British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Early Results from the UK Geo-Electric Field Monitoring Project

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To understand how space weather impacts the national power grid, BGS models the surface electric field that rapid geomagnetic variations can produce. This electric field is the source of electrical currents that can damage transformers in the grid. However, the electric field has not been routinely measured anywhere in the UK.

Recently we initiated a project to provide long term measurements of the electric field at our UK geomagnetic observatories. These measurements will help to constrain our electric field models and hence should improve the prediction of induced currents in the UK power system. Over the longer term, the project will also provide magnetotelluric data for study of deep Earth conductivity.

1. Instrumentation

BGS began making measurements of the surface electric field in November 2012, with the installation of probes at Eskdalemuir. Since then, there have been two further installations at Lerwick in March 2013, and Hartland in May 2013.

Measurements of the electric field are made by recording the voltage difference between two points in the ground, separated by a known distance in a given orientation.

At each site two electrode pairs are used, spaced approximately 100m apart, in a North-South and East-West configuration to capture the strength and direction of the surface electric field vector.

Non-polarising electrodes (LEMI-701, $CuSO_4$ Chemistry) are used to make the voltage measurement as they minimise any self-potential effects caused by the interaction of the electrode conductor with the surrounding soil and offer very good stability for long term measurements. They are buried at a depth of at least 70 cm to reduce temperature fluctuations and transient soil-conductivity changes due to heavy rainfall.

Figure 1. Locations of the BGS geomagnetic observatories in the UK

Figure 2. Installation of the electrodes at Lerwick (left) and Hartland (right)

2. The Data

The data are automatically sent to BGS every 10 minutes, as 1 Hz samples. Plots of the electric field are generated alongside magnetic data from the UK observatories for comparison and analysis, and can be viewed via the BGS geomagnetism website: www.geomag.bgs.ac.uk/data_service/space_weather/geoelectric.html

We see the best correlation between the electric and magnetic fields during geomagnetic storms - this is when signal due to the magnetic field will be strongest.

