Geomagnetic Disturbances
Grid Code Review Panel
21 November 2012

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National Grid

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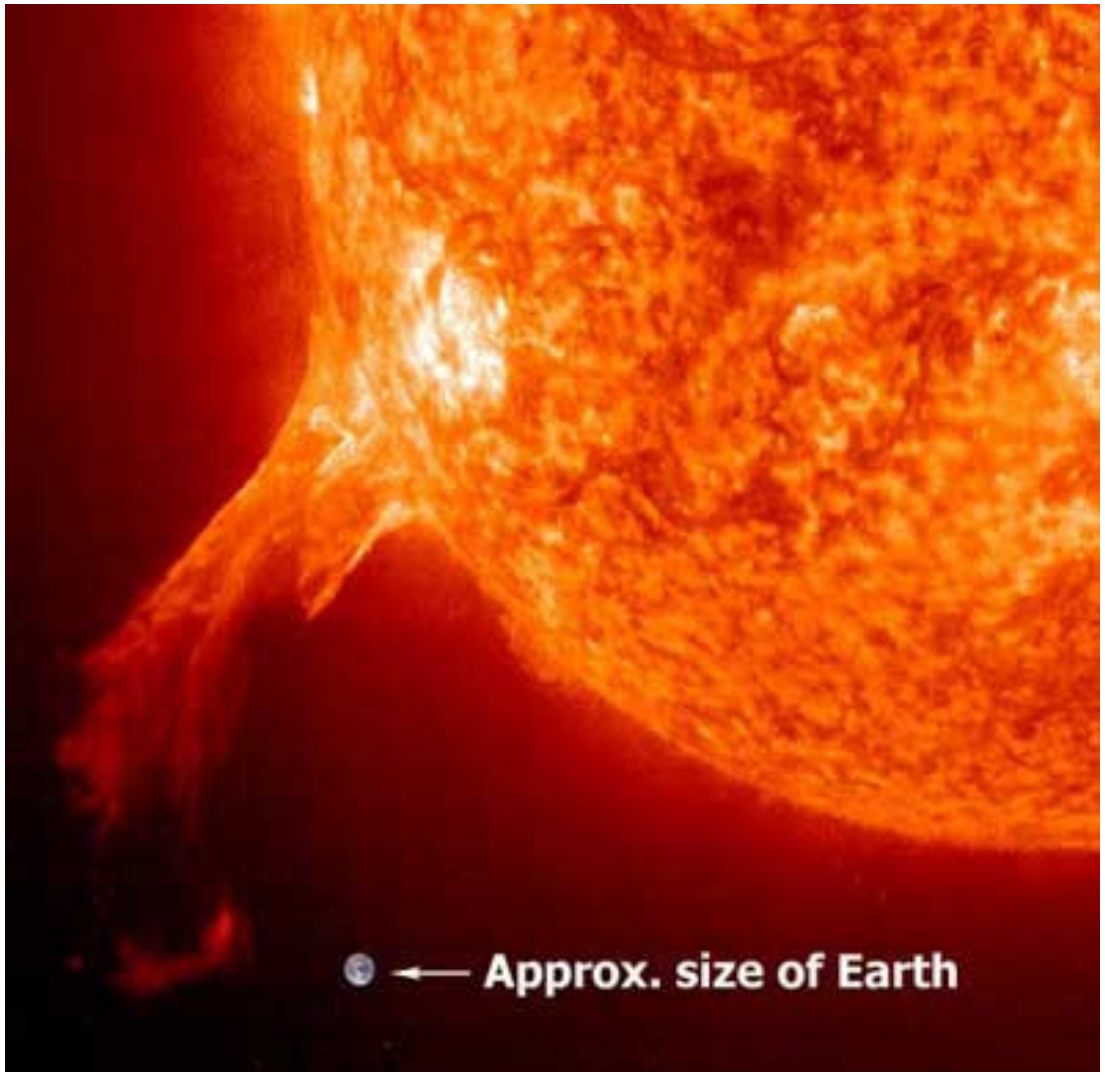
Coronal Mass Ejection



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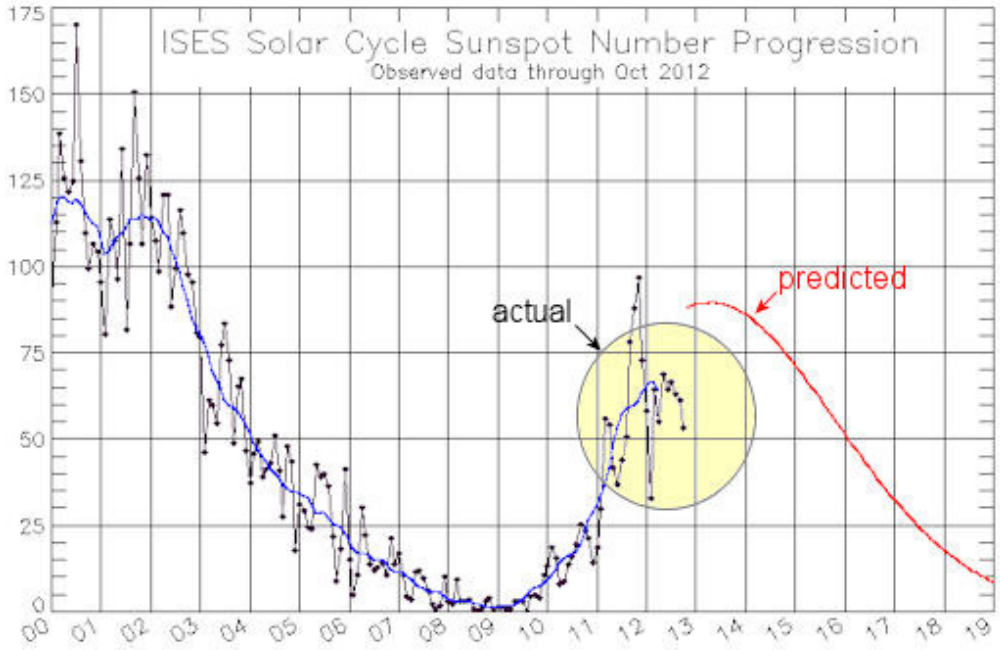
Solar Cycles

- Sun follows a cycle, roughly 11 years
- Number of sunspots indicates how much activity
- Cycle 24 will reach maximum in March 2013
- 2 to 3 years after maximum most active for solar storms
- Cycle 24 was predicted to be weakest for 100 years
- It's turned out even weaker than predicted



