover and thunderstorm activity, and anomalous rainfall patterns which follow solar flare and auroral activities. To explain some of the features, physical mechanisms based on changes in the character of solar particulate and electromagnetic radiation and their interactions with the Earth's atmospheric, hydrospheric and magnetic environment were proposed in an earlier paper. This hypothesis is further advanced to explain the anomalous rainfall pattern, i.e. increased rainfall at 55°N and reduced rainfall at 35°N latitudes following solar flare activity. The explanation involves interaction between descending streams of charged particles with global circulations in the presence of Earth's magnetic dipolar field whose axis does not coincide with Earth's North-South geographic axis." (R23)

X27. Statistical analysis. "In a recent paper, Nastrom and Belmont have found an interesting correlation between the 11-year sunspot cycle and the upper troposphere and lower stratosphere. They have thoroughly and carefully analysed data from the Northern Hemisphere for a period covering 1949 to 1973, i.e., just over two solar cycles. Their results indicate that during the winters of this period, the average position and, to a lesser extent, the strength of the jet stream and the intensity of features such as the Siberian upper level trough, have a strong correlation with solar activity. It is not so much the statistical significance of the results which is surprising, but rather that in certain areas of the hemisphere 50% of the interannual variance is explained." (R24)

X28. General observation. "Despite almost 180 years of study, we have little evidence to support the hypothesis that solar activity significantly affects the troposphere. There is a plethora of statistical correlations, but many of these have been produced by over-filtering and selecting the data and the remainder have nearly all failed where the data sets have been extended in time." (R24) This comment of course applies to correlations with lunar phase. (WRC)

X29. Statistical analysis. After noting that climatic oscillations with a period of about 20 years have been detected in U.S. midwest drought records, dendrochronological data, and sea surface temperature anomalies, the authors present their studies of Greenland ice core records. "To gain more insight into such 20-yr oscillations, we have examined characteristic oscillations in Greenland ice core oxygen isotope records. The results show that the strongest spectral peak occurs at a period of 20 $\pm$ 0.5 yr with a statistically significant amplitude. This period is essentially the same as that found in eastern North American winter temperatures. Moreover this 20-yr oscillation is found to be coherent in phase with the dominant variation in the Sun's motion about the centre of mass of the Solar System. This motion has been hypothesised to be closely linked with sunspots. On the basis of these observations we speculate here that a 20-yr oscillation may be a more fundamental solar and/or climatic oscillation than the nominal 22-yr cycle often mentioned." (R25)

X30. Statistical analysis. Abstract. "July Palmer Drought Severity Indices (PDSI) have been reconstructed for the Hudson Valley region of New York State from the annual ring-width variations of local old trees. Using additional, subsequently developed tree-ring chronologies, we have developed a new July drought reconstruction that extends back to 1694. Variance spectra of the new PDSI series reveal statistically significant quasi-periodicities of 11.4 and 26 yr." (R26) The 11.4-year period is, of course, close to that of the sunspot cycle, while the 26-year period correlates with the soli-lunar tidal period. (WRC)

X31. Statistical analysis. Leona M. Libby and colleagues at the University of California at Los Angeles have found periods of 10.4 and 6.7 years in sequoia tree rings dating from 2,000 years ago, using isotopic measurements as indicators of temperature. There was, however, no trace of the 21-year solar magnetic cycle. (R27)

X32. Statistical analysis. Studies of North American temperature records by Robert Currie, Goddard Space Flight Center, reveal the 11-year sunspot cycle to be present in temperature data east of the Rockies and north of about 35°N. The winds in this region are part of the circumpolar vortex that helps determine the climate of the earth. (R27)

X33. Statistical analysis. "In 1980, Minze Stuiver of the University of Washington compared ten different records of climate from around the world with the varying carbon-14 content of tree rings over the last 1000 years; carbon-14 is an indirect measure of changing solar activity. Stuiver failed to find a significant correlation between solar activity and any of the climate records." (R28) Obviously, conflicting results, such as this and X30-31, make for a muddled picture and undermine confidence in the reality of solar influence. (WRC)

X34. Statistical analysis. Records of drought from the American west, added to newly obtained data from the Great Plains, show the 22-year solar magnetic cycle very strongly---at a high level of significance. (R28)

X35. Statistical analyses. Examination of drought records from the American west (X34) seem to show that in addition to the the 22-year solar magnetic cycle there exists a 18.6-year effect of lunar tidal action. These cycles are superimposed on one another, making a most confusing situation. (R29)

X36. Statistical analysis. 1784-1869. A positive correlation was found between the sunspot number are: March-April rainfall in France; arrivals of birds in France; thickness of annual growth rings in sequoias; commodity prices in Great Britain and Ireland; and auroral frequency. (R30)

X37. Statistical analysis. A review of studies of tree-ring growth cycles. Concluding statements. "In a general way it is safe to say that the sunspot cycle and its double and triple value are very general. The double value has persisted in Arizona for five hundred years and in some north European localities for the century and a half covered by our tree groups. The triple period, essentially Bruckner's cycle, has operated in Arizona for the last two hundred years and in Norway for four hundred at least. A hundred-year cycle is very prominent throughout the three thousand years of sequoia records and also in the five hundred years of yellow pine. It is still uncertain whether the eleven-year cycle can be judged by the variations in its double value, which, from the absences of certain interfering periods, is more easily traced through long periods. But a very in-complete review of the sequoia record suggests that from 1300 B. C. to well after 1000 B. C. the eleven-year cycle was well developed; then it slowly decreased. From 300 B. C. on it was increasing and was very conspicuous during the first two centuries of our era. Then it decreased, and from 400 to 650 A. D. was only occasionally evident. From 650 to 850 or 900 it seems fairly continuous. Then it appears only occasionally until about 1250, when it again becomes fairly continuous, except for the changes in the seventeenth century above noted." (R31)

X38. Statistical analysis, 1871-1973. New York, New York. The January mean temperatures show a strong 20-year cycle. (R32)

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GWS6 The Influence of Lunar Phase on Atmospheric Ozone

Description. The apparent increase in the amount of atmospheric ozone at the vernal equinox about the first and third lunar quarters, with a corresponding descrease at the same phases at the autumnal equinox.

Data Evaluation. A single study with data from only two stations. Rating: 3.

Anomaly Evaluation. The mechanism by which the moon's position could influence the production of atmospheric ozone is a mystery, and there are few obvious candidates considering our present knowledge of geophysics and astronomy. Rating: 2.

Possible Explanations. Since the lunar effect appears when the earth crosses the plane of the ecliptic, one suspects a lunar shielding of the earth from some ozone-producing mechanism confined to that plane.

Similar and Related Phenomena. Lunar phase correlated with thunderstorms (GWS2); lunar phase correlated with rainfall (GWS1).

Examples of the Influence of Lunar Phase on Atmospheric Ozone

X1. Statistical analysis. "Abstract. Evidence is presented for a lunar effect on the amount of atmospheric ozone at Arosa in Switzerland and Canberra in Australia. The amount of ozone increases at the vernal equinox about the first and third lunar quarters and decreases at the same lunar phases at the autumnal equinox. There is no effect at midwinter or midsummer. The explanation of this lunar effect is unknown, and further investigation is needed." (R1)

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GWS7 The Lunar Temperature Effect

Description. The apparent correlation of sharp falls in daily temperature minima with the full moon.

Data Evaluation. Some striking correlations have been published in proof of this phenomenon, but so have analyses illustrating negligible or zero effect. On top of this confusion, the statistical techniques employed have been faulted. Rating: 3.

Anomaly Evaluation. Although the tidal action of the moon on the earth's atmosphere is a reasonable driving force, no widely accepted cooling mechanism based upon it has been proposed. Rating: 2.

Possible Explanations. The moon's tidal effect on the atmosphere causes adiabatic expansion and consequent cooling.

Similar and Related Phenomena. The moon's effects on the weather (GWS1), thunderstorms (GWS2), atmospheric ozone (GWS6), cloud cover (GWC11).

Examples of the Lunar Temperature Effect

X1. Statistical analysis. A period piece. "The author commenced by saying that, although the question of lunar influence on the atmosphere of our planet was very generally considered as set at rest by the investigations of M. Arago, yet he felt very confident that he was in a position to prove the law he was now about to announce without fear of contradiction. He had reduced and thrown into the form of tables and of curves 280 lunations, with the corresponding mean temperatures; and the laws at which he had arrived were, first, between the first and second octant the temperature immediately after the first quarter, both on the average, and also, with rare exceptions, in each individual lunation is higher than the temperature shortly before the first quarter; secondly, and more particularly, the mean temperature of the annual means of the second day after the first quarter (or the tenth day of the moon's age) is always higher than that of the third day before the first quarter (or the fifth day of the lunation). The tables and curves accompanied the essay, which illustrated these laws at great length." (R1, R2) R1 is a summary of R2, which is more difficult to comprehend, if that is possible! (WRC)

X2. Statistical analysis. North Wales, 1947-1951. Daily records of mimimum temperatures have been kept during many years by observatories and meteorological stations, but such records have appeared in the form of long columns of numbers, among which an abnormality might remain unnoticed, unless special search were made for it. In a previous publication from similar lists of minimum night temperatures taken in North Wales, monthly graphs were drawn, with temperatures as ordinates and days of the month as abscissae, for each of the years 1947, 1948, and 1949. When temperature curves were drawn, there appeared a regular fall in the minimum night temperature at or near the date of full moon at each lunation during the three years.... The temperature fall was sometimes gradual, its incidence being as much as a week before and its lowest point occurring on the date of full moon, or generally within 48 hr of it. Mostly, however, the curve of the fall was more sudden, being limited to 2 or 3 days." The author also acquired temperature records from other stations around the globe, which confirmed the lunar effect detected in the data from Wales. (R3) In a second paper, the author noted that the fall of minimum temperature near the full moon was less in the summer than in winter; a phenomenon paralleling oceanic low tides. He then postulated that the temperature effect, too, was tidally induced and due, perhaps, to the adiabatic expansion of the atmosphere under lunar influence. (R4)

X3. Statistical analysis. Syracuse, New York. Data from 1931-1946. "The results were striking. During the summer period there is a gradual increase in temperature from just prior to the new moon until a week after the full moon, followed by a rapid fall of 4° within the next week. The lowest point is reached two days prior to the new moon. The situation during the winter period is not quite as clear-cut. From just prior to the new moon until the first quarter, an irregular but marked rise in temperature takes place, over a range of approximately 4°. Between the first quarter and the full moon, a slump occurs, with a fairly distinctive high ending it immediately following the full moon. This slump is a crude inverse of the rise during the same interval of the summer period. Another marked slump follows, between the full moon high and the new moon, reaching its lowest point two days prior to the new moon. The slump is essentially the inverse of the rise that occurs during the summer period following the full moon." (R5)

X4. Statistical analysis. Yakima, Washington, 1949-1952. Daily minimum temperatures for 45 lunations. "In each case, counting in the occasions when two equal falls occurred, one at full moon and one at some other time, the greatest fall came at full moon on only 20 occasions out of 45. Although this is more than would be expected, since the 6-day period around full moon is only about one fifth of the total time, it is far from being the rule. Of the 14 occasions of greatest fall at full moon during the past 3 1/2 years, 3 came in 1949, 8 in 1950, 3 in 1951, and none so far in 1952. Thus the distribution is erratic." (R5)

X5. Statistical analysis. Riverside, California; data from 1942-1951. The analysis showed no significant different in minimum temperature fall between the full-moon interval and any other interval. (R5)

X6. Statistical analysis. Ottawa, Regina, and Edmonton, Canada. Minimum temperature data from 1950 and 1951 . "On the basis of the data analyzed here there is no indication of any tendency for the greatest consecutive fall of minimum temperatures within 48 hr of the full moon to be significantly greater than falls for any other phase of the moon." (R5)

X7. Statistical analyses. Several Canadian weather stations; data from 1947. This study suggested that the fall of temperature near a full moon is greater than at other times but not overwhelmingly so. (R5)

X8. Statistical analysis. Boston, Massachusetts. Temperature records for 78 years. No significant relationship between minimum temperatures and lunar phase found. But the critiques of other attempts to establish this phenomenon are more pertinent than the Boston results. "Unfortunately the data and methods employed by Henstock (X2) appear to invalidate his findings from the start. The acceptance of his results even as a working hypothesis for further research is not warranted. His data, at most 5 years at one station and single years at others, are absolutely insufficient in any attempt to evaluate such effects as lunar influences. It should be pointed out that, for example, the establishment of the magnitude of the lunar tide in the atmospheric pressure---which can be shown to exist theoretically---necessitated the use of about 350,000 observations even in tropical latitudes, where the other random effects upon the pressure are small! When dealing with minimum temperatures we must contend with large random effects introduced by air mass changes, variations of insolation, and other factors, which result in a large standard deviation of such temperature values." The author goes on to note that the lunar period is almost the same as that of solar rotation as well as one of the possible, stable, free oscillations of the atmosphere. (R5) The above criticisms should be applied to all GWS phenomena, including some of the analyses presented above that show no lunar effects on minimum temperatures. (WRC)

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R2. Harrison, J. Park; "Evidences of Lunar Influence on Temperature," Report of the British Association, 1857, part 1, p. 248. (X1)

R3. Henstock, Herbert; "Minimum Night Temperatures at or near Full Moon," Science, 116:257, 1952. (X2)

R4. Henstock, Herbert; "Fall in Minimum Night Temperature at or near Full Moon: Part II," Science, 117:302, 1953. (X2)

R5. Edwards, Robert L., et al; "Night Temperature and the Moon," Science, 117: 305, 1953. (X3-X8)

GWS8 The Purported Effects of the Planets on the Weather

Description. The statistical correlation of any of the various terrestrial weather phenomena, such as mean temperatures and rainfall, with the planets, particularly the positions of the major planets.

Background. While scientists can now hypothesize some physical mechanisms by which the sun can directly affect the earth's weather, the slowly wandering planets have no known physical ties of significant magnitude with the earth. In addition, planetary influences are redolent of astrology---science's ancient enemy. Astrological trappings are to be avoided at all costs. Still, solar activity has been correlated with planetary position in respectable journals (ASO). Planetary position, therefore, may correlate with terrestrial weather as a secondary effect. Of course, the means by which the planets modulate solar activity, if they do, is unknown, for gravitational tides seem far too weak.

Data Evaluation. Few scientists have dared to investigate this possible anomaly; so the data are sparse and of poor quality. Rating: 3.

Anomaly Evaluation. Modulation of the earth's weather by the planets, even if indirectly accomplished via solar activity, would be an anomaly of the first rank, because none of the recognized forces involved; viz., gravity; is strong enough. Rating: 1.

Possible Explanations. Terrestrial weather modification by the planets could be an indirect result of their effect on solar activity; but this is just an appeal to another anomaly.

Similar and Related Phenomena. The correlation of solar activity (sunspot number) with planetary positions (ASO), terrestrial radio propagation and the effect of planetary position (GER), and, to be complete, all of astrology, a subject not explicitly included in this catalog.

