British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

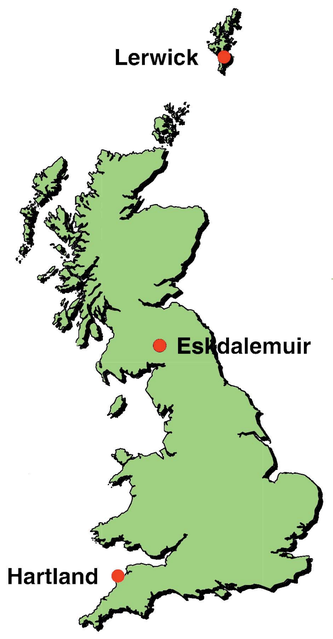
Ingredients for a successful space weather service

Orsi Baillie (orba@bgs.ac.uk), Ellen Clarke, Sarah Reay, Alan Thomson, Christopher Turbitt and Simon Flower
British Geological Survey, West Mains Road, Edinburgh EH9 3LA, United Kingdom

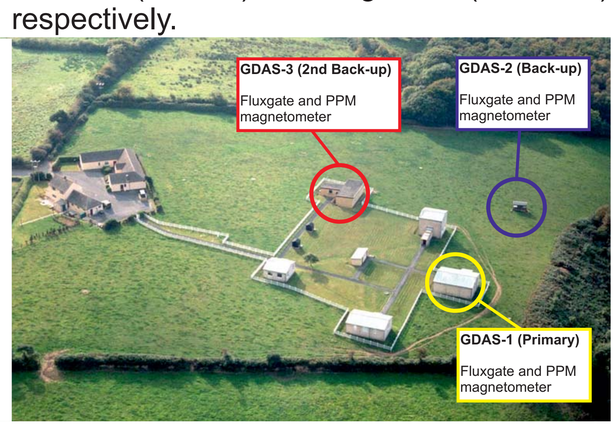
Introduction

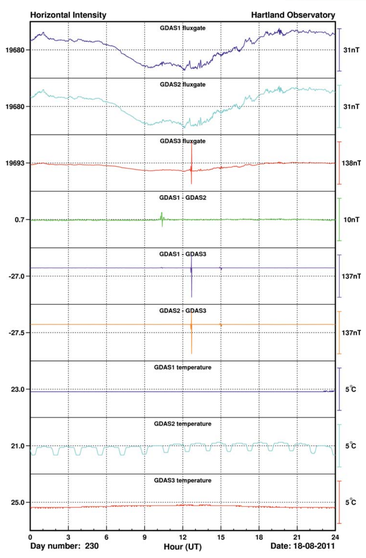
A successful operational space weather service needs to provide 24/7 access to good quality data and information with a high level of **reliability.** To do this it needs to be **resilient** with built in **redundancy** at all possible critical points of failure. Often near **real-time** outputs will be required based on real-time measurements from a variety of instruments and locations. This adds to the complexity of maintaining the service.

1. Observatory data processing



The **British Geological Survey** (BGS) operates three observatories in the UK. Each observatory has three identical systems with vector (fluxgate) and scalar (proton precession magnetometer - PPM) instruments recording the magnetic field direction (at 1 Hz) and magnitude (at 0.1 Hz) respectively.





