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TERRESTRIAL MAGNETISM

MAGNETIC DECLINATION IN THE UNITED STATES IN 1925

By

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MAGNETIC DECLINATION IN THE UNITED STATES IN 1925

By DANIEL L. HAZARD, *Assistant Chief, Division of Terrestrial Magnetism and Seismology*

CONTENTS

	Page
Introduction	1
Other publications on terrestrial magnetism	2
Available data	3
Construction of isogonic chart	4
Lines of equal annual change	4
Accuracy of isogonic chart	5
Derivation of secular change tables	5
Use of secular change tables	7
Secular change tables	9
Diurnal variation	23
Determination of the true meridian	23
Determination of the magnetic declination	38
Isogonic chart ... to face	38

INTRODUCTION

The magnetic work of the United States Coast and Geodetic Survey, begun as one of the essential parts of the preparation of nautical charts of the coastal waters, has been extended to cover the interior of the country to meet the needs of the land surveyor. Nearly all of the early land surveys in the United States were made by compass and the boundaries in the deeds were defined by compass bearings, and in many localities and for certain kinds of surveying (especially the retracing of the lines of old compass surveys) the compass is still in use.

The compass does not, in general, point true north nor is its direction at any place constant, hence knowledge of the compass variation (magnetic declination) and its changes is required by those who make use of the compass. The object of this publication is to supply that information for the United States. The distribution of the magnetic declination and its annual rate of change for the beginning of 1925 are shown graphically on an isogonic chart. The change of declination with time, since 1750 or the date of the earliest observations, is given in tabular form for places distributed over the whole country at intervals of 2° of latitude or longitude. Tables are also given to show the manner in which the direction of the compass needle changes in the course of the day. Methods of determining the true meridian are explained, so that the surveyor may determine the magnetic declination for himself at places where there is no meridian line or other true bearings available.

As there is much confusion in the use of the word "variation," the following notation will be adhered to in this publication:

Magnetic declination is the angle between the true north and the magnetic north and is considered east or west according as the com-

pass needle points east or west of true north. It is often called "variation of the compass" or simply "variation."

Secular change of the magnetic declination is the change with time extending over a long period of years.

Annual change is the amount of secular change in one year.

Diurnal variation is the change in declination in the course of a day. While this change is usually not taken into account in compass surveys, its effect may be considerable, as will be seen from a concrete example. If a line a mile long was run about 8 o'clock in the morning and again about 2 o'clock in the afternoon, using the same starting point and the same compass bearing in each case, the terminal points of the two lines might be 20 feet or more apart because of the change in the direction of the compass needle during the day.

The secular change of declination appears to be periodic in character; at least it does not go on indefinitely in one direction. Eventually a turning point is reached and a change in the opposite direction sets in. Several centuries are required for its full development, a period longer than is covered by reliable observations. In the United States we have record of one turning point, as shown in the secular change tables, and at some stations, for which there is a long series of observations, there are indications of a second. The rate of change is quite irregular, so that we can not predict much in advance what the change will be. On this account secular change tables must be revised and brought up to date as new information becomes available. It is the practice of this bureau to issue a new isogonic chart and new secular change tables every five years. Magnetic observations are repeated at approximately five-year intervals at selected stations scattered over the whole country to provide the data necessary for bringing the secular change tables up to date. Special Publication No. 90, issued in 1922, containing the isogonic chart for 1920 and the tables giving the secular change to January 1, 1920, is superseded by the present publication.

OTHER PUBLICATIONS ON TERRESTRIAL MAGNETISM

The Coast and Geodetic Survey has issued numerous publications containing the results of its work in terrestrial magnetism and general information on the subject. The following are of especial interest to surveyors and others having occasion to use the compass or the results of compass surveys.

The Earth's Magnetism, issued in 1925, contains a historical sketch of the development of our knowledge of this phenomenon, a general description of the methods and instruments used for measuring the earth's magnetism, and a statement of the extent at that time of the accumulated data. The theories which have been advanced to account for the earth's magnetism are outlined, and its relations to other phenomena are touched on.

United States Magnetic Tables and Magnetic Charts.—The publications of this series, issued at intervals of about 10 years, contain the collected results of magnetic observations made by this bureau in the United States, together with corresponding reduced values for a specified date (dip and horizontal intensity as well as declination), and charts showing the lines of equal magnetic declination, dip, horizontal intensity, vertical intensity, and total intensity for the

specified date. Special Publication No. 44 for 1915, the latest publication of this series, is now out of print, but one for 1925 is in preparation.

Results of magnetic observations made by the Coast and Geodetic Survey for the years 1916 to 1925, inclusive (Special publications Nos. 42, 51, 55, 64, 72, 87, 94, 102, 116, and 124), contain for each calendar year the results of observations made during the year, together with descriptions of the stations occupied, and occasionally the results of special investigations.

Magnetic declination in Arkansas, Florida, North Carolina, Missouri (Serial Nos. 237, 262, 303, 323).—Separate publications on the magnetic declination have been issued for these four States. Besides the values of declination they contain descriptions of the stations, an isogonic chart of the State, and a secular change table for each county. Similar publications for California, Nevada, and Texas are in preparation and others will follow.

AVAILABLE DATA

For the construction of the isogonic chart values of the magnetic declination at over 5,000 places in the United States and at many places in Canada, Mexico, and the West Indies were available. For the extension of the isogonic lines over adjacent waters use has been made of the results obtained on the vessels of this bureau and on the *Carnegie* of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, also of the isogonic chart of the world for 1925, issued by the United States Hydrographic Office.

In the prosecution of the magnetic survey of the United States observations have been made by this bureau at nearly every county seat and at many other places. At most of the stations a stone or other durable marker was placed and the true bearings of several prominent objects were determined, so that they might be available for future use. With changing local conditions either the marker or the objects have disappeared in many cases or the station has for other reasons ceased to be available for further use. Through the cooperation of local surveyors reports on the present condition of many of the stations have been received, indicating that about half of them are still in good condition. Descriptions of the stations in any locality can be obtained from this office by anyone desiring to make use of them.

In addition to the work of this bureau use has been made of results of recognized accuracy obtained by others in this country, Canada, Mexico, Central America, and the West Indies. Most of the results in Canada are contained in two publications, namely, Magnetic Results in Western Canada (Bulletin 52, Topographic Survey of Canada, 1924) and Magnetic Results 1907 to 1920, by C. A. French (Publications of the Dominion Observatory, Vol. V, No. 5). The secular change data contained in these publications and later results furnished in manuscript by the two bureaus issuing them have been of great assistance in fixing the position and direction of the lines of equal annual change of declination along our northern border. The work of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington in Mexico, Central America, and the West Indies has been of great value in extending the isogonic lines and lines of equal annual change in that direction.

CONSTRUCTION OF ISOGONIC CHART

It is customary to represent graphically the results of a magnetic survey by means of isomagnetic charts; that is, maps on which lines are drawn through places where the values of a particular magnetic element are the same. In the case of the magnetic declination, the map showing the lines of equal magnetic declination is called an isogonic chart. As the declination is changing from year to year, an isogonic chart is made for a selected epoch—in this case January 1, 1925—and all of the observed values of declination must be reduced to that epoch before they can be used in the construction of the chart. The tables for making this reduction are based on observations made at intervals of about five years at "repeat" stations scattered over the whole country. The reduced values are plotted on a map and the lines of equal magnetic declination are then drawn to conform as closely as may be to the plotted values. Because of the prevalence of local disturbance and the consequent irregular distribution of the earth's magnetism this process generally becomes more and more difficult as the number of stations in a given area increases, and in greatly disturbed regions the sinuosities of the lines must be taken as an indication of disturbance rather than as an accurate representation of the observations. In some regions it is inadvisable to attempt to represent the large local disturbances by continuous lines, but a disturbed area of limited extent may be indicated by a small closed curve, and isolated abnormal values can best be given on the chart.

For an area as large as the United States it is usual to draw the isogonic lines only at intervals of 1°. In general, there are very few values which are exactly the amount selected for a particular line—for example, there are very few stations at which the reduced declination is exactly 6° east—so that the location of the line must depend largely upon interpolation between values a little larger and a little smaller than the selected amount. At first sight it would appear that a particular line should be drawn so that all greater plotted values will fall on one side and all smaller values on the other. This practice can be followed where the distribution is regular or nearly so, but where there is local disturbance—the usual condition—a little consideration will show that this method will not give the best representation of all the data. The aim should be to draw the lines in such a way that the average difference between the plotted values and corresponding values derived by interpolation between the lines will be a minimum, since the isogonic chart is designed, primarily, to afford means for estimating the value of the declination at any place where observations have not been made.

The method outlined above has been followed in preparing the isogonic chart for 1925. The secular change tables were brought up to date with the aid of the observations at repeat stations during the past five years, and the earlier portions of the tables were modified somewhat as a result of a new discussion of the older data.

LINES OF EQUAL ANNUAL CHANGE

In order that the isogonic chart may be used to obtain values of declination for years subsequent to 1925, the rate of change of declination has been shown by means of lines of equal annual change, the blue lines. These are based, primarily, on the average annual

change between 1920 and 1925, but they represent the best estimate of the change after 1925 at present available. As additional repeat observations are made it will be possible to derive improved values.

In the extreme southern part of the United States the north end of the compass needle is moving eastward and east declination is increasing. North of the line of no annual change the north end of the needle is moving to the westward; where the declination is west it is increasing and where it is east it is decreasing.

ACCURACY OF ISOGONIC CHART

From what has been said regarding the construction of the isogonic chart it will be seen that a close representation of the observed values is possible only when they are few in number or in a region free from local disturbance. Under ordinary conditions the position of the lines can be modified considerably without changing the accuracy of representation of the plotted values. The stations are so close together that it is not feasible to show the actual values on the chart, but the larger disturbances are indicated by plotting the isolated values which differ by more than 1° from the chart value for the same place. There are a considerable number of values not shown which differ by nearly that amount, and a difference of half a degree is not infrequent, even where the isogonic lines do not appear very irregular. As an illustration of what may be expected, for 11 stations in southeastern Kansas east of longitude 96° and between latitudes 37° and 38° the differences between observed and chart values are 0.2, 0.6, 0.1, 0.1, 0.6, 0.4, 0.4, 0.2, 0.3, 0.2, 0.3. Farther south the differences are smaller on the average, and farther north they are larger. In general, it may be said that the declination at a place where observations have not been made may differ from the chart value for that place by as much as any observed value in that general region differs.

DERIVATION OF SECULAR CHANGE TABLES

While it is probable that the secular change of declination is affected somewhat by local conditions—for example, by the presence of local disturbance—our observational data are not as yet sufficiently extensive or detailed to permit more than an approximate representation of average conditions. There are very few stations in the United States for which we have accurate results as early as 1850, and it has not been possible, as a rule, to make later observations at the exact spot at which the early observations were made. Even in recent years, when magnetic stations have been selected with particular reference to their future availability, it often happens that the observer finds a station no longer suitable for use when he goes to reoccupy it after the lapse of 5 or 10 years.

From the observations made by early navigators it has been possible to get a general idea of the declination along the Atlantic coast as early as 1700 and along the Pacific coast as early as 1780. For the interior of the country the results as early as the first settlements are very few in number. The secular change tables for any place have been extended back as far as the date of the earliest observations in that general locality.

The general features of the secular change appear to vary with comparative uniformity in passing across the country, and this has been the fundamental idea in deriving a homogeneous set of tables from more or less heterogeneous data. The results at all the repeat stations in a limited region were combined to obtain a table of values representing approximately the average secular change for that region. This table was compared with similar tables for adjoining regions, and a general smoothing out of inconsistencies was made. From these tables other similar tables were derived by interpolation for the greater number of places for which it was intended to publish secular change tables. For a final smoothing out the values of the change for each decade were plotted on a base map of the United States and lines of equal annual change drawn to conform closely to the plotted values. Corrected values of the change for the decade were then scaled from the map and corrected tables were prepared.

On the succeeding pages will be found tables for every even degree of latitude and longitude, more than twice as many as were given in Special Publication No. 90. It is believed that the arrangement by latitude and longitude will be found much more convenient than the one by States formerly in use. The values of declination for 1925 were scaled from the isogonic chart, and the values for earlier years were then computed by applying the change for each 5 or 10 year interval derived from the auxiliary maps referred to in the last paragraph.

Each table shows the change of declination at any place in the immediate vicinity of the specified latitude and longitude. For other places a somewhat better result may be obtained by interpolating between adjoining tables, as explained below. The change is given for 10-year intervals up to 1900 and for 5-year intervals since that time. For all practical purposes the annual change may be assumed as uniform for the interval between the tabular values, though such is not the case, as will be seen by referring to the following table showing the change of declination from year to year at magnetic observatories, where a continuous record is kept.

Change of declination at observatories

Year	Vieques, P. R.	Cheltenham, Md.	Toronto, Canada	Tucson, Ariz.	Sitka, Alaska	Honolulu, Hawaii
	° ′	° ′	° ′	° ′	° ′	° ′
1910	2 20.6 W.	5 41.4 W.	6 03.9 W.	13 25.8 E.	30 16.4 E.	9 29.7 E.
1911	2 29.9	5 45.6	6 09.0	13 29.7	30 19.1	9 32.2
1912	2 39.0	5 50.0	6 13.7	13 33.5	30 20.9	9 34.8
1913	2 49.6	5 54.6	6 18.4	13 37.0	30 22.0	9 37.3
1914	3 00.4	5 59.8	6 23.8	13 39.9	30 22.9	9 39.6
1915	3 10.1	6 04.0	6 28.5	13 42.5	30 23.2	9 41.6
1916	3 19.2	6 07.7	6 33.4	13 44.4	30 23.9	9 43.9
1917	3 27.0	6 10.4	6 36.2	13 46.1	30. 24.7	9 46.3
1918	3 34.0	6 12.4	6 38.3	13 47.1	30 24.9	9 48.6
1919	3 39.9	6 15.0	6 41.0	13 47.8	30 26.7	9 50.8
1920	3 46.1	6 18.5	6.45.4	13 48.0	30 28.2	9 53.2
1921	3 53.3	6 22.4	6 50.6	13 47.7	30 28.7	9 55.3
1922	4 00.9	6 27.7	6 56.2	13 47.5	30 29.2	9 57.1
1923	4 08.3	6 32.0	7 00.9	13 47.3	30 28.9	9 58.9
1924	4 15.5 W.	6 35.8	7 05.8	13 46.4	30 28.7	10 00.2
1925	----------	6 39.2 W.	7 11.0 W.	13 45.3 E.	30 27.2 E.	10 01.8 E.

USE OF SECULAR CHANGE TABLES

Whenever a surveyor is called upon to redetermine the boundary lines of a tract of land surveyed by compass at some previous date and can find in the vicinity a well-defined line known to have been established with the same compass at about the same time as the lines of the tract in question, he can not do better than determine the amount of change in the compass bearing of that well-defined line and use it to obtain the present compass bearings of the boundary lines to be reestablished. In this way he will eliminate possible errors in the two compasses used and the uncertainty inherent in the secular change tables. Only in the absence of such definite information is the use of the secular change tables recommended.

In using these tables the surveyor must bear in mind the uncertainties incident to the use of the compass and should not be surprised if, for example, the change of declination since the early part of the nineteenth century, as given by the tables, differs by as much as half a degree from the value indicated by his own retracing of old lines. Even at the present time some compasses are in error by as much as a quarter of a degree, owing to imperfect construction or lack of proper care, and 100 years ago the state of affairs was much worse. The tables are intended to give the actual change in the magnetic declination, eliminating as far as possible the errors of individual instruments, but they are only approximate, and the earlier portions are less reliable on account of the inferior character and limited amount of data on which they are based.

The figures on any line of the tables refer to the beginning of the year given in the first column. A value for any other date must be obtained by interpolation from the tabular quantities. In this operation it is convenient to express the month and day as a decimal fraction of the year, as follows:

Jan. 19 to Feb. 24=0.1	July 21 to Aug. 25=0.6
Feb. 25 to Apr. 1=0.2	Aug. 26 to Oct. 1=0.7
Apr. 2 to May 8=0.3	Oct. 2 to Nov. 7=0.8
May 9 to June 13=0.4	Nov. 8 to Dec. 13=0.9
June 14 to July 20=0.5	Dec. 14 to Dec. 31=1.0

While the rate of change is not constant for even a period of five years, it is accurate enough for all practical purposes to assume that the annual change is uniform for the intervals between the tabular values. The use of the tables may be best explained by a few examples.

1. What was the change in declination at Millen, Ga., between June 1, 1778, and September 15, 1916?

Millen is in latitude 32° 48′ and longitude 82° 00′. In the table for longitude 82° and latitude 32° the values for 1770 and 1780 are 3° 42′ E. and 4° 12′ E., respectively, showing a change of 30′ in 10 years, or an average annual change of 3′.0. In 8.4 years—from January, 1770, to June 1, 1778—the change would be 3′.0×8.4=25′ and the value for the latter date would be 3° 42′ E.+25′=4° 07′ E. In the same way the value for September 15, 1916, is found to be 0° 49′ E.; hence the change between the two dates was 4° 07′−0° 49′=3° 18′. In a similar manner the change is found from the table for longitude 82° and latitude 34° (3° 51′−0° 19′=3° 32′). For longi-

tude 82° and latitude 32° 48′ the amount of change would be 3° 24′ (found by interpolating between 3° 18′ and 3° 32′); hence at Millen the north end of the compass needle pointed 3° 24′ more to the east in 1778 than in 1916.

2. The magnetic declination at Zanesville, Ohio, was 1° 19′ W. on September 15, 1904. What was it on January 1, 1810?

Zanesville is approximately in longitude 82° and latitude 40°. From the table for that position are derived the values 3° 06′ E. for January 1, 1810, and 1° 17′ W. for September 15, 1904, a change of 4° 23′. Consequently, the north end of the needle pointed 4° 23′ more to the east in 1810 than it did in 1904, and the declination in 1810 was 3° 04′ E. (4° 23′ − 1° 19′).