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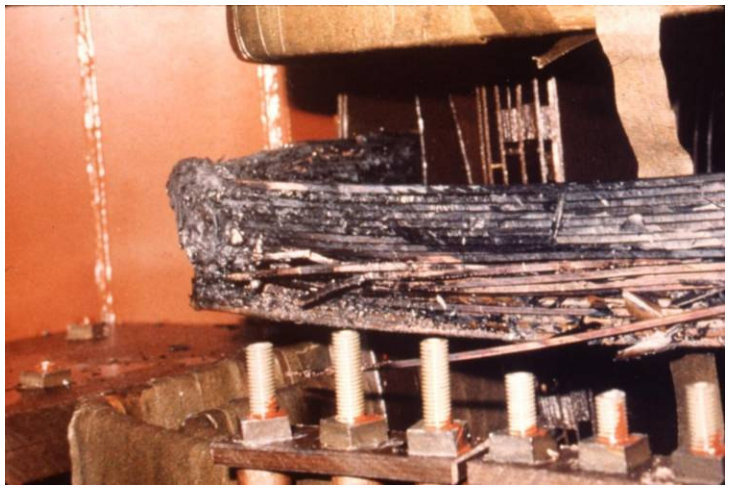
Effects on the system

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



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Risk Factors

- Geographic Location
  - Further north
  - Geological structure – down to 500km
- Line length
- Line resistance
- Last two explain why no disturbance ever observed in low voltage network

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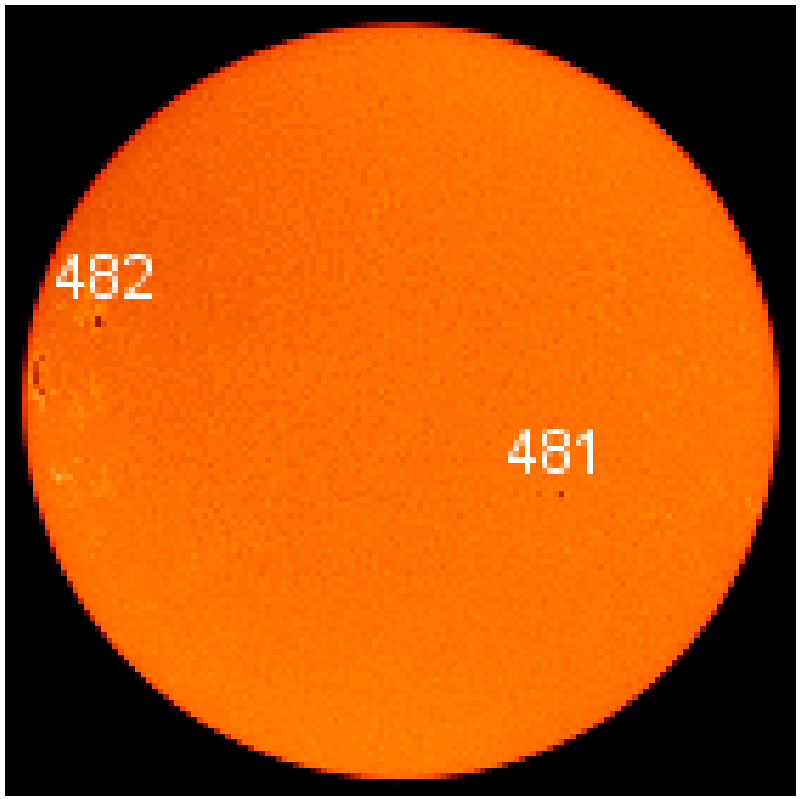
Sunspots

- 18 October 2003



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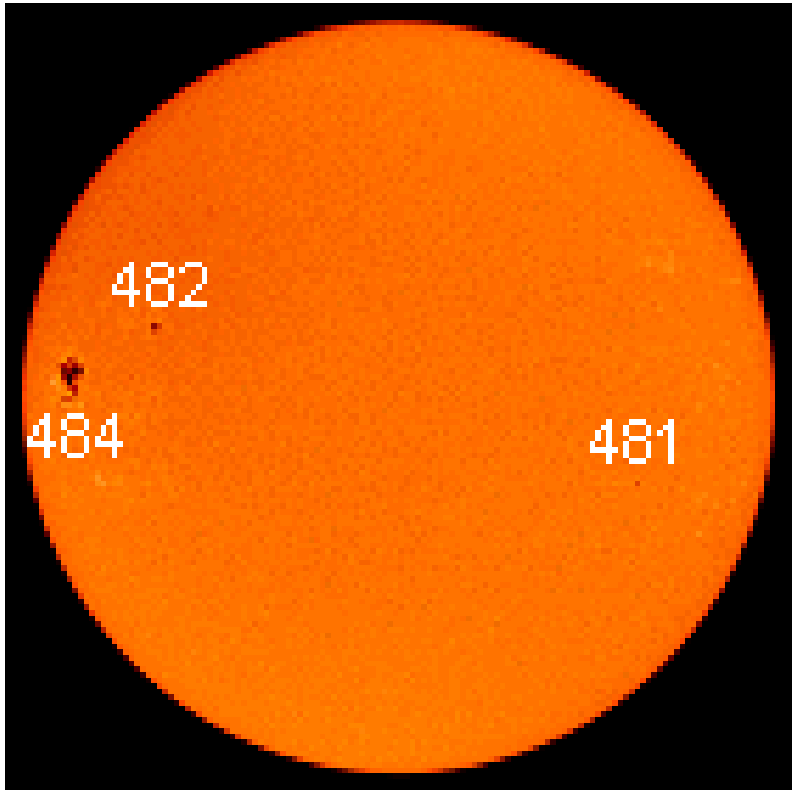
Sunspots