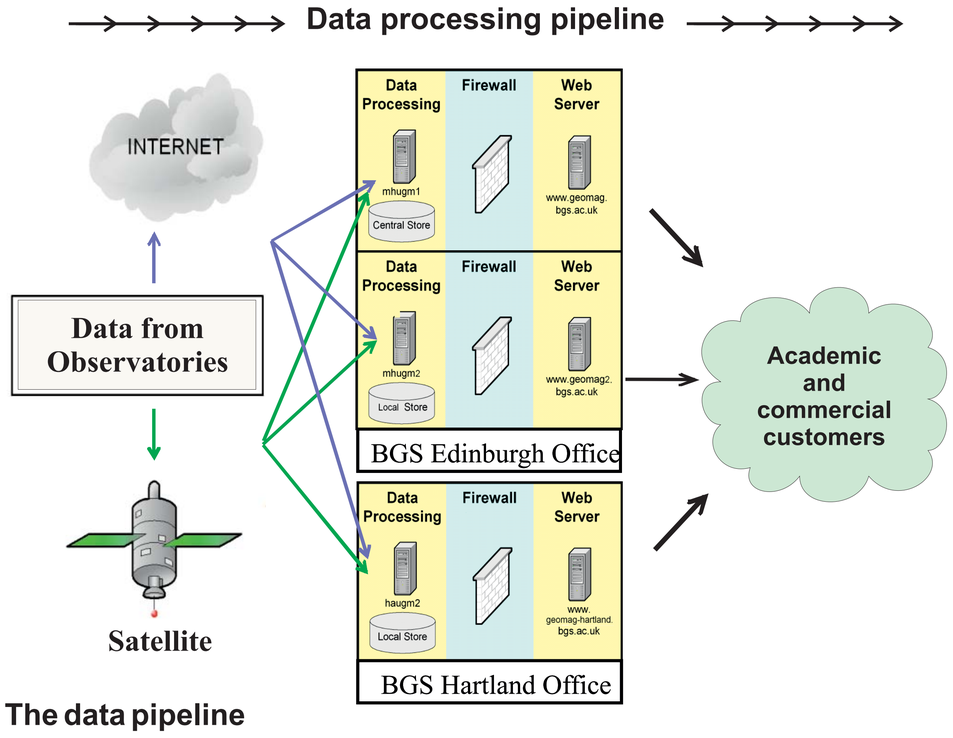
Quality control

Real-time data from the BGS observatories are an important component of the BGS space weather services. The configuration of observatory instrumentation allows us to do the following in real time to ensure high quality data:

- Reliably identify instrument problems or interference in the data by comparing recordings from vector and scalar instruments.
- Check for temperature related effects.
- Replace corrupt data with data from an unaffected system.
- Detect timing errors.

The plot shows one-minute recordings of the horizontal intensity made by the three fluxgate magnetometers at Hartland observatory on 18 August 2011. This example illustrates corruption of data due to planned site maintenance (grass cutting). It also shows that a complete noise-free data set can be obtained by combining the records.

2. Resilience with built in redundancy



The data pipeline

BGS has undertaken an extensive development programme to ensure the reliability of the flow of data from sensor to user. There are several critical elements:

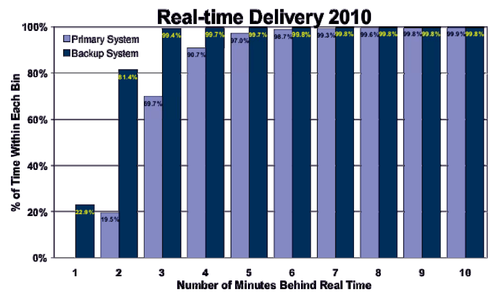
- **Power** – we have installed back-up power supplies at the observatories and at BGS offices where data processing is carried out.
- **Communications** – we have primary (Internet) and back-up (satellite) links between the observatories and BGS offices.
- **Software** – we have independent and identical data collection and processing software operating on three processing servers at two sites. Weekly synchronization between the main server and the two back-up servers ensures that all software is identical.
- **Web servers** – there are three mirrored web servers at two sites. Users can access data from any of the web sites in real-time.

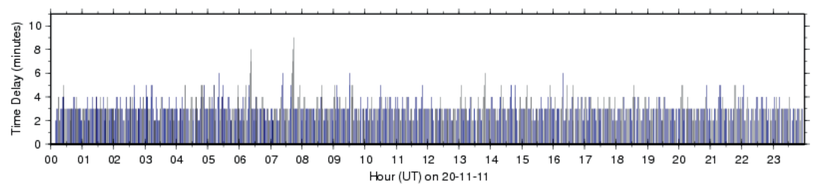
3. Real-time data delivery and Reliability

How successful are the BGS real time services?

To assess and improve the performance of real time data delivery to BGS customers, we:

- Monitor the time lag between the time-stamp of data and delivery to the web servers for users to access data products.
- Issue text message alerts when there is a deterioration in performance so that it can be resolved promptly by BGS staff.



