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Space Weather



Andrew Richards – Severe Risk Analyst

April 2013

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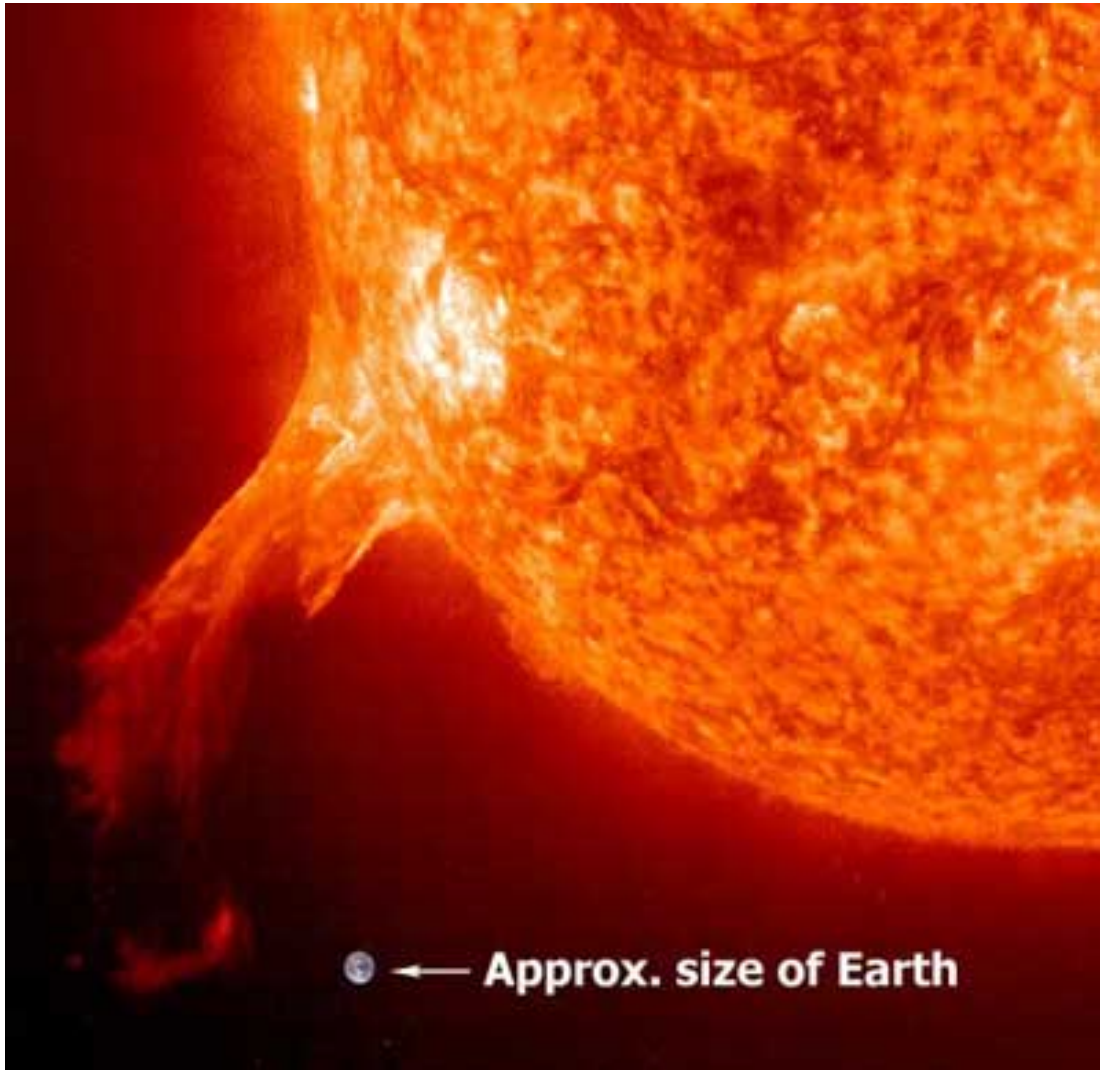
Coronal Mass Ejection - CME



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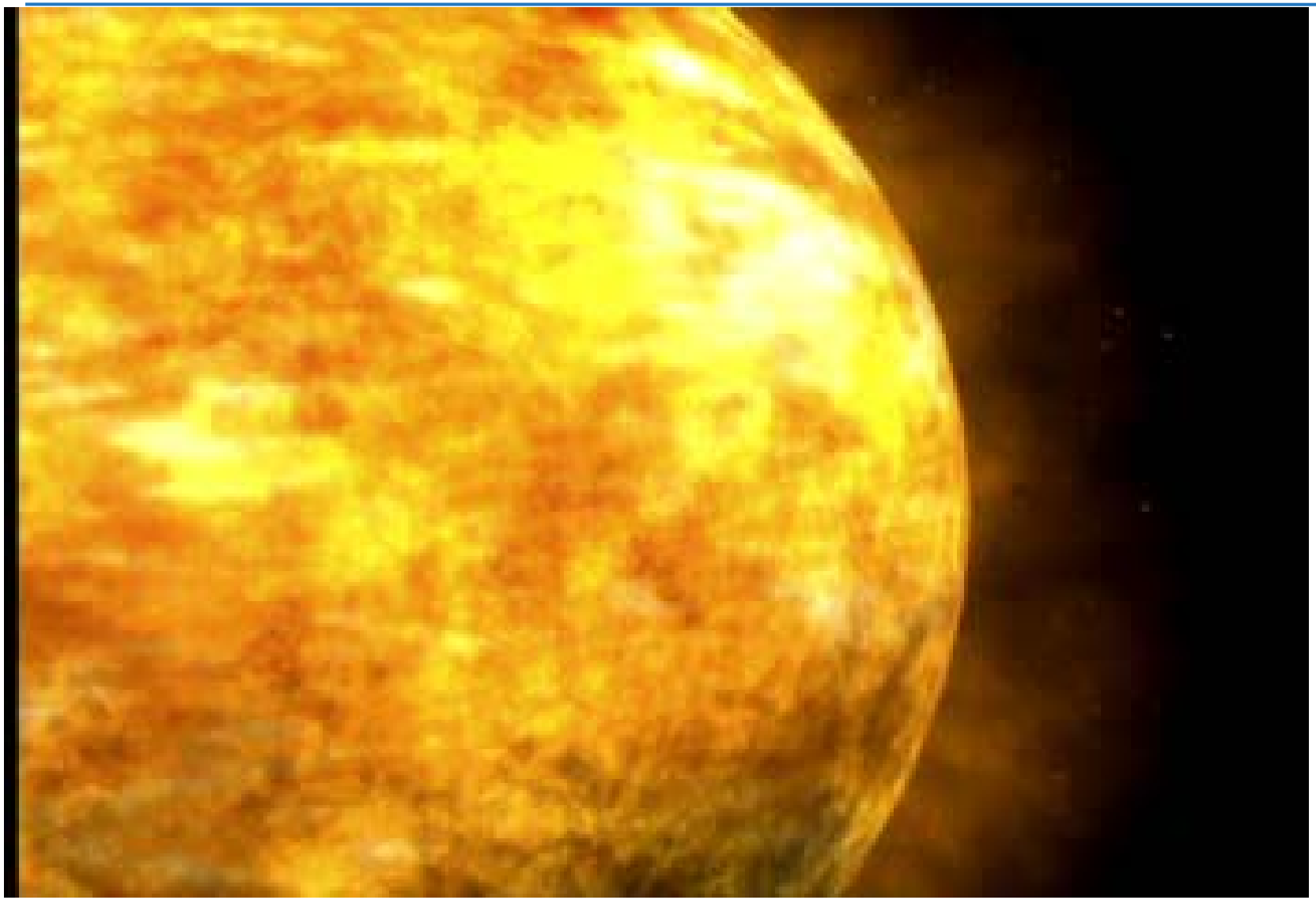
CME propagation



