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BGS UK Repeat Station Programme

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ABSTRACT

The British Geological Survey (BGS) is responsible for conducting the UK geomagnetic repeat station programme. The measurements made at UK repeat station sites provide secular variation data that supplement observatory data to improve the accuracy of the regional model for the UK. Best practices for conducting repeat station measurements continue to evolve as advances are made in survey instrumentation and as the usage of the data continues to change. Techniques employed in removing the transient external field variations and the format of submitted repeat station data often differs from country to country. This poster provides an up to date report on the current status of the UK repeat station programme, the measurement technique, the data processing used to reduce the data and some examples of the main applications of the data.

INTRODUCTION

The UK repeat station network consists of 51 absolute sites that are re-occupied with period of 4-5 years. Measurements are carried out by a single person between the months of May to September; typically three stations are covered in one week. The stations are distributed evenly over the UK with an average spacing of about 75 km. This spatial distribution is more than sufficient for modelling the main-field which is typically concerned with wavelengths much larger than this [1]. From permanent magnetic observatory observations, it can be seen that secular variation varies significantly over the length of the UK (Figure 2). Repeat station measurements allow a more complete measure of this variation to be modelled throughout the UK. The general procedures for making repeat station measurements, current instrumentation, data processing and recent results are discussed. When the UK repeat station programme was setup, the locations of the sties were carefully chosen with similar selection criteria as would be for a magnetic observatory, i.e., low gradients and well removed from possible sources of magnetic contamination. However, due to the relatively small area of the UK, the use of the land can often change and in recent years this has presented a number of obstacles when occupying repeat sation sites - often resulting in re-location of the site. On average, one repeat station site per year has to be relocated due to this type of problem.

MEASUREMENT PROCESS

Sites are located approximately using a hand-held GPS, programmed with the stored latitude and longitude way points. The precise measurement position is accurately marked by a stone slab buried in the ground. Locating the stone ensures the re-occupation position is to within 20 cm, which is close enough to ensure the local crustal variations do not contribute to the measurement (assuming gradients are low [<1nT/m]).

Before making absolute observations, a total field survey is conducted with a Proton Precession Magnetometer (PPM) to check that the local magnetic gradients are less than 1nT/m, over a 40 m grid centred on the observing position.

A PPM records the total field variations during the period of the survey and is sampled at 1 minute intervals. This total field data is translated to the absolute observing position by performing a site-difference measurement. A second PPM is run in parallel at the absolute site and both are sampled at 10 second intervals for a period of at least 15 minutes to provide a scalar correction to the 1 minute F data.

The primary method for determining true north still relies on gyroscope observations (WILD GAK1) although the differential GPS method has also been used on occasion. This process typically takes up to an hour to complete and produces a TN reference with an accuracy of approximately 10".

Eight absolute observations are performed at regular intervals during the seven hours spent at the site. Each observation is based on the DI-fluxgate-theodolite null-method using a non-magnetic tripod.

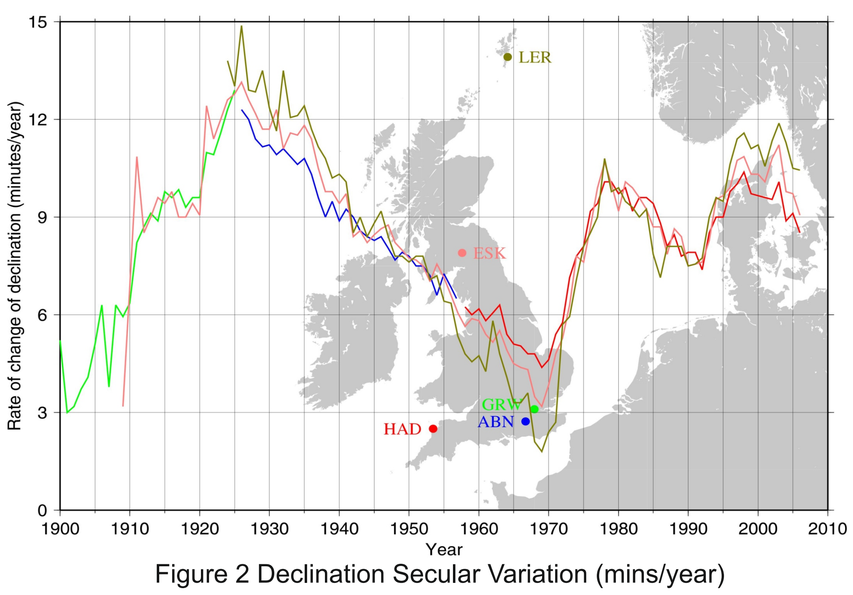

Figure 2 Declination Secular Variation (mins/year)

