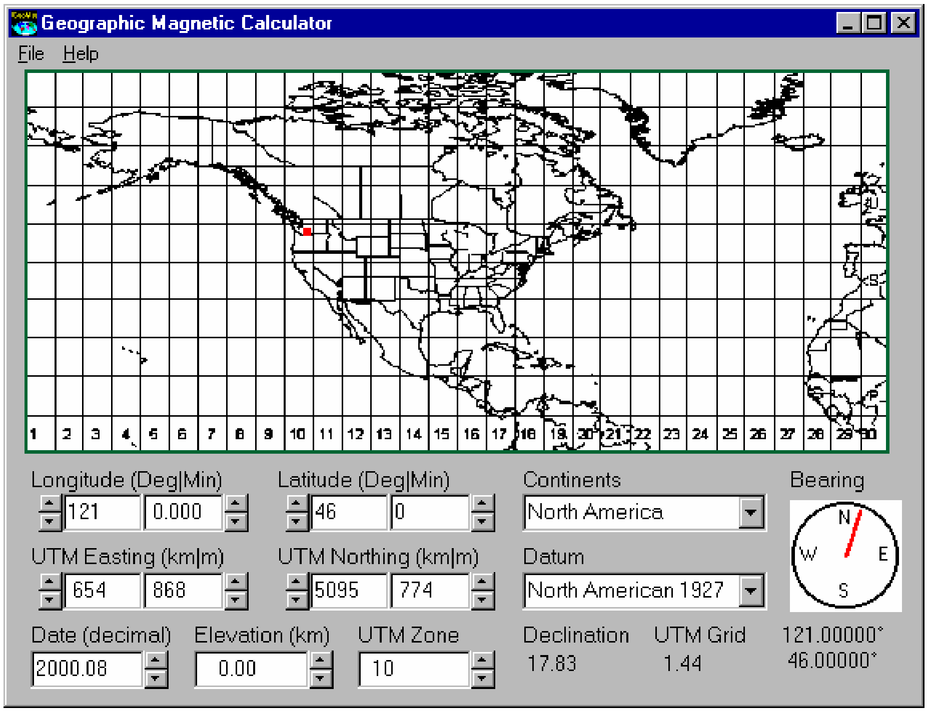
GeoMag

Using GeoMag



GeoMag is a very simple program to use. Data items can be directly typed into any of the white fields, except the Datum and Continents. These items must be selected from a fixed number of predefined choices in drop down lists. For each of the data fields, the up/down arrow on their sides will increment or decrement the value in the field. Whenever a data item changes, the dependent fields will change according to the parameters of the conversion. For example, changing a Longitude will change the X/Y UTM coordinates and zone, based on the new Longitude and the old Latitude. The UTM Convergence, Magnetic Declination and the Bearing Compass will always be updated for changes in position and time.

Below are the valid ranges for each data field.

Data Item	Range
Date	1900.00 to 2004.99
Elevation	0.0 to 599.99 kilometers
Longitude	0.0 to 179 degrees, 59.99 minutes
Latitude	0.0 to 89 degrees, 59.99 minutes
UTM Easting	160 to 800 kilometers, 999.99 meters, depends on Y/Latitude
UTM Northing	0.0 to 9999 kilometers, 999.99 meters
UTM Zone	1 to 60 for the northern hemisphere, -1 to -60 for the southern hemisphere

UTM Coordinate System

The UTM (Universal Transverse Mercator) grid was devised as one way of solving the cartographer's dilemma: how to represent the (nearly) spherical earth's surface on a fiat sheet of paper. Latitude and longitude coordinates are sufficient when long distances are to be covered. (Pilots and sailors use them almost exclusively.) However, for ground teams who cover only a few miles, latitude-longitude is much too cumbersome to be practical. For example, subdividing tic-marks for latitude-longitude are shown only in two places along the edge of a 7-1/2 minute quad map. Furthermore, the subdivisions of the units (minutes and seconds) are one-sixtieth of the larger unit. We are not accustomed to dividing lengths by sixtieths, as were the Babylonians who invented this system 4000 years ago. Another limitation is that a unit of longitude, a degree, represents less distance as one moves away from the equator. This complicates matters when one needs to calculate the distance or bearing from one point to another.

Spherical trigonometry or other complex mathematical methods must be used to make these calculations. These are not impossible of course, just inconvenient.

The UTM system was developed with guidelines that it would: (1) be a square grid; (2) have no negative numbers in the coordinates; (3) read left-to-right and bottom-to-top and (4) be decimal - based.

To accomplish these goals, the UTM system divides the earth's sphere into 60 zones; each is six degrees of longitude wide. The zones are numbered I through 60, west-to-east, beginning at 180 degrees west longitude. **Figure 1** shows the zone numbering system on a continental outline map. Although not shown on this map, the zones cover only the area between 80 degrees south and 84 degrees north latitudes. Different grids (not described here) cover the polar areas.

