Project 'SWIMIC': A Geomagnetically Induced Current Monitoring Service for the Scottish Power Grid

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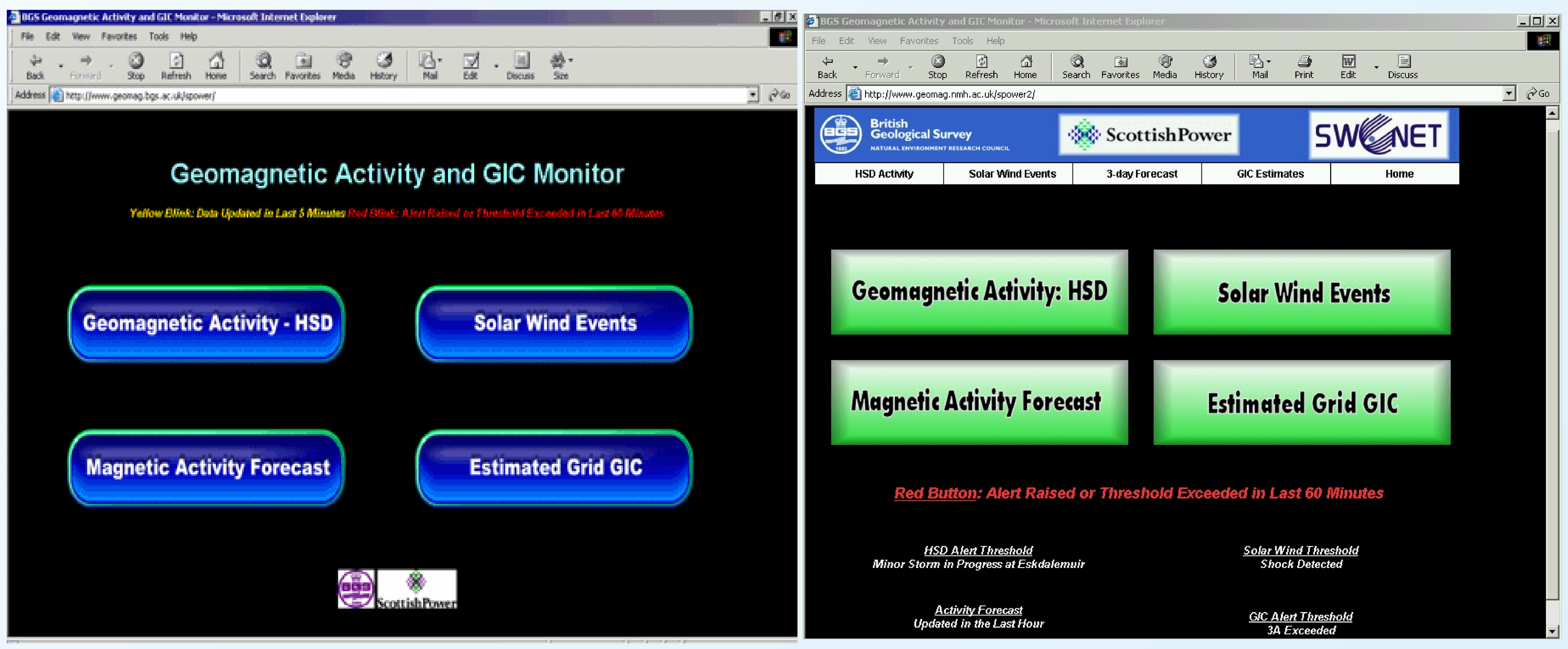
Geomagnetically induced currents (GIC), occurring as a result of space weather and geomagnetic storms, can pose problems for the secure and safe operation of electrical power grids and oil/gas pipelines. We describe the current status of a British Geological Survey project, part funded through the ESA 'Pilot Project' program, to develop a web-based GIC monitoring and analysis tool for the Scottish part of the UK power grid. This tool provides near real time data for monitoring the growth and development of geomagnetic storm variations and the resulting changes in GIC levels throughout the grid. Forecasts of geomagnetic storms up to three days ahead are also made available through the tool and an automated solar wind shock detector offers advance warning of storm and GIC commencement. We discuss the accuracy of the various models embedded in the tool and describe some likely future developments. A public access version of the web tool is also available.