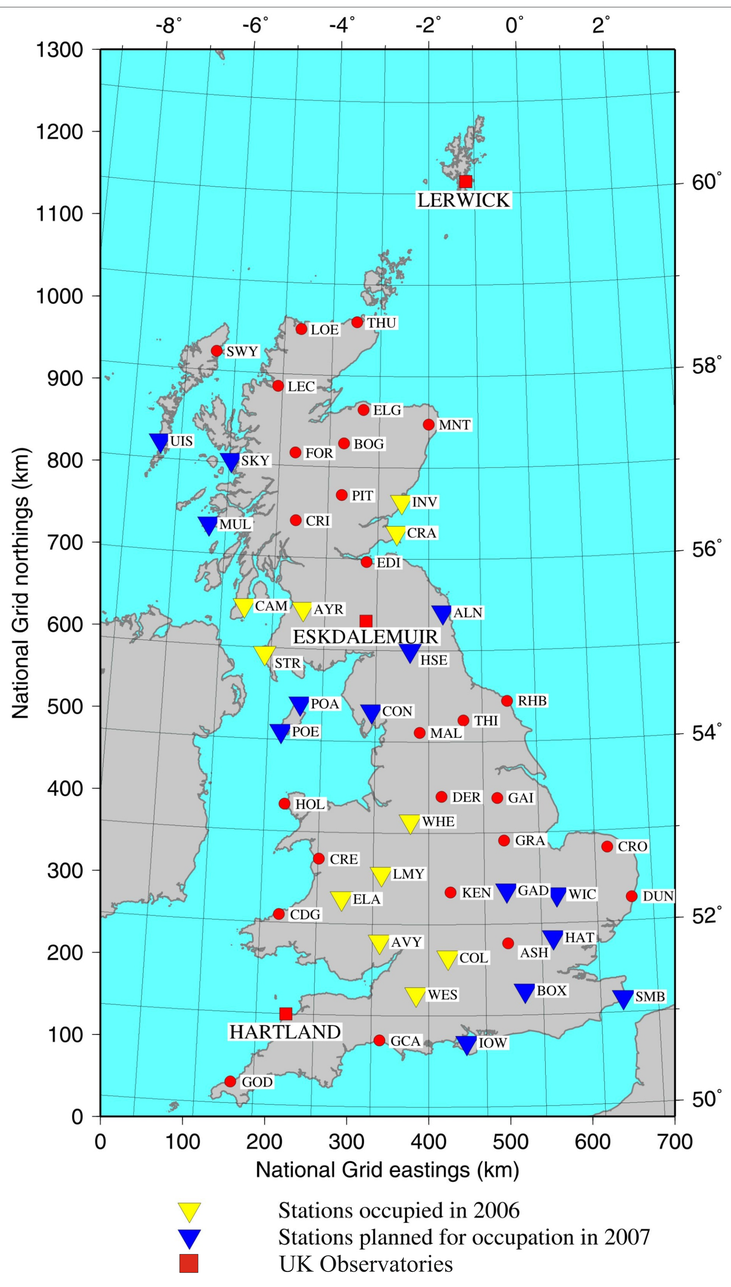

Figure 1 UK Repeat Station Network

APPLICATION OF DATA

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 (Figure 3) 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 (Figure 1). The declination contour map must be adjusted to account for map convergence before it can be used in the Ordnance Survey land maps. In 2006, the Ordnance Survey requested data from the BGS regional model for over 140 of their land maps.

Ordnance Survey®

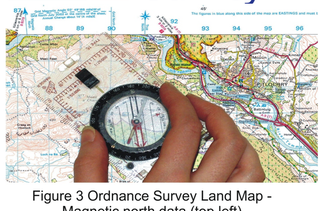

Figure 3 Ordnance Survey Land Map - Magnetic north data (top left)

REDUCTION OF DATA

Due to the relative proximity of the BGS magnetic observatories (Figure 1) and the mid-lattitude position of the UK, reduction of the repeat station observations to a quiet level can be carried out by interpolation (latitude weighted) between two UK observatories closest in latitude to the station. In the case of stations south of Hartland only Hartland data is used. Quiet-time values are selected by examining data from the observatories for the eleven-day period centred on the observation day.