3. A four-sided piece of land in western Kentucky in longitude 88° and latitude 37° was surveyed in June, 1842, and the bearings recorded as follows: N. 20° 15′ W., N. 75° 30′ E., S. 18° 45′ E., and S. 78° 00′ W. What bearings should be used to retrace the lines in March, 1927?

From the tables for longitude 88° and latitudes 36° and 38° are derived the values 6° 59′ E. for 1842 and 3° 39′ E. for 1927, using the annual change in 1925 to find the change from January, 1925, to March, 1927. East declination, therefore, will have decreased 3° 20′ in the interval, and the bearings must be changed by the same amount, increasing those in the northeast and southwest quadrants and decreasing those in the northwest and southeast quadrants. The bearings to be used are, therefore, N. 16° 55′ W., N. 78° 50′ E., S. 15° 25′ E., and S. 81° 20′ W.

4. For continued work in a single locality it will be found convenient to compute a table for the latitude and longitude of the locality, so that further interpolation between the published tables may be avoided. If, for example, a table for longitude 95° and latitude 42° 25′ was desired, the tables for longitude 94° and latitudes 42° and 44° would first be combined to get a table for longitude 94° and latitude 42° 25′; then the tables for longitude 96° and latitudes 42° and 44° would be combined to get a table for longitude 96° and latitude 42° 25′; then these two auxiliary tables would be combined to get the desired table.

Secular change of the magnetic declination in the United States

Longitude	° 68	° 68	° 68	° 70	° 70	° 70	° 70	° 72	° 72
Latitude	44	46	48	42	44	46	48	40	42
State	At sea	Maine	Canada	Massachusetts	Maine	Maine	Canada	At sea	Connecticut
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	10 18 W	12 28 W	----------	7 48 W	9 34 W	11 30 W	13 42 W	5 21 W	6 46 W
1760	10 05	12 18	----------	7 27	9 14	11 12	13 27	4 51	6 16
1770	10 02	12 18	----------	7 14	9 02	11 02	13 18	4 30	5 55
1780	10 12	12 33	----------	7 11	9 02	11 06	13 26	4 18	5 43
1790	10 28	12 53	----------	7 15	9 09	11 16	13 41	4 14	5 40
1800	10 56	13 24	16 05 W	7 33	9 29	11 40	14 08	4 23	5 48
1810	11 31	14 03	16 50	7 57	9 56	12 11	14 44	4 38	6 04
1820	12 12	14 46	17 37	8 27	10 31	12 50	15 27	5 01	6 29
1830	12 58	15 36	18 30	9 05	11 12	13 35	16 16	5 32	7 02
1840	13 46	16 26	19 21	9 48	11 57	14 22	17 04	6 11	7 43
1850	14 36	17 17	20 13	10 34	12 44	15 10	17 54	6 53	8 26
1860	15 21	18 03	21 00	11 17	13 29	15 57	18 42	7 34	9 08
1870	15 50	18 32	21 28	11 49	14 00	16 28	19 12	8 09	9 43
1880	16 12	18 53	21 48	12 18	14 30	16 57	19 40	8 42	10 19
1890	16 27	19 02	21 52	12 41	14 50	17 12	19 48	9 09	10 45
1900	16 47	19 19	22 04	13 12	15 16	17 35	20 08	9 43	11 18
1905	17 03	19 34	22 17	13 31	15 33	17 51	20 23	10 05	11 37
1910	17 32	20 03	22 44	14 01	16 03	18 21	20 52	10 33	12 07
1915	18 01	20 28	23 04	14 31	16 33	18 50	21 16	11 01	12 35
1920	18 16	20 40	23 14	14 50	16 50	19 05	21 28	11 20	12 55
1925	18 40 W	21 00 W	23 30 W	15 15 W	17 15 W	19 25 W	21 45 W	11 45 W	13 20 W
Annual change in 1925	4′.7 incr.	3′.9 incr.	3′.2 incr.	5′.0 incr.	5′.0 incr.	4′.1 incr.	3′.4 incr.	5′.0 incr.	5′.6 incr.

Longitude	° 72	° 72	° 74	° 74	° 74	° 74	° 76	° 76	° 76
Latitude	44	46	40	42	44	46	34	36	38
State	New Hampshire	Canada	At sea	New York	New York	Canada	At sea	North Carolina	Maryland
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	8 31 W	10 55 W	4 27 W	6 16 W	8 00 W	10 49 W	0 08 W	1 18 W	2 07 W
1760	8 01	10 25	3 50	5 36	7 19	10 08	0 25 E	0 43	1 30
1770	7 39	10 03	3 21	5 06	6 46	9 32	0 53	0 13 W	0 58
1780	7 26	9 50	3 00	4 43	6 18	9 02	1 14	0 09 E	0 34
1790	7 24	9 50	2 50	4 32	6 05	8 48	1 27	0 23	0 18
1800	7 33	10 00	2 50	4 30	6 03	8 44	1 29	0 27	0 12
1810	7 51	10 20	2 58	4 38	6 11	8 52	1 25	0 24	0 15
1820	8 19	10 52	3 16	4 57	6 31	9 14	1 13	0 12 E	0 27
1830	8 55	11 31	3 44	5 25	7 01	9 46	0 52	0 09 W	0 48
1840	9 37	12 14	4 19	6 02	7 40	10 27	0 25 E	0 37	1 17
1850	10 21	12 59	4 59	6 43	8 21	11 09	0 09 W	1 12	1 53
1860	11 05	13 44	5 38	7 23	9 02	11 52	0 45	1 48	2 30
1870	11 40	14 19	6 17	8 02	9 41	12 31	1 25	2 28	3 10
1880	12 18	14 58	6 55	8 43	10 26	13 20	2 00	3 04	3 48
1890	12 42	15 18	7 25	9 12	10 54	13 46	2 33	3 37	4 21
1900	13 14	15 48	8 00	9 47	11 29	14 19	3 07	4 13	4 58
1905	13 31	16 04	8 21	10 06	11 47	14 35	3 24	4 31	5 17
1910	14 01	16 34	8 47	10 34	12 16	15 05	3 42	4 51	5 39
1915	14 31	17 02	9 13	11 01	12 45	15 33	3 58	5 10	6 00
1920	14 50	17 18	9 31	11 20	13 05	15 51	4 12	5 25	6 16
1925	15 15 W	17 40 W	9 55 W	11 45 W	13 30 W	16 15 W	4 25 W	5 40 W	6 35 W
Annual change in 1925	5′.0 incr.	4′.4 incr.	4′.7 incr.	5′.0 incr.	5′.0 incr.	4′.8 incr.	2′.5 incr.	3′.0 incr.	3′.8 incr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 76	° 76	° 76	° 78	° 78	° 78	° 78	° 78	° 78
Latitude	40	42	44	34	36	38	40	42	44
State	Pennsylvania	Pennsylvania	New York	North Carolina	North Carolina	Virginia	Pennsylvania	Pennsylvania	Canada
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	3 32 W	5 31 W	7 03 W	0 48 E	0 12 W	1 36 W	2 32 W	3 26 W	5 22 W
1760	2 52	4 49	6 20	1 22	0 24 E	0 57	1 51	2 43	4 37
1770	2 18	4 11	5 39	1 53	0 57	0 22 W	1 13	2 01	3 54
1780	1 49	3 39	5 05	2 18	1 23	0 06 E	0 41	1 27	3 18
1790	1 31	3 19	4 43	2 35	1 42	0 26	0 19	1 03	2 51
1800	1 22	3 09	4 31	2 43	1 52	0 37	0 07	0 50	2 35
1810	1 24	3 10	4 31	2 43	1 53	0 39	0 05	0 47	2 31
1820	1 36	3 22	4 44	2 35	1 45	0 31	0 13	0 55	2 39
1830	1 58	3 45	5 08	2 17	1 27	0 13 E	0 31	1 14	2 58
1840	2 28	4 17	5 41	1 52	1 01	0 14 W	0 59	1 43	3 28
1850	3 04	4 54	6 18	1 20	0 29 E	0 47	1 32	2 16	4 02
1860	3 42	5 32	6 57	0 46	0 06 W	1 23	2 08	2 53	4 39
1870	4 22	6 12	7 37	0 06 E	0 46	2 03	2 48	3 33	5 19
1880	5 03	6 57	8 28	0 30 W	1 24	2 43	3 29	4 20	6 11
1890	5 36	7 30	9 01	1 06	2 00	3 19	4 06	4 58	6 50
1900	6 13	8 07	9 38	1 40	2 35	3 55	4 44	5 36	7 29
1905	6 33	8 26	9 56	1 56	2 51	4 13	5 03	5 54	7 46
1910	6 57	8 52	10 23	2 11	3 08	4 32	5 23	6 17	8 11
1915	7 21	9 18	10 50	2 24	3 24	4 50	5 44	6 40	8 35
1920	7 38	9 36	11 10	2 35	3 37	5 03	6 00	6 57	8 55
1925	8 00 W	10 00 W	11 35 W	2 45 W	3 50 W	5 20 W	6 20 W	7 20 W	9 20 W
Annual change in 1925	4′.4 incr.	4′.9 incr.	5′.0 incr.	2′.0 incr.	2′.6 incr.	3′.3 incr.	4′.0 incr.	4′.6 incr.	5′.0 incr.

Longitude	° 80	° 80	° 80	° 80	° 80	° 80	° 80	° 80	° 80
Latitude	26	28	30	32	34	36	38	40	42
State	At sea	At sea	At sea	At sea	South Carolina	North Carolina	Virginia	Pennsylvania	Pennsylvania
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	3 50 E	3 11 E	2 42 E	2 02 E	1 32 E	0 20 E	0 28 W	1 42 W	2 13 W
1760	4 20	3 42	3 14	2 36	2 08	0 58	0 12 E	1 00	1 29
1770	4 47	4 10	3 44	3 08	2 42	1 33	0 49	0 20 W	0 46
1780	5 08	4 33	4 09	3 35	3 10	2 03	1 20	0 13 E	0 11 W
1790	5 24	4 50	4 27	3 54	3 30	2 25	1 44	0 39	0 17 E
1800	5 31	4 59	4 37	4 05	3 42	2 39	1 59	0 55	0 35
1810	5 30	4 59	4 38	4 07	3 45	2 43	2 04	1 01	0 42
1820	5 22	4 53	4 33	4 02	3 40	2 38	1 59	0 56	0 38
1830	5 05	4 37	4 18	3 48	3 26	2 24	1 45	0 41	0 23 E
1840	4 44	4 16	3 56	3 26	3 04	2 01	1 22	0 17 E	0 02 W
1850	4 15	3 48	3 28	2 58	2 35	1 32	0 53	0 13 W	0 32
1860	3 43	3 16	2 55	2 25	2 02	0 58	0 19 E	0 48	1 07
1870	3 08	2 40	2 18	1 47	1 24	0 19 E	0 19 W	1 27	1 46
1880	2 33	2 04	1 41	1 09	0 45	0 21 W	0 59	2 08	2 32
1890	2 03	1 32	1 08	0 34	0 09 E	0 58	1 37	2 48	3 13
1900	1 32	1 02	0 36	0 02 E	0 24 W	1 32	2 13	3 25	3 51
1905	1 25	0 53	0 26	0 09 W	0 38	1 47	2 29	3 42	4 08
1910	1 20	0 47	0 19	0 18	0 49	2 01	2 44	4 00	4 27
1915	1 20	0 44	0 14	0 25	0 59	2 14	2 59	4 18	4 47
1920	1 22	0 44	0 12	0 30	1 07	2 24	3 11	4 32	5 03
1925	1 25E	0 45 E	0 10 E	0 35 W	1 15 W	2 35 W	3 25 W	4 50 W	5 25 W
Annual change in 1925	0′.5 incr.	0′.1 incr.	0′.4 decr.	1′.0 incr.	1′.5 incr.	2′.2 incr.	2′.9 incr.	3′.7 incr.	4′.4 incr.

Secular change of the magnetic declination in the United States—Continued

Longitude / Latitude	80° 44°	82° 26°	82° 28°	82° 30°	82° 32°	82° 34°	82° 36°	82° 38°	82° 40°
State	Canada	Florida	Florida	Florida	Georgia	South Carolina	North Carolina	West Virginia	Ohio
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	3 50 W	3 47 E	3 23 E	3 13 E	2 34 E	2 13 E	1 12 E	0 07 E	----------
1760	3 05	4 28	3 55	3 46	3 09	2 50	1 51	0 47	----------
1770	2 21	4 58	4.26	4 18	3 42	3 25	2 28	1 26	----------
1780	1 45	5 22	4 52	4 46	4 12	3 56	3 00	1 59	----------
1790	1 14	5 41	5 12	5 07	4 34	4 19	3 25	2 26	2 37 E
1800	0 54	5 51	5 24	5 20	4 49	4 35	3 43	2 45	2 57
1810	0 46	5 53	5 27	5 25	4 56	4 42	3 50	2 53	3 06
1820	0 49	5 49	5 25	5 24	4 54	4 40	3 48	2 51	3 05
1830	1 05	5 37	5 14	5 14	4 44	4 30	3 37	2 40	2 54
1840	1 31	5 19	4 56	4 55	4 25	4 10	3 17	2 20	2 33
1850	2 01	4 53	4 31	4 30	4 00	3 44	2 51	1 53	2 06
1860	2 36	4 22	4 00	3 59	3 29	3 13	2 19	1 21	1 34
1870	3 16	3 48	3 26	3 24	2 53	2 36	1 42	0 44	0 57
1880	4 08	3 13	2 50	2 47	2 15	1 56	1 02	0 04 E	0 16 E
1890	4 49	2 42	2 17	2 11	1 38	1 18	0 22 E	0 36 W	0 25 W
1900	5 27	2 15	1 48	1 41	1 07	0 45	0 11 W	1 10	1 02
1905	5 44	2 10	1 42	1 34	0 59	0 34	0 24	1 24	1 18
1910	6 05	2 10	1 39	1 30	0 53	0 26	0 34	1 36	1 32
1915	6 27	2 14	1 39	1 28	0 49	0 20	0 43	1 47	1 47
1920	6 45	2 19	1 42	1 20	0 48	0 16	0 51	1 57	1 58
1925	7 10 W	2 25 E	1 45 E	1 30 E	0 45 E	0 10 E	1 00 W	2 10 W	2 15 W
Annual change in 1925	5′0 incr.	1′1 incr.	0′6 incr.	0′1 incr.	0′5 decr.	1′1 decr.	1′8 incr.	2′6 incr.	3′4 incr.

Longitude / Latitude	82° 42°	82° 44°	82° 46°	84° 30°	84° 32°	84° 34°	84° 36°	84° 38°	84° 40°
State	Lake Erie	Lake Huron	Canada	Florida	Georgia	Georgia	Tennessee	Kentucky	Ohio
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	----------	----------	----------	3 42 E	3 04 E	2 33 E	1 11 E	----------	----------
1760	----------	----------	----------	4 16	3 40	3 10	1 50	----------	----------
1770	----------	----------	----------	4 49	4 15	3 46	2 28	----------	----------
1780	----------	----------	----------	5 20	4 47	4 20	3 02	----------	----------
1790	----------	----------	----------	5 44	5 12	4 46	3 29	----------	----------
1800	1 48 E	0 05 E	0 41 W	6 00	5 30	5 05	3 49	4 28 E	4 03 E
1810	1 58	0 17	0 27	6 10	5 40	5 15	3 59	4 39	4 15
1820	1 58	0 18	0 25	6 12	5 41	5 16	4 00	4 41	4 17
1830	1 46	0 06 E	0 37	6 06	5 35	5 09	3 53	4 34	4 09
1840	1 25	0 16 W	1 00	5 52	5 20	4 53	3 36	4 17	3 51
1850	0 58	0 43	1 27	5 31	4 58	4 30	3 12	3 53	3 26
1860	0 26 E	1 15	1 59	5 02	4 28	4 00	2 42	3 23	2 56
1870	0 11 W	1 52	2 36	4 30	3 55	3 26	2 07	2 48	2 21
1880	0 58	2 42	3 28	3 52	3 16	2 46	1 27	2 08	1 40
1890	1 40	3 25	4 12	3 15	2 37	2 06	0 46	1 26	0 57
1900	2 16	4 02	4 50	2 47	2 07	1 35	0 14	0 53	0 22
1905	2 31	4 17	5 05	2 42	2 01	1 27	0 04 E	0 42	0 09 E
1910	2 48	4 35	5 25	2 42	1 59	1 22	0 02 W	0 33	0 02 W
1915	3 05	4 54	5 46	2 44	1 59	1 19	0 09	0 25	0 14
1920	3 19	5 11	6 03	2 47	2 01	1 19	0 13	0 17	0 24
1925	3 40 W	5 35 W	6 30 W	2 50 E	2 00 E	1 15 E	0 20 W	0 05 E	0 40 W
Annual change in 1925	4′2 incr.	4′8 incr.	5′4 incr.	0′6 incr.	0′0	0′8 decr.	1′5 incr.	2′4 decr.	3′2 incr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 84	° 84	° 84	° 86	° 86	° 86	° 86	° 86	° 86
Latitude	42	44	46	30	32	34	36	38	40
State	Michigan	Michigan	Michigan	Florida	Alabama	Alabama	Tennessee	Kentucky	Indiana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	----------	----------	----------	4 10 E	3 33 E	2 47 E	3 34 E	----------	----------
1760	----------	----------	----------	4 45	4 09	3 25	4 13	----------	----------
1770	----------	----------	----------	5 20	4 45	4 03	4 53	----------	----------
1780	----------	----------	----------	5 52	5 18	4 37	5 28	----------	----------
1790	----------	----------	----------	6 17	5 45	5 05	5 58	----------	----------
1800	2 48 E	2 26 E	1 06 E	6 37	6 06	5 27	6 21 E	5 50 E	5 04 E
1810	3 01	2 41	1 23	6 50	6 19	5 40	6 34	6 04	5 20
1820	3 04	2 45	1 29	6 55	6 23	5 45	6 39	6 09	5 26
1830	2 56	2 37	1 21	6 52	6 20	5 42	6 35	6 05	5 22
1840	2 38	2 19	1 02	6 42	6 09	5 30	6 23	5 52	5 09
1850	2 13	1 54	0 37	6 24	5 50	5 10	6 03	5 31	4 48
1860	1 43	1 24	0 07 E	5 59	5 24	4 43	5 35	5 03	4 20
1870	1 07	0 48 E	0 29 W	5 29	4 54	4 12	5 04	4 31	3 48
1880	0 22 E	0 00	1 20	4 52	4 16	3 32	4 24	3 51	3 08
1890	0 22 W	0 45 W	2 05	4 13	3 36	2 51	3 42	3 08	2 24
1900	0 58	1 22	2 44	3 47	3 08	2 21	3 11	2 36	1 50
1905	1 10	1 34	2 57	3 45	3 04	2 16	3 04	2 28	1 41
1910	1 25	1 50	3 14	3 49	3 06	2 14	3 00	2 21	1 32
1915	1 38	2 06	3 32	3 54	3 09	2 15	2 57	2 16	1 24
1920	1 50	2 22	3 48	4 00	3 13	2 17	2 56	2 11	1 15
1925	2 10 W	2 45 W	4 15 W	4 05 E	3 15 E	2 15 E	2 50 E	2 00 E	1 00 E
Annual change in 1925	4′.0 incr.	4′.7 incr.	5′.4 incr.	1′.0 incr.	0′.3 incr.	0′.4 decr.	1′.2 decr.	2′.1 decr.	3′.0 decr.

