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ON THE TELEGRAPHIC DETERMINATIONS OF LONGITUDE BY THE BUREAU OF NAVIGATION.

By Lieut. J. A. Norris, U. S. N.

The following definitions are given by Chauvenet in his Spherical and Practical Astronomy.

"The longitude of a point on the earth's surface is the angle at the Pole included between the meridian of that point and some assumed first meridian. The difference of longitude between any two points is the angle included between their meridians." To describe the practical methods of obtaining this difference or angle, by means of the electric telegraph both overland and submarine, and especially those employed by the expeditions sent out by the Navy department, is the object of this paper.

Before the invention of the telegraph various methods more or less accurate in their results were employed, and are still in use where the telegraph is not available. The one most used and giving the best results was that in which a number of chronometers were transported back and forth between two places the difference of whose longitudes was required. "For," as the author quoted above says, "the determination of an absolute longitude from the first meridian or of a difference of longitude in general, resolves itself into the determination of the difference of the time reckoned at the two meridians at the same absolute instant." If a chronometer be regulated to the time at any place *A*, and then transported to a second place *B*, and the local time at *B*, be determined at any instant, and at that instant the time at *A*, as shown by the chronometer is noted, the difference of the times is at once known, and that is the difference of longitude required. The principal objection to this plan is that the best chronometers vary. If the variations were constant and regular, and the chronometer always gained or lost a fixed amount for the same interval of time, this objection would disappear. But the variation is not constant, the rate of gain or loss, even in the best instruments, changes from time to time from various causes. Some of these causes may be discovered and allowed for in a measure, others are accidental and unknown. Of the former class are variations due to changes of temperature. At the Naval Observatory, chronometers are rated at different temperatures, and the changes due thereto are noted, and serve to a great extent as a guide in their use. But the transportation of a chronometer, even when done with great care is liable to cause sudden changes in its indications, and of course in carrying it long distances, numerous shocks of greater or less violence are unavoidable. Still, chronometric measurements, when well carried out with a number of chronometers and skilled observers have been very successful. Among notable expeditions of this sort was that undertaken in 1843, by Struve between Pulkova and Altona, in which eighty-one chronometers were employed and nine voyages made from Pulkova to Altona and eight the other way. The results from thirteen of the chronometers were rejected as being discordant, and the deduced longitude was made to depend on the remaining 68. The result thus obtained differs from the latest determination by $0^s.2$.

The U. S. Coast Survey instituted chronometric expeditions between Cambridge, Mass., and Liverpool, England, in the years 1849, '50, '51 and '55. The probable error of the results of six voyages, three in each direction, in 1855 was $0^s.19$, fifty chronometers being carried.

Among other methods of determining differences of time may be mentioned the observation of certain celestial phenomena, which are visible at the same absolute instant by observers in various parts of the globe, such as the instant of the beginning or end of an eclipse of the moon, the eclipses of Jupiter's satellites by the shadow of the planet, the bursting of a meteor, and the appearance or disappearance of a shooting star. The difficulty of identifying these last mentioned objects and the impossibility of foretelling their occurrence prevents the extended use of this method.

Terrestrial signals may be used and among these can be included those sent by the electric telegraph. But when two stations are near together a signal may be made at either or at an intermediate station, which can be observed at both, the time may be noted at each of the stations and the difference found directly. These signals may be made by flashes of gunpowder, or the appearance and disappearance of a strong light, or a preconcerted movement of any object easily seen. The heliotrope reflecting the image of the sun from one station to the other with an arrangement for suddenly eclipsing it, is a useful and efficient apparatus.

Various truly astronomical methods have been employed with good results, of these may be mentioned moon-culminations, azimuths of the moon, lunar distances, etc.

Coming now to the use of the electric telegraph for this purpose the following is a rough outline of the methods employed. Suppose two stations A and B connected by wire, and provided with clocks, chronographs and transit instruments. A list of suitable fixed stars is compiled and each observer furnished with a copy. The observer at A the eastern station, selects a star from his list and sets his transit instrument upon it. He is furnished with a key by which he can send telegraphic signals over the line and also mark the time on his own chronograph. The instant he observes the star crossing the spider line which represents the meridian, he taps his key, thus registering the time on his own chronograph and on that at station B and this operation he repeats with as many stars as necessary. B has his instrument set for the first star, and when it crosses his meridian, he taps his key marking the time on his own chronograph and also on A's. Then, disregarding instrumental and personal errors and the rate of the clock, A has a record of the times at which the star passed both meridians. The difference of these times is the difference of longitude sought, except for an error due to the time occupied in the transmission of the signal over the wire between the stations. B also has a record of the same difference of time with the same error affecting it in the opposite way. A mean of these two differences, will be the true difference with the error of transmission eliminated. This method has the advantage of not depending upon the computed position of the star. The instrumental errors may be allowed for, as well as the rate of the clocks, and the personal error may be eliminated by the exchange of stations.

There are disadvantages inseparable from this method, however, especially when the meridian distance is great. A star observed at the first station, may be obscured by clouds at the time of its meridian passage at the second. And the weather generally, at the two stations may be cloudy, so that while stars can be observed at intervals, yet it may be impossible to note the meridian passage of the same star at both places on the same night. Then the telegraph lines are usually the property of some commercial company and while their use for a short time might be freely granted, yet a protracted occupation of them as necessary when the meridians are distant from each other, would prove a serious hindrance to their regular business.

The method at this time most generally employed, is to observe at each station a number of stars entirely independently of the other. From these stars are deduced the clock errors and rates upon the respective local times. Then at some prearranged period, communication is opened between the stations, and a comparison of the clocks made which shows their exact difference at a given instant. By applying the error to the time as shown by the clock at this instant, the exact local time at each station is the result, and applying the difference between the clocks as shown by the comparison, the required difference of longitude is readily obtained.

These methods originated, as did the electric telegraph, in the United States, and soon after Morse's invention came into practical use, they were extensively employed by the Coast Survey, in accurately determining points in every part of the country that could be reached, no pains being spared to make the determinations as accurate as possible. Upon the completion of the first successful Atlantic cable in 1866, an expedition was organized and placed in charge of Dr. B. A. Gould, for the purpose of measuring the meridian distance between Greenwich and the Naval Observatory at Washington. This was successfully carried out in spite of numerous difficulties, and the result proved that the determinations already made upon which the most reliance was placed were decidedly in error. The result from the chronometric expedition in 1855 previously referred to differing over a second of time.

In constructing charts for use at sea, the accurate determination of latitude and longitude is of the utmost importance. The navigator starting on a voyage must know the exact position of his destination as well as the location of dangers to be avoided. He must know the error and rate of his chronometer when he sets out, but as the rate is not constant he should have some means of re-rating it at any place where he may stop. If the longitude of this place is well determined, the operation of obtaining the error and rate is an easy one, and may save his vessel from loss.

Surveys, of coasts or countries must have well established starting points, and while the latitude of a place is comparatively easy to determine, the longitude, except when the telegraphic method is used, is attended with more or less uncertainty.

In 1873, Commodore R. H. Wyman, U. S. N. Hydrographer to the Bureau of Navigation, organized by permission of the Navy Department, an expedition for the telegraphic determination of longitude in the West Indies and Central America. The submarine cables of the West India and Panama Telegraph Co. had just been completed, extending from Key West through Havana and Santiago de Cuba, south to Jamaica and Aspinwall, and east through the Virgin and Windward Islands to the northeast coast of South America, thus affording admirable facilities for the accurate determination of many points. It had long been known that the longitudes of various points in the West Indies and in Central and South America, did not harmonize, there having been no systematic attempt to determine them with relation to each other or to a common base. Longitudes in the western part of the Caribbean Sea depended upon the position of the Morro lighthouse at Havana, which had been determined by occultations. Further to the eastward, positions depended upon that of Fort Christian at St. Thomas. This in its turn depended upon the observatory of Major Lang in the Island of Santa Cruz about forty miles distant. This position depended upon numerous observations of moon culminations and occultations. Martinique and Guadeloupe in the Windward Islands had been surveyed by French officers who based their positions upon longitudes derived from moon culminations. The absolute determination of these starting points would of course fix all points derived from them.

The U. S. Steamer Fortune was designated by the Navy Department for the conveyance of the expedition, and Lieut. Commander (now Commander), F. M. Green, U. S. N. was placed in charge. This officer had given great attention to the subject, was a practiced observer, and exceptionally well qualified for the position. The services of Mr. Miles Rock, a skillful astronomer and computer who is now chief of the boundary survey of Guatemala, were obtained as principal astronomical assistant. The breaking out in the autumn of 1873, of the trouble with Spain and Cuba, over the Virginius affair, delayed the expedition until the next year, but in November 1874, a start was made from Washington, and after a short stay in Kingston, Jamacia, Aspinwall was reached early in December. Mr. Rock with one set of instruments proceeded immediately to Panama, while Lieut. Commander Green remained in Aspinwall with the other. The outfit for each party consisted of :—first, a portable observatory. This was made of wood in sections, framework of ash, covered with tongued and grooved pine boards. The sections were connected when set up by iron knees and bolts. When packed it was not difficult to transport, and it could be put up, or taken down in an hour. When set up it was about eight feet square, with doors in all sides, and a shed roof. The roof was made in three sections, the middle one being hinged so that it could be raised for observing. These observatories proved to be very strong and serviceable. They remained in use for a number of years with occasional slight repairs, were transported many thousand miles and set up in a great number of places in Europe, Asia, North and South America. They were designed by Mr. J. A. Rogers, and constructed at the Washington Navy Yard. Upon arriving at a point where observations were to be made, after obtaining the necessary permits from the local authorities, a suitable location for the observatory was the first consideration. The essential requirements were, a clear view of the heavens in the meridian, firm ground, a spot secluded enough not to attract attention from inquisitive idlers, and proximity to the telegraph office, or end of the telegraph line. Such a spot being found and permission being obtained from the owner for its use, an approximate meridian line was laid out by compass, and the house set up with reference to it. Experience soon showed the advisability of making certain additions to the observatory not contemplated by the designer, but which added much to convenience and comfort.

A foundation was made, of timbers about six inches square, mortised together at the ends which could be placed in position and leveled before the observatory was set up, rendering this operation much easier and giving greater stability. A floor was laid upon joists supported by this foundation. Shelves were put up at various points, affording resting places for tools and small instruments, while a table in one corner, supported the chronometer, and offered a convenient place for an assistant to record observations, etc.

The principal instrument used was the transit. Those furnished for the use of the expedition were designed by Mr. J. A. Rogers, and constructed under his supervision in the repair shop of the Hydrographic office. The object glasses, made by the Clarks at Cambridge, were of 2½ inches clear aperture with a focal length of thirty inches. The instruments were of the prismatic or "broken" form in which the eye piece is at one end of the axis, and the light is reflected from the object glass to the eye by a prism placed at the junction of the telescope tube with the axis. The observer does not have to change the position of his eye, no matter what the zenith distance of the star may be. This renders observation much less fatiguing and conduces to accuracy. The eye-piece was furnished with the usual spider line reticle and also with a filar micrometer for the measurement of zenith distances for latitude. A vertical finding circle was on the eye-piece end of the axis, and the instrument was provided also with a horizontal circle, fourteen inches in diameter, graduated to ten seconds. Other necessary parts were the striding and zenith telescope levels, and the illuminating lamps. The ends of the axis were supported by Ys at the ends of a transverse arm which in its centre was screwed to the top of a vertical axis supported in a socket surmounting the tripod. This vertical axis was slightly conical in shape and accurately fitted into its socket. A screw was so placed underneath, that the axis, and with it the instrument, could be raised slightly, when it was easily revolved horizontally into any desired position, a reverse movement of the screw then lowered the axis into its seat, when the instrument was held firmly by the friction. For supporting the instrument there was used at first, a portable pier made in the shape of the frustrum of a cone, of strong oak staves, firmly bound with iron hoops, and when set up, filled with sand or earth. Subsequently a brick pier was found to be more stable and the wooden ones were discarded.

Of equal importance with the transit was the Chronometer. The expedition was supplied with four of these made by Negus of New York. They were regulated to sidereal time, and provided with a break circuit arrangement. This consists of a toothed wheel acting on a jewel pallet attached to a light steel spring. In this spring is a platinum point, which touches another platinum point, except when the spring is acted upon by the toothed wheel. These points are connected respectively with terminals on the outside of the chronometer, and are insulated from each other except at their point of contact. The electric circuit is complete through the chronometer except when the teeth of the wheel acting on the jewel pallet separate the points. The circuit is opened for about one-fortieth of a second and closed during the rest of the time. One tooth in the wheel is omitted and the circuit remains unbroken at that point which is the beginning of each minute. Each chronometer is provided with a condenser to take up the extra current, and avoid burning the contact points. These chronometers were most excellent instruments, the rate was generally small and very regular, and did not seem to be influenced in any way by the passage of the current. They are still in use, and are as efficient as ever.

The expedition was at first provided with a substitute for the chronograph in the shape of the old fashioned Morse telegraph register. In this a steel point or stylet was pressed by the action of an electro-magnet against a long fillet of paper, unwound by clock-work at a rate more or less regular. This magnet was in circuit with the chronometer and with a break circuit key in the observer's hand. As long as the electric circuit was closed the stylet made a continuous indented straight line on the paper; but as soon as it was broken, either by the chronometer or the observer's key, the stylet flew back and left the paper unmarked until the circuit was again closed. The effect of the action of the chronometer was to graduate the fillet of paper into a series of straight indentations, from one to two inches in length, separated by unmarked spaces from $\frac{1}{16}$ to $\frac{1}{8}$ inch in length. When the key was pressed an independent clear space was left on the paper, and by the relation in distance between the beginning of this space and the beginning of the second spaces immediately preceding and following, the time of pressing the key was determined. The omission of the break at the sixtieth second, made the mark of double length, and hence the beginning of the minute was easily recognized. These instruments served their purpose very well, but had several disadvantages. The rate of movement of the paper was not regular; when the clock-work was first wound up the motion was rapid and the second spaces long, and as the spring ran down the marks became shorter and shorter. Another drawback was the great length of the fillet; with spaces only an inch in length, it required five feet of paper to record a minute in time, and after a night's observation, there would be several hundred feet to examine, measure and record, occupying the greater part of the following day. By stopping the instrument between the observations something was gained in this respect, but this tended somewhat to confusion and error in keeping the record. They were only used for one season's work, and in their stead were procured two cylinder chronographs, made by Bond of Boston. These were fine instruments, but somewhat too delicate to stand the necessary transportation. In these instruments as in most other chronographs, a cylinder about six inches in diameter is made to revolve by clock-work once in a minute. An electro-magnet mounted on a carriage actuated by the same clock-work moves alongside the cylinder, in a direction parallel with its axis, at the rate of about an eighth of an inch in a minute. The armature of the magnet carries attached to it a pen, the point of which rests upon a sheet of the paper wrapped around the cylinder. While the circuit through the coils of the magnet is complete, the pen makes a continuous spiral line upon the paper, but when the circuit is broken by the chronometer, or key, it flies to one side making an offset, and immediately returns to its position, as soon as the circuit is again closed. The result is to graduate the whole surface of the paper into second spaces, from which the observations can be read off with the greatest ease.

