State Cartographer's Office

One of a series of guides covering various mapping topics in Wisconsin

Wisconsin MAGNETIC DECLINATION

Guide 3, 2nd edition **January 1999**

At very few places on the Earth does the needle of a compass point toward the true north pole. The angle between the direction that a compass points and true north is called **magnetic declination**. The 1998 values for magnetic declination across Wisconsin range from -4° in Door County to +1.5° in St. Croix County. While these values are not as great as the -16° declination in Boston, MA or +20° declination in Seattle, WA, they are still of concern to surveyors, map makers and navigators, and others who use maps or compasses.

This brochure will familiarize you with magnetic declination, reference frames on earth, the compass, maps that show magnetic declination values, and Internet sources for current and historical declination values. It also describes and defines methods of correction and terms associated with magnetic declination.

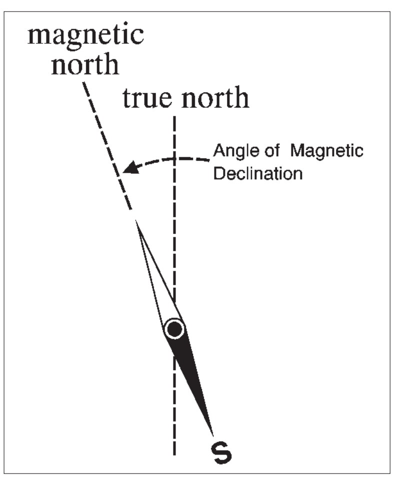


***Figure 1:** A negative angle of magnetic declination as would be common in the eastern U.S.*

REFERENCE SYSTEMS

In order to navigate or locate points on the Earth's surface, we need a reference system to determine, measure and describe relative movement and location.

Latitude and Longitude

Our most common global reference system is the latitude-longitude system. The north-south lines of this system (the lines of longitude) form geographic meridians which converge at the geographic poles, while the east-west lines (the lines of latitude) form geographic parallels. This reference system uses the nearly constant axis of the earth's rotation as a reference, making it essentially fixed over time.

Magnetic Field

A second reference system, using the magnetic meridian, is based on the lines of force of the Earth's magnetic field. Similar to the lines of longitude, these lines run in a generally north-south direction, and are nearly parallel (at least within a small geographic area). The latitude-longitude system provides a constant and predictable reference framework, while the magnetic system is constantly changing.

Generally, the Earth's magnetic field is predictable even as it drifts somewhat from year to year. The rate isn't constant, but typically in recent decades has been continuing in the same direction.

Map Grids

There is a third type of reference system that is as varied as are the many flat maps of the spherical globe. Most geometrically accurate maps have a grid system to simplify and standardize the description of positions. The orientation of these grid systems—that use rectangular coordinates much like graph paper—depend mostly on the method by which the curved surface of the Earth is portrayed as flat. Each such projection causes some distortion which then becomes associated with rectangular coordinate grid placed upon it.

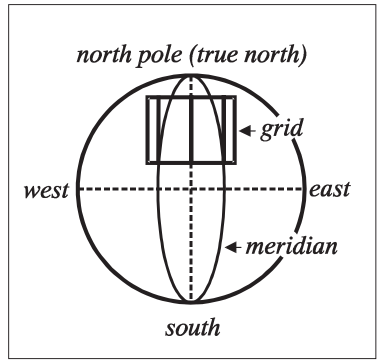


***Figure 2:** Relationship of true north and map coordinate grid north*

The third north, "grid north", lies at one end of one set of grid reference lines. Unlike the latitude-longitude system, the rectangular lines of a grid system never converge. As a result, there is no single point which is grid north, but rather grid north is a direction at any point on the map. *(see figure 2)*

The first edition of this guide was published in 1992 and revised in 1993. Over the intervening five years, the Internet has emerged to provide a variety of mapping-related information, including magnetic declination. This second edition contains updated statistics and maps, and explains what further information is available on the Internet.

Magnetic declination lines are interpolated from point values spaced at 1-degree intervals of latitude and longitude. Values from the *National Geophysical Data Center*.