Longitude	° 86	° 86	° 86	° 88	° 88	° 88	° 88	° 88	° 88
Latitude	42	44	46	30	32	34	36	38	40
State	Michigan	Michigan	Michigan	Alabama	Alabama	Alabama	Tennessee	Indiana	Illinois
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1750	----------	----------	----------	4 20 E	4 00 E	4 11 E	----------	----------	----------
1760	----------	----------	----------	4 56	4 37	4 49	----------	----------	----------
1770	----------	----------	----------	5 32	5 15	5 28	----------	----------	----------
1780	----------	----------	----------	6 05	5 49	6 03	----------	----------	----------
1790	----------	----------	----------	6 32	6 18	6 33	----------	----------	----------
1800	4 36 E	4 20 E	3 36 E	6 54	6 41	6 57	6 49 E	6 43 E	6 25 E
1810	4 53	4 39	3 56	7 10	6 57	7 14	7 06	7 01	6 44
1820	5 00	4 47	4 07	7 17	7 05	7 22	7 15	7 10	6 54
1830	4 56	4 43	4 03	7 18	7 06	7 22	7 15	7 10	6 54
1840	4 42	4 29	3 48	7 11	6 58	7 14	7 06	7 01	6 44
1850	4 20	4 07	3 26	6 57	6 43	6 58	6 48	6 43	6 25
1860	3 52	3 39	2 58	6 36	6 21	6 35	6 24	6 18	5 59
1870	3 20	3 06	2 25	6 08	5 53	6 06	5 55	5 48	5 29
1880	2 37	2 20	1 36	5 33	5 17	5 28	5 15	5 08	4 49
1890	1 52	1 34	0 49	4 54	4 37	4 47	4 33	4 25	4 05
1900	1 16	0 58	0 12	4 30	4 11	4 19	4 03	3 53	3 33
1905	1 07	0 49	0 02 E	4 31	4 10	4 16	4 00	3 48	3 28
1910	0 56	0 36	0 13 W	4 38	4 15	4 18	3 59	3 45	3 22
1915	0 45	0 22	0 28	4 47	4 22	4 23	4 00	3 43	3 17
1920	0 34	0 08 E	0 44	4 54	4 27	4 26	4 00	3 40	3 09
1925	0 15 E	0 15 W	1 10 W	5 00 E	4 30 E	4 25 E	3 55 E	3 30 E	2 55 E
Annual change in 1925	3′.9 decr.	4′.6 incr.	5′.2 incr.	1′.2 incr.	0′.5 incr.	0′.2 decr.	1′.0 decr.	2′.0 decr.	2′.9 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 88	° 88	° 88	° 88	° 90	° 90	° 90	° 90	° 90
Latitude	42	44	46	48	30	32	34	36	38
State	Illinois	Wisconsin	Michigan	Lake Superior	Louisiana	Mississippi	Mississippi	Arkansas	Illinois
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1800	6 01 E	----------	----------	----------	7 17 E	7 35 E	7 36 E	7 28 E	7 16 E
1810	6 21	6 07 E	5 42 E	5 22 E	7 37	7 55	7 56	7 49	7 38
1820	6 32	6 19	5 56	5 39	7 47	8 06	8 07	8 01	7 51
1830	6 32	6 20	5 57	5 40	7 52	8 11	8 12	8 05	7 55
1840	6 22	6 10	5 46	5 29	7 47	8 06	8 06	7 59	7 49
1850	6 03	5 51	5 28	5 11	7 36	7 54	7 53	7 46	7 35
1860	5 37	5 25	5 02	4 45	7.18	7 35	7 33	7 25	7 14
1870	5 07	4 54	4 31	4 14	6 54	7 10	7 07	6 58	6 47
1880	4 27	4 10	3 44	3 25	6 21	6 36	6 31	6 21	6 09
1890	3 42	3 24	2 57	2 37	5 44	5 57	5 51	5 40	5 27
1900	3 07	2 49	2 22	2 00	5 22	5 33	5 25	5 12	4 57
1905	3 01	2 41	2 14	1 52	5 25	5 34	5 24	5 12	4 56
1910	2 53	2 32	2 04	1 42	5 34	5 41	5 29	5 15	4 56
1915	2 44	2 20	1 51	1 25	5 45	5 50	5 36	5 18	4 57
1920	2 33	2 07	1 36	1 08	5 54	5 56	5 40	5 20	4 54
1925	2 15 E	1 45 E	1 10 E	0 40 E	6 00 E	6 00 E	5 40 E	5 15 E	4 45 E
Annual change in 1925	3′.7 decr.	4′.4 decr.	5′.2 decr.	5′.7 decr.	1′.3 incr.	0′.7 incr.	0′.0	0′.9 decr.	1′.9 decr.

Longitude	° 90	° 90	° 90	° 90	° 90	° 92	° 92	° 92	° 92
Latitude	40	42	44	46	48	30	32	34	36
State	Illinois	Illinois	Wisconsin	Wisconsin	Minnesota	Louisiana	Louisiana	Arkansas	Arkansas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1800	7 21 E	7 36 E	----------	----------	----------	7 44 E	7 55 E	8 09 E	8 06 E
1810	7 44	7 59	----------	----------	----------	8 06	8 17	8 31	8 29
1820	7 58	8 14	7 57 E	7 20 E	7 19 E	8 20	8 31	8 46	8 45
1830	8 02	8 19	8 03	7 26	7 26	8 29	8 40	8 55	8 54
1840	7 56	8 13	7 57	7 20	7 20	8 28	8 39	8 54	8 53
1850	7 42	7 58	7 42	7 05	7 06	8 21	8 31	8 45	8 43
1860	7 20	7 36	7 20	6 43	6 44	8 07	8 17	8 30	8 26
1870	6 53	7 08	6 52	6 14	6 15	7 45	7 55	8 08	8 03
1880	6 13	6 28	6 10	5 30	5 29	7 15	7 24	7 35	7 29
1890	5 30	5 44	5 25	4 44	4 42	6 40	6 48	6 57	6 49
1900	4 58	5 12	4 52	4 11	4 07	6 20	6 26	6 33	6 23
1905	4 56	5 10	4 49	4 07	4 04	6 26	6 29	6 34	6 25
1910	4 53	5 05	4 43	4 01	3 57	6 37	6 38	6 42	6 31
1915	4 51	4 58	4 34	3 50	3 44	6 49	6 49	6 50	6 36
1920	4 44	4 48	4 22	3 35	3 29	6 58	6 56	6 55	6 40
1925	4 30 E	4 30 E	4 00 E	3 10 E	3 00 E	7 05 E	7 00 E	6 55 E	6 35 E
Annual change in 1925	2′.8 decr.	3′.6 decr.	4′.4 decr.	5′.1 decr.	5′.7 decr.	1′.4 incr.	0′.8 incr.	0′.0	0′.9 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 92	° 92	° 92	° 92	° 92	° 92	° 94	° 94	° 94
Latitude	38	40	42	44	46	48	30	32	34
State	Missouri	Missouri	Iowa	Minnesota	Minnesota	Minnesota	Texas	Louisiana	Arkansas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1800							8 01 E	8 14 E	8 27 E
1810							8 25	8 38	8 51
1820	9 01 E	9 12 E	9 32 E	9 09 E	9 04 E	8 43 E	8 42	8 55	9 09
1830	9 10	9 21	9 42	9 19	9 15	8 55	8 54	9 07	9 21
1840	9 08	9 19	9 40	9 18	9 14	8 54	8 56	9 09	9 23
1850	8 57	9 08	9 28	9 06	9 03	8 43	8 53	9 05	9 18
1860	8 39	8 50	9 09	8 47	8 44	8 24	8 44	8 55	9 07
1870	8 15	8 25	8 44	8 21	8 17	7 57	8 26	8 36	8 48
1880	7 40	7 49	8 07	7 42	7 36	7 14	7 59	8 08	8 19
1890	6 59	7 07	7 24	6 58	6 51	6 28	7 27	7 34	7 43
1900	6 31	6 37	6 53	6 27	6 18	5 55	7 10	7 15	7 21
1905	6 33	6 38	6 53	6 26	6 18	5 55	7 17	7 20	7 25
1910	6 36	6 39	6 51	6 24	6 17	5 53	7 29	7 31	7 34
1915	6 40	6 39	6 46	6 17	6 08	5 42	7 43	7 44	7 44
1920	6 39	6 33	6 38	6 06	5 55	5 28	7 53	7 51	7 50
1925	6 30 E	6 20 E	6 20 E	5 45 E	5 30 E	5 00 E	8 00 E	7 55 E	7 50 E
Annual change in 1925	1′.8 decr.	2′.7 decr.	3′.5 decr.	4′.2 decr.	5′.0 decr.	5′.6 decr.	1′.4 incr.	0′.8 incr.	0′.1 incr.

Longitude	° 94	° 94	° 94	° 94	° 94	° 94	° 94	° 96	° 96
Latitude	36	38	40	42	44	46	48	28	30
State	Arkansas	Missouri	Missouri	Iowa	Minnesota	Minnesota	Minnesota	At sea	Texas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1800	8 43 E	9 10 E							
1810	9 07	9 35							
1820	9 26	9 55	10 11 E	10 20 E	11 05 E	10 41 E	10 41 E	8 32 E	9 00 E
1830	9 38	10 07	10 23	10 33	11 18	10 55	10 56	8 45	9 14
1840	9 40	10 09	10 25	10 35	11 21	10 58	10 59	8 52	9 20
1850	9 34	10 02	10 18	10 27	11 13	10 50	10 51	8 53	9 20
1860	9 22	9 49	10 03	10 12	10 57	10 34	10 35	8 47	9 13
1870	9 02	9 29	9 42	9 50	10 34	10 10	10 10	8 36	9 01
1880	8 32	8 57	9 09	9 16	9 58	9 32	9 31	8 14	8 38
1890	7 54	8 18	8 29	8 35	9 16	8 49	8 47	7 45	8 08
1900	7 31	7 53	8 02	8 07	8 46	8 18	8 15	7 35	7 55
1905	7 35	7 56	8 05	8 09	8 48	8 20	8 18	7 45	8 04
1910	7 42	8 02	8 09	8 10	8 49	8 23	8 20	8 00	8 17
1915	7 50	8 08	8 12	8 09	8 45	8 16	8 11	8 17	8 32
1920	7 54	8 09	8 08	8 02	8 35	8 04	7 58	8 30	8 43
1925	7 50 E	8 00 E	7 55 E	7 45 E	8 15 E	7 40 E	7 30 E	8 40 E	8 50 E
Annual change in 1925	0′.9 decr.	1′.8 decr.	2′.6 decr.	3′.4 decr.	4′.1 decr.	4′.8 decr.	5′.5 decr.	1′.9 incr.	1′.4 incr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 96	° 96	° 96	° 96	° 96	° 96	° 96	° 96	° 96
Latitude	32	34	36	38	40	42	44	46	48
State	Texas	Oklahoma	Oklahoma	Kansas	Kansas	Iowa	Minnesota	Minnesota	Minnesota
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1820	9 12 E	9 35 E	10 11 E	11 05 E	11 09 E	11 28 E	11 36 E	12 23 E	12 22 E
1830	9 27	9 50	10 26	11 20	11 25	11 44	11 53	12 41	12 40
1840	9 33	9 56	10 32	11 26	11 31	11 51	12 00	12 48	12 47
1850	9 33	9 55	10 31	11 24	11 28	11 48	11 57	12 44	12 43
1860	9 26	9 47	10 23	11 15	11 18	11 37	11 45	12 32	12 31
1870	9 12	9 32	10 07	10 58	11 00	11 18	11 25	12 11	12 09
1880	8 47	9 06	9 40	10 30	10 31	10 47	10 53	11 38	11 34
1890	8 15	8 33	9 05	9 53	9 52	10 07	10 12	10 50	10 51
1900	8 00	8 15	8 45	9 32	9 29	9 42	9 46	10 28	10 21
1905	8 07	8 21	8 51	9 37	9 33	9 46	9 50	10 33	10 27
1910	8 20	8 32	9 00	9 45	9 40	9 51	9 55	10 39	10 32
1915	8 33	8 44	9 10	9 52	9 45	9 52	9 53	10 34	10 24
1920	8 41	8 49	9 14	9 53	9 42	9 46	9 44	10 23	10 12
1925	8 45 E	8 50 E	9 10 E	9 45 E	9 30 E	9 30 E	9 25 E	10 00 E	9 45 E
Annual change in 1925	0.′8 incr.	0.′1 incr.	0.′8 decr.	1.′7 decr.	2.′5 decr.	3.′2 decr.	3.′9 decr.	4.′6 decr.	5.′3 decr.

Longitude	° 98	° 98	° 98	° 98	° 98	° 98	° 98	° 98	° 98
Latitude	26	28	30	32	34	36	38	40	42
State	Mexico	Texas	Texas	Texas	Oklahoma	Oklahoma	Kansas	Kansas	Nebraska
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1820	8 26 E	8 51 E	9 09 E	9 30 E	10 12 E	10 41 E	11 02 E	11 51 E	12 24 E
1830	8 44	9 09	9 27	9 48	10 30	10 59	11 21	12 10	12 44
1840	8 54	9 19	9 37	9 58	10 40	11 09	11 31	12 20	12 54
1850	8 57	9 21	9 39	10 00	10 42	11 10	11 32	12 20	12 54
1860	8 55	9 18	9 36	9 57	10 38	11 05	11 26	12 13	12 46
1870	8 49	9 11	9 28	9 48	10 28	10 54	11 13	11 58	12 30
1880	8 31	8 52	9 08	9 27	10 05	10 30	10 48	11 32	12 03
1890	8 05	8 25	8 40	8 57	9 34	9 57	10 13	10 56	11 25
1900	7 58	8 17	8 31	8 46	9 20	9 41	9 56	10 37	11 04
1905	8 12	8 29	8 41	8 55	9 28	9 48	10 02	10 43	11 10
1910	8 29	8 45	8 56	9 00	9 41	9 59	10 12	10 52	11 17
1915	8 48	9 02	9 12	9 23	9 53	10 10	10 21	10 58	11 20
1920	9 04	9 16	9 23	9 31	9 59	10 14	10 23	10 57	11 15
1925	9 15 E	9 25 E	9 30 E	9 35 E	10 00 E	10 10 E	10 15 E	10 45 E	11 00 E
Annual change in 1925	2.′3 incr.	1.′8 incr.	1.′3 incr.	0.′8 incr.	0.′1 incr.	0.′7 decr.	1.′6 decr.	2.′4 decr.	3.′0 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 98	° 98	° 98	° 100	° 100	° 100	° 100	° 100	° 100
Latitude	44	46	48	28	30	32	34	36	38
State	South Dakota	North Dakota	North Dakota	Mexico	Texas	Texas	Texas	Oklahoma	Kansas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1830	12 59 E	13 27 E	14 36 E	9 35 E	9 54 E	10 34 E	10 57 E	11 42 E	12 10 E
1840	13 09	13 37	14 46	9 47	10 06	10 46	11 09	11 54	12 22
1850	13 09	13 36	14 45	9 51	10 10	10 50	11 13	11 58	12 25
1860	13 00	13 27	14 36	9 51	10 10	10 49	11 12	11 56	12 22
1870	12 43	13 09	14 16	9 47	10 05	10 43	11 05	11 48	12 13
1880	12 15	12 40	13 46	9 30	9 47	10 24	10 45	11 27	11 50
1890	11 35	11 59	13 04	9 05	9 20	9 56	10 16	10 57	11 19
1900	11 12	11 35	12 39	8 59	9 12	9 48	10 06	10 46	11 06
1905	11 18	11 41	12 46	9 12	9 24	9 59	10 16	10 54	11 13
1910	11 26	11 50	12 53	9 29	9 41	10 14	10 30	11 07	11 25
1915	11 26	11 47	12 47	9 48	9 58	10 29	10 43	11 19	11 35
1920	11 18	11 37	12 35	10 01	10 09	10 37	10 50	11 23	11 37
1925	11 00 E	11 15 E	12 10 E	10 10 E	10 15 E	10 40 E	10 50 E	11 20 E	11 30 E
Annual change in 1925	3′7 decr.	4′4 decr.	5′0 decr.	1′8 incr.	1′2 incr.	0′7 incr.	0′0	0′7 decr.	1′4 decr.

