British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Jim Carrigan Observatory and Directional Drilling in Alaska

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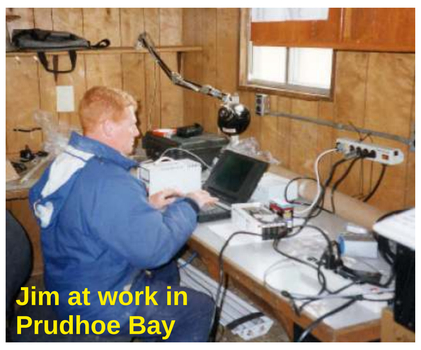
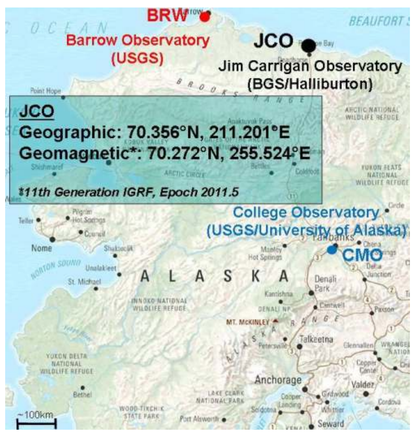
INTRODUCTION

External field variations, such as those observed in one-minute observatory data are sources of error for magnetic down-hole survey tools used in directional drilling. These tools, which include magnetic probes, are used in measurement while drilling (MWD) methods to monitor the well-bore position and navigate to the planned oil or gas target[3,4,6]. Significant deviations from the well plan can be avoided by using measurements from magnetic observatories to correct the surveys. Jim Carrigan Observatory (JCO) was first established in 1997 in a joint scientific/industry venture to support directional drilling operations in Prudhoe Bay, Alaska. The site was chosen to be as near to drilling operations as possible, providing the necessary data to combine the measured external field variations with global and crustal field models and thus provide accurate reference values for well-bore surveys.



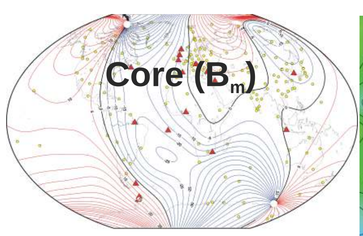
OBSERVATORY OPERATIONS

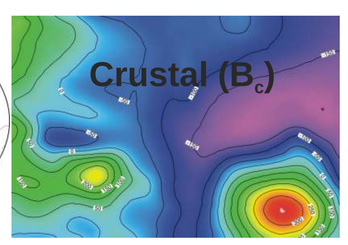


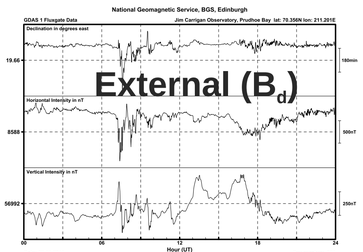
JCO was upgraded in 2003 with the installation of the BGS GDAS system[1,2,5] and has operated at full observatory status since. The remote conditions of the Alaskan North Slope provide many technical problems to be overcome such as maintaining continuous communications and power supply, and working in extreme cold temperatures and other adverse weather with limited daylight during winter. One-second variations are sampled using a suspended DMI (now DTU Space) FGE magnetometer. This fluxgate is a standard observatory instrument, used globally due to its long-term stability with low temperature coefficient and built in tilt compensation. The two standard absolute instruments in operation are a scalar Overhauser magnetometer providing 5-second values and a fluxgate-theodolite for manual observations, two sets of which are made every two weeks.

GEOMAGNETIC REFERENCE FIELD VALUES

To accurately estimate reference field values at the drilling location all sources of the Earth's magnetic field need to be accounted for. The main (core) field can be represented by a global geomagnetic field model. Locally, crustal magnetic fields can cause significant biases in the field vector. Magnetic survey scalar data can be used to determine variations in the crustal magnetic field vector using Fourier transformation techniques.