For supplying the electric current, there was used at first, a modification of the Smee battery, but this proving very uncertain in strength, a gravity battery was substituted, and afterwards a number of LeClanché cells were procured.

Upon the first expedition, no telegraph instruments were carried, but the use of such as were needed was easily obtained from the telegraph companies. The line between Aspinwall and Panama was in good condition and no trouble was experienced in exchanging the time signals by which was effected the comparison of the chronometers. Wires were stretched from the observatories in each place to the respective telegraph offices, and for the exchange of signals were connected directly to the ends of the line.

Everything being ready, the routine of the work was as follows:—The transit being carefully leveled was placed in the meridian by observation of zenith and circumpolar stars. From six to ten time stars, and two or three circumpolars were then observed, the instrument was reversed in the Ys and nearly the same number of stars observed in the new position. At some time agreed upon, generally when the regular work of the telegraph line was over for the day, the wires were connected up and one of the operators came to the observatory to assist in holding communication. By a simple arrangement of relays, in the line and chronograph circuits the chronometer at one station was made to register its second beats on the chronograph at the other, which was all the time being graduated into second spaces by its own chronometer. This was done for about five minutes and the times of beginning and ending noted. Then the connections were reversed and both chronometers allowed to beat for five minutes on the chronograph at the first station.

This method of exchanging signals was only practicable on land lines or very short cables. The ordinary relay used on a land line requires a strong current to work it, and would not be affected in the least by the delicate impulse sent over a long cable, consequently when the expedition came to compare chronometers over the 600 miles of cable between Aspinwall and Kingston, it was necessary to use another method. At that time the instrument in general use on submarine cable lines was what is known as Thompson's mirror galvanometer. It consists of a coil of very fine insulated wire wound with great care on a spool or bobbin of vulcanite, about three inches in diameter and 1¼ inches thick. In a hole in the centre of the spool is made to slide a small tube, so that the end of the tube will be in the centre of the coil. In the end of the tube is mounted a small mirror, swung in a vertical position on a single upright fibre of silk. Horizontally across the back of this mirror is secured a small permanent magnet, in length about the diameter of the mirror or about one-eighth to one-quarter of an inch. The mirror and magnet together weigh only one or two grains. When an electric current is sent through this coil it deflects the magnet and with it the mirror to the right or left. The apparatus is exceedingly sensitive so that it is influenced by very feeble currents. Communication has been maintained with an instrument of this kind over the Atlantic cables, by the current proceeding from a battery composed of a single copper percussion cap with a small scrap of zinc and a drop of acidulated water. The use of the mirror is to make visible the movements of the magnet. The coil is mounted upon a standard so as to be about eight inches above the table. At the distance of eighteen inches or two feet is placed a lamp. This is surrounded by a screen which cuts off all the light, except that which passes through a tube directed towards the mirror. Lenses in the tube focus the light on the mirror and thence it is reflected to a vertical white surface, a sheet of paper for instance, at a suitable distance and appears as a small and brilliant spot. A movement of the magnet causes a horizontal deflection of this spot to the right or left depending upon the direction of the current passing through the coil. As these movements can be produced at will by means of the key at the sending station, it is only necessary to apply to them the dots and dashes of the Morse alphabet, to have a very ready and perfect means of communication. To the uninitiated spectator the facility with which the practiced operator translates these apparently meaningless movements is remarkable. If the cable is long and not in good condition the signals are sometimes almost imperceptible, while any slight jar of the table or apparatus will produce a large and irregular effect. Earth currents also will cause vibrations hard to distinguish from the signals, and if, as sometimes happens, the battery is connected in the wrong way, the signals will be reversed. In spite of these drawbacks the skillful operator reads off the message and rarely makes an error. This instrument is still in use on some of the cable lines, but on most of them it has been replaced by a recording instrument, also the invention of Sir Wm. Thompson, which is almost as sensitive, and of which I will speak later on. The key used in connection with these instruments, both the mirror and recorder, is arranged with two levers, so connected that pressing one of them causes a current to be sent over the line in one direction, while the other sends it in the opposite.

The method adopted for comparing chronometers by means of these instruments was as follows:—Everything being ready for the exchange of signals, the observer at one station seated himself, where he could see the face of the chronometer, with his hand on the cable key. At ten seconds before the beginning of a minute as shown by the second hand, he pressed his key several times in quick succession, thus sending a series of impulses through the line, which appeared at the other end as a rapid movement of the light to and fro. This was a warning signal, and the observer at the second station with his eye on the light, tapped his chronograph key in the same way making a series of marks, which indicated the beginning of the comparison. The first observer exactly at the sixtieth second by his chronometer pressed his key quickly and firmly and repeated this operation at every fifth second for one minute. The second observer tapped his key promptly as soon as he saw the light move, thus registering the time on his chronograph. The minute at which the first signal was sent, was then telegraphed, and repeated back, to insure against error, and the operation was repeated until sixty-five signals had been sent from one station and received at the other. Then the second observer sent the same number of signals to the first in precisely the same manner, thus giving sixty-five comparisons of the chronometers in each direction. The results derived from this method are affected by errors from two causes. One is the personal error of the observers in sending and receiving signals and the other the time consumed by the electric impulse in traveling over the line and through the instruments. If the same strength of battery is used at each station, and the resistance of the instruments is the same, the errors arising from this latter source will be eliminated by the double exchange. The observer sending the signals kept his eye on the chronometer and counted the second beats by both eye and ear, moving the hand which he had on the key slightly in unison with the beats, and could thus be sure of pressing the key at the proper time within a very small fraction of a second. At the other end of the line, considerable time is lost after the actual movement of the light before the observer can press his chronograph key, and the principal error affecting the result is the difference of this time in the two observers, which was found to be very small.

As I have said, the cable was first used in the measurement between Kingston and Aspinwall, Lieut. Commander Green occupying the former station, and Mr. Rock the latter. After the successful completion of this link, measurements were made from Santiago de Cuba to Kingston, and to Havana. It was the intention to measure from this last point to Key West, but about this time yellow fever broke out there and the expedition was ordered by the Secretary of the Navy to return. The Fortune arrived at Washington in April, 1875, and the time until November was spent in working up the winter's observations. Speaking in a general way this work is as follows :—From observations extending over many years, the exact positions in the heavens of a large number of fixed stars have been found, so that their times of passing any meridian can be computed with great accuracy. The transit instrument is furnished with an eye-piece containing a number of parallel lines usually made of spider silk. These are placed in the focus of the instrument, and it is set in position, so that the middle line of the group is in the plane of the meridian. The observer provides himself with a list of desirable stars, and setting his instrument on those he may choose, records the time at which they pass each of the spider lines, by tapping his chronograph key. If there were no instrumental errors to be discovered and allowed for, if the star's place were known absolutely, and the observer had no personal equation, then it would be only necessary in order to find the error of the clock, to observe one star upon the middle line of the reticle. The difference of the clock time of transit and the real time as already known, would be the clock error and no further trouble would be required. But as none of these conditions are fulfilled, it is necessary to multiply observations in order to eliminate accidental errors, and to obtain instrumental corrections which may be applied so as to get the most probable result. Accidental errors of eyesight and perception are nearly eliminated by taking the star's transit over several lines instead of one and using the mean. Some of the instrumental errors are from the following causes. If the pivots which support the telescope are unequal in size the axis of the tube will be thrown to one side or the other of the meridian, and the star will be observed either before or after it crosses. The weight of all transit instruments causes a flexure of the horizontal axis and this effect is at its maximum in those of the prismatic pattern. The spider lines must be adjusted so that the middle one is exactly in the axis of the tube, or as this can seldom be done the resulting error, called the collimation, must be found. The horizontal axis of the instrument must be as nearly level as possible, and the error in this respect must be found by frequent applications of a delicate spirit level. Finally the instrument must be directed as nearly as possible to the north and south points of the horizon, and a correction must be made for any error in this respect. The result of each of these errors is to cause the star's transit to be recorded too early or too late, and to get the true result they must all be found and applied with their proper signs. The inequality of pivots and the flexure correction are found by delicate measurement and observations, when the instrument is first used, and are recorded as constants to be applied in all subsequent work. The level tubes are graduated and the value of their divisions obtained in angular measure. The collimation error is found by observing stars near the zenith in one position of the instrument and then reversing and observing others, or by taking the transit of a slow moving star over a portion of the spider lines then reversing and observing the same intervals in the opposite order. The error of azimuth, or deviation from the north and south line, is found by comparing the observations of stars whose zenith distances differ considerably. These corrections all being found and applied to the observation of each star, the result is the correct time of transit as shown by the chronometer, and the difference between that time and the true time, is the error of the chronometer. A mean of the observations of several stars on the same night, gives a very accurate value for this clock error, and by comparing the results of several nights' work, the rate is found. By applying the rate to the clock error it is reduced to any required epoch, as for instance, the mean time of the exchange of time signals, and the difference of longitude is easily found. As may be imagined the computation and application of all these errors, exercising the greatest care to insure accuracy is a long and tedious process. The operations described give a very close result, but in order to arrive at the greatest accuracy obtainable the computations are made again by the method of least squares.

In the Autumn of 1875, the expedition again took the field, this time in the side wheel steamer Gettysburg, which was much better adapted to the work than the Fortune. The first link measured was between Key West and Havana. Key West had already been telegraphically determined by the Coast Survey, and now afforded a base for the system of measurements completed and for those to follow. The next measurement was between Kingston and St. Thomas. Then from the latter place to Antigua and to Port Spain, Trinidad. From Port Spain, measurements were made to Barbadoes and Martinique. The position at St. Thomas was then re-occupied, and measurements made thence to San Juan, Porto Rico, and to Santa Cruz. This ended the work in the West Indies, differences of longitude having been measured between nearly all the important points connected by telegraph. The Latitude of all the stations, was also determined by the zenith telescope method, and the position of the stations was referred either to the observation spot previously used, when that could be identified, or to some prominent landmark.

Between St. Thomas and Santa Cruz, the measurement was made twice, the observers exchanging stations at the completion of the first series of observations. This was to eliminate the effect of their personal errors, and to obtain a value of these, which might be applied to the other measurements. It has long been known that different people perceive the same phenomenon at different times, varying with different individuals, but reasonably constant with the same individual. In the particular case of observing the transit of a star, most people will record it on a chronograph from one to three tenths of a second after it happens. In the method of observing by eye and ear the error is generally much greater. The whole question of personal equation, however, is a mixed one and I will not attempt to discuss it, but will only give some of the results obtained in this particular work. In longitude measurements the error from this cause is half the difference of the personal equation of the two observers. If this difference remained constant, then it would be easy to find it once for all, and apply it to all measurements made by the same observers. In the West India work, it was assumed that it did remain constant, and half the difference between the two measurements made from St. Thomas to Santa Crux, was applied to all the other links. The correction was quite small, being only $0^s.025$. In subsequent work by the same and other observers it was deemed wiser not to apply any corrections at all, rather than one that was probably not exact, and might be much in error. To show the fluctuations to which this elusive quantity is subject, I will cite the results of some observations made to determine it, by observers engaged in this same work at a subsequent period. In April and May, 1883, at Galveston, Texas, two observers D. and N. having just completed a telegraphic measurement between that place and Vera Cruz, Mexico, made some observations for the determination of their relative personal equation, by observing transits of alternate stars under the same conditions as near as possible. Both used the same instruments, transit, chronometer and chronograph. On April 30, two sets of observations were made, showing the difference of the equations to be 0ˢ.26. On May 1, one set gave 0ˢ.32, and another 0ˢ.29. On May 2, only one set was made giving 0ˢ.36, a variation of 0ˢ.07 in two days. In June 1884, one year later, another series of observations of the same character was made at the Naval Observatory in Washington, and on the same nights the personal equation machine invented by Prof. Eastman, was used as a comparison. This is an instrument in which an artificial star is made to record its own transit over the wires of a reticle, while the observer records the same with a chronograph key. The difference is manifestly the personal error of the observer. This gives the absolute equation of the observers, and their difference is the relative equation, and should accord with that found by the method of alternate stars. Some of the results were as follows :—On June 4, the difference by machine of their personal errors was 0ˢ.16 and by star observations 0ˢ.24, on the 15th of June the machine gave 0ˢ.10 and the stars 0ˢ.24, on the 16th, machine 0ˢ.14, stars, 0ˢ.13, a very close agreement, on the 17th, machine gave 0ˢ.07 and stars 0ˢ.18. The observer N. combined with another, C., who had not had as much experience in observing, gave still more discordant results. On June 20, the machine gave as their relative equation, 0ˢ.08, while star observations gave 0ˢ.27, on June 23, machine 0ˢ.13, stars 0ˢ.51, and on June 28, machine, 0ˢ.20, stars 0ˢ.35. In the case of the first two observers a mean of the determinations amounting to about 0ˢ.20 might have been applied to the measurements made by them, but as these were made under all conditions of climate, in latitudes varying from 30° N. to 36° S. and in different states of health and bodily comfort, it was concluded not to introduce any correction at all rather than one that might be considerably in error. In all of the work it has been the custom as far as possible to place the observers alternately east and west of each other, so that the result of personal error in one measurement is neutralized to a greater or less extent in the next. Of course the method of exchanging stations and making two measurements of each meridian distance would afford the best solution of this problem, but except in certain favorable conditions, this is precluded by considerations of time and expense. In the measurement between Galveston and Vera Cruz mentioned above, it had been the intention to exchange stations, but by the time the first measurement was finished the season was rather far advanced, there was danger of yellow fever in Vera Cruz and an observer going there at that time, if he escaped disease would have had the certainty of being quarantined from entering the United States for three weeks or a month after leaving Mexico.

