British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

DEVEX 2012

Improving directional drilling accuracy using magnetic referencing techniques

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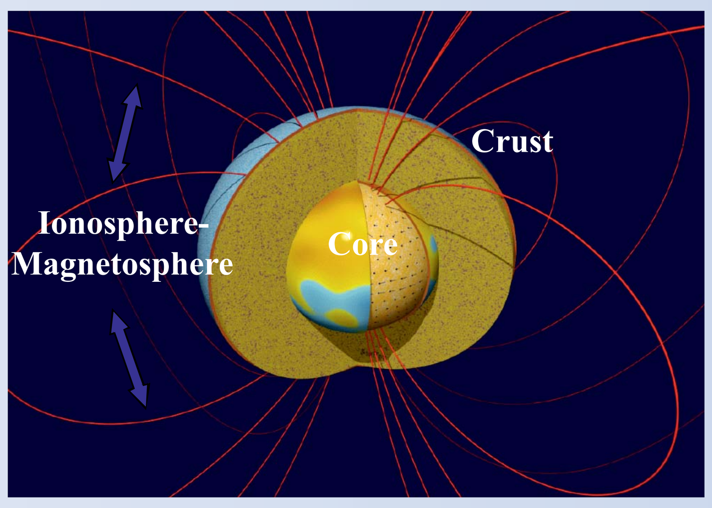
Directional drilling requires accurate positioning information. This can be achieved with gyroscopic or magnetic survey tools.

The British Geological Survey (BGS) has developed a number of techniques and services to reduce the uncertainty in magnetic referencing for the oil & gas industry.

In general, accuracies of 0.1° in declination, 0.05° in inclination (dip) and 50nT in total field strength are desired.



The Earth's magnetic field comprises:

- The main field from the Earth's core
  - varies slowly with time (months to years)
- Local fields from magnetised rocks in Earth's crust
  - relatively stable with time
- Fields due to currents in the ionosphere and magnetosphere
  - variations from seconds to years

Reducing Uncertainty

BGS Global Geomagnetic Model (BGGM)

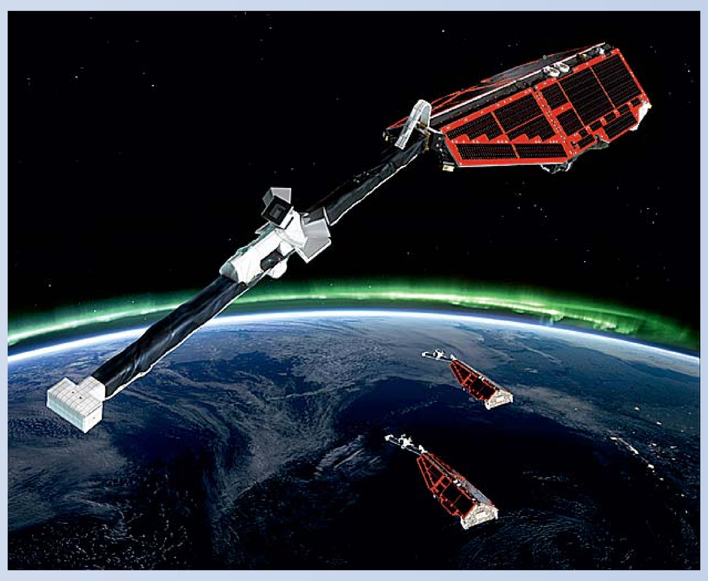
The **BGS Global Geomagnetic Model (BGGM)** is an industry-standard main field model. It represents a combination of the time-varying main field generated in the Earth's fluid outer core, the steady component of the external field arising from ever-present magnetospheric currents, and large scale crustal fields down to approximately 800 km in scale.

It is a mathematical model describing these fields and their annual rates of change. Recent advances in core-flow modelling are now being developed to enhance its predictive capability.

The model is based on data collected from magnetic survey satellites which make accurate observations of the strength and direction of the Earth's magnetic field at altitudes above 300 km and from a network of around 160 geomagnetic observatories around the world.