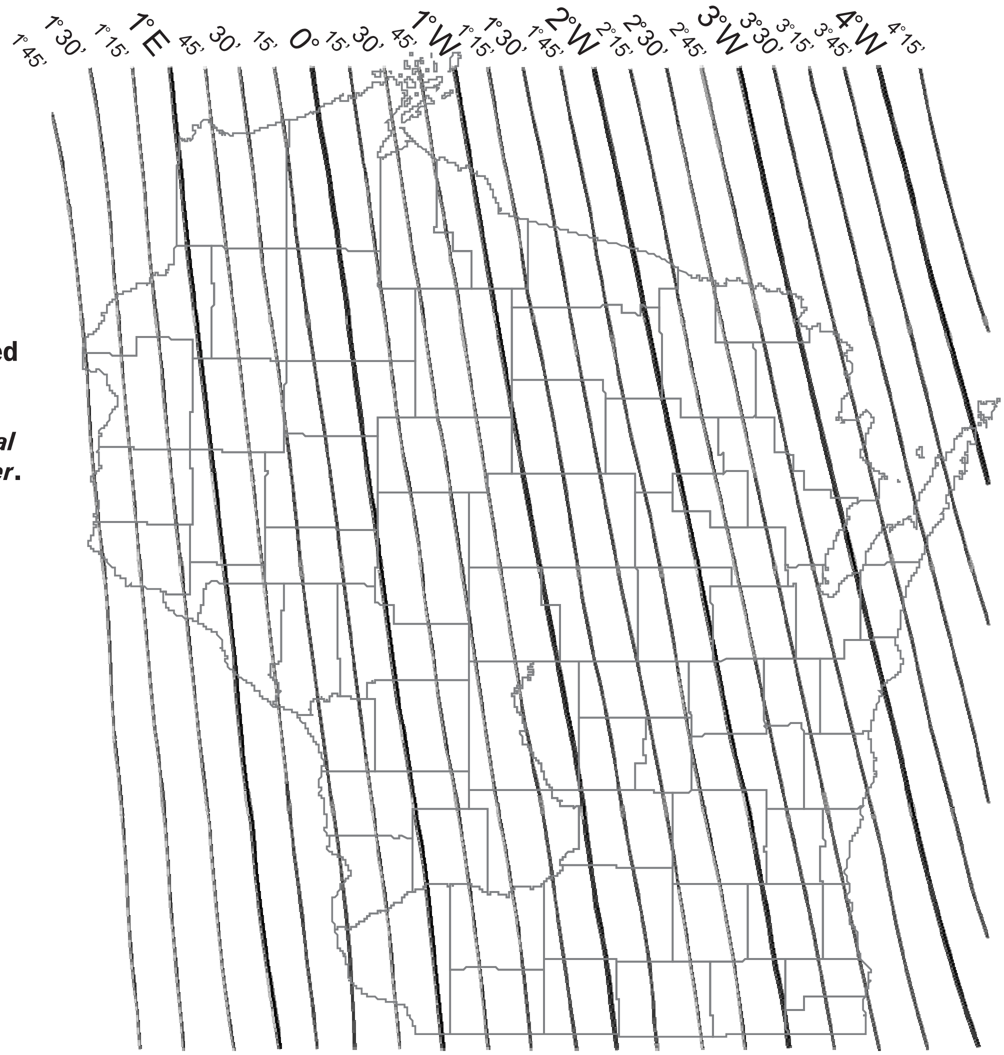


Figure 3: *mid-1998 Magnetic Declination*

MAGNETIC DECLINATION

The angular difference between the geographic and the magnetic meridians at a point is called magnetic declination. *(see figure 1)* This angle varies worldwide, is affected by many factors, and changes over time. To translate the difference between the geographic and magnetic meridian, the angle of magnetic declination must be used.

When using magnetic declination values keep in mind that when you are located west of the 0° line-of-declination, the declination is east (or positive). When located east of the 0° line, the declination is west (or negative). For example, Oshkosh, located east of the 0° line *(see figure 3)*, has a 1998 magnetic declination reading of approximately 2° west. When east of the 0° line (as in the Oshkosh example), true north is east (clockwise) of magnetic north.

To correct a magnetic compass reading to true north, east declination values should be subtracted from the magnetic north reading, while west declination values should be added to the magnetic north reading (since subtracting a negative value is the same as adding). Where the declination is zero, a compass needle will point true north.

