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U. S. COAST AND GEODETIC SURVEY

E. LESTER JONES, DIRECTOR

PROGRESS OF WORK IN TERRESTRIAL MAGNETISM

OF THE U. S. COAST AND GEODETIC SURVEY

JANUARY 1, 1925, to JUNE 30, 1927

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(Report to the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union, International Research Council)

BY

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PROGRESS OF WORK IN TERRESTRIAL MAGNETISM OF THE UNITED STATES COAST AND GEODETIC SURVEY, JANUARY 1, 1925, TO JUNE 30, 1927

By N. H. Heck, *Chief*, and D. L. Hazard, *Assistant Chief, Division of Terrestrial Magnetism and Seismology*

There has been little change in the condition of the magnetic survey of the United States during the period covered in this statement. The survey has covered the area of the United States proper, with observations in Alaska and the various insular groups under the jurisdiction of the United States. In certain regions, especially in the western mountain regions of the United States and in Alaska off the main lines of travel, additional observations are needed. The main object at present is to occupy the selected repeat stations every five years, to outline the extent of disturbed areas, and to occupy such new stations as are found practicable. Owing to the use of magnetic methods by land surveyors in many parts of the United States, there is strong demand in many places for the maintenance of magnetic stations to test magnetic instruments so used, and such stations, in so far as practicable, are replaced when defective or missing.

UNITED STATES PROPER

The work since 1924 has been chiefly the occupation of repeat stations. However, a number of new stations have been occupied in regions not hitherto reached, especially in Texas, Montana, Utah, and Nevada. A large number of stations have been replaced for the benefit of local surveyors, with the consequent obtaining of magnetic information, but these requests have been met only in part. A magnetic survey of the State of North Carolina in cooperation with the State authorities has been completed.

Information in regard to the magnetic stations is furnished in a publication issued every 10 years (1915–1925, etc.), giving the values of the magnetic elements at all stations, but without descriptions of stations, and containing maps giving the isogonic, isoclinic, and lines of equal horizontal intensity for the epoch of the publication. A five-yearly publication (1920–1925, etc.) gives tables for secular change covering the period from the earliest observations to January 1 of the year for which the publication is issued. This publication contains an isogonic map of the United States for the same date. The most recent one, that for January 1, 1925, contains tables of secular change on a new plan. Instead of designating the approximate area concerned, as heretofore, values are given for every two degrees of latitude and longitude. This makes interpolation easy.

In addition to the publications covering the country as a whole, a demand for information on a larger scale has been met by publications covering individual States or groups of States. These publications contain values of the declination at all stations, descriptions of the stations, a large-scale map, and secular-change tables at frequent intervals, so that little or no interpolation is needed. Up to the present time those for Arkansas, Missouri, Florida, and North Carolina have been issued, and several others are in course of preparation.

In connection with the use of magnetic stations by local surveyors the condition of more than half of 3,700 marked stations in the United States have been voluntarily reported. This indicates the interest in the subject, which is indicative of future progress in the work.

A special effort has been made to secure rather intensive observations along the coast, and the surveying vessels make many more observations of declination than is possible for the country as a whole. The Coast and Geodetic Survey does not possess a nonmagnetic vessel, and, while use is made of the results of occasional cruises along our shores of the *Carnegie*, of the Carnegie Institution of Washington, magnetic information for mariners' charts is chiefly obtained from shore observations. The results with a nonmagnetic ship are so much superior that observations at sea by the vessels of the Coast and Geodetic Survey have ceased, except in areas of local magnetic disturbance where exact values are not important.

ALASKA AND ISLAND POSSESSIONS

Alaska covers a large area, much of which is inaccessible by road, railroad, or water transportation. Accordingly, most of the magnetic observations are confined to regions readily reached, except in the case of the boundary where many observations were made at the time of its demarcation. The present effort is to occupy repeat stations every 10 years. During the past three years observations have been made at new stations in the Aleutians and at various points along the shores of southeastern and southwestern Alaska.

During the period covered by this report repeat observations were made in the Hawaiian Islands and in the Philippine group. Observations were made in the island group between Luzon and the Japanese Islands to the north, and in Palawan and various small islands in the Sulu Sea.

Special observations were made during the total solar eclipse of January 24, 1925, at Ithaca, N. Y., in cooperation with Cornell University. Atmospheric electric observations were also made (potential gradient) in cooperation with the department of terrestrial magnetism, Carnegie Institution of Washington.

