SPACE WEATHER SERVICES FOR THE OFFSHORE DRILLING INDUSTRY

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ABSTRACT

Directional drilling is a technique, which has developed over the last few decades, to enable the oil industry to maximise the extraction of oil whilst minimising costs. Although the required directional accuracy (0.1 degrees) can be achieved using gyroscopic instruments, these surveys are expensive. A cheaper method is to use magnetic survey instruments to make measurements while drilling. Here the accuracy is limited to how accurate the direction of the Earth's magnetic field is known. In the North Sea this typically changes by up to 0.2 degrees throughout the day, and is much greater during magnetic storms. The British Geological Survey has developed the technique of Interpolated In-Field Referencing (IIFR) to remove this source of error by using data from its magnetic observatories. Data are supplied to well-bore surveyors in near-real time, allowing decisions to be made on well steering. When using IIFR, an accuracy similar to that achieved with gyroscopic survey tools can be achieved with magnetic survey tools. IIFR has been applied in more than 30 offshore oilfields around the UK, and has been applied in other high latitude oilfields offshore Canada and the USA.

1. INTRODUCTION

The requirement to extract the maximum amount of oil from reservoirs while continually striving to reduce drilling costs has led to the development of the technique of directional drilling over the last few decades. The oil industry now has the capability to drill dozens of wells from a single platform in many different directions, extending typically to 5km horizontally. The world record for extended reach drilling is in excess of 11km. The size of the geological targets requires an accuracy in direction of the order of 0.1 degrees in navigating the well-bore. Surveys of this accuracy can be made using gyroscopic instruments, but these require drilling to stop for the duration of the survey, which may be some hours. When the cost of the rig hire is taken into account it makes these surveys expensive to conduct. A cheaper method is to use magnetic survey instruments in a non-magnetic part of the drill string near the drill bit, which can make measurements while drilling. These magnetic surveys rely on the principle of measuring the direction of the well-bore relative to the direction of the local geomagnetic field [1]. Thus, the accuracy is limited by the accuracy with which the direction of the Earth's magnetic field is known at the drilling location. In the North Sea this may typically change by up to 0.2 degrees throughout the day, and during magnetic storms deviations of the order of a few degrees may be experienced. The British Geological Survey (BGS) has developed the technique of Interpolated In-Field Referencing (IIFR) to remove this source of error by using data from its magnetic observatories.

2. MAGNETIC OBSERVATORIES

BGS operates three observatories in the UK: One at Lerwick in the Shetland Islands, one at Eskdalemuir in the Scottish borders and one at Hartland in North Devon. These are shown in Fig. 1.

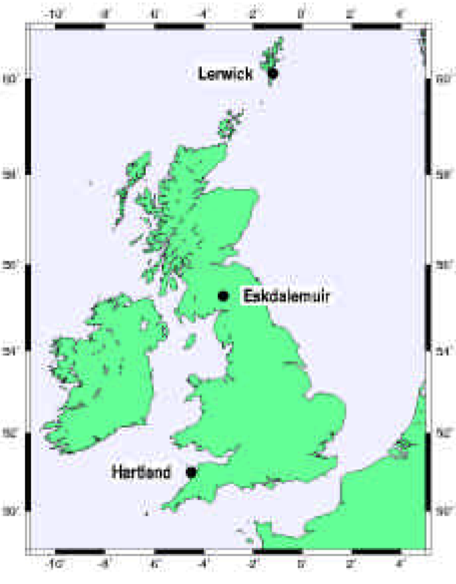

Fig. 1 The UK Magnetic Observatories

Data from the observatories are transferred to Edinburgh in near real-time. Data products such as one-minute values are derived and can be made available to the oil industry within minutes of being recorded.

BGS also operates a magnetic observatory on Sable Island, which is a small sandbank 290 km off the coast of Nova Scotia, Canada. This observatory was established specifically for IIFR.

3. INTERPOLATED IN-FIELD REFERENCING

IIFR was jointly developed by BGS and Sperry-Sun Drilling Services to give one-minute magnetic values at the oil well locations, enabling the technique of measurement-while-drilling (MWD) to achieve the accuracy required.