Longitude	° 100	° 100	° 100	° 100	° 100	° 102	° 102	° 102	° 102
Latitude	40	42	44	46	48	30	32	34	36
State	Kansas	Nebraska	South Dakota	North Dakota	North Dakota	Texas	Texas	Texas	Texas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1830	12 46 E	13 04 E	14 10 E	15 03 E	15 37 E	10 14 E	10 58 E	11 30 E	12 08 E
1840	12 58	13 16	14 22	15 15	15 49	10 28	11 12	11 44	12 22
1850	13 01	13 19	14 24	15 17	15 51	10 34	11 18	11 50	12 28
1860	12 58	13 15	14 19	15 12	15 46	10 37	11 20	11 52	12 30
1870	12 48	13 04	14 06	14 58	15 30	10 36	11 18	11 49	12 26
1880	12 24	12 39	13 40	14 31	15 03	10 21	11 02	11 32	12 08
1890	11 51	12 04	13 03	13 52	14 22	9 56	10 36	11 05	11 40
1900	11 36	11 47	12 45	13 32	14 01	9 50	10 30	10 58	11 32
1905	11 44	11 54	12 52	13 40	14 10	10 03	10 42	11 09	11 41
1910	11 55	12 03	13 02	13 51	14 20	10 22	10 59	11 25	11 56
1915	12 02	12 08	13 04	13 50	14 15	10 40	11 15	11 39	12 09
1920	12 01	12 04	12 57	13 41	14 04	10 50	11 23	11 45	12 13
1925	11 50 E	11 50 E	12 40 E	13 20 E	13 40 E	10 55 E	11 25 E	11 45 E	12 10 E
Annual change in 1925	2′2 decr.	2′8 decr.	3′5 decr.	4′2 decr.	4′8 decr.	1′0 incr.	0′5 incr.	0′0	0′6 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 102	° 102	° 102	° 102	° 102	° 102	° 104	° 104	° 104
Latitude	38	40	42	44	46	48	30	32	34
State	Kansas	Kansas	Nebraska	South Dakota	North Dakota	North Dakota	Texas	Texas	New Mexico
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1830	----------	----------	----------	----------	----------	----------	10 35 E	11 19 E	12 00 E
1840	----------	----------	----------	----------	----------	----------	10 50	11 34	12 15
1850	13 02 E	13 45 E	14 37 E	15 31 E	16 31 E	17 13 E	10 58	11 42	12 23
1860	13 03	13 46	14 37	15 31	16 30	17 12	11 04	11 47	12 28
1870	12 58	13 40	14 30	15 23	16 20	17 01	11 06	11 48	12 29
1880	12 39	13 20	14 09	15 00	15 57	16 37	10 54	11 34	12 14
1890	12 10	12 50	13 37	14 26	15 21	15 59	10 31	11 10	11 49
1900	12 01	12 40	13 25	14 13	15 06	15 43	10 28	11 06	11 44
1905	12 10	12 50	13 34	14 22	15 15	15 54	10 43	11 20	11 57
1910	12 24	13 02	13 45	14 33	15 27	16 06	11 03	11 39	12 15
1915	12 35	13 11	13 51	14 37	15 28	16 03	11 22	11 56	12 30
1920	12 36	13 10	13 48	14 31	15 19	15 53	11 30	12 03	12 36
1925	12 30 E	13 00 E	13 35 E	14 15 E	15 00 E	15 30 E	11 35 E	12 05 E	12 35 E
Annual change in 1925	1′.3 decr.	2′.0 decr.	2′.6 decr.	3′.2 decr.	3′.9 decr.	4′.6 decr.	1′.0 incr.	0′.4 incr.	0′.1 decr.

Longitude	° 104	° 104	° 104	° 104	° 104	° 104	° 104	° 106	° 106
Latitude	36	38	40	42	44	46	48	30	32
State	New Mexico	Colorado	Colorado	Nebraska	South Dakota	North Dakota	North Dakota	Mexico	Texas
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1850	13 09 E	13 42 E	14 26 E	15 39 E	16 22 E	17 16 E	18 29 E	11 18 E	12 00 E
1860	13 14	13 47	14 30	15 43	16 26	17 20	18 33	11 27	12 08
1870	13 14	13 46	14 28	15 40	16 21	17 14	18 25	11 32	12 12
1880	12 58	13 29	14 10	15 21	16 01	16 53	18 03	11 22	12 01
1890	12 32	13 02	13 42	14 51	15 30	16 20	17 28	11 02	11 40
1900	12 27	12 56	13 35	14 43	15 21	16 10	17 17	11 01	11 38
1905	12 39	13 07	13 47	14 54	15 32	16 21	17 29	11 18	11 54
1910	12 55	13 23	14 01	15 08	15 45	16 33	17 42	11 40	12 14
1915	13 09	13 34	14 10	15 14	15 50	16 36	17 41	11 59	12 32
1920	13 13	13 36	14 09	15 12	15 45	16 28	17 32	12 06	12 39
1925	13 10 E	13 30 E	14 00 E	15 00 E	15 30 E	16 10 E	17 10 E	12 10 E	12 40 E
Annual change in 1925	0′.6 decr.	1′.2 decr.	1′.9 decr.	2′.5 decr.	3′.0 decr.	3′.6 decr.	4′.3 decr.	0′.8 incr.	0′.2 incr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 106	° 106	° 106	° 106	° 106	° 106	° 106	° 106	° 108
Latitude	34	36	38	40	42	44	46	48	30
State	New Mexico	New Mexico	Colorado	Colorado	Wyoming	Wyoming	Montana	Montana	Mexico
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1850	12 50 E	13 27 E	14 24 E	15 11 E	15 55 E	16 47 E	17 57 E	19 16 E	11 29 E
1860	12 58	13 35	14 32	15 19	16 03	17 05	18 06	19 25	11 41
1870	13 02	13 38	14 34	15 21	16 04	17 05	18 05	19 23	11 48
1880	12 50	13 24	14 19	15 05	15 48	16 48	17 47	19 04	11 41
1890	12 28	13 01	13 55	14 40	15 22	16 20	17 18	18 33	11 24
1900	12 26	12 58	13 52	14 37	15 18	16 15	17 13	18 28	11 25
1905	12 41	13 12	14 05	14 49	15 30	16 27	17 25	18 40	11 43
1910	13 00	13 29	14 22	15 04	15 46	16 42	17 39	18 53	12 06
1915	13 16	13 44	14 34	15 14	15 53	16 48	17 43	18 54	12 25
1920	13 21	13 48	14 35	15 13	15 51	16 44	17 37	18 45	12 33
1925	13 20 E	13 45 E	14 30 E	15 05 E	15 40 E	16 30 E	17 20 E	18 25 E	12 35 E
Annual change in 1925	0′.2 decr.	0′.6 decr.	1′.0 decr.	1′.7 decr.	2′.3 decr.	2′.8 decr.	3′.4 decr.	4′.0 decr.	0′.5 incr.

Longitude	° 108	° 108	° 108	° 108	° 108	° 108	° 108	° 108	° 108
Latitude	32	34	36	38	40	42	44	46	48
State	New Mexico	New Mexico	New Mexico	Colorado	Colorado	Wyoming	Wyoming	Montana	Montana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1850	12 17 E	12 58 E	13 43 E	14 28 E	15 30 E	16 25 E	17 33 E	18 44 E	20 10 E
1860	12 29	13 10	13 55	14 40	15 42	16 37	17 45	18 56	20 22
1870	12 36	13 17	14 01	14 46	15 47	16 41	17 49	18 59	20 24
1880	12 28	13 07	13 50	14 34	15 34	16 27	17 34	18 43	20 07
1890	12 10	12 48	13 30	14 13	15 12	16 04	17 10	18 18	19 41
1900	12 11	12 48	13 31	14 13	15 11	16 04	17 10	18 18	19 40
1905	12 29	13 05	13 46	14 28	15 25	16 18	17 23	18 31	19 54
1910	12 50	13 26	14 06	14 47	15 42	16 34	17 40	18 47	20 10
1915	13 08	13 41	14 20	14 59	15 53	16 42	17 46	18 51	20 12
1920	13 15	13 46	14 23	15 00	15 53	16 40	17 43	18 46	20 04
1925	13 15 E	13 45 E	14 20 E	14 55 E	15 45 E	16 30 E	17 30 E	18 30 E	19 45 E
Annual change in 1925	0′.0	0′.2 decr.	0′.6 decr.	1′.0 decr.	1′.6 decr.	2′.1 decr.	2′.7 decr.	3′.2 decr.	3′.8 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 110	° 110	° 110	° 110	° 110	° 110	° 110	° 110	° 110
Latitude	32	34	36	38	40	42	44	46	48
State	Arizona	Arizona	Arizona	Utah	Utah	Wyoming	Wyoming	Montana	Montana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1850	12 25 E	13 10 E	13 50 E	14 49 E	15 54 E	17 03 E	18 12 E	19 20 E	20 33 E
1860	12 40	13 25	14 05	15 04	16 09	17 18	18 27	19 35	20 48
1870	12 50	13 34	14 14	15 13	16 17	17 26	18 35	19 42	20 55
1880	12 45	13 28	14 06	15 04	16 07	17 15	18 23	19 29	20 41
1890	12 31	13 13	13 50	14 47	15 49	16 56	18 03	19 09	20 20
1900	12 34	13 16	13 53	14 50	15 51	16 59	18 06	19 13	20 24
1905	12 54	13 34	14 10	15 06	16 07	17 14	18 21	19 28	20 39
1910	13 16	13 56	14 31	15 26	16 26	17 32	18 38	19 44	20 56
1915	13 34	14 12	14 45	15 39	16 37	17 41	18 45	19 50	20 59
1920	13 41	14 17	14 49	15 40	16 37	17 40	18 42	19 45	20 53
1925	13 40 E	14 15 E	14 45 E	15 35 E	16 30 E	17 30 E	18 30 E	19 30 E	20 35 E
Annual change in 1925	0′.1 decr.	0′.4 decr.	0′.7 decr.	1′.0 decr.	1′.5 decr.	2′.0 decr.	2′.5 decr.	3′.0 decr.	3′.5 decr.

Longitude	° 112	° 112	° 112	° 112	° 112	° 112	° 112	° 112	° 112
Latitude	32	34	36	38	40	42	44	46	48
State	Arizona	Arizona	Arizona	Utah	Utah	Utah	Idaho	Montana	Montana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1850	12 37 E	13 16 E	14 06 E	15 09 E	16 18 E	17 26 E	18 30 E	19 27 E	20 59 E
1860	12 55	13 34	14 24	15 27	16 36	17 44	18 48	19 45	21 17
1870	13 07	13 46	14 36	15 39	16 47	17 55	18 59	19 56	21 28
1880	13 06	13 44	14 32	15 34	16 41	17 48	18 50	19 46	21 17
1890	12 56	13 33	14 20	15 21	16 28	17 34	18 36	19 31	21 01
1900	13 02	13 38	14 25	15 26	16 33	17 40	18 42	19 38	21 08
1905	13 23	13 58	14 44	15 44	16 50	17 56	18 58	19 54	21 25
1910	13 46	14 21	15 05	16 05	17 10	18 15	19 16	20 11	21 42
1915	14 05	14 37	15 20	16 18	17 22	18 25	19 24	20 18	21 47
1920	14 11	14 42	15 24	16 20	17 22	18 24	19 21	20 14	21 41
1925	14 10 E	14 40 E	15 20 E	16 15 E	17 15 E	18 15 E	19 10 E	20 00 E	21 25 E
Annual change in 1925	0′.2 decr.	0′.4 decr.	0′.7 decr.	1′.0 decr.	1′.4 decr.	1′.8 decr.	2′.2 decr.	2′.8 decr.	3′.2 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude Latitude	° 114 32	° 114 34	° 114 36	° 114 38	° 114 40	° 114 42	° 114 44	° 114 46	° 114 48
State	Mexico	Arizona	Arizona	Utah	Utah	Utah	Idaho	Montana	Montana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1840	12 21 E	12 59 E	13 52 E	14 54 E	15 57 E	17 09 E	18 16 E	19 27 E	21 05 E
1850	12 39	13 17	14 11	15 13	16 16	17 29	18 36	19 48	21 27
1860	13 01	13 38	14 32	15 34	16 37	17 50	18 57	20 09	21 48
1870	13 17	13 54	14 47	15 49	16 52	18 04	19 11	20 23	22 02
1880	13 19	13 55	14 47	15 48	16 49	18 01	19 07	20 17	21 55
1890	13 12	13 48	14 39	15 40	16 41	17 52	18 58	20 08	21 47
1900	13 20	13 56	14 47	15 48	16 49	18 00	19 07	20 18	21 59
1905	13 42	14 17	15 07	16 07	17 08	18 18	19 24	20 35	22 16
1910	14 06	14 41	15 30	16 29	17 29	18 39	19 44	20 54	22 34
1915	14 25	14 58	15 45	16 43	17 41	18 49	19 53	21 01	22 40
1920	14 32	15 03	15 49	16 45	17 41	18 48	19 50	20 58	22 35
1925	14 30 E	15 00 E	15 45 E	16 40 E	17 35 E	18 40 E	19 40 E	20 45 E	22 20 E
Annual change in 1925	0′.3 decr.	0′.5 decr.	0′.8 decr.	1′.0 decr.	1′.3 decr.	1′.7 decr.	2′.0 decr.	2′.6 decr.	3′.0 decr.

Longitude Latitude	° 116 32	° 116 34	° 116 36	° 116 38	° 116 40	° 116 42	° 116 44	° 116 46	° 116 48
State	Mexico	California	California	Nevada	Nevada	Nevada	Idaho	Idaho	Montana
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1820	11 22 E	12 16 E	13 07 E	----------	----------	----------	----------	----------	----------
1830	11 51	12 45	13 36	----------	----------	----------	----------	----------	----------
1840	12 16	13 10	14 01	15 03 E	15 53 E	17 09 E	18 14 E	19 55 E	21 08 E
1850	12 36	13 30	14 22	15 24	16 15	17 31	18 37	20 18	21 32
1860	13 00	13 54	14 46	15 48	16 39	17 55	19 01	20 42	21 56
1870	13 20	14 13	15 05	16 06	16 57	18 13	19 18	20 59	22 13
1880	13 26	14 17	15 08	16 08	16 59	18 14	19 18	20 57	22 10
1890	13 23	14 14	15 04	16 04	16 55	18 10	19 15	20 55	22 10
1900	13 33	14 24	15 15	16 15	17 06	18 21	19 27	21 09	22 24
1905	13 57	14 46	15 36	16 36	17 26	18 40	19 46	21 27	22 43
1910	14 22	15 11	15 59	16 59	17 48	19 02	20 07	21 47	23 02
1915	14 41	15 28	16 15	17 13	18 01	19 13	20 17	21 55	23 09
1920	14 47	15 33	16 19	17 15	18 01	19 13	20 14	21 52	23 04
1925	14 45 E	15 30 E	16 15 E	17 10 E	17 55 E	19 05 E	20 05 E	21 40 E	22 50 E
Annual change in 1925	0′.4 decr.	0′.6 decr.	0′.8 decr.	1′.0 decr.	1′.2 decr.	1′.6 decr.	1′.9 decr.	2′.3 decr.	2′.8 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 118	° 118	° 118	° 118	° 118	° 118	° 118	° 118	° 118
Latitude	32	34	36	38	40	42	44	46	48
State	At sea	California	California	Nevada	Nevada	Nevada	Oregon	Oregon	Washington
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1780	10 40 E	11 31 E	12 11 E	12 59 E	----------	----------	----------	----------	----------
1790	10 55	11 47	12 29	13 19	----------	----------	----------	----------	----------
1800	11 10	12 03	12 47	13 39	----------	----------	----------	----------	----------
1810	11 25	12 19	13 05	13 59	----------	----------	----------	----------	----------
1820	11 40	12 35	13 23	14 19	----------	----------	----------	----------	----------
1830	11 55	12 51	13 41	14 39	15 41 E	16 53 E	18 00 E	19 25 E	20 51 E
1840	12 14	13 11	14 02	15 01	16 04	17 17	18 25	19 50	21 16
1850	12 36	13 33	14 25	15 24	16 27	17 41	18 50	20 15	21 42
1860	13 03	14 00	14 52	15 51	16 53	18 08	19 17	20 42	22 09
1870	13 25	14 21	15 13	16 12	17 14	18 28	19 37	21 02	22 29
1880	13 34	14 29	15 20	16 18	17 19	18 32	19 40	21 04	22 30
1890	13 33	14 28	15 19	16 18	17 19	18 33	19 42	21 07	22 36
1900	13 46	14 42	15 33	16 32	17 32	18 47	19 57	21 23	22 53
1905	14 12	15 06	15 56	16 55	17 54	19 08	20 17	21 43	23 13
1910	14 37	15 31	16 20	17 18	18 18	19 30	20 39	22 04	23 34
1915	14 57	15 49	16 36	17 33	18 31	19 43	20 50	22 13	23 42
1920	15 02	15 53	16 39	17 35	18 31	19 43	20 49	22 11	23 38
1925	15 00 E	15 50 E	16 35 E	17 30 E	18 25 E	19 35 E	20 40 E	22 00 E	23 25 E
Annual change in 1925	0′.4 decr.	0′.6 decr.	0′.8 decr.	1′.0 decr.	1′.2 decr.	1′.6 decr.	1′.8 decr.	2′.1 decr.	2′.6 decr.