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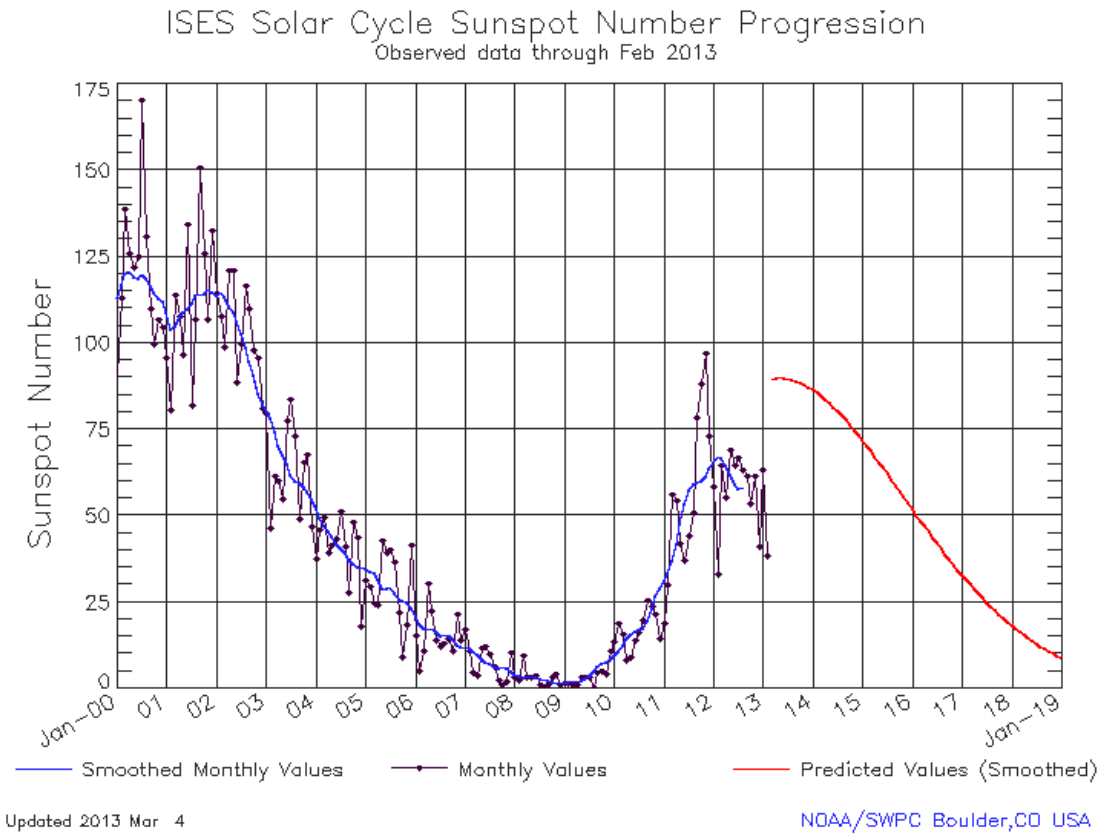
Solar Cycles

- Sun follows a cycle, roughly 11 years
- Cycle 24 much lower than predicted
- Cycle 24 maximum possibly during 2012
- 2 to 4 years after maximum most active for solar storms
- Large storms not strongly correlated with the cycle



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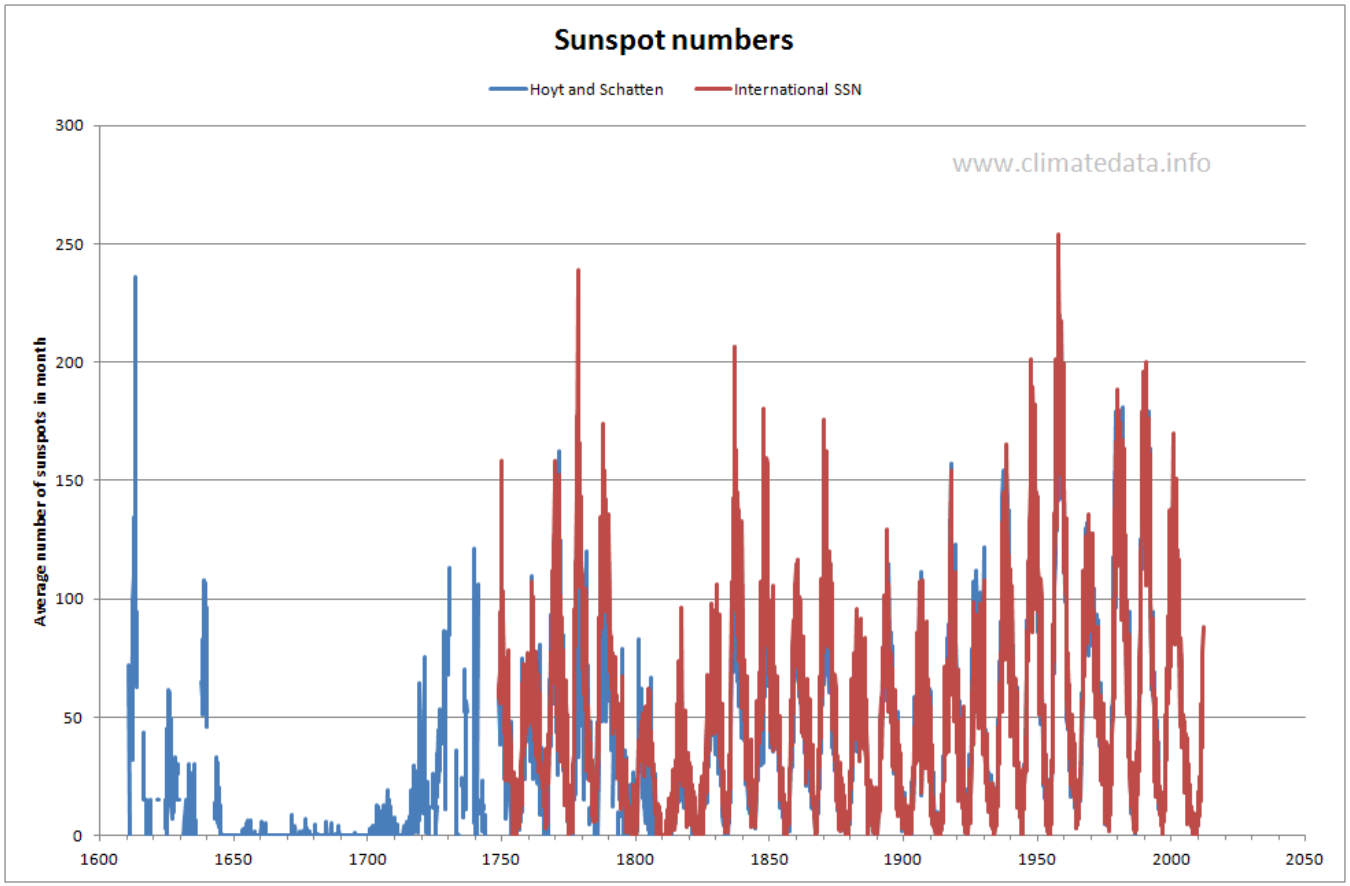
Sunspot Numbers 1600 onwards

