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NATURAL ENVIRONMENT RESEARCH COUNCIL

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The Making of Ground-Based Vector Magnetic Field Observations and the Application of Results

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Ground-Based Observations (Repeat Stations)

In the UK, ground-based vector measurements are made over a network of 41 repeat stations; typically 10 stations per year. This results in an average spacing of around 90 km and repeat period of 4 years.

LOCATION & ANOMALY SURVEY
The absolute observing position is located, using GPS and triangulation from reference points, to within 0.5m. This is normally sufficient to minimise the magnetic contribution from local geology to subsequent secular variation estimates. A total field survey is made over a 40m x 40m grid, centred on the observing position, using a Proton Precession Magnetometer (PPM) to check for any 'man-made' sources of contamination (ferrous materials).

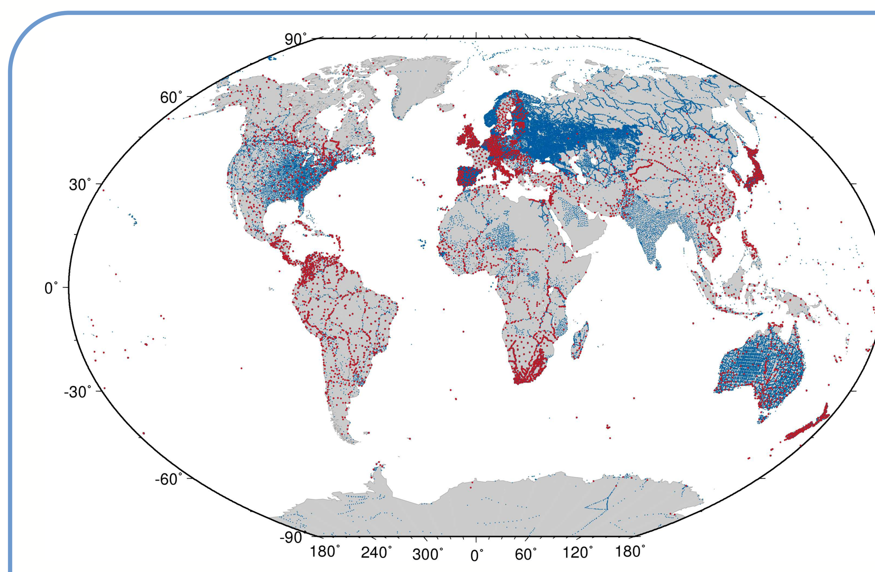
SCALAR DATA
A PPM records 1-minute samples of total field intensity over the period of the survey (~7 hours). This total field data is 'translated' to the absolute observing position by performing a site-difference measurement using a second PPM run concurrently at the absolute position for around 15 minutes.

VECTOR DATA
True North (TN) is determined, using a geodetic-grade differential GPS (Leica 500), with a north-seeking gyroscope (WILD GAK1) used as a backup. This takes one hour to complete and produces a TN reference with an accuracy of about 10". Eight absolute observations of Declination & Inclination are performed during the day, using a non-magnetic fluxgate-theodolite.

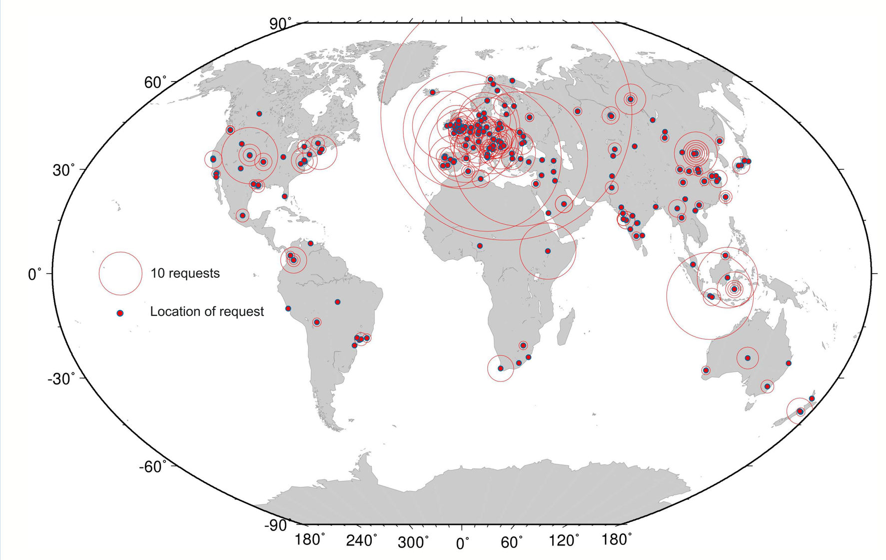
DATA PROCESSING
Raw measurements are post-processed using nearby observatory data as a reference, to remove the external field sources, a process known as reduction to quiet time.

