The Effect of Space Weather on Drilling Accuracy in the North Sea

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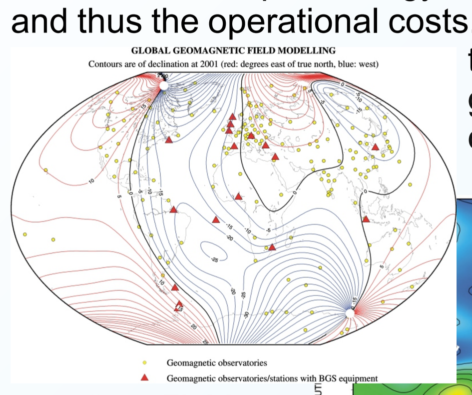
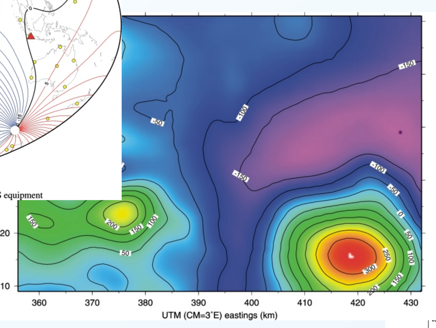
Directional Drilling and BGS Services to the Oil Industry

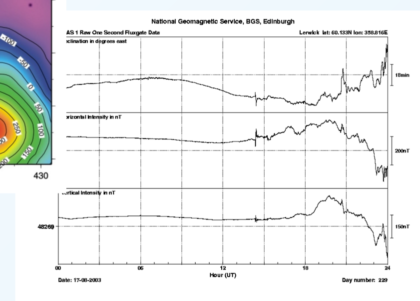
Directional drilling is now a firmly established technique in use within the oil industry. Using magnetic survey instruments to make measurements while drilling (MWD) instead of accurate, but expensive, gyroscopic instruments, can significantly reduce the drilling time and thus the operational costs. Information on the Earth's magnetic field is needed to attain the required levels of accuracy for MWD magnetic surveys. In general, the oil industry requires accuracies of 0.1° in declination(D), 0.05° in inclination (I) and 50nT in total field strength(F)[1].



