Filling the gaps: New variometers in the UK for space weather monitoring

Sarah Reay, Ciaran Beggan, Victoria Thompson, Chris Turbitt, Thomas Martyn, Rob Lyon, Josie Parrianen, Ewelina Lawrence, John Williamson, Juliane Hübert

British Geological Survey, The Lyell Centre, Research Avenue South, Edinburgh, United Kingdom

INTRODUCTION

In 2022, 3 new variometer sites were installed in western Northern Ireland (Florence Court, FLO), central England (Market Harborough, LEI) and south-eastern England (Herstmonceux, HTX) to complement the existing magnetic observatory network in the UK. These sites were chosen to optimise the spatial distribution and ensure that no location in the British Isles is more than 300 km from a variometer measurement (Fig 1). These provide high quality magnetic variation data, though not absolute level, for space weather monitoring.

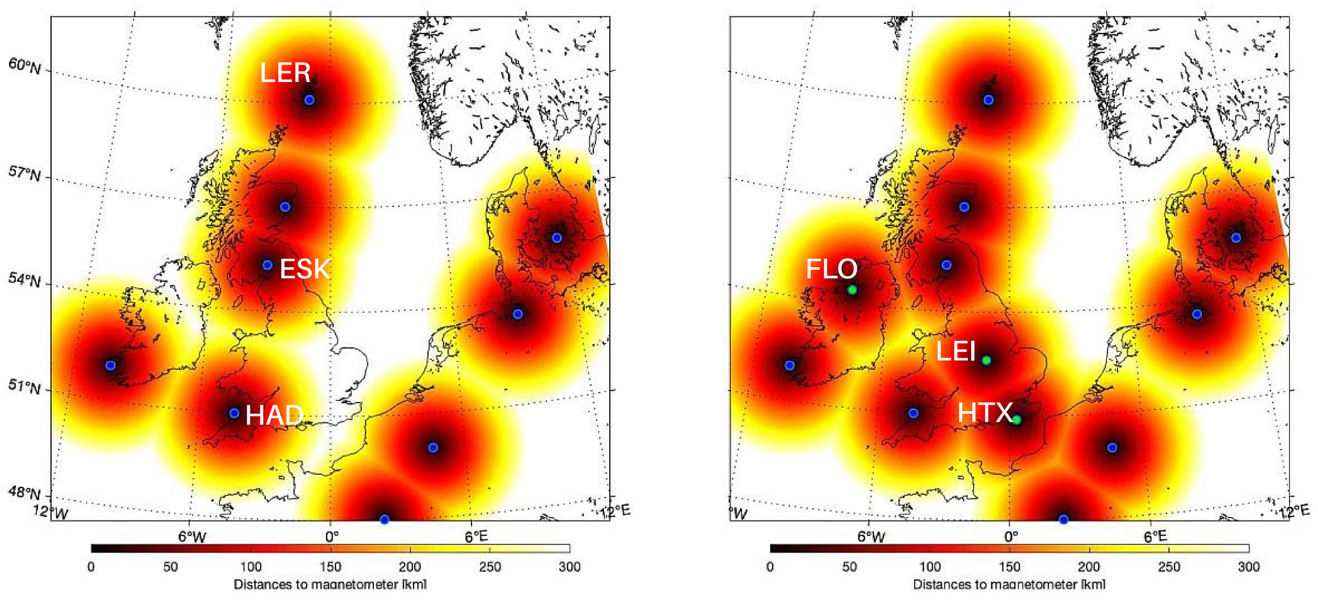

Figure 1: Heat map of distances to nearest magnetic observatory or variometer station.
Left: Locations of existing magnetic observatories, including Lerwick (LER), Eskdalemuir (ESK) and Hartland (HAD) (blue circles).
Right: Coverage including the new BGS variometers (green circles).

DATA QUALITY

Fig 2 demonstrate that the variometer data compares well with variations at the three UK observatories.

However, each variometer site has environmental challenges.