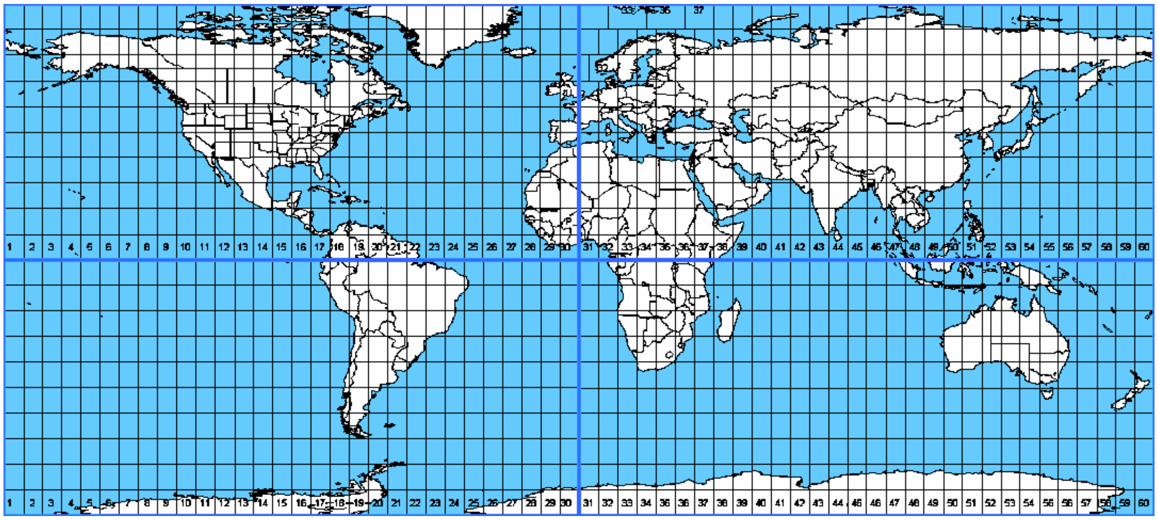


Figure 1: The numbering system for UTM zones. The zones extend from 80 degrees south to 84 degrees north latitudes.

The metric system is used as the units of the UTM coordinates. It may be convenient to remember (as a possible trivia answer) that the distance from the equator to either pole is 10,000,000 meters or 10,000 kilometers. To be exact, a kilometer is equal to nearly 0.625 of a mile or 0.62137 miles.

A square grid is superimposed on each zone and aligned so its vertical lines are parallel to the center of the zone. This centerline is called the central meridian, and is three degrees of longitude from each zone boundary.

The UTM coordinates (measures of distance) are arranged so they always read from left-to-right and from bottom-to-top. This is done as follows. In the Northern Hemisphere the origin, or zero point, of the horizontal lines is at the equator, while in the Southern Hemisphere the origin is at the South Pole.

Establishing coordinates for the vertical lines was done differently. The vertical line at the center of each zone (central meridian) was arbitrarily assigned the value of 500 km to avoid having negative coordinate values. Assigning the value of 500 km to the center of each zone causes the zero point to fall in another zone - the one to its left (west). For this reason, you will never see a zero value for an east-west coordinate. The smallest value is 160 km and it is at the equator. As one moves away from the equator, the UTM east coordinate at the zone's western edge has larger and larger values. At 84 degrees north latitude it is 465 km. Likewise, the eastern (right) zone boundaries will have coordinates of 834 km at the equator and 515 km at 84 degrees north latitude. The way the square grid is placed on each zone is shown in **Figure 2**. Note that this drawing is not to scale; the horizontal axis is highly exaggerated.