- 19 October 2003



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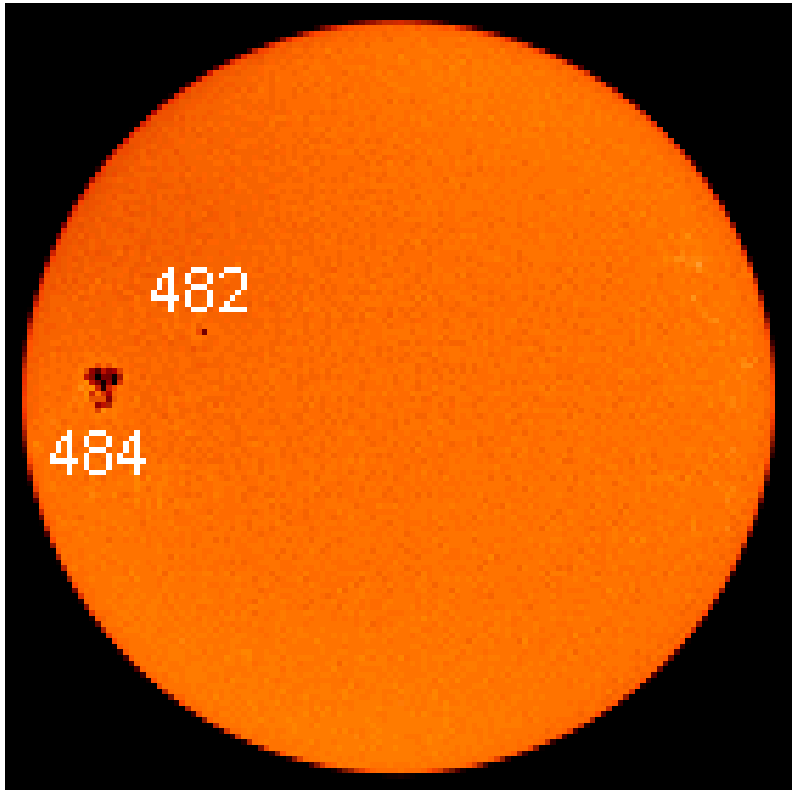
Sunspots

- 20 October 2003



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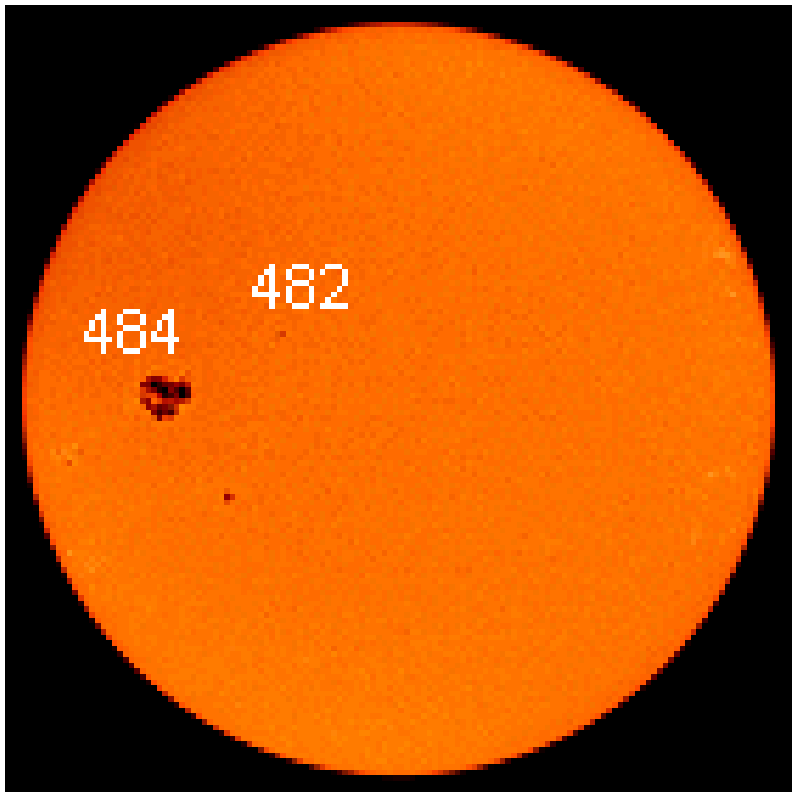
Sunspots

- 21 October 2003



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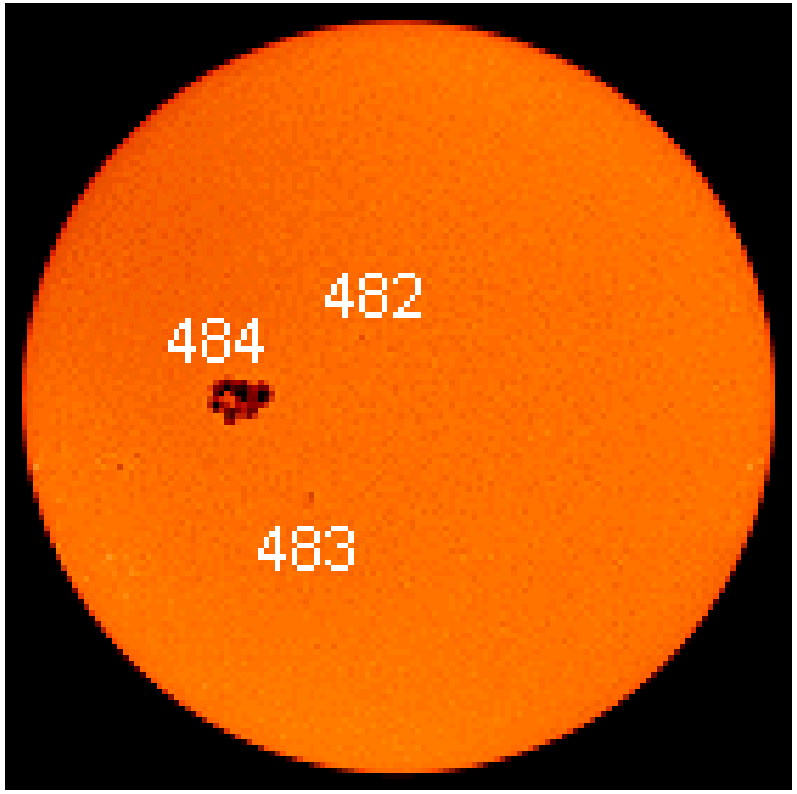
Sunspots