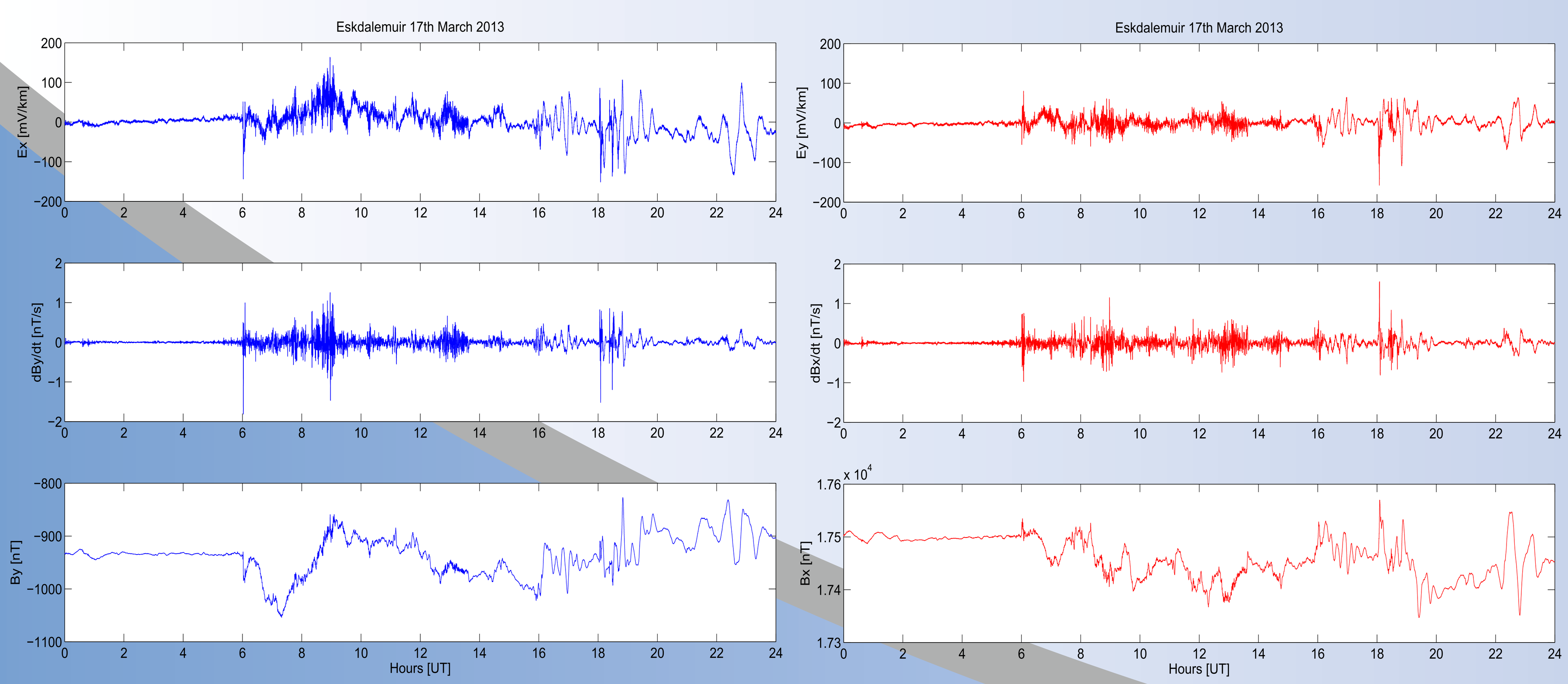

Figure 3. Comparison of orthogonal magnetic (B) and electric (E) field components at Eskdalemuir observatory for a geomagnetically active day in March 2013. dB/dt is the rate of change of the magnetic field calculated over 20 seconds.

3. Comparison with Models

At the BGS we compute the surface electric field across the UK, using measurements of the magnetic field and a geologically based model of UK conductivity structure, an example of which is shown in Figure 4.