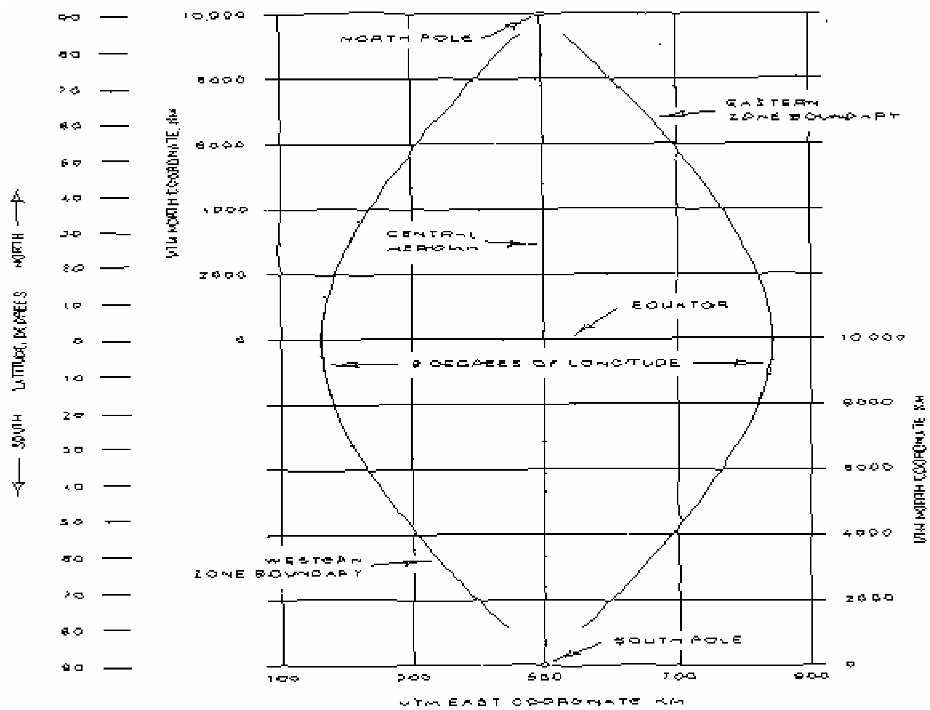


Figure 2: The square UTM grid that is superimposed on each zone. This drawing is not to scale.

Figure 3 shows a portion of zones 10 and 11 in the western U.S. Nevada, quite accidentally, lies totally in zone 11, while California falls in both zones 10 and 11. The latitude-longitude and UTM coordinates are both shown in this figure to illustrate their relationship. Note that the UTM lines at zone boundaries meet at slight angles, and the width (number of kilometers) of the zones is greater near the bottom (south) than at the top in this illustration. Observe also the square UTM grid is parallel to the central meridian.

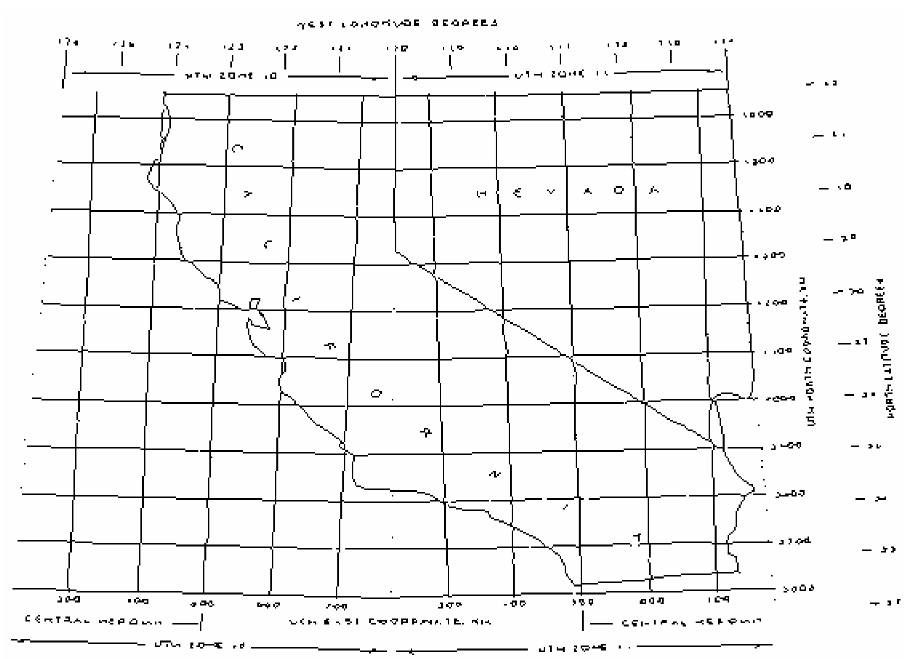


Figure 3: UTM zones 10 and 11 in California and Nevada.

Taking a closer look at the UTM grid, refer to **Figure 4**, which is a familiar 7 .5 minute quad with emphasized UTM grid lines 1000 meters (I kilometer) apart. All USCS topographic maps published in the last 30 years or so have this grid. Since about 1982, the grid lines have been printed on the map, while earlier maps show only the positions of the grid lines on the map's edges as blue tic-marks. A close-up view of a comer of a 7.5 minute quad is shown in Figure 5. On the lower right edge of the map is the notation 5095000mN. The numerals 9 and 5 are printed in larger type size than the others, but ignore the difference in type size. This number is the UTM coordinate of the black line just to its left. It is 5,095,000 meters (5095 kilometers) north of the equator and is called the UTM north coordinate. The other numbers along the edge are also UTM north coordinates but are expressed in kilometers. Again, ignoring type size, the next number up the map edge is 5096, one kilometer greater than the first one. Along the bottom of the map there is the notation 606000mE, a UTM east coordinate. The vertical line above it is 606 kilometers east (right) of the zone's zero point. Put another way it is 500 minus 606 or 106 kilometers west (left) of the central meridian. The next grid line to the left of this one has no number under it. The UTM coordinates are sometimes omitted if they interfere with the printing of other information. The number corresponding to this line is 605, one kilometer less than the one to its right.