Longitude	° 120	° 120	° 120	° 120	° 120	° 120	° 120	° 120	° 122
Latitude	34	36	38	40	42	44	46	48	36
State	At sea	California	California	California	California	Oregon	Washington	Washington	At sea
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1780	11 28 E	12 18 E	12 52 E	13 50 E	14 47 E	15 59 E	16 36 E	17 08 E	12 22 E
1790	11 44	12 36	13 12	14 12	15 13	16 29	17 10	17 48	12 39
1800	12 00	12 54	13 32	14 34	15 39	16 59	17 44	18 28	12 56
1810	12 16	13 12	13 52	14 56	16 05	17 29	18 18	19 08	13 13
1820	12 32	13 30	14 12	15 18	16 31	17 59	18 52	19 48	13 30
1830	12 48	13 48	14 32	15 40	16 57	18 29	19 26	20 28	13 47
1840	13 08	14 09	14 54	16 03	17 21	18 54	19 52	20 55	14 08
1850	13 31	14 33	15 18	16 28	17 47	19 21	20 19	21 23	14 34
1860	14 02	15 03	15 48	16 58	18 16	19 50	20 48	21 52	15 07
1870	14 26	15 27	16 12	17 22	18 40	20 13	21 11	22 15	15 33
1880	14 37	15 37	16 21	17 30	18 47	20 20	21 17	22 21	15 45
1890	14 39	15 39	16 23	17 33	18 51	20 25	21 24	22 32	15 49
1900	14 56	15 56	16 40	17 50	19 08	20 42	21 42	22 52	16 08
1905	15 21	16 21	17 04	18 13	19 30	21 04	22 03	23 13	16 35
1910	15 46	16 45	17 28	18 37	19 54	21 27	22 26	23 36	16 59
1915	16 04	17 01	17 43	18 50	20 07	21 39	22 37	23 45	17 16
1920	16 08	17 04	17 45	18 51	20 07	21 39	22 35	23 42	17 19
1925	16 05 E	17 00 E	17 40 E	18 45 E	20 00 E	21 30 E	22 25 E	23 30 E	17 15 E
Annual change in 1925	0′.6 decr.	0′.8 decr.	1′.0 decr.	1′.2 decr.	1′.5 decr.	1′.8 decr.	2′.0 decr.	2′.4 decr.	0′.8 decr.

Secular change of the magnetic declination in the United States—Continued

Longitude	° 122	° 122	° 122	° 122	° 122	° 122	° 124	° 124	° 124
Latitude	38	40	42	44	46	48	38	40	42
State	California	California	California	Oregon	Washington	Washington	At sea	California	California
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
1780	13 20 E	13 51 E	14 33 E	15 37 E	16 20 E	17 04 E	13 00 E	13 49 E	14 48 E
1790	13 39	14 13	14 58	16 06	16 54	17 44	13 18	14 11	15 13
1800	13 58	14 35	15 23	16 35	17 28	18 24	13 37	14 33	15 38
1810	14 17	14 57	15 48	17 04	18 02	19 04	13 56	14 55	16 03
1820	14 36	15 19	16 13	17 33	18 36	19 44	14 15	15 17	16 28
1830	14 55	15 41	16 38	18 02	19 10	20 24	14 34	15 39	16 53
1840	15 17	16 04	17 02	18 27	19 36	20 51	14 56	16 02	17 17
1850	15 43	16 31	17 29	18 55	20 05	21 21	15 24	16 30	17 46
1860	16 16	17 04	18 01	19 27	20 37	21 53	16 00	17 05	18 21
1870	16 42	17 30	18 27	19 54	21 04	22 20	16 29	17 34	18 50
1880	16 54	17 41	18 38	20 04	21 14	22 29	16 43	17 48	19 04
1890	16 59	17 47	18 46	20 13	21 25	22 44	16 50	17 56	19 14
1900	17 18	18 07	19 05	20 33	21 46	23 06	17 11	18 18	19 36
1905	17 43	18 31	19 28	20 56	22 09	23 28	17 37	18 44	20 01
1910	18 08	18 55	19 53	21 20	22 33	23 52	18 02	19 09	20 26
1915	18 23	19 10	20 07	21 33	22 45	24 03	18 18	19 25	20 42
1920	18 25	19 11	20 07	21 33	22 44	24 01	18 20	19 26	20 42
1925	18 20 E	19 05 E	20 00 E	21 25 E	22 35 E	23 50 E	18 15 E	19 20 E	20 35 E
Annual change in 1925	1′.0 decr.	1′.2 decr	1′.4 decr.	1′.6 decr.	1′.8 decr.	2′.1 decr.	1′.0 decr.	1′.2 decr.	1′.4 decr.

Longitude	° 124	° 124	° 124
Latitude	44	46	48
State	Oregon	Oregon	Washington
	° ′	° ′	° ′
1780	15 33 E	16 11 E	16 50 E
1790	16 02	16 45	17 30
			18 10
1800	16 31	17 19	18 50
1810	17 00	17 53	19 30
1820	17 29	18 27	
1830	17 58	19 01	20 10
1840	18 24	19 28	20 38
1850	18 54	19 59	21 10
1860	19 29	20 34	21 45
1870	19 59 E	21 04 E	22 15 E

Longitude	° 124	° 124	° 124
Latitude	44	46	48
State	Oregon	Oregon	Washington
	° ′	° ′	° ′
1880	20 12 E	21 17 E	22 28 E
1890	20 25	21 32	22 46
1900	20 49	21 56	23 11
1905	21 13	22 20	23 34
1910	21 38	22 46	24 00
1915	21 53	22 59	24 12
1920	21 53	22 59	24 10
1925	21 45 E	22 50 E	24 00 E
Annual change in 1925.	1′.6 decr.	1′.8 decr.	2′.0 decr.

DIURNAL VARIATION

The magnetic declination undergoes a systematic change in the course of the day. During the night it ordinarily differs very little from the average value for the day, but in the early morning an easterly motion sets in, the extreme easterly position being reached about 8 or 9 a. m. This is followed by a westerly motion, the extreme westerly position being reached about 1 or 2 p. m. By 6 p. m. it is back again to the average. The magnitude of this variation is indicated in the following table, which gives the average diurnal variation for a series of years at three of the magnetic observatories of this bureau. For individual days of ordinary character, the departures from the daily mean may be 50 per cent greater than the values given in the table and at the time of a magnetic storm the daily range not infrequently amounts to half a degree or more.

While the diurnal variation can ordinarily be neglected for the class of work done with a compass, yet, where as great accuracy as possible is sought, it should be taken into account. The difference in declination between morning and afternoon may easily amount to 10 minutes, and an angle of 10 minutes subtends an arc of 15 feet at a distance of a mile. The surveyor should also be on the lookout for magnetic storms, which may be indicated by an unsteady needle.

Diurnal variation of declination at magnetic observatories

[A plus sign indicates that east declination is greater or west declination is less than the mean for the day]

Hour	January, February, November, December			March, April, September, October			May, June, July, August		
	Sitka	Cheltenham	Tucson	Sitka	Cheltenham	Tucson	Sitka	Cheltenham	Tucson
	′	′	′	′	′	′	′	′	′
1 a. m.	−0.2	−0.2	−0.2	−0.2	+0.1	0.0	−0.9	+0.1	0.0
2 a. m.	−0.1	−0.3	−0.2	−0.2	+0.3	+0.1	−0.7	+0.2	+0.1
3 a. m.	+0.1	−0.1	−0.2	+0.1	+0.5	+0.2	−0.4	+0.3	+0.2
4 a. m.	+0.2	+0.1	−0.1	+0.4	+0.8	+0.3	+0.9	+0.8	+0.5
5 a. m.	+0.4	+0.3	0.0	+1.0	+1.1	+0.5	+2.6	+1.7	+1.0
6 a. m.	+0.6	+0.6	+0.2	+2.1	+2.0	+1.2	+4.5	+3.5	+2.1
7 a. m.	+1.1	+1.1	+0.6	+3.4	+3.4	+2.5	+6.1	+4.9	+3.5
8 a. m.	+1.7	+2.0	+1.3	+4.6	+4.2	+3.2	+7.1	+5.3	+4.0
9 a. m.	+1.9	+2.6	+1.7	+4.6	+3.7	+2.5	+6.7	+4.0	+2.8
10 a. m.	+1.5	+2.0	+1.4	+3.4	+1.8	+0.8	+4.7	+1.1	+0.5
11 a. m.	+0.6	+0.2	+0.2	+1.5	−0.9	−1.0	+1.2	−1.9	−1.6
Noon	−0.2	−1.7	−1.1	−0.6	−3.2	−2.3	−1.8	−4.1	−2.8
1 p. m.	−1.0	−2.7	−1.7	−2.2	−4.3	−2.7	−3.6	−5.0	−3.2
2 p. m.	−1.5	−2.6	−1.6	−3.0	−4.2	−2.3	−4.8	−4.7	−2.8
3 p. m.	−1.6	−2.0	−1.1	−3.2	−3.1	−1.5	−5.3	−3.5	−2.0
4 p. m.	−1.4	−1.2	−0.5	−3.0	−1.8	−0.8	−4.8	−2.2	−1.1
5 p. m.	−1.1	−0.5	0.0	−2.5	−0.8	−0.4	−3.7	−0.8	−0.4
6 p. m.	−0.6	0.0	+0.2	−1.9	−0.4	−0.2	−2.3	0.0	−0.1
7 p. m.	−0.2	+0.3	+0.4	−1.3	−0.1	−0.1	−1.2	0.0	−0.3
8 p. m.	0.0	+0.5	+0.4	−0.9	0.0	0.0	−0.8	−0.1	−0.2
9 p. m.	−0.1	+0.6	+0.4	−0.6	+0.2	0.0	−0.8	0.0	−0.2
10 p. m.	−0.1	+0.5	+0.2	−0.7	+0.2	0.0	−0.9	+0.1	−0.1
11 p. m.	−0.1	+0.4	0.0	−0.5	+0.2	0.0	−0.8	+0.1	−0.1
Midnight	0.0	+0.1	−0.1	−0.4	+0.2	0.0	−0.9	+0.1	0.0

DETERMINATION OF THE TRUE MERIDIAN

Because of the irregular distribution of the earth's magnetism, only an approximate value of the magnetic declination can be given for a place at which it has not been determined by observation.

When a more accurate value is needed, the true meridian must be determined, as the declination is the angle between the true meridian and the magnetic meridian. This may be done by observations of the sun or Polaris. Five methods will be explained—three involving the use of a surveyor's transit and two requiring no instrumental equipment.

With care the methods involving the use of a surveyor's transit should give the true meridian within 1 minute of arc, the other methods within 2 or 3 minutes, an accuracy ample for ordinary compass surveys.

(*a*) *With a plumb line and peep sight.*—I. By observations of Polaris at elongation. II. By noting when Polaris and another star are in the same vertical plane.

(*b*) *With a surveyor's transit.*—III. By observations of Polaris at elongation. IV. By observations of Polaris at any hour. V. By observations of the sun.

Detailed tables are given each year in the American Ephemeris and Nautical Almanac for use in determining the true meridian by observations of Polaris. From these have been prepared the abridged tables which are given in this publication. Many approximations have been made, but they give results of sufficient accuracy, so far as compass surveys are concerned. Those who can do so are advised to use the American Ephemeris for the year of observation, which may be obtained from the Superintendent of Documents, Washington, D. C., for $1, as the full tables are more convenient to use.

The position of a star in the celestial sphere is usually given in terms of declination (not to be confused with magnetic declination) and right ascension, corresponding to latitude and longitude on the earth. The poles of the celestial sphere are in the prolongation of the earth's axis, and the celestial equator is the great circle of the celestial sphere whose plane coincides with the plane of the earth's Equator. The declination of a star is its angular distance north or south of the celestial equator. Its right ascension is measured along the Equator east from a fixed point called the vernal equinox, just as longitude on the earth is measured east or west from the meridian of Greenwich. Because of the relative motion of the star and the solar system these quantities change slowly from year to year, and because of the motion of the earth about the sun they go through a systematic change in the course of the year.

As a result of the rotation of the earth about its axis, Polaris, like other stars, appears to move in a circle about the pole of the heavens. It is said to be at culmination when it is in the vertical plane defined by the observer and the pole (upper culmination when it is above the pole) and at elongation when it reaches its extreme easterly and westerly positions with respect to the pole. At culmination its apparent motion is nearly horizontal—from east to west at upper culmination and from west to east at lower culmination. At elongation its apparent motion is nearly vertical—upward at eastern elongation and downward at western elongation.

The azimuth of Polaris is the angle at the observing station between the vertical plane through the pole and the one through the star. For a short time before and after elongation there is practically no change in the azimuth of Polaris, and that time is usually selected for observing it for the purpose of determining the true meridian.

I. OBSERVATIONS OF POLARIS AT ELONGATION

Attach the plumb line to a support situated as far above the ground as practicable, such as the limb of a tree or a piece of board fastened to a telegraph pole or a building, affording a clear view in a north and south direction.

The plumb bob may consist of any heavy material, a brick or a piece of iron or stone weighing 4 or 5 pounds serving to keep the plumb line straight and vertical as well as one of turned and finished metal.

Strongly illuminate the plumb line just below its support by a flash light or lantern, care being taken to obscure the source of light from the view of the observer.

For a peep sight nail two strips of tin or thin board with straight edges to a squared block of wood so that they will stand vertical about one-sixteenth of an inch apart when the block rests on a horizontal surface.

Provide a rest for the peep sight at a convenient height above the ground, at such a distance south of the plumb line that when viewed through the peep-sight Polaris will appear about a foot below the support of the plumb line. The top of this rest must be level and large enough to allow for sliding the peep sight east or west. The position of the rest should be fixed by trial the night preceding that set for observations, and it should be firmly secured in the proper position.

About 30 minutes before the time of elongation, as given by Tables 1 and 2, bring the peep sight into the same line of sight with the plumb line and Polaris.

The star will move off the plumb line to the east as it approaches eastern elongation; to the west for western elongation. Move the peep sight to the west or east, as the case may be, keeping it in line with the star and the plumb line, until the star appears stationary, thus indicating that it has reached elongation. The peep sight will then be secured in place by a clamp or weight and further operations will be deferred until daylight.

By daylight place a slender rod at a distance of 200 or 300 feet from the peep sight and exactly in range with it and the plumb line; carefully measure this distance.

Find from Table 3 the azimuth of Polaris for the year of observation and the latitude of the place.

Find from Table 4 the natural tangent of this angle and multiply it by the distance from the peep sight to the rod. The product will be the distance to be laid off from the rod, to the west in the case of eastern elongation, or to the east for western elongation, to a point which with the peep sight will define the direction of the true meridian with a fair degree of accuracy. Set a stub at this point and another exactly below the peep sight, if the meridian is needed for future use.

TABLE 1.—*Local civil time of upper culmination of Polaris in the year 1926*

[Computed for 90°, or 6 hours west of Greenwich]

Date, 1926	Civil time of upper culmination	Variation per day	Date, 1926	Civil time of upper culmination	Variation per day
	h. m. s.	*m. s.*		*h. m. s.*	*m. s.*
Jan. 1	18 51 29	−3 57	July 10	6 24 11	−3 55
Jan. 11	18 11 59	3 57	July 20	5 45 03	3 55
Jan. 21	17 32 28	3 57	July 30	5 05 55	3 55
Jan. 31	16 52 58	3 57	Aug. 9	4 26 46	3 55
Feb. 10	16 13 28	3 57	Aug. 19	3 47 37	3 55
Feb. 20	15 33 58	3 57	Aug. 29	3 08 27	3 55
Mar. 2	14 54 30	3 57	Sept. 8	2 29 16	3 55
Mar. 12	14 15 04	3 57	Sept. 18	1 50 04	3 55
Mar. 22	13 35 40	3 56	Sept. 28	1 10 50	3 55
Apr. 1	12 56 17	3 56	Oct. 8	0 31 35	3 56
Apr. 11	12 16 57	3 56	Oct. 17	23 52 18	3 56
Apr. 21	11 37 39	3 56	Oct. 27	23 12 59	3 56
May 1	10 58 23	3 55	Nov. 6	22 33 39	3 56
May 11	10 19 09	3 55	Nov. 16	21 54 17	3 56
May 21	9 39 56	3 55	Nov. 26	21 14 52	3 57
May 31	9 00 45	3 55	Dec. 6	20 35 26	3 57
June 10	8 21 35	3 55	Dec. 16	19 55 58	3 57
June 20	7 42 26	3 55	Dec. 26	19 16 30	3 57
June 30	7 03 19	3 55	Jan. 5, 1927	18 37 00	3 57

TABLE 2.—*Mean time interval between upper culmination and elongation*

Latitude	Time interval	Latitude	Time interval	Latitude	Time interval	Latitude	Time interval
°	*h. m.*	°	*h. m.*	°	*h. m.*	°	*h. m.*
10	5 58.2	35	5 56.0	48	5 54.2	58	5 52.1
15	5 57.8	40	5 55.4	50	5 53.8	60	5 51.5
20	5 57.4	42	5 55.1	52	5 53.4	62	5 50.8
25	5 57.0	44	5 54.8	54	5 53.0	64	5 50.1
30	5 56.5	46	5 54.5	56	5 52.6		

Eastern elongation precedes and western elongation follows upper culmination by the time interval given in Table 2. Lower culmination precedes or follows upper culmination by $11^h\ 58.0^m$ It should be noted that there are two upper culminations on one day in October (16th in 1926) and two lower culminations in April (15th in 1926). There are also two western elongations on one day in January and two eastern elongations on one day in July.

(*a*) *To refer the times in Table 1 to other years*—

		m			*m.*
1927	add	1.3	1931	add	3.0
1928, up to Mar. 1	add	2.6	1932, up to Mar. 1	add	4.4
1928, on and after Mar. 1	subtract	1.3	1932, on and after Mar. 1	add	0.5
1929	add	0.1	1933	add	2.1
1930	add	1.6	1934	add	3.7
			1935	add	5.3

(*b*) *To refer to other than the tabular days.*—Subtract from the time for the preceding tabular day the product of the variation per day and the days elapsed, as given below:

Days elapsed	Variation per day			Days elapsed	Variation per day		
	3 m. 57 s.	3 m. 56 s.	3 m. 55 s.		3 m. 57 s.	3 m. 56 s.	3 m. 55 s.
	m. s.	m. s.	m. s.		m. s.	m. s.	m. s.
1	3 57	3 56	3 55	6	23 42	23 36	23 30
2	7 54	7 52	7 50	7	27 39	27 32	27 25
3	11 51	11 48	11 45	8	31 36	31 28	31 20
4	15 48	15 44	15 40	9	35 33	35 24	35 15
5	19 45	19 40	19 35				

(*c*) *To refer to any other than the tabular longitude* (90°).—Add 0.1^m for each 10° east of the ninetieth meridian or subtract 0.1^m for each 10° west of the ninetieth meridian.