Upon the completion of the West Indian work, and the publication in 1877, of the results, it was determined by the Bureau of Navigation to send an Expedition for the same purpose to the east coast of South America. Cables were in use extending from Para in northern Brazil to Buenos Ayres in the Argentine Republic. A cable had at one time connected this system with the West Indies, through British Guiana and Trinidad, but one of the links was broken and there was no prospect of its repair, otherwise the Station established at Trinidad in 1874 might have been taken as the starting point. There was direct communication however between England and Brazil, by the way of Portugal, and the Madeira and Cape de Verde Islands. Lisbon seemed to afford the most convenient place to start from, but its longitude had never been determined by telegraph and it was decided to request the French Bureau of Longitudes to coöperate by making this measurement from Paris. This request was readily granted, but for some reason the agreement was not kept. For the use of the Expedition the old fashioned sailing ship *Guard* was furnished and Lieut. Com. Green was given command. Mr. Rock being otherwise employed his place was taken by Lieut. Com. (now Commander) C. H. Davis, U. S. N. The instruments having been placed in good order, and new supplies furnished where necessary, the expedition sailed from New York for Lisbon in the latter part of October, 1877. The Guard was a slow sailer, the weather was rough and the wind generally ahead, consequently a month was consumed in making the passage. It was the intention to make the first measurement between Lisbon and Funchal, Madeira. Lieut. Com. Davis with party and instruments occupied the latter station, proceeding by mail steamer at the first opportunity. The cable from England does not land directly at Lisbon, but at a small town called Carcavellos on the coast about twelve miles from the city. As it was not practicable to connect the land line from Lisbon direct to the cable, it was necessary in making the exchange of signals to adopt another method, or rather combination of methods. An officer of the ship was sent to Carcavellos, furnished with a chronometer and chronograph. When the time came for exchanging signals, he first compared his chronometer with that at Lisbon, by the automatic method, in use on land lines, then with the Funchal chronometer over the cable using the mirror galvanometer. Finally a second automatic comparison was made with Lisbon. From the data furnished by these comparisons it was an easy matter to compute the difference between the chronometers at Lisbon and Funchal. The Lisbon party had been received with great courtesy by the director of the Royal Observatory, Capt. Oom of the Portuguese Navy, and had been given the use of a small detached observatory near the main building. The party at Funchal selected a site on the ramparts of an old fort, which afforded a clear view and was near the landing place of the cable. Here occurred an accident to the transit instrument, which fortunately was easily remedied. Near the beginning of the observations on the first night the wind, which was blowing almost a gale, lifted a part of the roof off the observatory, and dropped one section of it inside. The transit was knocked off the pier, and was at first thought to be much injured. Fortunately the precaution had been taken to bring along a couple of spare instruments, borrowed from the Transit of Venus Commission for use in case of such an accident. The Funchal party was provided with one of these, which was set up for use by the next night, and the injured one was sent to Lisbon for repairs. The injury proved to be less than supposed and the repairing was an easy matter. Upon the completion of this measurement the Lisbon party proceeded to St. Vincent one of the Cape de Verde Islands. This is a barren and desolate spot of volcanic formation, but being on the route of steamers from Europe to Africa and South America is of much importance as a coaling station. Measurements were made from this point to Funchal and to Pernambuco in Brazil, and the Guard then sailed for Rio Janeiro. Upon arriving at that point after a long passage, it was found that the cable between Rio and Pernambuco was broken, and there being no immediate prospect of its being repaired, the Pernambuco party was ordered by mail steamer to Rio, and thence to Montevideo. A measurement was made between Rio and Montevideo and then between the latter place and Buenos Ayres, Lieut. Com. Green occupying the Montevideo station for that purpose. The position of the observatory at Buenos Ayres was referred to that occupied by Dr. B. A. Gould, Director of the Argentine National Observatory, in a similar measurement a short time before between that place and Cordova.

Both parties now returned to Rio, only to find that the cable was still broken. In order to be ready for work as soon as it should be repaired, Lieut. Com. Green proceeded to Bahia with the ship and established a station there, Lieut. Com. Davis with his party remaining in Rio. After waiting a month, and there still seeming to be no prospect of the repair of the cable, the expedition finally sailed for home, arriving at Norfolk, Va., after a pleasant and uneventful voyage of forty-five days. Repairs to the cable were not completed until several months afterward. In May of the next year, the party was again sent out, to complete the measurement on the Brazilian Coast, and also to measure from Greenwich to Lisbon, the French Bureau of Longitudes having failed to carry out its promise to measure from Paris. There being no ship available for the purpose the traveling was done by mail steamer. Upon arrival in England, an interview was had with the Astronomer Royal, who readily agreed to assist in the work. Lieut. Com. Green accordingly established his observatory at the landing place of the cable at Porthcurnow in Cornwall, and Lieut. Com. Davis proceeded to Lisbon and occupied the station used there the year before. Owing to the foggy and rainy weather prevalent in England at that season, it was found impossible to make any astronomical observations at the Porthcurnow observatory. The work was therefore done in this way:—Observations were made at Greenwich and at Lisbon, and Porthcurnow and Carcavellos were used as transmitting stations. The chronometer at Porthcurnow was compared automatically with the clock at Greenwich, and by cable with the chronometer at Carcavellos. The latter was compared automatically with that at Lisbon, before and after the cable exchange. At this time there were made at Carcavellos, some experiments with a view to making the receipt of the time signals over the cable automatic, thus doing away with the personal equation of the receiver. The instrument in use for the regular business of the cable was what is known as the siphon recorder, also the invention of Sir Wm. Thompson. In this a small coil of fine wire is suspended by a fibre of silk, between the poles of a powerful permanent magnet. The currents from the cable pass through this coil and the action is to deflect it to the right or left, just as the mirror is deflected in the instrument already described. Attached to this coil is a siphon made of a capillary glass tube. One end of the siphon dips into a reservoir of aniline ink, and the other hangs immediately over the centre of a fillet of paper, which is unwound by clock-work. If the siphon touched the paper, the feeble currents sent through the cable would be powerless to move it, on account of the friction, and in order to produce a mark some means must be found of forcing the ink through the capillary tube. This is accomplished by electrifying the ink positively and the paper negatively, by means of a small inductive machine; driven by an electric motor. The effort of the two electricities to unite, forces the ink through the tube and it appears on the paper as a succession of small dots. When the paper is in motion and the coil at rest, a straight line is formed along the middle of the fillet by these dots, but as soon as a current is sent through the coil the siphon moves to the right or left making an offset to this line. These offsets on one side or the other are used as the dots and dashes of the Morse alphabet. A time signal sent over the cable while this instrument was in circuit, appeared as a single offset on the paper, and it was only necessary to graduate the paper into seconds spaces by the local chronometer, in order to have the automatic record required. The ordinary chronometer circuit could not be put through the coil directly, as it would then charge the cable and interfere with the signals, and besides, the current, unless by the introduction of a high resistance it was reduced in strength, would infallibly give such a violent motion to the coil as to break the siphon, if it did no other damage. The result was obtained in this way; an ordinary telegraph relay was put in the chronometer circuit and the armature of course moved with the beats. To this armature was fastened one end of a fine thread. The other end was attached to a slender piece of elastic brass which was fixed at one end to the framework supporting the paper, in such a way that the other end touched the metallic vessel holding the ink, except when the thread was drawn tight enough to pull it away. This the armature of the relay did while the circuit through the chronometer was complete, but as soon as it was broken at the beginning of a second, the tension of the thread was relaxed and the brass sprung back against the ink well, allowing the positive and negative electricities to unite independently of the siphon. The ink then ceased to flow, until the spring was drawn away, thus leaving a small blank space in the line of dots and forming a very good chronographic record. This was liable to a small error due to the length of time that elapsed between the release of the spring by the armature and its impact on the ink well. Had there been time for more extensive experiment this difficulty might have been overcome. Or if the same method had been adopted at both stations, the result would have been affected by only the difference between the times of movement of the brass spring which would have been minute. Lack of time for experiment, and the fact that the observers were averse to introducing untested methods into a chain of measurements most of the links of which were already completed, prevented any use being made of this achievement. The measurement between Greenwich and Lisbon being satisfactorily completed. Lieut. Com. Green by order of the Navy Department returned to the United States, and the links between Rio and Pernambuco and between the latter place and Para, were measured by Lieut. Com. Davis and the writer, completing the work of the expedition, after which the party returned to Washington.

The computation of this work, showed the somewhat surprising fact that the heretofore accepted position in longitude of Lisbon, differed from the true one by about two miles. The longitude of Rio Janeiro had always been more or less in doubt, various determinations had differed by as much as nine miles, but the position finally decided upon by the best authorities agreed very closely with that obtained by telegraph.

The next expedition was sent out by the Bureau of Navigation to China, Japan and the East Indies, Lieut. Com. Green being still in charge. The officers composing the party sailed from San Francisco by mail steamer in April, 1881, for Yokohama, where they joined the U. S. Steamer Palos. From Hong Kong north to Vladivostok in Eastern Siberia the cables were owned by a Danish company. From Hong Kong to the south and west they were the property of English companies. Beginning at Vladivostok observations were made at all stations on the Asiatic coast except Penang, as far as Madras, India. It was intended to try and make some use of the automatic method of receiving time signals, on this work, but on arriving in Japan it was found that the recording instrument used by the Danish company was entirely different from that used by the English lines. It consisted of a series of electro-magnets acting on a single armature, which carried a siphon made of silver. The signals consisted of long and short movements, to one side of the middle line, instead of equal deflections on both sides as in the Thompson recorder.

An attempt was made to convert this instrument into a relay, by causing the siphon to make and break a circuit, but it was not successful. The movements of the siphon were not regular enough, and the contact was not firm. Consequently the mirror method of exchanging signals was still adhered to.

The longitude of the position occupied in Vladivostok, had been determined telegraphically from Pulkova, by the Russians, using the land lines across Siberia. The English had also determined the position at Madras, using the cables through the Mediterranean and Red Seas. The work of the United States Expedition joined these two positions, completing a chain of measurements extending over many thousand miles, made by observers of different nationalities in various climates. It was to be expected that considerable discrepancy would be found in the final result, but taking the longitude of Vladivostok as brought from Madras, and comparing it with that determined by the Russians, the difference was only $0^s.39$. Taking everything into consideration, this result was gratifyingly close. Upon the conclusion of this series of determinations, the connection of Lieut. Commander Green with the work was severed, he receiving his promotion to the rank of Commander.

The next work was under the charge of Lieut. Com. Davis, and consisted in the determination in 1883-84, of positions in Mexico, Central America and the west coast of South America. Cables had just been completed, extending from Galveston, Texas, to Vera Cruz, thence across Mexico to the Pacific and down that coast to Lima, Peru, where connection was made with another system extending to Valparaiso. Galveston was a point determined by the Coast Survey, and the measurement thence to Vera Cruz was the first one made. It was completed in May '83, and in the Autumn of the same year the party proceeded to the South American coast, and stations were established and observations made at various points from Valparaiso to Panama, and at one point, La Libertad, in Central America. It was at first the intention to extend the series across the Isthmus of Tehuantepec and connect with Vera Cruz, but lack of time prevented this, and as the station at Panama determined nearly ten years before, afforded a convenient starting point, the idea was abandoned. From Valparaiso, a measurement was made with the coöperation of Dr. Gould to his observatory at Cordova, using the line across the Andes, and exchanging signals automatically. These measurements constituted the final links in a long chain, extending from the prime meridian Greenwich across the Atlantic to the United States, thence via the West Indies to Panama, down the west coast of South America to Valparaiso, across the Andes to Cordova and Buenos Ayres, up the east coast to Pernambuco, across the Atlantic to Lisbon, and thence to Greenwich, altogether a distance of eighteen to twenty thousand miles. The two longitudes of Cordova, as brought from Greenwich by the two routes, differed from each other by only $0^s.048$, a result which speaks well for the accuracy of the methods employed. When preparations were being made for this expedition, it was determined to accomplish if possible something in the way of getting rid of the personal equation in exchanging signals. An idea which had been suggested by work done by Major Campbell, R. E. in the measurement between Bombay and Aden, seemed to promise well. It was to be used with the siphon or other form of recorder. The ordinary double current cable key with two levers, was arranged with an additional lever in such a manner that while in ordinary use in the telegraph office, it could also be put in circuit with the chronometer and chronograph in the observatory, and a signal sent through the cable would have its time of sending registered on the chronograph. Ordinarily in speaking over a cable line, connection is made in such a way that the current sent does not pass through the recorder at the sending station, as a violent movement of the siphon would result. By means of a shunt, however, it is possible to control this movement somewhat. Suppose now, that the connections at each station are made in such a way, by means of this key and the shunt, that a signal sent from one, is registered on both recorders and on the sender's chronograph. The observers leaving their assistants to take care of the chronographs, go to the respective telegraph offices, and all being ready, the observer A taps his key. This sends an impulse through the cable, which appears on A's recorder, as a violent jump or kick of the siphon. On B's recorder it is registered as a deflection like the ordinary dot or dash, at the same instant is recorded on A's chronograph the time of sending. As soon as B sees the signal on his recorder, he taps his key also registering the signals on both recorders and on his chronograph. A, seeing B's signal again taps his key, and so on, as long as desired. The result is that each observer has a record on his siphon fillet of all signals sent and received, while the times of those he sent are recorded on his chronograph. By the use of the diagonal scale and the Rule of Three, he can without difficulty find the times of the signals received. The siphon recorders are well made, and the paper moves with great regularity. This system was used in the measurement between Galveston and Vera Cruz with great success. It was intended to employ the same method throughout the measurement on the west coast of America, but on arriving at Lima, it was found that the company owning the lines south of that point still used the mirror galvanometer, and it was of course necessary to return to the old method. The improved key was used however, which eliminated the error in sending signals.

After this work was completed and the results published in 1885, nothing was done in this line by the Bureau of Navigation for some years. Upon the return of the writer in the spring of 1888, from a cruise in the South Pacific, he found that the subject of sending an expedition to complete the measurements in Mexico and Central America was under consideration in the Bureau of Navigation and the Hydrographic office. It was finally decided that the work should be done, and the writer was placed in charge. The instruments were brought out of their retirement, and by the aid of the Hydrographic Office a very complete outfit was furnished, and in November of last year a start was made from New York, the expedition proceeding by mail steamer to Vera Cruz. Here the spot occupied by Lieut. Com. Davis in '83 was found, his transit pier, which was still standing was repaired, and instruments mounted. Lieut. Charles Laird, U. S. N., who had been identified with the longitude work since the China expedition in 1881, was left in charge of the observatory at Vera Cruz, and the writer proceeded with his party to the small town of Coatzacoalcos, at the mouth of the river of the same name. This point is about one hundred and twenty miles southeast of Vera Cruz, and is the landing place of the cable. A land line extends from this point to Salina Cruz on the Pacific coast, a distance of about two hundred miles. In exchanging time signals between Vera Cruz and Coatzacoalcos, the automatic method was employed, the cable being short. The old wooden observatories were used at these points, but as they were too heavy for transportation across the Isthmus, tents made especially for astronomical purposes were substituted for them in the observations made on the Pacific coast. The journey across the Isthmus was slow, about two weeks being employed in traveling two hundred miles, though as the route was devious, the actual distance was nearer three hundred. Some of the instruments were heavy, and after being taken in canoes a hundred miles up the Coatzacoalcos river, against a rapid current, they were loaded on a train of pack mules, and carried the rest of the way by land. While the first party was crossing the Isthmus, the other was on its way from Vera Cruz, and being ready at about the same time, a successful measurement was made between Coatzacoalcos and Salina Cruz, exchanging signals automatically. The Coatzacoalcos party then crossed to Salina Cruz, while the other proceeded to La Libertad in Salvador, where the station established in the Spring of '84, was again occupied. The measurement between these places being completed, the Libertad party went on to San Juan del Sur, in Nicaragua, near the terminus of the proposed interoceanic canal. In the measurement between this point and Salina Cruz, as well as in the one preceding, the exchange was effected by mirror signals. This completed the season's work, and the two parties made the best of their way home via. Panama, arriving in Washington in April and May respectively. The computation of the observations is not yet complete though well advanced ; it was the intention to publish preliminary results this Fall, but owing to lack of time that can not be done.

