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
- Lias with Scottish Power on delivery UK magnetic observatories

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?

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

Hourly Standard Deviation (HSD)
- Gives an indication of the total magnetic spectral power during the hour: \( E(w) = 2\pi \sum_{w} H(w) \)
- 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

**BRITISH GEOLOGICAL SURVEY: GLOBAL SEISMOLOGY AND GEOMAGNETISM GROUP**

**GEOMAGNETIC ACTIVITY FORECAST FOR SCOTTISH POWER**

<table>
<thead>
<tr>
<th>Forecast Interval (GMT)</th>
<th>Forecast Global Activity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noon 15-JUL-2000 to Noon 16-JUL-2000</td>
<td>MAJOR-STORM</td>
</tr>
<tr>
<td>Noon 16-JUL-2000 to Noon 17-JUL-2000</td>
<td>MINOR-STORM</td>
</tr>
<tr>
<td>Noon 17-JUL-2000 to Noon 18-JUL-2000</td>
<td>ACTIVE</td>
</tr>
</tbody>
</table>

**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 will 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.

**TODAY'S FORECASTER:** Ellen Clarke

**BGS CONTACT PHONE:** 0131 667 1000 (switchboard)
**BGS CONTACT FAX:** 0131 668 4368

**Global Activity Level**
- QUIET-UNSETTLED: <20 nT
- ACTIVE: 20-50 nT
- MINOR-STORM: 50-150 nT
- MAJOR-STORM: >150 nT

**Real Time GIC Monitor – Recent Results**

**New Developments for SWIMIC**
- Real Time, High Accuracy Monitor – Compensates for Missing Data or ‘Drifting’ Baselines
- Scottish Power data Monitoring
- Web Delivery

**Next Stage: Forecast Accuracy**

<table>
<thead>
<tr>
<th>BGS One Day Ahead Observations</th>
<th>False Alarm Rate</th>
<th>Percent Correct of Detect.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Storm</td>
<td>238 (234)</td>
<td>4 (10)</td>
</tr>
<tr>
<td>Storm</td>
<td>12 (15)</td>
<td>6 (8)</td>
</tr>
</tbody>
</table>

**New Developments for SWIMIC**
- Web delivery
- Add glossary of terms

**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
- Scottish Power data Monitoring
- Web Delivery

**Estimated Maximum GIC ~ 30 A During ‘Superstorm’**

**Real Time GIC Monitor – Recent Results**

Above: Measured and calculated GIC at Neilston during April 2000 storm (top = transfer function method; bottom = from A rate-of-change).
Right: 4-station data during recent activity (note: data gaps in measured data; level differences at some stations; un-modelled long period 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

**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)

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**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 2003)
- Uses a 4-6 sigma threshold for product 
\[
\frac{\delta(V)}{\delta(V)} \cdot \frac{\delta(V)}{\delta(V)} \cdot \frac{\delta(density)}{\delta(density)} \plus SSI
\]

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

- 09:55 25/09/2003
  - Estimated Shock Type: Slow Reverse Shock

  - Estimated Shock Type: Fast Forward Shock

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

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

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**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...
**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