

Magnetic Declination, Magnetic Variation, Grid Magnetic Angel

Intro

Many people are surprised to learn that a magnetic compass does not normally point to true north. In fact, over most of the Earth it points at some angle east or west of true (geographic) north. The direction in which the compass needle points is referred to as magnetic north, and the angle between magnetic north and the true north direction is called magnetic declination. You will often hear the terms "variation", "magnetic variation", or "compass variation" used in place of magnetic declination, especially by mariners.

What causes magnetic declination?

The elements iron, nickel and cobalt possess electrons in their outer electron shell, although the next inner shell is not filled. Their electron "spin" magnetic moments are not cancelled, thus they are known as ferromagnetic. Iron is especially abundant in the universe, since it is the final unbearable stellar nuclear ash. These dense elements sank to the core of the molten Earth (the molten metallic region that lies from 2800 to 5000 km below the Earth's surface) as it accreted from a nebula of exploded stars.

Earth's core has remained molten due to heat from ongoing radioactive decay. Convection currents flowing in the outer core generate a magnetic field this movement is known as secular variation, this variation changes with time in an unpredictable manner. The poles of this field do not coincide with true north and south, so you ask why are they know as the north and south poles? Its because these are the axis of rotation of the Earth. In mid 1999, the average position of the modelled north magnetic dip pole (according to the IGRF-95 geomagnetic model) is 1418.6 miles N, and 1902.2 miles W, 75 kilometres northwest of Ellef Ringnes Island in the Canadian Arctic. This position is 1140 kilometres from the true (geographic) North Pole.

The geomagnetic field can be quantified as total intensity, vertical intensity, horizontal intensity, inclination and declination. The total intensity is the magnetic strength, which ranges from about 23 microteslas around Sao Paulo, Brazil to 67 microteslas near the south magnetic pole near Antarctica. Vertical and horizontal intensity are components of the total intensity. The angle of the field relative to the level ground is the inclination, or dip, which is 90° at the north magnetic pole. Finally, the angle of the horizontal intensity with respect to the north geographic pole is the declination, also called variation in mariners' and aviators' jargon. In other words, declination is the angle between where a compass needle points and the true North Pole.

Do compasses point to the north magnetic pole?

Most people incorrectly believe that a compass needle points to the north magnetic pole. But since the Earth's field is the effect of complex convection currents in the magma, which must be described as several dipoles, each with a different intensity and orientation, the compass actually points to the sum of the effects of these dipoles at your location. In other words, it aligns itself with the magnetic lines of force. Other factors, of local and solar origin, further complicate the resulting field. It may be all right to say that a compass needle points "magnetic north" but it only roughly points to the north magnetic dip pole.

What Factors Influence Declination?

Location: Each position on the Earth has a particular declination. Working out the change in its value as one travels is a complex task to master. If the navigator happens to be travelling along a rather straight line of equal declination, called an isogonics line, it can vary very little over thousands of kilometres. However for one crossing isogonics lines at high latitudes, or near magnetic anomalies, the declination can change at over 18 mils per kilometre. Navigators need periodically update the value to stay on course.

Altitude: This factor is normally negligible. According to the IGRF, a 20,000-meter climb even at a magnetically precarious location as Resolute, 500 kilometres from the north magnetic pole, would result in a 36 mil reduction in declination.

Secular change: Where were/are/will be the magnetic poles?

As convection currents churn in apparent chaos in the Earth's core, all magnetic values change erratically over the years. The north magnetic pole has wandered over 1000 kilometres since Sir John Ross first reached it in 1831. The rate of displacement has been accelerating in recent years and is currently moving about 24 kilometres per year, which is several times faster than the average of 6 kilometres per year since 1831. The magnetic pole positions can be determined more precisely by using a calculator that returns magnetic inclination. Latitudes and longitudes can be entered by trial and error, until the inclination (I) is as close as possible to 1600.

A given value of declination is only accurate for as long as it stays within the precision of the compass, preferably one degree. Typical secular change or variation (do not confuse with mariners' and aviators' variation) is 2-25 years per 18 mils. A map that states: "annual change increasing 18.0mils would suggest 60 years per degree, but that rate of change just happened to be slow on the year of measurement, and will more than likely accelerate.

The field has even completely collapsed and reversed innumerable times, which have been recorded in the magnetic alignment of lava as it cooled. One theory to explain magnetic pole reversals is related to large meteorite impacts, which could trigger ice ages. The movement of water from the oceans to high latitudes would accelerate the rotation of the Earth, which would disrupt magnetic convection cells into chaos. These may reverse when a new pattern is established. Another theory is that the reversals are triggered by a slight change the angular momentum of the earth as a direct result of the impacts. These theories are challenged by the controversial Reversing Earth Theory, which proposes that the entire crust could shift and reverse the true poles in a matter of days, but that the molten core would remain stationary, resulting in apparent magnetic reversal. The Sun would then rise in the opposite direction.

Diurnal change: The stream of ionised particles and electrons emanating from the Sun, known as solar wind, distorts Earth's magnetic field. As it rotates, any location will be subject to this. This has the effect of moving the magnetic poles around an ellipse several tens of kilometres in diameter, even during periods of steady solar wind without gusts. The Geological Survey of Canada shows a map of this daily wander or diurnal motion in 1994.

The resulting diurnal change in declination is negligible at tropical and temperate latitudes. For example, Ottawa is subject to plus or minus 1.8 mils of distortion. However; in Resolute, 500 kilometres from the north magnetic pole, the diurnal change cycles through at least plus or minus nine degrees of declination error. This error could be corrected, but both the time of day and the date would have to be considered, as this effect also varies with seasons.

Solar magnetic activity: The solar wind varies throughout an 11-year sunspot cycle, which itself varies from one cycle to the next. In periods of high solar magnetic activity, bursts of X-rays and charged particles are projected chaotically into space, which creates gusts of solar wind. These magnetic storms will interfere with radio and electric services, and will produce dazzling spectacles in the skies. The varied colours are caused by oxygen and nitrogen being ionised, and then recapturing electrons at altitudes ranging from 100 to 1000 kilometres. The term "geomagnetic storm" refers to the effect of a solar magnetic storm on the Earth (geo means Earth).

The influence of solar magnetic activity on the compass can best be described as a probability. The chance that the declination will be deflected by 18 mils in southern Canada over the entire 11-year cycle is 1% per day. This implies about four disturbed days per year, but in practice these days tend to be clustered in years of solar maxim. These probabilities drop off rapidly at lower latitudes. During severe magnetic storms, compass needles at high latitudes have been observed swinging wildly.

"Bermuda Triangle" type anomalies: These are very rare but there are Legends of compasses spinning wildly in this area of the Atlantic, before sinking a ship, or blowing up an airplane, may be related to huge pockets of natural gas suddenly escaping from the ocean floor. As the gas bubbles up, it could induce a static charge or could ionise the gas, which would create erratic magnetic fields. The gas would cause a ship to lose buoyancy, or a plane flying through a rising pocket of natural gas could ignite it. The ionised gas may show as an eerie green glow at night. It could make people feel light headed and confused because the gas replaces the air, but it would not have the extra bits that gas companies add to gas to give it its distinctive odours. At enormous pressures and low temperatures (as at the bottom of the sea), water and gas molecules form gas hydrates. These compounds resemble ice but, unlike ordinary ice, the water molecules form cages that trap gas molecules such as methane. The solid hydrates retain their stability until conditions, such as higher temperatures or lower pressures, cause them to decompose. The gas may remain trapped under silt, until an earthquake triggers a release. This phenomenon is not restricted to the "Bermuda Triangle".