- **FLO** – located on National Trust property in a field for livestock. After installation, the magnetometer barrel rotated due to cattle disturbance. This was later relevelled, and a fence was installed around the equipment.
- **LEI** – located on a small hill on arable land. Issues have included wind damage, loose wiring connections, and agricultural activity.
- **HTX** – located on the grounds of BGS Space Geodesy Facility. The site is close to DC rail lines causing a regular 10-20 nT noise in X & Z components (Fig 3).

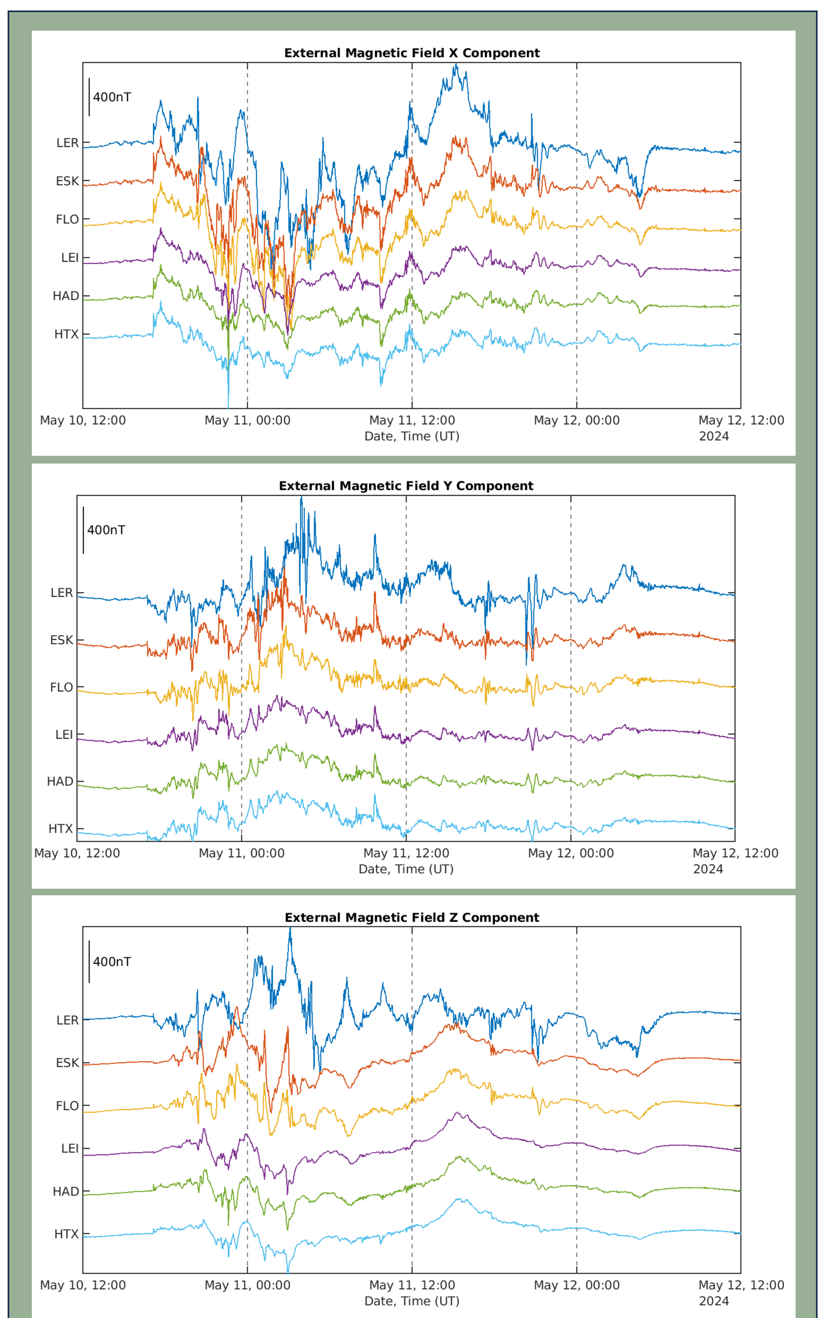

Figure 2: Magnetic field variations in Bx, By and Bz respectively, during the peak of the May 2024 storm at each BGS site in the UK, sorted by latitude. 1-min data are plotted, with quiet-time averages removed to isolate variations caused by magnetospheric and ionospheric currents (Lawrence et al., 2025)