- Cycle 24 was predicted to be weakest for 100 years
- It's turned out even weaker than predicted
- Low activity cycles have occurred before



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Past Events affecting Electrical Networks

- 1859 Carrington Event: Largest known storm
- 1921 New York Railroad Storm: Damaged equipment and fires
- 1940 Easter Sunday Storm: First Power Grid effects
- 1989 Quebec Blackout: First major storm of the Electricity Grid Age
- 2003 Halloween Storm: Malmö, Sweden blackout. Transformers in South Africa damaged

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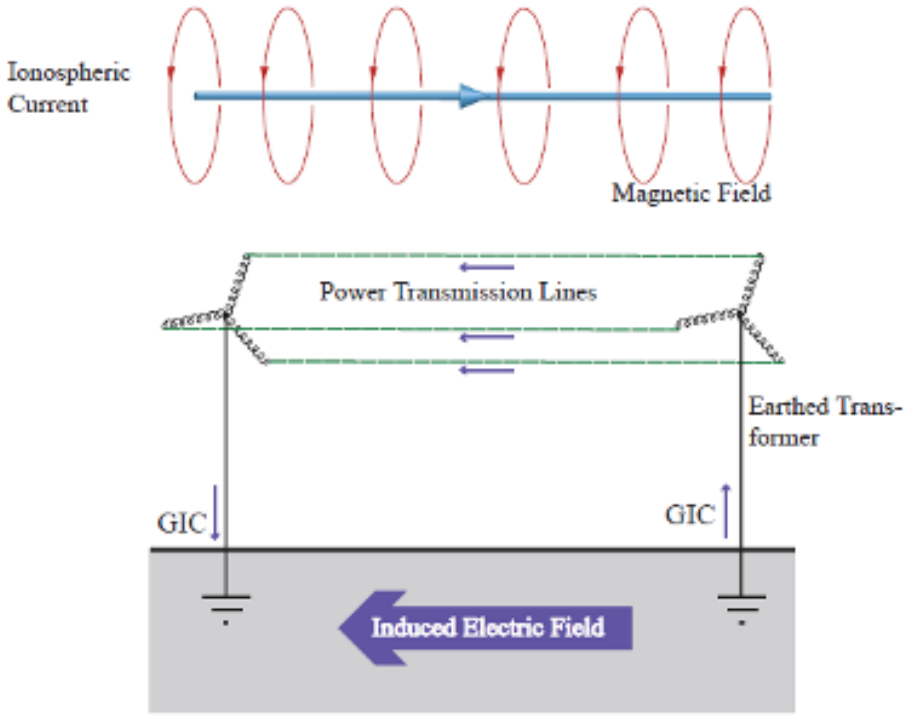
Geomagnetically Induced Current - GIC

- Geomagnetic Disturbance
- Induce Electric fields inside Earth's crust
- GICs flow out of earth, along transmission lines
- Earth themselves again through transformer neutrals
- Slowly varying, quasi-DC currents



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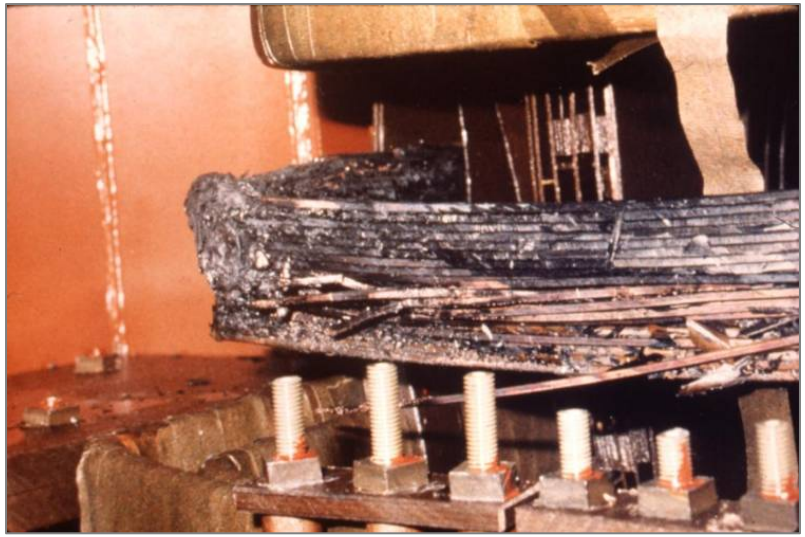
Effects on the system

- Magnetic flux leakage from core
  - Overheating, gassing, shutdown
  - Potentially catastrophic failure
- Increased reactive power consumption
  - Voltage instability
  - Power outages
- Distorted output waveform
  - Higher harmonics present
  - Protective relays triggered
  - Control assets switched out