The SWIMIC Package: Front Page

The SWIMIC front page provides a simple interface to the four main components of the monitoring and analysis package. Version *A* is shown below, left, and has been operational since November 2003. A new version *B* is being developed (below right) to improve the data presentation. This will replace version *A* in December 2004. A public access version is being developed. This has limited access to historical data only (http://www.geomag.bgs.ac.uk/gicpublic). The near real time data and products are available only to Scottish Power plc, BGS, ESTEC and, in time, through SWENET.

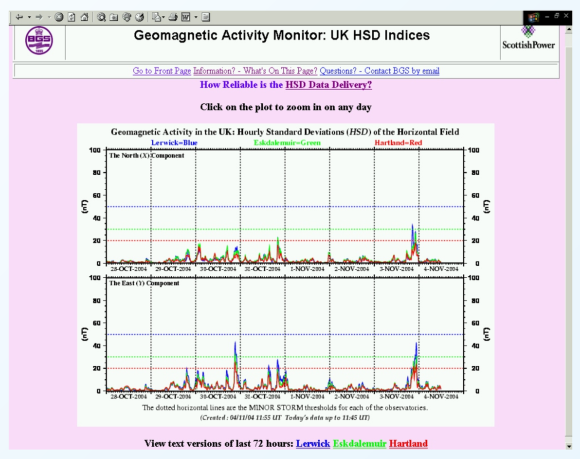


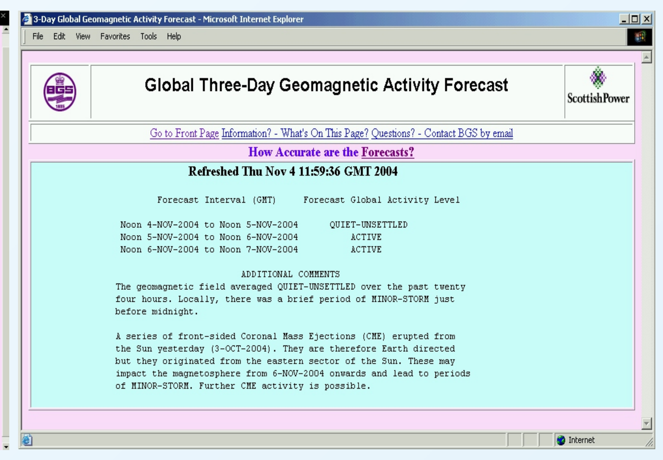
Clicking any button on the front page reveals basic monitoring, analysis or forecast data that provides near real time information on estimated GIC, geomagnetic and solar wind activity. Additional links provide information/education text and data download options.

Future Developments: Complete the web page redesign; Update power grid model to 2006; Fully implement 3D geoelectric field model in near real time mode; Examine feasibility of prediction of GIC from solar wind and geomagnetic data to extend warning time.

The SWIMIC Package: Behind the Version A Buttons

Right: The Hourly Standard Deviation (*HSD*) index page. Click individual days to view in closer detail. Data are updated every 10 minutes. Click links to get text data files and delivery reliability statistics.

