



Experiences of Forecasting the Magnetic Storms of March and June 2015 and Analysis of the Resulting Ground Effects in the UK

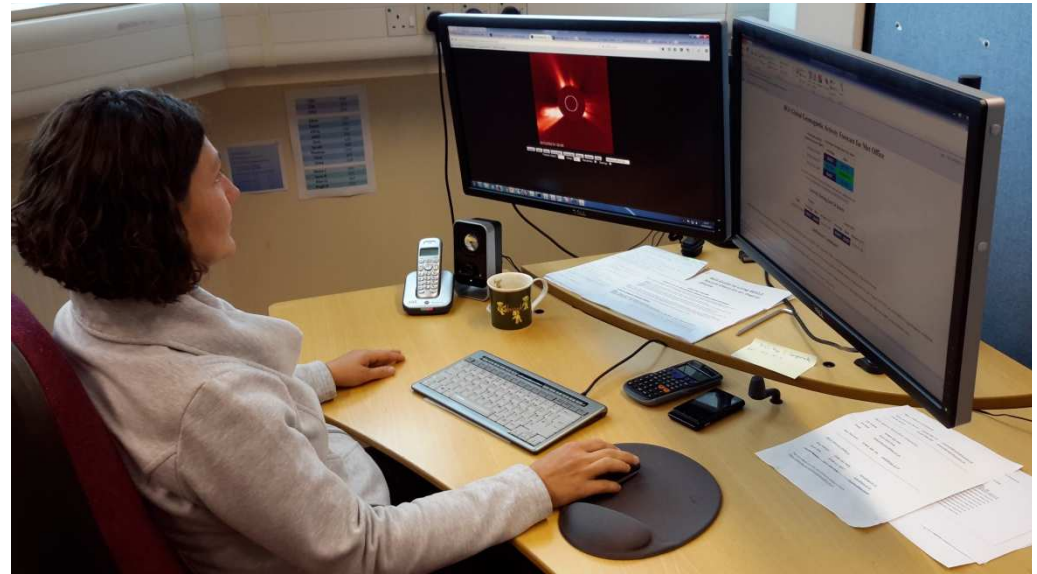
Sarah Reay (sjr@bgs.ac.uk), Laurence Billingham, Gemma Kelly, and Alan Thomson

British Geological Survey

SCOSTEP-WDS Workshop on
'Global Data Activities for the Study of Solar-Terrestrial Variability'
28-30th Sep 2015 Tokyo, Japan



BGS Geomagnetic Activity Forecasting



- Forecasting since 1990's
- Issue daily (Mon-Fri) three-day ahead geomagnetic activity forecast
- Data and analysis to Met Office Space Weather Operations Centre as part of UK's Natural Hazard Partnership
- Recipients include power companies (National Grid) and oil industry (for directional drilling)
- Currently six operational forecasters on weekly rota



St Patrick's Day storm
17 – 18th March 2015

Image: Zoltan Kenwell

BGS Global Geomagnetic Activity Forecast for Met Office

Monday

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
16 MAR-17 MAR	QUIET	ACTIVE
17 MAR-18 MAR	ACTIVE	STORM G1
18 MAR-19 MAR	QUIET	ACTIVE

For more information about the forecast and activity categories see www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 72 hours

Global				Local (UK)		
Date	Average	Max	At time (UT)	Average	Max	At time (UT)
13 MAR-14 MAR	QUIET	ACTIVE	12:00-15:00	QUIET	ACTIVE	12:00-15:00
14 MAR-15 MAR	QUIET	QUIET	21:00-00:00	QUIET	QUIET	21:00-00:00
15 MAR-16 MAR	QUIET	QUIET	18:00-21:00	QUIET	QUIET	03:00-09:00