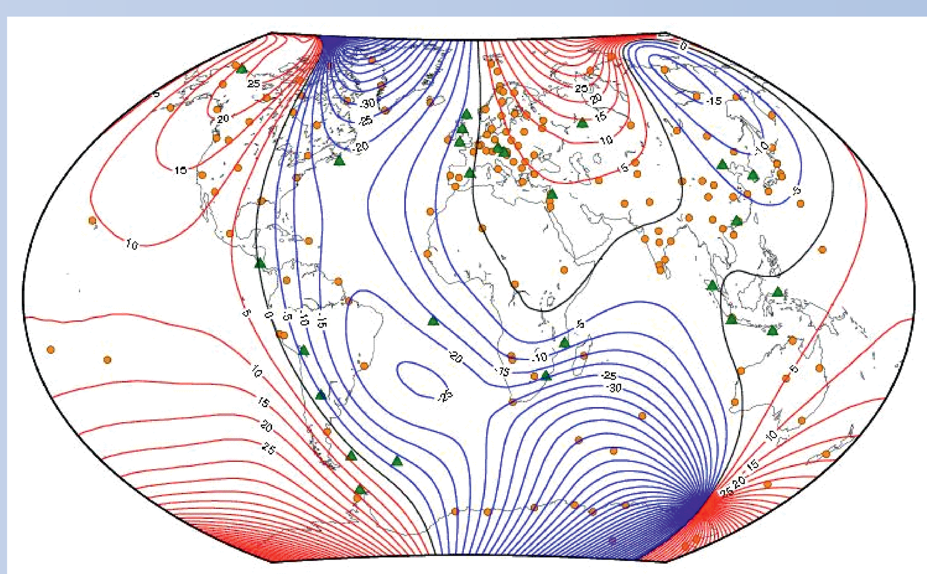
Error analysis has been carried out using independent data and published in *Macmillan, Susan and Steve Grindrod, 2010. Confidence Limits Associated With Values of the Earth's Magnetic Field used for Directional Drilling. SPE Drilling & Completion, 25(2), 230-238.*

Main Field



Global magnetic field models are dependent on data from magnetic survey satellites. The BGGM make use of data from the Danish-led Ørsted and German-led CHAMP satellite missions.

The European Space Agency (ESA) is due to launch a new magnetic survey mission, SWARM, in July 2012 (pictured above). The BGS are principal investigators in the satellite mission validation team and will use SWARM data in future revisions of the BGGM.



The BGGM also makes use of ground measurements from 160 magnetic observatories around the world. Pictured above, the green triangles show BGS observatories, or those that use BGS equipment. Orange dots show other magnetic observatories.

The chart shows the BGGM chart for declination (***D***) variation in 2011: Red contours show where the main field points east of True North. Blue contours where it is west of True North.

In-Field Referencing (IFR)

In-Field Referencing (IFR) utilises the BGGM and the harmonic properties of magnetic fields from airborne or marine surveys to estimate the combined core and crustal field vector at surface and at depth. It improves the resolution of the local field down to kilometre scales.

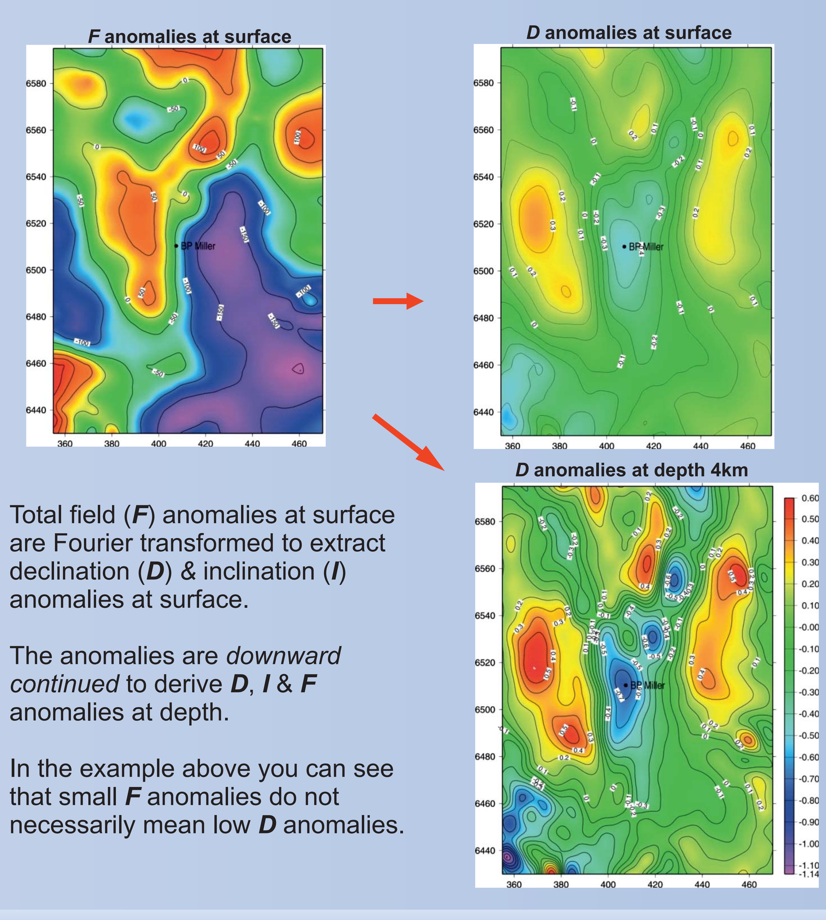
Crustal field anomalies are often significant for directional drilling (several tenths of a degree and more). The crustal field varies only on geological timescales, and can therefore be considered as a static offset to values derived from global models.