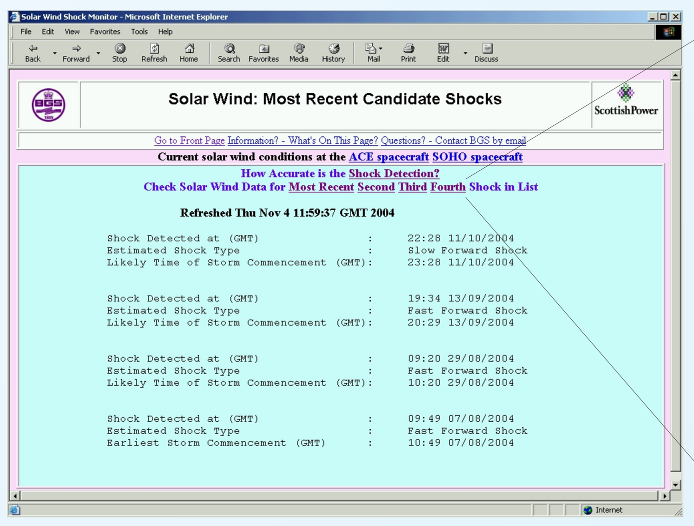


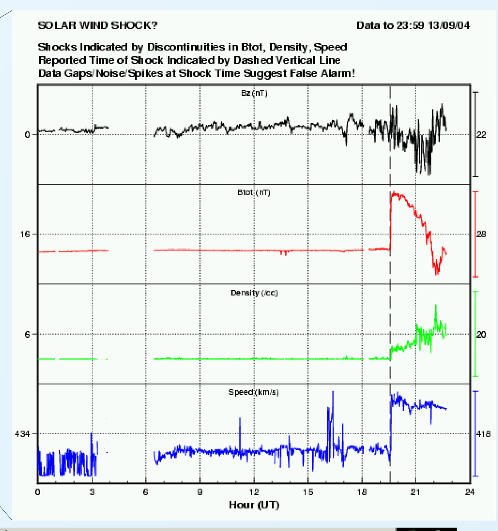


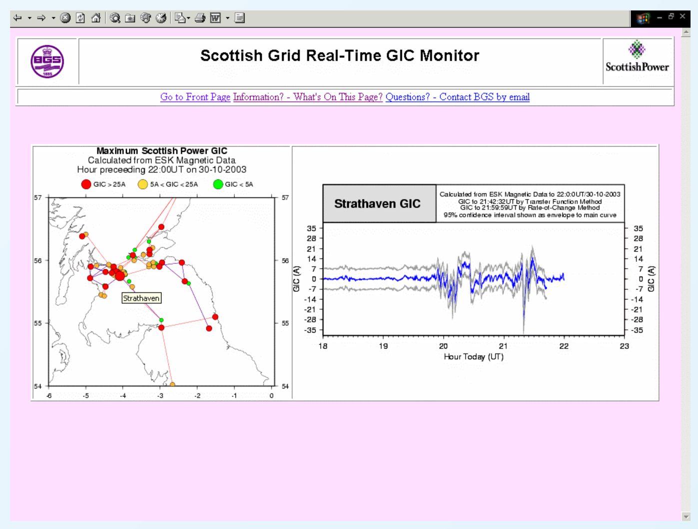
Left: An example of a 3-day ahead daily global forecast. Comments may refer to local activity.

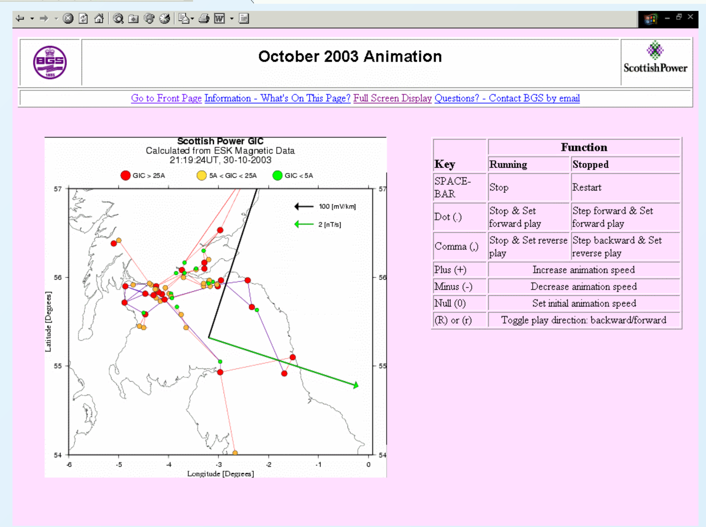
Right: Last 4 candidate shocks and likely times of storm commencement, based on solar wind speed.

Far Right: Click links to view data for individual shocks, e.g. to confirm truth.