- 22 October 2003



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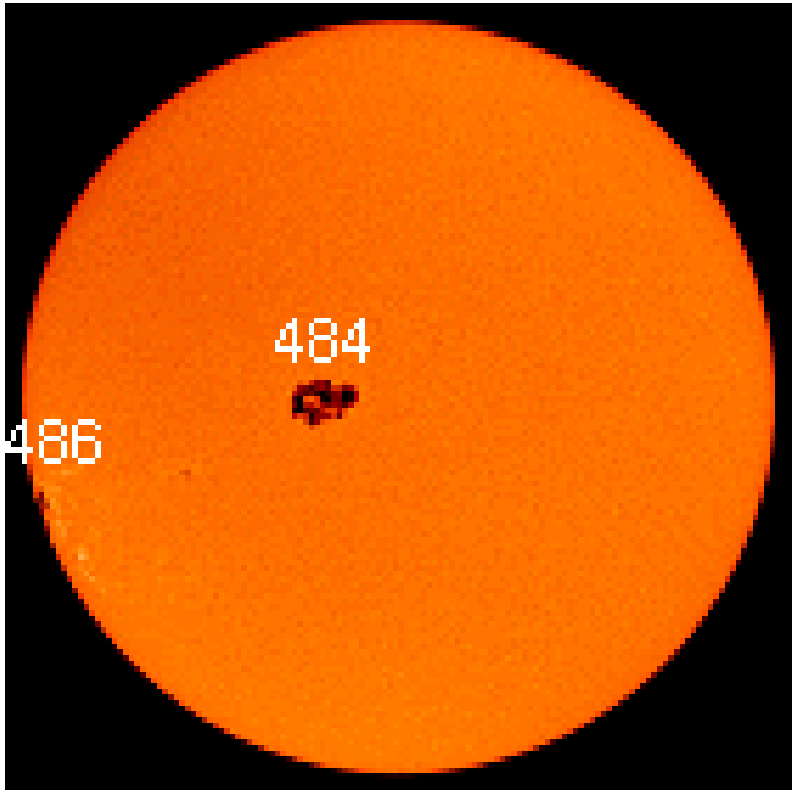
Sunspots

- 23 October 2003



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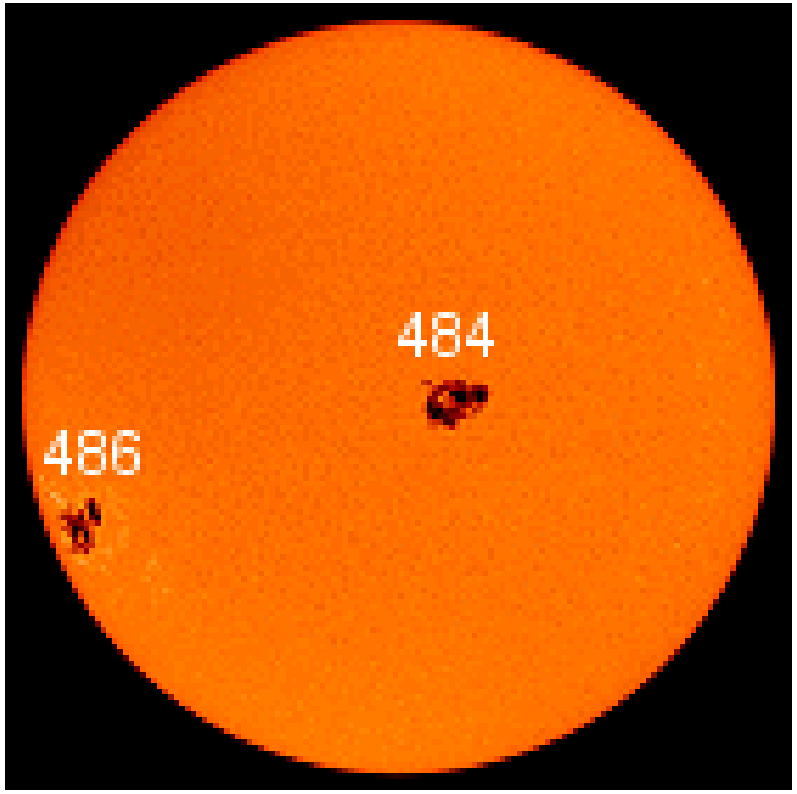
Sunspots

- 24 October 2003



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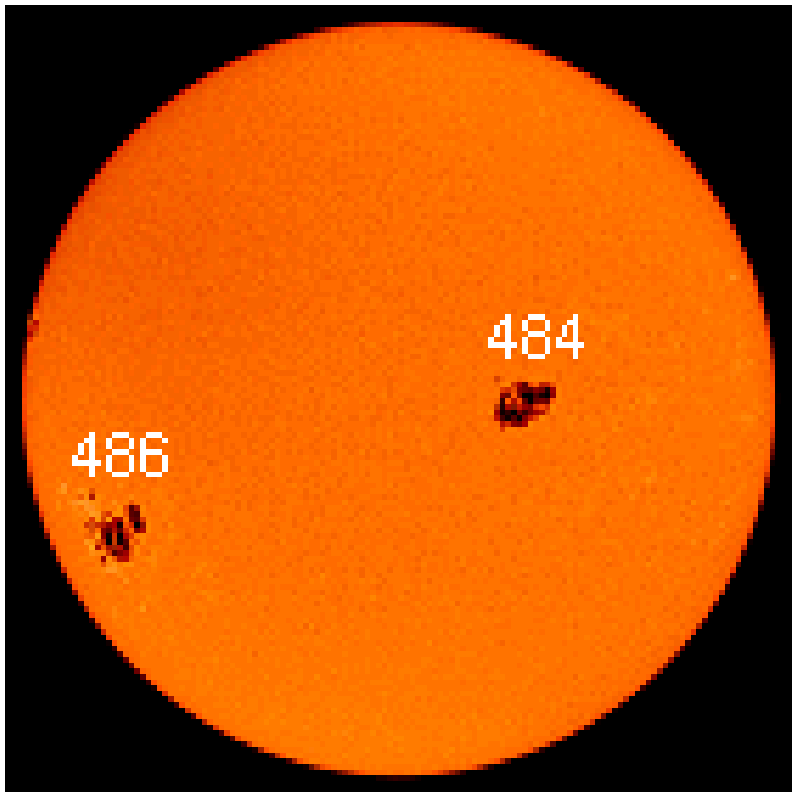
Sunspots