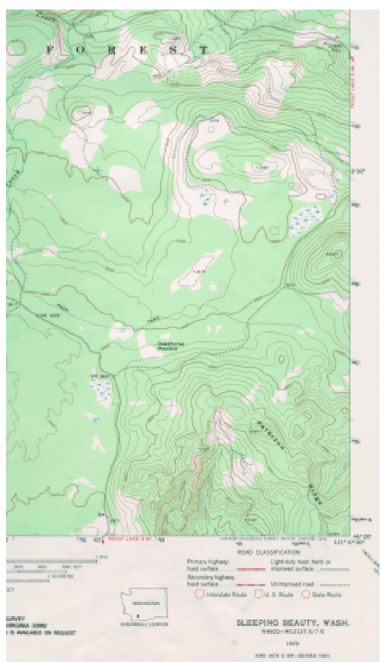


Figure 4: UTM grid on a 7.5 minute USGS topographic map.

Dividing the space between them into tenths may specify locations between grid lines. For example, in the upper right-hand comer of **Figure 5** is the elevation notation 4180, printed in black. The digit 4 in this number is about two-tenths of the distance between the 605 and 606 vertical lines. The UTM east coordinate would then be 605.2 kilometers. Likewise the 4 is about one-tenth of the distance up from the 5096 line and its UTM north coordinate is 5096.1 kilometers. Just by giving these two numbers, 605.2 east and 5096.1 north, plus the zone number, you have uniquely specified this point on the earth's surface. And just looking at the map with no calculations or measurements needed did it. For more accurate subdivision between UTM grid lines, you can use a transparent overlay or the metric scale at the bottom of the map.

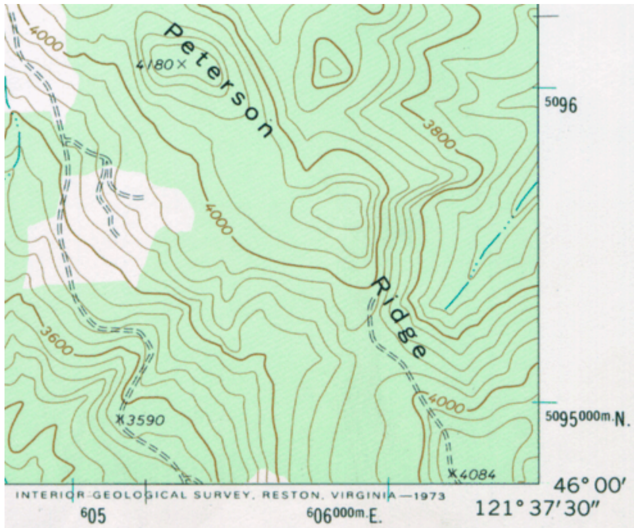


Figure 5: A corner of a 7 .5 minute USCS topographic map showing UTM coordinates

As taught in the U.S. Army, it should be noted that some teams learn UTM coordinates as a six-digit number. This number is created using the two large, bold-type UTM numbers from the map and the tenths from dividing the space between the grid lines. The decimal point is omitted. In addition, they learn to "read right up"; thus, presenting the number in the correct format. Therefore, the coordinates mentioned above would be transmitted as 052-961.

The UTM zone number will be found in the information printed on the lower left-hand corner of the map.

If you are plotting bearings very accurately, as you would during radiolocation of an ELT, one additional factor should be considered.

The only place where the UTM grid is aligned exactly true north is at the midpoint of a zone (at the central meridian). The grid will be rotated slightly counterclockwise for locations west (left) of the central meridian. This can be seen in Figure 4. Note how the UTM grid is not quite parallel to the edges of the map. Similarly, it will have a small clockwise rotation east of the central meridian. The amount of rotation increases as you move away from the central meridian and is maximized at the zone boundaries. This difference between true north and UTM grid north is called the convergence, so named because the meridians converge as they approach the poles. In the continental U.S. the convergence will never exceed 2.5 degrees. If you need to know the convergence, it is shown on a diagram on the map in Figure 6. The vertical line with the star at its end represents true north, while the line with the notation GN (abbreviation for grid north) at its end shows the angle (not to scale) of the UTM grid. The convergence for this map is shown as 0 degrees, 57 minutes, which is the same as 57 divided by 60 or about 1.0 degrees. On this map grid north is counterclockwise from true north by 1.0 degrees.

Figure 6 also shows the relation between true north and magnetic north. Note the legend below the figure gives a year that is associated with the magnetic declination. That's because declination is not a constant value - it changes with time. The change is slow; one degree every 10 years is common in parts of the U.S. But if you're using a 30-year-old map, the declination printed on it may be wrong by three degrees. On this map, the difference between magnetic north (in 1984) and UTM grid north is 21.0 degrees minus 1.0

degrees, or 20.0 degrees. Knowing the exact values of convergence and declination is not important unless you are doing precise navigation or making extremely accurate plots of bearings.

