Solar Wind Monitoring and Induced Current (SWIMIC) Modelling for the UK

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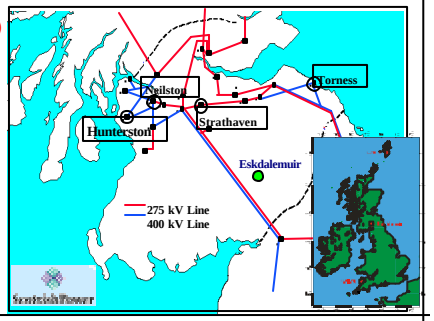
Current Activities (Apr-Oct 2003)

- *Prototype shock detector in service*
- *Real time GIC monitor for 4 Scottish Power sites in service*
- *Web data delivery under development*

Future Activities (Nov 2003-)

- Shock monitor*: Add a wavelet detector; Do shock detection statistics*
- GIC Monitor & Prediction*: Extend real time monitor (where are GIC anywhere in the grid?); Predictions of geomagnetic variations and resulting GIC*
- *Liase with Scottish Power on delivery*

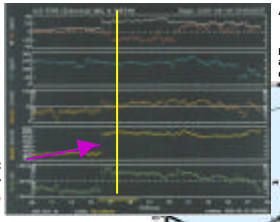


What are the Scottish Grid Operator Issues?

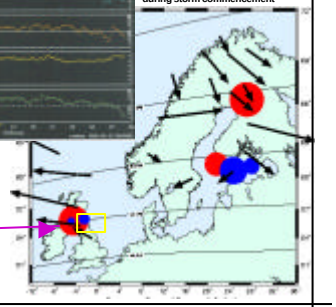
Key Issues for Improved Service to Industry – *based on discussions with Scottish Power*

1. Increased warning time of CME arrival and geomagnetic storms, based on L1 monitor *automated shock monitoring*

2. Estimates of peak GIC magnitude anywhere in the grid – *where are the biggest currents flowing in response to geomagnetic drivers?*



ACE Data for July 2000 Storm



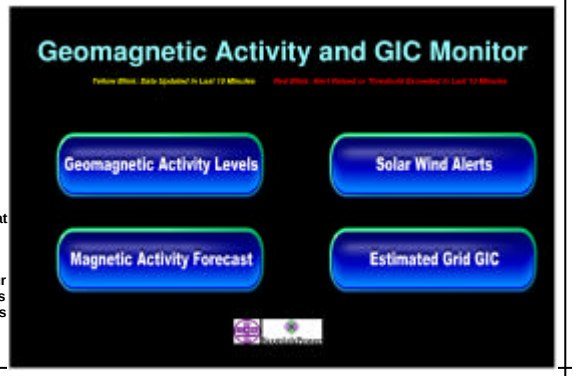
Excerpt from BGS/FMI animation of July 2000 Storm, during storm commencement

Current Activities for SWIMIC: Web Delivery of Data

Provide a simple Interface to data products

Each button links to page with graphical data plus explanatory material and contact point at BGS

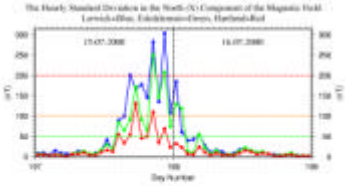
Blinking colour around buttons alerts operators to change in conditions

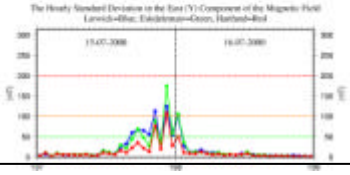


1. Building on Previous Work: Geomagnetic Activity Monitoring

Hourly Standard Deviation (HSD)

- Gives an indication of the total magnetic spectral power during the hour - $E(w)=Z(w)H(w)$
- Simple index to compute - real-time on-line provision possible
- Magnetic substorms typically last 10 minutes to a few hours
- Single data spikes unlikely to have an effect





New Developments for SWIMIC

Increase frequency of update (to 5 minutes)

Web delivery of both raw data (as at present) and plots

2. Building on Previous Work: Geomagnetic Forecasts

Geomagnetic Activity Forecasts

- gives broad view of likely activity for non-specialist
- attempts to relate to conditions observed in UK

New Developments for SWIMIC

Web delivery
Add glossary of terms

BRITISH GEOLOGICAL SURVEY: GLOBAL SEISMOLOGY AND GEOMAGNETISM GROUP
GEOMAGNETIC ACTIVITY FORECAST FOR SCOTTISH POWER

Forecast Interval (GMT)	Forecast Global Activity Level
Noon 15-JUL-2000 to Noon 16-JUL-2000	MAJOR-STORM
Noon 16-JUL-2000 to Noon 17-JUL-2000	MINOR-STORM
Noon 17-JUL-2000 to Noon 18-JUL-2000	ACTIVE

ADDITIONAL COMMENTS

Yesterday the magnetic field was at MINOR-STORM levels both globally and in the UK.