(*d*) *To refer to standard time.*—Add to the quantities in Table 1 four minutes for every degree of longitude the place of observation is west of the standard meridian (60°, 75°, 90°, etc.). Subtract when the place is east of the standard meridian.

TABLE 3.—*Azimuth of Polaris at elongation, 1926 to 1935*

Latitude (degrees)	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
10	1 06.5	1 06.2	1 05.9	1 05.6	1 05.3	1 05.0	1 04.7	1 04.4	1 04.1	1 03.8
11	1 06.7	1 06.4	1 06.1	1 05.8	1 05.5	1 05.2	1 04.9	1 04.6	1 04.3	1 04.0
12	1 07.0	1 06.7	1 06.4	1 06.0	1 05.7	1 05.4	1 05.1	1 04.8	1 04.5	1 04.2
13	1 07.2	1 06.9	1 06.6	1 06.3	1 06.0	1 05.7	1 05.3	1 05.0	1 04.7	1 04.4
14	1 07.5	1 07.2	1 06.9	1 06.6	1 06.3	1 05.9	1 05.6	1 05.3	1 05.0	1 04.7
15	1 07.8	1 07.5	1 07.2	1 06.9	1 06.6	1 06.2	1 05.9	1 05.6	1 05.3	1 05.0
16	1 08.1	1 07.8	1 07.5	1 07.2	1 06.9	1 06.6	1 06.2	1 05.9	1 05.6	1 05.3
17	1 08.5	1 08.2	1 07.9	1 07.5	1 07.2	1 06.9	1 06.6	1 06.3	1 06.0	1 05.7
18	1 08.9	1 08.6	1 08.2	1 07.9	1 07.6	1 07.3	1 07.0	1 06.6	1 06.3	1 06.0
19	1 09.3	1 09.0	1 08.6	1 08.3	1 08.0	1 07.7	1 07.3	1 07.0	1 06.7	1 06.4
20	1 09.7	1 09.4	1 09.1	1 08.7	1 08.4	1 08.1	1 07.8	1 07.4	1 07.1	1 06.8
21	1 10.2	1 09.8	1 09.5	1 09.2	1 08.9	1 08.5	1 08.2	1 07.9	1 07.6	1 07.2
22	1 10.7	1 10.3	1 10.0	1 09.7	1 09.3	1 09.0	1 08.7	1 08.4	1 08.0	1 07.7
23	1 11.2	1 10.8	1 10.5	1 10.2	1 09.8	1 09.5	1 09.2	1 08.9	1 08.5	1 08.2
24	1 11.7	1 11.4	1 11.0	1 10.7	1 10.4	1 10.0	1 09.7	1 09.4	1 09.0	1 08.7
25	1 12.3	1 11.9	1 11.6	1 11.3	1 10.9	1 10.6	1 10.3	1 09.9	1 09.6	1 09.3
26	1 12.9	1 12.5	1 12.2	1 11.9	1 11.5	1 11.2	1 10.9	1 10.5	1 10.2	1 09.9
27	1 13.5	1 13.2	1 12.8	1 12.5	1 12.2	1 11.8	1 11.5	1 11.1	1 10.8	1 10.5
28	1 14.2	1 13.8	1 13.5	1 13.2	1 12.8	1 12.5	1 12.1	1 11.8	1 11.4	1 11.1
29	1 14.9	1 14.6	1 14.2	1 13.9	1 13.5	1 13.2	1 12.8	1 12.5	1 12.1	1 11.8
30	1 15.6	1 15.3	1 14.9	1 14.6	1 14.2	1 13.9	1 13.5	1 13.2	1 12.8	1 12.5
31	1 16.4	1 16.1	1 15.7	1 15.4	1 15.0	1 14.6	1 14.3	1 13.9	1 13.6	1 13.2
32	1 17.2	1 16.9	1 16.5	1 16.2	1 15.8	1 15.4	1 15.1	1 14.7	1 14.4	1 14.0
33	1 18.1	1 17.7	1 17.4	1 17.0	1 16.7	1 16.3	1 15.9	1 15.6	1 15.2	1 14.9
34	1 19.0	1 18.6	1 18.3	1 17.9	1 17.5	1 17.2	1 16.8	1 16.4	1 16.1	1 15.7
35	1 20.0	1 19.6	1 19.2	1 18.9	1 18.5	1 18.1	1 17.7	1 17.4	1 17.0	1 16.6
36	1 21.0	1 20.6	1 20.2	1 19.8	1 19.5	1 19.1	1 18.7	1 18.3	1 18.0	1 17.6
37	1 22.0	1 21.6	1 21.3	1 20.9	1 20.5	1 20.1	1 19.7	1 19.4	1 19.0	1 18.6
38	1 23.1	1 22.7	1 22.4	1 22.0	1 21.6	1 21.2	1 20.8	1 20.4	1 20.0	1 19.7
39	1 24.3	1 23.9	1 23.5	1 23.1	1 22.7	1 22.3	1 21.9	1 21.6	1 21.2	1 20.8
40	1 25.5	1 25.1	1 24.7	1 24.3	1 23.9	1 23.5	1 23.1	1 22.7	1 22.3	1 22.0
41	1 26.8	1 26.4	1 26.0	1 25.6	1 25.2	1 24.8	1 24.4	1 24.0	1 23.6	1 23.2
42	1 28.2	1 27.7	1 27.3	1 26.9	1 26.5	1 26.1	1 25.7	1 25.3	1 24.9	1 24.5
43	1 29.6	1 29.2	1 28.7	1 28.3	1 27.9	1 27.5	1 27.1	1 26.7	1 26.3	1 25.8
44	1 31.1	1 30.6	1 30.2	1 29.8	1 29.4	1 29.0	1 28.5	1 28.1	1 27.7	1 27.3
45	1 32.6	1 32.2	1 31.8	1 31.4	1 30.9	1 30.5	1 30.1	1 29.6	1 29.2	1 28.8
46	1 34.3	1 33.9	1 33.4	1 33.0	1 32.5	1 32.1	1 31.7	1 31.2	1 30.8	1 30.4
47	1 36.1	1 35.6	1 35.2	1 34.7	1 34.3	1 33.8	1 33.4	1 32.9	1 32.5	1 32.0
48	1 37.9	1 37.4	1 37.0	1 36.5	1 36.1	1 35.6	1 35.2	1 34.7	1 34.3	1 33.8
49	1 39.9	1 39.4	1 38.9	1 38.5	1 38.0	1 37.5	1 37.1	1 36.6	1 36.1	1 35.7
50	1 41.9	1 41.4	1 41.0	1 40.5	1 40.0	1 39.5	1 39.1	1 38.6	1 38.1	1 37.7

Table 3 was computed using the mean declination of Polaris for the beginning of each year. A more accurate result will be obtained by applying to the tabular values the following corrections, which depend on the difference between the mean and apparent place of the star.

Month	Correction	Month	Correction	Month	Correction
	′		′		′
January	−0.3	May	+0.2	September	0.0
February	−.3	June	+.3	October	−.2
March	−.2	July	+.3	November	−.5
April	.0	August	+.2	December	−.7

TABLE 4.—*Natural tangent of angles from 1° 00′ to 1° 50′*

Angle	Tangent	Angle	Tangent	Angle	Tangent	Angle	Tangent	Angle	Tangent
° ′		° ′		° ′		° ′		° ′	
1 00	0.01746	1 10	0.02036	1 20	0.02328	1 30	0.02619	1 40	0.02910
1 01	.01775	1 11	.02066	1 21	.02357	1 31	.02648	1 41	.02939
1 02	.01804	1 12	.02095	1 22	.02386	1 32	.02677	1 42	.02968
1 03	.01833	1 13	.02124	1 23	.02415	1 33	.02706	1 43	.02997
1 04	.01862	1 14	.02153	1 24	.02444	1 34	.02735	1 44	.03026
1 05	.01891	1 15	.02182	1 25	.02473	1 35	.02764	1 45	.03055
1 06	.01920	1 16	.02211	1 26	.02502	1 36	.02793	1 46	.03084
1 07	.01949	1 17	.02240	1 27	.02531	1 37	.02822	1 47	.03114
1 08	.01978	1 18	.02269	1 28	.02560	1 38	.02851	1 48	.03143
1 09	.02007	1 19	.02298	1 29	.02589	1 39	.02881	1 49	.03172
1 10	.02036	1 20	.02328	1 30	.02619	1 40	.02910	1 50	.03201

II. NOTING WHEN POLARIS AND ANOTHER STAR ARE IN THE SAME VERTICAL PLANE

For places north of latitude 35° the true meridian may be determined by taking advantage of the fact that two bright stars in the northern heavens cross the meridian on opposite sides of the pole only a few minutes before Polaris. These stars are the ones known as Zeta (ζ) Ursæ Majoris or Mizar and Delta (δ) Cassiopeiæ. Their positions in the constellations are shown in the accompanying diagram.

Select that one of the two stars which at the time of the year when observations are to be made passes the meridian below the pole. When the star passes the meridian above the pole it is too near the zenith to be used. Delta Cassiopeiæ is on the meridian below the pole at midnight about April 10 and is therefore the proper star to use at that date and for three months before and after. For the other six months of the year Zeta Ursæ Majoris will be the proper star to use. In the long days of June and July the lower culmination of both stars occurs during daylight, so that the method can not be used.

Using the apparatus described under I, Observations of Polaris at Elongation, keep the peep sight in line with the plumb line and Polaris until the selected star also appears upon the plumb line. Carefully note the time when this occurs. Then, by moving the peep sight, continue to preserve its alignment with Polaris and the plumb line (paying no further attention to the other star). At the expiration

of 14 minutes (in 1926) Polaris will be on the meridian and the peep sight and plumb line will then define a true north and south line, which may be permanently marked for future use. *For each year subsequent to 1926 the interval increases approximately one-third of a minute.*

As the pole distance of Delta Cassiopeiæ is 35° and that of Zeta Ursæ Majoris is 40°, this method can not be used for the southern part of the United States where the stars are below the horizon at lower culmination.

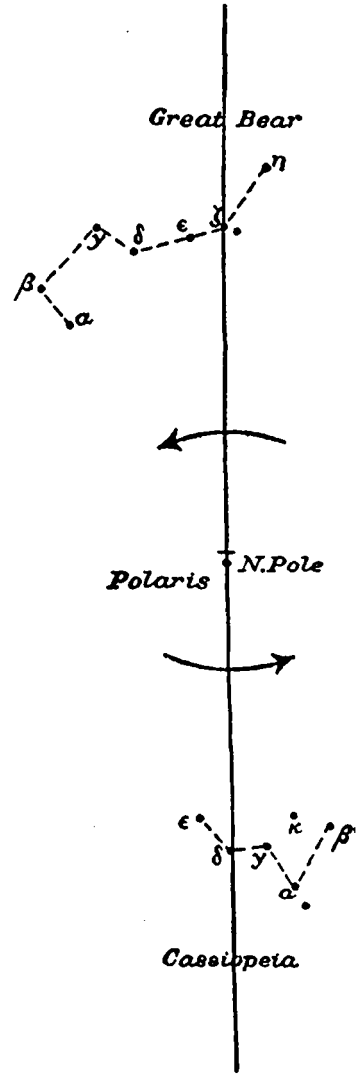

Diagram showing the principal stars of the constellations Cassiopeia and Great Bear (Ursa Major) with Delta Cassiopeiae, Zeta Ursæ Majoris, and Polaris on the meridian (represented by the straight line), Polaris being at lower culmination.

III. OBSERVATIONS OF POLARIS AT ELONGATION

With a surveyor's transit the true meridian may be determined by observing Polaris at elongation as follows:

Select a station for observing which affords a good view of the northern sky and with the ground clear for at least 100 yards to the north.

If the station is to be used for determining the magnetic declination, care should be taken to have it well removed from electric car lines, buildings, and other possible sources of disturbance. If a meridian line is to be established for future use, the ends should be placed so that they may be protected from disturbance.

Mark the observing station in a suitable manner; for example, by a stone post with a drill hole in the top, set firmly in the ground.

About 30 minutes before the time of elongation of Polaris, derived from Tables 1 and 2, set up the transit with its vertical axis exactly over the station mark and carefully level the instrument. It is essential that the transverse axis of the telescope be horizontal. This should be tested in the daytime by pointing on the vertical edge of a house and noting whether the vertical cross wire continues to coincide with the edge of the house as the telescope is turned in altitude.

Illuminate the cross wires by the light from a bull's-eye lantern or a pocket flashlight directed obliquely into the object end of the telescope by an assistant.

Point the telescope at the star and clamp the horizontal circle. Keep the star covered by the vertical cross wire by means of the

tangent screw of the vernier plate until a point is reached where it appears to move up or down along the wire without moving away from it, thus indicating that elongation has been reached.

Depress the telescope to the horizontal position; about 100 yards north of the instrument drive a stake and mark a point on its top exactly coincident with the vertical wire of the telescope. This will require a second assistant and light. Turn the vernier plate 180° and again set the vertical wire on the star, clamp the horizontal circle, depress the telescope, and mark another point on the stake. The point midway between the two marks, with the point under the instrument, will define on the ground the vertical plane through Polaris at its eastern or western elongation, as the case may be.

Near elongation the azimuth of the star changes very slowly, not more than 0′.1 in the 10 minutes before or after elongation in the United States, so that there is plenty of time to make the second pointing after reversal, if there is no unnecessary delay.

By daylight lay off the proper angle taken from Table 3, to the east for western elongation and to the west for eastern elongation and place a suitable marker to mark the north end of a meridian line of which the station marker will be the south end. The angle should be measured both before and after reversal, as in the case of the star.

IV. OBSERVATIONS OF POLARIS AT ANY HOUR

The methods thus far described have the great advantage that an accurate knowledge of the time is not required, but they are not always convenient, as the elongation or culmination of Polaris does not always come at a convenient time for observing, and the star may happen to be obscured just at that time.

The true meridian may be determined to the nearest minute of arc by observations of Polaris at any hour when the star is visible, provided the local mean time is known within 1 minute, as in the extreme case when Polaris is at culmination its azimuth changes 1 minute of arc in about 2 minutes in latitude 50° and 1 minute of arc in about 3 minutes in latitude 20°. The standard time can usually be obtained at a telegraph office or directly by radio from the signals sent out from observatories. From this the local mean time may be derived by subtracting 4 minutes of time for every degree of longitude west of the standard meridian or adding 4 minutes for every degree east of the standard meridian.

The selection and marking of the observing station and the adjustment of the theodolite will be done as in the case of observations of Polaris at elongation. As the observations are to be made when the azimuth of the star is changing, it will be preferable to provide an azimuth mark, such as a light showing through a slit in a box, and make a series of measures of the angle between the mark and the star. The light used to illuminate the cross wires of the telescope may be used also in reading the horizontal circle.

Begin by pointing on the mark and reading the horizontal circle. Point on the star, record the exact time and the reading of the circle. Turn the vernier plate 180° in azimuth and again point on the star, recording the time and circle reading as before. Finally, point on the mark again and read the circle. The number of pointings in a set may be increased or additional sets may be taken to secure greater

accuracy. The azimuth of Polaris for the local mean time of observation will be derived from Table 5 in the manner explained below.

The following example explains the use of the table and the derivation of the hour angle of Polaris:

Position, latitude 36° 20′ N., longitude 80° 07′ .5 or 5^h 20^m 30^s W. of Greenwich.

	h.	m.	s.
Time of observation, July 10, 1927, standard (seventy-fifth meridian) mean time	20	52	40
Reduction to local time	−	20	30
Local mean time	20	32	10
Reduction to sidereal time (Table III, Amer. Ephem.)	+	3	22
Sidereal time, midnight, Greenwich, July 10, 1927	19	07	41
Correction for longitude 5^h 20^m 30^s (Table III, Amer. Ephem.)	+	0	53
Local sidereal time	15	44	06
Apparent right ascension of Polaris, July 10, 1927	1	35	12
Hour angle after upper culmination	14	08	54

	°	′	″
Declination for which Table 5 applies	88	54	55
Apparent declination, July 10, 1927	88	54	31
Decrease in declination			24

	°	′
Azimuth from Table 5 (interpolated)	0	42.6
Correction for 24″ decrease in declination, Table 6	+	0.3
Computed azimuth	0	42.9 east of north.

It is to be remembered that Polaris is east of the meridian for 12 hours before and west of the meridian for 12 hours after upper culmination.

Without the American Ephemeris the table may be conveniently used for obtaining the true meridian, in connection with Table 1 giving the approximate mean times of culmination of Polaris.

	h.	m.	s.	
Time of observation, July 10, 1927, standard (seventy-fifth meridian) mean time	8	52	40	p. m.
Reduction to local mean time	−	20	30	
Local mean time	8	32	10	p. m.
Local mean time of upper culmination of Polaris (Table 1 and (*a*) and (*b*))	6	25	35	a. m.
Mean time of observation after upper culmination	14	06	35	
Reduction to sidereal time	+	2	19	
Hour angle after upper culmination	14	08	54	

	°	′	″
Declination for which Table 5 applies	88	54	55
Declination July 15, 1927	88	54	32
Decrease in declination			23

	°	′
Azimuth from Table 5	0	42.6
Correction for 23″ decrease in declination, Table 6	+	0.3
Computed azimuth	0	42.9 east of north.

Tables are generally given in books on surveying for reducing mean solar to sidereal time, but for this computation it is near enough to consider the correction 10^s an hour, as the stars gain very nearly 4 minutes on the sun each day.