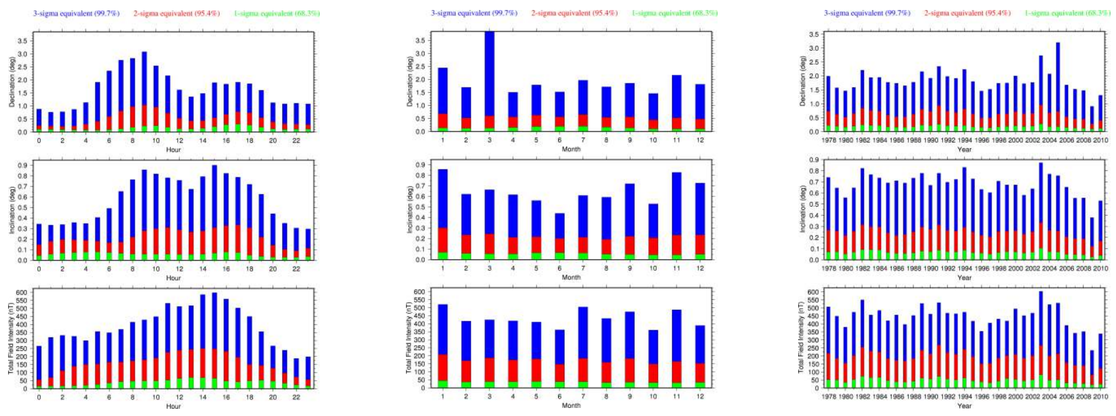


$$B_{ref} = B_m + B_c + B_d$$

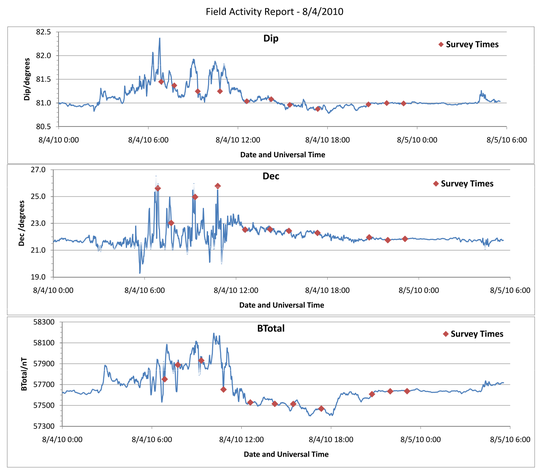
At mid to high geomagnetic latitudes it is important to also include the disturbance field variations, which can be estimated for the drilling location using observatory one-minute values[3,4,6]. This becomes essential at locations like Alaska, where B_d is greatest due to the proximity of the auroral electrojet.

DISTURBANCE FIELD IN ALASKA

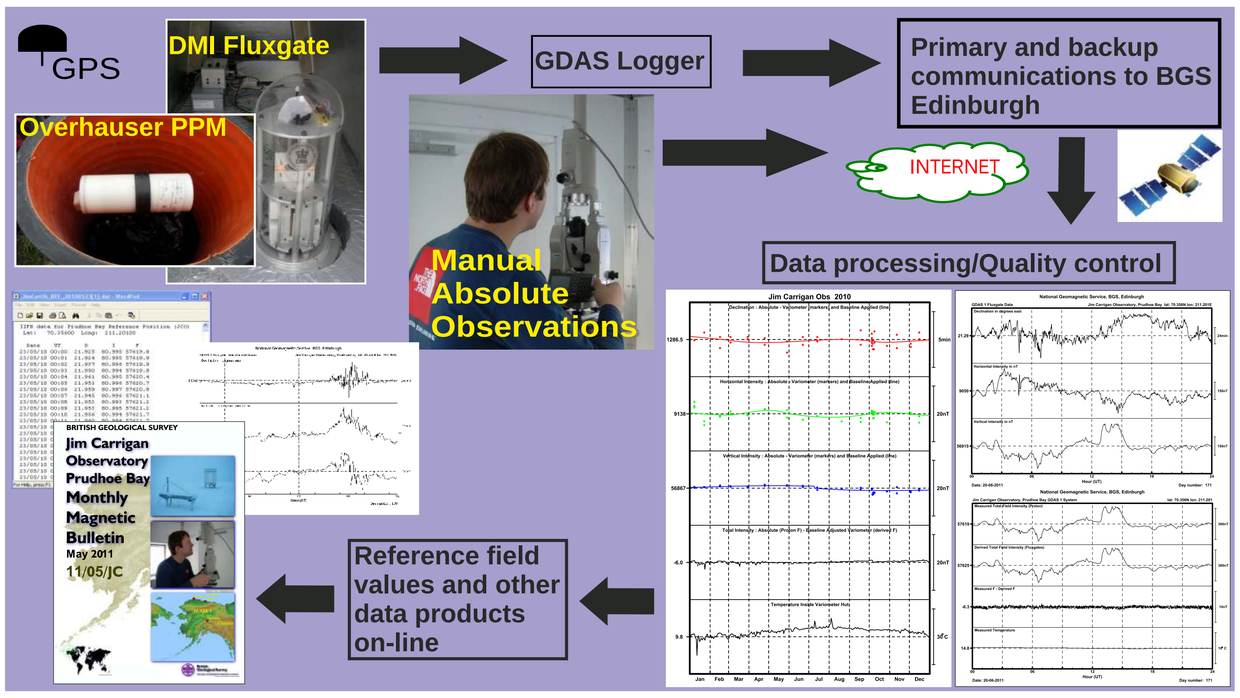
Using one-minute values from JCO (2003-2010) and Barrow (BRW) observatory (1978-2008), operated by USGS, B_d for the Prudhoe Bay drilling location can be derived. By ordering the data over a given period, the 99.7, 95.4 and 68.3 percentiles can be found, which represent the additional error in the reference field estimates when B_d is not included. The results as a function of UT hour, month and year are shown below. When combined with errors associated with the derivation of B_m and B_c, these correspond to the 3-, 2- and 1-sigma confidence limits (for a Gaussian distribution) of the estimates.