All field instruments used in the above surveys were standardized at the observatory at Cheltenham, Md.

Especial attention is called to the relations with Canada. That country makes field observations over a large portion of its area, even in relatively inaccessible regions. Results in the vicinity of the border are exchanged between the two countries in advance of publication when necessary, so that each has the benefit of the other country's results in preparing the isomagnetic maps.

OBSERVATORY RESULTS

The observatories at Cheltenham, Md., Sitka, Alaska, and Honolulu, Hawaii, each completed 25 years of continuous observation without change of site during 1926. The Tucson observatory completed 17 years. The Porto Rico observatory on Vieques Island was discontinued at the close of 1924, after 21½ years' observations, because of difficulties with the site. A new site was obtained on the Island of Porto Rico at which most of the difficulties with the previous station have been eliminated. Operation began January 1, 1926, and it is hoped the new series will cover a long period. Difficult climatic conditions, especially extreme moisture, make special precautions necessary.

At Cheltenham a small experimental building without temperature control has been in practically constant use. Problems of temperature compensation of variometers and improvements in variometer design have been worked out here. The Carnegie Institution of Washington has also made use of this building in similar work. The working relations with the latter organization are excellent.

Efforts have been directed toward modernizing the observatory equipment and keeping it up to modern standards. Improvements have been especially directed toward meeting the requirements of direct scaling of magnetograms, which will be described in a separate report. This program has included remodeling of the observatory magnetometers, which has also made possible intercomparisons of instruments. The program has included the placing of a spare magnetometer, compared at Cheltenham, at each observatory, while the magnetometer of the observatory is being remodeled. Each observatory magnetometer is compared with the spare and then at Cheltenham before and after remodeling. It is then compared with the spare, which goes on to the next observatory. In this way the spare is, in effect, being constantly compared with Cheltenham and, on its return to Washington, will again be compared at Cheltenham. In accordance with a resolution at the Rome meeting of the International Geodetic and Geophysical Union, asking each country to designate a special observatory for comparison of instruments, Cheltenham was selected along with the standardizing observatory of the Carnegie Institution of Washington.

The improvements of these instruments will enhance the value of intercomparison in the future. In case of a cruise of the *Carnegie*, for example, it might become desirable to compare at Honolulu, for instance, and Kakioka, Japan, which would be quite advantageous.

At Sitka systematic observations were made of the aurora and a study made between radio disturbances and magnetic storms and aurora. Sitka is not an ideal place for aurora observation, both because of considerable distance from the belt of maximum frequency and because it is in the coastal belt of high humidity, with much rain and cloudy weather. Fairbanks, Alaska, is a more logical site, but at present there appears no prospect of activity there.

The records of Cheltenham have been regularly furnished during the past two years to various investigators of radio disturbance and magnetic conditions, and Dr. Greenleaf W. Pickard has found definite correlations between them. Magnetic-observatory results have been used by various investigators searching for oil and minerals

by magnetic methods. Several universities have installed courses in geophysics and have received assistance from the division of terrestrial magnetism and seismology of the Coast and Geodetic Survey. This indicates that the interest in magnetic-observatory results from the practical viewpoint is probably greater at present than at any time. Personnel shortage has prevented the publication of observatory results after 1922. However, because of the development of direct scaling, there is not the accumulation of unfinished results that might be expected, and much of the work now received from the observatories is ready for publication, except for final revision. It is hoped that this will be true of all results in the not distant future. Lack of sufficient personnel has also prevented adequate attention being given to the important matter of discussion of observatory results. It is hoped to accomplish more of this in the future.

There is very little overlapping of the work of the Carnegie Institution of Washington and that of the Coast and Geodetic Survey. Considerable mutual benefit accrues from the fact that the headquarters of both organizations are in close proximity, making possible a constant interchange of ideas and mutual assistance in the development of instruments, training of observers, and other ways, with resulting important contributions to the progress of the study of terrestrial magnetism.