Another piece of work is laid out for the same party for the coming winter, which is the measurement from Santiago de Cuba, through Hayti and San Domingo to La Guayra in Venezuela, over the cables of a French company, which have just been completed. This work will consume about six months, and the expedition which is to start almost immediately will probably return in April or May next. The determination of the longitude of La Guayra will give a point from which many other measurements may be made along the north coast of South America, furnishing material for extensive corrections of the charts of that region.

Having presented an outline of the work done so far, as well as that proposed for the near future, I will now mention some of the trials and tribulations, as well as the pleasures experienced in carrying out the object desired in an expedition of this kind. The greatest politeness and kindness have always been experienced from the officials and employees of the various telegraph companies over whose lines work has been carried on. The government officials of the foreign countries visited, have also invariably shown the utmost politeness, but sometimes this politeness has been visibly tinged with suspicion. The measurements in Peru and Chili were made amid the closing scenes of the war between the countries. Upon the arrival of the expedition in Lima, an interview was had with the Chilian Commander-in-Chief who had possession of the city, and permission was requested and readily granted to occupy a station in Arica. Upon arriving at the latter place some days after, the Chilian governor in charge was found to have instructions to facilitate the work, and readily granted permission to establish the observatory in a convenient locality, but flatly refused to allow a wire to be extended to the telegraph office, and also refused to forward to his immediate superior, a request that it might be allowed. He evidently supposed the party were emissaries of the United States, sent to treat secretly with conquered Peru, but how he expected this was to be done remains a secret. By a vigorous use of the telegraph in communicating with the U. S. Ministers to both Chili and Peru, his objections were silenced, and the wire was put up. The observatory at Arica was erected on the side of a hill to the windward of the town, because it afforded a clear view, and was less dirty than other eligible sites. It also was a safe position in case of a possible earthquake or tidal wave, by which Arica had already been twice visited with disastrous effect. In digging for a foundation for the transit pier, several mummies of the ancient Peruvians were unearthed at a depth of a foot. They had evidently belonged to the poorer class of people, as their wrappings were composed of coarse mats, instead of the fine cloth with which the wealthier people were usually interred. One was the body of a female with long hair, which had been turned to a reddish yellow color by the alkali in the soil. The whole coast of Peru is barren and desolate, except in the river valleys, it being seldom visited by rain, while it is nearly always overhung with heavy clouds and fog banks, which render astronomical work exceedingly difficult. Even when partially clear in the day time, it generally becomes cloudy at night. Many times the observer would be at his place before sunset ready to seize the first suitable star revealed by the darkness, only to be baffled by thick banks of cloud which would cover the entire sky in from five to ten minutes.

In northern Peru, with a latitude of about five degrees south, is the town of Paita. It is an assemblage of mud-colored houses, at the foot of high, mud colored bluffs. On top of these bluffs is a perfectly barren table land extending inland and up and down the coast for many miles. Before visiting it the observers were informed that its one good point was the perfect astronomical weather which always prevailed. Clouds were unknown, and such a thing as rain had never been heard of. The extreme dryness of the atmosphere was so favorable to health that no one ever died, and when a consumptive invalid was imported by the inhabitants in the hope of starting a cemetery, he blasted their expectations by recovering. Judge then of their feeling, when upon arriving at this delightful place, they were met with the information that while it was true that the sky was, in general, perfectly clear both by night and day, yet about once in seven years, rain could be expected, and that the year then present was the rainy one. And sure enough it did rain. The usually dusty streets became rivers and quagmires, the rocky valleys in the vicinity were transformed into roaring torrents, and the table land usually an arid desert became a swamp with a rank growth of vegetation. However by using every opportunity and snatching stars between clouds and showers the work was finally completed.

Upon arriving in Panama shortly after this experience, the party was met with the pleasant intelligence that yellow fever was prevalent, and that the foreigners were dying like sheep. Nearly every day of the party's stay, some one died of sufficient importance to have the church bells tolled for his funeral, while of the ordinary people little notice was taken. Every morning, the writer remembers passing a carpenter's shop where nothing was made but coffins, and the supply was evidently not equal to the demand, for finally the proprietor began to import them, apparently by the ship load. The weather however was delightful, and the nights were the most perfect, astronomically speaking, that could be desired.

The observers who went from Japan to Vladivostok were obliged to wait several weeks at Nagasaki, before an opportunity offered for proceeding to their destination, and when they finally arrived, the getting away again was a problem. Communication with the outside world by water was only open during the summer months, and even then it was more accidental than otherwise. The party established the observatory however, and settled down to work, letting the future take care of itself. In the early part of the work, rather an amusing incident occurred. As the community was full of all sorts and conditions of men, Koreans, Chinamen and Russian exiles, the last not political but criminal offenders; it was thought wise to have a sentry stationed at the observatory to guard against any possible harm to the instruments. So the Governor of the town was asked to furnish a soldier for that purpose, which request was readily granted, and one night the sentry was posted with orders to let no one touch the observatory. These orders he construed literally, and when the observers appeared to commence their night's work, he kept them off at the point of the bayonet. His only language being Russian with which the observers were not familiar, it was impossible to explain the true state of affairs, and it was only after hunting up an interpreter and communicating with his commanding officer that an entry was finally effected. A good deal of bad weather was experienced at this place, but at the end of six weeks enough observations had been made for the required purpose, and the party was fortunate enough to secure passage to Nagasaki, in a small steamer that had brought a load of coal out from Germany.

In the expedition to the Asiatic coast one of the most interesting experiences was the trip to Manila in the Philippine Islands. This is quite a large town when intact, but a great portion of it is usually in the condition of being shaken down by an earthquake or blown over by a typhoon. The inhabitants are full of energy, however, and find time between downfalls to build up again. The cable from Hong Kong lands at a point about one hundred and twenty miles from Manila, and the writer was directed to proceed thither, with a chronometer and chronograph for the purpose of transmitting time signals. The first part of the journey was made in a small coasting steamer uncommonly dirty, and occupied about thirty-six hours. At the end of that time the village of Sual in the Gulf of Lingayen was reached. This was distant from the cable station about thirty miles, and the remainder of the journey was made in a native boat, with mat sails, and bamboo outriggers, part of the time through channels between numerous small islands and for some distance in the open sea. The progress was slow, but it was a pleasant way of traveling, except for the sleeping accommodations which were primitive; consisting of a palm leaf mat thrown over a platform made of split bamboo, in which all the knots had been carefully preserved.

About three days, including stoppages, were consumed in this thirty mile voyage, and the traveler finally reached his destination to be received with the greatest hospitality by the staff at the telegraph station, and just in time to allay the fears of the observers at Hong Kong and Manila who had begun to think him lost. About three weeks were spent here, and as the work only occupied a short time at night, the days were pleasantly passed in exploring the surrounding country, making friends with the natives, shooting and photographing the scenery. The return to Manila was by the same route and occupied nearly the same length of time.

The measurement from Singapore to Madras was over one of the longest lines of cable ever used for this purpose, the distance being about 1600 nautical miles. The Atlantic cables used by Dr. Gould in 1866 were a little more than 1,850 miles in length. There was an intermediate station at Penang about 400 miles from Singapore, where all the work of the line was repeated. For the longitude measurement however the cables were connected through to form an unbroken line. The mirror was the only instrument that could be used and even with this the signals were feeble and much affected by earth currents.

The observing parties have never been troubled by wild beasts, but while at Saigon in Cochin, China, a rifle was always kept handy for use in case of the appearance of a tiger. The observatory here was located near the edge of a jungle, and alongside the telegraph station, on the veranda of which a large tiger had been shot by one of the operators only a short time before.

In the expedition of last winter to Mexico and Central America, the principal annoyance was caused by insects which were numerous and malignant. At Coatzacoalcos they were found in the greatest abundance, though the whole isthmus of Tehuantepec is alive with them. Fleas and mosquitoes were expected of course, but added to this were numerous others much worse. Of the family of "ticks" four varieties were seen and felt, ranging in size from almost microscopic to a length of a third of an inch. The most numerous were about as large as a grain of mustard seed, and one who walked or rode through the bushes or high grass would find himself literally covered. One of the worst insects encountered was the "nigua" which is in appearance something like a small flea. It burrows into the toes and soles of the feet, lays a number of eggs, which hatch and produce painful sores. A gruesome story is current in that region, about an enthusiastic English naturalist, who found specimens of these encamped in his feet, and concluded to take them home in that way, in order to observe the effect, but died of them before reaching England. All the party were afflicted with these pests, but were always fortunate enough to discover them and dig them out with the point of a knife before any bad results were experienced. The village of Coatzacoalcos is prettily situated, the climate, especially in winter, is very agreeable and the river offers a commodious harbor, but as long as the insects are so unpleasant, few people will care to live there if they can avoid it.

There have been directly determined by these various expeditions, about forty secondary meridians. Many more positions depend upon these, so they may be said to have made a large addition to our accurate knowledge of the earth's surface. Telegraphic facilities are being constantly extended, and as the Bureau of Navigation has now a very complete outfit for this work, which only needs occasional repairs, it is hoped that it may be kept up for some time in the future.

REPORT—GEOGRAPHY OF THE LAND.

By Herbert G. Ogden.

In my annual report a year ago, I presented to you briefly our knowledge of the great geographic divisions of the world. It might be instructive to continue the subject this evening by relating the additional information we have acquired during the year; but as the items are not of great value and the most important are more in the form of rumors than of facts, I have restricted myself more to the interests of the western hemisphere, and particularly to those affecting the United States.

In Europe we have still the visions of war that have agitated her peoples for years past; the decapitation of the Turk, and division of his European empire to appease the ambition of "friendly powers." It is not until we pass by this civilized section and reach the far east, that we recognize the dawn of progress in the year; the birth of events that may in time increase the happiness and welfare of many people.

The influence of the United States in extending the principle so early enunciated, "that all men are born free and equal" has been most marked. The western hemisphere is virtually under the rule of men chosen by the people, and though we cannot claim that in all instances the result has been satisfactory, there has, nevertheless, been a steady advance; political disturbances have become less frequent and with prolonged tranquillity the arts of peace, commercial enterprise and internal improvements, have received an impetus that will wed more strongly the advocates of personal liberty to their ideal God.

Educated men in both hemispheres predict ultimate success or failure for our form of government and advance cogent arguments in support of the views they express. The complications of the great economic questions that confront us afford texts for arguments that cause many to doubt the wisdom of entrusting the welfare of a great nation to the votes of the masses; nevertheless, the people are firm in the belief that they can conduct their own affairs; and those whom they intrust with temporary power are seldom so short-sighted as not to realize that a violation of the trust will meet with certain retribution. Those appointed to govern must also be teachers, and if in the enthusiasm of a new creed it shall be shown they have taught the people error instead of truth, a national uprising sweeps them from control, and for a time conservatism becomes the guide. To the people of the old world, the apparent prosperity that has followed our system doubtless receives the most earnest thought; and the contrast to their own condition excites their desires to experiment themselves in more liberal forms, and reap the rewards they believe have followed such measures in America.

While American methods may extend their influence in this manner to European nations, and even to the nations of Asia, we should not rest self-confident of the superiority of our institutions, and that they alone are the permeating influence that inspire so many with the thoughts of liberal government that brings disquiet to crowned heads. The application of recent discoveries and inventions, to the affairs of every-day life, have raised the power of the individual and caused such a general increase of intellectual vigor, that independence of rulers by divine right is no longer a cause for wonder, but is considered by the intelligent as the natural state for the modern man.

Since the expedition of Com. Perry our influence in Japan has been marked, and this most progressive of the Eastern nations has sought counsel and advice from new America and the men who constitute the nation. But the progressive people of these isles have been too earnest in their efforts to advance, to rely solely upon one set of men, or the example of one nation, and we find they have been gathering in that which is good from all sections of the civilized world. The record of their progress, however, bears the stamp of America, and we may justly claim that it was the influence of freedom that first led these interesting people into the paths they have followed with such gratifying results, and which many believe will culminate in the establishment of a powerful and enlightened nation. Recent advices announce the formation of a legislative body, organized on the principle of the Congress of the United States—a step that indicates Japan may yet find a place in the category of states that are destined to exert a marked influence in the control of human affairs.

How different is the neighboring empire of China. Within a stone's throw, almost, of the advancing civilization of Japan, inhabited by a people of marked ability but restricted by race traditions to a condition of inactive conservatism, that seems almost to preclude the possibility of material advance in centuries to come. The population of this empire is so great that the density has been averaged at two and three hundred persons per square mile, and in some districts that it is as great as seven hundred. We can readily conceive the poverty that must exist in such an average population for such an extended area. And we may realize the cries of distress that come from great calamities by the experiences in our own history, even modified as they have been by our superior facilities for affording relief, and the comparative insignificance of the numbers who have required assistance. Recall for a moment one of the great floods of the Yellow river, where thousands have perished and tens of thousands have been rendered destitute within a few hours, and conceive the sufferings, hardships, and greater number that must yet succumb before those who survived the first great rush of the waters can be furnished relief; remembering that the means of intercommunication are the most primitive, and that the immediate neighbors of the sufferers are in no condition to render more assistance than will relieve the most urgent necessities of a comparatively insignificant number. May we not, then, if only from a humanitarian point of view, greet with pleasure the reception of the imperial decree authorizing the introduction in the empire of useful inventions of civilized man, and directing the construction of a great railroad through the heart of the empire, with Pekin as one of the termini. This road will cross the Yellow river, affording relief to this populous district in time of disaster; and it is understood will eventually be extended to traverse the empire, forming a means of rapid communication between distant provinces. We may believe, also, that in time it will be the medium of opening to us a new region for geographic research, not in the celestial empire alone, but also in the rich fields of central Asia that are now being occupied by Chinese emigration.