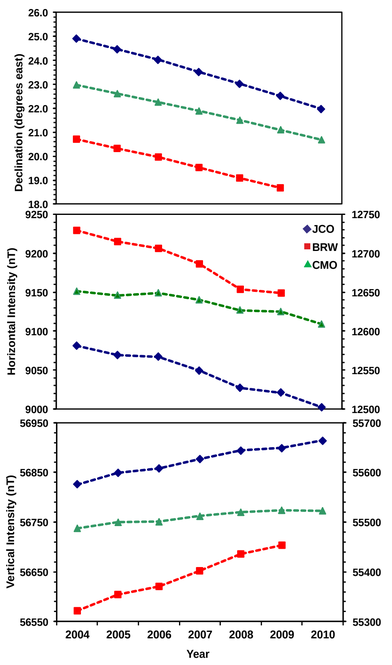
INDUSTRY EXAMPLE



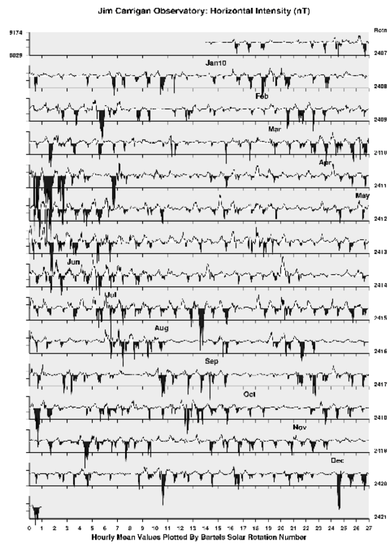
The plot shows an example of the reference field applied while drilling over a 30 hour period in August 2010. The red points indicate the time at which magnetic directional surveys were acquired down hole. By coincidence the directional surveys were taken at times of maximum declination variation. Without reference values the measured direction of the well would have been in error by several degrees. With each survey the directional driller would have steered the well back to what appeared to be the planned direction. When activity subsided the driller would again observe a well direction error and further steering would be required. These corrections to wellbore direction can reduce the length of hole drilled in a given time, adding to the costs. In addition, there is increased risk of complications in well construction due to the increased tortuosity introduced by the additional steering. Real time corrections for declination prevented this from happening here and enabled 466 feet of hole to be drilled over the period.



JCO RESULTS



Despite the difficulties, JCO results are good quality and have been successfully used in directional drilling for over a decade. The observatory may have been purpose-built for this application, but the data, including one-second samples, one-minute, hourly (right), daily, monthly and annual mean values (compared to BRW and CMO left), are available for non-commercial scientific research. Membership of INTERMAGNET will be sought for JCO. Hourly and annual values are available from the WDC, Edinburgh. The provisional results are published monthly in bulletins and are available on-line at www.geomag.bgs.ac.uk/data_service/data/bulletins/jco.html



SUMMARY

INDUSTRY OBJECTIVES

- Save time and money on drilling operations
- Maximise production of oil and gas
- Hit the driller's target within a given error ellipse
- Avoid collisions with other wells
- Ensure safe working conditions for rig workers

WHAT IS REQUIRED?

- Accurate estimates of the full geomagnetic field vector along the well bore
- Accurate assessment of uncertainties for standard industry error models
- Continuous 24/7 reliable real time data
- The best and most up to date knowledge and skills in geomagnetism and observatory operations

SCIENTIFIC OBJECTIVES

- Better understanding of secular variation and core dynamics
- Improved models of geomagnetic field sources
- Observatory data to support satellite missions (e.g. ESA SWARM mission)
- Better understanding of ionospheric and magnetospheric processes
- Improved space weather predictions and real time monitoring

WHAT IS REQUIRED?

- Improved global coverage of ground-based measurements
- Operation of observatories to highest standards
- Availability of quasi-definitive observatory data
- Improved high time resolution variometer networks
- Long term continuous data from fixed location
- Continuous 24/7 real time data

EVERYONE WINS

- Increased number of high standard observatories
- Better global models for science and industry
- Real time quasi-definitive data
- Resilient systems with built in redundancy
- Improved MWD accuracies to compare with gyros
- Financial contribution from industry to science
- Knowledge exchange from science to industry

REFERENCES

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ACKNOWLEDGMENTS

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