Examples of the Purported Effects of the Planets upon the Weather

X1. Unsystematic observations. A curious theory with strong astrological overtones. The author believes that the positions of the planets affect terrestrial temperatures and provides numerous examples from various localities to substantiate his claim. Of more value here is his own statement of philosophy. "You will thus see, Mr. Editor, that by the aid of the planetary philosophy I have enunciated that I am not only able to show a remarkable similarity of phenomena, but to trace each occurrence up through the several years, solving the difficulty of their occurrence at times varying with the motion of the planets in the zodiac, and thus demonstrating them to be caused by planetary attraction, and not by solar influence, the same phenomena marking ten other positions, in which the planets are totally independent of solar combination. (R1, R2, R5) We do not record the author's supposed examples of success because, with the world's varied weather at any given moment, one can always find a temperature change that will "prove" the influence of any planet. (WRC)

X2. Unsystematic observations. "To the many popular and scientific opinions as to the cause of rain I would beg to add one that I have not yet seen described in any book---viz., the influence of the moon when passing Venus, Jupiter, and other planets. It may only be a peculiarity of this 'station', but I have noticed over and over again that rain falls when the moon at night is two or three degrees to the west of Venus or Jupiter, when these planets are in the west, or when the moon in the morning is two or three degrees to the east of a planet situated in the east." (R3)

X3. General observation and speculations about the possible influence of the planets on the sun and consequent solar effects on terrestrial weather. "While it is true that a conjunction of the great planets produces no marked disturbance, it is believed by high authority that sun events have slight influence on the Sun through media and in ways, not yet understood. When either Jupiter, Venus or Mercury passes nearest the Sun in their respective orbits, the solar surface seems to show greater activity than usual, though no marked changes have been observed, nor could they be naturally expected from such a cause. On the other hand, it is well established that intense solar activity produces magnetic storms in the earth's atmosphere, some of which have been singularly powerful in recent years. Whatever influence the perihelion passage of certain planets may have in agitating the solar surface, it is plain that the earth must share in the results. If these be very small, or too delicate to measure by known methods, it should not be forgotten that they may be constant and extend over considerable period of time, and that conjunctions, or near groupings, of the major planets are favorable times for the exercise of these unknown cosmic forces, whatever they may be in kind or extent.... Recent interesting coincidences invite astronomers to this study. The year 1883, very probably marks the maximum of a passing sun-spot period. In some locations, certainly, last year will be long remembered for its cyclones and tornadoes. In a group of nine Western States, the Signal Service reports the occurrence of over forty of these dreadful storms within the space of four months." (R4)

X4. Statistical analysis. "The nineteenth century discarded horoscopy of the weather with the other appurtenances of astrology. Dr. Z. Kamerling would have us reverse this verdict and employ the motions of the planets as the basis of long-range forecasting. His thesis is that widespread periodicities must have a cosmic origin, and sunspots having failed, there remain only the planets. Accordingly he investigates periodicities of the length of the 'synodic rotations,' that is, the intervals between the dates at which the various planets are nearest to the earth. (It appears that the theoretical basis of this planetary connexion has been given in a previous paper; one wonders what it can possibly be.) These give him in years: Venus 1.60, Mars 2.13, Jupiter 1.09, Saturn 1.035, Uranus 1.018. As material he has forty years of average monthly rainfall over east Java and over west Java, twenty years' rainfall at Pernambuco, and temperatures at Winnipeg, Konigsberg, and Zwanenburg. The method is to write down the monthly data in sets corresponding with the 'synodic year,' so that, for example, all the months of perigee come in the same vertical column, and to plot the smoothed means of these columns. From his graphs, Dr. Kamerling concludes that there are real periodicities corresponding with the synodic periods of each planet, giving maxima generally near perigee and secondary maxima near apogee.

Such a result would be of considerable importance if substantiated, as explaining the origin of a number of periodicities of a little more than a year which have been suggested from time to time, but unfortunately the author has not done all he might to prove his case. He does not express his periodicities as Fourier series, nor does he attempt to determine their exact length. The original data are given only for the east Java rainfall, and here inspection shows that the annual variation has not been completely eliminated. They show, in fact, a residual mean annual variation with a range of 16 mm., which is of the same order as the ranges of the planetary periods. The normal used apparently covers the first thirty-three years, so that the error is entirely concentrated in the last seven years, and falsifies any apparent periods up to 1.1 year. The supposed period for Uranus (1 year 4 days), with a range of 18 mm. is almost entirely due to this residual annual variation. The author does not give the standard deviations of the data which he uses, so that no test of reality can be made. The Venus period in east Java, which has by far the largest range of any, may be taken as a test case. The amplitude of the corresponding Fourier series is found to be 9 mm., and the standard deviation of the original 480 values is 63 mm. The amplitude is therefore 4.5 times the expectancy on a chance basis, and the period seems to be real. Its exact length, however, turns out to be 1.58 year, while the 'synodic year' of Venus is 1.60 year; this means that the maximum phase shifts by about 120° in forty calendar years, which seems too great, and the interpretation suggested is that there is a periodicity in the east Java rainfall which happens nearly, but not quite, to coincide with the Venus synodic year." (R6)

X5. Statistical analysis. "If sunspots influence the course of the weather on the earth (and presumably also on other planets) the planets in their turn influence the formation of sunspots, and thus indirectly their own weather events. A statistical study of correlations between the positions of the three planets nearest the sun---Mercury, Venus, and earth---and the numbers and positions of sunspots has been made by Dr. Fernando Sanford of Palo Alto. Dr. Sanford has reported his results through the Smithsonian Institution, whose secretary, Dr. Charles G. Abbot, has been a leading investigator into the question of a possible connection between sunspots and weather." (R7)

X6. Statistical analysis. "A 1980 paper, "The Effect of Planet Movement on Changes in Climate,' by Ren Zhenqiu of the Peking Meteorological Institute and Liu Zhilin of the astronomy department of the Chinese Science Institute, has just arrived in the U.S. Through charts and graphs, it tracks 19 past planetary alignments and finds (according to a translation privately commissioned by this newspaper) that 'for the past 3,000 years, China's temperatures have changed in accordance with the seasons of the planetary alignments.'

Most alignments came at intervals of 178.7 years, some more frequently. The most recent was Jan. 24, 1844. Eight alignments came in the summer half of the year, and 'all of those eight periods were relatively warm ones,' the paper says. Nine alignments came in the winter half with the planets close enough to be inside an arc of 70 degrees (as they will be this year), and in each case temperatures were below normal except for one in 631 A.D., when weather data in China was unavailable. Two other alignments came in winter, but with wide arcs of 84 and 100 degrees; temperatures were mixed but on the warm side. Two previous alignments, in 1415 B.C. and 1595 B.C. were in summer and accompanied by warm periods.

Messrs. Ren and Liu found that the narrower the arc (the closer the planets), the more extreme the temperatures. 'During 1665, when the angle of convergence was smallest---only 43 degrees---this corresponded to... when China and the Northern

Hemisphere had the coldest temperatures of the past 3,000 years,' they said. They calculated that during alignments 'the radius of the earth's orbit around the mass center of the solar system' is 1% longer than normal, extending one or another season according to formulas they provide. They also studied Greenland's weather during the past five alignments, and found it 'consistent with the trend.'" (R8) These planetary alignments gained recent fame under the guise of the Jupiter Effect. Another summary of the Chinese study by John Gribbin, one of the authors of the book The Jupiter Effect, is found in R9.

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R1. Pratt, Frederic; "Extraordinary Temperatures," English Mechanic, 7:387, 1868. (X1)

R2. Pratt, Frederic; "Lunar Influences and the Weather," English Mechanic, 13:89, 1871. (X1)

R3. Carruthers, G.P.; "Planetary Rain," English Mechanic, 27:264, 1878. (X2)

R4. Payne, Wm. W.; "The Planets and Cyclones," Sidereal Messenger, 3:164, 1884. (X3)

R5. Pratt, F.; "The Riddle of the Weather ---Opposition of Uranus and Neptune," English Mechanic, 83:107, 1906. (X1)

R6. "Planets and Periodicities," Nature, 119:298, 1927. (X4)

R7. "Planets Help Make Weather by Influence on Sunspots," Science News Letter, 30:9, 1936. (X5)

R8. Kwitny, Jonathan; "A Controversial Theory of the Weather," Wall Street Journal, March 9, 1982. (X6)

R9. Gribbin, John; "Stand by for Bad Winters," New Scientist, 96:220, 1982. (X6)

GWS9 Comets and the Weather

Description. The dependence of terrestrial weather on the passage of comets through the inner solar system, particularly those that pass close to the earth's orbit.

Background. Comets have long inspired fear in humanity and been regarded as harbingers of change---usually change for the worse. Not surprisingly, the onset of bad weather was frequently blamed on comets in our unscientific past.

Data Evaluation. No data even remotely approaching satisfactory quality exist. Only one scientist (Arago) is known to have dared to touch this subject. Rating: 4.

Anomaly Evaluation. Comets being much less massive than the planets should exert even less influence on the earth, either directly or through their effects on solar activity. One would thus be tempted to classify comet-induced weather as even more anomalous than planetary modulation (GWS8). This might be incorrect because the passage of comets could affect the earth's weather in a straightforward cause-and-effect manner, as described below. Rating: 2.

Possible Explanations. The passage of a comet may leave a huge wake of dust and gases, which if encountered by the earth might result in the influx of precipitation nuclei. These in turn might lead to cloudiness, precipitation, and lower temperatures.

Similar and Related Phenomena. Meteors correlated with weather (GWS4), auroras correlated with meteors (GLA11).

Examples of the Purported Effects of Comets on the Weather

X1. Review paper. Mankind's curious preoccupation with the baleful influences of comets is discussed as well as some comet-weather folklore. Only in a very few instances have scientists deigned to examine this subject. "Yet, though the wide-spread and long continued belief in the influences of comets upon the weather has even survived the belief in their direct baleful influence upon the fortunes of humanity, we must, nevertheless, place it in the same category as the supposed lunar influence. In the words of the late Professor Young, we may say that 'there is no observable change of temperature or of any meteorological condition, nor any effect upon vegetable or animal life produced by a comet, even of the largest size.' Arago, more than half a century ago, made some attempts to deal statistically with the question. He took the mean temperature at Paris for the years 1735 to 1853, placing side by side the number of comets observed in each year, and thus showed that years fruitful in comets, such as 1808 and 1846, were marked by temperatures lower or hardly equal to those of years in which few or no comets were seen. Sixty-nine years with comets gave a mean annual temperature of 51.46 F, twenty-seven years in which no comets were seen gave a mean of 50.94. He considered this slight difference as explained by the fact that years without comets were most frequently more cloudy than the others, the prevalence of clouds concealing comets from observation." (R1)

References

R1. Henkel, F. W.; "Comets and the Weather," Symons's Meteorological Magazine, 45:128, 1910. (X1)

GWT THE IDIOSYNCRACIES OF TORNADOS AND WATERSPOUTS

Key to Phenomena

GWT0 Introduction
GWT1 The Tornado as an Electrical Machine
GWT2 Burning and Dehydration during Tornados
GWT3 Tornados and Waterspouts with Horizontal Funnels
GWT4 Multiwalled Waterspouts
GWT5 Anomalous Historical Incidence of Tornados
GWT6 Reversal of Rotation in Waterspouts
GWT7 Pranks of the Tornado
GWT8 Tornado Incidence Correlated with Magnetic Variation
GWT9 Landspouts or Dustspouts
GWT10 Waterspouts between Clouds
GWT11 Forked Waterspouts
GWT12 Abnormally Thin Waterspouts
GWT13 Waterspout Funnel-Knots
GWT14 Bull's-Eye Squalls or White Squalls

GWT0 Introduction

Ostensibly, tornados and waterspouts are the same species of rotary storm. The passage of a tornado from land to water converts it automatically into a waterspout, or so the prevailing theory goes.

A controversial theory that unites the two phenomena is that of their purported electrical origin. Both tornados and waterspouts are usually accompanied by severe lightning, but the hypothesis of electrical origin requires powerful cloud-earth currents to keep the storm's motor running. The effects of this large-scale flow of electricity should be observable. The "tornado lights" cataloged under GLD10 may be considered evidence of electrical action of some kind. Other confirmatory phenomena are: large terrestrial current flow in the neighborhood of the funnel, the smell of ozone or sulphur, and burning and dehydrating effects noticed along the path of the tornado. The latter effects, however, are also attributed to the aerodynamic heat created by the tornado. Whatever the truth may be, the auxiliary phenomena accompanying tornados are most curious.

The theory of the waterspout is not as completely worked out as some meteorologists would like. They find that the hollow-tube geometry of the waterspout is different from what some theories imply. Along this vein, conventional wisdom also has trouble dealing with forked waterspouts, waterspouts between clouds, and multiwalled waterspouts.

Both tornados and waterspouts can be dangerous phenomena; the former generally being the more violent. One must also ask whether there is a continuous gradation in size and violence from the small mischievous dust devil to the town-levelling tornado a mile wide. Do all of these rotary phenomena have the same cause? Meteorologists, in fact, do not understand completely the genesis of atmospheric vortices. Something seems to trigger these atmospheric maelstroms; perhaps electricity or natural surface features or even automobile traffic!

GWT1 The Tornado as an Electrical Machine

Description. Electrical attributes of tornados above and beyond the intense lightning normally expected during a severe storm. Collectively, these phenomena imply that tornados may owe their origins and maintenance to electricity. Pertinent phenomena are: (1) Tornado lights, which are dealt with at length in GLD10; (2) Anomalous heat generation and the dehydration of vegetation, as described in GWT2; (3) The smell of ozone or sulfur; (4) Buzzing or other sounds typical of electrical discharges; (5) Radio noise (sferics); (6) Strong earth currents in the neighborhood of tornado funnels; and (7) The apparent impossibility of generating tornado force winds by means of any conceivable temperature differences attainable in the atmosphere.

Background. Today's meteorologists doubt that electricity plays any significant role in tornado genesis and maintenance. A century ago, however, the major importance of electrical forces was widely accepted.

Data Evaluation. Tornados are attended by many electrical phenomena; this fact is widely acknowledged. It is a question of whether electricity is essential to the birth and maintenance of the tornado. If electricity is important, electrical phenomena in and around all tornados should be strong. This does not seem to be the case. Rating: 2.

Anomaly Evaluation. The current scientific consensus denies a major role to electricity in generating and sustaining tornados. Rating: 2.

Possible Explanations. Powerful electrical discharges between clouds and the earth (not lightning but something more akin to a glow discharge) may contribute to the formation and maintenance of tornados. The mechanism by which electrical energy is converted into vortex energy is not well-understood.

Similar and Related Phenomena. Tornado lights (GLD10), earthquake lights (GLD8), the electrical properties of whirlwinds (GWW4).

Examples of the Tornado as an Electrical Machine

X0. Cross reference. Luminous phenomena, probably of electrical origin, have been observed around many tornados. These anomalies have been collected under the category GLD10 in another volume of this Catalog.