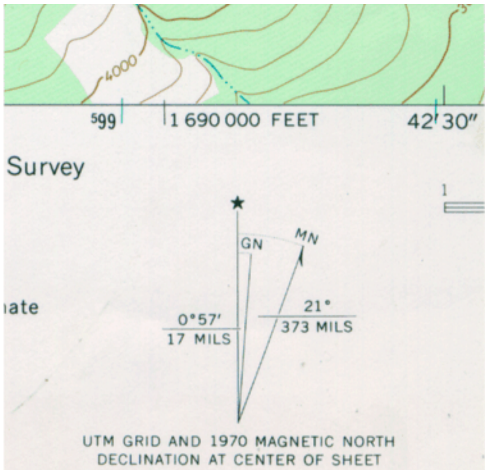


Figure 6: Diagram on USGS topographic maps that shows the angular relations among grid north, true north and magnetic north.

One further advantage the UTM system offers is its coordinates can be convened to latitude-longitude and vice versa. The mathematical equations for doing this are very complicated, but are easily handled by computers, including small hand held ones. Being able to make these conversions is quite useful when coordinating search operations involving both ground teams and air resources. If a ground team requests a victim evacuation by helicopter and gives its location in UTM coordinates, these can be converted to latitude-longitude. The aircraft crew can then use its on-board navigation equipment to locate the pickup site. Another use of the conversion process is in the plotting of locations on a map. In searches for missing aircraft, the FAA is sometimes able to furnish a record of the aircraft's flight path from its radar records (NTAP). These locations are always given in latitude-longitude coordinates. Plotting these on a map can be very time-consuming. But, if they are converted to UTM coordinates, then they can be plotted very quickly.

These are the features of the UTM coordinate system that you need to use in the field. It provides a rapid, simple and accurate way to report your location. All that remains to be done is adding the UTM grid lines to your maps. Use a long straightedge to connect the blue tic-marks with a pencil or fine-point pen. This would be a good project for a cold winter night or at a team meeting when discussing map reading. Then, on your next mission, the UTM grid will be waiting for you to use it.

For those interested in more details about the UTM system the following references are recommended:

Maps for America, by Morris M. Thompson, published by the United States Geological Survey, 1979. This is an excellent reference book that describes all the features on USGS maps. The appendix has a thorough description of the UTM coordinate system.

United States Army Technical Manuals TM 5-241-1, "Grids and Grid References", and TM 5-241-8, "Universal Transverse Mercator Grid". The first of these describes the way the UTM system forms the basis for the Military Grid Reference System. The latter provides the mathematical equations for converting UTM coordinates to latitude - longitude and vice versa.

Geodetic Datums and Ellipsoids

Hundreds of geodetic datums are in use around the world. The Global Positioning system is based on the World Geodetic System 1984 (WGS-84). The Defense Mapping Agency publishes parameters for simple XYZ conversion between many datums and WGS-84. Coordinate values resulting from interpreting latitude, longitude, and height values based on one datum as though they were based in another datum can cause position errors in three dimensions of up to one kilometer.

Datum conversions are accomplished by various methods. Complete datum conversion is based on seven parameter transformations that include three translation parameters, three rotation parameters and a scale parameter. Simple three parameter conversion between latitude, longitude, and height in different datums can be accomplished by conversion through Earth-Centered, Earth Fixed XYZ Cartesian coordinates in one reference datum and three origin offsets that approximate differences in rotation, translation and scale. GeoMag uses the Standard Molodensky formulas to convert latitude, longitude, and ellipsoid height in one datum to another datum.

Datums and their Parameters Available with GeoMag

Datum	Ellipsoid	DX	DY	DZ
Adindan	Clarke 1880	-162.0	-12.0	206.0
Arc 1950	Clarke 1880	-143.0	-90.0	-294.0
Arc 1960	Clarke 1880	-160.0	-8.0	-300.0
Australian 1966	Australian National	-133.0	-48.0	148.0
Australian 1984	Australian National	-134.0	-48.0	149.0
Camp Area Astro	International 1909	-104.0	-129.0	230.0
Cape	Clarke 1880	-136.0	-108.0	-292.0
European 1950	International 1909	-87.0	-98.0	-121.0
European 1979	International 1967	-86.0	-98.0	-119.0
Geodetic 1949	International 1967	84.0	-22.0	209.0
Hong Kong 1963	International 1967	-156.0	-271.0	-189.0
Hu Tzu Shan	International 1967	-634.0	-549.0	-201.0
Indian	Everest	289.0	734.0	257.0
North American 1927	Clarke 1866	-8.0	160.0	176.0
North American 1983	GRS 80	0.0	0.0	0.0
Oman	Clarke 1880	-346.0	-1.0	224.0
Ordnance Survey 1936	Airy	375.0	-111.0	431.0
Pulkovo 1942	Krassovsky 1942	27.0	-135.0	-89.0
South American 1956	International 1967	-288.0	175.0	-376.0
South American 1969	South American 1969	-57.0	1.0	-41.0
Tokyo	Bessel 1841	-128.0	481.0	664.0
WGS 1972	WGS 72	0.0	0.0	-4.5
WGS 1984	WGS 84	0.0	0.0	0.0

Early ideas of the figure of the Earth resulted in descriptions of the Earth as an oyster (The Babylonians before 3000 BC), a rectangular box, a circular disk, a cylindrical column, a spherical ball, and a very round pear (Columbus in the last years of his life). Flat Earth models are still used for plane surveying, over distances short enough so that Earth curvature is insignificant (less than 10 km).