At any location near the Earth's surface, the magnetic field (**B**) may be expressed as the vector sum of the contributions from three main sources: the main field generated in the Earth's core ($\mathbf{B}_m$), the crustal field from local rocks ($\mathbf{B}_c$) and a combined disturbance field from electrical currents flowing in the upper atmosphere and magnetosphere, which also induce electrical currents in the sea and the ground ($\mathbf{B}_d$):

$$\mathbf{B} = \mathbf{B}_m + \mathbf{B}_c + \mathbf{B}_d$$

In directional drilling, magnetic declination (the difference between true or geographic north and magnetic north) is required to convert the survey measurements to the geographic reference frame. Additionally the total field intensity and inclination (the angle the field direction makes with the horizontal plane) are required for algorithms which remove interference from the drill string. When using magnetic data to improve drilling accuracy, one can make an estimate of **B** from a spherical harmonic model of the geomagnetic field, which includes the secular variation element, such as the International Geomagnetic Reference Field (IGRF). The assumption is then made that this is a good estimate of **B**. However, spherical harmonic models of the geomagnetic field are only intended to provide estimates of $\mathbf{B}_m$, and the contributions of $\mathbf{B}_c$ and $\mathbf{B}_d$ may be large enough in many parts of the world to cause significant error if it is assumed that the model value alone is an estimate of the local field, **B**.

The IIFR technique must therefore also consider $\mathbf{B}_c$ and $\mathbf{B}_d$ sources. Detailed crustal field anomalies are obtained from aeromagnetic and marine surveys of the oil field areas. Both $\mathbf{B}_m$ and $\mathbf{B}_c$ are not influenced by space weather effects and are not considered further here.

The disturbance or external field contributions ($\mathbf{B}_d$) are estimated for the location of the oil well using data from the magnetic observatories. The levels of accuracy required by directional drillers are 0.1 degrees in declination, 0.05 degrees in inclination and 50 nT in total field intensity. Fig. 2 gives an indication of why the external field, $\mathbf{B}_d$ needs to be accounted for when drilling wells at UK latitudes.

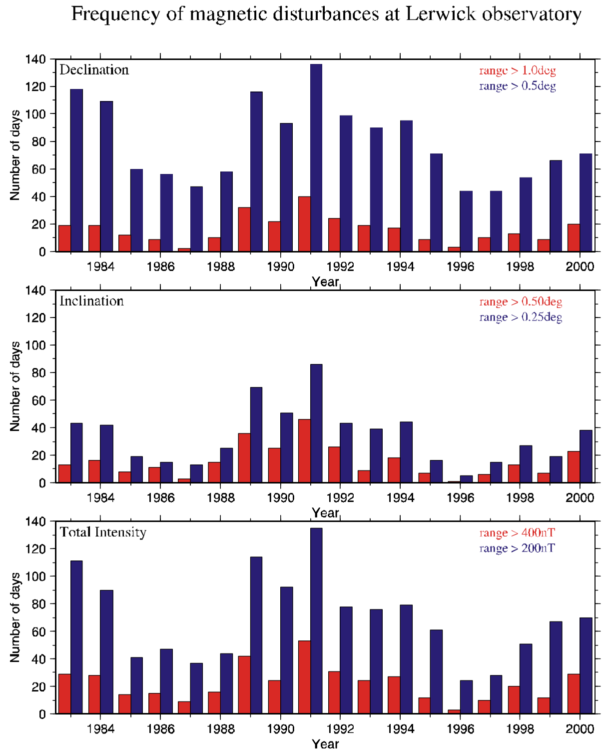

Fig. 2. Frequency of magnetic disturbances at Lerwick observatory

One-minute values in declination, inclination and total field are derived for all oil wells using the IIFR technique. Data for the wells currently drilling are made available to borehole surveyors throughout the day in close to real-time - updates are available every 10 minutes. An example of a complete day of data for a single well location is shown in Fig. 3.

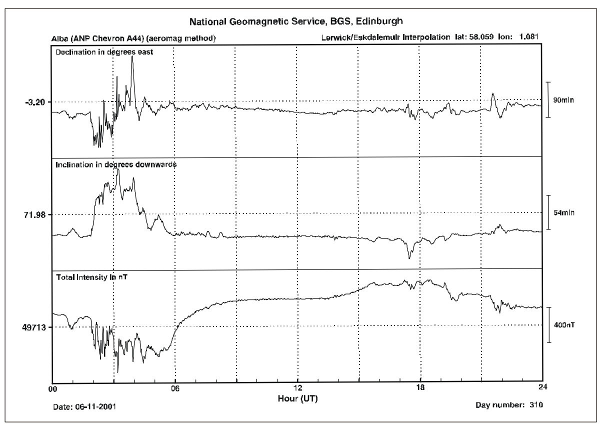

Fig. 3 Magnetogram showing one-minute field values at the location of an oil well drilled in the Alba oil field

In borehole surveying, MWD techniques are now firmly established as an alternative to gyroscopic surveys. A similar accuracy can be achieved if IIFR is used to correct for local magnetic variations and it is a faster and cheaper option.