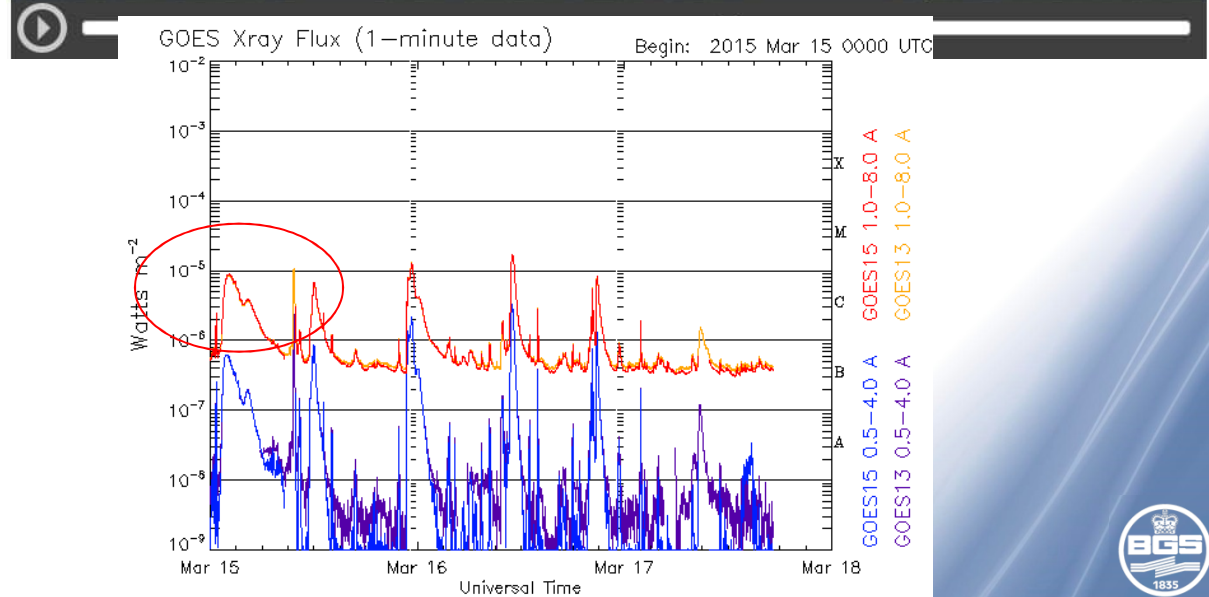
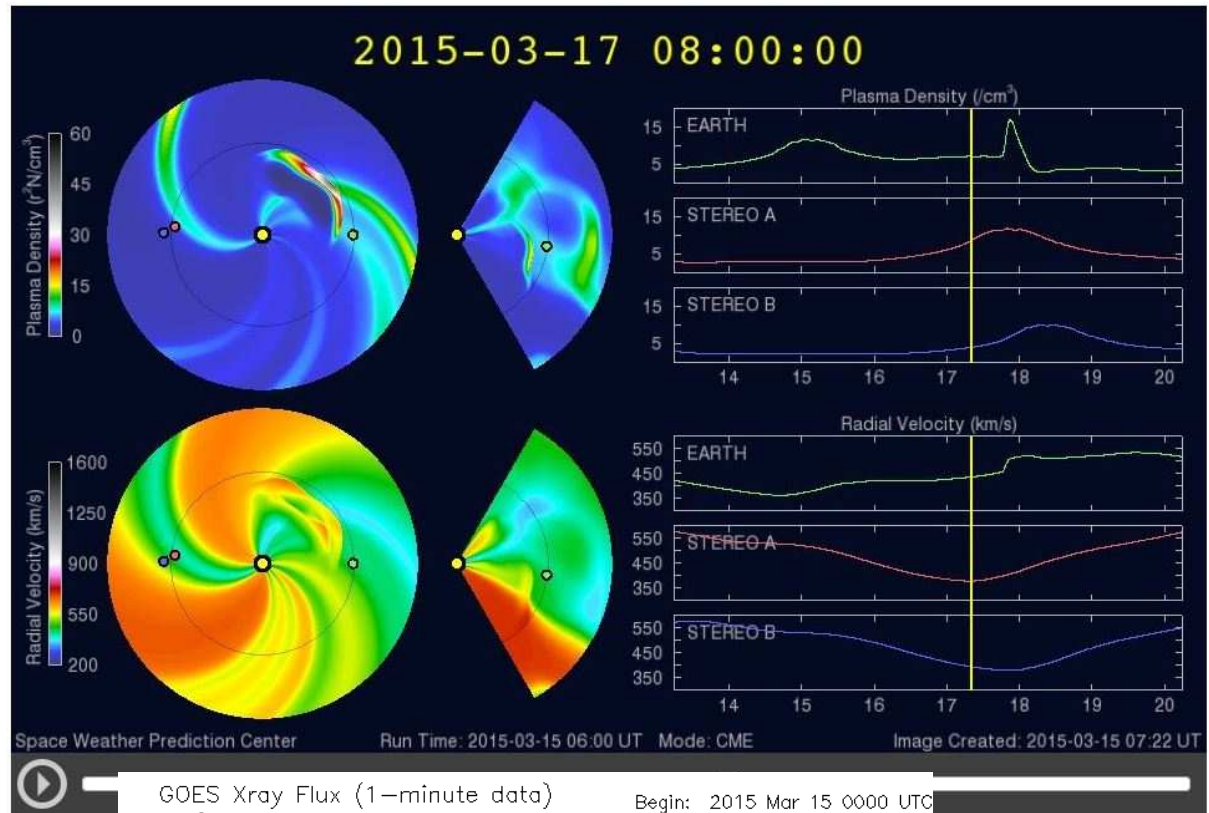