X1. June 3, 1860. American Midwest. A tornado leaves a strong sulphurous odor in many places. (R2, R3)

X2. April 10, 1885. North Atlantic Ocean. When a ship encountered a waterspout, much St. Elmo's Fire was observed around the ship. (R4)

X3. May 27, 1962. Tulsa, Oklahoma. Earth current measurements near a large tornado.

Abstract. "Measurements of the magnetic field and earth current in the vicinity of a tornado show large step-like deflections coincident with the touching down of the funnel. Calculations with a simple current model indicate that a minimum current of several hundred amperes must be postulated to account for the observed deflection in magnetic field. The existence of a steady current of 225 amperes for a period of about 10 minutes provides joule heat at the rate of approximately 10^{10} joules per second, and involves a total charge transfer of 135,000 coulombs. The calculations imply that a tornado is electrically equivalent to several hundred isolated thunderstorm cells active simultaneously." (R7)

X4. March 24, 1975. Atlanta, Georgia. Sferics associated with a tornado. Abstract. "Joint observations by radio and high-frequency sferics detectors at Georgia Institute of Technology provided unique data on the Atlanta tornado of 24 March 1975. The classic hook echo was detected by radar at a range of about 26 km, 15 min before the tornado touched down. While the tornado was on the ground the sferics burst rate was very low, despite very high values recorded immediately before and after this interval. This observation, together with visual reports of a strong cloud-to-ground discharge at the time of tornado touchdown, suggests an interaction of the tornado with the electric field of the storm." (R9)

X5. General observations. "Water-spouts often leave behind a sulphureous (sic) smell, and there are examples of a disagreeable smell remaining along the whole tract traversed by them. One individual, however, who became involved in a water-spout perceived no odor. We seldom read accounts of water-spouts without finding also that electrical phenomena were noticed at the same time. Lightning is almost never wanting; thunder is likewise often connected with them, and it has been remarked that the loud noise which follows water-spouts easily prevents feeble peals of thunder from being heard. Now and then, a more widely dispersed light has been seen; so that people imagined that the corn in the fields was on fire, but afterwards to their joyful astonishment found it uninjured. It has been reported of one water-spout that fire balls proceeded from it, one of which was accompanied by a report like that of a musket." (R1)

X6. Summary of field observations. Abstract. "Eighteen close range tornado observations reveal that electrical activity near or within the funnel is far too infrequent to lend credence to electrical theories of tornado genesis and maintenance." (R8)

X7. Laboratory experiments made to check the possibility that electricity might play an important role in a tornado's life cycle indicated that a continuous electrical discharge in the center of a vigorous vortex actually inhibited vortex circulation. (R6)

X8. Theoretical arguments. The remarkable feature of the tornado is not its energy but rather its energy density. "Some idea of the extraordinary energy concentration in the tornado can be obtained by estimating the temperature differences that would have to exist in the atmosphere to cause its winds. We can compute an absolute minimum temperature difference that would be required by considering the atmosphere as a perfect heat engine in which all processes are reversible and in which dissipative processes such as turbulence, entrainment, and friction do not occur..... From the foregoing considerations it can be seen that in order to cause the winds of near sonic velocity that appear to exist in the tornado, temperature contrasts must occur between air masses that are well in excess of the theoretical minimum of 70°C, and probably of the order of several hundred degrees centigrade. The puzzling fact is that none of the soundings made during conditions that cause tornadoes shows the possibility of such temperature contrasts. Even the most unstable atmospheric conditions..... are capable of giving rise to thermal contrasts of only 25°C between air masses. This is well below the theoretical minimum that would be required to produce tornado velocities..... The clue that may provide the answer to the riddle of the tornado is the very intense electrical display that is commonly observed to accompany these storms. According to modern thinking, this unusual electrical activity does not play a significant role in tornado dynamics. McEachron and Jones suggested that perhaps the tornado itself somehow causes electrification. This appears unlikely, however, for both Jones and the Air Weather Service sferics observers at Tinker Field, Oklahoma, have shown that very intense electrical activity both precedes and follows the appearance of the funnel. If the tornado does produce the lightning that is observed to accompany it, then its energy is even more remarkable, for it will be shown that the power required for the lightning display is commensurate with the power required to produce the tornado winds themselves. It appears to the author that the ancient idea that electricity is a cause, rather than a result, of tornadoes may afford a better explanation of the facts. The vivid electrical displays observed, particularly with nocturnal tornadoes, are so striking that the obvious deduction that tornadoes might be caused by electricity is old indeed." (R5)

X9. Laboratory experiments. Abstract. "Laboratory experiments showed that under certain conditions of vorticity the electrical heating produced by a high-voltage discharge at atmospheric pressure can cause the formation of a miniature tornado-like vortex. Once it forms, this vortex stabilizes the electrical discharge along its axis and changes its character from that of a spark to a high-pressure variety of glow discharge. Electrical and dynamic parameters were measured. By relating observations and measurements made in these experiments to previous work and to analogous situations in nature, it is concluded that the heating produced by electrical discharges in a large storm may play a significant role in forming and maintaining natural tornadoes." (R10)

References

R1. Oersted, Hans C.; "On Water-Spouts," American Journal of Science, 1:37:250, 1839. (X5)
R2. Howig, Frank A.; "The Great Tornado in the Far West," Scientific American, 3:19, 1860. (X1)
R3. "Phenomena of Storms," Scientific American, 22:302, 1870. (X1)
R4. Science, 5:391, 1885. (X2)
R5. Vonnegut, Bernard; "Electrical Theory of Tornadoes," Journal of Geophysical Research, 65:203, 1960. (X8)
R6. Wilkins, E. M.; "The Role of Electrical Phenomena Associated with Tornadoes," Journal of Geophysical Research, 69:2435, 1964. (X7)
R7. Brook, Marx; "Electric Currents Accompanying Tornado Activity," Science, 157:1434, 1967. (X3)
R8. Davies-Jones, R. P., and Golden, J. H.; "On the Relation of Electrical Activity to Tornadoes," Journal of Geophysical Research, 80:1614, 1975. (X6)
R9. Greneker, E. F., et al; "The Atlanta Tornado of 1975," Monthly Weather Review, 104:1052, 1976. (X4)
R10. Ryan, R. T., and Vonnegut, B.; "Miniature Whirlwinds Produced in the Laboratory by High Voltage Electric Discharges," Science, 168:1349, 1970. (X9)

GWT2 Burning and Dehydration during Tornados

Description. The observation of the effects of intense heat along the track of a tornado, such as evidence of fusion, charred bodies, and vegetation that has been scorched, dehydrated and/or exploded. The smell of sulphur, possibly indicative of electrical action (GWT1) is also frequently present. Curiously, a disproportinate number of examples come from France, where tornados are much less frequent than in the United States.

Data Evaluation. Although this pheomenon is sometimes described as if it were well-supported by observations (R10), high quality examples are scarce in the literature. Rating: 2.

Anomaly Evaluation. Burning and dehydration along a tornado track suggests extremely hot winds and/or intense electrical discharges. Neither are accepted characteristics of tornados. Rating: 2.

Possible Explanations. Powerful electrical currents generated by the tornado (GWT1). An oscillating ring current around the funnel (R10). Aerodynamic heating of the tornado core is a possibility, although the temperatures required for the observed effects are probably several hundred degrees. However, if tornados can drive straws into trees (GWT7), aerodynamic heating may not be unreasonable.

Similar and Related Phenomena. Tornado electrical characteristics (GWT1); tornado pranks (GWT7); whirlwinds of fire and smoke (GLD11); tornado lights (GLD10).

Examples of the Drying and Burning Effects of Tornados

X1. June 1839. Chatenay, France. An account of an especially violent tornado. "In this hasty account I have, with the intention of returning to this portion of the subject, omitted to speak particularly of its effect upon trees. All those which came within influence of the tornado, presented the same aspect; their sap was vaporized, and their igneous fibres had become dry as if kept for forty-eight hours in a furnace heated to ninety degrees above the boiling point. Evidently there was a great mass of vapor instantaneously formed, which could only make its escape by bursting the tree in every direction; and as wood has less cohesion in a transverse direction, these trees were all, throughout one portion of their trunk, cloven into laths. Many trees attest, by their condition, that they served as conductors to continual discharge of electricity, and that the high temperature produced by this passage of the electric fluid, instantly vaporized all the moisture which they contained, and that this instantaneous vaporization burst all the trees open in the direction of their length, until the wood, dried up and split, had become unable to resist the force of the wind which accompanied the tornado. In contemplating the rise and progress of this phenomenon, we see the conversion of an ordinary thunder gust into a tornado; we behold two masses of clouds opposed to each other, of which the upper one, in consequence of the repulsion of the similar electricities with which both are charged, repelling the lower towards the ground, the clouds of the other descending and communicating with the earth by clouds of dust and by the trees. This communication once formed, the thunder immediately ceases, and the discharges of electricity take place by means of the clouds, which have thus descended, and the trees." (R1, R3, R10)

X2. August 19, 1845. Rouen, France. The famous tornado of Monville. "The trees in the vicinity were flung down in every direction, riven and dried up for a length of from six to twenty feet and more. While clearing away the ruins, in the attempt to rescue the unfortunate people buried beneath them, it was noticed that the bricks were burning hot. Planks were found completely charred, and cotton burned and scorched, and many pieces of iron and steel were magnetized. Some of the corpses showed traces of burning, and others had no visible cuts or contusions, but seem to have been killed by lightning. Workmen who were hurled into the surrounding fields, all agreed in saying that they had seen vivid flashes and had noticed a strong smell of sulphur. Persons who happened to be on the adjacent heights, alleged that they saw the factories wrapped in flames and smoke as the cloud enveloped it." (R2, R4)

X3. 1860. Iowa. A tornado left a sulphurous odor and blackened bodies of victims. (R5)

X4. Circa 1880. No place given. "The tornado was preceded by a dark cloud from which there was considerable thunder and lightning, but there was very little, if any, near the tornado. After the storm had passed, the air was saturated with ozone to such a degree that even the small children noticed it, who compared it to the odor of burning brimstone or burning matches. Unfortunately, I once stood a few rods from a tree when it was struck by lightning, and I distinctly remember the peculiar odor which I attributed to ozone which had been formed by the passage of lightning through the air. As the odor which followed or accompanied the tornado was similar, I concluded there must have been electricity with it. I followed the path of destruction, which was not over ten rods wide, for a couple of miles, and at different places saw small hickory and white oak trees, from one to two inches in diameter, ruptured or burst open, with crevices on all sides as though they had been exploded with some explosive; the fine splinters standing out, brush-fashion, on all sides. These small trees grew on ground which had once been farmed, and were of slow growth and the toughest which grow. There was such a marked difference between these, and those which had been twisted by the wind, that I had no difficulty in distinguishing one from the other. They were ruptured by electricity. At other places I saw small roots which had been laid bare, split open without any other marks about them, and I believe them to have been split by electricity. Had they been split by any visible or hard object, it must have left some other marks upon them. This, again, must have been the work of electricity." (R6)

X5. August 18, 1890. Domagne, France. Ozone smell and scorched vegetation left behind by tornado. (R7)

X6. August 18, 1891. Dreux, France. After the passage of a tornado, traces of melting were found in poorly conducting bodies. (R8)

X7. May 24, 1948. Mauritius. "In the middle of the afternoon a whirlwind touched down to earth over a hard tennis court, causing considerable damage to its hard compact surface. A trench running in a north-south direction, 60 feet long and 1 to 2 1/2 feet wide, was cut in the bare surface of the court to a depth varying from 1 to 4 inches. The material lifted from the trench was all thrown to the west to a distance of 50 feet; pieces weighing about one pound were thrown as far as 30 feet. The surface material was slightly blackened as if by heating, and a crackling like that of a sugar-cane fire was heard for two or three minutes. The court was made of a ferruginous clay, which packs down to a surface more smooth than that of the hard tennis courts usually made in Great Britain. Unfortunately, there were no very reliable witnesses of the phenomenon. The impressions gained by two servants of the tennis club who saw the incident differed considerably on important details. One claims to have seen a ball of fire about two feet in diameter which crossed from a football pitch to the tennis court through a wire-netting fence without leaving any evidence of its passage until it bounced along the court, making the trench in the surface before disappearing completely." (R9) This might very well be an example of ball lightning rather than tornado burning. (WRC)

X8. Theoretical explanation. Abstract. "The explanation generally offered for the observed dehydration, heating and burning effects associated with tornadoes is based on either of two mechanisms. The first involves a hot wind while the second involves corona discharges sometimes called St. Elmos fire, while the smell of 'brimstone' often often appears to be overlooked. An alternate explanation which could deal with both phenomena is obtained by assuming that a pulsed oscillatory 'ring current' exists within the tornado cloud whose radiation field at large distances can be associated with the observed and measured tornado sferics and at close distances could be responsible for the observed heating effect along with the smell of burning 'sulfur.'" (R10)

References

R1. Peltier, M.; "Account of a Whirlwind, Accompanied by Immense Electrical Discharges....," Franklin Institute, Journal, 31:62, 1841. (X1)

R2. "Whirlwind near Rouen, August 19th, 1845," Franklin Institute, Journal, 40: 420, 1845. (X2)

R3. Hare, R.; "On Tornados as an Electrical Storm," Franklin Institute, Journal, 54: 28, 1852. (X1)

R4. Zurcher, Frederic; "The Tornado of Monville," Meteors, Aerolites, Storms, and Atmospheric Phenomena, New York, 1876, p. 154. (X2)

R5. Howig, Frank A.; "Remarkable Tornado," Scientific American, 47:17, 1882. (X3)

R6. Moore, H. D.; "Electricity and Tornadoes," American Meteorological Journal, 2:517, 1886. (X4)

R7. Hazen, H. A.; "Electric Storms and Tornadoes in France on Aug. 18 and 19, 1890," Science, 17:304, 1891. (X5)

R8. Nature, 44:112, 1891. (X6)

R9. Davy, E. S.; "Unusual Damage by a Tornado," Weather, 4:156, 1949. (X7)

R10. Silberg, P. A.; "Dehydration and Burning Produced by the Tornado," Journal of the Atmospheric Sciences, 23:202, 1966. (X1, X8)

GWT3 Tornados and Waterspouts with Horizontal Funnels

Description. Tornado and waterspout funnels that extend horizontally from the parent cloud for long distances, often terminating in midair. Some tornados display long sinuous funnels that deviate from the vertical but not to the degree described below.

Data Evaluation. Horizontal funnel clouds, while rather rare, have been reliably reported and photographed. Rating: 1.

Anomaly Evaluation. Theory does not require that funnel clouds be vertical. In fact, one theory of waterspout formation has the funnel forming inside the parent cloud in a horizontal position and arching down toward the water only at its terminus. We must classify this phenomenon as simply a curiosity. Rating: 3.

Possible Explanations. Funnel cloud orientation is determined more by meteorological forces than by gravity.

Similar and Related Phenomena. Horizontal roll clouds (GWC12).