Spherical Earth models represent the shape of the Earth with a sphere of a specified radius. Spherical Earth models are often used for short range navigation (VOR-DME) and for global distance approximations. Spherical models fail to model the actual shape of the Earth. The slight flattening of the Earth at the poles results in about a twenty-kilometer difference at the poles between an average spherical radius and the measured polar radius of the Earth.

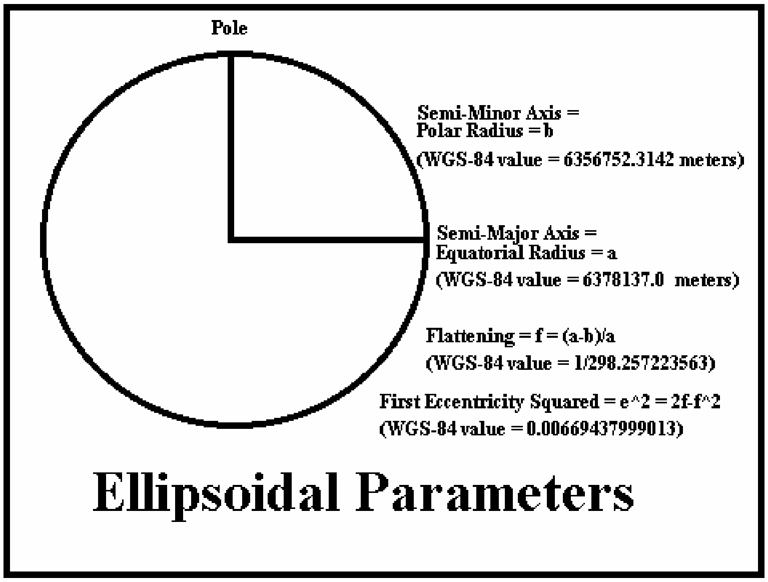


Figure 1: Ellipsoidal Parameters

Ellipsoidal Earth models are required for accurate range and bearing calculations over long distances. Loran-C, and GPS navigation receivers use ellipsoidal Earth models to compute position and waypoint information. Ellipsoidal models define an ellipsoid with an equatorial radius and a polar radius. The best of these models can represent the shape of the Earth over the smoothed, averaged sea-surface to within about one hundred meters.

Ellipsoids and their Parameters Available with GeoMag

Ellipsoid	Semi-Major Axis	Semi-Minor Axis	1/f
Clarke 1866	6378206.4	6356583.8	294.979
Clarke 1880	6378249.145	6356514.86955	293.465
Australian National	6378160.0	6356774.719	298.240
International 1909	6378388.0	6356911.94613	297.000
International 1967	6378157.5	6356772.2	298.250
Everest	6377276.3452	6356075.4133	300.802
GRS 80	6378137.0	6356752.31414	298.257
Airy	6377563.396	6356256.91	299.325
Krassovsky 1942	6378245.0	6356863.0188	298.300
South American 1969	6378160.0	6356774.7192	298.250
Bessel 1841	6377397.155	6356078.96284	299.153
WGS 72	6378135.0	6356750.519915	298.260
WGS 84	6378137.0	6356752.31414	298.257

A Brief Introduction to Geomagnetism

The following is intended to give those users unfamiliar with Earth magnetism an introduction to the various parameters calculated by the GeoMag program and an understanding of the changing nature of the Earth's magnetic field. If you are interested in pursuing the subject further, some references are listed at the end of this section.