Word Data Centre Holdings (Supply & Demand)

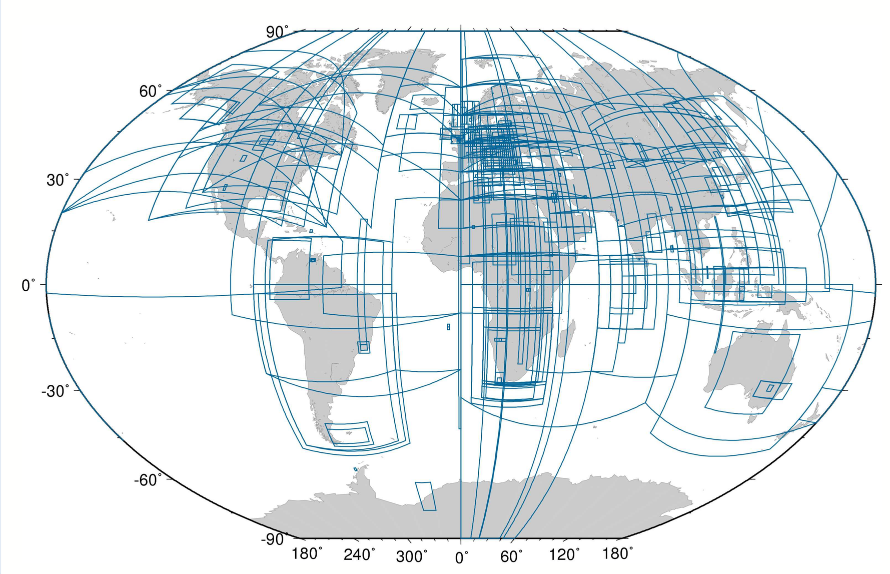
The BGS World Data Centre, based in Edinburgh, maintains a catalogue of global survey data (scalar & vector). Each year requests for survey data are sent to all organisations operating magnetic observatories. Data received are stored on backed-up servers in a database that has been maintained by BGS for over 30 years. Raw data are quality controlled through comparison with global models to identify gross errors before inclusion in the catalogue. Data are made available to the public and scientific community through the WDC and BGS websites. The catalogue holdings and requests for vector data are shown in the figures (right) and summarised below.



Distribution of global vector data (red - repeat stations, blue - one-off survey)



Distribution of global data requests (red dots - source, red circles - number)



Distribution of global data by latitude and longitude area requested

VECTOR DATA HOLDINGS (TOP)
- Time coverage: 1900 - 2013
- 86261 ground-based vector values
- 67720 one-off survey values (blue)
- 18541 repeat station values (red)

EXTERNAL REQUESTS (CENTRE)
- Period: Nov 2011 - July 2013
- 1094 requests for data (red circles)
- 281 external users (solids)
- 64 countries

REQUESTS BY AREA (BOTTOM)
- Broad distribution of areas requested

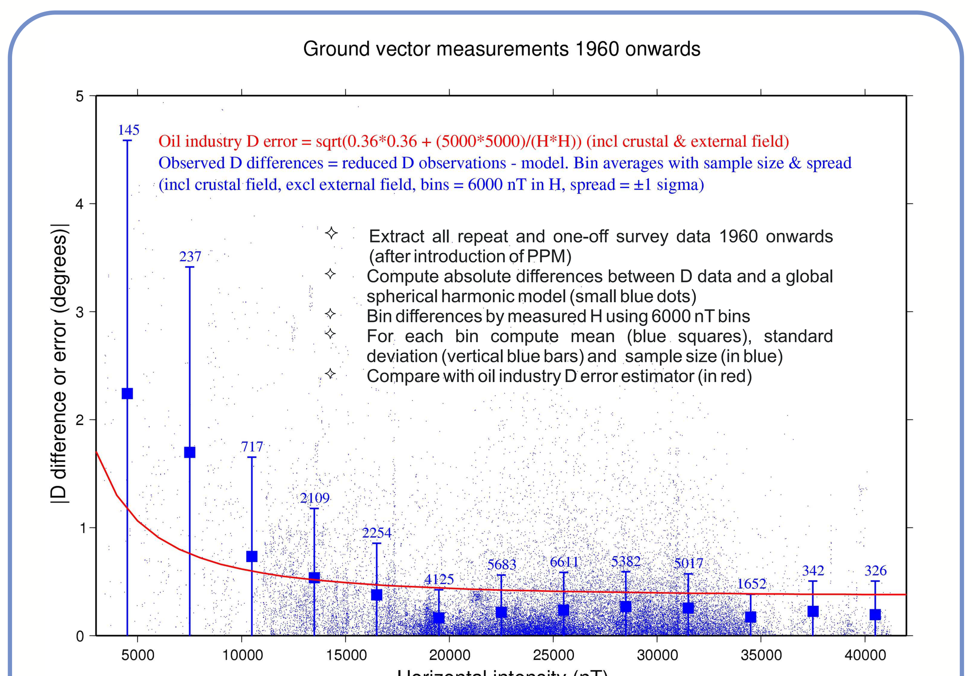
These statistics show the well-distributed spatial and temporal coverage of ground-based vector data held in the WDC, and that there is significant demand for this type of data worldwide, particularly from Europe.