Examples of Horizontal Funnel Clouds

X1. May 24, 1909. Dijon, France. A tornado with a horizontal, serpent-like funnel that terminated in mid-air. (R1)

X2. May 28, 1956. North Atlantic Ocean. "A most unusual waterspout was observed bearing due E. from the ship. It originated from a large Cb with rain falling, and stretched diagonally towards the horizon, as illustrated.....The waterspout lasted about 3 min before dissolving." (R2)

X3. June 29, 1976. Near Shawnee, Oklahoma. (R4)

X4. July 9, 1977. Waco, Texas. A horizontal funnel cloud was photographed near the top of a line of light thunderstorms. (R3)

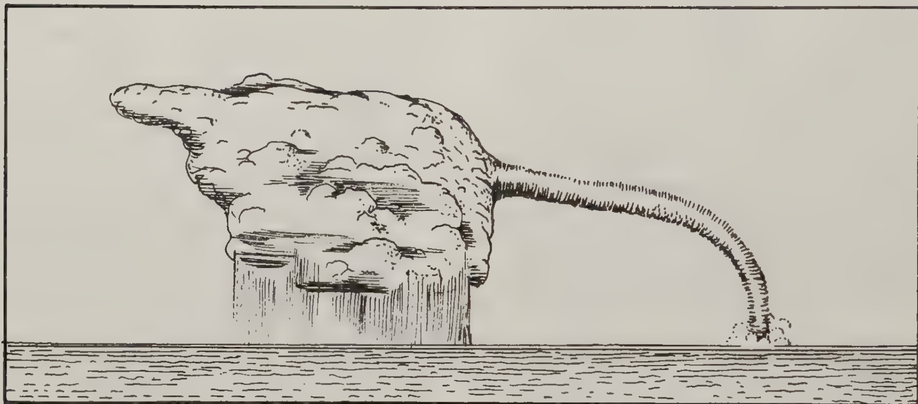
References

R1. Loisier, M. l'abbe L.; "Meteorologie," L'Astronomie, 23:316, 1909. (X1) (Cr. L. Gearhart)

R2. McCrone, J.; "Waterspout," Marine Observer, 27:80, 1957. (X2)

R3. McCauley, Gerald W.; "Horizontal Funnel Cloud," American Meteorological Society, Bulletin, 59:291, 1978. (X4)

R4. Pielke, Roger A.; "Another Horizontal Funnel Cloud," American Meteorological Society, Bulletin, 59:1168, 1978. (X3)



Waterspout with a long horizontal section (X2)

GWT4 Multiwalled Waterspouts

Description. Waterspouts consisting of two or more hollow concentric tubes, which may rotate at different angular velocities. One tube is the rule but several double-walled and one triple-walled spout have been recorded.

Data Evaluation. Several detailed, seemingly reliable field observations of multiwalled waterspouts have been found. Further, the double-wall structure has been verified by laser probes. Rating; 1.

Anomaly Evaluation. Conventional waterspout theory deals fairly well with single-walled spouts but does not accomodate multiwalled spouts with concentric walls rotating at various velocities. Rating: 2.

Possible Explanations. None.

Similar and Related Phenomena. None.

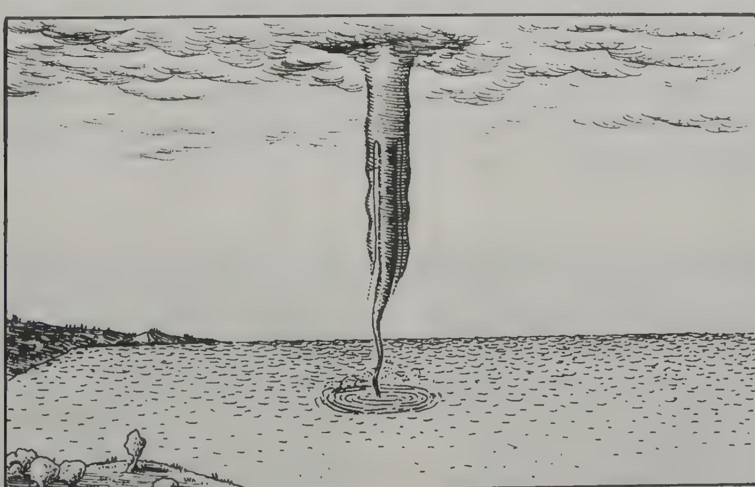
Examples of Multiwalled Waterspouts

X1. June 30, 1922. Lake Victoria, Uganda. A waterspout passed 100 yards offshore. "The pedicle arose from a well-marked circular area on the water, which was otherwise only faintly rippled by the preliminary puff of wind before the approaching storm. This circular area was evidently very violently disturbed as a cloud of vapour, greatly agitated, rose from it for a little distance. The pedicle was extremely narrow at its lower end, and not quite straight, being sinuous in outline. It broadened out gradually into a column which went up into the low cloud; the core of this column was much less dense than the periphery, and the violent upward spiral ascent of the water could be clearly seen. So far I have described nothing unusual, but the following was quite new to me and seemed of great interest.

Surrounding the central core, but separated from it by a clear narrow space, was a sheath, the lower end of which faded away some distance above the water. The profile of this sheath was undulating, it being thicker in some places than others. A curious point is that this sheath seemed to pulsate rhythmically, but I could not say whether the appearance of pulsation might not have been an illusion caused by waves travelling up its outer surface. This pulsation gave an uncanny suggestion of a live thing, which was aided by the violent spiral movement upwards in the central core, the clouds of vapour boiling round its base, and the movement of the whole across the water---indeed, we watched it spellbound until the pedicle dissolved away at the bottom, and the ascent of the part above brought the phenomenon to an end." (R1, R2)

X2. February 22, 1923. North Atlantic Ocean. A report from the American steamship Warwick. "The spout was seen late in the afternoon of February 22 and was described as 'close aboard' so that with glasses its peculiar structure could easily be observed. The inner spout was apparently darker than the outer and at times it would be withdrawn into the heavy globular appearing cloud above, leaving the outer spout still 'drawing water.' The compound spout was something of the shape of an S, extending in a nearly horizontal direction to near the horizon, where it descending vertically to the water. After about fifteen minutes the inner spout was suddenly withdrawn and ten minutes later the whole mass moved eastward and a heavy rain set in." (R3)

X3. May 27, 1951. South China Sea. A three-walled waterspout. "It began as a faint tube of cloud particles emerging from a cumulus bank estimated to be slightly above 2,000 ft. Directly underneath, the sea was disturbed and throwing up spray to about 100 ft. in a circular area 300 ft. wide. In the second stage the tube, which appeared to be hollow, extended downwards to meet the surface spray. In its third stage, the tube which was about 30 ft. in diameter, apparently formed a second hollow cloud tube inside the first tube for about the middle third of its length.



Double-walled waterspout over Lake Victoria (X1)

In the fourth stage, a thick cloud sleeve about 400 ft. long and 150 ft. wide grew downwards from the cloud base, concealing the original spout and a similar sleeve or annulus grew from the sea at the same time. The spray from the sea surface remained visible outside the sleeve. The reverse processes now took place, and when the spout had reached the second stage again a shower spread from the north, enveloped it and hastened its decay, although it was possible to discern foam on the sea surface five minutes after the spout was no longer visible. No rotation was visible at any time, except in the spray which appeared to drift slowly in a clockwise direction." (R4)

X4. Laser probes of waterspouts off the Florida Keys, 1976. "With the laser device it was possible to measure windspeeds and identify the dynamic difference---the difference in velocity within the spout that indicates two cylinders rotating about a common axis. Preliminary analysis of the data suggests that the two vortices of a double spout are in fact two separate, concentric funnels which rotate in the same direction, but at different speeds." (R5)

References

R1. Carpenter, G. D. Hale, and Brunt, D.; "Waterspouts," Nature, 110:414, 1922. (X1)
R2. "Some Observations of Waterspouts and Allied Phenomena," Meteorological Magazine, 57:248, 1922. (X1)
R3. Science, 57:sup xvi, April 6, 1923. (X2)
R4. Phillips, P. E.; "Triple-Walled Waterspout," Meteorological Magazine, 81:88, 1952. (X3)
R5. "NOAA, University Scientists Probe Double Waterspouts," Mariners Weather Log, 21:387, 1977. (X4)

GWT5 Anomalous Historical Incidence of Tornados

Description. The apparent four-fold increase in the incidence of U.S. tornados during the period 1950-1973 and, on a weekly time frame, a dramatic reduction in tornado incidence on Saturdays compared with the rest of the week.

Data Evaluation. Little has been found to date in the literature on this purported anomaly. The authors of the single study available admit possible problems with nonuniform reporting down the years but claim to have this factor under control Rating: 2.

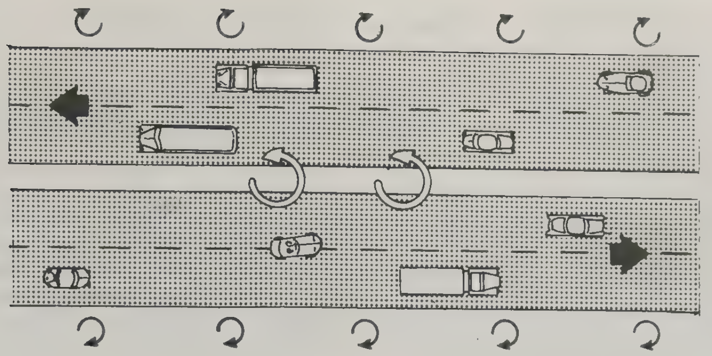
Anomaly Evaluation. No known natural forces account for this strange distribution of tornados in time. Manmade sources of atmospheric vorticity, as mentioned below, have not been accepted as yet. Rating: 2.

Possible Explanations. Automobile traffic may add vorticity to the atmosphere and account for both the general historical increase in tornados and the Saturday phenomenon.

Similar and Related Phenomena. None.

Examples of Anomalous Historical Incidence of Tornados

X1. Statistical analysis. "We have obtained the detailed record of all US tornadoes (15,234) reported between 1950 and 1973 in the 48 contiguous states. The annual incidence shows an increase over the period of a factor of four. Changes in observation and reporting are undoubtedly serious and we have applied tests that are relatively independent of secular changes in reporting. .....The data display a strong weekly periodicity. Over the entire record the reported number of tornadoes on Saturdays is less than the daily average by more than 7.1 standard deviations (1,868 on Saturdays as against a daily average of 2,176). The statistical probability of this record occurring by chance from a random sample is $P<10^{-9}$. This hebdomadal event dominates in 18 of the 24 yr and in most states. (Thirty-seven of the forty-eight states show a Saturday incidence below the average.) Nineteen states show Saturday's incidence to be a minimum." (R1) The "Saturday Effect" was suggested to be a consequence of vag-



How motor vehicle traffic creates atmospheric vorticity (X1)

aries in reporting by letters to Nature commenting on R1. Several letter writers believed that auto traffic, which occurs on a small scale when compared to cloud didimensions, could contribute no net vorticity to the atmosphere. (R2)

References

R1. Isaacs, John D., et al; "Effect of Vorticity Pollution by Motor Vehicles on Tornadoes," Nature, 253:254, 1975. (X1)

R2. Kessler, Edwin, et al; "Tornado Forum," Nature, 260:457, 1976. (X1)

GWT6 Reversal of Rotation in Waterspouts

Description. The apparent reversal of the direction of rotation in some waterspouts.

Data Evaluation. A single observation. Rating: 3.

Anomaly Evaluation. The only known way for a waterspout to reverse its direction of rotation and still obey the laws of physics is to slow down, die out, and reform on the same spot rotating in the opposite sense. This is unlikely and did not occur in the example below. If waterspouts actually do reverse rotation suddenly and spontaneously, theory cannot account for it. Rating: 2.

Possible Explanations. The supposed change of direction is merely an optical illusion.

Similar and Related Phenomena. The apparent direction of rotation of phosphorescent wheels sometimes varies with the observer (GLW4).

Examples of Reversal of Rotation in Waterspouts

X1. August 18, 1951. North Pacific Ocean. "A waterspout formed to the NE at a distance of about one mile and moved westwards at 10 to 15 kt. It appeared to rotate rapidly, first clockwise, then anti-clockwise, continually changing the direction of rotation. At no time did it reach cloud level. Just before it disappeared at 2039 it ceased rotating and dispersed temporarily. It finally disappeared veering WNW, leaving a cloud of spray." (R1)

References

R1. Hutchinson, W.; "Waterspout," Marine Observer, 22:123, 1952. (X1)

GWT7 Pranks of the Tornado

Description. The propensity of the tornado to carry out curious, improbable, and sometimes seemingly impossible actions; such as, defeathering chickens, driving boards through thick trees, and carrying people long distances without hurting them.

Background. Tornados, in common with lightning and whirlwinds, do the unlikely. At least these "pranks' and "freaks" seem improbable to us. The chief variety of tornado prank might be termed "surgical violence" because incredibly strong forces are exerted over curiously delimited regions while adjacent areas are untouched. One should remember in this context that tornados do not normally carry people 100 yards and set them down unhurt; they usually kill and mangle people. Our statistics are thrown off because we tend to remember the unusual rather than the usual.

Data Evaluation. Tornado tales are legion. Only a sampling from the science-oriented literature is recorded here. Tornado pranks are well-accepted phenomena. Rating: 1.

Anomaly Evaluation. Most of the peculiar actions of tornados could probably be explained if we could divine the detailed structure of the tornado. That is, if we knew wind velocities throughout the storm, present physical laws could give us a cause-and-effect accounting of each and every prank. Rating: 3.

Possible Explanations. Extremely high, localized winds probably account for almost all of the so-called tornado pranks.

Similar and Related Phenomena. The pranks of lightning (GLL11) and whirlwinds (GWW2).