IFR makes use of existing non-exclusive surveys and commissioned surveys, where necessary. BGS has also conducted marine magnetic surveying in the North Sea with Tech21 and have carried out land surveys for operations in the UK, Alaska and Azerbaijan.

Error analysis is carried out using surveys and independent vector ground measurements and observatory data from around the world.

Main + Crustal Field

Local magnetic surveys are carried out by air, sea or land in the vicinity of the drill area. Scalar aeromagnetic data are checked against direct measurements of the field where available.



Total field (***F***) anomalies at surface are Fourier transformed to extract declination (***D***) & inclination (***I***) anomalies at surface.

The anomalies are *downward continued* to derive ***D***, ***I*** & ***F*** anomalies at depth.

In the example above you can see that small ***F*** anomalies do not necessarily mean low ***D*** anomalies.

Interpolation In-Field Referencing (IIFR)

Interpolation In-Field Referencing (IIFR) completes the picture by combining IFR with data from nearby observatories to estimate the real-time field at the drill site. Where no nearby observatories exist, BGS has worked in partnership with drilling companies to install one.

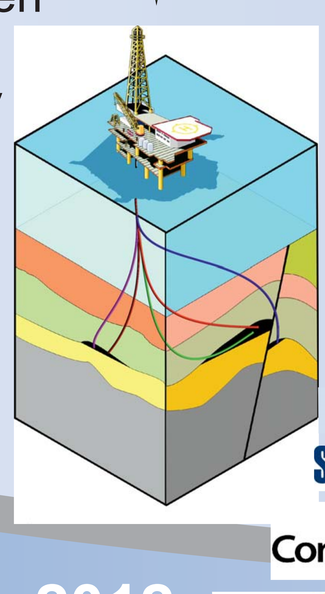
The Earth's magnetic field (***B***) varies with time due to solar-driven external fields that can be both regular daily variations and irregular disturbances. Even at UK latitudes during solar minimum on an undisturbed day in the winter, the daily range of the magnetic field direction exceeds the desired threshold accuracy of one tenth of a degree.

By combining the IFR results with the external field as measured at nearby magnetic observatories the sources of ***B*** are all accounted for. Thus, IIFR provides accurate estimates at the drilling site for correction of borehole surveys. See: *Reay SJ, Allen W, Baillie O, Bowe J, Clarke E, Lesur V and Macmillan S (2005) Space weather effects on drilling accuracy in the North Sea. Ann Geophys 23:3081–3088*

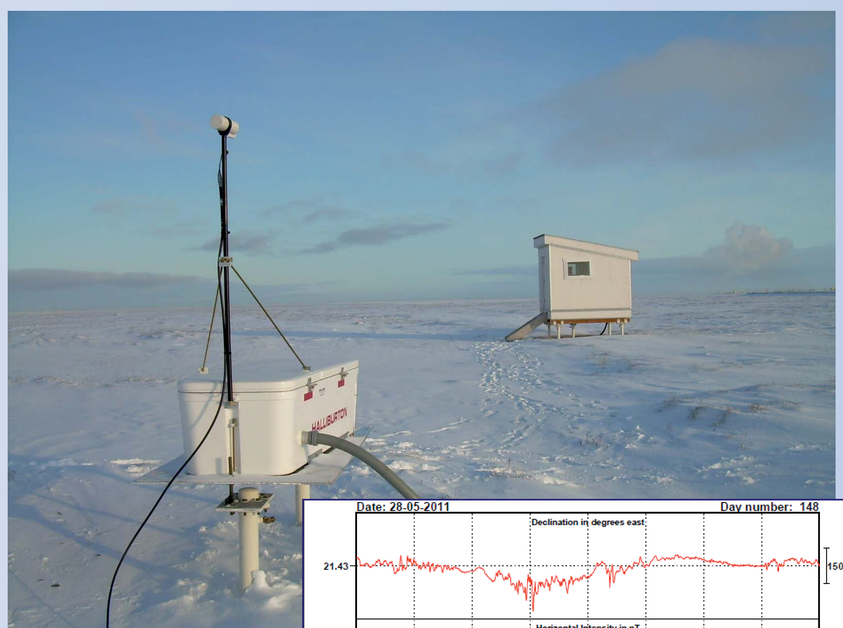
BGS maintain high-quality magnetic observatory operations to meet the demands of the oil & gas industry. A programme of infrastructure improvements has been conducted to maintain data supply installing back-up or fail-over systems at all parts of the data processing chain from observatory to customer.