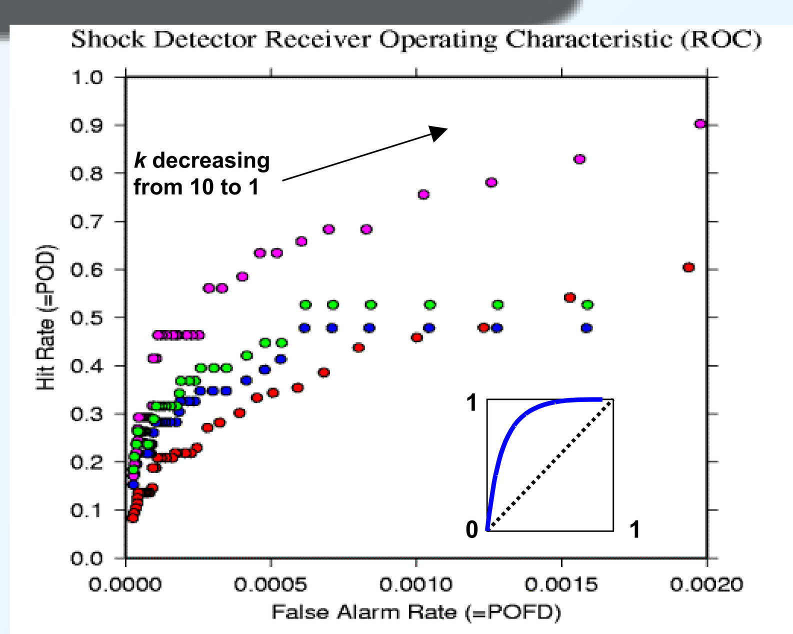




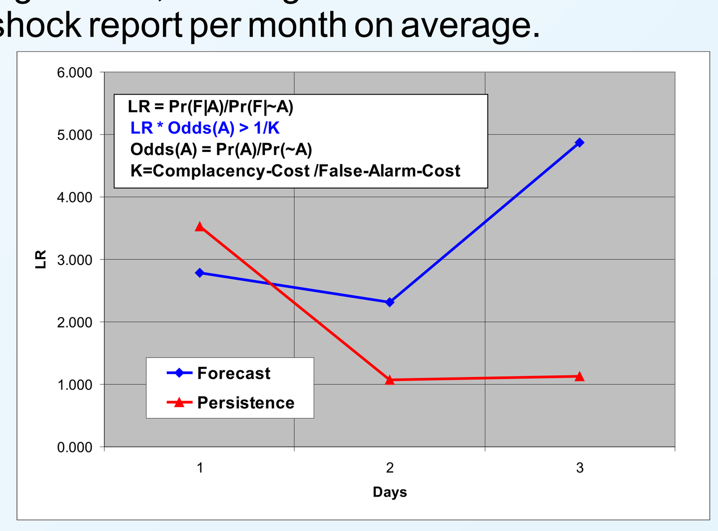
Upper Left: Grid GIC from network model, shown as geographic plot (also available as grid schematic map). Move cursor over plot to view individual station GIC (on right), with 95% confidence limits and with data estimated by accurate transfer function technique (see box below). October 2003 storm is shown.
Upper Right: Animation of network GIC output for last hour. Snapshot from October 2003 storm shown.

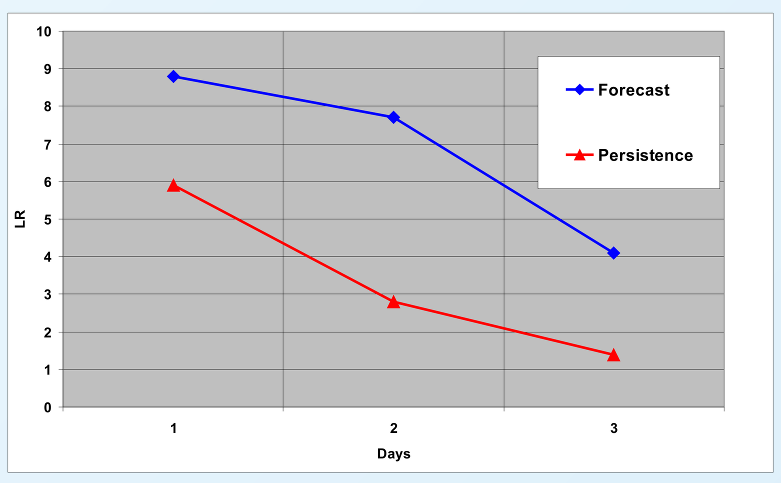
Validation: Solar Wind Shocks, HSD and Forecasts