Examples of Tornado Pranks

X1. June 3, 1860. American Midwest. A tornado crossed Iowa, Illinois, and Michigan, a total distance of 560 miles. "When the spout reached the Iowa river, the spray was seen to come out of its apex, making a picture even more impressive than Niagra Falls. The evidences of the amazing power of the wind were innumerable. In one instance a joist was driven directly through a tree. At the time of the passing of the spout an odor of sulphur was noticed by many persons, and one of the most curious of the phenomena attending the storm was that many fowls were entirely stripped of their feathers, while the fowls themselves remained uninjured." (R1)

X2. May 18, 1883. Sangamon County, Illinois. A tornado attended by the odor of sulphur and fireballs. "The family of Mr. T, who had also sought shelter in a cellar from the same storm, were covered with a gummy substance, which would not wash off! This substance might have been formed from the sap of trees and juice of leaves, combined with the moist heated atmosphere.....A thrifty young maple-tree, twelve inches in diameter, stood apart from other trees, near the edge of the storm's track. About six feet from the ground the bark was peeled entirely off for a distance of two feet. No broken limb, or other missile, lay near the tree, and its top was uninjured!.....A flock of geese were plucked of their feathers, which were deposited in a hedge-fence, giving it a complete coating." (R2)

X3. 1890. Louisville, Kentucky. A tornado tore the roof off a house and pulled a child from its mother's arms, depositing it safely at another house six blocks away. (R5)

X4. May 11, 1892. Novska, Slavonia. During a powerful tornado, a young girl was transported more than 90 meters without receiving any injury. (R3)

X5. May 27, 1896. Saint Louis, Missouri. "Willis L. Moore, then chief of the Weather Bureau, who visited St. Louis, Missouri, the day following the great tornado of May 27, 1896, reported seeing a two-by-four pine scantling which had been blown through solid iron five-eighths of an inch thick on the Eads Bridge, the end of the scantling protruding several feet through the hole it had gouged in the iron. He also reported seeing a six by nine timber driven four feet almost straight down into hard, compact soil, a gardner's spade shot six inches into the limb of a tree, and wheat straws forced into the trunk of a tree to a depth of more than an inch.....a man driving a team to a heavily loaded wagon suddenly found the team missing, blown away, but the wagon and himself uninjured, except, of course, for the tongue of the wagon." (R8)

X6. Circa 1905. Oklahoma. "In the Associated Press dispatches concerning the recent tornado in Oklahoma, mention is made of the occurrence of some remarkable phenomena which cannot be explained by our accepted physical laws. Among these is a statement that 'all the corpses in the track of the storm were found without shoes.' 'In some instances the hair was taken from the head without injuring the scalp beneath.' Similar storms have been reported with like curious phenomena, such as the removal of the feathers from one-half a chicken, leaving the bird otherwise uninjured; driving a piece of straw several inches into the trunk of a tree without breaking the straw, etc." (R4)

X7. March 18, 1925. The Tri-State tornado. "..... a large plank, several feet long, was found driven horizontally into a tree trunk so firmly that the far end of the plank was capable of supporting the weight of a man without loosening it from the tree." (R8)

X8. June 3, 1927. Topeka, Kansas. ".... a rafter, badly weathered and charred with old age, was blown from an old barn through the siding and two-inch sill of a nearby comparatively new house, pointed end first, and left sticking in the hole it punched. The most incredible part was that the charred, tapered end of the old rafter showed no battering effect whatever. The speed of its impact must have been tremendous." (R8)

X9. March 14, 1933. Nashville, Tennessee. The following were observed by the official in charge of the local weather station. "A cornstalk was found driven endwise through a piece of weather boarding. A 2 x 4 inch timber plunged through a panel door without causing the slighest splitting or splintering. The timber exactly fitted the opening. A 1 x 6 inch plank was forced through the trunk of a sturdy young tree, splitting the latter in half." (R7)

X10. June 1, 1943. Lansing, Michigan. "..... thirty chickens, stripped entirely of their feathers, were found after the storm sitting in the poultry house, stiffly at attention. All were dead." (R8)

X11. June 23, 1944. West Virginia. "When the destructive tornado of June 23, 1944, passed over West Fork River, West Virginia, the water was actually sucked up and the river left dry, momentarily, at the place where the storm crossed it." (R8)

X12. April 9, 1947. Higgins, Texas. "According to the account, two Texans, Al and Bill, last names not given, were visiting in Al's home near Higgins, Texas, when the tornado that later struck Woodward passed over them. Al, hearing the roar, stepped to the door and opened it to see what was happening. It was torn from his grasp and disappeared. He was carried away, over the tree tops. Bill went to the door to investigate the disappearance of his friend and found himself, also, sailing through the Texas atmosphere, but in a slightly different direction from the course his friend was taking. Both landed about two hundred feet from the house with only minor injuries. Al started back and found Bill uncomfortably wrapped in wire. He unwound his friend and both headed for Al's house, crawling because the wind was too strong to walk against. They reached the site of the house only to find that all the house except the floor, had disappeared. The almost incredible part of the story is that Al's wife and two children were huddled on a divan, uninjured. The only other piece of furniture left on the floor was a lamp." (R8)

X13. April 29, 1947. Worth, Missouri. "Mr. Ferguson arrived on the scene of devastation shortly after the tornado struck and observed not only dead, deplumed fowls, but also others deplumed and dazed which expired in a short period of time." (R10)

X14. May 30, 1951. Scottsbluff, Nebraska. "After the passage of a tornado at Scottsbluff, Nebraska, on May 30, 1961, a bean was found embedded one inch deep in an egg without having cracked the shell." (R8) One assumes that a hole was made without cracking around its edges, as in X9. (WRC)

X15. June 8, 1953. Flint, Michigan. "Also, in our files, is a rather aged and yellow supplement to the Flint (MI) Journal showing a picture of a deplumed chicken, 'pecking around a truck twisted like a steel pretzel' in the aftermath of the famous Flint Tornado of 8 June 1953. While it is not the mission of the National Severe Storms Forecast Center (NSSFC) to record tornadoes which deplumed fowls, enough events of this phenomenon have been documented over the past one hundred and forty years to warrant its acceptance." (R10)

X16. No date or place given. "No account of tornadoes is complete without the recital of some of the many 'freaks' which such storms are wont to perform. The removal of feathers from chickens, the complete destruction of houses, the clean sweeping through deep forests, and the carrying of objects great distances, are examples frequently recounted.....Here are some excerpts from the numerous accounts....An automobile locked in a garage was undamaged, although the garage was blown to splinters. Half a dozen glass jars of fruit were carried 100 yards by the winds and not damaged." (R6)

X17. No date given. Texas. From a study of survivors in a small Texas town that was struck by two tornados a year apart. "But the tornadoes did leave their mark. After the first one, Moore says, 73 percent of the people admitted some member of their family suffered from emotional problems, apparently induced by the tornado. The second tornado was milder, and resulted in more than half of the people with this complaint. Sample emotional ills: One woman developed a limp although her doctor could find no physical cause. Another reported blindness for several days after the storm. A third experienced temporary amnesia. Several other persons reported unexplained weakness, insomnia, nightmares, and general depression. More than a year after a tornado, one survivor still could not use her home air-conditioner because of the sound of air being pulled through it." (R9)

References

R1. "Phenomena of Storms," Scientific American, 22:302, 1870. (X1)
R2. Smith, George Clinton; "Cyclones and Tornadoes," Popular Science Monthly, 23:748, 1883. (X2)
R3. "Trombe," Ciel et Terre, 14:144, 1893. (X4) (Cr. L. Gearhart)
R4. Lewis, F. Park; "Freaks of the Tornado," Scientific American, 92:423, 1905. (X6)
R5. Walsh, George E.; "Freaks of the Tornado," Harper's Weekly, 57:25, May 17, 1913. (X3)
R6. Meisinger, C. LeRoy; "Tornadoes," Science, 52:293, 1920. (X16)
R7. "Tornado Freaks," American Meteorological Society, Bulletin, 14:118, 1933. (X9)
R8. Flora, Snowden D.; "Freaks of the Storm," Tornadoes of the United States, Norman, Oklahoma, 1953, p. 13, 78. (X5, X7, X8, X10, X11, X12, X14)
R9. "Finds Mental Ills Are Aftermath of Tornadoes," Science Digest, 43:20, May 1958. (X17)
R10. Galway, Joseph G., and Schaefer, Joseph T.; "Fowl Play," Weatherwise, 32:116, 1979. (X13, X15)

GWT8 Tornado Incidence Correlated with Magnetic Variation

Description. The tendency of tornados to be more frequent along lines of 8-10° magnetic variation, at least in Missouri, where a study was made.

Data Evaluation. One old analysis from a limited geographical area. Rating: 3.

Anomaly Evaluation. Any cause-and-effect relationship between the variation of the earth's magnetic field and tornado frequency would be startling in terms of present meteorological theory. Rating: 2.

Possible Explanations. Trends in magnetic variation may be related to geology and topology, which in turn might affect tornado development.

Similar and Related Phenomena. Geography strongly influences weather, as exemplified by "Tornado Alley" in the American midwest.

Examples of a Relationship between Tornados and Magnetic Variation

X1. Statistical analysis. "The following may be of interest as to the possible relation between tornadoes and whatever causes variation of compass. The variation in Missouri was determined by a magnetic survey made by Prof. F.E. Nipher. The number of tornadoes was obtained from Signal Service publications, Missouri Weather

Reports, newspapers and individuals. None but genuine twisters were listed. The greatest variation is in the extreme N. W. part of the state, the least in the S. W.

On the line of:

11° variation	3 counties had	7 tornadoes	
10	5	15	
9	20	22	
8.3	18	13	
8	14	7	
7.3	23	8	
7	11	5	
6.3	8	4	
6	4	1	(R1)

References

R1. Llewellyn, J. F.; "Relation between Tornadoes and Variations of the Compass," American Meteorological Journal, 4:135, 1887. (X1)

GWT9 Landspouts or Dustspouts

Description. The formation of the waterspout's typical hollow tube from dust and sand rather than water and mist. In contrast to dust devils and whirlwinds, a parent cloud is present. On the other hand, except for its marked tubular structure, the dustspout is very tornado-like and may, in fact, be just an unusual subspecies of this phenomenon.

Data Evaluation. A single but well-observed example. Rating: 3.

Anomaly Evaluation. The dustspout is curious for its hollow-tube structure, which is much more obvious than in a normal tornado. Otherwise, it seems no more mysterious than the ordinary tornado. Rating: 3.

Possible Explanations. Dustspouts are probably just weak tornados.

Similar and Related Phenomena. All tornados, waterspouts, dust devils, and whirlwinds. (GWW).

Examples of Dustspouts

X1. December 27, 1915. Persia. Description of a "waterspout" formed of dust 150 miles from the nearest sea. "Its distance from myself as observer was about two miles, and it was viewed through a pair of Zeiss glasses with a magnification of eight. As the pendant gradually dropped from the cloud, a hollow column of dust from the plain rose to meet it. The pendant and column eventually joined, the whole swaying about in a particularly beautiful manner. The height of the column from the plain to the cloud was about 2,000 feet, and the motion of the column about fifteen miles per hour but very irregular. I have no note on the direction of rotation of the column. The whole phenomenon lasted about fifteen minutes, and the pendant portion withdrew into the cloud first, leaving the lower portion rotating at the bottom. At the base of the column there was a fountain of large fragments thrown out, stones, sticks and anything that was loose. The whole column appeared like a translucent glass tube, but flexible, that is, there was a dark edge and a brighter middle..... A solid column of mist would have given an exactly opposite effect, namely, a dark middle and a bright edge. There is no doubt in my mind at any rate that the column was hollow, and that the lower part of it was composed of dust, which was of a browner colour than the cloud above it. Such a 'landspout' is, of course, not to be confused with the ordinary dust devil, which is quite common in any desert on a bright day." (R1) Dust devils (GWW) do not have parent clouds. (WRC)

References

R1. Busk, H. G.; "Land Waterspouts," Meteorological Magazine, 61:289, 1927. (X1)

GWT10 Waterspouts between Clouds

Description. The formation of waterspouts between two clouds rather than from cloud to water.

Data Evaluation. Only two observations have been uncovered in the meteorological literature. The observations are difficult because it is often impossible to determine whether the funnel-like structures are composed of water or are simply clouds. Rating: 3.

Anomaly Evaluation. Waterspouts or funnel clouds between clouds can be classified as unusual but there seems to be no theoretical reason why vortexes cannot form between clouds, even to the point of one drawing vapor from another. Rating: 3.

Possible Explanations. The chance connection of two clouds by a funnel or vortex, perhaps encouraged by different meteorological conditions existing at two cloud levels.

Similar and Related Phenomena. Horizontal funnel clouds (GWT3), which sometimes end in mid-air; cloud arches (GWC2), which connect widely separated clouds.

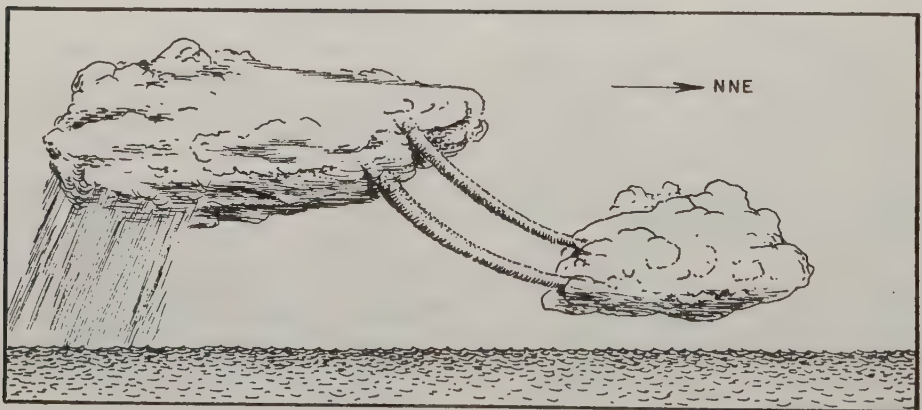
Examples of Waterspouts between Clouds

X1. May 10, 1928. South China Sea. "Sky three parts clouded with heavy Cumulus. Rain squalls around the horizon. Observed peculiar cloud formation to Eastward. Altitude about 3500'. It appeared as if a heavy rainfall was taking place from one cloud to another. It was quite apparent that no rain was falling into the sea. This rain was 'funnel—shaped, and it is considered that a small waterspout had formed in the sky and was sucking rain from a heavy cumulus cloud to another cloud (small, fluffy and whitish) above it." (R1)

X2. June 14, 1928. North Atlantic Ocean. "...at 1.55 p.m., a nimbus cloud bearing W.N.W. and moving in a N.N.E.'ly direction was observed to be connected to a bank of cumulus cloud by two waterspouts, which did not reach sea, but merely stretched between the two cloud-banks." (R2)

References

R1. Haselfoot, F.E.B.; "Cloud Phenomenon," Marine Observer, 6:102, 1929. (X1)
R2. Major, T.W.; "Waterspouts between Cloud," Marine Observer, 6:127, 1929. (X2)



Two waterspouts linking two clouds over the North Atlantic (X2)

GWT11 Forked Waterspouts

Description. A single waterspout funnel that splits into two diverging branches.

Data Evaluation. A solitary example has been found, which is weakened by the possibility that a closer spout may conceal the upper portion of a second, more distant spout, making it seem as if the first spout possesses two lower branches. Rating: 3.

Anomaly Evaluation. Forked waterspouts, if a fact, present serious problems in explanation, because at the fork there would seem to be two vortex walls rotating in opposite directions. Rating: 2.

Possible Explanations. Forked waterspouts may be simply illusions due to perspective and bad seeing.

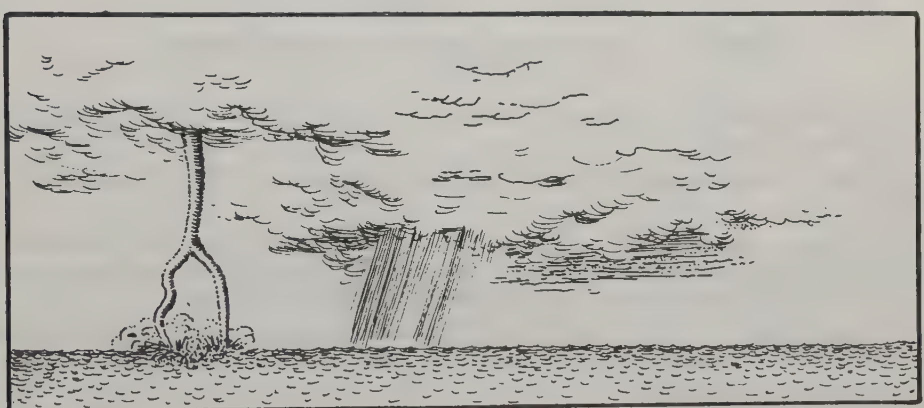
Similar and Related Phenomena. None.