Doubtless the greatest geographic discoveries of the age have been made in central Africa. It was but a few years ago that we were in doubt as to the true sources of the Nile, and the location of the mouths of great rivers that had been followed in the interior, was as much a mystery as though the rivers had flowed into a heated cauldron and the waters had been dissipated in mist, by the winds, to the four corners of the earth. It was then that grave fears were aroused for the safety of Livingstone, who had done so much, and whose efforts it was hoped would yet solve the great geographic problems his travels had evolved. A man, patient in suffering, and with a tenacity of purpose that overcomes the greatest obstacles, he had endeared himself to those who sought knowledge from his labors, and it was, therefore, with unfeigned regret that men spoke of the possibility that calamity had overtaken him, and that the work of the last years of his life would possibly be lost. The editor of an influential New York journal, sympathizing with the deep interest that was felt, and doubtless actuated to some extent by the notoriety success would bring to his journal, determined upon organizing an expedition to ascertain Livingstone's fate, and thus brought before the world the hitherto obscure correspondent Henry M. Stanley. The rare good judgment that selected Mr. Stanley for the command of such a hazardous expedition was more than demonstrated by subsequent events. The first reports that Livingstone had been succored were received with incredulity, but as the facts became known incredulity gave way to unstinted praise, and Mr. Stanley was accorded a place among those who had justly earned a reward from the whole civilized world.

A few years after his return from his successful mission for the relief of Livingstone, he was commissioned in the joint interests of the *New York Herald* and *London Daily Telegraph*, to command an expedition for the exploration of central Africa. Traversing the continent from east to west, he added largely to our knowledge of the lake region and was the first to bring us facts of the course of the Congo. This expedition placed him before the world as one of the greatest of explorers, and it seems, therefore, to have been but natural that, when a great humanitarian expedition was to be organized nearly ten years later to penetrate into the still unknown regions of the equatorial belt for the relief of Emin Pasha, that he should have been selected to command it. How faithfully he performed this task we are only just learning, and our admiration increases with every new chapter that is placed before us. That he was successful in the main object of the expedition is self-evident, having brought Emin Pasha and the remnant of his followers to the coast with him. The expedition has also been fruitful in geographic details, and though we have not as yet the data to change the maps to accord with all the newly discovered facts, we may feel assured of their value. Perhaps the best summary of the more important discoveries can be given in the explorer's own words, which I have taken from one of his recent letters:

"Over and above the happy ending of our appointed duties we have not been unfortunate in geographical discoveries. The Aruwimi is now known from its source to its bourne. The great Congo forest, covering as large an area as France and the Iberian peninsula, we can now certify to be an absolute fact. The Mountains of the Moon, this time beyond the least doubt, have been located, and Ruwenzori, 'The Cloud King,' robed in eternal snow, has been seen and its flanks explored and some of its shoulders ascended, Mounts Gordon Bennett and MacKinnan Cones being but great sentries warding off the approach to the inner area of 'The Cloud King.'

"On the southeast of the range the connection between Albert Edward Nyanza and the Albert Nyanza has been discovered, and the extent of the former lake is now known for the first time. Range after range of mountains has been traversed, separated by such tracts of pasture lands as would make your cowboys out west mad with envy. And right under the burning equator we have fed on blackberries and bilberries and quenched our thirst with crystal water fresh from snow beds. We have also been able to add nearly six thousand square miles of water to Victoria Nyanza.

"Our naturalist will expatiate upon the new species of animals, birds and plants he has discovered. Our surgeon will tell what he knows of the climate and its amenities. It will take us all we know how to say what new store of knowledge has been gathered from this unexpected field of discoveries. I always suspected that in the central regions, between the equatorial lakes, something worth seeing would be found, but I was not prepared for such a harvest of new facts."

The exploration of Africa, however, has not been confined to the central belt. Expeditions have been developing the southern section of the continent; the French have been active in the watershed of the Niger, and in the east there seems to have been a general advance of English, Germans, Portuguese and Italians. The latter, it is stated, have acquired several million square miles of territory in Mozambique, an acquisition that would indicate our maps have heretofore given this particular division of territory an area much too insignificant.

We also learn that Capt. Trevier, a French traveler, has crossed the continent by ascending the Congo to Stanley Falls, thence southeasterly through the lake region to the coast at some point in Mozambique, in a journey of eighteen months; a journey that must bring us a harvest of new facts.

On the western hemisphere there has been considerable activity in a variety of interest, tending to develop the political, commercial and natural resources.

Four new states have been admitted to the American Union, and measures have been introduced in the Congress looking to the admission of two more. These acts mark an era in the progress of the great northwest significant of a national prosperity that a generation ago would have been deemed visionary. We have also to record a tentative union formed by the Central American states, that at the expiration of the term of ten years prescribed by the compact, we may hope will be solidified by a bond to make the union perpetual. In South America a bloodless revolution presented to the family of nations a new republic in the United States of Brazil. All thoughtful men must at least feel a throb of sympathy for Dom Pedro, who in a night lost the allegiance of his people and the rule of an empire. Sympathy, perhaps, that he does not crave, for history affords us no parallel of a monarch who taught his people liberalism, and knowing it could but lead to the downfall of his empire. It seems to be true, also, that although depriving him of power, the people whom he loved and ruled with such liberality, have not forgotten his many virtues, and that the Emperor Dom Pedro will be revered in republican Brazil as heartily as though his descendants had been permitted to inherit the empire. We cannot tell if the new order of affairs will prove permanent, but the education of the Brazilians in the belief that a republic was inevitable, gives strong grounds to hope the experiment of self-government will not be a failure. The influence the successful establishment of this republic is to exert in other parts of the world is a problem that has already brought new worries to the rulers of Europe, and not without a reason, for a republican America is an object lesson that the intelligence of the age will not be slow to learn.

The assembly of the "Three Americas Congress" in Washington, is also an event that may wield an influence in the future. Perhaps it may not be seen for years to come, but it lays the foundation for commercial and geographic developments that would redound to the credit of the western hemisphere.

We have seen during the year the virtual failure of the Panama Canal company; for it is unreasonable to believe that a corporation so heavily involved with such a small proportion of its allotted labor accomplished, can secure the large sum that would be requisite to continue operations to completion. The failure of this company has imparted a fresh impetus to the Nicaragua scheme and ground was broken on this route in October last. As the Nicaragua route presents many natural advantages and is free from such stupendous engineering works as were contemplated at Panama, we may hope for its completion. The surveys were conducted with deliberation and have evidenced great skill on the part of those who supervised them, so that we may reasonably expect the construction will proceed with the same care, and resolve the question of success into the simple problem of cost.

A partial account has been furnished by Dr. Nansen of his journey across Greenland a year ago. The result will be disappointing to those who anticipated the discovery of open country with green fields and the general reversal of the Arctic conditions. He describes the region as being covered with a great shield of ice, dome-like in shape, and which he estimates to have a maximum thickness of six or seven thousand feet. For a great part of his journey he traveled at an elevation of about eight thousand feet, and the cold at times was so intense that he believes the temperature must have been at least 50° below zero on the Fahrenheit scale. No land was visible in the interior and he estimates the highest mountains must be covered with at least several hundred feet of snow ice. The expedition was one of great danger, and we may say was accomplished only through the good judgment of the explorer. The scientific results have not yet been considered, but the explorer suggests it is an excellent region to study an existing ice field, and estimates that persistent observations might prove productive of value in the science of meteorology.

The Canadians have been active during the year in the exploration of the vast territory to the northward of their supposed habitable regions. In the report of Dr. Dawson relating the result of his labors in the northwest, up to the date of its compilation, we find much that is new and a great deal that is of interest. We cannot enter into the details of his itinerary, but we may note as one fact that surely will excite surprise, the conclusion he reaches that there is a territory of about 60,000 square miles, the most part to the northward of the sixtieth parallel, in which agricultural pursuits may be successfully followed in conjunction with the natural development of the other resources of the territory. This does not imply that it may become an agricultural region, and should hardly be construed as more than a prediction that the pioneers who attempt to develop the region need not die of starvation.

We have also to record as a matter of interest in the Arctic region, the successful establishment of the two parties sent out by the United States to determine the location of the 141st meridian, the boundary line between Alaska and the British Provinces north of Mt. St. Elias. The parties are located on the Yukon and Porcupine rivers above their confluence at Ft. Yukon. They are well equipped, and it is expected they will explore a considerable territory and bring back with them valuable information beyond the special object of the expedition. Indeed, it may be said, this is but the beginning of a thorough examination of Alaskan territory, that will eventually form a basis for the demarkation of the international boundary. This country is full of surprises in its details, and whatever examinations are made must be thorough to be effective. Only recently, a small indentation, as it has been carried on the maps since Vancouver's time, and known as Holkham Bay, has been found to be a considerable body of water, extending back from Stephen's passage in two arms, each nearly thirty miles in length and nearly reaching the assumed location of the Alaska boundary. So perfectly is the bifurcation and extension of the arms hidden by islands, that it was only during the past summer when in the regular course of work the shores of the bay were to be traversed, that the extent of the bay became known.

The determination of the boundaries of the land areas on the surface of the earth has ever been a matter of the greatest interest to the students of geography. It was the incentive that led the daring navigators of old to undertake the perilous voyages that in these days read like romances; and in the light of the more perfect knowledge we now have of the hidden dangers to which they were exposed, we may pass by their shortcomings in the admiration we must feel for their heroism and endurance. To these men we owe our first conception of the probable distribution of the areas of land and water, but the lines they gave us were only approximate; and had not scientific effort followed in their tracks we may reasonably believe the progress of civilization would have been retarded by generations. True it is, also, that even to-day we have not that precise knowledge that is requisite for the safety of quick navigation, nor to calculate the possibility of the future improvement of undeveloped regions. The commerce of the world in coming years will demand the accuracy in the location of distant regions as great as we now have in civilized centres, for time will be too precious to lose a day of it in the precautions that the navigator must now follow in approaching undeveloped coasts. That these truths have guided those who seek to do their share for the future in the labor of the present, we have ample evidence in the activity of all civilized governments during the last century. It is a source of shame and infinite regret that our own government has done so little in this vast field : that the intelligence of our people has not been awakened to put forth their energy in so good a cause, that would eventually increase their own prosperity. But we have not been altogether inactive and complaint must be in the quantity, not the quality of our labors. The establishment of "definite locations," for the control of sections and regions, is the first step in eliminating errors that have been committed and in providing greater accuracy in the future. At a recent meeting of the Society we had a paper presented on this subject, from which we can judge of the good work that has been done by our navy in these determinations, and gain an insight of the similar labor that has been prosecuted by other nations. The bands of electric cables that girdle the earth, afford the most approved means of ascertaining the longitudes of these positions ; and if we but study a cable chart, it will be found the work yet to be accomplished before the facilities the cables now afford are exhausted, is not inconsiderable. We hope, therefore, this good work may be continued, and that surveying and charting the regions thus approached, will shortly follow. There is much labor of this character still required on our own continent, and we will be delinquent in our duty as a progressive people if we do not follow the good beginning already made to its legitimate conclusion.

The duties of government are manifold, and for the benefit of those governed must include legislation that will make manifest the natural resources of the State. The geographic development and political advancement of our own country in the century of our national existence, is a marked instance of the wisdom of preparing for the future by such acts as legitimately fall within the province of legislation.

The new nation began her existence under extraordinary circumstances. With only an experimental form of government, she was to develop a vast region of unknown resources; but happily imbued with the belief that "knowledge is power," it was not long before systematic efforts were put forth to learn the wealth we had and how it might be utilized. The congress of the confederation provided the first act in 1785, for the organization of the land surveys and land parcelling system, that title to the unoccupied territories in the west might be securely vested in the individual. We have record of the stimulus this act gave to the settlement of a large territory, and raised the demand for surveys in the still further west, developing the geography of a vast region that has since become the home of millions of people. The original act was amended as early as 1796, and since then has frequently been added to in the effort to meet the new conditions evolved in the rapid development of the country. Other great regions were explored by the army, sometimes under special acts, until finally we had learned with some degree of reliability, the general adaptability of our whole territory. The discovery of the great mineral wealth of the west, and the improved means of communication afforded by the construction of continental railways, however, imposed new conditions and it was found more detailed information would be necessary to meet the demands of the increasing population. We thus reached another stage where expeditions equipped for scientific investigation were organized, and through their labors brought us knowledge of still greater value; and to-day we see these merged into one body in the geological survey, whose special duty is the scientific exploration and study of our great territory.

While this had been passing in the interior, bringing life to unoccupied regions, the districts on the coast that had long been settled, were also struggling with new problems. The material progress of the civilized world, and the pressure from the regions behind them that had been recently peopled, demanded greater commercial facilities. Early in the century, almost coincident with the establishment of the land surveys, provision had been made for the survey of the coasts, and although through various causes it was not vigorously prosecuted until a third of the century had passed, when the time came for its economic use in meeting the new conditions imposed by the general progress of the nation, the knowledge had been gained that was essential to advance and develop the great interests affected. The improvements required, however, could only be secured through active exertion, the actual work of man; but so pressing has been the want and so persistent has been the labor, that should we chart the results it would be a surprise to those who believe the "local geography" has not been changed.

The demands upon the older communities arising from the increase in commercial and industrial enterprise, have caused them too, to feel the want of more detailed information of their surroundings, and they have, in consequence, undertaken more precise surveys of their territories, generally availing themselves of the assistance offered by the general government. This work will doubtless extend in time to all the States, and be followed, when its value has been made manifest, by the detailed surveys of precision that have been found necessary as economic measures in the civilized States of the old world.

It is rarely we can foresee the full results of great national enterprises; the special object that calls forth the exertion may be readily comprehended, but the new conditions evolved from success, and sometimes from only the partial accomplishment of the original design, may be factors in governing the future beyond our power to surmise.

The work of improving the navigation of the Mississippi River, is an instance of this character so marked, and apparently destined to extend its influence through so many generations, that a brief record of the change it has effected in geographic environment will not be without interest, and, perchance, not without value.

The area drained by the Mississippi river and tributaries, is forty-one per cent. of the area of the United States, exclusive of Alaska; and by the census of 1880 the population of this great district was forty-three per cent. of the whole Union. It seems probable that a large proportion of this population is directly interested in the river system, and if we add to it the number of those who are indirectly benefited, we should doubtless find a majority of our people more or less dependent upon its maintenance. It is only to the alluvial valley, however, the great strip from Cairo to the Gulf, that I wish particularly to call your attention this evening. This is really the great highway for traffic; the cause of the great work that has been prosecuted; and the scene of the geographic development that will mark an epoch in the history of the river.

Ten years ago the importance of the improvement of this water-way was so forcibly impressed upon Congress, that an act was passed organizing a "Mississippi River Commission," to make an exhaustive study of the whole subject and submit plans for the improvement of the river and to prevent the destructive floods that are of almost annual occurrence. Or in the language of the act: "It shall be the duty of said Commission to take into consideration and mature such plan or plans, and estimates, as will correct, permanently locate, and deepen the channel and protect the banks of the Mississippi river; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade, and the postal service."