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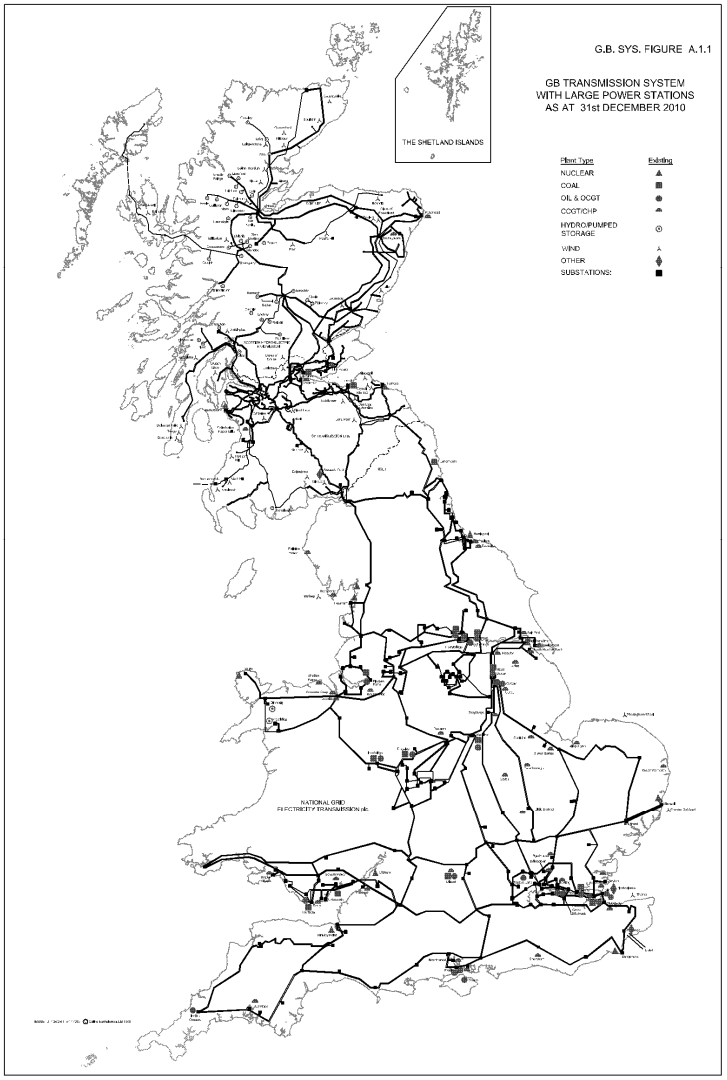
Risk Factors

- Geographic Location
  - Further north
  - Geological structure – down to 800km
  - Coastal effects
  - Edge of system
- Longer lines
- Higher voltage
- Transformer design



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Risk Levels of Possible Effects

- Widespread damage/destruction of high voltage transformers
  - Major disruption to electricity network
  - Recovery time of years

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  - Possibly one or two nodes disconnected for some weeks

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- Widespread damage/destruction of high voltage transformers
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- Widespread damage/destruction of high voltage transformers
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- Damage to small number of high voltage transformers
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  - Possibly one node disconnected for some weeks
- Reactive Power demands lead to widespread voltage disturbances **1 in 30 years**
  - Possible local power outages **1 in 50 years**

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Categorisation of Disturbances

Category	Frequency	Description	Action
Category 1	4 or 5 per 11 year cycle	Media Interest. No effects on system	None
Category 2	2 or 3 per 11 year cycle	Minor Disturbance. Small voltage fluctuations seen on system.	MAGIC deployed. Heightened Awareness. Within NG normal working parameters
Category 3	1 per 11 year cycle	Storm. Voltage disturbances needing to be managed.	MAGIC deployed. Notice of system disturbance issued. Extra reactive power support. All transformers at high risk substations swithched in.
Category 4	1 in 30 year event	Major Storm. Very high reactice power demands. Likelihood of high voltage disturbance. Possibility of Bucholtz alarms on a few high risk transformers	DECC informed. Silver Command convened. All-in procedure. Circuits returned to service. All transformers connected. Extra generation synchronised. Extra reactive support. Interconnectors set to float.
Category 5	1 in 100 year event	Extreme storm. Carrington-like. Very high reactice power demands. Possibility of local voltage collapse. Likelihood of thermal damage to 10 - 20 transformers..	DECC informed. Silver Command convened. All-in procedure. Circuits returned to service. All transformers connected. Extra generation synchronised. Extra reactive support. Interconnectors set to float.

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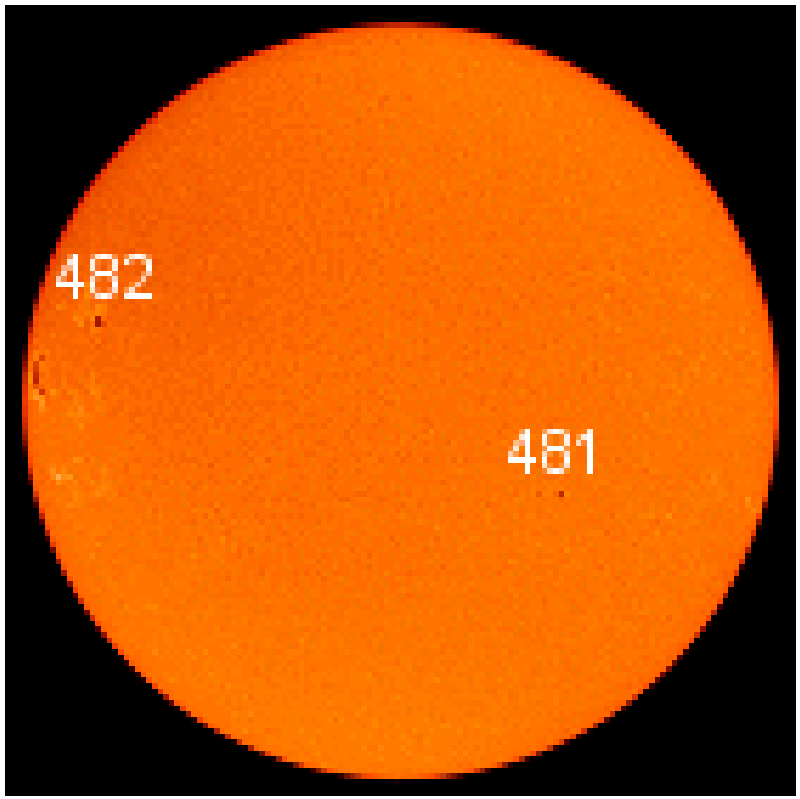
Sunspots

- 18 October 2003



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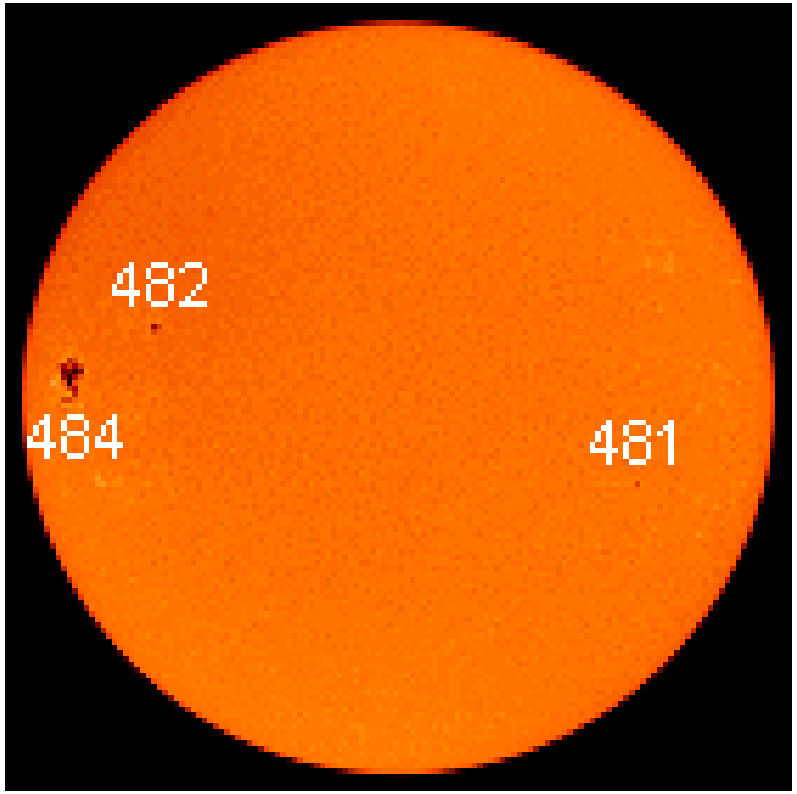
Sunspots