Examples of Forked Waterspouts

X1. May 19, 1967. South China Sea. "A waterspout which divided into two branches about half-way between the cloud base and the sea, as shown in the sketch, was seen at 0715 LMT about 10 miles off. The two parts joined together about 10 min later to form a single column, at the base of which great turbulence was observed." (R1)

References

R1. Rippon, R. G.; "Forked Waterspout," Marine Observer, 38:62, 1968. (X1)



A forked waterspout observed in the South China Sea (X1)

GWT12 Abnormally Thin Waterspouts

Description. Waterspouts with very thin funnels (less than 1 foot in diameter) or very low diameter-to-height ratios (less than 0.01).

Data Evaluation. A few accounts of rather poor quality have been found. One difficulty here is that the visible dimensions of a waterspout, as defined by the spray and vapor, may not mark the true bounds of the atmospheric vortex. Rating: 3.

Anomaly Evaluation. Atmospheric vortexes can be almost any diameter---there seem to be no physical restrictions---but it is remarkable to find stable waterspouts a hundred times their diameters in height, at least from the standpoint of stability. Rating: 3.

Possible Explanations. It may be that our physical expectations are faulty here and natural vortexes are much more stable at very low diameter-to-height ratios than we predict from intuition. Another possibility is the presence of an unappreciated stabilizing factor, such as an electrical discharge.

Similar and Related Phenomena. Other atmospheric vortexes may also display low diameter-to-height ratios (indeed, we would expect them to based on the similarity of the phenomena), but so far we have found no such records.

Examples of Abnormally Thin Waterspouts

X1. May 16, 1898. Eden, Australia. "The longest recorded waterspout occurred off Eden, Australia, on May 16, 1898. Pilot Newton described it as being 'straight as a shaft' and 'thirty times as high as a clipper ship.' Theodolite measurements verified its actual height at 5,014 feet---nearly a full mile above sea level. Central funnel diameter, however, was a mere ten feet."(R1)

X2. December 18, 1917. Rabat, Morocco. Spout 1000 feet high, but only 3 inches in diameter. (R1)

References

R1. Mooney, Michael J.; "Sea Squirts," Oceans, 6:42, May 1973. (X1, X2)

GWT13 Waterspout Funnel-Knots

Description. The appearance of knots or bulges at irregular intervals along an otherwise uniform waterspout funnel.

Data Evaluation. A single report casually mentions the existence of this phenomenon. Rating: 3.

Anomaly Evaluation. Waterspout theory does not predict funnel bulges, but said theory is based upon uniform atmospheric conditions. It is conceivable that waterspout diameters may expand as atmospheric parameters change at various altitudes. Rating: 3.

Possible Explanations. Varying atmospheric conditions (temperature, pressure, humidity, wind velocity, etc.) along the spout's funnel may dictate different funnel diameters.

Similar and Related Phenomena.

Examples of Waterspout Funnel-Knots

X1. General observations. "Other strange aberrations have produced 'funnel-knots' at irregular intervals, a great bulge in the upper funnel, and a classic 'hourglass' shape." (R1)

References

R1. Mooney, Michael J.; "Sea Squirts," Oceans, 6:42, May 1973. (X1)

GWT14 Bull's-Eye Squalls or White Squalls

Description. Tornados, strong whirlwinds, and squalls that descend from a clear sky, often presaged by the appearance of a bright region overhead.

Data Evaluation. A brief description in a popular article. Rating: 3.

Anomaly Evaluation. Vortexes and turbulence invisible to the naked eye certainly exist in the upper atmosphere; viz., clear-air turbulence (CAT). Here, our curiosity is attracted by the sudden descent of such vortexes in clear weather. The bull's eye or white area in the sky is also intriguing. Rating: 3.

Possible Explanations. Clear-air turbulence descending to ground level.

Similar and Related Phenomena. Clear-air turbulence (CAT), the explosive onset of whirlwinds (GWW1).

Examples of Bull's-Eye Squalls

X1. General observations. "Undoubtedly the most dangerous spout of all is the dreaded 'Bull's-Eye Squall' or 'White Squall.' Slater Brown explains that: 'On rare occasions, when the air is too dry to produce water in a spout, though all the other conditions are present, there occurs what is known as a white or Bull's Eye Squall.... The Portugese describe a Bull's-Eye Squall as first appearing like a bright white spot at or near the zenith, in a perfectly clear sky and fine weather, and which, rapidly descending, brings with it a furious white squall or tornado. They generally occur off the west coast of Africa." (R1)

References

R1. Mooney, Michael J.; "Sea Squirts," Oceans, 6:42, May 1973. (X1)

GWW WHIRLWINDS AND DUST DEVILS

Key to Phenomena

GWW0 Introduction
GWW1 The Explosive Onset of Whirlwinds
GWW2 Pranks of Whirlwinds and Dust Devils
GWW3 Steam Devils
GWW4 Electrical Properties of Whirlwinds and Dust Devils
GWW5 Energetic Miniature Vortexes

GWW0 Introduction

Whirlwinds and dust devils are rotary disturbances of the atmosphere like tornados and waterspouts, but they are less energetic and often seem a different class of phenomena altogether. The playful vortex that spins up a cloud of leaves on a sun-warmed hillside or tosses a farmer's hay up on the telephone wires is certainly less fearful than the death-dealing tornado that can drive a straw into a telephone pole like a nail. Size and strength are the obvious differences between these classes of vortexes. Another salient feature of whirlwinds and dust devils is their fair-weather occurrence. Unlike tornados and waterspouts, they appear on sunny days without menacing clouds overhead. Their pranks are legend, but they are not entirely harmless either. The larger whirlwinds may be violent enough to rip off roofs; rarely they generate their own thunder and lightning. Even a small whirlwind a couple feet in diameter can upset lawn furniture and cause considerable mischief.

Whirlwinds and dust devils are set in motion by rising columns of warm air that are somehow invested with rotary motion. No one knows if electricity is important in starting these vortexes, but electrical phenomena are often present; viz., lightning and electric-field variations. On rare occasions, whirlwinds seem to be born violently with a sharp, explosive sound, the precise source of which is uncertain. Once in motion, they seem to have lives of their own and do not expire easily. Dust devils, those denizens of hot desert expanses, not only persist but may spawn progeny, or line up with other devils and march along in formation. Spiral dust-devil tracks are well known. But such amusing aspects of vortex behavior are not sufficiently anomalous to be included in this Catalog.

Finally, a special type of vortex called a "steam devil" makes its appearance in this chapter. Seen when the air temperature is much lower than water temperature, steam devils frequently reach hundreds of feet into the air to join clouds overhead---much like tornados and waterspouts. Despite the similarity, the steam devil is a mild-mannered vortex, possibly a hybrid between the whirlwind and the waterspout; and we include it in this section along with the other less energetic vortexes.

GWW1 The Explosive Onset of Whirlwinds

Description. The tendency of small but obviously energetic whirlwinds to begin suddenly, without warning, "out-of-the-blue," often with an explosive sound or a noise akin to distant thunder. Usually, the skies are fair and winds calm before the phenomenon begins.

Data Evaluation. Surprisingly, sudden and noisy debuts of whirlwinds have been recorded rather frequently. Rating: 1.

Anomaly Evaluation. The typical whirlwind is thought to originate when the warm sun causes convection currents, turbulence, and the subsequent formation of vortexes. All of the small lazy whirls of air seen in woods and fields are probably of this type. The explosive commencement of whirlwinds---especially accompanied by a detonation---is not in accord with this surface convection hypothesis. Something more seems required (see below), but it is not likely that current theory will have to be bent very far. Rating: 3.

Possible Explanation. Since the affected area is usually calm prior to the appearance of the whirlwind, it is possible that the vortexes may form aloft and descend suddenly to the surface, perhaps suddenly enough to generate considerable sound.

Similar and Related Phenomena. Bull's-eye squalls (GWT12). The explosive sounds from this phenomenon may account for some Barisal Guns and mistpouffers (GSD).

Examples of the Explosive Onset of Whirlwinds

X1. June 2, 1779. Aberdeenshire, Scotland. "The 2nd of June (1779) sitting by the water we saw a pillar of water rise as high as the tallest tree, and fall down again, after which it rolled along for a considerable space in large rolls as if a cask had been under the water, (and out of those rolls sprung up small strings of water, rising pretty high, as out of the strup of a razor)---The noise it made was such as a firework of powder makes when first set off, but much louder. The day was clear, fine sunshine and not a breath of wind." (R10)

X2. June 29, 1842. Cupar, Scotland. "About half past 12 o'clock, whilst the sky was clear, and the air, as it had been throughout the morning, perfectly calm, a girl employed in tramping clothes in a tub in the piece of ground above the town called the common, heard a loud and sharp report overhead, succeeded by a gust of wind of most extraordinary vehemence, and only of a few moments duration. On looking round, she observed the whole of the clothes, sheets, &c, lying within a line of certain breadth, stretching across the green, several hundred yards distant; another portion of the articles, however, consisting of a quantity of curtains, and a number of smaller articles, were carried upwards to an immense height, so as to be almost lost to the eye, and gradually disappeared altogether from sight in a south-eastern direction and have not yet been heard of. At the moment of the report which preceeded the wind, the cattle in the neighboring meadow were observed running about in an affrighted state, and for some time afterwards they continued cowering together in evident terror. The violence of the wind was such that a woman, who at the time was holding a blanket, found herself unable to retain it in fear of being carried along with it." (R1)

X3. Circa 1879. Signy-le-Petit, France. "The weather was clear, there were no clouds, the air was cold, but still; there was not the least sign of wind. At Signy is an isolated house occupied by one named Chailloux-Binet. It is built of stone and roofed with slate. Suddenly a dull sound was heard, somewhat like the rumble of a carriage drawn by a horse at full gallop, then a whirlwind of irresistible force was formed, which suddenly and instantaneously carried off the roof of the house, and dispersed it in all directions. This whirlwind was neither preceeded nor followed by any rain. It is also extraordinary that this house alone was affected, and at ten metres distance no disturbance of any kind was experienced." (R2)

X4. September 3, 1879. Montgomery County, Maryland. A small but destructive whirlwind began its course with a roar. Several people heard sounds like explosions during its progress. (R4)

X5. Circa 1880. East Kent, Ontario, Canada. Two men were in a field "... when they heard a sudden loud report, like that of a cannon.

They turned just in time to see a cloud of stones flying upward from a spot in the field. Surprised beyond measure they examined the spot, which was circular and about 16 feet across, but there was no sign of an eruption nor anything to indicate the fall of a heavy body there. The ground was simply swept clean." (R3)

X6. August 27, 1886. Lough Neagh, Northern Ireland. "While standing with Mr. S. A. Stewart in a recently-mown meadow, near Portmore Lough, on the eastern side of Lough Neagh, our attention was attracted by a rumbling noise. The day was very fine and warm, and dead calm, not a leaf stirring, and a few very light clouds were in the sky. The noise was like a short distant peal of thunder, but sounded faint rather than distant. While we watched, a whirlwind suddenly appeared in the direction whence the sounds had come (the north), and at a distance of about a hundred yards from us. A quantity of loose hay was instantly whirled upward to a height of about 100 feet, and, after floating about in circles, slowly settled down. A haycock at the spot was much disturbed, and presented the appearance of having endured a gale of wind. The time between the rumbling sound (which closely resembled the distant report of a cannon) and the appearance of the whirlwind was about half a minute, and the whirlwind lasted somewhat over a minute." (R6)

X7. June 21, 1894. Reigate, England. A clear and brilliant day, no wind stirring. A violent whirlwind appeared without warning within a few yards of the observer, carrying hay to great heights." (R5)

X8. 1918. Launceston, England. A small localized whirlwind attracted the attention of observers because it made a noise like distant thunder. (R7)

X9. October 20, 1949. Shoeburyness, England. "Mr. Whitaker, who happened to be outside his office at the time, said that while watching what appeared to be a frontal cloud he heard a muffled sound like distant thunder or an explosion, and on turning to the south-west saw that at a distance of about 1,000 yd. the air was filled to a considerable height with leaves, twigs and similar light debris swirling violently as though after a large but smokeless explosion. He called out two other observers, who saw the subsequent events with him. Almost at once the wind increased to gale force, torrential rain began to fall, and the debris, now quite dense and only a few hundred yards away, was travelling towards them from a south-westerly direction and was observed to be rotating from left to right, i. e. counter-clockwise. The disturbance very quickly arrived where they were standing. Tall trees in leaf were bent over and thrashed about wildly, and one or two broke. These trees had trunks about 1 ft. in diameter and were about 30 ft. high in a row across the path of the disturbance..... The disturbance was all over in about a minute and the heavy rain ceased almost at the same time. The damage was confined to a narrow track about 100 yd. wide or less." (R8)

X10. September 3, 1955. Pilsden Pen, England. During a picnic. "Suddenly at about 1305 BST a sound was heard from the west like sand being loaded into a truck. But only a level stretch of coarse grass was to be seen. Some of the grass in the direction of the sound was then observed to be moving and becoming flattened, while bits of paper were seen whirling in the air, though the wind was light where the party was. In a few seconds the miniature whirlwind was upon the picnickers. It removed a small paper bag, and lifted up an umbrella which had been left open on the ground. This was moved in an anticlockwise manner away north-eastwards over the earthen rampart of the prehistoric fort and about twenty feet up into the air." (R9)

References

R1. "Singular Phenomenon," London Times, July 5, 1842. (X2)
R2. English Mechanic, 29:262, 1879. (X3)
R3. "A Curious Phenomenon," Scientific American, 43:25, 1880. (X5)
R4. Farquhar, William Henry, and Hallowell, Henry C.; "A Miniature Cyclone," Popular Science Monthly, 18:264, 1880. (X4)
R5. "A Whirlwind in Surrey," Symons's Monthly Meteorological Magazine, 29: 90, 1894. (X7)
R6. Praeger, R. Lloyd; "Barisal Guns and Similar Sounds," Nature, 53:296, 1896. (X6)
R7. Rogers, R. B.; "Local Whirlwind," Symons's Meteorological Magazine, 53: 68, 1918. (X8)
R8. Hemens, L. G.; "Whirlwind at Shoeburyness," Meteorological Magazine, 79:256, 1950. (X9)
R9. Ward, Cyril G.; "A Whirlwind," Weather, 11:170, 1956. (X10)
R10. Meaden, G. T.; "A Meteorological Explanation for Some of the Mysterious Sightings on Loch Ness and Other Lakes and Rivers," Journal of Meteorology, U. K., 1:118, 1976. (X1)

GWW2 Pranks of Whirlwinds and Dust Devils

Description. A catch-all category of curious observations connected with whirlwinds and dust devils, such as the propensity of these phenomena to lift up people and things and set them down in unusual places and, more remarkably, the dust devil's "inquisitive" behavior.