ACCESS TO DATA
- www.wdc.bgs.ac.uk

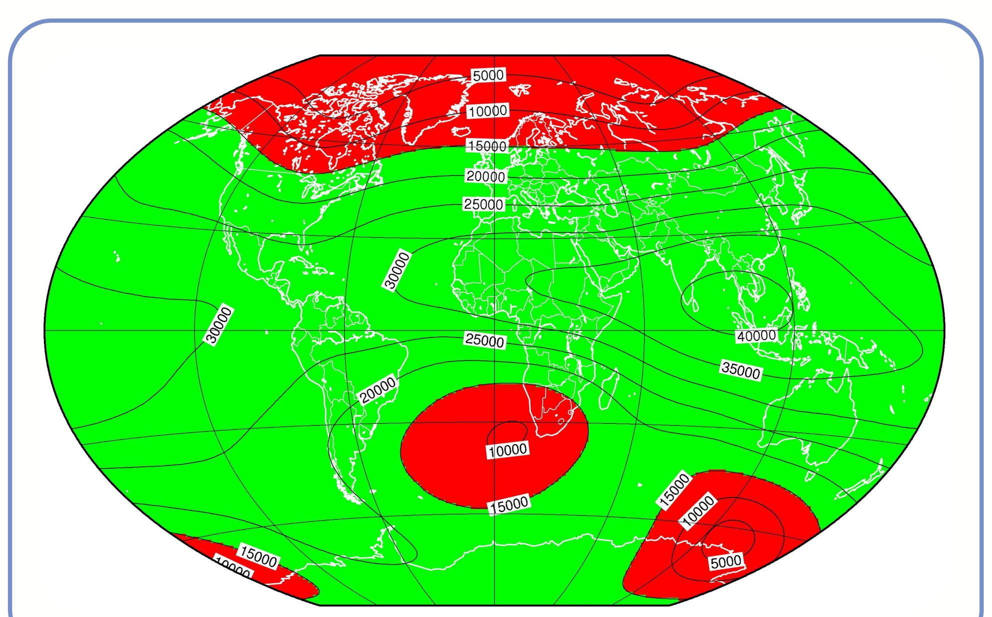
SUBMISSION OF DATA
- wdcgeomag@bgs.ac.uk

Global Applications (Quantifying Errors)

Repeat station declination (D) data reduced to quiet levels can be useful in assessing errors assigned to values from global spherical harmonic models. In directional drilling with magnetic survey tools these models are used to convert well path azimuths from a local geomagnetic coordinate frame to a geographic frame. The assigned magnetic field errors are important for determining the along-path error ellipsoids, crucial for ensuring well paths are within geological targets and have sufficient clearance from neighbouring well paths. A widely used oil industry error estimator [1] is intended to include errors in the model as well as field sources not modelled i.e. crustal and external, and for D is dependent on the horizontal intensity (H). Here we investigate its performance by using global vector data holdings at the WDC for Geomagnetism (Edinburgh). The plot (above) shows that for H < 15000 nT the oil industry D error estimator underestimates the real error. And this without taking account of external fields which at high latitudes are significant.