- 19 October 2003



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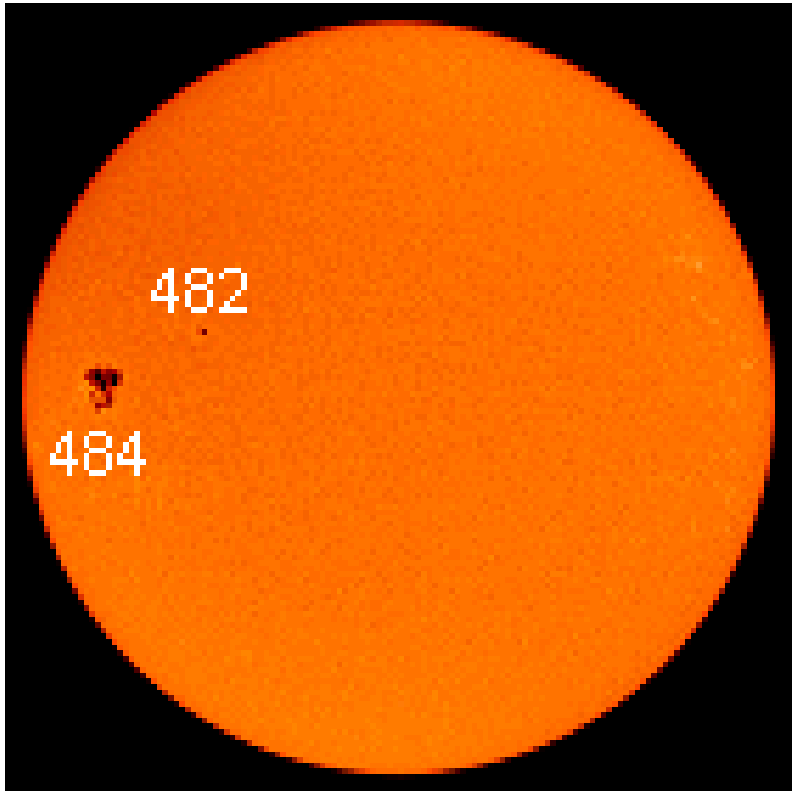
Sunspots

- 20 October 2003



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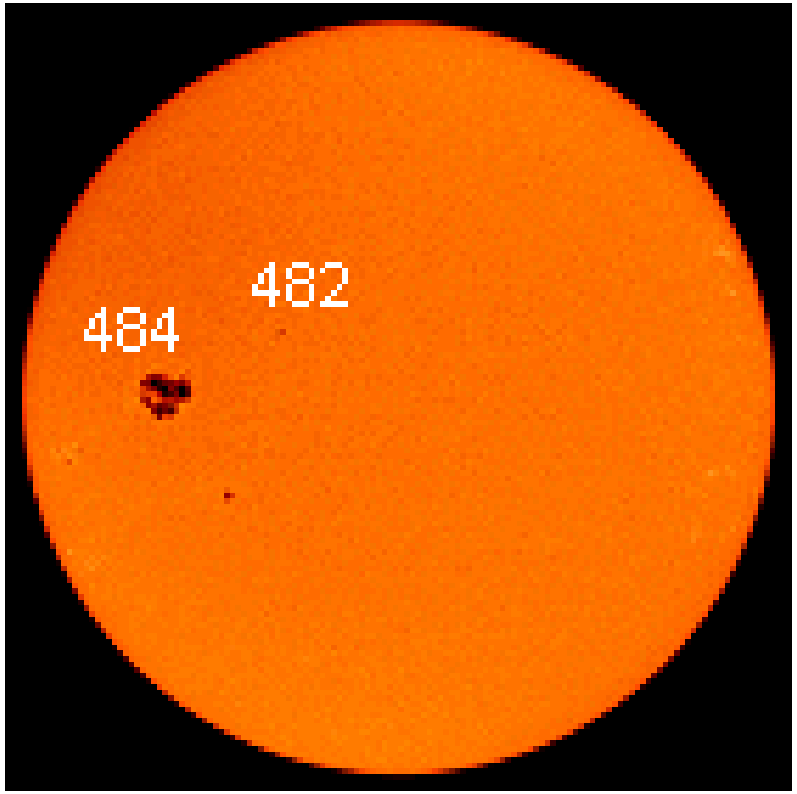
Sunspots

- 21 October 2003



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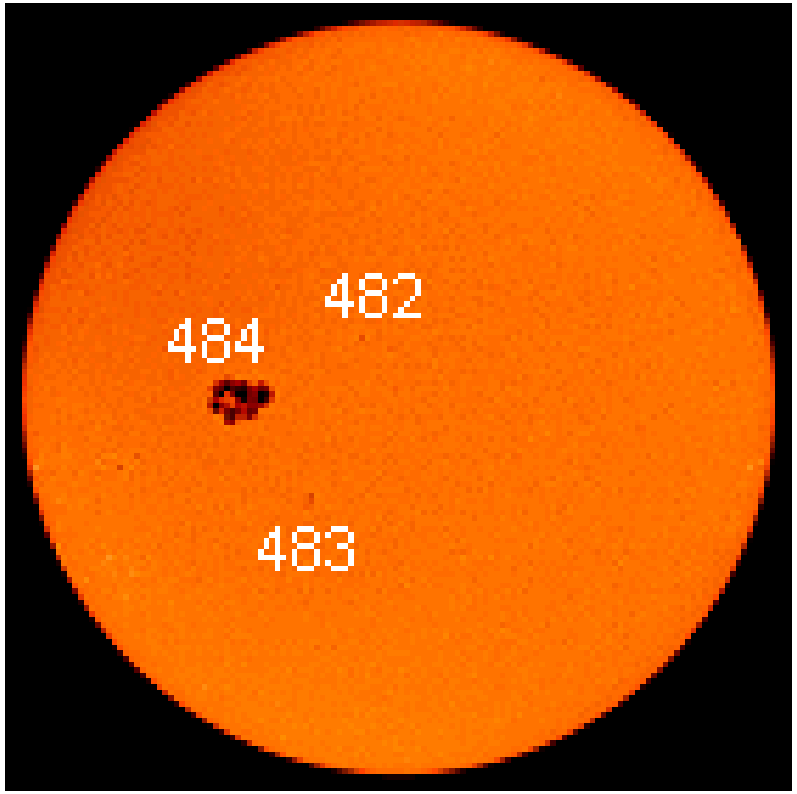
Sunspots