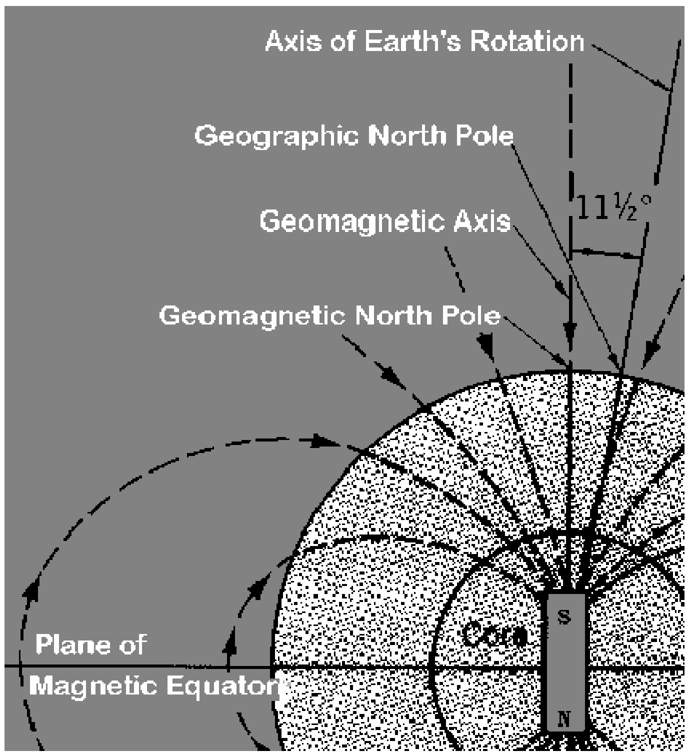


Figure 1: Earth's Magnetic Field

The Earth's magnetic field resembles, in general; the field generated by a dipole magnet (i.e., a straight magnet with a north and South Pole) located at the center of the Earth. The axis of the dipole is offset from the axis of the Earth's rotation by approximately 11 degrees. This means that the north and south geographic poles and the north and south magnetic poles are not located in the same place. At any point, the magnetic field is characterized by a direction and intensity, which can be measured. The geomagnetic poles are located in the area where the lines of force are perpendicular to the Earth's surface and are sometimes referred to as the dip poles (dip = 90 degrees). The physical location of the magnetic pole is actually an area rather than a single point. Because of the changing nature of Earth's magnetic field, the location of the magnetic poles also changes. The current locations of the magnetic poles are approximately:

North Pole: 78.5 N and 103.4 W degrees, near Ellef Ringnes Island, Canada

South Pole: 65 S and 139 W degrees, in Commonwealth Bay, Antarctica

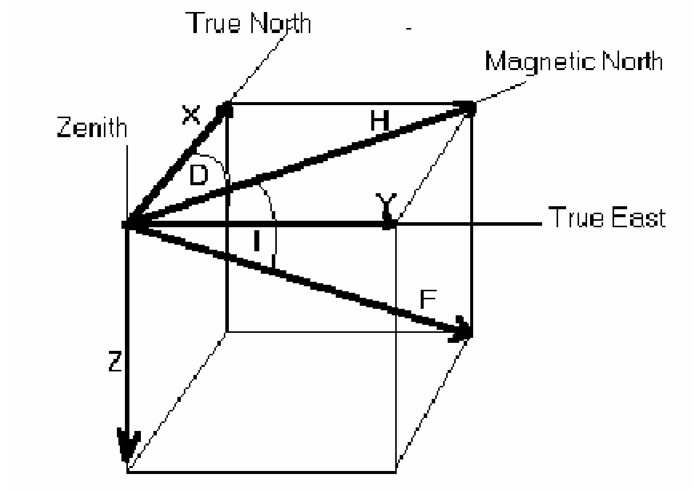


Figure 2: Magnetic Field Vector

The Earth's magnetic field is described by seven parameters. These are declination **(D),** inclination **(I)**, horizontal intensity **(H),** vertical intensity **(Z),** total intensity **(F)** and the north **(X)** and east **(Y)** components of the horizontal intensity. The parameter most frequently requested and most often misunderstood is magnetic declination or variation (D). This is the angle made between the trace of the total magnetic field in the horizontal plane (H) and true north. D is considered positive when the angle measured is east of true north and negative when west. The inclination or dip, I, is the angle between the horizontal plane and the total magnetic field. Inclination, also called magnetic dip, is considered positive when downward pointing. These elements, D, I and H give a full vector representation of the magnetic field, F. Vertical intensity is the trace of the total intensity in the vertical plane and is considered positive when I is positive, that is downward pointing. The east component, Y, is considered positive when pointing east and the north component, X, is positive when pointing towards geographic north.

At any specific point, the values of the magnetic elements are changing. The changes are not uniform over area or time. Some types of change are distinguishable. Three important, classifiable changes are the diurnal, secular and storm variations. The small regular fluctuations in the magnetic field that occur more or less regularly every 24 hours are called diurnal variations. Secular changes extend over years with generally smooth increases or decreases in the field. Magnetic storms are sudden and potentially large disturbances in the magnetic field, which may last hours or days. Of these changes, the least understood is the long-term change that occurs over years in the main magnetic field. Mathematical models can approximate the magnetic field over short periods of time, but because the secular change is not predictable, the potential for error increases the further in time from the base epoch the calculations are. For this reason, it is important to use the most current accepted models of the magnetic field. These models are produced about every 5 years and are available from NGDC and the World Data Centers.