LONGITUDE AND MAGNETIC LINES

In the northern hemisphere, the points where the lines of the Earth's magnetic field have converged in recent years are in Northwest Territories, Canada: the north magnetic pole is currently about 11° south of the geographic noth pole, and about 105° west longitude. However, in contrast to the longitude lines, the entire magnetic field is quite irregular. This causes a compass needle rarely to point exactly toward the north magnetic pole. The needle usually aligns with the magnetic meridian at that location *(see figure 1)*. As a result, the value of magnetic declination for a particular area must be applied to a magnetic reading at a point to obtain a true north reading. The final determination of the direction to true north will only be as good as the approximation of magnetic declination for the point and the quality of the compass involved *(see figure 4)*.

Components of the Magnetic Field

For map and navigation use, we typically are concerned only with the direction of the horizontal component of the overall magnetic field.

There is a vertical component, too, which when integrated with the horizontal component describes the strength and direction of the entire magnetic field at a point.

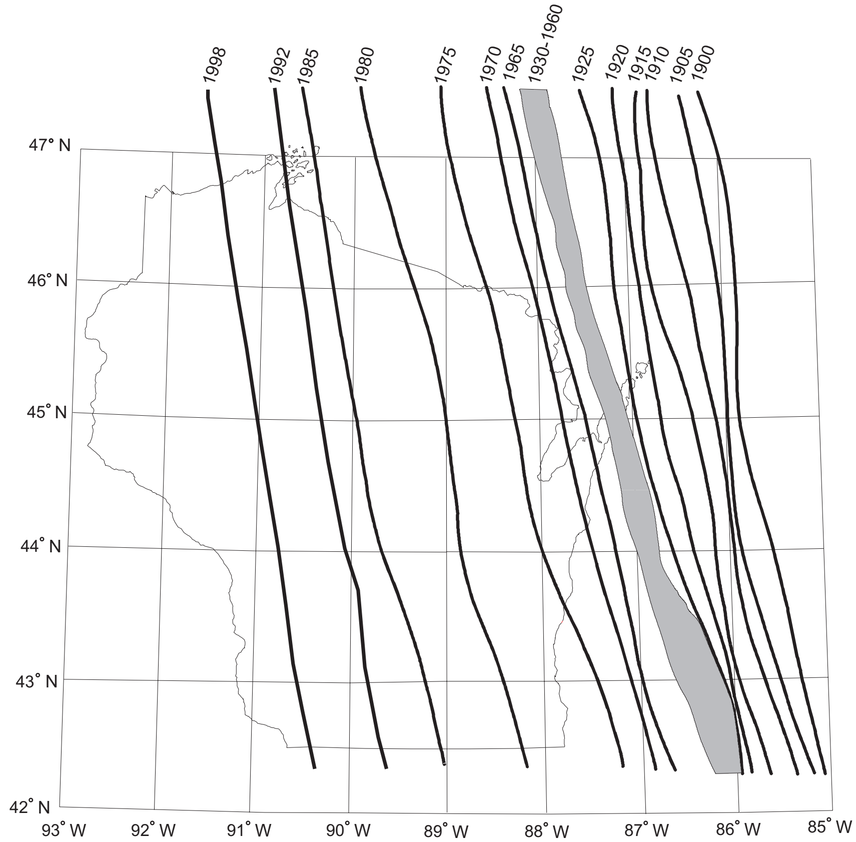


Figure 5: *Westward drift of the 0° declination (agonic) line, 1900-1998*

MAGNETIC COMPASS

A magnetic compass is an instrument that is designed to align itself (at some level of accuracy) with a magnetic meridian at a location. The force that moves this needle is that of magnetic attraction. As long as other magnetic fields do not interfere, the needle of a compass will align itself with the Earth's magnetic field lines. Higher quality compasses allow a magnetic declination adjustment to be set as a convenience.

Magnetic Deviation

Globally, the magnetic field lines (which make up the magnetic meridian) are similar to the lines of longitude which form the geographic meridian. That is, they encircle the globe and converge at a common point. On a more detailed level however, the magnetic lines are not straight, but bend and arc depending on local magnetic conditions. This bending and arcing is called deviation.

Deviation results from local concentrations of magnetic material. These local concentrations–called magnetic anomalies–may be the result of ore deposits relatively close to the surface, or irregularities in the composition of the earth. In Wisconsin, anomalies vary from 5.9° to -5.5°, enough to cause navigation errors.

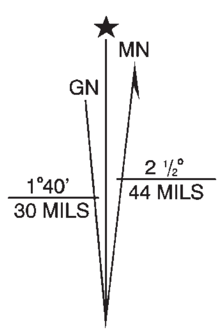
Most anomalies in our state occur in the north. To ascertain where and to what extent local anomalies may be a problem, check with local surveyors or geologists. Others who regularly work in the field may be another source of advice.