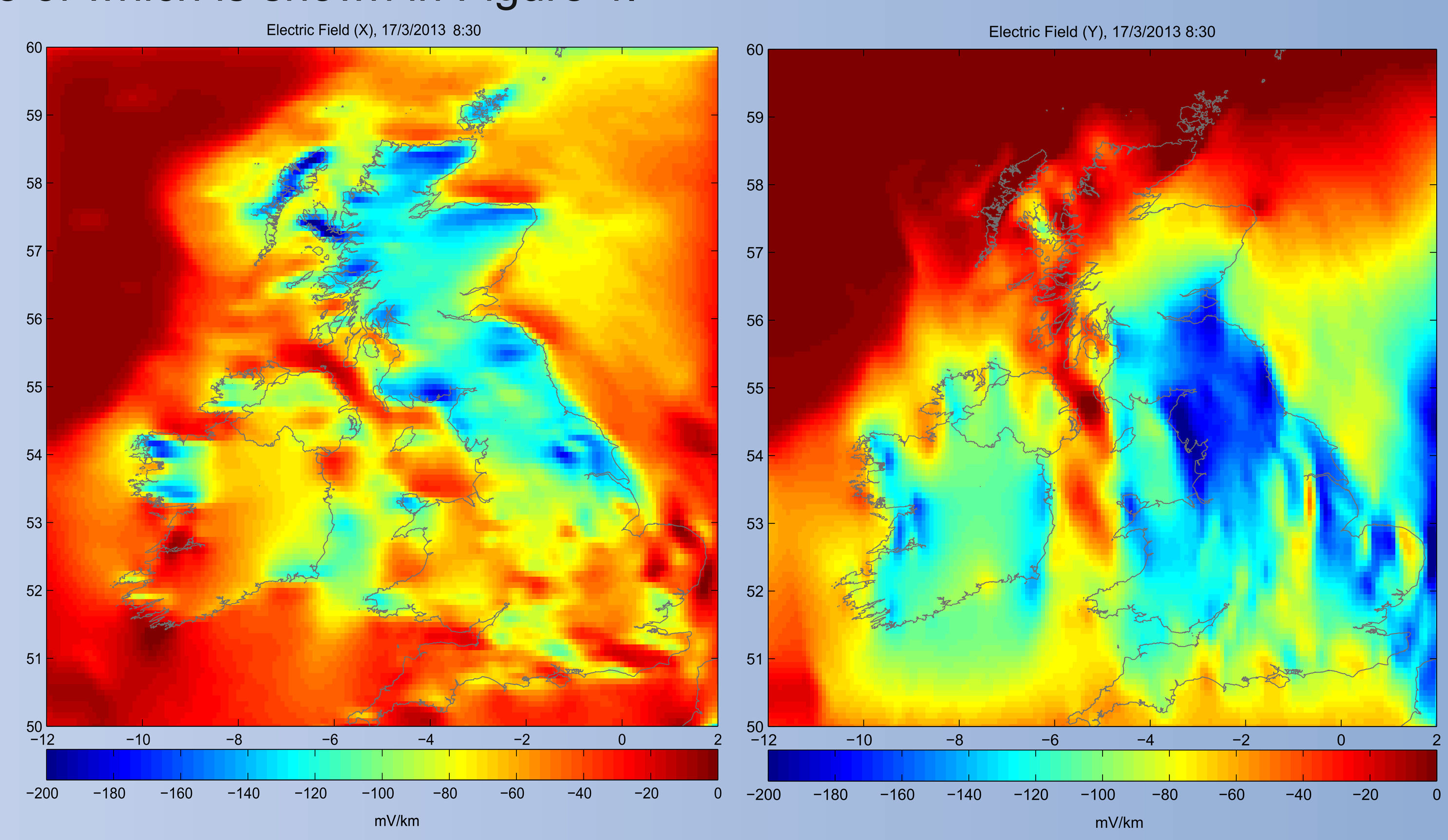

Figure 4. A snapshot of the X (left) and Y (right) components of our electric field model during the geomagnetic storm on 17th March 2013.

Previously we had no data with which to ground truth our models, but we can now assess our model performance at the three sites. Figure 5 shows the measured and modelled electric field at Eskdalemuir on 17th March 2013. In this example the model is clearly over-estimating the electric field, however, it does capture the onset of the storm and other features during the storm.

The model in Figure 5 is estimated using a period of 300 seconds. In testing we see that longer periods result in smaller estimates of the electric field, which are closer to the measurements. This is most likely an effect of the conductivity model we are using. We also find that reducing the grid size over which the electric field is integrated, from the full grid to a 100x100 point grid also improves the fit. Figure 6 shows the effect of reducing the grid size and increasing the period.