- 22 October 2003



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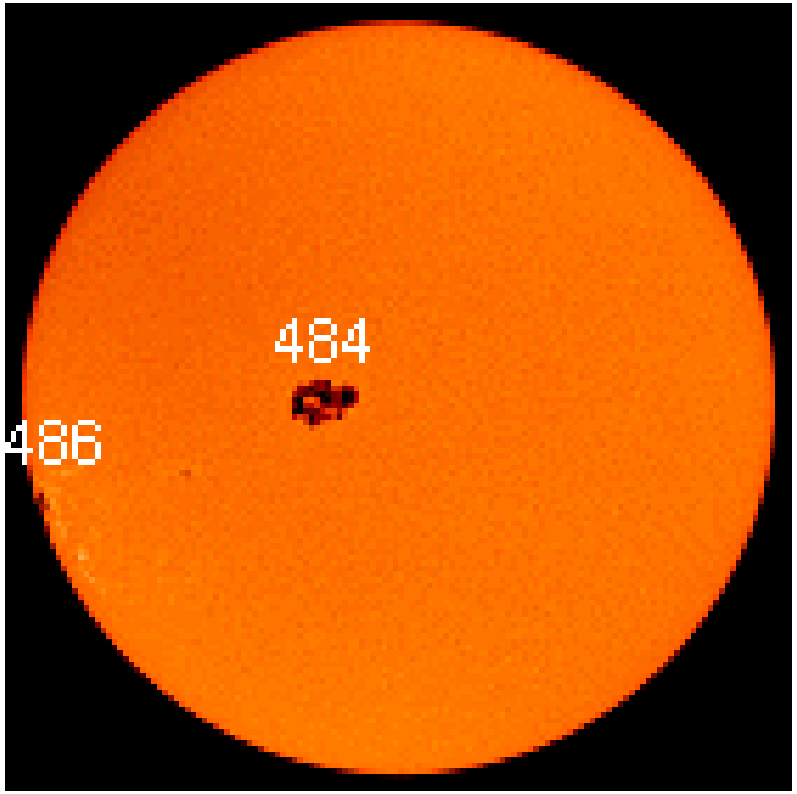
Sunspots

- 23 October 2003



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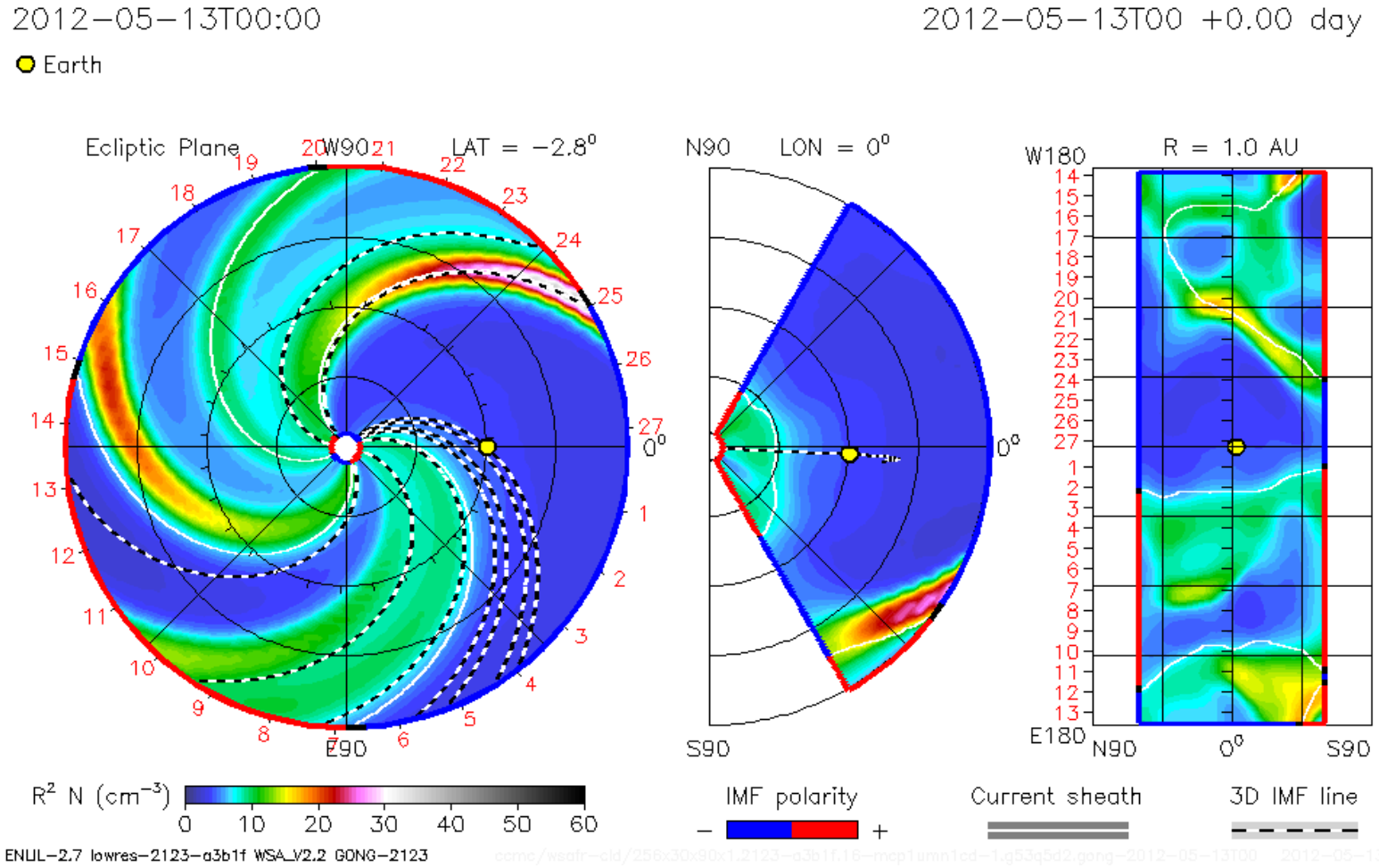
ENLIL Model