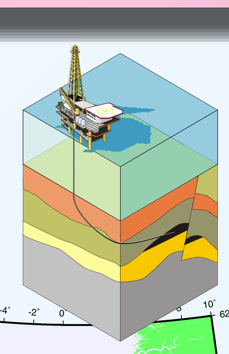
Core Field

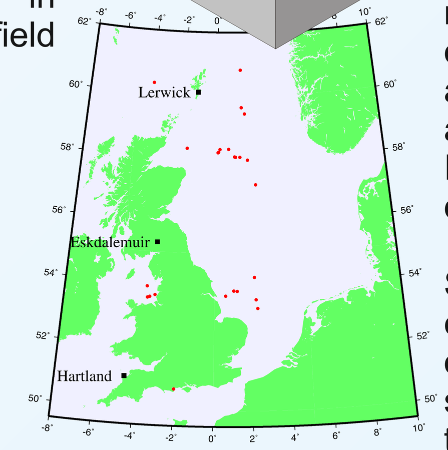


Crustal Field



External Fields

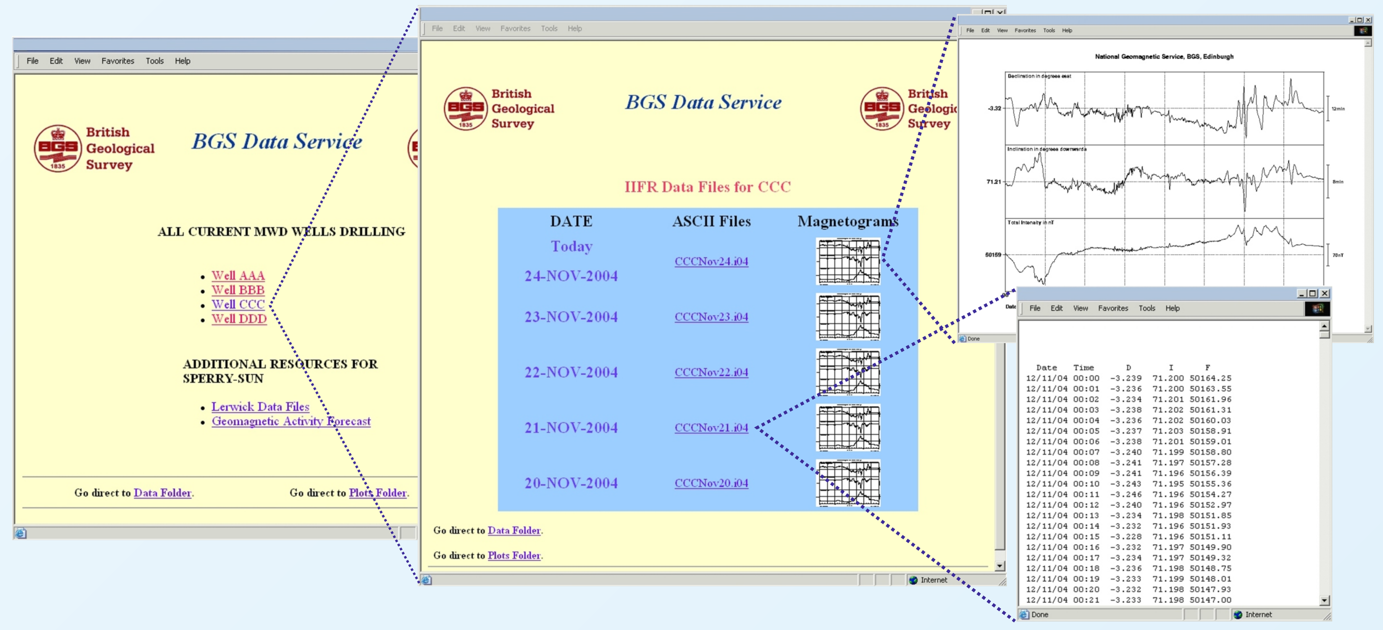




Oil fields at high, mid and low latitudes where geomagnetic data have been applied

The British Geological Survey (BGS) provides information to surveyors as part of our In-Field Referencing (IFR) service. Information on the core field, generated by the fluid motion in the Earth's core, and the crustal field, due to the magnetisation of local rocks, is given. Using data from magnetic observatories estimates of the external field, and therefore the space weather effects, can also be provided to produce real-time Interpolation In-Field Referencing (IIFR) data.

Setting up IIFR for a particular well is equivalent to setting up a virtual geomagnetic observatory at the rig and includes the most significant sources of the field. The errors, in the generation of IIFR data, are estimated to be less than 0.01° for D and I and 10 nT for F[2].



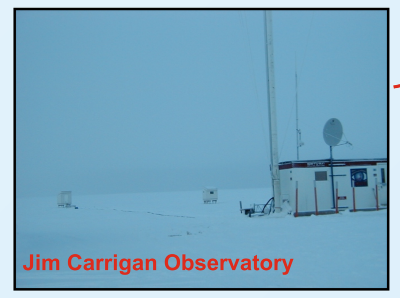
Our Online Data Service

Above: Real-time values can be accessed by the surveyors via a secure website displaying both digital one-minute data and associated magnetograms. These are currently updated every 10 minutes.

