3.2 The magnetic field of the earth

- The main dipole field
- Components of the vector field
- Secular variation in the main field
- External sources and the geomagnetic frequency spectrum

To a good approximation the magnetic field of the Earth is that of a magnetic dipole located slightly off center and inclined some 15° to the axis of rotation. The field is believed to be created by a self-exciting dynamo driven by convection currents in the molten core. New theories explain not only the field and its long term variations but also the reversals which have occurred in the geologic record.

The observed field could also be explained by an almost uniformly magnetized sphere which also produces a dipole field on the surface. This is not likely because the interior of the earth is hot and ferromagnetic minerals are known to lose their magnetization above the Curie temperature which is in the range of 300-600°C. A uniformly magnetized shell, the crust below the Curie point, is also implausible because the magnetization would have to be much higher than the observed magnetization of crustal rocks (there isn’t enough iron in the crust to provide the required susceptibility).

The Earth’s dipole moment is approximately $7.5 \times 10^{22} \text{ Am}^2$

The field at the magnetic pole, $B_p \approx 6 \times 10^{-5} \text{T}$

The field at the magnetic equator, $B_e \approx 3 \times 10^{-5} \text{T}$
The variation of the magnetic field over the surface of the earth is much more dramatic than the variations of $g_z$. In gravity surveys it is really only feasible to measure changes in $g$ in the vertical direction and the anomalies seen are a tiny fraction of the main field. Correction for the latitude and elevation variations are essential to reveal the anomalies. The anomalies from magnetic susceptibility contrasts are enormous on a relative scale - reaching values equal to the Earth’s field over magnetite ore bodies. For surveys on a scale of 100’s km or less the variation in the main field is usually not removed.

The main magnetic field at any point on the surface is a vector field and is described by 3 rectangular components and two angles as shown in the sketch below.
In the northern hemisphere the magnetic vector, $T$, points down towards north at an angle $I^\circ$ below horizontal (the inclination). The horizontal component, $H$, has an angle $D^\circ$ from geographic north (the declination).

At Berkeley:

$T \approx 52,000 \text{ nT}$

$D \approx 16^\circ \text{ E}$

$I \approx 60^\circ \text{ N}$

The internal source of the Earth’s field changes with time (occasionally flipping and reversing the dipole) and these are called secular changes.

Superimposed on the internal main field are time varying fields caused by current systems in the Earth’s ionosphere and magnetosphere. These currents produce the spectrum of magnetic fields called the geomagnetic, or natural magnetic, field spectrum shown in Figure 3.1.1. These fields are small compared to the main field but they can be comparable to some anomalies. There is a diurnal variation caused by the rotation of the Earth and its magnetic field in the constant stream of plasma ejected from the Sun. This diurnal variation is on the order of 30 nT. Occasionally, during solar sunspot ‘storms’, time variations of 1000 nT or more can occur. Time variations can have a large effect on field surveys and a means for removing them must be an integral part of survey design.