The quiet night-time value for each observatory is taken to be the mean of the two hourly means either side of midnight from two days showing minimal external field disturbance. Night-time values are used because the regular external variation is at a minimum at this time. Periods of minimal irregular external field disturbance are selected by examining the three-hourly K indices from the reference observatories. If an observation of magnetic field element E is made at time t then the final value of E, reduced to a quiet level, is calculated as follows:

$$E_q(t,station) = E(t,station) + C$$

Where:

$$C = \frac{\Delta\theta_2(E_q(t,obs1) - E(t,obs1)) + \Delta\theta_1(E_q(t,obs2) - E(t,obs2))}{\theta_1 - \theta_2}$$

θ_1 = latitude of the observatory north of the station
θ_2 = latitude of the observatory south of the station
θ_s = latitude of the station
$\Delta\theta_1 = \theta_1 - \theta_s$
$\Delta\theta_2 = \theta_s - \theta_2$

$E(t,station)$ = value of E at the station at time t
$E(t,obs1)$ = value of E at observatory-1 at time t
$E(t,obs2)$ = value of E at observatory-2 at time t
$E_q(t,obs1)$ = quiet level of E at observatory-1 at time t
$E_q(t,obs2)$ = quiet level of E at observatory-2 at time t

The results for each site are based on a simple average of all the observations performed. If any observation is significantly inconsistent or the collimation errors are large then it will not be included in the averaging process. Once the data are reduced to quiet-time levels they are then reduced to epoch (e.g., 2006.5). This is done using a series of annual models of the secular variation of each component, derived from data collected at observatories in Western Europe and at the British repeat stations.

CALIBRATION OF INSTRUMENTATION

Each piece of survey equipment used for making repeat station measurements is calibrated before and after a field measurement session. The instruments are taken to Eskdalemuir Magnetic Observatory (left) for comparison and calculation of instrument-specific offsets.

The gyroscope alignment with the theodolite optical axis is always offset by a collimation error that should remain consistent. Determination of this offset is essential for accurate True North readings to be made in the field and by checking this value regularly, the quality of the instrument can be assured.

A series of absolute observations are made with the survey fluxgate-theodolite and then with the observatory instrument to check for consistency between the two sets of baseline results.

Both survey PPM's are calibrated prior to repeat station occupation by comparing the frequency measurement electronics of the PPM against a 1 Mhz transmitted reference frequency signal (modulated on 198 kHz), which is traceable to the National Physical Laboratory (NPL).

INSTRUMENTATION

Fluxgate-Theodolite:
Type: Carl-Zeiss Theo 010A (non-magnetic)
Resolution: 1 arc-second
Magnetometer type: Bartington Instruments Mag-01H
Magnetometer Maximum Resolution: 0.1 nT
Magnetometer Offset Drift: 0.01 nT/deg. C

Global Positioning System:
Type: Leica GPS System 500
Typical data collection time required: ~ 60 minutes
Processing software: SKI-Pro-L1
Operation mode: Differential
Typical accuracy: ~ 20 arc-seconds

Gyroscope:
Type: WILD GAK1 Gyro Attachment
Typical accuracy at mid latitudes: ~ 10 arc-seconds
Typical observation time: ~ 60 minutes

Proton Precession Magnetometer:
Type: GEM Systems GSM-19 (Overhauser Effect)
Resolution: 0.01 nT
Minimum Sampling Period: 3 seconds

As a precaution, two sets of each piece of instrumentation are carried out in the field should any part fail.

2006 RESULTS

Figures 4-8 show the current regional model (2007) values based on the most recently acquired data in 2006. Figure 4 illustrates the discrepancy between the 2006 measured values at each repeat station site and the computed values, reduced to epoch 2006.5 from the current model.

It can be seen that in the north western parts of the UK, particularly around the Outer Hebrides and Mull, there are large anomalies in the comparisons. Aeromagnetic surveys have shown this to be caused by highly magnetic rocks in the area that contribute significant crustal field variations over relatively short distances of a few kilometres and will also vary over time.

Figures 5-8 show the derived rate of change of declination, declination, inclination and total field for the UK based on the 2007 model. The final model derived was based on a degree 2 polynomial weighted fit to the data using a recently derived global spherical harmonic model as an a priori model.