A more temporary type of disturbance, called compass deviation, is the result of less predictable magnetic factors such as power lines, automobiles, a wrist watch, or an electrical storm. Any temporary abnormal compass change may be compass deviation.

Magnetic Variation

Another factor that alters the value of magnetic declination is called variation, which occurs over long periods of time. Due to the dynamic nature of the Earth's interior, the magnetic field is constantly changing. This causes "drift" of magnetic north and oscillations of the magnetic meridian. This change in magnetic declination is called annual change (also secular variation). *(see figure 5)* It follows trends in the short term, but is very unpredictable in the long term. Lines of annual change drift and vary similarly to lines of magnetic declination. In recent years, annual change in Wisconsin has been between 0 to 6' west.

Currently, values for magnetic declination and secular variation are not considered accurate beyond five years. For this reason, to use a magnetic compass reading from the past, it must first be converted to a true geographic reading using a value of magnetic declination. This magnetic declination value must have been recorded at about the same time as the original compass reading. Then, to find the current magnetic compass reading, the current magnetic declination must be applied to the true geographic reading.



UTM Grid and 1974 Magnetic North Declination at Center of Sheet

Figure 4: *Sample set of north arrows from a USGS topo map. From left to right: grid north; true or geographic north symbolized by the star representing Polaris, the "North Star"; and magnetic north (which would have drifted counterclockwise since 1974).*

Year	Degrees	Minutes	Direction
1850	5	55	E
1900	3	10	E
1950	3	12	E
1960	3	3	E
1970	2	28	E
1980	1	3	E
1990	0	13	W
2000	1	20	W

Historical and predicted horizontal declination at Madison, WI.

Maps

There are several other terms associated with magnetic declination. Maps are sometimes produced that show smoothed curves of equal magnetic declination. These lines are called isogonic lines. One of these isogonic lines has a value of 0°magnetic declination, meaning that anywhere along this line a compass will point toward true as well as magnetic north. This 0° line is called the agonic line. This line currently passes through Wisconsin, but did not years ago, and may not years from now *(see figure 5)*.

As discussed earlier, the magnetic field of the Earth changes over time. This variation in the short term is predictable and can also be plotted. The lines generated by such a plot would show annual change of magnetic declination over an area. These lines are called isoporic lines. Note, however, that the actual movement of the field maybe erratic as compared to its predicted change.

The smoothed lines of magnetic declination shown in *figure 3* are based on data collected at widely scattered sample locations which is then interpolated to a grid. The map generally predicts magnetic deviation for an area.

The U.S. Geological Survey formerly produced a printed map of the U.S. showing lines of both equal magnetic declination as well as annual change. The last map in that series (produced every five years) was published in 1992 based on 1990 values. The 1990 map is available from:

Branch of Distribution
U.S. Geological Survey
Box 25286, Federal Center
Denver, CO 80225

Request map number: GP-1002-D. Include $4.00 per map, and $3.50 postage and handling. on each order.

The 1995 map is not available on paper, but page-size black-and-white maps are available on the Web, showing declination, inclination, and intensity along with their rates of change.

Internet Sources

We developed the map in *figure 3* from values derived through an Internet web service provided by the National Geophysical Data Center (NGDC) in Boulder, CO. You can access NGDC's offerings by visiting the State Cartographer's Office web site and navigating to: *Maps: Earth-Related Maps.*

One NGDC on-line program predicts magnetic declination for any point world-wide, and for any time (or span) in the 20th century. This program provides all the components of the magnetic field's strength and direction as well as their rates of change. Another program, which is limited to North America, provides historical declination as early as 1750.

Another Internet site is hosted by the National Geomagnetic Information Center, a unit of the U.S. Geological Survey. Periodically we will provide an updated version of figure 3 (for Wisconsin) on our web site. We will also maintain links to other web sites that provide useful information on geomagnetism and compass navigation.

Visit our web site for background information, updated maps, and links to other web sites. The URL is **feature.geography.wisc.edu/sco/**.

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Muehrcke, P.C., 1998, *Map Use: Reading, Analysis, and Interpretation* (4th ed), Madison, WI: JP Publications, 647 p. Includes illustrations, bibliography and index.

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