A major solar event has been observed from a region near the centre of the solar disk and a full halo CME was observed. These observations mean that the event is very likely to be geoeffective. The shock is expected to impact the earth's magnetosphere sometime during the latter half of the 15th July, but the exact timing is difficult to predict.

TODAYS FORECASTER: Ellen Clarke
BGS CONTACT PHONE: 0131 667 1000 (switchboard)
BGS CONTACT FAX : 0131 668 4368

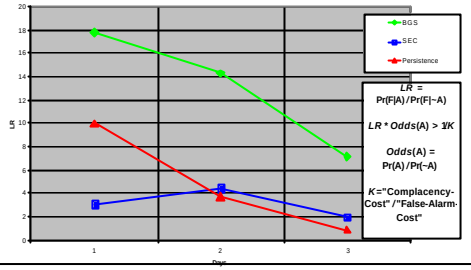
Global Activity Level	Typical Maxima of UK Observatory Hourly Standard Deviations (nT) LERWICK	ESKDALEMUIR	HARTLAND
QUIET-UNSETTLED	<20	<20	<15
ACTIVE	20-50	20-30	15-20
MINOR-STORM	50-150	30-60	20-40
MAJOR-STORM	>150	>60	>40

Next Stage: Forecast Accuracy

BGS One Day Ahead Forecasts

One Day Ahead Observations	No Storm	Storm
No Storm	238 (234)	4 (10)
Storm	12 (15)	5 (8)

	False Alarm Rate	Percent Correct	Prob. of Detect.
BGS	44 (67)	94 (90)	29 (30)
SEC	82 (68)	89 (90)	18 (30)
Persistence	59 (73)	92 (89)	41 (30)



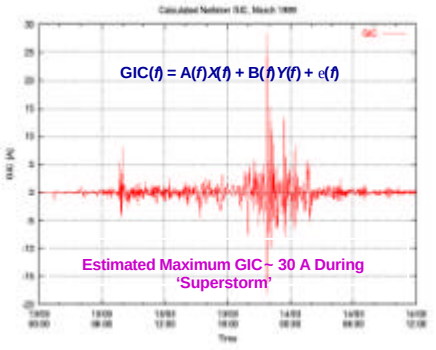
3. Building on Previous Work: GIC Analysis

Transfer Functions for the Four Monitoring Sites Derived from April 2000 Storm Data at Eskdalemuir

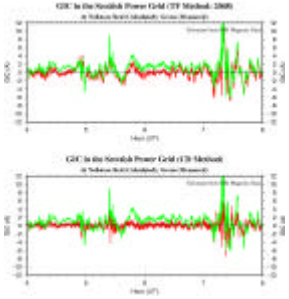
New Developments for SWIMIC

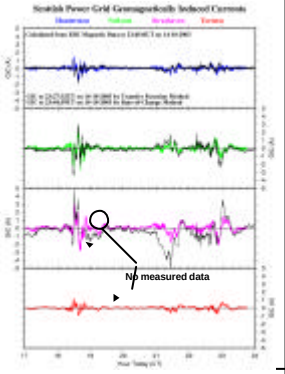
Real Time, High Accuracy Monitor – Compensates for Missing Data or 'Drifting' Baselines In Scottish Power data Monitoring

Web Delivery



Real Time GIC Monitor – Recent Results



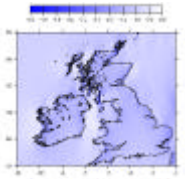


Above: Measured and calculated GIC at Neilston during April 2000 storm (top = transfer function method; bottom = from *H* rate-of-change)

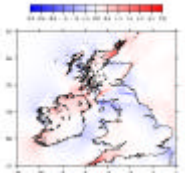
Right: 4-station data during recent activity (note: data gaps in measured data (black); level differences at some stations; un-modelled long period (~30 mins) variations at Strathaven)

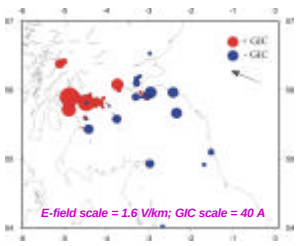
Next Stage: 3D Conductivity + Sea Water + Bathymetry ® Electric Field + Grid Model ® GIC

'Regional' East-West *E*-field from thin sheet model for E-W electrojet



'Anomalous' North-South *E*-field resulting from lateral variation in conductivity





E-field scale = 1.6 V/km; GIC scale = 40 A

Next Developments for SWIMIC:

- Monitor GIC in real time at all sites from measured geomagnetic variations – interface with FMI modelling
- Predict variations from solar wind data and predict GIC (hard scientific problem!)