By comparing the survey results for a bore-hole drilled using MWD with and without IIFR corrections, the effect of a magnetic storm is observed. Fig. 4 shows the changes in the measured (drilling) azimuth with depth highlighting the importance of correcting by using IIFR.

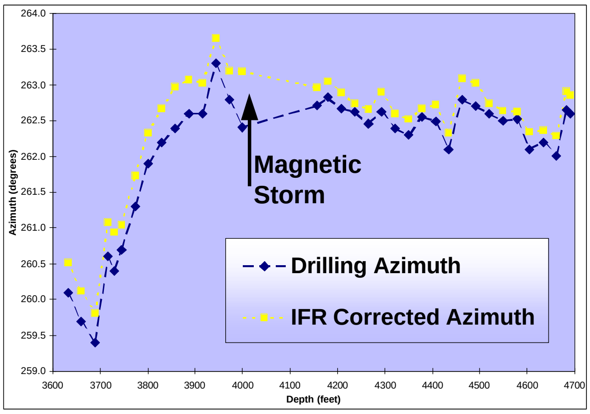

Fig. 4 Uncorrected drilling azimuth compared to IIFR corrected values

IIFR has now been applied in more than 30 offshore oilfields around the UK, and has been applied in other high latitude oilfields offshore Canada and the USA. Fig. 5 shows the locations, where BGS have used the observatory data to supply the oil industry with IIFR values.

The world's longest extended-reach well, which was drilled at Wytch Farm, can access oil reserves extending in excess of 11km offshore beneath Poole Bay on the southern coast of England. The application of IIFR in MWD surveys has contributed to this world record.

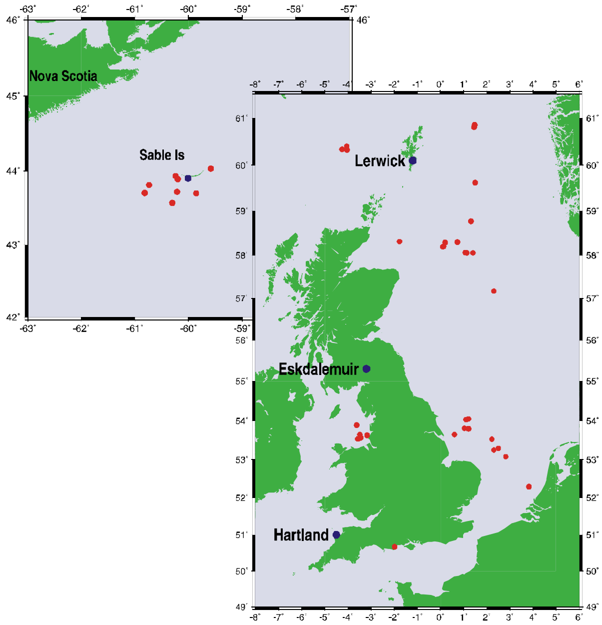

Fig. 5 Locations of oil fields where external field variations have been used to improve drilling accuracy.

4. CONCLUSIONS

As a space weather service, IIFR can be characterized primarily as a near real-time monitoring service. Forecasting does not play, and is not likely to play, a significant role because no decisions are made affecting drilling operations based on a space weather forecast. IIFR has been applied in more than 30 offshore oilfields around the UK, and has been applied in other high latitude oilfields offshore Canada and the USA. It is unlikely that the benefits would be significant at geomagnetic latitudes much lower than the North Sea.

Acknowledgement This report is published by permission of the Director of the British Geological Survey (NERC).

Reference

1. Russell J.P., Shiells G., and Kerridge D.J., Reduction of Well-bore Positional Uncertainty Through Application of a New Geomagnetic In-Field Referencing Technique, Society of Petroleum Engineers, Paper 30452, 1995.