Large sums of money had already been expended by the general government in local improvements, but no consistent plan had been developed that would be an acceptable guide in conducting operations along the whole river, when this act went into effect. It is not necessary to refer here to the various systems that were presented to the Commission for consideration; nor to enter upon the details of the plan finally adopted; our record being more the effects and primary causes, than the intermediary processes through which the results have been produced. The general plan followed by the Commission has been the construction of works in the bed of the river, to form new banks where a contraction of the river bed has been deemed necessary; and the erection of levees, with grading, revetment, and other protection of the banks, in localities where the natural banks seem particularly liable to give way under the pressure of a great flood. The object of such works being to control the river by confining the low water channels in fixed lines, causing the recurrence of the scour in low water stages in the same channel in successive low waters; and preventing the diversion of the stream into new channels during high water stages by overflow of the banks. A diversion of the stream would leave the works in the bed of the river below of no greater value than as monuments to the energy and skill displayed in the details of their construction, and preclude the ultimate benefit that may be derived from these works in permanently lowering the bed of the river. The probability of such diversion of the water, however, seems to have been reduced to a minimum, through the conservative action of the Commission in coöperating with the States having jurisdiction over the alluvial bottoms, in reorganizing their levee systems and thus securing the greatest control over the volume of water brought down in the flood seasons, that is possible by the construction of well planned and substantially built levees. It having been demonstrated that the levees subserve a double purpose, that they are essential in the general plan to improve the navigation of the river adopted by the Commission, and are likewise needed to render the bottom lands habitable, it is not surprising that we find the State authorities and the Commission jointly engaged in their construction.

It has thus been brought about that the effort to improve the navigation of the river for the general welfare, has resulted in such great changes in the geography of the locality, that a large district has been reclaimed for agricultural purposes. The alluvial valley of the Mississippi river has an area of thirty thousand square miles, and is naturally divided into four great basins that have been designated the St. Francis, Yazoo, Tensas and Atchafalaya. Two of these basins are now fairly protected from the overflows of the Mississippi, by the levees that have been constructed, or repaired, incidental to the work of the Commission, viz: the Yazoo basin extending from below Memphis to the mouth of the Yazoo river; and the Tensas basin from the high land south of the Arkansas river to the mouth of the Red river; and the Atchafalaya basin, from the Red river to the gulf, has been protected on the Mississippi fronts. These three basins have an aggregate area of nearly twenty thousand square miles that is now reasonably secure from inundation. Measures have also been instituted by the State authorities looking to the reclamation of the St. Francis basin; and the work is half accomplished on the White river section.

Nearly the whole of this valley was under protection thirty years ago, but the disasters of the late civil war, and subsequent inability of the people to repair the damaged levees, resulted in the practical abandonment of many sections, and it was not until about ten or twelve years ago that the protective works again presented an appearance of continuity. The supposed security, however, was of short duration, as the great floods of 1882 overtopped the works in more than one hundred and forty places, causing such widespread destruction that cultivation of the soil was rendered impossible over large districts. The floods of succeeding years but added to the misfortunes of the valley, and land values became so depreciated that sales were impracticable, taxes could not be collected, and there was a general feeling that square miles of fertile land must be given over to the destructive agencies of the great river that had made it.

It was while suffering under this distressing situation that the work of the Mississippi River Commission was brought forward as a possible means of salvation. With a recuperative power that seems almost marvelous, the people have contributed of their labor and their means, until now this great area of nearly twenty thousand square miles has been once more reclaimed, and seems to have entered upon an era of prosperity that will eclipse the prophecies of even the most sanguine. It is believed that the levees that have now been constructed will prove reasonably secure. They have been built for a double purpose; and the proportion of the expense incurred by the general government, about one-third, under the direction of the Commission, has insured a supervision and inspection by competent engineers such as was not exercised in the earlier history of such works on the river.

We cannot foretell the developments that will follow the improvement of this water way and the reclamation of the alluvial bottoms on an enduring basis. That the works erected by the Commission will maintain an increased depth of water at the low stages of the river, seems to be demonstrated, as during the low water of November last a depth of nine feet was found on the Lake Providence and Plum Point bars, an increase of thirty-three and forty-four per cent. respectively. When the depths on the other bars have been increased in like proportion the free navigation of the river will be assured, and we may point to the result as one of the greatest engineering achievements of modern times.

The increased value of the land adjacent to the river redeemed from waste, more than doubled on the average, and in many instances quadrupled; the replenishing of the state and county treasuries by the collection of taxes on land that was before unremunerative; and the building of railroads through sections where it had been impracticable to maintain them before in consequence of their liability to destruction by the periodic floods; are marked evidences of the material prosperity that has already followed the great work. During the last four years, forty thousand settlers have taken up lands in the Yazoo basin alone, and it was estimated that in the fall of 1889 twenty thousand more would seek homes in the same district. These settlers have been mostly negroes from the worn out high lands to the eastward. If the change in their environment proves beneficial to the individual we may expect an increased migration, that may in turn be an aid in solving the political problem involved in the citizenship of the negro.

The settlement of these bottom lands will also influence the prosperity of many commercial centers, as trade statistics indicate the general abandonment of the plantations that followed the great floods of 1882, caused a marked diminution in the shipments by the lower river, as well as in the receipts from that section; and that the partial reclamation of the lands and restoration of agricultural pursuits has already influenced the receipt and distribution of commercial products.

The project to reclaim by irrigation large districts of the arid region of the west, if successfully accomplished, may also exert an influence in the political and commercial relations of the future that cannot now be foretold. Two-fifths of the territory of the United States has been classed as arid; not in the sense that there is no water, for the greatest rivers on the continent have their sources almost in the midst of the region; but rather that the water is not available for enriching the ground. The rainfall is generally not in the season when the crops would require it, or is too small and uncertain for the husbandman to depend upon it. The whole region is not of this character; many districts are susceptible of the highest cultivation as nature has left them, and others have been redeemed by the application of the water supply through the simpler devices customary in irrigated countries; until now nearly all the districts have been occupied that are susceptible of agricultural pursuits, either in the natural state or by irrigation, unless water is secured by means generally beyond the reach of the individual or combination of individuals who may use it. And yet, it is believed there are millions of acres of rich land that may be redeemed and converted to the support of a large population, by the application of capital in the construction of works of irrigation. The progress of the surveys of the region, therefore, that have been instituted by the general government, are watched with absorbing interest. The districts susceptible of such extensive improvement are only approximately known, and as it is only through these surveys their availability will be made manifest, the importance of the work can hardly be overestimated. The prosperity of several states will be largely influenced by the success of operations of this kind within their borders, and in turn their greater development and increased wealth, must react upon the older communities and benefit them, on the principle that the healthful growth of a single member is strength to all.

The science of geography, as taught in the present day, is more comprehensive than the brief descriptions and delineations of the areas of land and water that satisfied the early explorers. The great strides that have been made in scientific research during the past century have opened new fields, and men are no longer content to picture that only which they can see. The varied features of the earth's surface, transformations now in progress and those which may be deduced from the facts we can observe, have led to many theories of the construction of the earth, ancient forms upon the surface and possibilities, if not probabilities, in the future. To ascertain the form of the earth has alone been the cause of heroic labor, and yet we have hardly passed the point that we can give it in probable terms with the general dimensions. Observations warrant the assumption that, discarding the accidents of nature—even the highest mountains—the sphere is far from being perfect. That it is flattened at the poles is now accepted as the true condition, but we have reason to believe, too, that this is not the only departure from the perfect sphere. The more thorough the research and precise the observations, the more certain does it appear that the crust has a form as though there had been great waves of matter that had been solidified. To locate the depressions of these great waves and measure their depths, to point to the crests and measure their extent, is a problem for the future to solve. Their study is claimed to be within the legitimate sphere of geography; and not until they have been satisfactorily answered can we assert the geographer is even approaching the end of the facts his science has yet to utilize.

In pre-historic geography we have had two papers presented to the Society during the past year, relating to the orographic features of the earth's surface in times past compared with the localities as we may see them to-day. In the first instance the comparison is evolved from an effort to trace the origin and growth of the rivers of Pennsylvania; and the second, in a description of the famed district around Asheville, North Carolina. These have a substantial interest to us, treating as they do of localities so well known; and they illustrate, too, the resources of induction in bringing to our view the probable wonders of ancient geographic forms.

The constitution of the interior of the earth is a subject of great interest in the science of geography, as many of the visible forms upon the crust have been wrought by the power of the agencies within it. The discussion has been warm in the past, and doubtless will be resumed with unabated interest as we find new phenomena for the argument. The apparent lull that has followed the promulgation of the theory, three years ago, that under the crust we should find a fluid, or semi-fluid, surrounding a solid nucleus, may not be of long duration. This hypothesis probably comes nearer to satisfying the conditions imposed by the physicist and geologist, than those which have preceded it, and may be accepted for the present; unless the processes of nature by which it is conceived this state of the interior of the earth has been produced, shall be demonstrated to have continued for sufficient time to have caused a condition of equilibrium and possible solidification of the whole sphere; when we might expect it to be repudiated by those who oppose the theory of isostacy, but commended by the physicists as supporting their claim that the earth must be substantially a solid even now. If we accept Mr. Frederick Wright's suggestion, isostacy may have an important bearing on the cause of the ice sheets that covered such great areas; a suggestion that opens to the vision of the imagination an orography beside which the grandest landscape we may see to-day would pale into insignificance. This is believed to be a new application of the isostatic theory, and may be a possible solution of a much vexed question when an initial cause for such great upheavals can be advanced that will not be inconsistent with other accepted conditions.

Theories are modified by new facts, and in any attempt to demonstrate the constitution of the interior of the earth, the increase of temperature with the depth is an important factor. The recent measures, therefore, in Germany, that indicate the figures generally accepted are not reliable, may be received with interest. The shaft was sunk especially for the purpose of observing temperatures at different depths, and every precaution that former experience had suggested seems to have been taken to secure accuracy. The greatest depth reached was about one mile. An elaborate discussion of the results fixes the increase of temperature at 1° F. for each 65 ft. increase of depth. This is about 15 ft. greater than the figures that have heretofore been given; a difference so large that we may question if they will be generally accepted until verified by further observations made with equally great care.

In conclusion permit me to note the fact that the United States was for the first time represented in the International Geodetic Association, at the meeting recently held in Paris; and also to record the successful conclusion of the fourth International Geographical Congress that assembled in Paris in August last. The reports from the Congress indicate a wide range of subjects discussed, and lead us to believe the interest in our science is progressive, and must receive the hearty appreciation of all who are inspired by the nobler instincts to develope the great sphere on which we live; that the riches, the beauties, and above all the grandeur of Nature, may be made manifest to ourselves and for our posterity.

REPORT—GEOGRAPHY OF THE AIR.

BY GEN. A. W. GREELY.

It is with a feeling of increased responsibility, shared doubtless by the Presidents of other sections, that the Vice-President of the Geography of the Air brings before you his modest annual contribution in one branch of geographical science.

We live in an age so imbued with earnest thought, and so characterized by patient investigation, that an eager gleaner in scientific fields finds at the very outset his mind filled with the garnered grain of golden facts. The more cautious searcher often follows with uncertain mind, and doubtless in his backward glances sees many fairer and heavier sheaves than those he bears with full arms, from the fruitful harvest. If, then, you do not find here dwelt on such geographical phases as you judge most important, attribute the fact I pray you, not to neglect, but to lack of observation, or to the exercise of an undiscriminating judgment.

First let us turn to the higher class of investigations, wherein that handmaid of science, a true and noble imagination, comes to supplement exact knowledge, to round out and give full form and perfect outline, either shaping a number of disjointed and apparently heterogeneous facts into a harmonious series, or evolving from a mass of confusing and seemingly inexplicable phenomena a theory or law consistent therewith.

In this domain Professor Ferrel's book on Winds is probably the most important theoretical meteorological discussion of the past year. It owes its value to the fact that it puts into comparatively simple and popular form the processes and results of his intricate mathematical investigations of the motions of the air, published by him years since, and later elaborated during his service with the Signal Office.

In connection with the subject of winds, Professor William M. Davis has formulated an excellent classification, depending first, on the ultimate source of the energy causing the motion ; second, on temperature contrasts which produce and maintain winds ;

and third, on their periodicity and the time of the first appearance of the motion.

Professor Russell, appropriately it seems to me, remarks regarding the landslide winds, that avalanche would be a better term than landslide as applied to winds associated with fallen masses of earth or snow.

With the enormous amounts of accumulated tabulated matter, and numerous studies bearing on isolated meteorological phenomena, it is a specially important consideration that some students pay constant attention to the investigations of the laws of storms. From such researches definite advances in theoretical meteorology may be made and fixed laws determined, which may be of practical utility with reference to the better forecasting of the weather. In the United States Signal Office, Professor Abbe has brought together the results of his studies and investigations for the past thirty years, under the title, "Preparatory studies for Deductive Methods in Storm and Weather Predictions." This report will appear as an appendix to the annual report of the Chief Signal Officer of the army. Professor Abbe finds that the source and maintaining power of storms depend on the absorption by clouds of solar heat, and in the liberation of heat in the cloud during the subsequent precipitation, which, as he endeavors to show, principally influences the movement of the storm-centre.

In this method one takes a chart showing current meteorological conditions, and the permanent orographic features of the continent; lines of equal density are also drawn for planes at several elevations above sea-level. On these latter, and on the lines of the orographic resistance, are based intermediate lines of flow, which show where conditions are favorable to cooling and condensation. The amount of condensation and its character, whether rain or snow, are estimated by the help of the graphic diagram. Numbers are thus furnished that can be entered on the chart and show at once the character of the new centre of buoyancy, or the directions and velocity of progress of the centre of the indraft and the consequent low barometer.

It is hoped that this work of Professor Abbe's may be, as he anticipates, of great practical as well as theoretical value. Steps are being taken to test the theoretical scheme by practical and exhaustive applications to current work.

Tiesserenc de Bort has continued his work, of improving weather forecasts for France, by studying the distribution of the great and important centres of high pressures, which prevail generally over the middle Atlantic ocean, and, at certain periods of the year, over Asia, Europe, and North America. His studies have proceeded on the theory that the displacements of centres of high pressure, whether in Asia, over the Azores, near Bermuda, in North America, or in the Polar regions, set up a series of secondary displacements, which necessarily cause storm centres to follow certain routes. M. de Bort concludes that a daily knowledge of the relation of these centres and their areas of displacement will eventually enable skilled meteorologists to deduce the position of unknown and secondary centres. He has endeavored to reduce these various displacements to a series of types and has made very considerable progress in this classification. Daily charts covering many years of observations have been prepared, and these separated, whenever the characteristics are sufficiently pronounced, into corresponding types. This plan of forecasting necessitates extended meteorological information daily, which France obtains not only from Russia, Algeria, Italy and Great Britain, but, through the coöperation of United States, from North America. The daily information sent by the Signal Office shows, in addition to the general weather over the United States and Canada, the conditions on the western half of the North Atlantic ocean, as determined by observations made on the great steamships, and furnished voluntarily by their officers to the Signal Office through the Hydrographic Office and the New York Herald weather bureau.