4. Developments for SWIMIC: Shock Detection Algorithms

Prototype Method:

-Threshold detector applied to difference between upwind and downwind properties at each time step (next slide)

-Experimentation (maximising detection versus minimising false alarms on recent 'significant' events, since 2000)

-Uses a 4-5 sigma threshold for product delta(V)*delta(V.n)*delta(density) plus SSI must be > -0.15 (Fry *et al* 2002)

-Runs automatically every 5 minutes using Level 1 ACE data

-Shock notification if initial identification is repeated on next run (builds confidence)

-Email alert to BGS staff

-Posted on web page

Shock Detected at (GMT) : 14:49 24/10/2003
Estimated Shock Type : Fast Forward Shock
Likely Storm Arrival (GMT) : 15:29 24/10/2003

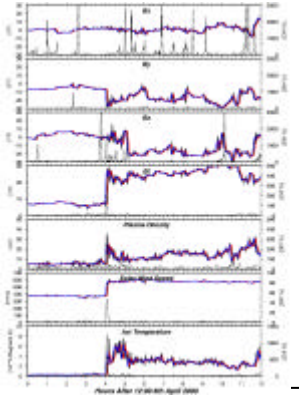
Shock Detected (GMT) : 09:55 25/09/2003
Estimated Shock Type : Slow Reverse Shock
Likely Storm Arrival (GMT) : 10:34 25/09/2003

Shock Detected (GMT) : 22:55 23/09/2003
Estimated Shock Type : Fast Forward Shock
Likely Storm Arrival (GMT) : 23:38 23/09/2003

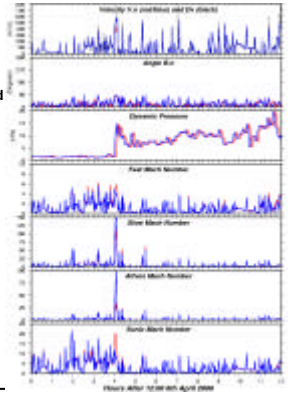
Shock Detected (GMT) : 15:17 16/09/2003
Estimated Shock Type : Unclassified Discontinuity
Likely Storm Arrival (GMT) : 16:10 16/09/2003

Shock Detected (GMT) : 10:42 21/08/2003
Estimated Shock Type : Fast Forward Shock
Likely Storm Arrival (GMT) : 11:22 21/08/2003

Real Time Shock Detection - Example



Plasma Properties During 6th April 2000 Solar Wind Event



Red: Upwind Smoothed

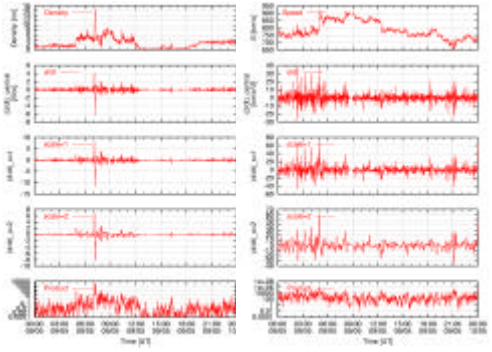
Blue: Downwind Smoothed

Next Stage: Alternative Shock Detection Algorithms

Under Development: ***Wavelets***

- By analogy to aero-acoustic shock waves generated by supersonic projectiles. Employs 'multiscale products' to enhance edge detection and estimation. (Walden, 1997)

-Exploit the fast rise time of the pressure pulse associated with a projectile and consider a detection strategy based on one or more scales of the 'Mallet-Zhong' DWT



Level 1 ACE data of 9th May 2003: multi-scale product of density (left) and bulk speed (right) highlight interesting events. Combined with similar plots for |B| and ion speed, we can better isolate events from noise.

SWIMIC: The Next Stage(s)

Model Development

Establish an initial working system and develop, modify and analyse it over the lifetime of the project

- ***Add***: Supplementary shock detection system (e.g. wavelets)
- ***Add***: Whole power grid modelling (*E*-field from geomagnetic variations) to single site monitors
- ***Add***: Predict geomagnetic variations from solar wind data (hard problem – important to establish how accurate this will be)

Model Testing

Systematic study of models (as opposed to the ad hoc analysis required to set up prototype system)

- ***Assess***: Accuracy of prototype shock detector (in terms of false alarm rate, probability of detection, …)
- ***Assess***: Accuracy of GIC monitor (e.g. rms/peak differences during storms)

Data Delivery

Interface to data products to be finalised with Scottish Power – User requirements to be decided

- Changes to interface to observatory data required by BGS