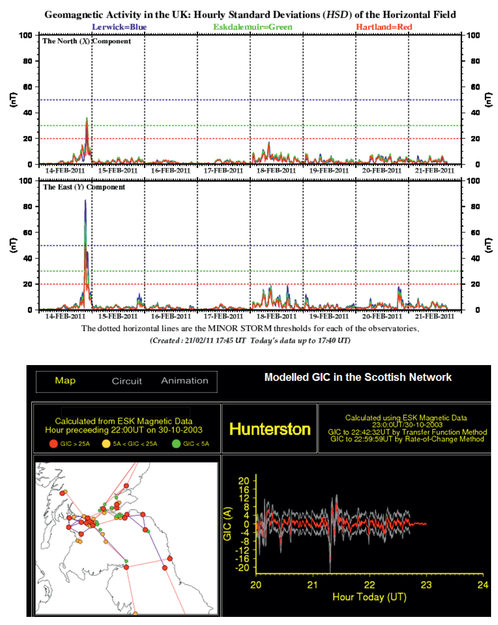


4. Monitoring and Analysis of Geomagnetically Induced Currents (MAGIC)

BGS is currently setting up a new space weather service tailored to the needs of National Grid UK Ltd, the company responsible for electrical power distribution in the UK. This service is called Monitoring and Analysis of Geomagnetically Induced Currents (MAGIC). It builds on previous work carried out by BGS (Thomson *et al.,* 2005) and also for the European Space Agency (ESA) as a space weather pilot project.

The **MAGIC** service already includes online access via a web-tool to:

- Hourly Standard Deviation (HSD) data from the UK magnetic observatories. This real-time geomagnetic activity information gives a simple indication of the likelihood of significant GICs flowing in the National Grid.
- Modelled values of GIC in the grid at Central Scotland transformer nodes.
- Solar wind shock detection.
- Daily geomagnetic activity forecasts and geomagnetic storm warning alerts.



The diagrams show:

- HSD data from the UK geomagnetic observatories during a storm on 14 February 2011.
- A model of GIC in a Scottish segment of the National Grid and at the Hunterston nuclear power station during the Halloween storm, 2003.

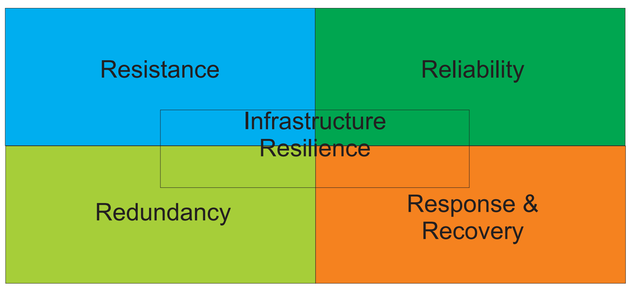
We plan to develop the service to include, amongst other things:

- Upgrades to the web-tool to incorporate the entire high voltage UK grid showing the locations of transformers and their resistance to ground.
- Automatically generated text message to NG when an agreed HSD threshold is exceeded.

5. Summary and future developments

BGS has worked over a number of years to create systems capable of delivering resilient space weather services. Such services are becoming more important as the vulnerability of ground- and space-based technological systems to disruption and damage caused by space weather events increase. It is important to maintain dialogue with the users of space weather services to ensure that relevant data products are developed and delivered efficiently.

At the same time the data processing pipeline needs to be maintained making improvements where technological developments create new opportunities. For example the next stage of development will be the replacing of the primary web server with a web server that will incorporate new fail-over technology. This will increase performance and reliability.



Credit: UK Cabinet Office report on Natural Hazards & Infrastructure

References

Thomson, Alan W. P., McKay, Allan J., Clarke, Ellen, Reay, Sarah J., 2005. Surface electric fields and geomagnetically induced currents in the Scottish Power grid during the 30 October 2003 geomagnetic storm. *Space Weather*, 3, S11002.

Acknowledgements

National Grid UK Ltd., European Space Agency, Scottish Power Plc.