- 25 October 2003



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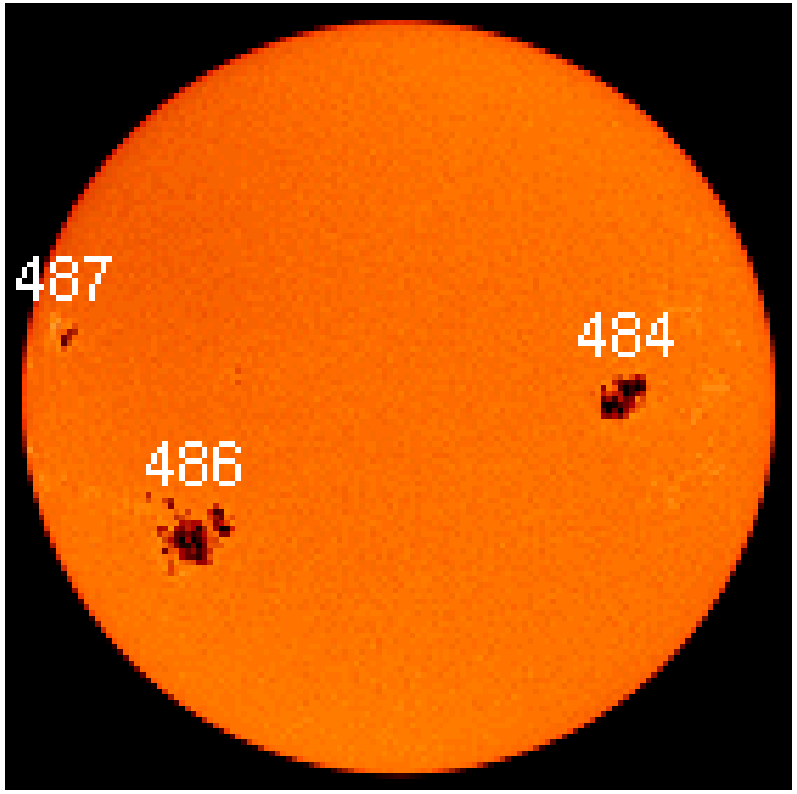
Sunspots

- 26 October 2003



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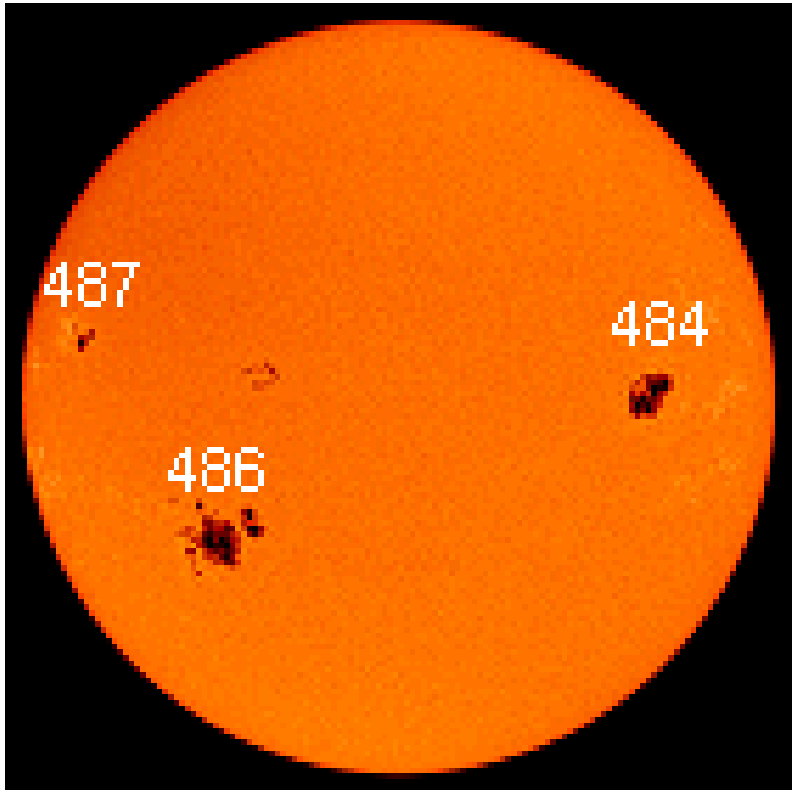
Sunspots

- 27 October 2003



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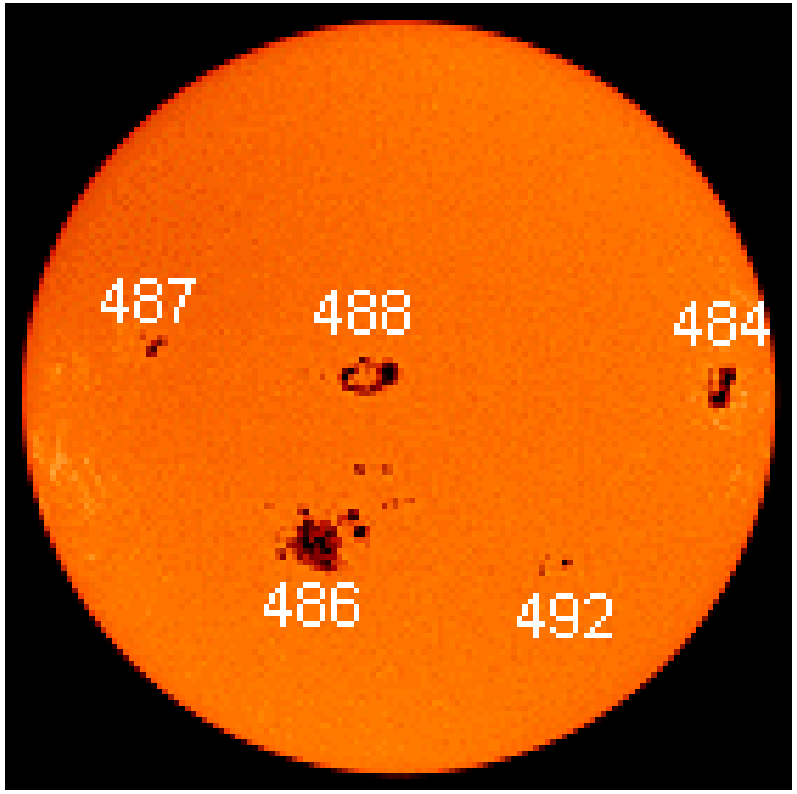
Sunspots