Right: Accuracy of the IMF strength solar wind shock detector, using the 'Receiver Operating Characteristic' (ROC), based on four 2001 shock databases (colour), as a function of decision threshold, *k*, where *k* is the discontinuity magnitude divided by IMF field standard deviation in the previous 5 minutes. We believe that the 'SOHO' catalogue (blue) probably shows most consistency and so we have based our results on this. For the simple field strength detector we have set dB/Bsigma=7, to get POD=0.3 and POFD=0.0001. This is equivalent to approximately one false report per week on average, using near real time ACE data, which suffer data gaps, spikes and variable noise.

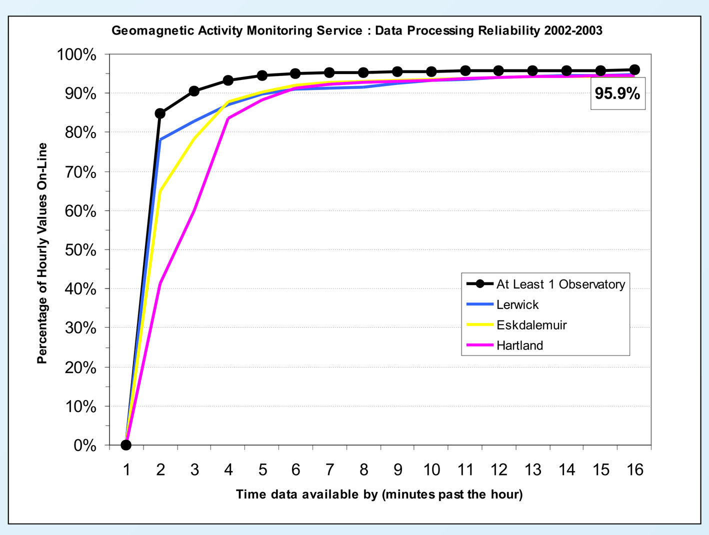


A more complicated shock monitor tests for changes in ACE solar wind velocity (V), density (D), total field (B) and component of velocity normal to the shock front (V.n). For dV/Vsigma=4; d(V.n)/(V.n sigma)=2; For dD/Dsigma=1.5; dB/Bsigma=2.5 we obtain POD=0.3 and POFD=0.00002. This POFD is equivalent to one false shock report per month on average.





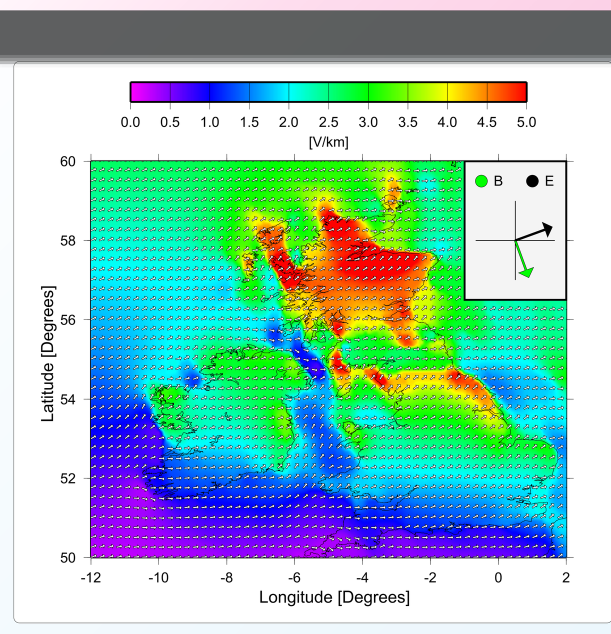
Above Left and Right: Likelihood ratios (*LR*) for forecast system, compared with actual outcomes at 1-3 days ahead, and compared with persistence. **Left**=2002-2003; **Right**=1999-2002. The storm forecast system proves most useful if the cost of missing an event is greater than that of a false alarm. Persistence has value but only at a 2-3 times higher minimum cost of missed event, and for *L*>1 day. Using 'Decision Theory', *F*=forecast of storm; *A*=actual storm occurrence; Pr=probability; ~='not'.