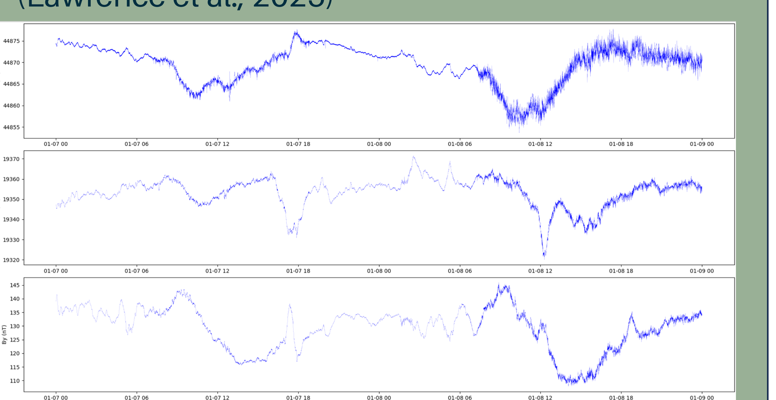

Figure 3: Data from HTX for two days. The first day has a reduced rail service due to strikes. The second day is with a normal rail service.

To examine long-term stability, interpolated data for these three locations were created using combinations of ESK & HAD to compare the data quality against observatory-standard measurements (Beggan et al., 2025).

The mean and standard deviation were computed using 15-months of data (Fig 4). Results show that data are not of the same standard at observatory-quality data.

Routine absolute observations and quality control would be needed if long-term stability is desired.

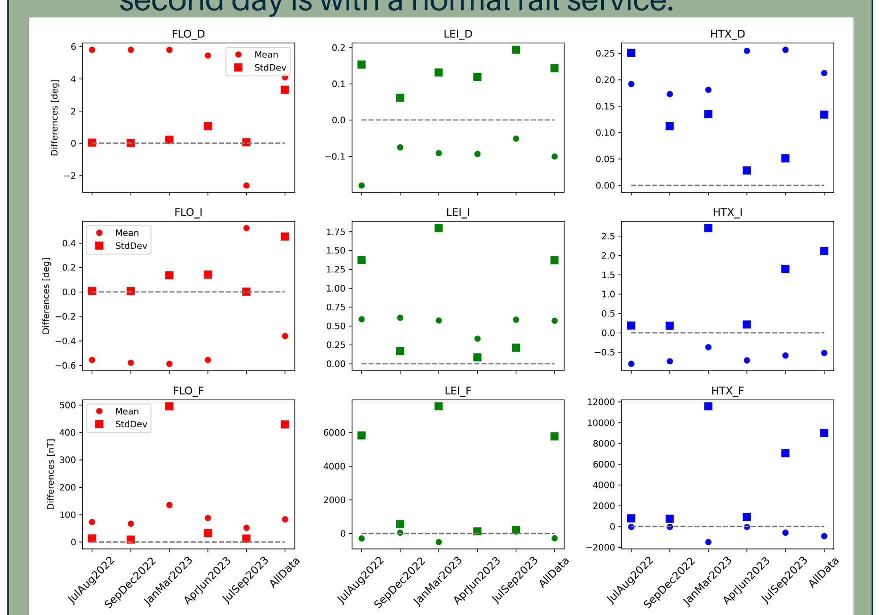

Figure 4: Mean and Std Dev for 3-month bins of data from FLO, LEI and HTX. Dotted line shows zero difference to observatory-standard data.

INSTRUMENTATION

The variometer systems consist of a *Sensys* 3-component fluxgate magnetometer, mounted on a wooden frame and buried in a barrel for temperature stability, an EarthData Digitiser/Logger running GPS synced Linux, a 4G modem, control electronics, 2 deep-cycle batteries for power and a solar panel to charge the batteries. The electronics and batteries are housed in a plastic shed (Fig 5).