TABLE 5.—*Azimuth of Polaris at all hour angles*

[Computed for declination 88° 54′ 55″. For hour angles 0ʰ to 12ʰ the star is west of north, and from 12ʰ to 24ʰ it is east of north]

Lat. / H. A.	10°	15°	20°	25°	30°	32°	34°	36°	Lat. / H. A.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	h. m.
0 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	24 00
0 10	0 02.9	0 03.0	0 03.0	0 03.2	0 03.3	0 03.4	0 03.5	0 03.6	23 50
0 20	0 05.8	0 05.9	0 06.1	0 06.3	0 06.6	0 06.8	0 06.9	0 07.1	23 40
0 30	0 08.7	0 08.8	0 09.1	0 09.5	0 09.9	0 10.1	0 10.4	0 10.7	23 30
0 40	0 11.5	0 11.8	0 12.1	0 12.6	0 13.2	0 13.5	0 13.8	0 14.2	23 20
0 50	0 14.4	0 14.7	0 15.1	0 15.7	0 16.4	0 16.8	0 17.2	0 17.7	23 10
1 00	0 17.2	0 17.5	0 18.1	0 18.8	0 19.7	0 20.1	0 20.6	0 21.1	23 00
1 10	0 19.9	0 20.4	0 21.0	0 21.8	0 22.9	0 23.3	0 23.9	0 24.5	22 50
1 20	0 22.7	0 23.2	0 23.9	0 24.8	0 26.0	0 26.5	0 27.2	0 27.9	22 40
1 30	0 25.4	0 25.9	0 26.7	0 27.7	0 29.1	0 29.7	0 30.4	0 31.2	22 30
1 40	0 28.0	0 28.6	0 29.5	0 30.6	0 32.1	0 32.8	0 33.6	0 34.4	22 20
1 50	0 30.6	0 31.3	0 32.2	0 33.4	0 35.1	0 35.8	0 36.7	0 37.6	22 10
2 00	0 33.1	0 33.8	0 34.8	0 36.2	0 38.0	0 38.8	0 39.7	0 40.7	22 00
2 10	0 35.6	0 36.4	0 37.4	0 38.9	0 40.8	0 41.7	0 42.6	0 43.7	21 50
2 20	0 38.0	0 38.8	0 39.9	0 41.5	0 43.5	0 44.5	0 45.5	0 46.7	21 40
2 30	0 40.3	0 41.2	0 42.4	0 44.0	0 46.2	0 47.2	0 48.3	0 49.5	21 30
2 40	0 42.6	0 43.5	0 44.8	0 46.5	0 48.7	0 49.8	0 51.0	0 52.3	21 20
2 50	0 44.8	0 45.7	0 47.0	0 48.8	0 51.2	0 52.3	0 53.5	0 54.9	21 10
3 00	0 46.9	0 47.8	0 49.2	0 51.1	0 53.6	0 54.7	0 56.0	0 57.4	21 00
3 10	0 48.9	0 49.8	0 51.3	0 53.2	0 55.8	0 57.0	0 58.4	0 59.9	20 50
3 20	0 50.8	0 51.8	0 53.3	0 55.3	0 58.0	0 59.2	1 00.6	1 02.2	20 40
3 30	0 52.5	0 53.6	0 55.2	0 57.3	1 00.0	1 01.3	1 02.8	1 04.4	20 30
3 40	0 54.2	0 55.4	0 57.0	0 59.1	1 02.0	1 03.3	1 04.8	1 06.4	20 20
3 50	0 55.8	0 57.0	0 58.6	1 00.9	1 03.8	1 05.1	1 06.7	1 08.3	20 10
4 00	0 57.3	0 58.5	1 00.2	1 02.5	1 05.4	1 06.9	1 08.4	1 10.1	20 00
4 10	0 58.7	0 59.9	1 01.6	1 03.9	1 07.0	1 08.5	1 10.0	1 11.8	19 50
4 20	1 00.0	1 01.2	1 03.0	1 05.3	1 08.4	1 09.9	1 11.5	1 13.3	19 40
4 30	1 01.1	1 02.4	1 04.2	1 06.5	1 09.7	1 11.2	1 12.9	1 14.7	19 30
4 40	1 02.2	1 03.4	1 05.2	1 07.7	1 10.9	1 12.4	1 14.1	1 15.9	19 20
4 50	1 03.1	1 04.4	1 06.2	1 08.7	1 11.9	1 13.4	1 15.2	1 17.0	19 10
5 00	1 03.9	1 05.2	1 07.0	1 09.5	1 12.8	1 14.3	1 16.1	1 18.0	19 00
5 10	1 04.6	1 05.8	1 07.7	1 10.2	1 13.5	1 15.1	1 16.9	1 18.8	18 50
5 20	1 05.1	1 06.4	1 08.3	1 10.8	1 14.1	1 15.7	1 17.5	1 19.4	18 40
5 30	1 05.5	1 06.8	1 08.7	1 11.3	1 14.6	1 16.2	1 18.0	1 19.9	18 30
5 40	1 05.8	1 07.1	1 09.0	1 11.6	1 14.9	1 16.5	1 18.3	1 20.2	18 20
5 50	1 06.0	1 07.3	1 09.2	1 11.8	1 15.1	1 16.7	1 18.5	1 20.4	18 10
6 00	1 06.1	1 07.4	1 09.3	1 11.8	1 15.1	1 16.7	1 18.5	1 20.4	18 00
6 10	1 06.0	1 07.3	1 09.2	1 11.7	1 15.0	1 16.6	1 18.4	1 20.3	17 50
6 20	1 05.8	1 07.1	1 09.0	1 11.5	1 14.8	1 16.4	1 18.1	1 20.0	17 40
6 30	1 05.5	1 06.8	1 08.6	1 11.1	1 14.4	1 16.0	1 17.7	1 19.6	17 30
6 40	1 05.0	1 06.3	1 08.1	1 10.6	1 13.9	1 15.4	1 17.1	1 19.0	17 20
6 50	1 04.5	1 05.7	1 07.5	1 10.0	1 13.2	1 14.7	1 16.4	1 18.3	17 10
7 00	1 03.8	1 05.0	1 06.8	1 09.2	1 12.4	1 13.9	1 15.6	1 17.4	17 00
7 10	1 03.0	1 04.2	1 05.9	1 08.3	1 11.4	1 12.9	1 14.6	1 16.4	16 50
7 20	1 02.0	1 03.2	1 04.9	1 07.3	1 10.3	1 11.8	1 13.4	1 15.2	16 40
7 30	1 01.0	1 02.1	1 03.8	1 06.1	1 09.1	1 10.6	1 12.2	1 13.9	16 30
7 40	0 59.8	1 00.9	1 02.6	1 04.8	1 07.8	1 09.2	1 10.8	1 12.5	16 20
7 50	0 58.5	0 59.6	1 01.2	1 03.4	1 06.3	1 07.7	1 09.2	1 10.9	16 10
8 00	0 57.1	0 58.2	0 59.8	1 01.9	1 04.7	1 06.1	1 07.5	1 09.2	16 00
8 10	0 55.6	0 56.7	0 58.2	1 00.3	1 03.0	1 04.3	1 05.7	1 07.4	15 50
8 20	0 54.0	0 55.0	0 56.5	0 58.5	1 01.2	1 02.4	1 03.8	1 05.4	15 40
8 30	0 52.3	0 53.3	0 54.7	0 56.6	0 59.2	1 00.4	1 01.8	1 03.3	15 30
8 40	0 50.5	0 51.4	0 52.8	0 54.7	0 57.2	0 58.3	0 59.6	1 01.1	15 20
8 50	0 48.6	0 49.5	0 50.8	0 52.6	0 55.0	0 56.1	0 57.4	0 58.8	15 10
9 00	0 46.6	0 47.5	0 48.7	0 50.5	0 52.7	0 53.8	0 55.0	0 56.3	15 00
9 10	0 44.5	0 45.4	0 46.6	0 48.2	0 50.4	0 51.4	0 52.5	0 53.8	14 50
9 20	0 42.4	0 43.2	0 44.3	0 45.8	0 47.9	0 48.9	0 50.0	0 51.2	14 40
9 30	0 40.1	0 40.9	0 41.9	0 43.4	0 45.4	0 46.3	0 47.3	0 48.4	14 30
9 40	0 37.8	0 38.5	0 39.5	0 40.9	0 42.7	0 43.6	0 44.6	0 45.6	14 20
9 50	0 35.4	0 36.1	0 37.0	0 38.3	0 40.0	0 40.8	0 41.7	0 42.7	14 10
10 00	0 32.9	0 33.6	0 34.4	0 35.6	0 37.2	0 38.0	0 38.8	0 39.7	14 00
10 10	0 30.4	0 31.0	0 31.8	0 32.9	0 34.4	0 35.1	0 35.8	0 36.7	13 50
10 20	0 27.8	0 28.4	0 29.1	0 30.1	0 31.5	0 32.1	0 32.8	0 33.6	13 40
10 30	0 25.2	0 25.7	0 26.3	0 27.3	0 28.5	0 29.1	0 29.7	0 30.4	13 30
10 40	0 22.5	0 22.9	0 23.5	0 24.4	0 25.4	0 26.0	0 26.5	0 27.2	13 20
10 50	0 19.8	0 20.2	0 20.7	0 21.4	0 22.4	0 22.8	0 23.3	0 23.9	13 10
11 00	0 17.1	0 17.4	0 17.8	0 18.4	0 19.3	0 19.6	0 20.1	0 20.6	13 00
11 10	0 14.3	0 14.5	0 14.9	0 15.4	0 16.1	0 16.4	0 16.8	0 17.2	12 50
11 20	0 11.4	0 11.6	0 11.9	0 12.4	0 12.9	0 13.2	0 13.5	0 13.8	12 40
11 30	0 08.6	0 08.7	0 09.0	0 09.3	0 09.7	0 09.9	0 10.1	0 10.4	12 30
11 40	0 05.7	0 05.8	0 06.0	0 06.2	0 06.5	0 06.6	0 06.8	0 06.9	12 20
11 50	0 02.9	0 02.9	0 03.0	0 03.1	0 03.2	0 03.3	0 03.4	0 03.5	12 10
12 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	12 00

TABLE 5.—*Azimuth of Polaris at all hour angles*—Continued

H. A. \ Lat.	36°	38°	40°	42°	44°	46°	48°	50°	Lat. / H. A.
h. m.	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	h. m.
0 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	24 00
0 10	0 03.6	0 03.7	0 03.8	0 03.9	0 04.0	0 04.2	0 04.3	0 04.5	23 50
0 20	0 07.1	0 07.3	0 07.5	0 07.8	0 08.0	0 08.3	0 08.7	0 09.0	23 40
0 30	0 10.7	0 10.9	0 11.3	0 11.6	0 12.0	0 12.5	0 13.0	0 13.5	23 30
0 40	0 14.2	0 14.6	0 15.0	0 15.5	0 16.0	0 16.6	0 17.3	0 18.0	23 20
0 50	0 17.7	0 18.2	0 18.7	0 19.3	0 19.9	0 20.7	0 21.5	0 22.4	23 10
1 00	0 21.1	0 21.7	0 22.3	0 23.1	0 23.8	0 24.7	0 25.7	0 26.8	23 00
1 10	0 24.5	0 25.2	0 25.9	0 26.8	0 27.7	0 28.7	0 29.8	0 31.1	22 50
1 20	0 27.9	0 28.7	0 29.5	0 30.5	0 31.5	0 32.6	0 33.9	0 35.4	22 40
1 30	0 31.2	0 32.1	0 33.0	0 34.1	0 35.2	0 36.5	0 38.0	0 39.6	22 30
1 40	0 34.4	0 35.4	0 36.4	0 37.6	0 38.9	0 40.3	0 41.9	0 43.7	22 20
1 50	0 37.6	0 38.6	0 39.8	0 41.1	0 42.5	0 44.0	0 45.8	0 47.7	22 10
2 00	0 40.7	0 41.8	0 43.1	0 44.5	0 46.0	0 47.7	0 49.5	0 51.6	22 00
2 10	0 43.7	0 44.9	0 46.3	0 47.8	0 49.4	0 51.2	0 53.2	0 55.5	21 50
2 20	0 46.7	0 48.0	0 49.4	0 51.0	0 52.7	0 54.6	0 56.8	0 59.2	21 40
2 30	0 49.5	0 50.9	0 52.4	0 54.0	0 55.9	0 57.9	1 00.2	1 02.8	21 30
2 40	0 52.3	0 53.7	0 55.3	0 57.0	0 59.0	1 01.1	1 03.5	1 06.2	21 20
2 50	0 54.9	0 56.4	0 58.1	0 59.9	1 02.0	1 04.2	1 06.7	1 09.5	21 10
3 00	0 57.4	0 59.0	1 00.8	1 02.7	1 04.8	1 07.2	1 09.8	1 12.7	21 00
3 10	0 59.9	1 01.5	1 03.3	1 05.3	1 07.5	1 10.0	1 12.7	1 15.8	20 50
3 20	1 02.2	1 03.9	1 05.7	1 07.8	1 10.1	1 12.7	1 15.5	1 18.7	20 40
3 30	1 04.4	1 06.1	1 08.1	1 10.2	1 12.6	1 15.2	1 18.2	1 21.4	20 30
3 40	1 06.4	1 08.2	1 10.2	1 12.4	1 14.9	1 17.6	1 20.7	1 24.0	20 20
3 50	1 08.3	1 10.2	1 12.3	1 14.5	1 17.1	1 19.9	1 23.0	1 26.4	20 10
4 00	1 10.1	1 12.1	1 14.2	1 16.5	1 19.1	1 22.0	1 25.1	1 28.7	20 00
4 10	1 11.8	1 13.8	1 15.9	1 18.3	1 20.9	1 23.9	1 27.1	1 30.7	19 50
4 20	1 13.3	1 15.3	1 17.5	1 19.9	1 22.6	1 25.6	1 28.9	1 32.6	19 40
4 30	1 14.7	1 16.7	1 19.0	1 21.4	1 24.2	1 27.2	1 30.6	1 34.4	19 30
4 40	1 15.9	1 18.0	1 20.3	1 22.8	1 25.5	1 28.6	1 32.1	1 35.9	19 20
4 50	1 17.0	1 19.1	1 21.4	1 24.0	1 26.7	1 29.9	1 33.3	1 37.2	19 10
5 00	1 18.0	1 20.1	1 22.4	1 25.0	1 27.8	1 31.0	1 34.4	1 38.4	19 00
5 10	1 18.8	1 20.9	1 23.2	1 25.8	1 28.7	1 31.9	1 35.4	1 39.3	18 50
5 20	1 19.4	1 21.5	1 23.9	1 26.5	1 29.4	1 32.6	1 36.1	1 40.1	18 40
5 30	1 19.9	1 22.0	1 24.4	1 27.0	1 29.9	1 33.1	1 36.7	1 40.7	18 30
5 40	1 20.2	1 22.4	1 24.7	1 27.4	1 30.3	1 33.5	1 37.1	1 41.0	18 20
5 50	1 20.4	1 22.6	1 24.9	1 27.6	1 30.5	1 33.7	1 37.2	1 41.2	18 10
6 00	1 20.4	1 22.6	1 24.9	1 27.6	1 30.5	1 33.7	1 37.2	1 41.2	18 00
6 10	1 20.3	1 22.5	1 24.8	1 27.4	1 30.3	1 33.5	1 37.1	1 41.0	17 50
6 20	1 20.0	1 22.2	1 24.5	1 27.1	1 30.0	1 33.2	1 36.7	1 40.6	17 40
6 30	1 19.6	1 21.7	1 24.0	1 26.6	1 29.5	1 32.6	1 36.1	1 40.1	17 30
6 40	1 19.0	1 21.1	1 23.4	1 26.0	1 28.8	1 31.9	1 35.4	1 39.3	17 20
6 50	1 18.3	1 20.4	1 22.6	1 25.2	1 28.0	1 31.1	1 34.5	1 38.3	17 10
7 00	1 17.4	1 19.5	1 21.7	1 24.2	1 27.0	1 30.0	1 33.4	1 37.2	17 00
7 10	1 16.4	1 18.4	1 20.6	1 23.1	1 25.8	1 28.8	1 32.2	1 35.9	16 50
7 20	1 15.2	1 17.2	1 19.4	1 21.8	1 24.5	1 27.4	1 30.7	1 34.4	16 40
7 30	1 13.9	1 15.9	1 18.0	1 20.4	1 23.0	1 25.9	1 29.1	1 32.7	16 30
7 40	1 12.5	1 14.4	1 16.5	1 18.8	1 21.4	1 24.2	1 27.4	1 30.9	16 20
7 50	1 10.9	1 12.8	1 14.8	1 17.1	1 19.6	1 22.3	1 25.4	1 28.9	16 10
8 00	1 09.2	1 11.0	1 13.0	1 15.2	1 17.7	1 20.3	1 23.3	1 26.7	16 00
8 10	1 07.4	1 09.1	1 11.0	1 13.2	1 15.6	1 18.2	1 21.1	1 24.4	15 50
8 20	1 05.4	1 07.1	1 09.0	1 11.1	1 13.4	1 15.9	1 18.7	1 21.9	15 40
8 30	1 03.3	1 04.9	1 06.8	1 08.8	1 11.0	1 13.5	1 16.2	1 19.2	15 30
8 40	1 01.1	1 02.7	1 04.4	1 06.4	1 08.5	1 10.9	1 13.5	1 16.4	15 20
8 50	0 58.8	1 00.3	1 02.0	1 03.8	1 05.9	1 08.2	1 10.7	1 13.5	15 10
9 00	0 56.3	0 57.8	0 59.4	1 01.2	1 03.2	1 05.4	1 07.8	1 10.5	15 00
9 10	0 53.8	0 55.2	0 56.7	0 58.4	1 00.3	1 02.4	1 04.7	1 07.3	14 50
9 20	0 51.2	0 52.5	0 54.0	0 55.6	0 57.4	0 59.3	1 01.5	1 04.0	14 40
9 30	0 48.4	0 49.7	0 51.1	0 52.6	0 54.3	0 56.2	0 58.2	1 00.6	14 30
9 40	0 45.6	0 46.8	0 48.1	0 49.5	0 51.1	0 52.9	0 54.8	0 57.0	14 20
9 50	0 42.7	0 43.8	0 45.1	0 46.4	0 47.9	0 49.5	0 51.4	0 53.4	14 10
10 00	0 39.7	0 40.8	0 41.9	0 43.2	0 44.5	0 46.1	0 47.8	0 49.7	14 00
10 10	0 36.7	0 37.6	0 38.7	0 39.9	0 41.1	0 42.5	0 44.1	0 45.8	13 50
10 20	0 33.6	0 34.4	0 35.4	0 36.5	0 37.6	0 38.9	0 40.3	0 41.9	13 40
10 30	0 30.4	0 31.2	0 32.0	0 33.0	0 34.0	0 35.2	0 36.5	0 38.0	13 30
10 40	0 27.2	0 27.9	0 28.6	0 29.5	0 30.4	0 31.5	0 32.6	0 33.9	13 20
10 50	0 23.9	0 24.5	0 25.2	0 25.9	0 26.7	0 27.7	0 28.7	0 29.8	13 10
11 00	0 20.6	0 21.1	0 21.7	0 22.3	0 23.0	0 23.8	0 24.7	0 25.6	13 00
11 10	0 17.2	0 17.6	0 18.1	0 18.7	0 19.2	0 19.9	0 20.6	0 21.4	12 50
11 20	0 13.8	0 14.1	0 14.5	0 15.0	0 15.4	0 16.0	0 16.5	0 17.2	12 40
11 30	0 10.4	0 10.6	0 10.9	0 11.2	0 11.6	0 12.0	0 12.4	0 12.9	12 30
11 40	0 06.9	0 07.1	0 07.3	0 07.5	0 07.7	0 08.0	0 08.3	0 08.6	12 20
11 50	0 03.5	0 03.6	0 03.7	0 03.8	0 03.9	0 04.0	0 04.2	0 04.3	12 10
12 00	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	0 00.0	12 00

The above table is taken from the American Ephemeris for 1927 and was computed for a declination of Polaris of 88° 54′ 55″. This is very nearly a mean value for the year, the declination varying through the year as follows:

	°	′	″		°	′	″
January 15	88	55	02	July 15	88	54	32
February 15		55	01	August 15		54	36
March 15		54	55	September 15		54	45
April 15		54	45	October 15		54	56
May 15		54	37	November 15		55	08
June 15		54	32	December 15		55	17

The approximate declination for succeeding years may be found by allowing an annual increase of 18″.