The study of thunder storms has received very elaborate and extensive consideration. M. Ciro Ferari in Italy finds that almost invariably the storms come from directions between north and northwest, the tendency in northern Italy being directly from the west, and in the more southern sections from the northwest. The velocities of storm movements are much greater from the west than from the east, considerably more so in the centre and south of Italy than in the north; and in the months, largest in July.

The velocity of propagation increases with greater velocities of the winds accompanying the storms, with also greater attendant electrical intensity. The front line of propagation while more often curved, is sometimes straight and sometimes zigzag, and appears to undergo a series of successive transformations, more or less affected by the topographical nature of the country passed over.

Ferari thinks their principal cause is to be found in high temperatures coincident with high vapor pressures. Thunder storms, he considers, are essentially local phenomena, superposed on the general atmospheric phenomena. A principal general cause of thunder-storms in Italy is the existence of a deep depression in northwest Europe, with a secondary depression in Italy dependent on the first. This secondary feeble area remains for several days over upper Italy, and nearly always is followed by thunder storms. Minimum relative humidity precedes, and maximum follows a storm, while the vapor pressure conditions are exactly reversed. Ferari notes, as one matter of interest, the passage of fully developed thunder storms from France into Italy over mountains 4,000 metres (13,000 feet) in elevation.

Dr. Meyer, at Gottingen, has investigated the annual periodicity of thunder storms, while Carl Prohaska has made a statistical study of similar storms in the German and Austrian Alps. The latter writer thinks they are most likely to occur when the barometer is beginning to rise after a fall, thus resembling heavy down-pours of rain.

In connection with Schmucher's theory on the origin of thunder storm electricity, Dr. Less has been able to satisfactorily answer in the affirmative an important point in the theory, as to whether the vertical decrement of temperature is especially rapid. Less finds evidences of very rapid decrement of temperature during thunder storms, as shown by the examination of records of 120 stations for ten years.

Mohn and Hildebrandsson have also published a work on the thunder storms of the Scandinavian peninsula. The rise in the barometer at the beginning of rain, they agree with Mascart in attributing largely to the formation of vapor and the evaporation of moisture from rain falling through relatively dry air.

A. Croffins has discussed thunder storms at Hamberg from observations for ten years. He believes that all such storms are due to the mechanical interaction of at least two barometric depressions.

As a matter of interest bearing on the much discussed phenomena of globular lightning, an incident is recounted by F. Roth, where a man feeding a horse was struck by lightning and lost consciousness. The man states that he felt no shock, but was suddenly enveloped in light and that a ball of fire the size of his fist, traveled along the horse's neck. This points to the fact that "ball" lightning is probably a physiological phenomenon.

In view of the recent extended interest in the question as to whether the climate of the United States is permanently changing, it should be remarked that this question has lately been under consideration with regard to Europe. Messrs. Ferrel, Richter, Lang, Bruchen and others conclude, from an examination of all available data, that there is no permanent climatic change in Europe. In connection with this discussion in Europe, long series of vintage records, going back to the year 1400, have been used. Apart from the ocean borders, extensive simultaneous climatic changes occur over extended areas, which changes—as might be expected—are more accentuated in the interior of the continents. These changes involve barometric pressure, rainfall and temperature, which all recur to that indefinite and complex phenomenon—the variation in the amount of heat received by the earth. The idea is advanced that these oscillations have somewhat the semblance of cycles, the period of which is thirty-six years. It may easily be questioned, however, in view of the fragmentary and heterogeneous character of the data on which this assumption is based, whether the error in the observations is not greater than the range of variation. Blanford, in one of his discussions, has pointed out that the temperature or rainfall data in India can be so arranged as to give a cycle with a period of almost any number of years, but, unfortunately, the possible error of observation is greater in value than the variations.

As to the United States, it is pertinent to remark that the Signal Office is in possession of temperature observations in Philadelphia, covering a continuous period of one hundred and thirty-two years. The mean annual temperature for the past ten years is exactly the same as for the entire period.

There have been criticisms in years past that the climatological conditions of the United States have not received that care and attention which their importance demanded. Much has been done to remedy defects in this respect, although, as is well known here in Washington, the general law which forbids the printing of any works without the direct authority of Congress, has been an obvious bar to great activity on the part of the Signal Office.

Within the year the rainfall conditions of twelve Western States and Territories have been published with elaborate tables of data and fifteen large charts, which set forth in considerable detail the rainfall conditions for that section of the country. In addition the climatic characteristics of Oregon and Washington have been graphically represented; and rainfall maps,—unfortunately on a small scale,—have been prepared, showing for each month, the average precipitation of the entire United States, as determined from observations covering periods varying from fifteen to eighteen years.

In Missouri, Professor Nipher has prepared normal rainfall charts for that State, unfortunately on rather a small scale. In New York, Professor Fuertes, and in Michigan, Sergeant Conger, of the Signal Service, have commenced maps showing, by months, the normal temperatures of their respective States on maps of fairly open scale. Work of a similar character has been carried on in Pennsylvania under the supervision of Professor Blodget, well known from his climatological work. In other directions and in other ways, work of a similar character is in progress.

Without doubt too much is anticipated from pending or projected irrigation enterprises in the very arid regions of the West. These unwarranted expectations must in part result from a failure on the part of the investors to consider the general question of these enterprises, in its varied aspects, with that scientific exactness so essential in dealing theoretically with extended subjects of such great importance.

Everyone admits the correctness of the statement that the amount of water which flows through drainage channels to the sea, cannot exceed the amount which has evaporated from adjacent oceans and fallen as precipitation on the land. Further it is not to be denied that the quantity of water available in any way for irrigation must be only a very moderate percentage of the total rainfall which occurs at elevations *above*, and perhaps it may be stated *considerably above*, that of the land to be benefited.

Elsewhere it might be appropriate to dwell in detail upon the importance of cultivated land in serving as a reservoir which parts slowly with the water fallen upon or diverted to it, and in avoiding the quick and wasteful drainage which obtains in sections devoid of extensive vegetation or cultivation; and also that water thus taken up by cultivated lands must later evaporate and may again fall as rain on other land. But the pertinence of meteorological investigations in connection with irrigation and this annual address, relates much more directly to important questions of the manner by, and extent to which, precipitation over the catchment basins of the great central valleys fails to return in direct and visible form, through the water courses, to the Gulf of Mexico.

The inter-relation of rainfall and river outflows is one of peculiar interest, in connection with the important matter of irrigation now under consideration in this country.

Probably more attention has been paid to this subject in the valley of the Seine, by Belgrand and Chateaublanc, than in any other portion of the globe. One of the curious outcomes of Chateaublanc's observations, is one bearing on the maximum value of the floods in the Seine for the cold season, from October to May, by which he says that the reading of the river gauge at Port Royal is equal to 12.7 minus the number of decimetres of rainfall which has fallen on an average throughout the catchment basin during the preceding year. This curiously shows that the intensity of the winter floods of the Seine is inversely proportional to the quantity of rain of the *preceding* year.

Sometime since, John Murray, Esq., in the Scottish Geographic Magazine, treated generally the question of rainfall and river outflows. The annual rainfall of the globe was estimated to be 29,350 cubic miles, of which 2,343, falling on inland drainage areas, such as the Sahara desert, etc., evaporate. The total annual discharge of rivers was estimated at 7,270 cubic miles. In the case of European drainage areas between a third and a fourth of the rainfall reaches the sea through the rivers. The Nile delivers only one thirty-seventh of the rainfall of its catchment basin, while tropical rivers in general deliver one-fifth.

The Saale river of Germany, from late data based on 45 rainfall stations in its catchment basin, during the years 1883 to 1886, discharged 30 per cent. of its rainfall.

During the past year Professor Russell, of the Signal Office, has determined carefully the rainfall and river outflow over the most important part of the United States, the entire catchment basin of the Mississippi river and its tributaries. This work was done as preliminary to formulating rules for forecasting the stage of the water several days in advance on the more important of the western rivers in the United States. The river outflows at various places on the Mississippi and Missouri and Ohio rivers, were tabulated from data given in the reports of the Mississippi and Missouri River Commissions. The tables were largely derived from the results of the measurement of current velocities. As gauge readings were taken at the time of discharge or outflow measurements, the discharges or outflows can be told approximately at other times when only the river gauge readings are known. The results for the outflow of rivers derived from measurements made under the supervision of these commissions, are of a high order of accuracy, and it is not probable that the results deduced from the gauge readings are much in error. Of 1881 and 1882, during which years measurements were made, 1881 was a year of great flood in the Missouri river, while the Mississippi river was not flooded. The year 1882, on the other hand, was marked by a great flood in the lower Mississippi river, with a stage in the Missouri much above the average. The rainfall in the six great valleys of the Mississippi, during the entire years 1881 and 1882, was charted from all observations available, and its amount in cubic miles of water calculated with the aid of a planimeter.

In connection with this investigation, and as a matter of value in showing the forces which are in operation to affect the river outflow, the fictitious or possible evaporation of the six great valleys referred to were calculated, in cubic miles of water, from July, 1887, to July, 1888, and also the average amounts of water in the air as vapor, and the amount required to saturate the air in the same valleys during the same period.

During the year 1882, the year of great flood in the lower Mississippi valley, the outflow at Red River Landing, La., was 202.7 cubic miles, of which the upper Mississippi river above St. Louis furnished 16 per cent., the Ohio 43, and the whole Missouri above Omaha, 4 per cent. The upper Missouri valley (that is, from the mouth of the Yellowstone up to the sources), and the middle Missouri valley (from the mouth of the Platte to the Yellowstone), each furnished only about 2 per cent. of the entire amount of the water which passed Red River Landing. The lower Mississippi valley, including the Arkansas, etc., furnished 32 per cent.

During March, April and May, 1882, the time of highest stage of the water of the lower Mississippi, the outflow at Red River Landing and through the Atchafalya measured 82.7 cubic miles, During this time there flowed through the upper Mississippi river above St. Louis, 14 per cent. of the amount; through the Ohio, 38 per cent., and through the Missouri 6 per cent.; while the rivers of the lower Mississippi valley contributed 41 per cent. The water that passed Omaha was 1.92 cubic miles, or 2 per cent. of the flow of the whole Mississippi during the same time. The water which flowed from the upper and middle Missouri valleys during March, April and May, 1882, was for each valley, probably only 1 per cent. of the water that flowed through the lower Mississippi river. The flood of the lower Mississippi was undoubtedly due to the great discharge of the Ohio, supplemented by heavy river inflow below the mouth of the Ohio, and the unusually heavy rainfall in the lower Mississippi valley.

The ratios of river outflow to rainfall over the catchment basins, as derived by Professor Russell from the two years' observations, 1881 and 1882, were as follows:

Upper and Middle Missouri valleys, about 335,000 square miles, 13 per cent.

Lower Missouri valley, about 210,000 square miles, 12 per cent.

Entire Missouri valley, about 545,000 square miles, nearly 13 per cent.

The upper Mississippi valley, about 172,000 square miles, 33 per cent.

Ohio valley, about 212,000 square miles, 40 per cent.

Lower Mississippi valley, about 343,000 square miles, about 27 per cent.

The above percentages, while showing the averages for two entire years, and so of decided value, are not to be depended upon for special years or months. For instance: in the Ohio valley in 1881, the outflow was 33 per cent., while in 1882 it was 50 per cent., and as the rainfall in 1882 was 180 cubic miles against 151 cubic miles in 1881, it appears evident that a much greater proportional quantity of water reaches the rivers during seasons of heavy rainfalls than when the precipitation is moderate or scanty.

Evaporation is also a very potent cause in diminishing river outflow, and as this depends largely on the temperature of the air and the velocity of the wind, any marked deviation of these meteorological elements from the normal, must exercise an important influence on the ratio of outflow to rainfall.

In connection with Professor Russell's work it is desirable to note that Professor F. E. Nipher has lately made a report on the Missouri rainfall based on observations for the ten years ending December, 1887, in which he points out as an interesting coincidence that the average annual discharge of the Missouri river closely corresponds in amount to the rainfall which falls over the State of Missouri. From Professor Nipher's figures it appears that the discharge of the Missouri river in the ten years ending 1887, was greatest in 1881 and next greatest in 1882, so that the averages deduced from Professor Russell's report of the outflow of the Missouri are too large, and should be somewhat reduced to conform to the average conditions. In different years the average of the discharge in the outflow of the Missouri varies largely, as is evidenced by the fact reported by Professor Nipher, that the discharge in 1879 was only 56 per cent. of the outflow in 1881.

In New South Wales, under the supervision of H. C. Russell, Esq., government astronomer, the question of rainfall and river discharge has also received careful attention, especially in connection with evaporation. The observations at Lake George are important, owing to the shallowness of the lake (particularly at the margin); its considerable surface area (eighty square miles), its moderate elevation (2,200 feet), and the fact that it is quite surrounded by high lands. Observations of the fluctuations of this lake have been made from 1885 to 1888, inclusive. In the latter year the evaporation was enormous, being 47.7 inches against a rainfall of 23.9 and an in-drainage of 5.3 inches, so that the total loss in depth was 18.5 inches for the year. It appears that the evaporation in different years on this lake varies as much as 50 per centum of the minimum amount. According to Russell the amount of evaporation depends largely on the state of the soil, going on much faster from a wet surface of the ground than from water; with dry ground the conditions are reversed. In 1887, the outflow from the basin of Lake George, the drainage from which is not subject to loss by long river channels, was only 3.12 per centum of the rainfall.

In the Darling river, above Bourke, says Russell, the rainfall is measured by 219 gauges. The average river discharge, deduced from observations covering seven years, is only 1.45 per centum of the rainfall, and in the wettest year known the discharge amounted only to 2.33 per centum of the rainfall, and has been as low as 0.09 per centum in a very dry year. In the Murray basin the average discharge relative to the rainfall is estimated to be about 27 per centum from a record of seven years, and has risen as high as 36 per centum in a flood year.

In connection with the regimen of rivers, it appears a proper occasion to again refute the popular opinion that the spring and summer floods of the Missouri and Mississippi valleys result from the melting of the winter snows. This is an erroneous impression which I have combatted since 1873, when my duties required a study of the floods of the entire Mississippi catchment basin. It is only within the last two years, however, that the meteorological data has been in such condition that the opinion put forth by me could be verified, namely: that the floods of the late spring and early summer owe their origin almost entirely to the heavy rains immediately before and during the flood period. Occasionally a very heavy fall of snow precedes extended general rains; but in this case the snow is lately fallen and is not the winter precipitation.