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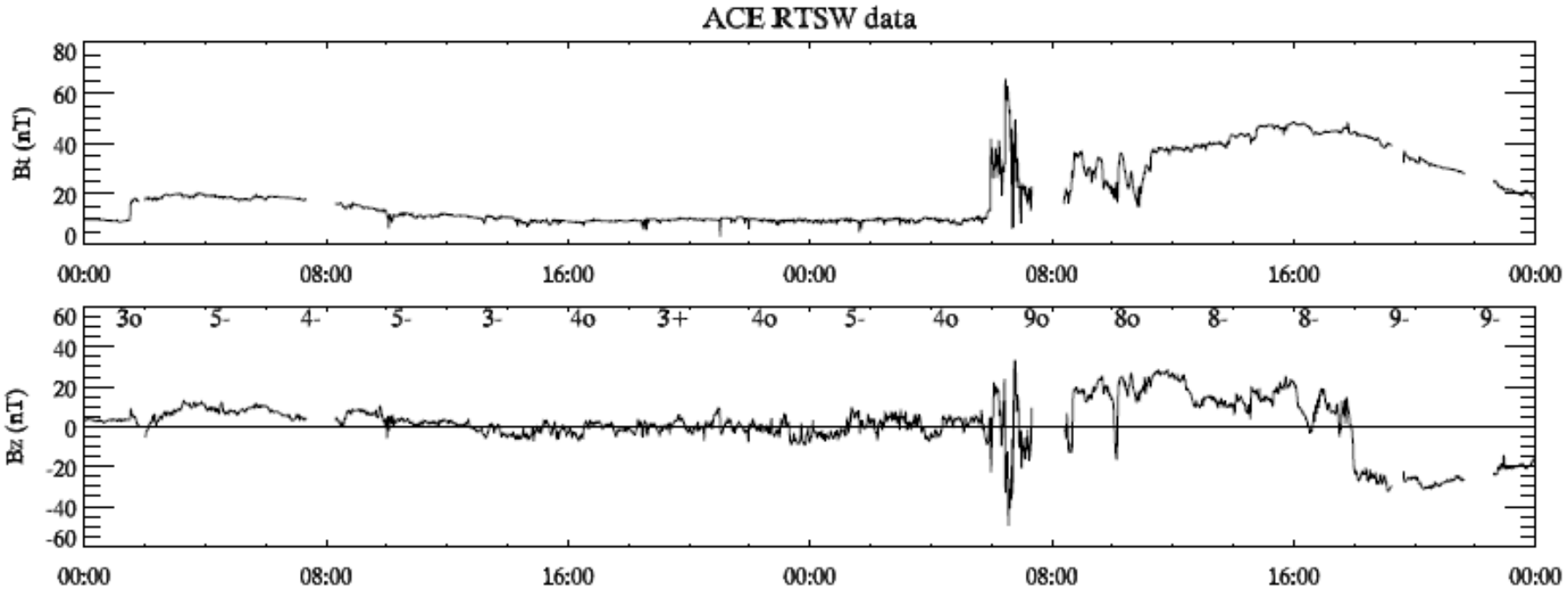
Arrival at ACE satellite



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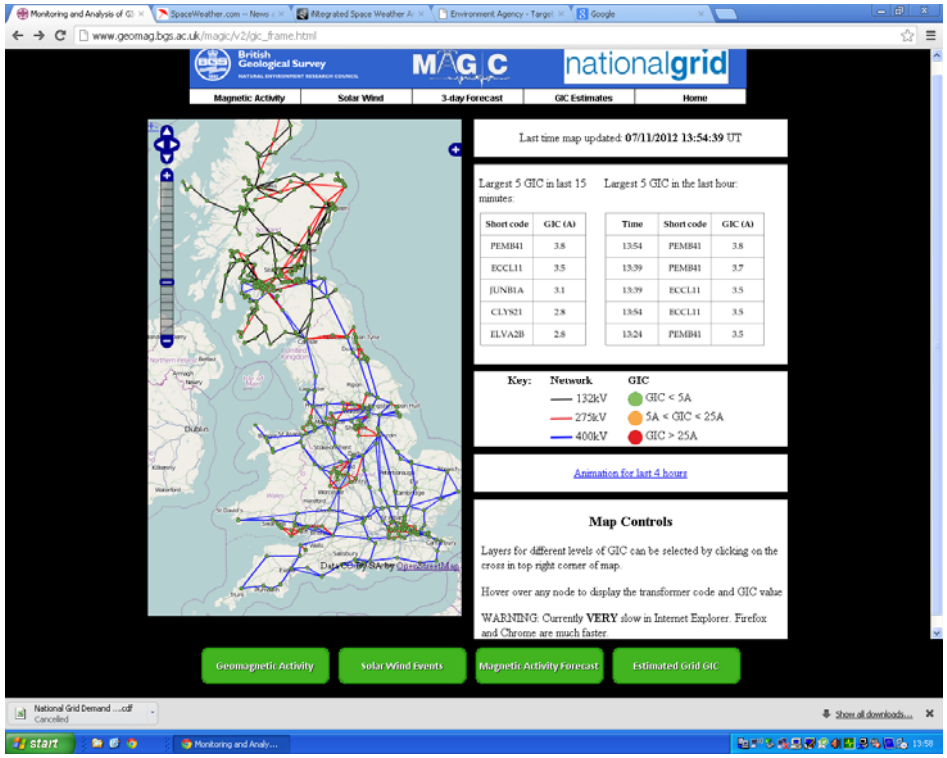
Mitigating the Risk: Operational

- Forecasting and Monitoring
- Increase reserves: more generation on line
- Stability of network: greater connectivity
- Share stress: utilise all available transformers
- Identify problem areas: specially designed tools