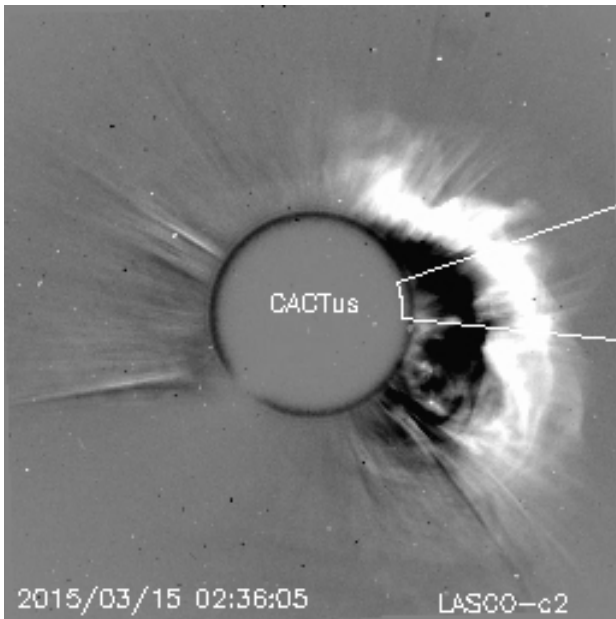
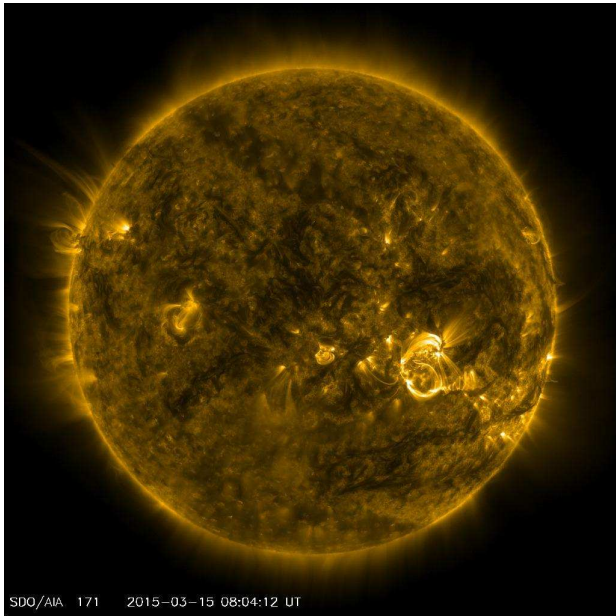
Additional Comments