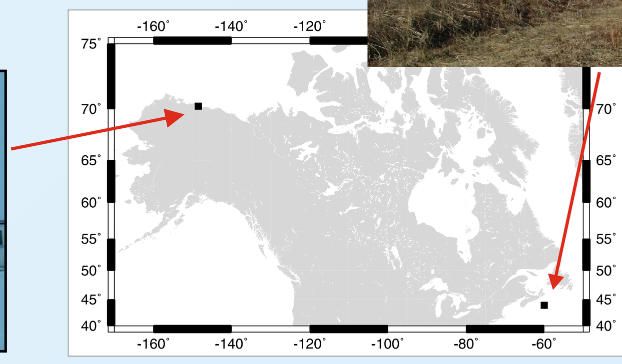
Below: The demand for real-time high-quality magnetic observatory data lead to the establishment of magnetic observatories in oil drilling areas. Sable Island Observatory off the coast of Nova Scotia became operational in 1999. A magnetic observatory, originally established by Halliburton and BGS in Prudoe Bay, Alaska, was recently upgraded and renamed the Jim Carrigan Observatory (JCO). Two further observatories have also been established by BGS with the aid of oil industry funds: Ascension Island in 1992 and Port Stanley in the Falkland Islands in 1994.

These observatories have contributed to a better global network of observatories and have improved the quality and distribution of data for main field modelling and other scientific studies.

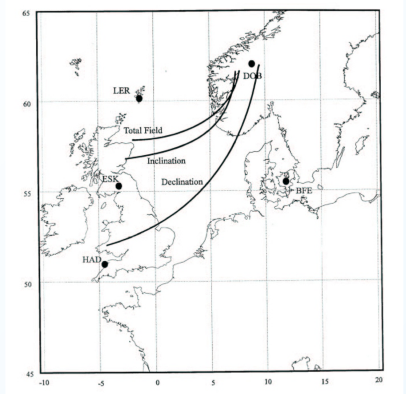
Sable Island Observatory



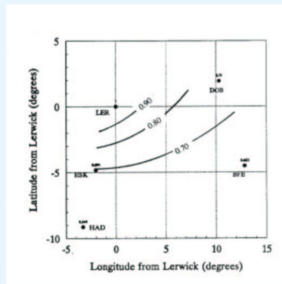
Jim Carrigan Observatory



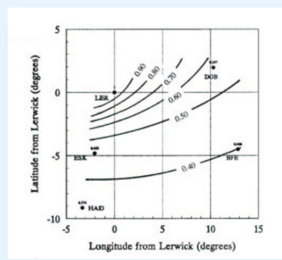
External-Field Error Analysis



Left: In 1994 an investigation was carried out to show the accuracy with which data from Lerwick observatory can be used to estimate magnetic variations for any area in the North Sea. Lerwick data were compared to data from four other observatories around the North Sea: Dombas observatory in Demark (supplied by the Danish Meteorological Institute), Brörfelde Observatory in Norway (supplied by the University of Bergen) and Eskdalemuir and Hartland observatories owned by BGS. This map shows the 95% confidence contours for thresholds of 0.1° in declination, 0.05° in inclination and 50nT in total field for any given day when magnetic activity levels are unknown[3]. If the user knows the magnetic field is quiet the confidence over most of the North Sea rises to 99%. Confidence drops below the 95% level during disturbed days (see **Right**)



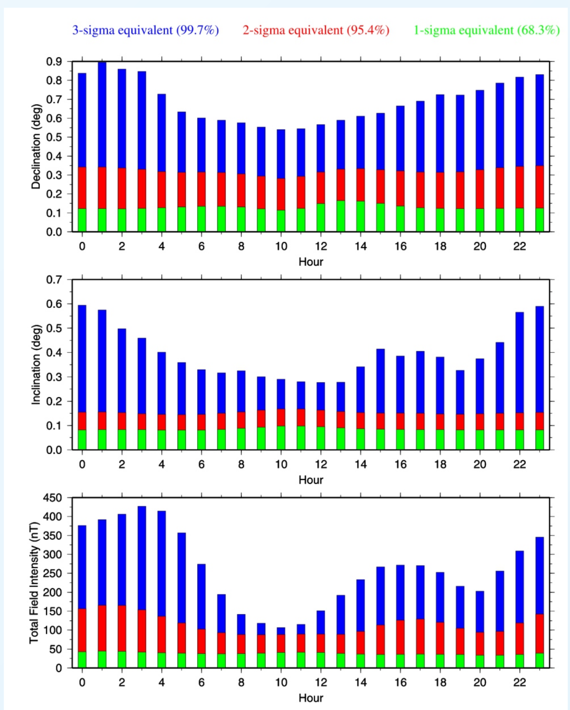
Left: The confidence limits during a major storm.