- 28 October 2003



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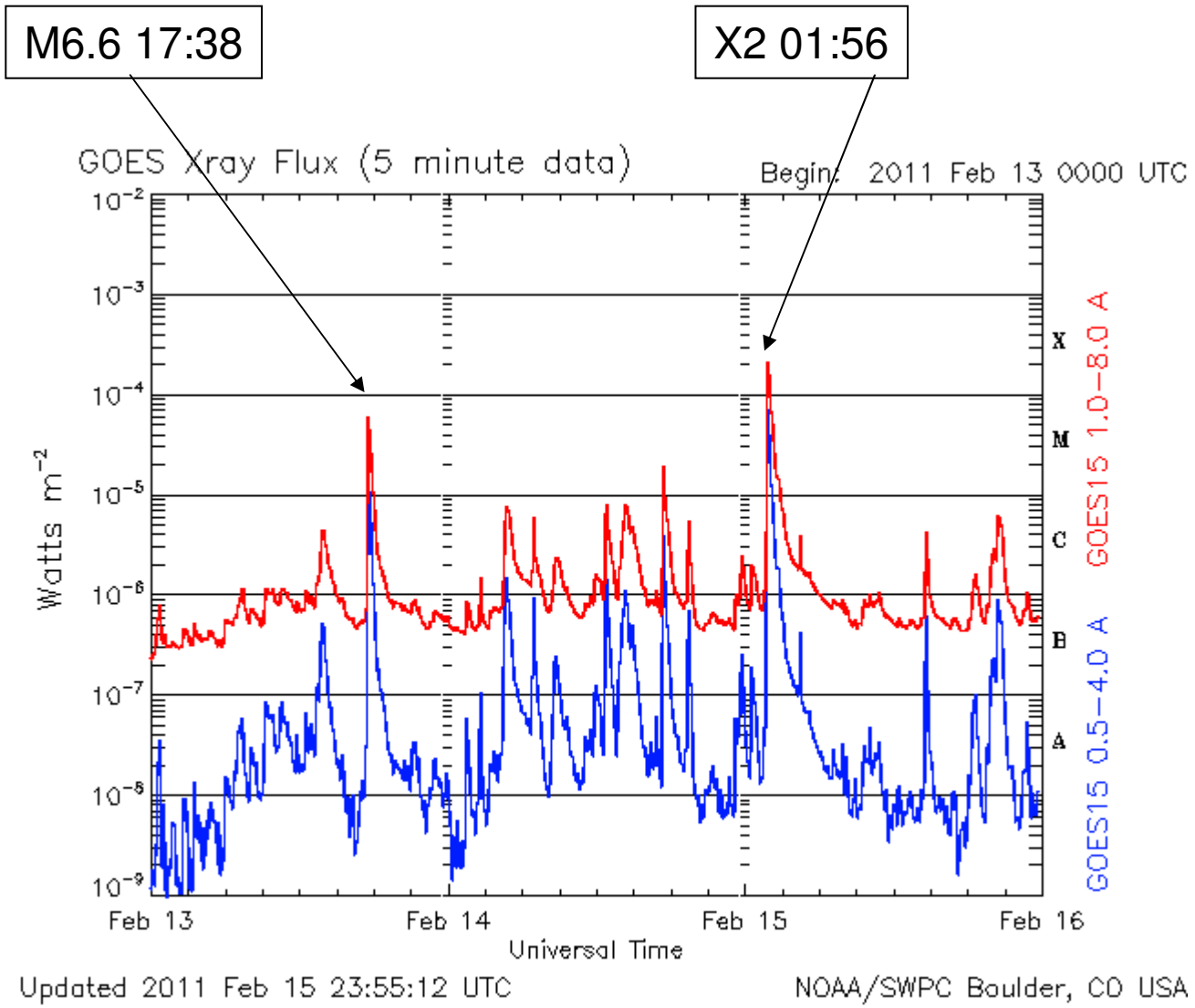
X-Ray burst from solar flare



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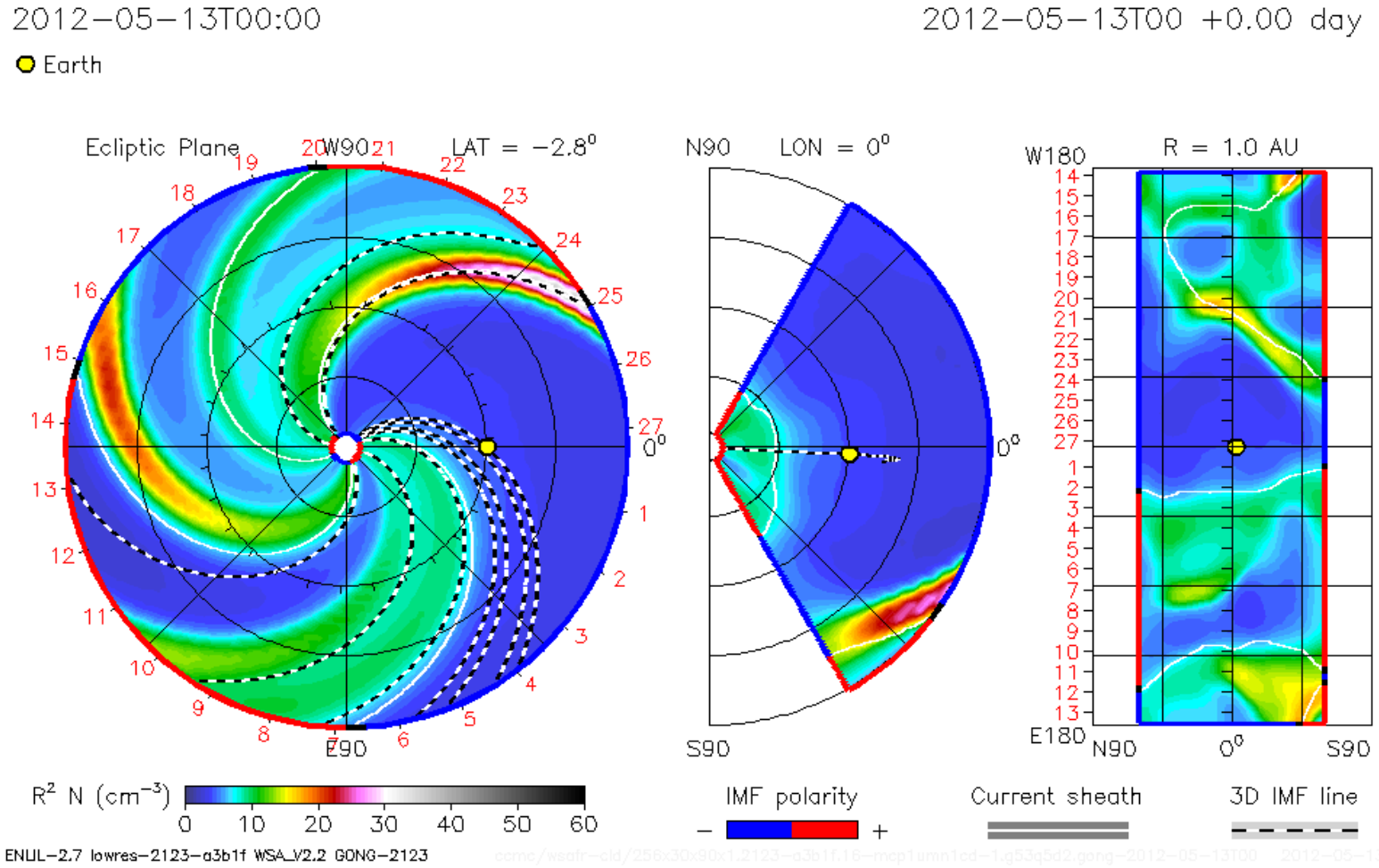
ENLIL Model