On the 15th a partial-halo coronal mass ejection (CME) was observed. This was associated with a C9 X-ray flare from region 12297. Models of the CME suggest this has an Earth-directed component and this is expected to arrive in the second forecast interval. ACTIVE conditions are likely with STORM periods possible. G1 is most likely with a chance of G2 if the magnetic field of the solar wind turns southwards for a sustained period of time.

Solar wind effects from two coronal holes extending toward the Sun's equator from both poles may also increase geomagnetic activity from the second forecast interval.

Region 12297 remains magnetically complex and there is the chance of further activity in the next few days.





```

#-----#
:Issued: 2015 Mar 16 1307 UTC
:Product: documentation at http://www.sidc.be/products/meu
#-----#
# DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC #
# (RWC Belgium) #
#-----#
SIDC URSIGRAM 50316
SIDC SOLAR BULLETIN 16 Mar 2015, 1303UT
SIDC FORECAST (valid from 1230UT, 16 Mar 2015 until 18 Mar 2015)
SOLAR FLARES : Active (M-class flares expected, probability >=50%)
GEOMAGNETISM : Active conditions expected (A>=20 or K=4)
SOLAR PROTONS : warning condition (activity levels expected to increase, b
numeric forecast given)
PREDICTIONS FOR 16 Mar 2015 10CM FLUX: 113 / AP: 016
PREDICTIONS FOR 17 Mar 2015 10CM FLUX: 112 / AP: 024
PREDICTIONS FOR 18 Mar 2015 10CM FLUX: 112 / AP: 028
COMMENT: Solar activity continued to be dominated by NOAA active region
  
```

```

:Product: 0316RSGA.txt
:Issued: 2015 Mar 16 2200 UTC
# Prepared jointly by the U.S. Dept. of Commerce, NOAA,
# Space Weather Prediction Center and the U.S. Air Force.
#
Joint USAF/NOAA Solar Geophysical Activity Report and Forecast
SDF Number 75 Issued at 2200Z on 16 Mar 2015

IA. Analysis of Solar Active Regions and Activity from 15/2100Z to
16/2100Z: Solar activity has been at moderate levels for the past 24
hours. The largest solar event of the period was a M1 event observed at
16/1058Z from Region 2297 (S17W52). There are currently 3 numbered
sunspot regions on the disk.

IB. Solar Activity Forecast: Solar activity is likely to be moderate
with a slight chance for an X-class flare on days one, two, and three
(17 Mar, 18 Mar, 19 Mar).

IIA. Geophysical Activity Summary 15/2100Z to 16/2100Z: The geomagnetic
field has been at quiet to unsettled levels for the past 24 hours. Solar
wind speed, as measured by the ACE spacecraft, reached a peak speed of
441 km/s at 16/1957Z. Total IMF reached 14 nT at 16/1615Z. The maximum
southward component of Bz reached -12 nT at 16/0522Z. Protons greater
than 10 MeV at geosynchronous orbit reached a peak level of 8 pfu at
16/0755Z.

IIB. Geophysical Activity Forecast: The geomagnetic field is expected
to be at quiet to active levels on day one (17 Mar), unsettled to minor
storm levels on day two (18 Mar) and unsettled to active levels on day
three (19 Mar). Protons are likely to cross threshold on days one, two,
and three (17 Mar, 18 Mar, 19 Mar).
  