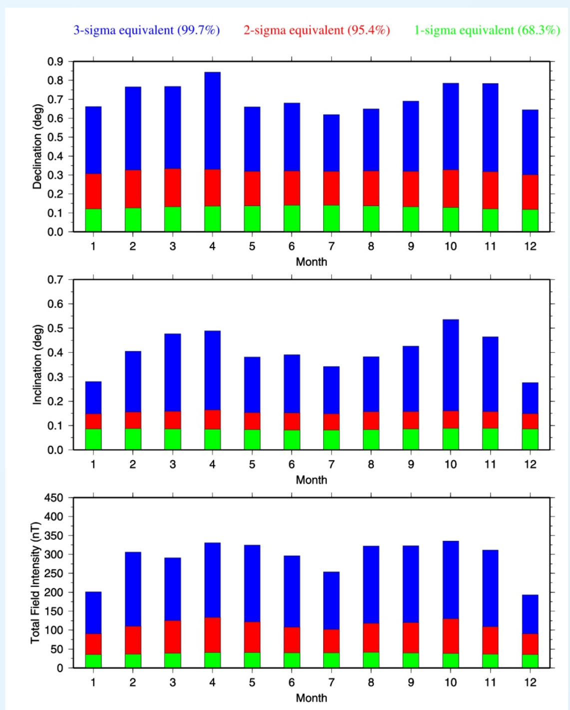


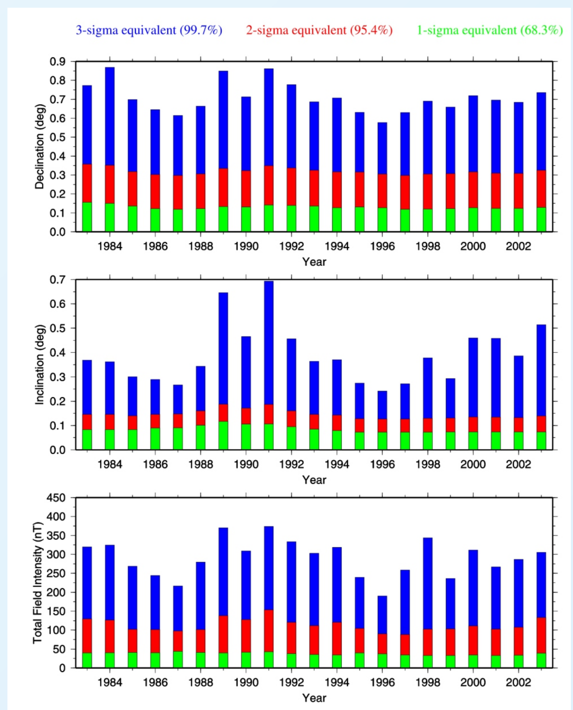
Right: The confidence limits during a severe storm.

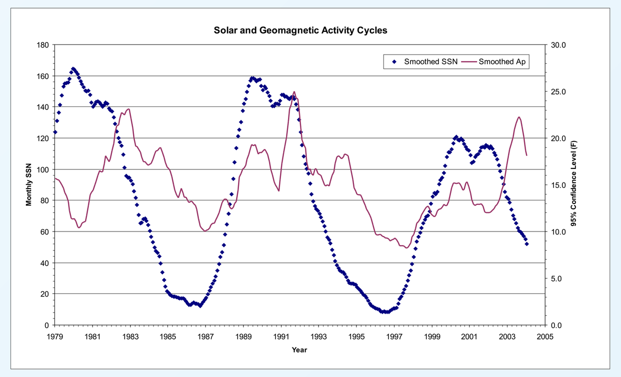
For a typical North Sea well, data were generated using all definitive one-minute values since 1983, when digital recording at the three UK observatories began. This covers two solar activity cycles. These are compared with the main and crustal field values. The differences, or errors, represent the external field variations. These data are used by surveyors at the well planning stage to calculate the error margin in the final target.