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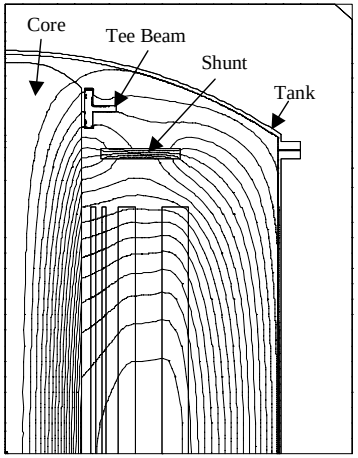
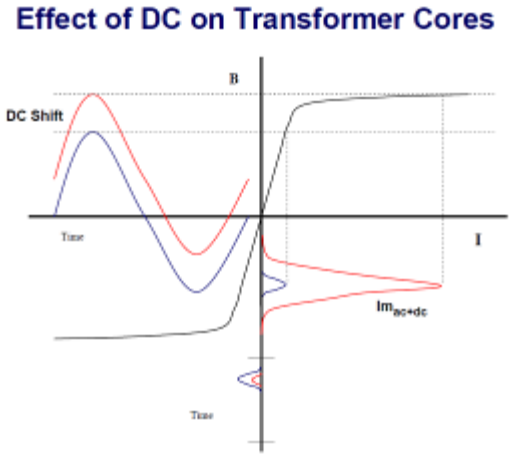
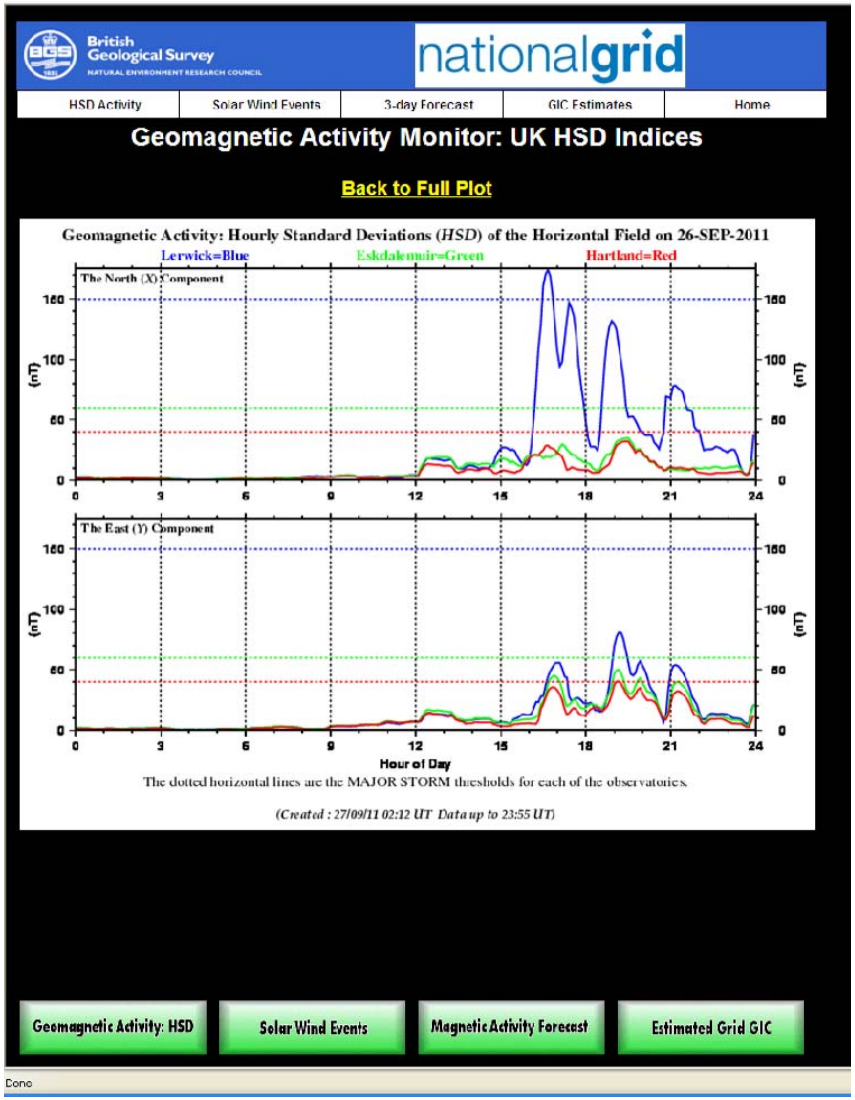
Mitigating the Risk: Design

- New transformers since 1999 have high GIC tolerance
- Increased transformer spares
- Highly connected network
- Redundancy of transformers at substations
- Short transmission line lengths
- No voltages above 400 kV





National Grid / BGS MAGIC Webtool Magnetometer records



National Grid / BGS MAGIC Webtool Network Model display

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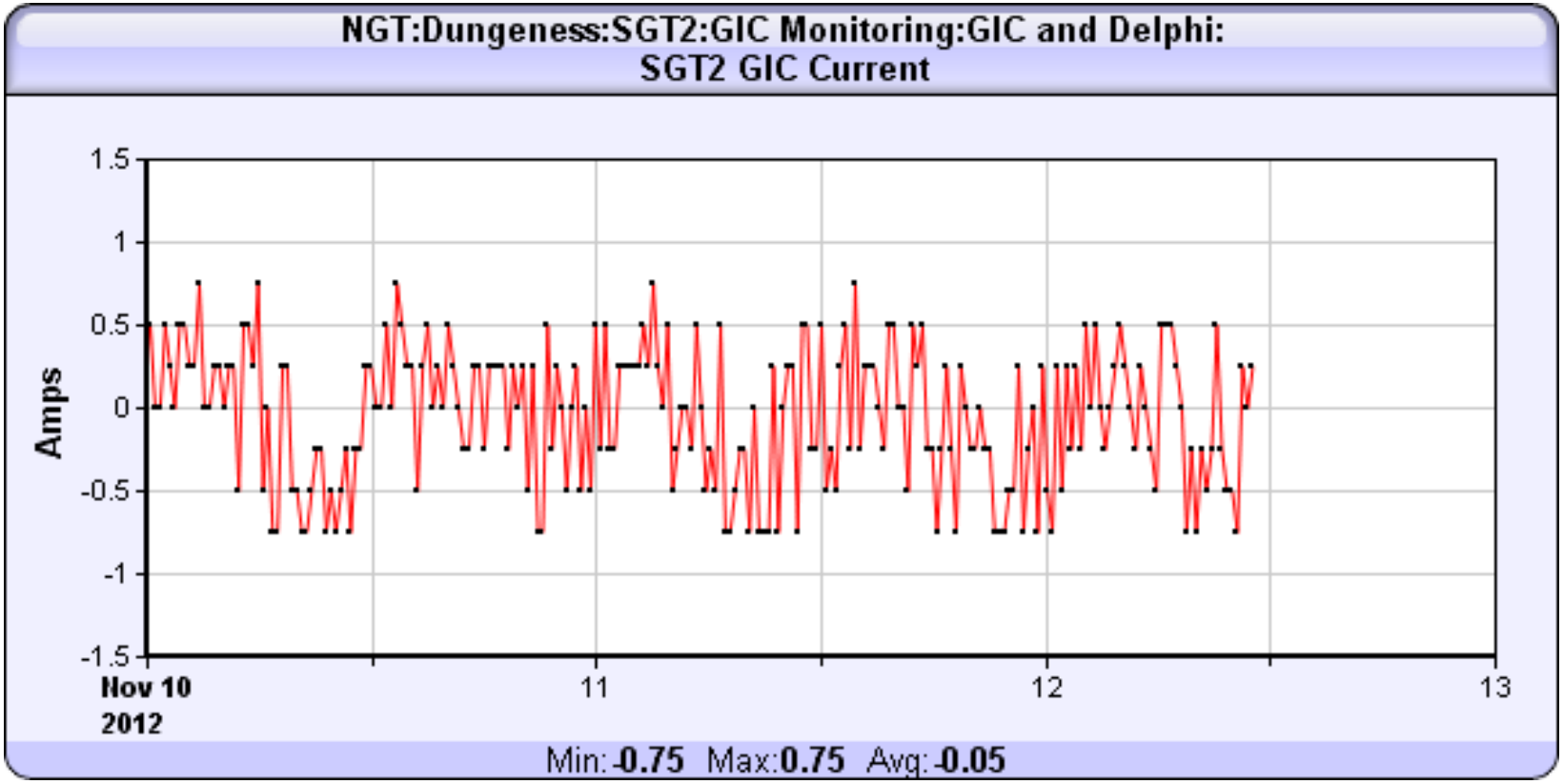
Monitoring of Transformers



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Cooperation for Cycle 24

RAL Space

SOLAR SHIELD

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

EPRI ELECTRIC POWER RESEARCH INSTITUTE

The Royal Academy of Engineering

Lancaster University
Manchester University
Cardiff University

NOAA
NASA
NERC (UK)
NERC (US)

National Grid UK
(4 SUNBURST sensors)
National Grid US
(2 SUNBURST sensors)

Met Office

Scottish Power
DECC
Cabinet Office

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Q&A

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