Data Evaluation. Only a few tales have been collected so far, but they seem authentic. Probably many stories never get into the scientific literature. Rating: 2.

Anomaly Evaluation. As in the cases of lightning and tornados, the pranks of these small vortexes can doubtless be handled by current theories of aerodynamics and physics. For example, the "inquisitve" behavior of dust devils is likely generated by the observer's modulation of wind patterns. Pranks are fascinating but hardly a challenge to basic scientific laws. Rating: 3.

Possible Explanations. See above.

Similar and Related Phenomena. The inquisitive nature of some ball lightning (GLB1), the pranks of the tornado (GWT7), lightning's pranks (GLL11).

Examples of Pranks Played by Whirlwinds and Dust Devils

X1. February 25, 1911. Bradford, England. A letter to the editor called the report of a girl being killed by a gust of wind preposterous and asked for an investigation. The editor replied: "Acting on this suggestion, we communicated with Mr. H. Lander, the rainfall observer at Lister Park, Bradford, who kindly sent us a copy of the Yorkshire Observer for February 25th, in which there was a fairly full report of the inquest on the school-girl who was undoubtedly killed by a fall from a great height in an extremely exposed playground during very gusty weather. One witness saw the girl enter the playground from the school at 8.40 a.m., and saw her carried in three minutes later. Another witness saw the girl in the air parallel with the balcony of the school 20 feet above the ground, her arms extended, and her skirts blown out like a balloon. He saw her fall with a crash. The jury found a verdict, 'Died as the result of a fall caused by a sudden gust of wind.'" (R1)

X2. No date given. Egypt. While walking over the desert. "Hearing a swishing sound behind me, I turned and observed a large revolving ring of sand less than a foot high approaching me slowly. It stopped a few feet away and the ring, containing sand and small pieces of vegetable debris in a sheet less than one inch thick, revolved rapidly around a circle of about 12 ft. diameter while the axis remained stationary. It then moved slowly around me after remaining in one spot for at least thirty seconds, and slowly died down. It would be interesting to know if others acquainted with the desert have come across similar examples of a broad, flat eddy. The ancient superstition among desert tribes that these whirlwinds are spirits, called 'afrit' or 'ginni' (the 'ginni' of the 'Arabian Nights'), would seem to have a reasonable foundation in face of such an 'inquisitive' apparition," (R2)

References

R1. Godden, William; "The Tale of---a Gust," Symons's Meteorological Magazine, 46:54, 1911. (X1)

R2. Capes, J. L.; "A Remarkable Whirlwind," Nature, 135:511, 1935. (X2)

GWW3 Steam Devils

Description. Long fingers or columns of vapor rising from a water surface and swirling upward into the cloud deck. Large arrays of steam devils may form geometrical patterns. This phenomenon requires warm water and very cold air.

Background. Even the most casual observer has seen mist rising from water surfaces when the air is colder than the water. Sailors call it "sea smoke." Air currents form it into eerie swirls and eddies. Much more rarely analogs of whirlwinds and waterspouts form.

Data Evaluation. A handful of good observations plus some excellent photos. Rating: 1.

Anomaly Evaluation. Thermal convection obviously gives birth to steam devils, but why are they so stable, considering their thinness and height? Why do they sometimes form in geometrical patterns? Since tornados and waterspouts have comparable height-to-diameter ratios, the explanation of steam devil formation will probably evolve from present meteorological theory. Rating: 3.

Possible Explanations. The theory of atmospheric vortexes is probably adequate to account for the genesis and maturation of large steam devils. The geometrical patterns of devils may arise from the tendency of convection cells, in both air and water, to assume a hexagonal geometry.

Similar and Related Phenomena. Dust devils sometimes advance en echelon and may be spawned in clusters. See also descriptions of water slicks and calms (GH).

Examples of Steam Devils

X1. January 4, 1910. Canandaigua Lake, New York. Bright sun, some low cumulus clouds, temperature 6°F. "The surface of the lake was covered by vapor caused by the difference in temperature between the cold air and the comparatively warm water. This vapor, white mist, gathered in spots in masses rising higher than the surrounding mist. As these masses of vapor reached a height of some twenty feet they appeared to take on a rotary motion and formed themselves into columns slowly rising until their apexes met the low-lying clouds, where they spread out in a funnel shape exactly as do water spouts. The columns varied from a foot to possibly ten feet in diameter; some of them ascending in a straight line and others bent into fantastic curves by the action of the wind. I saw a great number of these mist whirls during a drive of some two hours, covering a distance of ten miles along the lake shore, and as they formed and drifted slowly across the water, illuminated by the rays of the setting sun, they were a beautiful and to me a unique spectacle." (R1)

X2. Circa 1932. Grecian waters. "Prof. (Johannes) Walther tells of a recent voyage in Grecian waters, when a snowstorm was brewing and the waves were high. The cold air striking the warm water caused numerous columns of white vapor to rise over the foamy caps of the waves. They hovered momentarily, then were caught up whirling by the wind, and as they spun away through the air it did not require any violent stretch of the imagination to see them as feminine figures dancing in filmy draperies." The professor wondered if these steam devils might not be the origin of the tales of the Daughters of Nereus who danced on the waves and helped endangered mariners. (R2)

X3. January 30, 1971. Lake Michigan off Milwaukee, Wisconsin. "The period Jan. 30-31, 1971 was intensely cold in Milwaukee, the highest temperature reaching only -6°F with west-northwest winds frequently gusting to 40 mi/hr. Lake snow squalls were present in excelsis along the lee shores of all the Great Lakes. But most interesting was the view from the upwind shoreline. During both days, one could see the typical shallow, dense steam fog near the lake surface (water temperature 33°F) and the cumulus clouds building a few miles offshore. What was unusual were the numerous distinct fingers of columns of vapor swirling out of the steam fog layer directly into the overlying cumulus clouds. It is estimated that they were 50-200 m in diameter, traveled more or less with the wind, were nearly vertical, and showed a slow but distinct rotation (mostly cyclonic) of up to several revolutions per minute. The steam devils tended to be rather short lived, the longest surviving perhaps for 3 or 4 min. An even more interesting view of the same phenomena was taken from a commercial airliner on Jan. 30, 1971..... Visible are small cumulus (which were forming further offshore on this day), plus the steam devils and a highly patterned effect on the surface steam fog. It definitely appears that there were quasi-hexagonal cells elongated along the surface wind direction, the largest steam devils being present at the vertexes of the hexagons."(R3)

References

R1. Lee, James S.; "A Curious Phenomenon," Scientific American, 102:103, 1910. (X1)

R2. "Pillars of Sea Mist May Be Foundation of Myth," Science News Letter, 22:84, 1932. (X2)

R3. Lyons, Walter A., and Pease, Steven R.; "'Steam Devils' over Lake Michigan during a January Arctic Outbreak," Monthly Weather Review, 100:235, 1972. (X3)

GWW4 Electrical Properties of Whirlwinds and Dust Devils

Description. Visual observation of electrical discharges associated with fair-weather dust devils and whirlwinds and instrumented measurements of their associated electric fields.

Data Evaluation. A few visual observations of overt electrical activity (lightning) complemented by data from electric-field meters. Rating: 1.

Anomaly Evaluation. Clouds of airborne particles (dust, snow, etc.) are normally electrically charged. It is therefore not surprising that dust devils and whirlwinds display some electrical properties. The unusual aspects of this phenomena are the actual production of thunder and lightning under clear skies and the difficult-to-model electric field profiles of passing dust devils. There are, however, no real challenges to prevailing meteorological theories. Rating: 3.

Possible Explanations. The electrical properties of whirlwinds and dust devils merely signify extreme cases of charge separation in dusty vortexes. Nevertheless, no ready explanation seems to exist for the curious electric-field profiles of dust devils.

Similar and Related Phenomena. Electrical phenomena accompanying snowstorms and duststorms (GLD5), electrical properties of tornados (GWT1).

Examples of the Electrical Properties of Whirlwinds and Dust Devils

X1. 1902. Arizona. "I was on the White Mountain Apache reservation, in Arizona, on the day in question, when an ordinary desert whirlwind whirled into view from just around a southerly projecting point of land north of White River from the now abandoned Fort Apache. I had just crossed a flat area among the hills where an ancient lava flow once spread out, forming a 'lava lake,' an area probably six miles across from the afore-mentioned point to the mountainous hills to the northwestward, up which I was then ascending. In a moment it began to gain momentum on entering the level country and in a minute more it was a roaring funnel that was hurling immense quantities of dirt and sand skyward so that they formed an umbrella-like cloud around the apex of the whirling center. As the twister was coming in my direction, I shifted southward over a gulch to another ridge to escape its fury. On it came. It entered the canyon in which I had been only a minute before. Here as the canyon both wedged-in and ascended toward the mountains in the direction it was going, the rushing whirl became 'angry,' as it were. The day had been perfectly clear. Yet in a moment there were chain lightning and ripping thunder on every side, while at the same time the whirler uprooted trees and tore large-sized boulders from their places on the canyon walls, finally destroying itself in that canyon. From my observations I am inclined to believe that the electrical display that accompanied this whirl was due to the friction caused by the whirling debris." (R1)

X2. September 29, 1959. Sahara Desert. Experimental observations. "At the time of obtaining measurements on the earth's electric field during an eclipse of the sun in the Sahara Desert at Kidal, French West Africa, an interesting record was obtained on the electric field associated with a large dust devil. This record is shown in Figure 1, where positive values of the field imply positive charge above the earth. The dust devil was estimated to be between 100 and 200 meters high and about 8 meters in diameter, and its distance of closest approach to the electric field mill was about 30 meters. It was of sufficient strength to raise an army-type sleeping cot several meters into the air, and it was followed by truck for about 1 mile beforeit dissipated its energy. Its speed across country was about 4 m/sec.

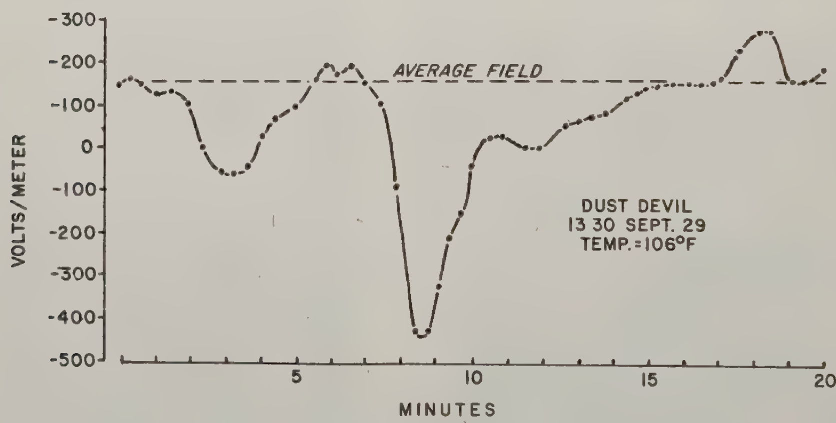
The two negative excursions with a tendency to go positive between them suggests a sort of dipole structure for the dust devil with negative charge above (inverted thunderstorm)." (R3)

X3. August 21, 1962. Socorro, New Mexico. Experimental observations. Measurements of the electric field of a New Mexico dust devil revealed a structure qualitatively similar to that of X2. Little success was had in constructing a model that would account for the electric field structure determined in the field. (R4)

X4. General observations. "A piece of metal inserted into a dust devil a few feet above the ground becomes strongly charged with respect to ground, the amount of charge and its polarity being apparently a function of the nature of the dust particles." (R2)

References

R1. Reagan, Albert B.; "Sand-Storm Electricity," Science, 71:506, 1930. (X1)
R2. Ives, Ronald L.; "Behavior of Dust Devils," American Meteorological Society, Bulletin, 28:168, 1947. (X4)
R3. Freier, G. D.; "The Electric Field of a Large Dust Devil," Journal of Geophysical Research, 65:3504, 1960. (X2)
R4. Crozier, W. D.; "The Electric Field of a New Mexico Dust Devil," Journal of Geophysical Research, 69:5427, 1964. (X3)



Electric field of a passing New Mexico dust devil (X3)

GWW5 Energetic Miniature Vortexes

Description. Powerful vortexes measuring just a few feet in diameter and perhaps as tall as a person. Many dust devils, whirlwinds, and incipient waterspouts are only a foot or two in diameter and yet display surprising power.

Background. Anyone who spends much time outdoors sees small whirlwinds kicking up loose leaves and grass. The justification for this entry is the word "energetic," which is admittedly vague but allows leeway for including a wide variety of small yet unexpectedly powerful vortexes.

Data Evaluation. Scrutiny of hundreds of whirlwind accounts has yielded only a few examples of tiny but energetic vortexes. Rating: 3.

Anomaly Evaluation. It is a real puzzle how any accepted meteorological mechanism, particularly thermal convection, can concentrate so much energy in a small vortex. Rating: 2.

Possible Explanations. None.

Similar and Related Phenomena. All rotary disturbances (GWT and GWW).