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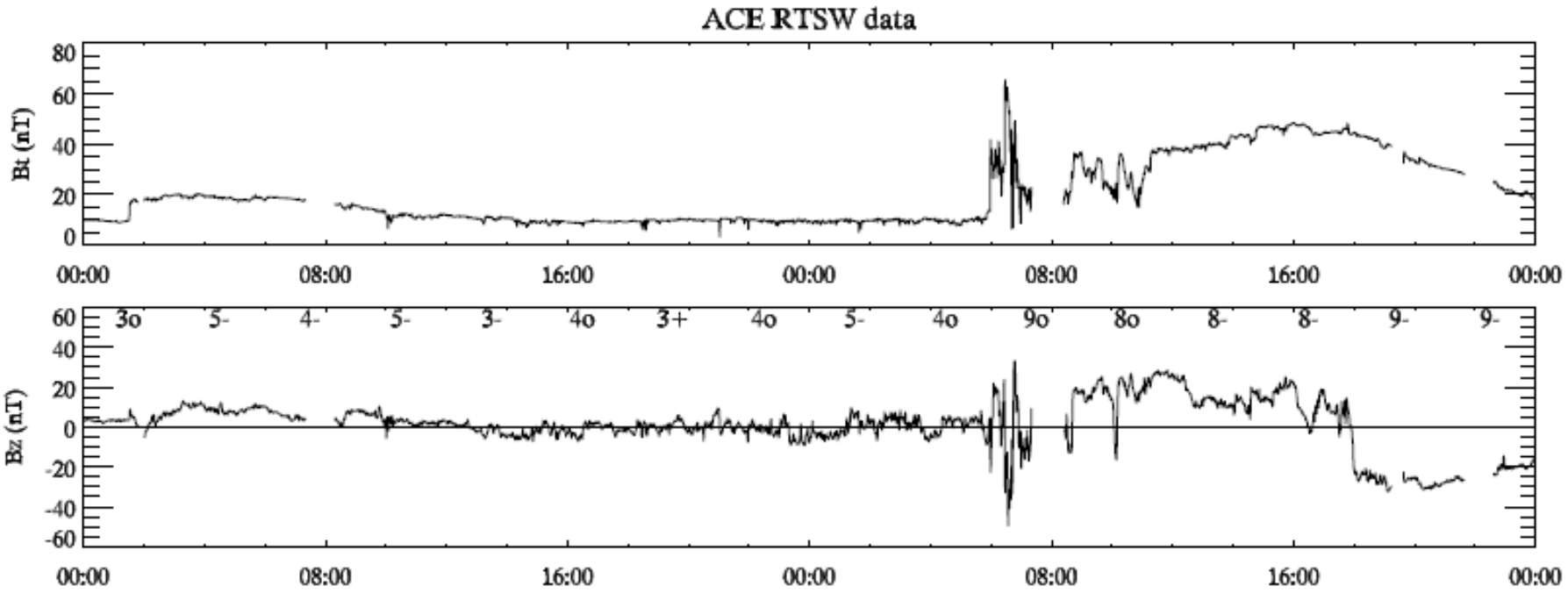
CME arrival at ACE



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Warning actions

- Day -4 onward
  - Monitor all available space weather sources carefully
- Day -1 Observe CME
  - Issue warning of possible system disturbance
- At T -15 minutes
  - Observe direction of Bz at ACE
  - Reissue warning of system disturbance

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NG Operational Mitigation

- **ALL IN**:
  - All circuits returned to service and switched in
  - All Supergrid Transformers connected
  - Substations run solid
  - Extra generation instructed to synchronise
  - Extra reactive support made available
  - All monitoring and warning systems utilised

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Notice of System Disturbance

- The same as any System Disturbance warning for any other cause
  - Flood, storm, lightning……..
- Continue to follow PNs
- Contribute to system integrity
- Market continues to operate unless……..
- National Grid may issue Emergency Instructions to depart from normal Balancing Market Operations in accordance with BC2.9
- Acceptance of an Emergency Instruction counts as acceptance of Bid-Offer Acceptance

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Modelling work for E3C

- Focuses on risk of physical damage to high voltage transformers
- Gives order of magnitude results for a couple of extreme (1 in 100 year) scenarios
- Work requested by E3C includes generator transformers in network model
- Can provide risk to individual transformers at different GIC levels
- Can't be used to identify transformers at risk in any GMD – GIC levels too dependent on individual storm