Right: HSD index data delivery reliability in 2002-2003. At least one observatory's *HSD* index was available by 15 minutes past each hour, in version *A*, at 95.9% reliability, when the data were computed once per hour. *HSD are however now computed every 10 minutes to improve storm monitoring.*

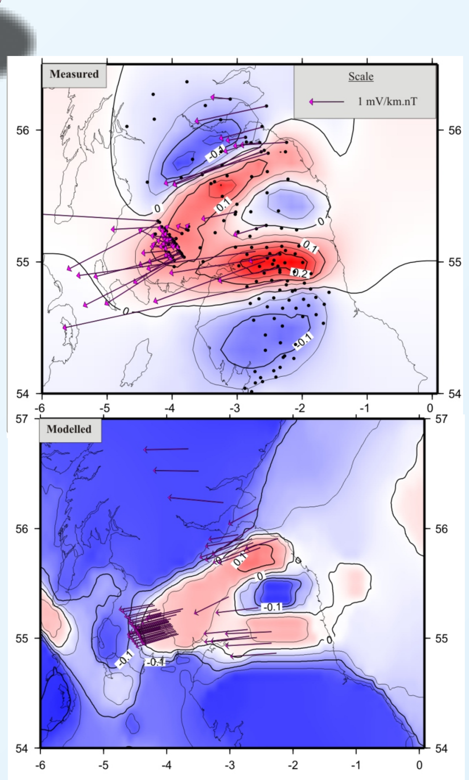
Acknowledgements:
Models: **BGS, FMI, Univ. Edinburgh**
Data: **BGS, Scottish Power, Univ. Edinburgh**
Other: **COST724 Action on Space Weather**

Validation: Power Grid GIC and Electric Fields

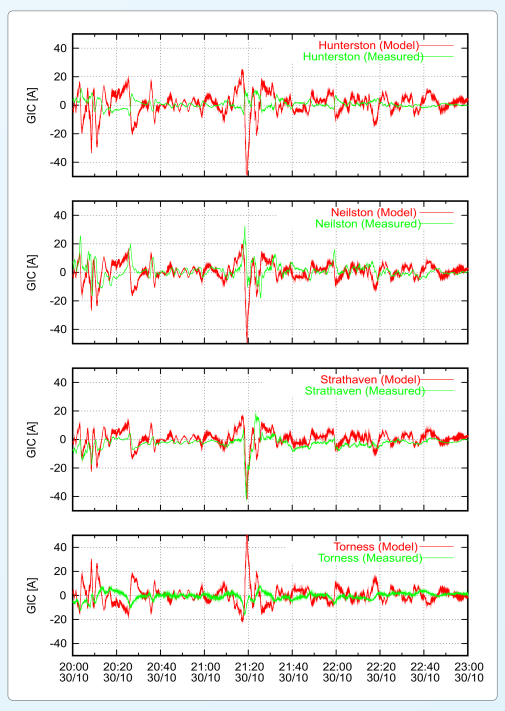


Left: An estimate of the geoelectric field at the peak of the 30th October 2003 storm (approx 21:20UT). The inset shows the direction of the surface electric field for a one-dimensional electrical model of the crust. The main map shows local variations due to the three-dimensional model employed.

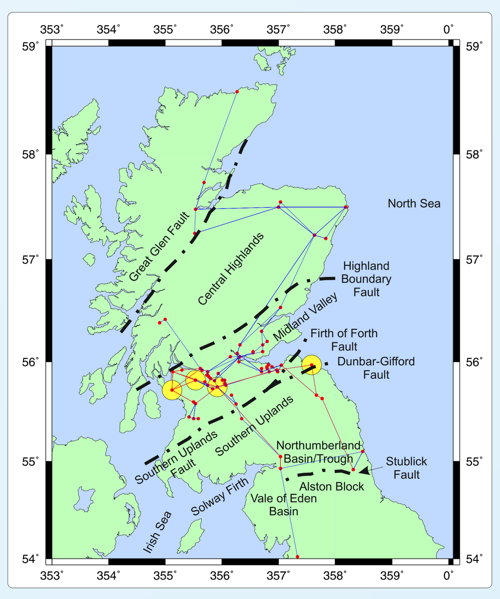
Right: Validating measured (top) and modelled (bottom) horizontal magnetic field (Bx [nT]; colour shading, maximum 25nT) and telluric vectors [mV/km.nT] in response to a 1nT field polarised north.