Right: The variation of the errors for a typical North Sea well at a high latitude are shown in the three histograms. The space weather effects are clearly highlighted with the 11-year solar cycle, the bi-annual (Russell-McPherron) effect and the local time effects are evident.

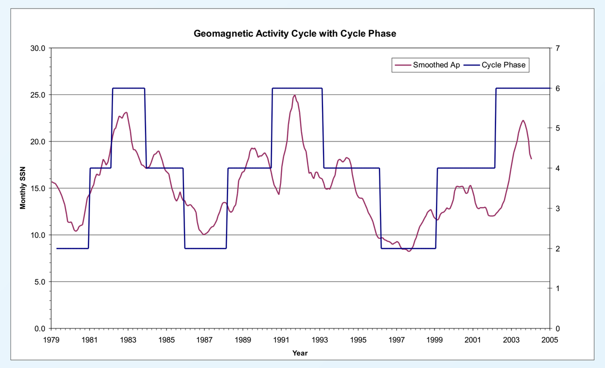








Left: The geomagnetic activity cycle has approximately the same 11-year period as the solar activity cycle but with a lag of 2-3 years.



Left: The four phases of the geomagnetic activity cycle that have been used in this analysis.

Potential Error Reduction In Magnetic Field Estimates Associated With The External Field Variation

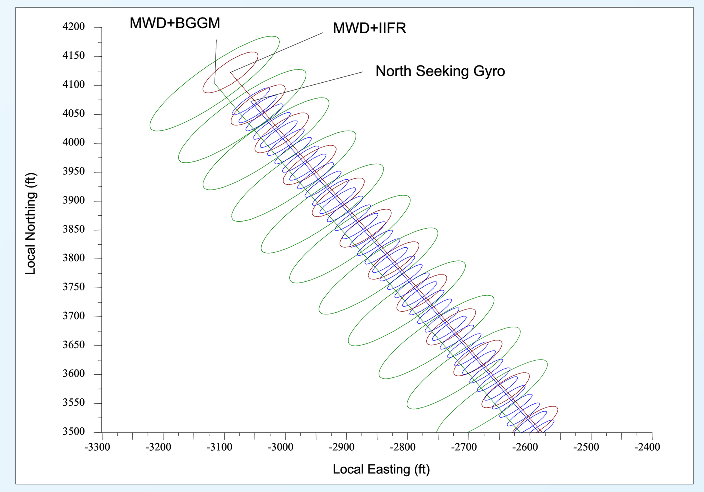
	Winter (Nov/Dec/Jan/Feb)			Equinoctial (Mar/Apr/Sep/Oct)			Summer (May/Jun/Jul/Aug)		
	D (°)	*I* (°)	*F* (nT)	*D* (°)	*I* (°)	*F* (nT)	*D* (°)	*I* (°)	*F* (nT)
A Well at Low Latitude									
Maximum Phase	19%	33%	9%	23%	25%	16%	23%	25%	20%
Declining Phase	12%	17%	7%	19%	25%	13%	15%	17%	13%
Minimum Phase	8%	17%	5%	12%	17%	11%	12%	17%	12%
Ascending Phase	12%	25%	5%	19%	25%	13%	19%	17%	14%
A Well at Mid Latitude									
Maximum Phase	23%	25%	21%	27%	25%	36%	27%	25%	34%
Declining Phase	19%	17%	13%	23%	25%	30%	23%	17%	20%
Minimum Phase	12%	17%	9%	15%	17%	14%	15%	17%	16%
Ascending Phase	15%	25%	12%	23%	33%	30%	23%	25%	22%
A Well at High Latitude									
Maximum Phase	27%	25%	43%	35%	25%	78%	27%	33%	70%
Declining Phase	23%	17%	32%	31%	25%	71%	27%	17%	43%
Minimum Phase	19%	17%	22%	23%	17%	34%	19%	17%	28%
Ascending Phase	19%	25%	28%	27%	33%	70%	23%	25%	47%

Left: The percentage reductions in error by accounting for the external variations are shown for three example wells at different latitudes in the North Sea. Percentage reductions vary with the four phases of the geomagnetic activity cycle.