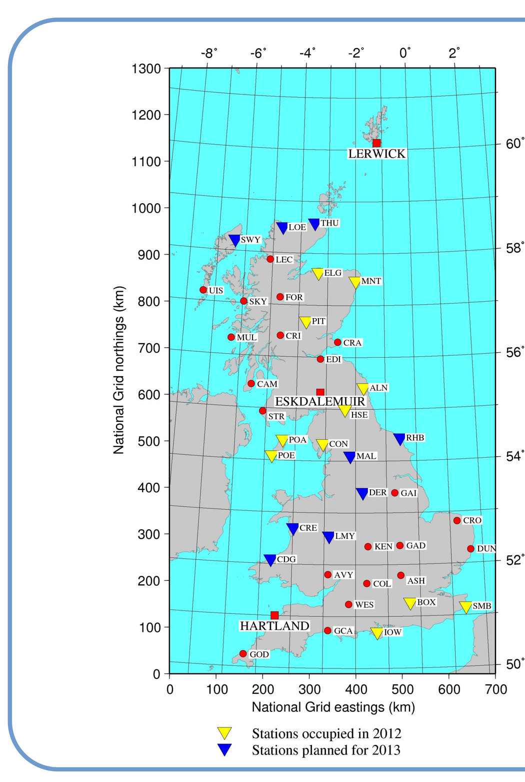
The regions of the world where currently H < 15000 nT are shown in red on this map (right). They include Alaska, some of the Canadian tar sands and offshore Norway. Errors in these areas are typically reduced using local magnetic field observations from observatories and/or aeromagnetic or ground surveys. This analysis demonstrates the continued usefulness of global observations of the full magnetic field vector. In addition, if the Swarm mission is not successful, they will be used as input data for global spherical harmonic models as in the pre-Ørsted era.

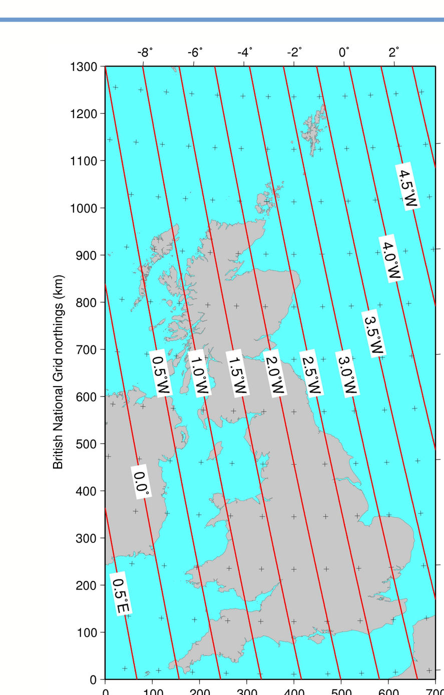


Regions of the world where horizontal component is less than 15000 nT (red)

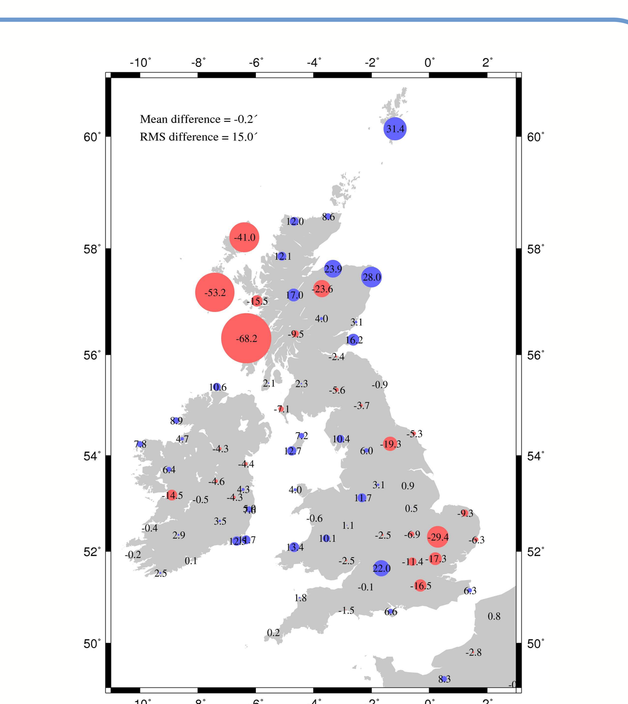
Local Applications (Regional Models)

One of the main applications for the UK repeat station data is to service requests for magnetic north information received from the Ordnance Survey (Great Britain's national mapping agency). This data is published with Ordnance Survey land maps (left) to allow users of the maps accurate magnetic north data for navigational purposes. The BGS supplies the Ordnance Survey with this data based on a regional model for the UK that is updated each year. The model is capable of predicting secular variation up to 3 years into the future. The primary source of data for this model is the repeat station network and magnetic observatories BGS operates (below, left). The declination contour map must be adjusted to account for map convergence before it can be used in the Ordnance Survey land maps (below, centre). In 2012, the Ordnance Survey requested data from the BGS regional model for over 153 of their land maps. The performance of the model can be quantified through comparison with raw repeat station measurements (below, right).





Predicted grid magnetic angle at mid 2014



Difference between model values and recent observations (arc-minutes)

References

[1] Williamson, H. S., 2000. Accuracy Prediction for Directional Measurement While Drilling. SPE 67616, *SPE Drill. & Completion*, **15** (4), December 2000.