The magnetic sensor is orientated to magnetic north (minimizing the east component at the time of installation).The magnetic field is sampled at 1Hz and sent back to the BGS across a 4G mobile phone network every five minutes. Data are collected via the *seedlink* protocol and then converted to ASCII for further data processing.

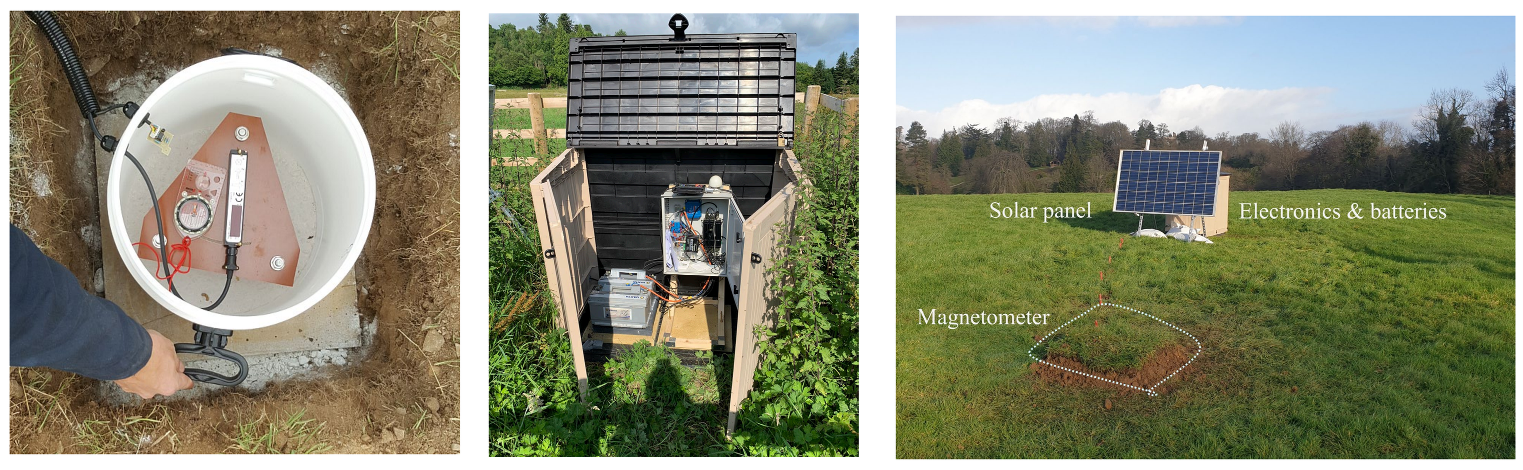

Figure 5
Left: The magnetometer within a barrel, in the pit.
Middle: Plastic shed containing the electronics and batteries.
Right: Photo of the complete installation at FLO

ASSESSING IMPROVEMENTS TO THE RESOLUTION OF MAGNETIC FIELD MODELLING

To evaluate the scientific value of the new variometers, data from the May 2024 storm were collated and compared in a spherical elementary current system (SECS) model to interpolate the variations in the external magnetic field (e.g. McLay & Beggan, 2010). The 6 BGS magnetometer sites along with Valentia (VAL), Dunsink (DUN), Dourbes (DOU) and Chambon-la-Foret (CLF) were chosen. Quiet-time averages were removed from each data set to extract the external magnetic field.