Industry Examples

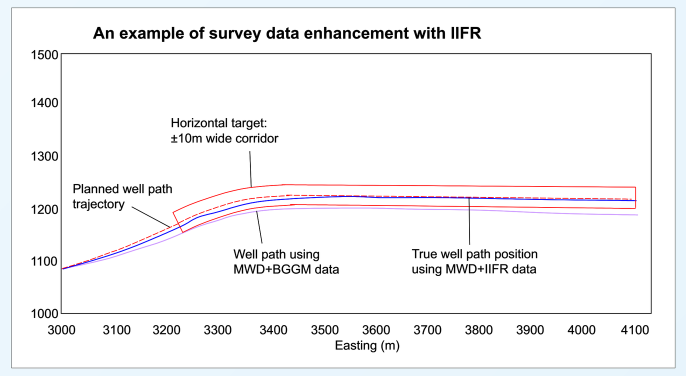
If the external field variations are accounted for drillers can continue operations during magnetic storms avoiding the time and expense of waiting for quiet magnetic conditions to re-survey. Even during quiet magnetic periods it can be used to identify other potential sources of error in the magnetic survey tools used, or with other down-well equipment and systems such as magnetically susceptible drilling fluid (magnetic mud).

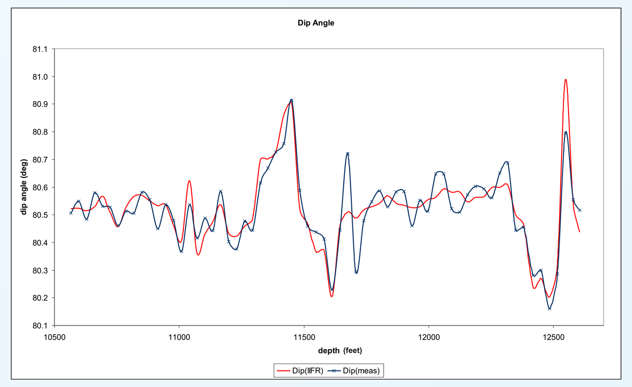
In Norway it is very common to use recycled oil-based mud as a drilling fluid. Over the many months that this same mud is used and re-used, large quantities of abraded steel become suspended in this fluid. This has the effect of attenuating the MWD sensor readings as the steel particles shield the tool from the full effects of the Earth's Magnetic Field.



Above: A wellpath with error ellipses for three different survey methods: MWD with main field corrections; MWD with all sources of the magnetic field corrected for, and gyroscopic corrections. The accuracy of the fully corrected MWD method is almost as good as that of the more expensive gyroscope method.

Right: The planned and actual wellpath of a near horizontal well are shown. The improvement gained by accounting for all sources of the magnetic field is clear.