BIBLIOGRAPHY SINCE THE MADRID MEETING

Results of observations made at the United States Coast and Geodetic Survey magnetic observatories in 1921 and 1922:
Honolulu, Hawaii.
Vieques, P. R.
Tucson, Ariz.
Sitka, Alaska.
Cheltenham, Md.
Results of Magnetic Observations in 1924.
Results of Magnetic Observations in 1925.
Magnetic Surveys: Methods, Instruments, and Purposes.
Compass Surveys (revised edition).
Magnetic Declination in North Carolina in 1925.
Magnetic Declination in Missouri in 1925.
The Earth's Magnetism.
Terrestrial Magnetism of the United States, by N. H. Heck, Military Engineer, Vol. XVI, No. 90, Nov.–Dec., 1924.
Terrestrial Magnetism in the Twentieth Century, by Daniel L. Hazard, Journal of the Washington Academy of Sciences, vol. 15, No. 6, Mar., 1925.
Altitude Changes of the Magnetic Elements as Deduced from Observations on Mountain Tops, by Daniel L. Hazard, Bulletin of the National Research Council, vol. 10, part 3, No. 53, July, 1925.
Direct Scaling of Absolute Magnetic Values, by W. N. McFarland, Terrestrial Magnetism and Atmospheric Electricity, vol. 31, No. 2, June, 1926.

COMPUTATION OF MAGNETIC-OBSERVATORY RESULTS

In the report made to the Madrid meeting of the International Geodetic and Geophysical Union an outline was given of the methods used by the United States Coast and Geodetic Survey in the computation and preparation for publication of the results from its five magnetic observatories. Various devices for facilitating the computations were explained, and attention was called to the adoption of the method of photographic reproduction for the publication of

the tables of hourly values and the consequent great saving in the cost of publication, and elimination of typographical errors and labor of proof reading.

Even with these improvements in methods there is still a very large amount of tedious computing to be done in deriving absolute hourly values of declination, horizontal intensity, and vertical intensity from the magnetograms. With the addition of seismological investigations to the functions of the division of terrestrial magnetism and the increasing demands of other phases of the work of the division, it has not been possible to keep the computation of the observatory results up to date. With no immediate prospect of increase of personnel, it has become of the utmost importance to devise ways and means for further curtailing the labor involved in this branch of the work in order to prevent it from getting too greatly in arrears. Two recent developments of great value promise to revolutionize the reduction of magnetic-observatory work in this bureau—first, the temperature compensation of horizontal-intensity variometers, and second, the direct scaling of absolute hourly values from the magnetograms. It is recognized that this is not merely a problem of the Coast and Geodetic Survey, but that magnetic stations throughout the world are being kept from complete publication of their results because of the amount of labor required and the corresponding cost of the work.

Dr. Adolf Schmidt many years ago worked out a method of compensating horizontal-intensity variometers for temperature and applied it to the instruments at the Seddin observatory. It was not, however, until the theory of the variometer had been worked out by George Hartnell, observer in charge of the Cheltenham magnetic observatory, and a simpler system of temperature control had been devised by him that it became feasible for this bureau to undertake the remodeling of its variometers to secure this much-desired result. The H variometers at San Juan, P. R., and at Cheltenham, Md., have already been provided with temperature compensation, and those at the other observatories will be similarly remodeled as soon as circumstances permit. With the H variometers provided with temperature compensation and the Z variometers modified so as to secure greater stability and permit a closer adjustment of the temperature compensation, one step in the reduction of the observations—application of correction for temperature—will be eliminated.

Until recently it was the practice of the Coast and Geodetic Survey to have the hourly ordinates scaled in millimeters at the observatories, leaving the conversion of these scalings from millimeters to gammas, the application of temperature correction, and the addition of the base-line value to be done in the office. It was recognized at the outset that scales could be made which would make it possible to read the ordinates in absolute measure instead of in millimeters, but, because of the difficulty and cost of securing the larger number of scales which would have been required to fit the varying H and Z scale values, this possibility was not given serious consideration. With the development of a method for the cheap and speedy production of scales and the increase in the stability of the variometers, and a corresponding decrease in the number of scales required, the possibility has become a reality.

The making of a scale involves first a drawing three times the size of the required scale, so that unavoidable errors in drawing will be reduced in the finished product. A photographic negative on glass is then made of the drawing, reduced to the required size. From this negative prints are made on thin aluminum plates. It is then a simple matter to cut out the scales, trim, and varnish them.

For declination and vertical intensity the graduations are equally spaced on the drawings. Because of the inherent instability of the vertical-intensity variometer there is frequently a considerable range of scale value, even when no changes of adjustment are made, and enough scales must be made to cover that range. To save photographic work it has been found convenient to draw side by side a series of scales differing by 1 per cent, as many as can be photographed on a single negative. By varying the amount of photographic reduction this drawing can be used for a wide range of scale values.