National Grid / BGS MAGIC Webtool Magnetometer records

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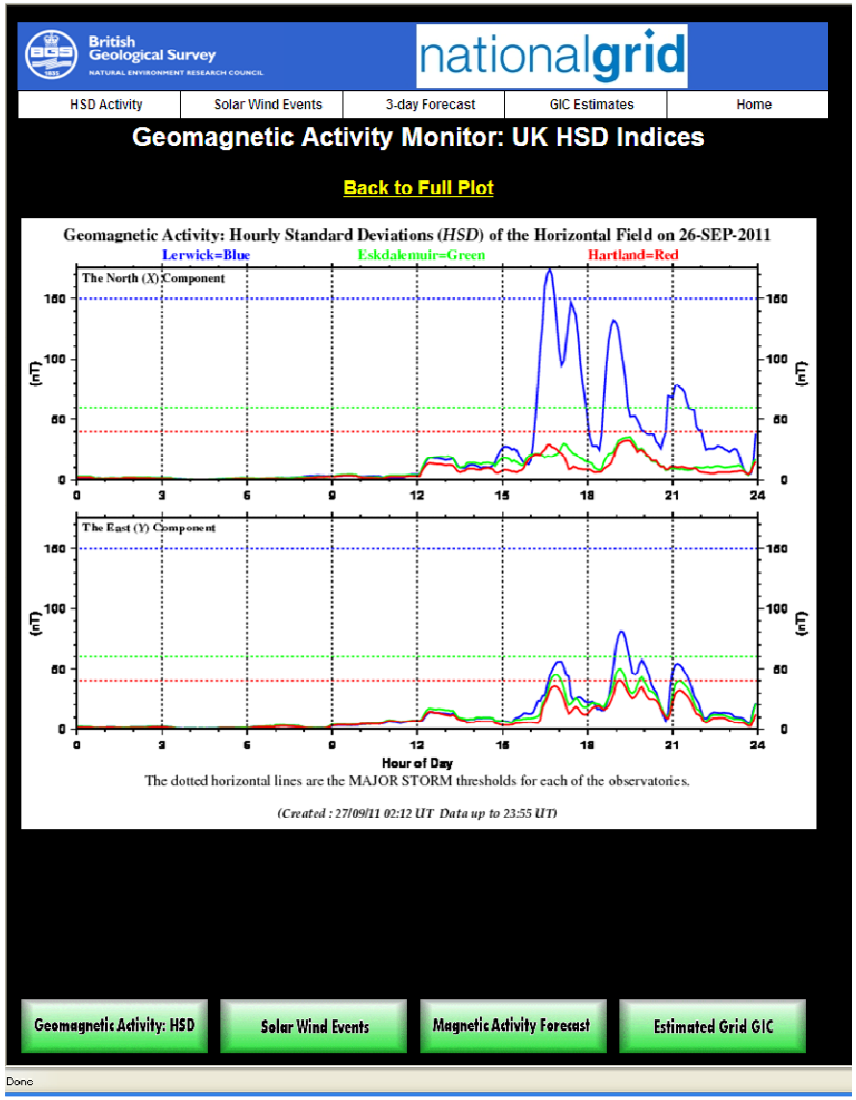

National Grid / BGS MAGIC Webtool Network Model display

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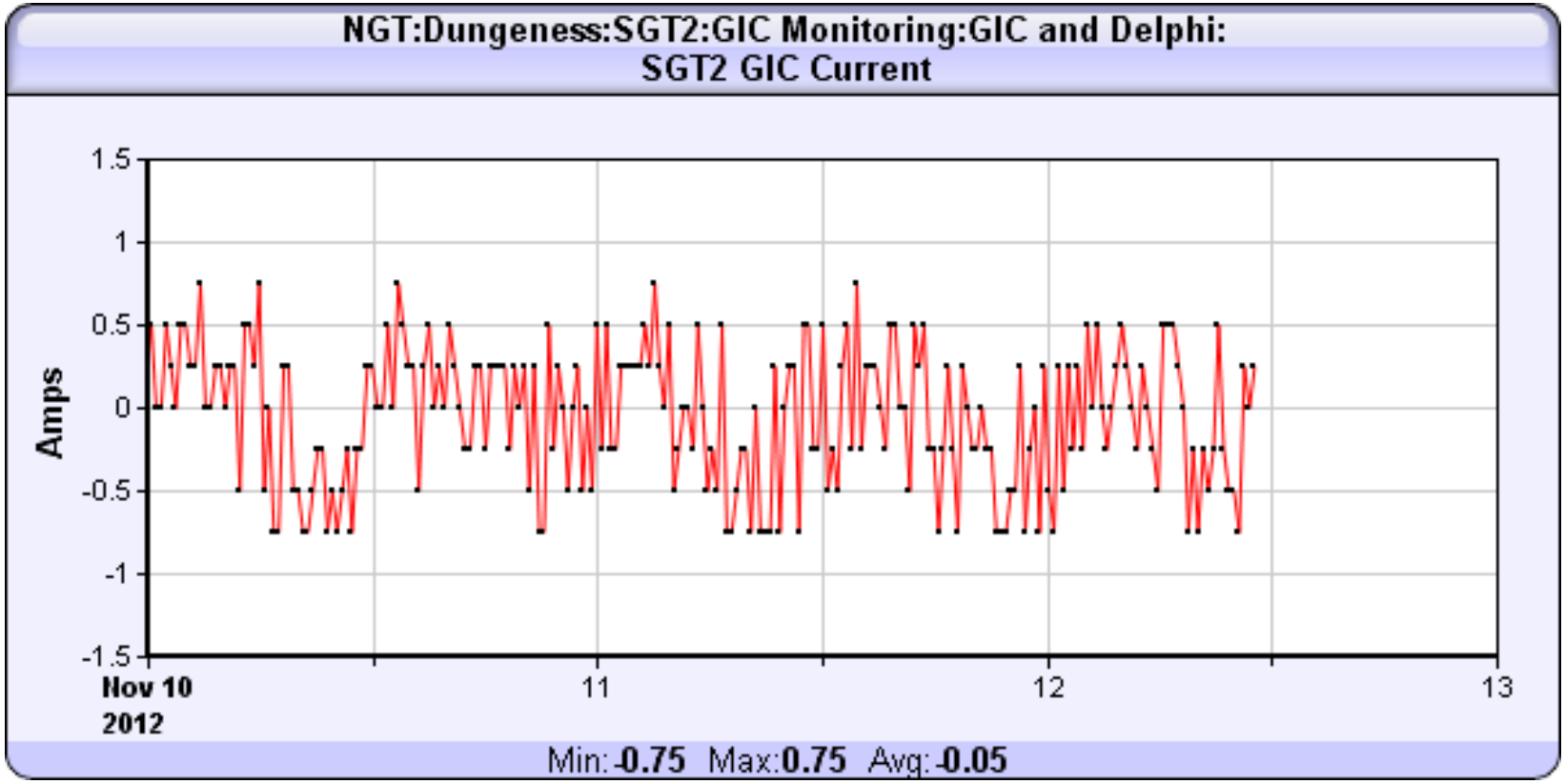
GIC Monitoring



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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