```

the late influence of a slow high speed stream from the equatorial coronal hole that crossed the central meridian early last week. Continued influence of the slow high speed stream may be anticipated over the rest of the day with late tomorrow a glancing blow by the CME of March 15. In both cases possible impact is expected to be initially minor, probably limited to active geomagnetic conditions. The extension of the southern negative polarity coronal hole may later, from March 18 onwards add to the geomagnetic activity
 TODAY'S ESTIMATED ISN : 043, BASED ON 15 STATIONS.

SIDC

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24)	
			(%)	(%)	(%)	(%)
Minor or Moderate	G1 to G2	N	40	40	30	20
Strong	G3	N	5	5		
Severe	G4	N	1	1		
Extreme	G5	N	1	1		

2B. MAGNETIC FORECAST

Date	Ap	Conditions
17 Mar	18	Quiet, with active to minor storm later
18 Mar	25	Active to Minor Storm
19 Mar	10	Quiet to Unsettled

IPS

UK Met Office

COMMENT: IPS Geomagnetic Warning 6 was issued on 15 March and is current for 16-18 Mar. Geomagnetic conditions over the Australian region were unsettled for much of the day, with a brief active period 06-09 UT. Conditions returned to quiet levels after 18 UT. Quiet conditions are expected to continue until late on 17-Mar, when the likely arrival of a 15-Mar CME will probably result in active to minor storm conditions. Those conditions are expected to persist into 18-Mar.

BGS Global Geomagnetic Activity Forecast for Met Office

Tuesday

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
17 MAR-18 MAR	STORM G1	STORM G2
18 MAR-19 MAR	QUIET	ACTIVE
19 MAR-20 MAR	QUIET	QUIET

For more information about the forecast and activity categories see www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 24 hours

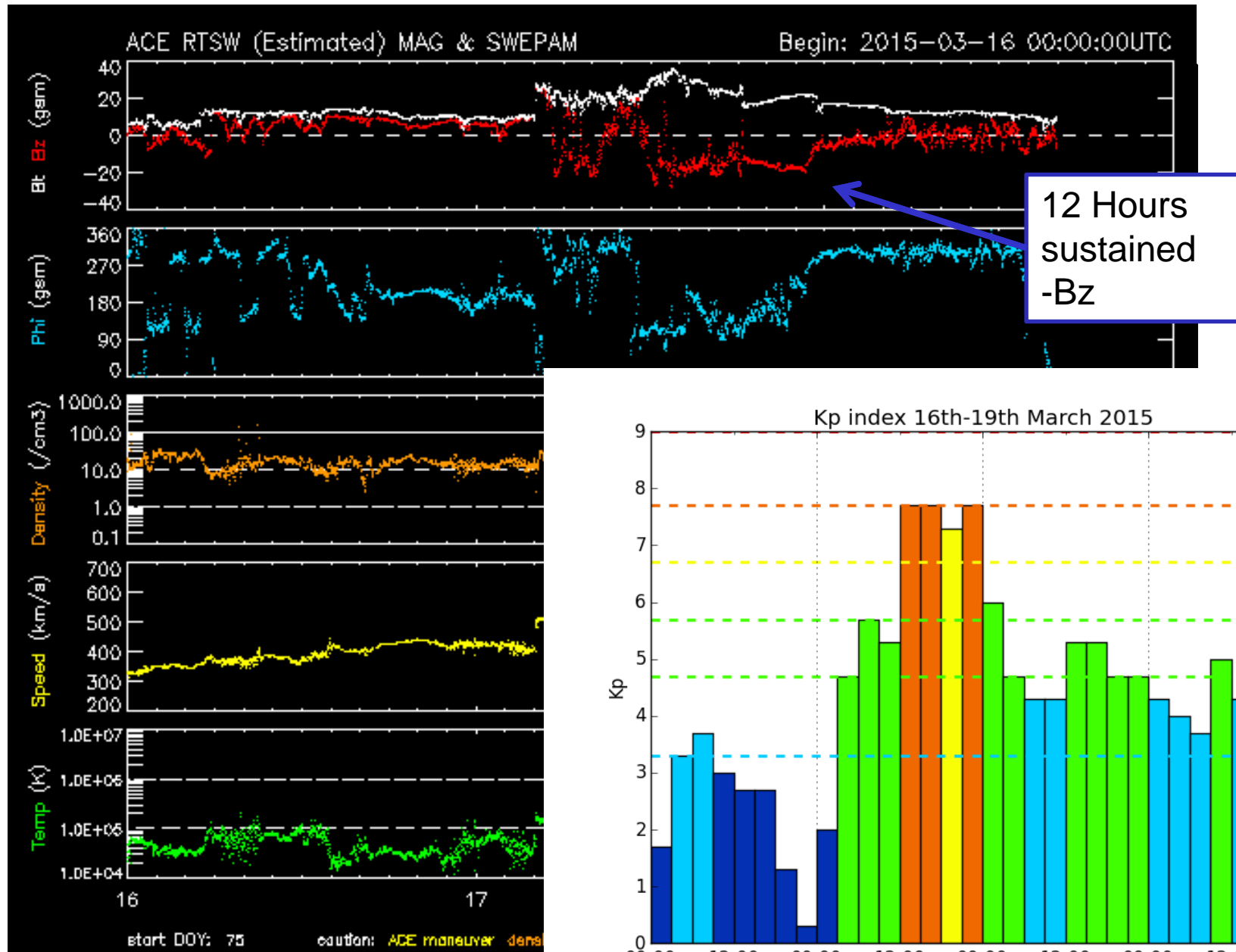
Date	Global			Local (UK)		
	Average	Max	At time (UT)	Average	Max	At time (UT)
16 MAR-17 MAR	ACTIVE	STORM G2	06:00-09:00	ACTIVE	STORM G3	06:00-09:00