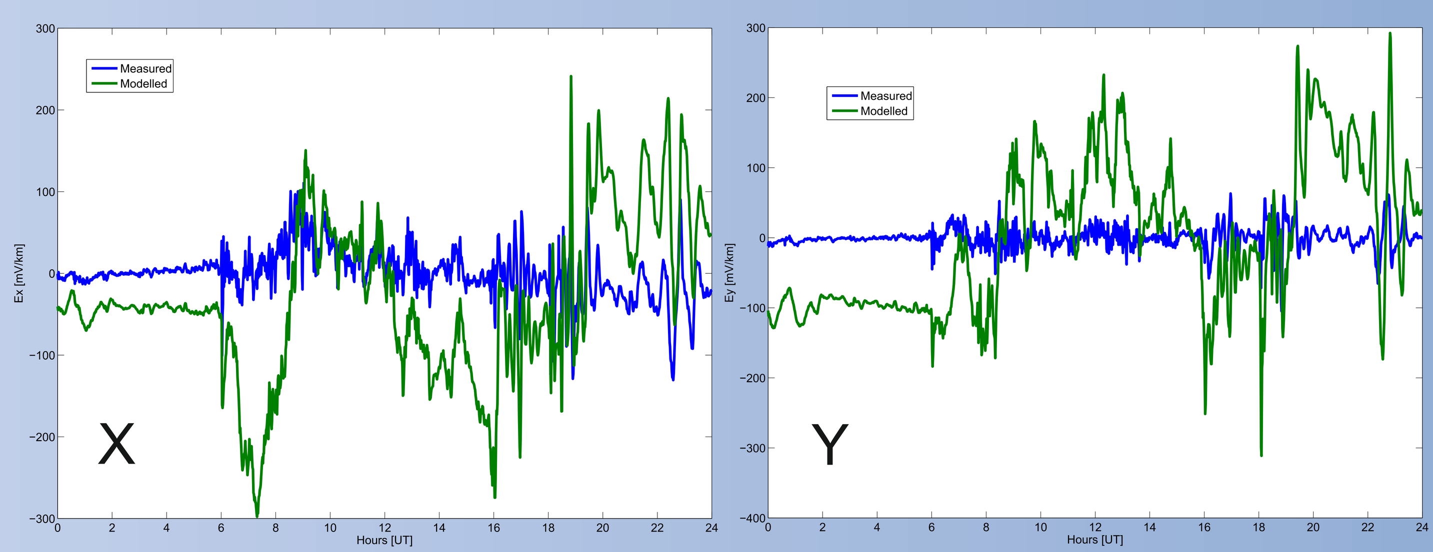

Figure 5. An example comparison between the measurements (1min sampling) and model values (calculated every 1min assuming a period of 300s) for the X (left) and Y (right) components of the electric field on 17th March 2013 at Eskdalemuir.

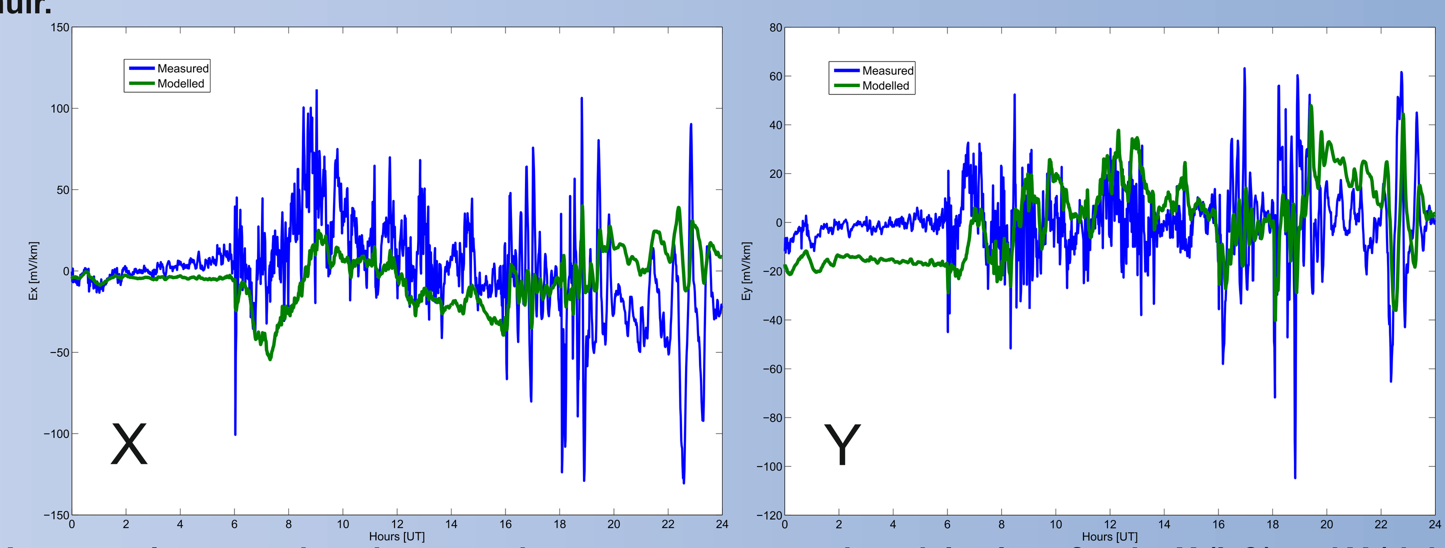

Figure 6. An example comparison between the measurements and model values for the X (left) and Y (right) components of the electric field on 17th March 2013 at Eskdalemuir. The model is now calculated using a period of 750s and integrates over a 100 point grid (instead of the whole grid as in Figure 5).

4. Summary

- The correlation with the magnetic field measurements is strongest during geomagnetic storms when this signal to noise ratio is highest.
- The correlation with the model is also highest during storms, partly due to the signal to noise ratio, and partly because our model is optimised for storms, when GIC estimates are required most.
- There will be local effects that we do not capture as the conductivity model is on a regional scale (10km grid spacing) and so does not contain local detail.
- These early measurements are already helping us to improve our electric field models, and there is scope for further improvement as we continue to gather data and, in particular, measure more storm events.

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www.geomag.bgs.ac.uk/data_service/space_weather/geoelectric.html