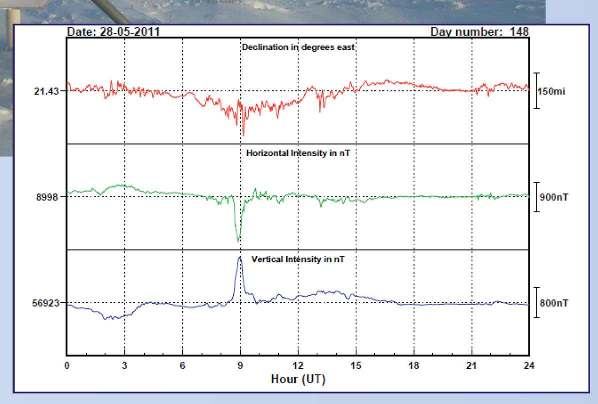
Error analysis has been carried out using UK magnetic observatories and in-situ vector field measurements:

Gaussian 2-sigma equivalent		
95.4% confidence limit		
D	*I*	*F*
0.26°	0.12°	73 nT



Main + Crustal + External Field

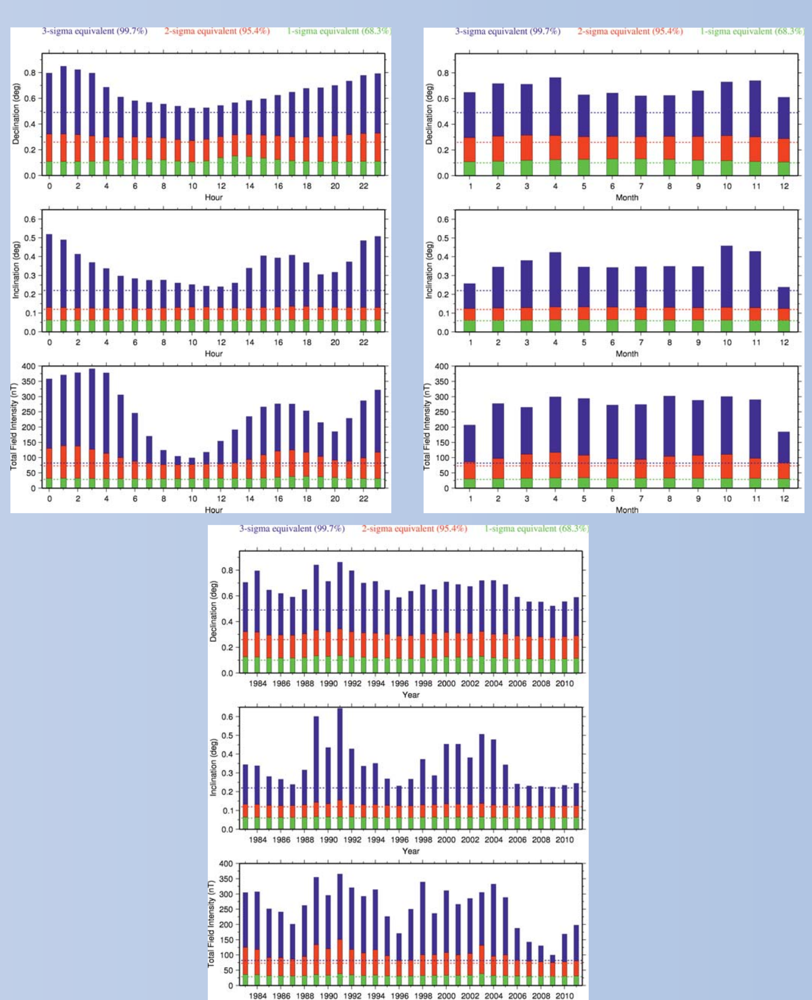




A magnetic observatory is a place where the geomagnetic field is monitored with accuracy and resolution sufficient to characterise its variations on time-scales ranging between seconds and decades.

BGS operate three observatories in the UK. Pictured above is an observatory installed in Alaska in partnership with Halliburton to support nearby drilling operations.

The graph shows an example *magnetogram* representing the vector magnetic field recorded at this observatory over a 24 hour period.



The variation of uncertainty in IFR data with time of day, month and phase of the geomagnetic activity cycle in the North Sea, is illustrated above.

The geomagnetic activity cycle has approximately the same 11-year period as the solar activity cycle but with a lag of 2-3 years.

Using IIFR both removes the variation in, and reduces the magnitude of, the uncertainties. Quality control of downhole data from individual surveys is also improved. The dashed lines on the plots above are the uncertainties when IIFR is used.

BGS magnetic referencing has been used by the following:

TALISMAN ENERGY, HALLIBURTON, bp, devon, PERENCO, wintershall, ExxonMobil, woodside, Schlumberger, BAKER HUGHES, BG GROUP, Canadian Natural, Eni, Marathon Oil Corporation, DET NORSKE, cenovus ENERGY, MAERSK, nexen, ConocoPhillips, SUNCOR ENERGY, DONG energy, Weatherford, e·on, Apache, HESS, Chevron, EnQuest, Husky, TOTAL, Statoil

More Information

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