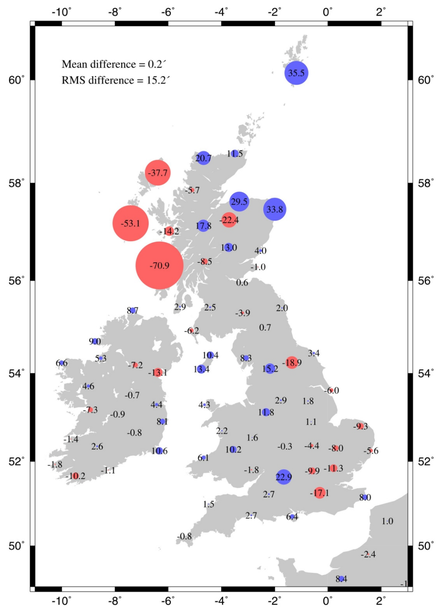

Figure 4 Comparison of Measured and Computed Declination (mins) for 2006.5

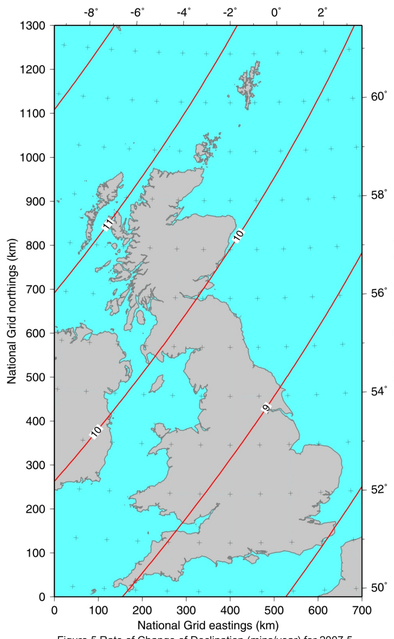

Figure 5 Rate of Change of Declination (mins/year) for 2007.5

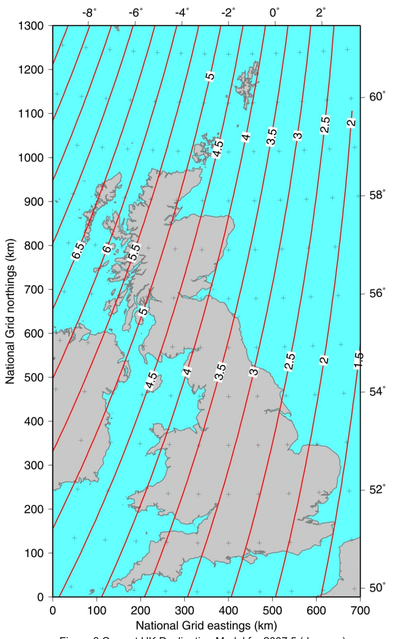

Figure 6 Current UK Declination Model for 2007.5 (degrees)

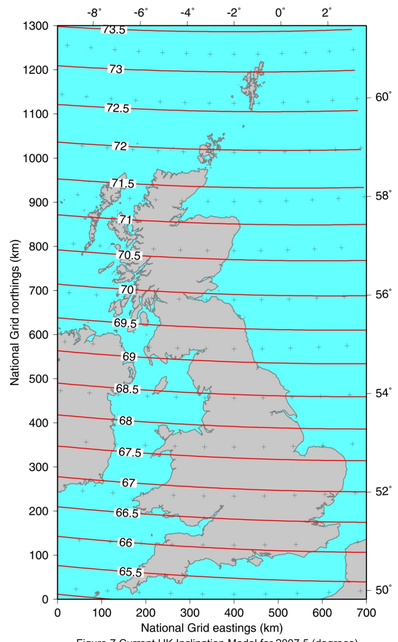

Figure 7 Current UK Inclination Model for 2007.5 (degrees)

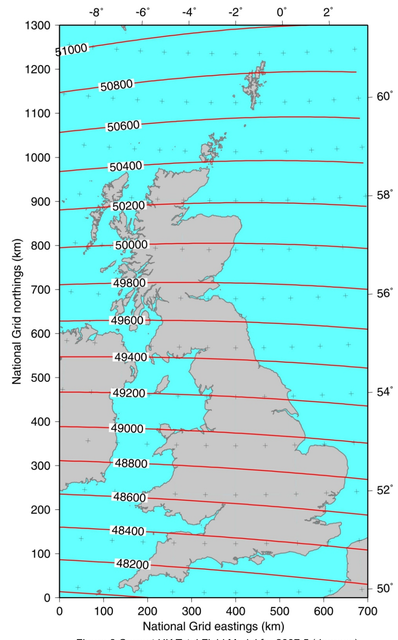

Figure 8 Current UK Total Field Model for 2007.5 (degrees)

DATA ACCESS

The BGS as a World Data Centre is responsible for maintaining a global data set of repeat station measurements from countries around the world. The data are made publicly available on-line via the BGS geomagnetism website (below). The repeat station results that are published on the website are maintained in the Project Magnet Format (PMF).

Website URL: www.geomag.bgs.ac.uk/on_line_gifs.html

ACKNOWLEDGEMENTS

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REFERENCES

[1] Newitt, L. R., Barton, C. E. & Bitterly, J., (1996), Guide for Magnetic Repeat Station Surveys