Earth Magnetic Field Maps

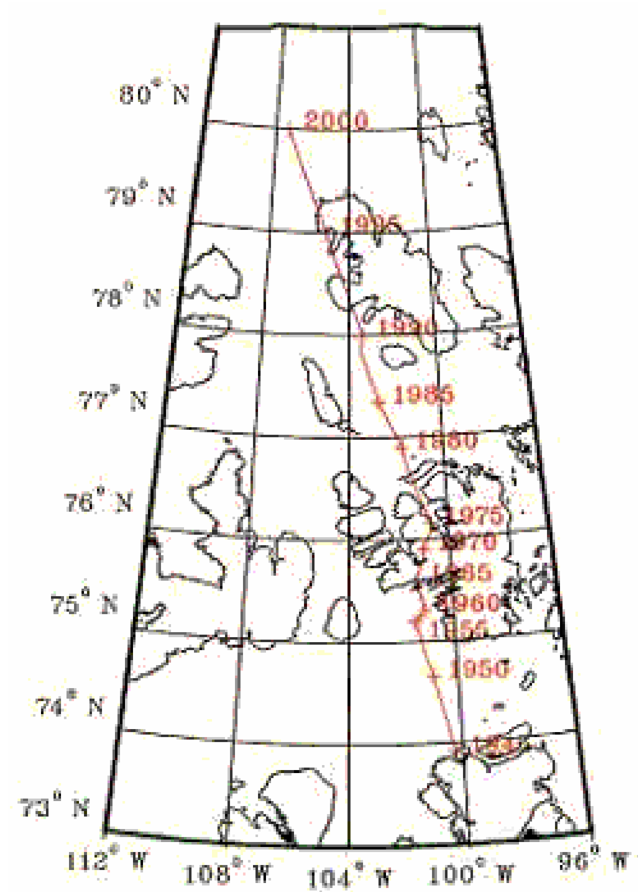


Figure 1: Migration of the Earth's North Pole over Time

Figure 1 shows how the Earth's magnetic north pole, located in far northern Canada, has moved over the past 50 years. The rate of change has been approximately one degree of latitude every five years. This is why older maps do not have the correct, current magnetic declination printed in their legends.

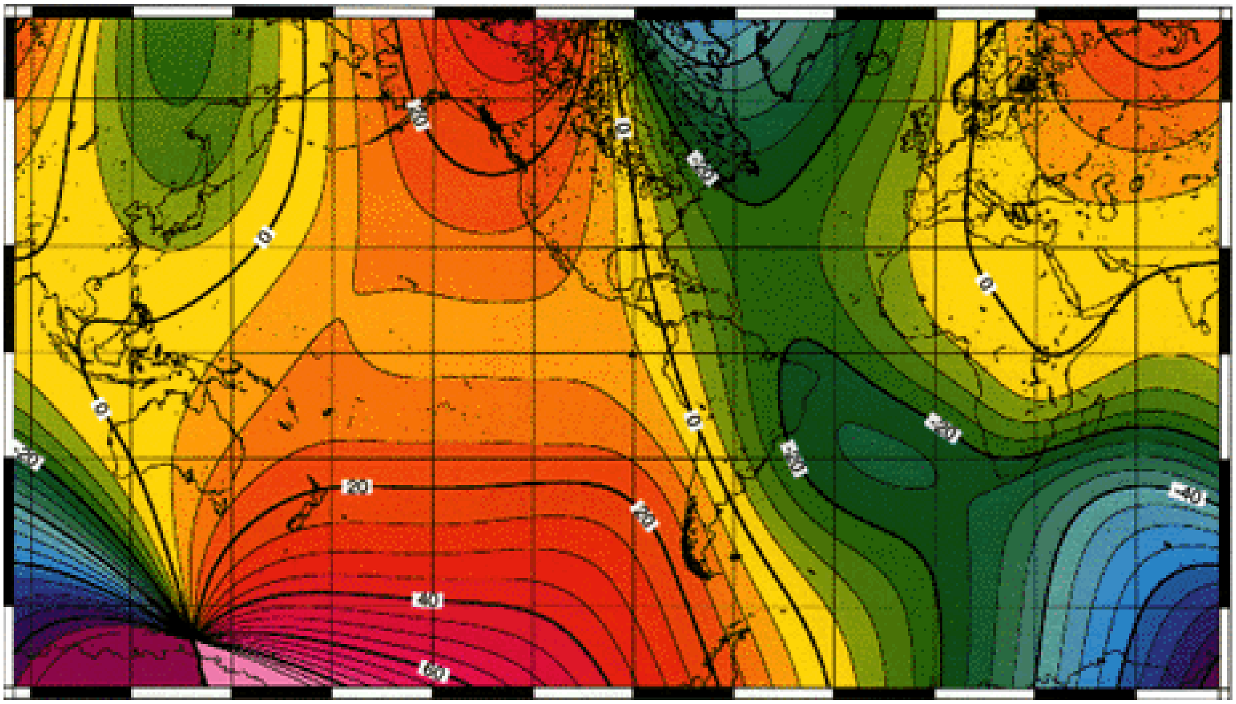


Figure 2: Transverse Mercator Projection with Magnetic Color Contours

In Figure 2, the warmer colors, e.g. red and orange, represent increasing values of positive magnetic declination. The cooler colors, e.g. green and blue, represent decreasing values of negative magnetic declination. Yellow represent near zero declination.

About GeoMag

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