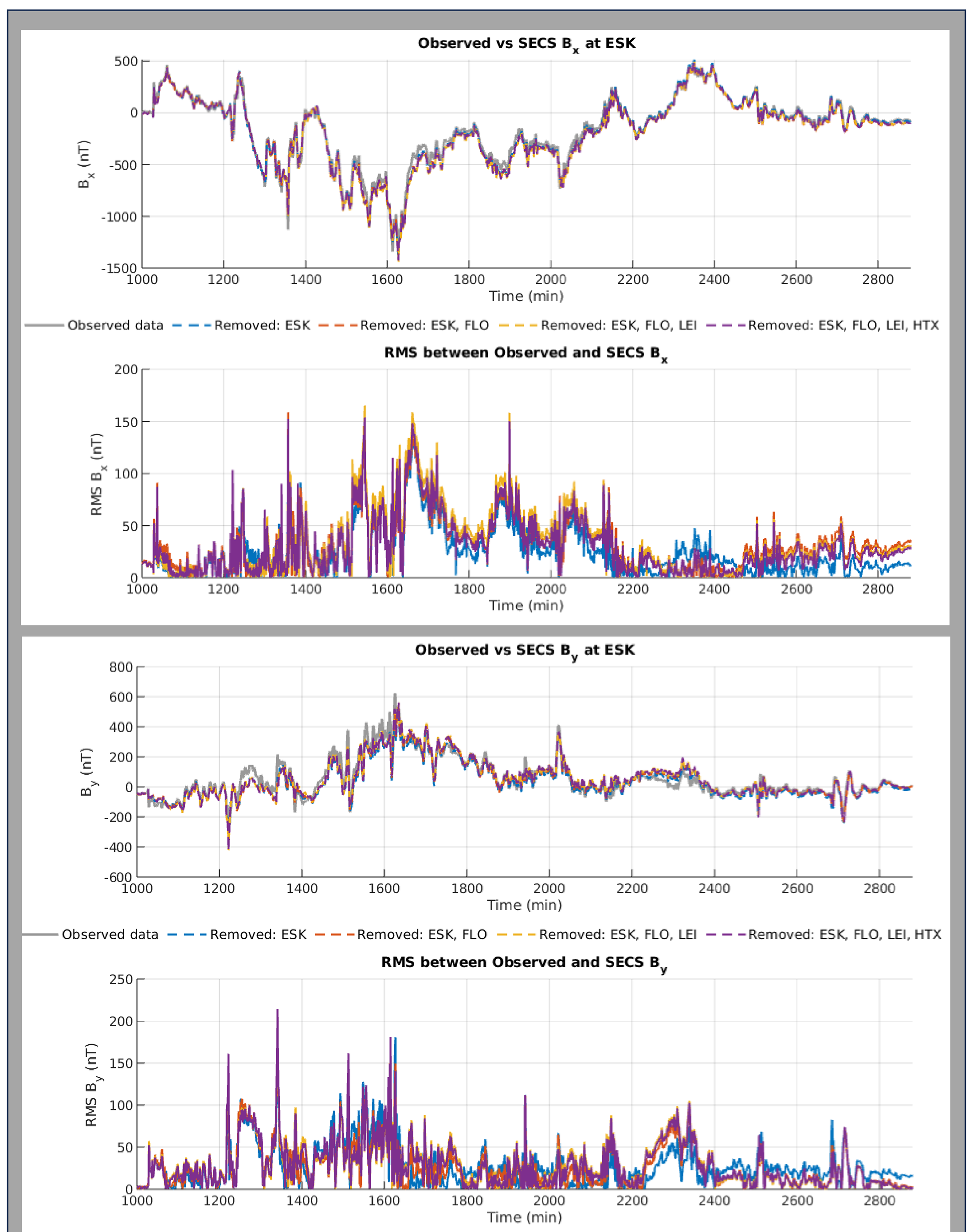

Figure 6: Observed and SECS modelled external magnetic field components, B_x (top) and B_y (bottom) , during the peak of the May 2024 storm in the UK at ESK, testing the removal of each variometer station. The RMS calculated at each timestep between the observed and modelled data to show the overestimation of the models without the variometers.

The SECS model was run for four scenarios; removing ESK data first, then the variometer stations sequentially based on their distance from ESK. Fig 6 shows the magnetic field components, $\boldsymbol{B_x}$ (top), $\boldsymbol{B_y}$ (bottom), for each scenario.

The Root Mean Square between the observed external field data and the modelled data was calculated. The largest differences occur during the peaks of the storm where, without the variometers, the model overestimates the magnetic field.

This demonstrates the value of these additional variometer measurements.

References

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CONTACT sjr@bgs.ac.uk

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geomag.bgs.ac.uk