Referring to the Missouri valley, the section of the country where the winter snowfall has been thought to exercise a dominating influence in floods, it has elsewhere been shown by me that about one-third of the annual precipitation falls over that valley during the months of May and June. In either of the months named the average precipitation over the Missouri valley is greater than the entire average precipitation for the winter months of December, January and February.

Woiekoff thinks that the anomalies of temperatures shown in forest regions, particularly in Brazil—with its abnormally low temperatures, are due to heavy forests promoting evaporation, and by causing the prevalence of accompanying fogs thus prevent more intense insolation. He considers this an argument for the maintenance of forests to sustain humidity and distribute rain over adjacent cultivated land, as well as to maintain the fertility of the soil, which diminishes rapidly by washing away of the soil after deforestation.

W. Koppen has devised a formula for deriving the true daily temperature from 8 A. M., 2 P. M. and 8 P. M. observations in connection with the minimum temperature, in which the minimum has a variable weight dependent on place and month. The results of Koppen's formula tested on six stations in widely different latitudes, indicate that it is of value.

Paulsen's discussion of the warm winter winds of Greenland is interesting. These unusual storm conditions last three or four days, or even longer, the temperature being at times from 35° to 40° Fahr. above the normal, and they appear principally with winds from northeast to southeast, which Hoffmeyer believes to be *foehn* winds. Paulsen contends that the extensive region over which these winds occur make the *foehn* theory untenable, and that a more reasonable explanation of these winds is to be found in the course of low areas passing along the coast or over Greenland. This appears evident from the fact that not the easterly winds only but the southerly winds share this high temperature, and that as low areas approach from the west, at first the regions of the Greenland coast within its influence have south to southwest winds.

The question of wind pressures and wind velocities is a most important one in these days of great engineering problems, particularly in connection with the stability of bridges and other large structures.

Experimental determination of the constants of anemometric formulæ have recently been made both in England and this country. From results obtained in the English experiments it was concluded that the very widely used Robinson anemometer is not as satisfactory and reliable an instrument as a different form of anemometer devised by Mr. Dines. These conclusions, however, are not sustained by the American experiments, which were made by Professor C. F. Marvin, Signal Office, by means of a whirling apparatus, and under the most favorable circumstances, which yielded highly satisfactory results. Professor Marvin has lately made very careful open air comparisons of anemometers previously tested on the whirling machine, which have shown that, owing in part to the irregular and gusty character of the wind movement in the open air, taken in connection with the effects arising from the moment of inertia of the cups, and the length of the arms of the anemometer, the constants determined by whirling machine methods need slight corrections and alterations to conform to the altered conditions of exposure of the instruments in the open air. This latter problem is now being experimentally studied at the Signal Office, and final results will soon be worked out.

Professor Langley has also made very elaborate observations of pressures on plane and other surfaces inclined to the normal, which it is believed will prove important contributions to this question, but the results have not yet been published. It is important in this connection to note experiments made by Cooper on the Frith of Forth Bridge, where a surface of 24 square metres, during a high wind, experienced a maximum pressure of 132 kilogrammes per square metre, while a surface of 14 square decimeters showed, under similar conditions, 200 kilogrammes per square metre, by one instrument, and 170 by another. The opinion expressed by Cooper that in general the more surface exposed to the wind, the less the pressure per unit of surface, seems reasonable, and if verified by more elaborate experiments must have an important bearing.

There are questions in connection with which even negative results are of an important character, particularly when such results are quite definite, and tend to remove one of many unknown elements from physical problems of an intricate character. In this class may be placed atmospheric electricity, with particular reference to its value in connection with the forecast of coming weather. The Signal Office, through Professor T. C. Mendenhall, a distinguished scientist peculiarly fitted for work of this character, has been able to carry out a series of observations, which have received from him careful attention, both as to the conditions under which the observations were made and in the elaboration of methods to be followed.

Professor Mendenhall also supervised the reduction of these observations, and after careful study presented a full report of the work to the National Academy of Sciences, in whose proceedings this detailed report will appear. Professor Mendenhall says, "Taking all the facts into consideration, it seems to be proved that the electrical phenomena of the atmosphere are generally local in their character. They do not promise, therefore, to be useful in weather forecasts, although a close distribution of a large number of observers over a comparatively small area would be useful in removing any doubt which may still exist as to this question." It may be added that Professor Mendenhall's conclusions bear out the opinions expressed to the speaker, in a discussion of this question, by Professor Mascart, the distinguished physicist.

It has been generally admitted that the aqueous vapor in the atmosphere plays a most important part in bringing about the formation of storms and maintaining their energy. It has been frequently commented on by the forecast officials of the Signal Service, that storms passing over the United States were in general preceded by an increase in moisture, but unfortunately little effort had been made on the part of previous investigators to determine any quantitative relation between the actual humidity and the amount of precipitation or its relation to the storm movement. It has long been regretted that the direct relations of this to other meteorological phenomena were not more fully defined. During the past year Captain James Allen, of the Signal Office, has endeavored to apply the results of his investigations and theories to the practical forecasts of storm conditions. Captain Allen has carefully studied the relations of the potential energy of the surface air, as represented by the total quantity of heat it contained, to the movement of storm centres and the extent of accompanying rain areas. In his first investigations the potential energy per cubic foot was estimated as follows: Supposing the air to have been originally 32° and the moisture in it as water at 32°, the total quantity of heat applied to reduce to the state of observation will be $A = \frac{(t-32)}{6} + Q$ in which A is total heat per unit volume; t is the temperature of the air, Q the total heat of vapor, and the specific heat of air at constant volume being taken as one-sixth (.168). From Regnault's formula we have $Q = 1091.7 + .305(t-32)$.

For the mechanical equivalent we have $J = 772A$. If we divide J by the pressure estimated in pounds per square foot, it will give the height through which the pressure can be lifted if all the heat is spent in work by expanding the air.

An approximate expression for the upward velocity V may be obtained from Torrecelli's theorem from which we have $V^2 = 2gh$, h in this case being being the height through which the pressure would be lifted if all the heat is spent in work. The theory has been that the storm centre will move over that section of the country where V is the greatest, and that the time of occurrence and amount of rain have a relation of conformity to the changes in Q and its actual amount.

Auxiliary charts were also made showing for each station the following following values of Q:

1st. Highest Q not followed by rain in 24 hours.

2d. Greatest plus change in Q not followed by rain in 24 hours.

3d. Lowest value for Q followed by rain in 12 hours.

A tentative application of the theory during December, 1889, has given very encouraging results. The problem can be approached in many different ways, but the basis of the solution is the determination of the actual energy of the air, both potential and kinetic, as well as differences of potential.

Probably the most important event of the past year to general meteorological students has been the publication of Part I, Temperature, and Part II, Moisture, of the Bibliography of Meteorology, under the supervision of the Signal Office, and edited by Mr. O. L. Fassig. The two parts cover 8,500 titles out of a total of about 60,000. This publication renders it now possible for any investigator to review the complete literature of these subjects, not only with a minimum loss of time, but with the advantage of supplementing his own work, without duplication, by the investigations of his predecessors. The publication is a lithographic reproduction of a type-written copy, the only available method, which leaves much to be desired on the grounds of appearance, space and clearness.

The experiments of Crova and Houdaille on Mount Venteux, elevation 1,907 metres, and at Bedoin, 309 metres, are of more than transient interest since they fix the solar constant at a height of 1,907 metres, at about three calories; agreeing with the value obtained by Langley on Mt. Whitney, Cal.

With this brief allusion to the important phenomena of sunheat, whereon depend not only the subordinate manifestations pertaining to this section, but those relating to all other departments, this report may appropriately close.

TREASURER'S REPORT.

YEAR ENDING DECEMBER 31, 1889.

C. J. Bell, Treasurer, in account with National Geographic Society.

Balance on hand as per last account		$626.70

Receipts.

To amount of annual dues for 1889	$865	
" " " " 1890	20	
To Life Members	50	
		935.00
Note for $1,000 with interest paid off, Nov. 16, 1869		1,032.08
Sale of Maps		1.41
Surplus from Field Meeting		25.35
		$2,620.54

Investments on Hand, Dec. 31, 1889.

Note dated March 27, 1889, for the sum of $750, with interest @ 6%, due March 27, 1890. Secured by real estate.

Disbursements.

	By Cost of Magazine, No. 2	$174.46	
	" " " No. 3	233.66	
	" " " No. 4	197.28	
	" Directory of Society	28.35	
	" Rent of Hall at Cosmos Club	45.00	
	" Printing, Stationery and Postage	108.72	
	" Sundries	13.00	
1889.			800.47
Mar. 26.	By Loan on collateral		1,000.00
	" Note for $750 and interest, from March 27, 1889, for 1 year @ 6%, due March 27, 1890		756.25
	Balance in Bank		63.82
			$2,620.54

REPORT OF AUDITING COMMITTEE.

December 27, 1889.

To the National Geographic Society:

The undersigned, having been appointed an auditing committee to examine the account of the Treasurer for 1889, make the following report :

We have examined the Treasurer's books and find that the receipts as therein stated are correctly reported. We have compared the disbursements with the vouchers for the same and find them to have been properly approved and correctly recorded We have examined the bank account and compared the checks accompanying the same. We find the balance (beside the sum of $756.25 invested in real estate note) as reported by the Treasurer ($63.82) consistent with the balance as shown by the bank-book ($82.82), the difference being explained by the fact that there are two outstanding checks for the sum of $19.00 not yet presented for payment.

Bailey Willis,
R. Birnie, Jr.,
Willard D. Johnson,
Auditing Committee.

REPORT

OF THE

RECORDING SECRETARY.

The first report of the Secretaries was presented to the Society, December 28, 1888. At that time the Society had a total membership of 209. Since that date this membership has been increased by the election of 36 new members; it has been decreased by the death of 3 and by the resignation of 14. The net increase in membership is thus 19 and the present membership is 228, including 3 life members. The deceased members are, Z. L. White, G. W. Dyer and Charles A. Ashburner.

The number of meetings held during the year was 17, of which 15 were for the presentation and discussion of papers; one was a field meeting held at Harper's Ferry, W. Va., on Saturday, May 11, 1889, and one, the annual meeting. The average attendance was about 65.

The publication of a magazine begun last year, has been continued, and three additional numbers have been published, being Nos. 2, 3 and 4 of Vol. I. Copies of the numbers have been sent to all members and also to about 75 American and foreign scientific societies and other institutions interested in Geography. As a result the Society is now steadily in receipt of geographical publications from various parts of the world.

Respectfully submitted,

HENRY GANNETT, *Recording Secretary.*

NATIONAL GEOGRAPHIC SOCIETY.

ABSTRACT OF MINUTES.

Nov. 1, 1889. Twenty-seventh Meeting.

A paper was read entitled, "Telegraphic Determinations of Longitudes by the Bureau of Navigation," by Lieutenant J. A. Norris, U. S. N. *Published in the National Geographic Magazine, Vol. 2, No. 1.*

Nov. 15, 1889. Twenty-eighth Meeting.

A paper was read by Ensign Everett Hayden, U. S. N., entitled, "Law of Storms considered with Special Reference to the North Atlantic," illustrated by lantern slides. It was discussed by Messrs. Greely and Hayden.

Nov. 29, 1889. Twenty-ninth Meeting.

A paper was read by Mr. H. M. Wilson entitled, "The Irrigation Problem in Montana." Discussion was participated in by Messrs. Dutton, Greely and Wilson.

Dec. 13, 1889. Thirtieth Meeting.

The paper of the evening was by Mr. I. C. Russell upon "A Trip up the Yukon River, Alaska," and was illustrated by lantern slides.

Dec. 27, 1889. Thirty-first Meeting—2d Annual Meeting.

Vice-President Thompson in the chair. The minutes of the first annual meeting were read and approved. Annual reports of the secretaries and treasurer and the report of the auditing committee were presented and approved. The following officers were then elected for the succeeding year :

President—GARDINER G. HUBBARD.

Vice-Presidents—HERBERT G. OGDEN, [land]; EVERETT HAYDEN, [sea]; A. W. GREELY, [air]; C. HART MERRIAM, [life]; A. H. THOMPSON, [art.]

Treasurer—CHARLES J. BELL.

Recording Secretary—HENRY GANNETT.

Corresponding Secretary—O. H. TITTMANN.

Managers—CLEVELAND ABBE, MARCUS BAKER, ROGERS BIRNIE, JR., G. BROWN GOODE, W. D. JOHNSON, C. A. KENASTON, W. B. POWELL and JAMES C. WELLING.

Jan. 10, 1890. Thirty-second Meeting.

The annual reports of Vice-Presidents Ogden and Greely were presented. *Published in the National Geographic Magazine, Vol. 2, No. 1.*

Jan. 24, 1890. Thirty-third Meeting.

A paper was read entitled, "The Rivers of Northern New Jersey," with notes on the "General Classification of Rivers," by Professor William M. Davis. The subject was discussed by Messrs. Davis, Gilbert and McGee.

Feb. 7, 1890. Thirty-fourth Meeting.

The annual report of Vice-President Merriam was presented. A paper on "Bering's First Expedition," was read by Dr. W. H. Dall.

Feb. 21st, 1890. Thirty-fifth Meeting.

Held in the Lecture Hall of Columbian University. The annual address of the President, Mr. Gardiner G. Hubbard, was delivered, the subject being "Asia, Its Past and Future." *Published in "Science," Vol. XV, No. 371.*

Feb. 28th, 1890. Special Meeting.

Held in the Lecture Hall of Columbian University. A paper was read by Lieut. Com'dr Chas. H. Stockton, U. S. N., entitled "The Arctic Cruise of the Thetis During the Summer and Autumn of 1889," which was illustrated by lantern slides.

March 7th, 1890. Thirty-sixth Meeting.

A paper was read by Mr. Romyn Hitchcock, entitled "A Glimpse of Chinese Life in Canton."

OFFICERS.

1890.

President.

GARDINER G. HUBBARD.

Vice-Presidents.

HERBERT G. OGDEN.
EVERETT HAYDEN.
A. W. GREELY.
C. HART MERRIAM.
A. H. THOMPSON.

Treasurer.

CHARLES J. BELL.

Secretaries.

HENRY GANNETT.
O. H. TITTMANN.

Managers.

CLEVELAND ABBE.
MARCUS BAKER.
ROGERS BIRNIE, Jr.
G. BROWN GOODE.
W. D. JOHNSON.
C. A. KENASTON.
W. B. POWELL.
JAMES C. WELLING.

MEMBERS OF THE SOCIETY.

---

a, original members.
l, life members.
* Deceased.
In cases where no city is given in the address, Washington, D. C., is to be understood.

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