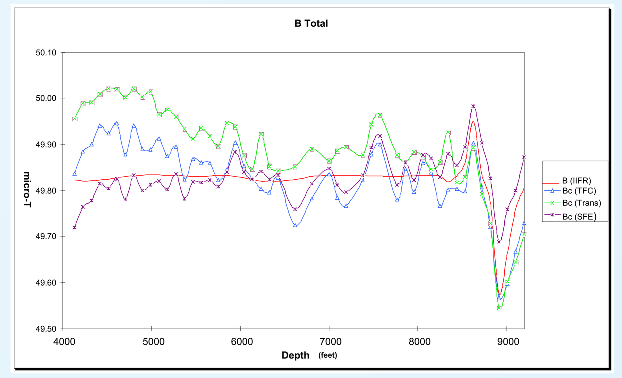


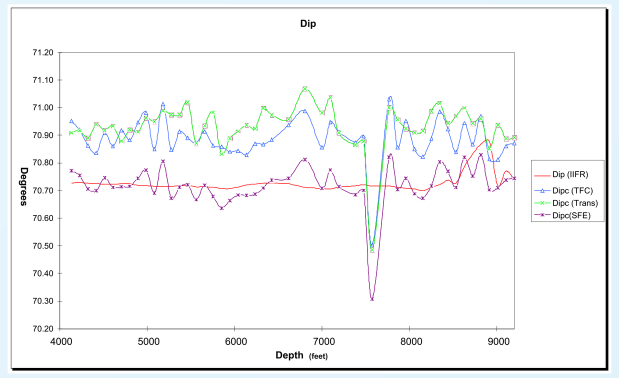
Left: This example is from a survey taken while drilling of a well in Alaska. This was surveyed during moderate conditions so compares favourably with the type of effects seen in the North Sea.

The blue line shows the magnetic survey measurements taken at the drill site. The red line is the magnetic data supplied from JCO Observatory. Two magnetic components are shown: Inclination (Dip) and Total Magnetic Field (Bt).

This shows how the magnetic data provide useful quality control information: if the survey measurements do not match the observatory data then it may suggest there is a problem with the survey tools or another source. (See **Right**)

The magnetic field data are a valuable aid to the decision making process.

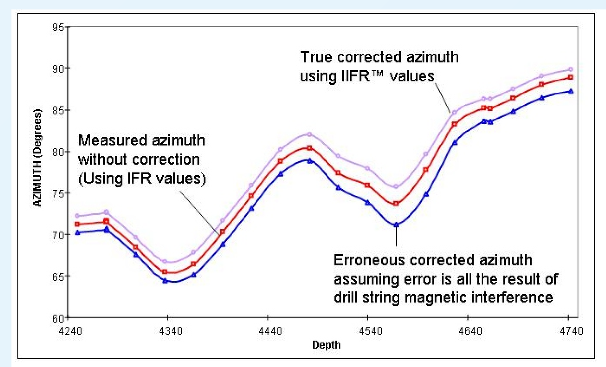




Left: This example is from a survey taken while drilling of a well in the North Sea. The purple line shows the magnetic survey measurements taken at the drill site and the red line shows the BGS data supplied. (The blue and green lines should be ignored). Two magnetic components are shown: Inclination (dip) and Total Magnetic Field (B).

The total magnetic field data correlates well throughout the survey. However, it is clear with inclination (dip) there is a mismatch between the observatory data and the survey results suggesting a error is present. The cause of this is currently unknown and is being investigated.

Right: Using external field values to correct a wellbore direction for the effect of interference caused by magnetic mud. If the normal assumption is made, which is that all the magnetic interference comes from the drill string, the result is an azimuth error of 3°. Without IIFR it would have been impossible to differentiate between the drill string interference error and the effect of the magnetic mud. When drilling wells that are close to horizontal the drill string correction algorithms are very sensitive to small errors in the magnetic field values used.



Acknowledgments:

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References:

1. Russell, J. P., Shiells G. and Kerridge D. J., 1995. Reduction of well-bore positional uncertainty through application of a new geomagnetic in-field referencing technique. Paper SPE 30452, presented at the 1995 SPE Annual Technical Conference and Exhibition, Dallas, October 22-25.

2. Williamson, H. S., Gurden P. A., Kerridge D. J. and Shiells G., 1998. Application of Interpolation In-Field Referencing to Remote Offshore Locations. Paper SPE 49061, presented at the 1998 SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, September 27-30.

3.Turbitt, C W and Clark, T D G, 1994. The Use of Lerwick variometer measurements to estimate magnetic disturbances over the North Sea. British Geological Technical Report WM/94/21C