In a horizontal-intensity variometer of the Eschenhagen type the scale value is in general not constant, but may be represented very closely by a formula of the form $S=a+bh$, in which h is the ordinate in millimeters and a is the scale value for a zero ordinate. A scale with the spacing of the graduations varying in accordance with such a formula may be used for all ordinates, so long as the values of a and b remain unchanged. The horizontal-intensity variometers of the Coast and Geodetic Survey have shown such stability in recent years that adjustments changing these quantities are rare. Accordingly, a scale has been made for each observatory corresponding to the established values of a and b. On each scale the point corresponding to the value of $S=a$ is marked, and this point must always be set at the base line on the magnetogram when readings are made. To make a drawing for such a scale it is necessary to compute the proper spacing of the graduations. However, the scale value changes so slowly that it is sufficient to carry out the computation for only a few points, the intervening graduations being spaced equally.

These scales give at once the distance between curve and base line in minutes in the case of declination and in gammas in the case of horizontal and vertical intensity, and do away with the tedious operation of multiplying each ordinate scaled in millimeters by the scale value. A simple device makes possible the addition of the base-line value at the same time, so that for declination or an intensity variometer compensated for temperature the absolute hourly values are read at once from the magnetogram, and in the case of an uncompensated variometer there remains only the process of correcting the hourly values for temperature effects.

The scales are not numbered, but the observer is furnished with the base-line values to be used. He fastens to the scale a strip of paper of such width as not to cover the graduation marks and writes the base-line value opposite the point on the scale which is to be set at the base line of the curve to be read. At the proper points on the paper lines are drawn in continuation of the scale divisions and numbered to indicate the values of the quantity which differ by 100 gammas (or 10′ in the case of declination).

To facilitate the use of these scales the observer is provided with a reading board, a set of three T squares (one for the scale of each

element), and a piece of squared plate glass, suitably etched. The reading board has spring clamps for holding the magnetogram in position. At its upper edge is a straightedge which may be adjusted in position by means of a slow-motion screw at either end. The scale is clamped to the arm of its T square with the graduation along the right edge when the head of the T square rests on the straightedge of the reading board. The piece of plate glass is of such thickness that its upper surface is even with the upper surface of the scale in position on its T square. On its under surface are etched a set of five vertical lines 2 centimeters apart (corresponding to the spaces between hour marks on the Eschenhagen magnetograms) and a single horizontal line. On the upper surface, directly over each end of this line, at the edge of the glass, is etched a short line a few millimeters long.

The magnetogram is placed on the reading board in such a position that the base line of the scale will coincide with the base line of the curve to be read, throughout its length, as the head of the T square to which the scale is attached is slid along the straightedge. The magnetogram is placed approximately in the proper position and then clamped. The accurate setting is made by the adjusting screws of the straightedge. The T square is then moved along the straightedge until the first hour interval of the curve to be read is inclosed by two vertical lines of the reading glass. The glass is then moved up or down along the edge of the scale until the space between the horizontal line and the curve is as much below the line as above. The scale is then read at the point indicated by the short line at the left edge of the upper surface of the glass.

This method is now in use at the observatories of the Coast and Geodetic Survey. At Cheltenham and Honolulu, where the change of temperature in the variation room in the course of the day is seldom more than two-tenths of a degree, the temperature correction is applied to the base-line value, and the final hourly values are read directly from the magnetograms. For the other observatories, until the variometers are compensated for temperature, the correction for temperature will be applied in the office at the same time that the printer's copy of the tables is prepared.

The scalings can be made with the same accuracy and with nearly the same rapidity as when the readings were in millimeters, and the cost of making the scales is comparatively small, so that there is a saving of practically all the labor formerly expended on conversion from millimeters to gammas and application of base-line values. Some small changes will, no doubt, be required in the provisionally adopted base-line values, but, as the base-line values for a month are not fixed until the observed values for two succeeding months are available, the corrections will be small and can readily be applied in connection with the preparation of the printer's copy. At least half, and probably more, of the work of computing the observatory results will be eliminated in this way.

In future publications of observatory results the diurnal variation tables, as well as the tables of hourly values, will be reproduced photographically, which will result in a further saving in cost of printing and labor of proof reading.

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