Examples of Miniature vortexes

X1. April 16, 1872. St. Asaph, England. "On Saturday last, April 16, whilst fishing in the river Elwys at a point about two miles above the well-known Cefn caves, and five from St. Asaph by the river, I witnessed a very singular phenomenon. My attention was suddenly called up-stream by a remarkably strange, hissing, bubbling sound, such as might be produced by plunging a mass of heated metal into water. On turning I beheld what I may call a diminutive waterspout in the centre of the stream, some forty paces from where I was standing. Its base, as well as I could observe, was little more than two feet in diameter. The water curled up from the river in an unbroken cylindrical form to a height of about fifteen inches, rotating rapidly, then diverged as from a number of jets, being thrown off with considerable force to an additional elevation of six or seven feet, the spray falling all round as from an elaborately arranged fountain, covering a large area. It remained apparently in the same position for about forty seconds, then moved slowly in the direction of the right bank of the river, and was again drawn towards the centre, where it remained stationary as before for a few seconds. As it moved in the former direction, gradually diminishing and losing force as it neared the bank, and finally collapsed in the shallow water. Strange to say, its course was perpendicular to the bank and not with the current." (R1)

X2. July 19, 1913. Hepple, England. "...a narrow strip of wind 1 1/2 ft. wide, drove through a hedge, lifting newly cut hay 60 yards high, proceeded through a tree with great violence, blowing off the leaves of a hedge and tree, and upset a haycock in an adjoining field. It lasted some 10 minutes and was accompanied by great noise." (R2)

X3. No date given. Egypt. "Dust-devils, or rotating columns of sand travelling rapidly across open spaces, are not uncommon objects to desert travellers. Their height and breadth is often very considerable and the evidence of the eddies causing them very great. The smallest of this type I have seen was only about 5 ft. high, that is, the visible column of sand, and less than a foot in diameter. It passed so close to me that it was easy to see its narrow cycloidal path marked on the sand, which was deposited and lifted as the eddy travelled on at not less than 15 miles an hour, although the wind was actually very light." (R3)

References

R1. Gray, J.; "A Waterspout," Nature, 5: 501, 1872. (X1)

R2. Clark, J. Edmund; "A Narrow Squall," Symons's Meteorological Magazine, 49: 52, 1914. (X2)

R3. Capes, J. L.; "A Remarkable Whirlwind," Nature, 135:511, 1935. (X3)

TIME-OF-EVENT INDEX

44 BC	---	GWD1-X1
30	---	GWD1-X2
96	---	GWD1-X3
358	Aug 22	GWD1-X4
409	---	GWD1-X5
536	---	GWD1-X6
567	---	GWD1-X7
626	---	GWD1-X8
689	---	GWF10-X1
733	Aug 19	GWD1-X9
860	---	GWF7-X19
934	---	GWD1-X10
1091	Sep 29	GWD1-X11
1106	Feb 12	GWD1-X12
1206	Feb 28	GWD1-X13
1208	---	GWD1-X14
1241	---	GWD1-X15
1295	Mar	GWP5-X1
1406	---	GWF7-X20
1547	Apr 23	GWD1-X16
1548	---	GWF7-X21
1557	---	GWF7-X22
1574	---	GWD1-X18
1638	Oct 21	GWF7-X1
1642	Jun	GWF3-X1
1646	May 16	GWF3-X2
1666	Spr	GWF10-X2
1673	---	GWF10-X3
1681	Jul	GWF2-X1
1682	May 31	GWP12-X1
1686	Jan 31	GWF9-X2
1691	---	GWF10-X4
1694	Aug	GWD3-X6
1695	---	GWF9-X14
1698	Jun 19-20	GWF10-X5
1706	---	GWD1-X17
	May 12	GWD1-X19
1716	Oct 21	GWD1-X20
1718	Mar 24	GWF7-X2
1720	Aug	GWD3-X7
1732	Aug 9	GWD1-X21
1741	Sep 21	GWF8-X1
1762	Oct 19	GWD1-X22
1769	---	GWP4-X1
1771	Sep 2-3	GWF10-X6
1772	Oct 28	GWP11-X1
1773	Sep 22	GWP11-X2
1779	Jun 2	GWW1-X1
1780	May 19	GWD1-X23
1783	Sum	GWD4-X1
1785	Oct 16	GWD1-X24
1786	May 5	GWF9-X20
1794	Sum	GWF11-X1
1795	---	GWF10-X7
	Jul 25	GWF10-X8
1796	---	GWF10-X9
	Mar 8	GWF7-X3
1800	---	GWD1-X56
	Apr 23	GWP1-X1
1802	May 8	GWF1-X2
1803	Jan 21	GWF7-X4
1804	---	GWF11-X3
	Aug	GWF11-X2
1806	---	GWP4-X44
1809	---	GWF10-X10
	Jun 9	GWP12-X2
	Jun 23	GWF11-X4
1811	May 12	GWF1-X3
1814	---	GWD1-X26
	Jul 3	GWD1-X25
	Aug	GWF11-X5
1815	---	GWF4-X3
1817	Mar	GWF10-X11
1818	Jul 24	GWF1-X4
1819	---	GWP4-X3
	Jun	GWF12-X1
	Jul 4	GWP4-X12
	Aug 13	GWF7-X5
	Nov 6-10	GWD1-X27
1820	---	GWF3-X3
	Aug 31	GWP5-X2
	Oct 1	GWF8-X2
1821	---	GWF10-X12
	Sum	GWF14-X8
	Aug	GWD4-X2
1822	Jan 25	GWP11-X3
	Apr 10	GWP5-X3
	May	GWD4-X3
	Aug	GWF11-X6
	Oct 25	GWP12-X3
1823	Jun 27	GWP4-X13
1824	---	GWF5-X1
		GWF10-X66
	Sum	GWF10-X14
	Jul	GWF10-X13
1825	---	GWF10-X15
	Jul 5	GWF10-X77
1826	---	GWF1-X5
	Jul	GWF10-X16
1828	---	GWF5-X2
	Apr 21	GWF10-X18
	May 28	GWF10-X17
	Sum	GWF10-X19
1829	Jun 15	GWF1-X6
		GWP4-X38
		GWP5-X4
	Jul 20	GWF10-X20
1830	---	GWF10-X22
		GWF11-X7
		GWF11-X8
	Feb 19	GWF10-X21
	Mar 9	GWF10-X23

1831	---	GWD4-X4
	May 16/17	GWF10-X24
1832	---	GWD3-X1
	Mar	GWF3-X3
	Apr 11	GWF3-X18
1833	---	GWF10-X25
	Jun	GWF11-X9
	Nov 13	GWF7-X6
		GWF7-X7
		GWF7-X8
		GWP1-X2
1834	---	GWF11-X36
	Aug 9	GWF14-X4
	Aug 26	GWP4-X2
		GWP4-X14
		GWP8-X1
1835	---	GWF10-X27
		GWF14-X5
	May	GWF10-X26
1836	Jul	GWD1-X28
1837	Aug 9	GWP1-X3
1838	---	GWF10-X28
	Apr	GWF1-X7
	May 22	GWF1-X8
	May 31	GWP1-X4
	Jul 30	GWF11-X10
1839	Jun	GWT2-X1
	Sep 20	GWF10-X29
1840	Mar 24	GWF9-X12
1841	---	GWF11-X12
	Spr	GWF5-X3
	Jun	GWF3-X4
		GWF11-X11
	Jun 30	GWF10-X30
	Jul 8	GWF10-X31
	Aug 17	GWF9-X3
	Oct	GWF10-X32
1842	Apr 21	GWP1-X5
	Jun	GWP8-X2
	Jun 29	GWW1-X2
1844	---	GWF11-X13
	Oct	GWF1-X9
	Oct 8	GWF7-X10
	Nov 1	GWP11-X4
1845	---	GWF6-X1
	Aug 19	GWT2-X2
1846	Jan	GWF5-X4
	Apr	GWF5-X4
	Sum	GWF2-X2
		GWF11-X14
	Nov 11	GWF7-X11
1847	---	GWF11-X15
	Jul 8	GWP12-X4
1848	---	GWD3-X2
	Apr 18	GWF5-X5
	Sep 24	GWF9-X6
1849	---	GWD3-X2
		GWP12-X5
	May 3	GWP12-X6
	Jul 25-26	GWP15-X1
	Aug	GWF1-X10

1850	---	GWF3-X5
	Jul 25	GWF10-X33
	Sep	GWF2-X3
1851	Mar 18	GWF2-X5
	Apr 30	GWF2-X6
	May	GWF14-X9
	May 22	GWF1-X11
		GWP5-X6
	Aug 13	GWP5-X5
	Sep 25	GWF2-X4
1852	Aug 3	GWF10-X34
1854	---	GWD1-X3
	Nov	GWF12-X2
1855	Jul 26	GWP1-X6
1856	May 13	GWF2-X7
	Jun 9	GWP6-X1
	Nov 14	GWF4-X7
1857	Mar 23	GWD1-X29
	Apr 17	GWP1-X7
	May 20	GWD1-X30
	Jun 17	GWF4-X10
	Aug	GWF1-X12
	Dec	GWF14-X14
1858	Apr 29	GWF2-X8
	Jun 12	GWF2-X10
1859	---	GWF11-X16
		GWS5-X1
	Feb 9	GWF10-X35
	May 29	GWP4-X51
		GWP7-X1
1860	---	GWF11-X17
		GWT2-X3
	Jan 14	GWP4-X39
	Mar 16	GWF1-X13
	Apr 11	GWD1-X31
	Jun 3	GWT1-X1
		GWT7-X1
	Jun 18	GWF3-X19
	Jul 3	GWF14-X15
1861	Feb 20	GWF10-X36
	Feb 21	GWF10-X36
	Feb 26	GWF10-X36
	Sep	GWF6-X2
1862	May 7	GWP4-X59
1863	---	GWP4-X4
	Jul 3	GWP6-X2
	Oct 16	GWD1-X32
	Nov 15	GWP4-X40
1864	---	GWF11-X18
	Jul	GWF5-X6
	Aug	GWP12-X7
1866	---	GWD3-X4
	Jun 27	GWP7-X2
1867	Mar 12	GWF3-X20
	Mar 28	GWP5-X7
	May 9	GWF9-X7
	Oct 18	GWF3-X6
1868	Apr 29	GWF2-X8
	Jun 9	GWF10-X37
	Sep 15- Oct 20	GWD1-X33

1869	May 25	GWF2-X9
	Jun 6	GWF14-X6
	Jun 9	GWP4-X5
	Jun 21	GWP4-X6
1870	Feb 14	GWF3-X7
		GWF3-X21
	Mar 22	GWC7-X1
	Jun 20	GWP4-X52
	Aug 18	GWC14-X1
	Oct 30	GWC3-X1
	Dec	GWF9-X17
1871	---	GWP8-X3
	Apr 8-9	GWC3-X2
	May	GWF12-X3
	Aug 12	GWF11-X19
	Oct	GWR2-X1
1872	Apr 10	GWC3-X3
	Apr 16	GWW5-X1
	Jun 18	GWC3-X4
	Jul 25	GWF12-X4
	Aug 20	GWF4-X4
	Oct 23	GWC3-X5
1873	---	GWF14-X17
	May 24	GWF10-X38
	Jun 3	GWP4-X61
	Jun 17	GWF3-X8
	Jul	GWF11-X20
	Jul 2	GWP4-X62
	Sep 11-12	GWC3-X6
1875	---	GWF10-X39
	Jul 27	GWF6-X3
	Aut	GWP5-X8
1876	---	GWP4-X7
		GWF9-X19
	Mar 31	GWP4-X15
1877	Jan 15	GWF14-X16
	May 3	GWP5-X9
1878	Apr 11	GWP4-X26
	Jun 14	GWP12-X8
	Dec 1	GWP4-X27
1879	---	GWF9-X1
		GWF10-X40
		GWW1-X3
	Jun 29	GWP4-X8
	Sep 3	GWW1-X4
1880	---	GWT2-X4
		GWW1-X5
	Apr 25	GWF3-X22
	Jun 14	GWP4-X45
	Jun 26	GWF2-X11
	Aug 21	GWP4-X28
	Sep 27	GWC16-X1
1881	---	GWC5-X1
	Jun	GWF1-X14
		GWP5-X10
	Jun 8	GWF14-X1
	Jul	GWP4-X29
	Sep 6	GWD1-X34
	Oct	GWF8-X4
	Oct 21	GWP12-X9
1882	Jan 22	GWD1-X35

	Jun 16	GWF11-X21
	Aug	GWF1-X15
1883	---	GWF2-X12
		GWF2-X15
	Apr 18	GWF3-X9
	May 18	GWT7-X2
	Jul 12	GWP5-X11
	Jul 16	GWP5-X12
	Aug 2	GWP12-X10
	Dec 15	GWF10-X41
1884	Apr 26	GWD1-X36
	Jun 17	GWF6-X4
1885	---	GWF4-X8
		GWF14-X10
	Apr 10	GWT1-X2
1886	---	GWF10-X42
		GWF14-X11
	Mar 19	GWD1-X37
	May 12	GWF3-X10
	Jul 8	GWF14-X12
	Aug 27	GWW1-X6
	Oct	GWD1-X38
1887	---	GWF5-X7
	Jan 7	GWP2-X1
	Jan 24	GWF10-X43
	Jan 28	GWP2-X2
	Apr 24	GWP4-X19
	May 2	GWP4-X58
	May 20	GWP4-X54
	Aug	GWF2-X16
	Nov 19	GWD1-X39
1888	---	GWF10-X44
	May	GWP5-X13
	Jun 9	GWP12-X11
	Jun 25	GWP4-X50
	Jul 22	GWP1-X8
	Nov 28	GWP4-X16
1889	---	GWF10-X45
	Apr 2	GWD1-X40
	Oct	GWF6-X10
	Oct 1	GWP4-X9
1890	---	GWT7-X3
	Apr 8	GWP4-X55
	Sum	GWF10-X46
		GWF11-X22
	Aug	GWF5-X8
	Aug 18	GWT2-X5
	Oct 15	GWF2-X17
1891	---	GWF11-X23
	Jul 26	GWF6-X5
	Aug 18	GWT2-X6
1892	---	GWF2-X18
		GWP1-X9
		GWP11-X5
	Mar 4	GWF3-X11
	May 11	GWT7-X4
	May 29	GWF10-X47
	Jun 30	GWF11-X24
	Jul 3	GWP12-X12
	Aug 9	GWF14-X7
	Sep 20	GWF8-X5

	Dec 6	GWP5-X14
1893	---	GWF10-X48
	Apr 28	GWF9-X10
	Jun	GWF4-X5
	Jul 2	GWP12-X13
	Aug 22	GWP4-X30
	Dec 6	GWF1-X16
1894	--	GWF11-X25
		GWP9-X1
	Jan 20	GWF14-X13
	Jan 24	GWP2-X3
	Apr 7	GWF6-X11
	Apr 13	GWF3-X12
	May 11	GWF14-X18
		GWP8-X4
	May 17	GWP4-X31
	Jun 2	GWP4-X41
	Jun 21	GWW1-X7
	Aug	GWF11-X26
		GWF14-X2
	Sep 2	GWD1-X41
1895	Feb 6	GWP1-X10
	Jun 15	GWF10-X49
1896	---	GWF13-X1
	May 27	GWT7-X5
	Jul	GWD1-X42
	Jul 26	GWF10-X50
1897	---	GWF12-X5
	Jun 30	GWF6-X6
	Aug	GWF1-X17
	Aug 10	GWP4-X42
1898	---	GWP12-X14
	Mar 21	GWF3-X13
	May 16	GWT12-X1
1900	Feb 25	GWP4-X32
	Mar	GWF5-X10
	Mar 12	GWC3-X7
	Mar 25	GWP2-X4
	Apr 1	GWF6-X12
	May 15	GWF10-X51
	Sum	GWF10-X52
1901	---	GWF11-X27
	Aug 8	GWP4-X47
1902	---	GWP1-X11
		GWW4-X1
	Jun 1	GWF3-X14
	Jun 7	GWP4-X20
	Sum	GWP5-X15
	Jun 27	GWF10-X53
	Jul 12	GWP4-X46
	Sep 12	GWD1-X43
1903	Jun 5	GWD1-X44
1904	Apr 15	GWD1-X45
	Mar 13-14	GWF13-X3
	Dec 2	GWD1-X46
1905	---	GWT7-X6
1906	Apr 8	GWF3-X23
	Jun 7	GWF6-X7
1907	May	GWP4-X21
	Jun 18	GWP12-X15
1908	---	GWP7-X3
	May 4	GWF3-X15
	May 21	GWF3-X15
	Jun 30	GWD1-X47
1909	Apr 14	GWF10-X54
	May 24	GWT3-X1
	Jul 13	GWF2-X20
1910	Jan 4	GWW3-X1
	May 8	GWP4-X22
	Aug 20-25	GWD1-X48
1911	---	GWF11-X28
	Feb 25	GWW2-X1
	Jun 24	GWF9-X13
	Sep 20	GWR1-X1
	Nov 4	GWR1-X2
	Nov 11	GWP9-X2
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	Dec 13	GWF13-X4		Aug 18	GWT6-X1
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