For finding the azimuth for any other declination than 88° 54′ 55″ the correction given in Table 6 should be applied to the value taken from Table 5. The correction is very nearly proportional to the azimuth and amounts to a decrease of 0.′9 in azimuth for an increase in declination of 1′ for an azimuth of 60′.

TABLE 6.—*Correction to tabular azimuths for other declinations*

Azimuth	0′	20′	40′	60′	80′	100′	120′
Declination: ° ′ ″	′	′	′	′	′	′	′
88 54 55	0.0	0.0	0.0	0.0	0.0	0.0	0.0
55 00	0.0	0.0	−0.1	−0.1	−0.1	−0.1	−0.2
55 05	0.0	0.0	0.1	0.2	0.2	0.3	0.3
55 10	0.0	−0.1	0.2	0.2	0.3	0.4	0.5
55 15	0.0	0.1	0.2	0.3	0.4	0.5	0.6
55 20	0.0	0.1	0.3	0.4	0.5	0.6	0.8
55 25	0.0	0.2	0.3	0.5	0.6	0.8	0.9
55 30	0.0	0.2	0.4	0.5	0.7	0.9	1.1
55 35	0.0	0.2	0.4	0.6	0.8	1.0	1.2
55 40	0.0	0.2	0.5	0.7	0.9	1.1	1.4
55 45	0.0	0.2	0.5	0.8	1.0	1.3	1.5
55 50	0.0	0.3	0.6	0.8	1.1	1.4	1.7
55 55	0.0	−0.3	−0.6	−0.9	−1.2	−1.5	−1.8

V. OBSERVATIONS OF THE SUN

The following method is the one usually employed to determine the true meridian in connection with the magnetic observations of the United States Coast and Geodetic Survey. It involves more computing than those already described but is more convenient in that it is available for use during daylight when the magnetic observations are in progress. In connection with the time signals sent out by telegraph from observatories it furnishes the means also of determining approximately the longitude of the place of observation. It requires a theodolite with graduated vertical circle and a prismatic eyepiece for observing the sun and a well-regulated timepiece. The observations at a place usually consists of four independent sets of observations, two in the morning and two in the afternoon, each set consisting of four pointings on the sun and two pointings on a reference mark, symmetrically arranged as in the following example. For each pointing on the sun the time is noted, and both horizontal and vertical circles are read. Observations are made from two to four hours from noon and at nearly the same altitudes morning and afternoon. The reference mark should be a well-defined object nearly in the horizon and at least 100 yards distant.

The instrument used in the following observations has a glass diaphragm on which are ruled one horizontal and one vertical line. The symbols in the first column indicate the limbs of the sun which were brought tangent to the lines of the diaphragm at the recorded time. The vertical circle is so graduated that it gives altitudes in one position and zenith distances in the other. The readings in the latter case have been subtracted from 90° when filling in the last column. The verniers allow readings on the horizontal and on the vertical circle to be made to minutes, half minutes being estimated.

Observations of sun for azimuth and time

A. M. OBSERVATIONS

[Station, Paducah, Ky.; theodolite of Mag'r No. 19; chronometer, Bond No. 175; date, Tuesday, July 2, 1901; observer, W. W.; temperature, 32°.2]

Sun's limb	V. C.	Chronometer time	Horizontal circle A	Horizontal circle B	Horizontal circle Mean	Vertical circle A	Vertical circle B	Vertical circle Mean
			° ′	′	° ′	° ′	′	° ′
	R	Mark	352 39.5	37.5	352 38.5			
	L		172 37.0	36.0	36.5			
		h. m. s.						
⊙	L	9 35 15	291 41.0	39.5	111 40.2	44 17.0	18.0	44 17.50
⊙	L	9 36 10	291 49.5	48.5	111 49.0	44 29.0	29.0	44 29.00
⊙	R	9 37 40	112 47.0	44.0	112 45.5	44 48.0	49.5	45 11.25
⊙	R	9 38 47	112 57.0	56.0	112 56.5	44 35.0	36.5	45 24.25
Mean		9 36 58.0			112 17.8			44 50.50
						Refr. and par		−0.78
⊙	R	9 39 46	113 07.0	05.5	113 06.2	44 23.0	25.0	45 36.00
⊙	R	9 40 49	113 16.0	18.0	113 17.0	44 10.5	12.0	45 48.75
⊙	L	9 42 20	292 50.0	48.0	112 49.0	45 41.5	42.0	45 41.75
⊙	L	9 43 24	292 60.0	58.5	112 59.2	45 54.0	55.0	45 54.50
Mean		9 41 34.8			113 02.8			45 45.25
						Refr. and par		−.76
	L	Mark	172 38.0	37.5	352 37.8			
	R		352 40.0	38.0	39.0			
					352 37.9			

P. M. OBSERVATIONS

[Station, Paducah, Ky.; theodolite of Mag'r No. 19; chronometer, Bond No. 175; date, Tuesday, July 2, 1901; observer, W. W.; temperature, 36°.8]

	R	Mark	112 20.5	19.0	112 19.8			
	L		202 20.5	19.0	19.8			
		h. m. s.						
⊙	L	4 21 28	226 01.0	01.0	46 01.0	44 13.5	14.0	44 13.75
⊙	L	4 22 26	226 10.0	11.0	46 10.5	44 02.0	03.0	44 02.50
⊙	R	4 23 45	45 32.0	35.0	45 33.5	45 49.0	47.0	44 12.00
⊙	R	4 25 04	45 45.0	48.0	45 46.5	46 03.0	04.5	43 56.25
Mean		4 23 10.8			45 52.9			44 06.12
						Refr. and par		−.79
⊙	R	4 34 24	47 17.0	14.5	47 15.8	47 53.0	56.0	42 05.50
⊙	R	4 35 36	47 25.0	27.0	47 26.0	48 07.5	10.0	41 51.25
⊙	L	4 37 12	228 28.0	26.0	48 27.0	41 07.0	08.0	41 07.50
⊙	L	4 38 19	228 38.0	37.5	48 37.8	40 53.0	53.5	40 53.25
Mean		4 36 22.8			47 56.6			41 29.38
						Refr. and par		−.89
	L	Mark	292 21.0	19.5	112 20.2			
	R		112 21.0	19.5	20.2			
					112 20.0			

The formulas used in computing the azimuth and local mean time from observations of the sun made in the manner just described are the following:

$$\operatorname{ctn}^2 \tfrac{1}{2} A = \frac{\sin (s-\phi) \sin (s-h)}{\cos s \cos (s-p)}$$

$$= \sec s \sec (s-p) \sin (s-h) \sin (s-\phi)$$

$$\tan \tfrac{1}{2} t = \frac{\sin (s-h) \sec (s-p)}{\operatorname{ctn} \tfrac{1}{2} A}$$

A = azimuth of sun, east of south in the morning, west of south in the afternoon.

ϕ = latitude of the place.

h = altitude of the sun corrected for refraction and parallax in altitude.

p = Polar distance of the sun at the time of observation, taken from the American Nautical Almanac.

$s = \tfrac{1}{2} (h+\phi+p)$.

t = The hour angle of the sun or apparent time of observation expressed in arc.

By combining the azimuth of the sun with the angle between the sun and mark the azimuth of the mark may be obtained. This is counted from 0 to 360° from south around by west. When the azimuth of the mark is known, the true meridian may be laid off at any time by turning off the proper angle.

The apparent time of observation must be corrected for equation of time (taken from the Nautical Almanac), in order to obtain the local mean time. The following is a convenient form of computation

Computation of azimuth and longitude

Date	Tuesday, July 2, 1901			
	° ′	° ′	° ′	° ′
h	44 49.7	45 44.5	44 05.3	41 28.5
ϕ	37 03.6	37 03.6	37 03.6	37 03.6
p	66 55.5	66 55.5	66 56.7	66 56.8
$2s$	148 48.8	149 43.6	148 05.6	145 28.9
s	74 24.4	74 51.8	74 02.8	72 44.4
$s-p$	7 28.9	7 56.3	7 06.1	5 47.6
$s-h$	29 34.7	29 07.3	29 57.5	31 15.9
$s-\phi$	37 20.8	37 48.2	36 59.2	35 40.8
log sec s	0.57056	0.58316	0.56090	0.52767
log sec $(s-p)$	0.00371	0.00418	0.00334	0.00222
log sin $(s-h)$	9.69339	9.68723	9.69842	9.71516
log sin $(s-\phi)$	9.78293	9.78743	9.77933	9.76586
log ctn² ½ A	0.05059	0.06200	0.04199	0.01091
log ctn ½ A	0.02530	0.03100	0.02100	0.00546
	° ′	° ′	° ′	° ′
A from South	86 39.8	85 54.8	87 13.8	89 16.8
Circle reads	112 17.8	113 02.8	45 52.9	47 56.6
S. Mer. reads	198 57.6	198 57.6	318 39.1	318 39.8
Mark reads	352 37.9	352 37.9	112 20.0	112 20.0
Az. of Mark	153 40.3	153 40.3	153 40.9	153 40.2
Mean	153 40.4			
log sec $(s-p)$ sin $(s-h)$	9.69710	9.69141	9.70176	9.71738
log tan ½ t	9.67180	9.66041	9.68076	9.71192
t in arc	50° 19′ 00″	49° 10′ 12″	51° 13′ 57″	54° 30′ 32″
	h. m. s.	h. m. s.	h. m. s.	h. m. s.
t	−3 21 16.0	−3 16 40.8	3 24 55.8	3 38 02.1
E	3 40.2	3 40.2	3 43.4	3 43.5
Local M. T.	8 42 24.2	8 46 59.4	3 28 39.2	3 41 45.6
Chron. time	9 36 58.0	9 41 34.8	4 23 10.8	4 36 22.8
Δt on L. M. T.	−54 33.8	−54 35.4	−54 31.6	−54 37.2
Δt on 75 M. T.	−6.8	−6.8	−6.9	−6.9
$\Delta\lambda$	54 27.0	54 28.6	54 24.7	54 30.3
Mean	54 27.6	=13° 36′.9	λ=	88° 36′.9

For computing observations of this type one requires a five-place table of logarithms of trigonometrical functions and the American Nautical Almanac, which gives the sun's apparent declination and the equation of time. For correcting the observed altitude of the sun for parallax and refraction the following table has been prepared, giving the combined correction for different altitudes and temperatures, to be subtracted from the observed altitude:

TABLE 7.—*Correction for parallax and refraction*

Apparent altitude (degrees)	Temperature, centigrade						
	−10°	0°	+10°	+20°	+30°	+40°	+50°
	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″	′ ″
0	36 36	35 15	34 00	32 50	31 45	30 45	29 50
1	26 10	25 12	24 18	23 28	22 42	22 00	21 20
2	19 35	18 51	18 11	17 34	16 59	16 26	15 57
3	15 20	14 46	14 15	13 46	13 18	12 53	12 30
4	12 31	12 03	11 37	11 13	10 50	10 30	10 11
5	10 29	10 05	9 44	9 24	9 05	8 48	8 32
6	8 59	8 38	8 20	8 03	7 47	7 32	7 18
7	7 40	7 31	7 15	7 00	6 46	6 33	6 21
8	6 55	6 39	6 25	6 12	5 59	5 48	5 37
9	6 11	5 57	5 44	5 32	5 21	5 11	5 01
10	5 34	5 22	5 10	4 59	4 49	4 39	4 30
11	5 04	4 52	4 42	4 32	4 23	4 14	4 06
12	4 39	4 29	4 19	4 10	4 01	3 53	3 46
13	4 17	4 07	3 58	3 50	3 42	3 35	3 28
14	3 58	3 49	3 41	3 33	3 26	3 19	3 13
15	3 42	3 34	3 26	3 19	3 12	3 06	3 00
16	3 27	3 19	3 12	3 05	2 59	2 53	2 47
17	3 14	3 07	3 00	2 54	2 48	2 42	2 37
18	3 02	2 55	2 49	2 43	2 37	2 32	2 27
19	2 52	2 45	2 39	2 33	2 28	2 23	2 19
20	2 42	2 36	2 30	2 25	2 20	2 15	2 11
21	2 33	2 27	2 22	2 17	2 12	2 08	2 04
22	2 26	2 20	2 15	2 10	2 06	2 02	1 58
23	2 18	2 13	2 08	2 03	1 59	1 55	1 51
24	2 12	2 07	2 02	1 58	1 54	1 50	1 46
25	2 05	2 00	1 56	1 52	1 48	1 44	1 41
26	2 00	1 55	1 51	1 47	1 43	1 39	1 36
27	1 55	1 50	1 46	1 42	1 38	1 35	1 32
28	1 49	1 45	1 41	1 37	1 34	1 31	1 28
29	1 45	1 41	1 37	1 33	1 30	1 27	1 24
30	1 41	1 37	1 33	1 30	1 26	1 23	1 21
32	1 33	1 29	1 26	1 23	1 19	1 17	1 15
34	1 26	1 22	1 19	1 16	1 13	1 11	1 09
36	1 19	1 16	1 13	1 10	1 08	1 05	1 03
38	1 13	1 10	1 07	1 04	1 02	1 00	0 58
40	1 08	1 05	1 02	1 00	0 58	0 56	0 54
42	1 03	1 00	0 58	0 56	0 54	0 52	0 50
44	0 59	0 56	0 54	0 52	0 50	0 48	0 47
46	0 54	0 52	0 50	0 48	0 46	0 45	0 43
48	0 51	0 49	0 47	0 45	0 44	0 42	0 41
50	0 47	0 45	0 43	0 41	0 40	0 38	0 37
55	0 39	0 37	0 36	0 35	0 33	0 32	0 31
60	0 32	0 30	0 29	0 28	0 27	0 26	0 25
65	0 25	0 24	0 23	0 22	0 21	0 20	0 20
70	0 20	0 19	0 18	0 17	0 17	0 16	0 15
75	0 14	0 14	0 13	0 12	0 12	0 12	0 11
80	0 10	0 09	0 09	0 09	0 08	0 08	0 08
85	0 04	0 04	0 04	0 04	0 04	0 04	0 03
90	0 00	0 00	0 00	0 00	0 00	0 00	0 00

DETERMINATION OF THE MAGNETIC DECLINATION

When the magnetic declination is to be determined with an ordinary compass or the needle of a surveyor's transit, care should be taken to have the instrument in good adjustment, and readings should be taken on both ends of the needle so as to eliminate outstanding error of eccentricity, whether due to the pivot not being exactly over the center of the graduated circle, to the needle being bent, or to the line of sight not passing through the zero points of the circle. Points requiring attention are:

Peep sights.—See that they are vertical by pointing on a plumb line or the vertical edge of a building.

Needle.—A sluggish or irregular motion may be due to a damaged jewel, a dull pivot, or loss of magnetism.

Balance of needle.—The balancing weight should be shifted if necessary, so that the needle will be horizontal.

Level.—The bubble should be adjusted to remain in the center throughout an entire revolution of the instrument.

Knives and other iron or steel objects should be removed from the person of the observer.

Observations should be made on several days if possible. The best time of day for observing is ordinarily toward the evening, about 5 or 6 o'clock, as the declination at that time is near its mean value for the day and is nearly stationary. The mean value of declination also occurs between 10 and 11 a. m. usually, but the change at that time is rapid. Observations made at other times of the day may be corrected approximately for diurnal variation by means of the table on page 23.

The observations on any one day should cover a period of half an hour (preferably more), with readings at intervals of 5 or 10 minutes. The time should be recorded for each set of readings, together with the date, weather, and the kind of time the observer's watch was keeping.

It is important that the surveyor should know the constant correction of his instrument, which may amount to 15 minutes or even more. This can be determined by observing with it at one of the magnetic stations established by this bureau. The difference between the declination for such a station furnished by this office and the value determined with the surveyor's compass represents the correction which must be applied to results with the latter.

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LINES OF EQUAL MAGNETIC DECLINATION AND OF EQUAL ANNUAL CHANGE IN THE UNITED STATES FOR 1925

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