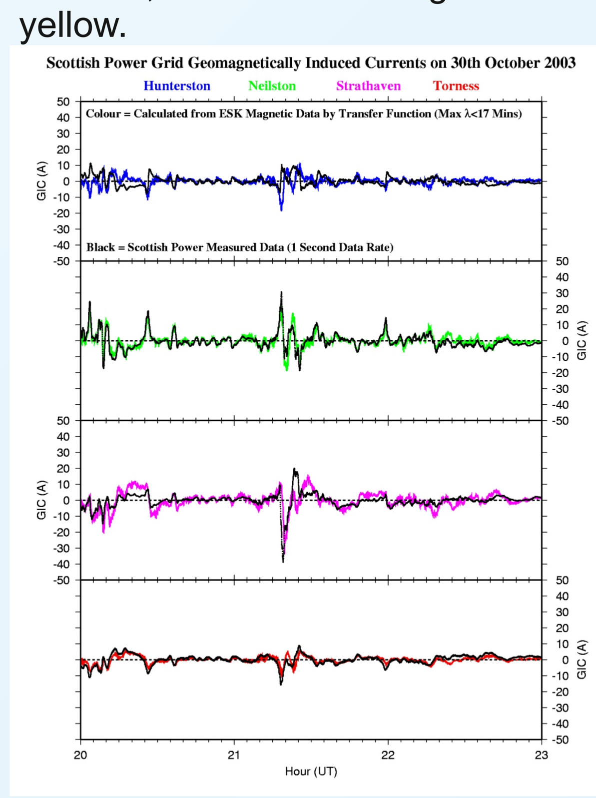


Right: Modelled and measured GIC at each of the four Scottish Power monitoring sites during the 30th October 2003 magnetic storm. In near real time a 1D model of the Earth is employed to calculate the geoelectric field from BGS magnetic observatory data. At one site (Strathaven) the model and measured GIC compare favorably, while at other sites the fit is less good. Work is in progress to include 3D thin-sheet modelling, and update the grid model.

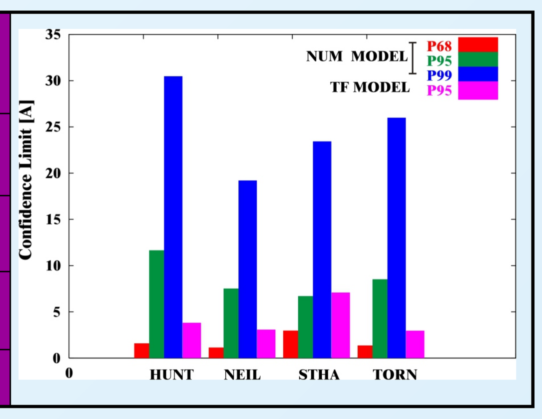


Far Right: The high voltage Scottish power network, with 4 monitoring sites shown in yellow.





	P_{68} [A]	P_{95} [A]	P_{99} [A]	P_{95} (TF) [A]
HUNT	1.6	11.7	30.5	3.8
NEIL	1.1	7.5	19.2	3.1
STHA	3.0	6.7	23.4	7.1
TORN	1.4	8.5	26.0	3.0



Left: A transfer function (*TF*) model is compared with measured GIC at each of the four Scottish Power monitoring sites during the 30th October 2003 magnetic storm. NB: Site *TF* were derived using 2000 storm data.
Above: Accuracy of transfer function model and grid model at various confidence levels, obtained by computing residuals and examining distributions. We estimate an average site error, over all sites, of at most +/-8.5A at 95% confidence.