Additional Comments

The anticipated coronal mass ejection (CME) arrived early than expected. A geomagnetic storm commencement was detected at BGS magnetometers at 04:46UT. At Eskdalemuir observatory a deviation of 45nT in H and 17.4mins in D was recorded.

Further G1 to G2 STORM conditions are possible in the next 24 hours due to continuing effects from the CME arrival and coronal hole influences.







‘Summer’ Solstice storms
22nd -24th June 2015

Image: Mike Kenney

BGS Global Geomagnetic Activity Forecast for Met Office

Monday

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
22 JUN-23 JUN	STORM G1	STORM G3
23 JUN-24 JUN	ACTIVE	STORM G2
24 JUN-25 JUN	ACTIVE	STORM G1

For more information about the forecast and activity categories see www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 72 hours

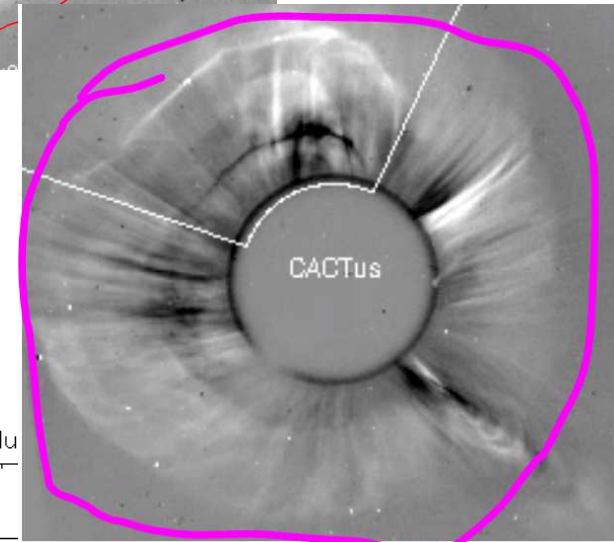
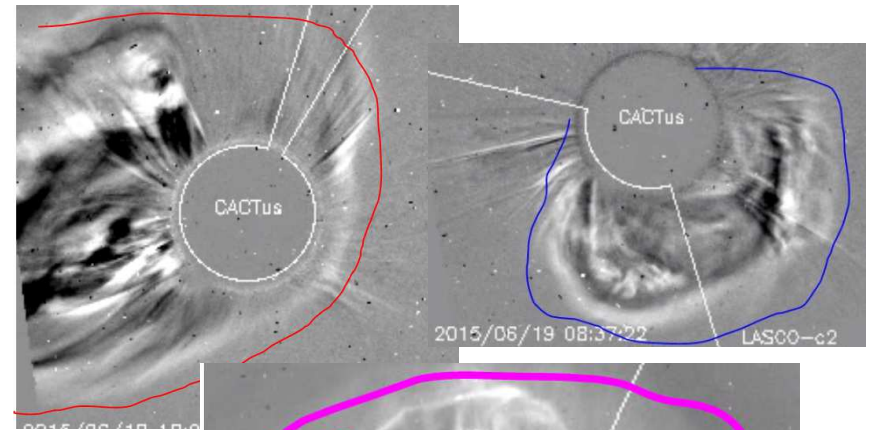
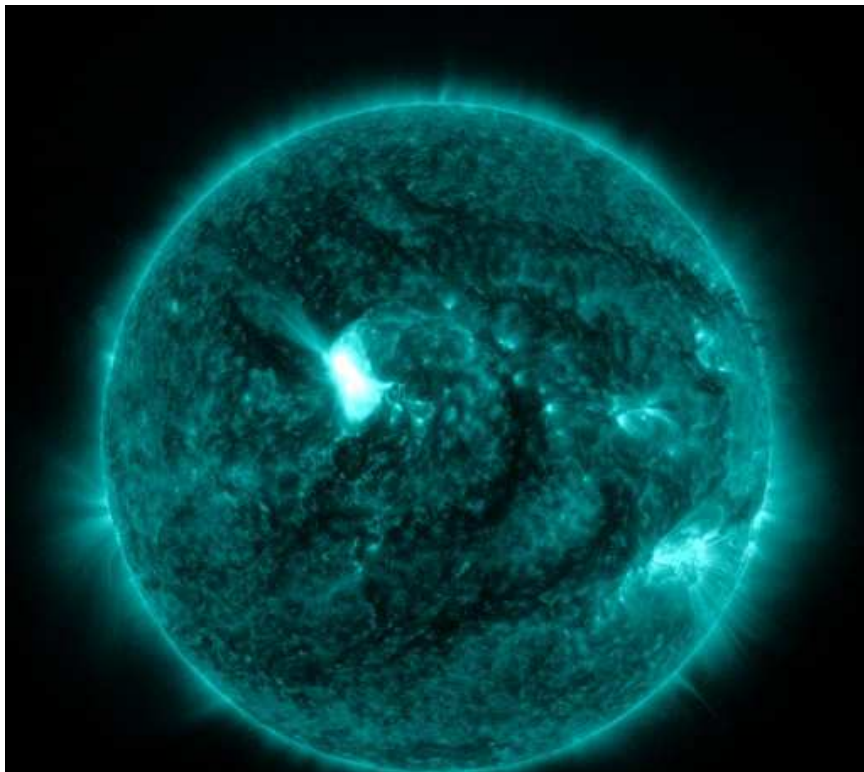
Global				Local (UK)		
Date	Average	Max	At time (UT)	Average	Max	At time (UT)
19 JUN-20 JUN	QUIET	QUIET	12:00-15:00	QUIET	QUIET	03:00-06:00
		QUIET	09:00-12:00			
20 JUN-21 JUN	QUIET	QUIET	00:00-03:00	QUIET	QUIET	00:00-09:00
		QUIET	09:00-12:00			
21 JUN-22 JUN	QUIET	ACTIVE	15:00-18:00	QUIET	ACTIVE	15:00-18:00
		ACTIVE	06:00-09:00		ACTIVE	06:00-09:00

Additional Comments

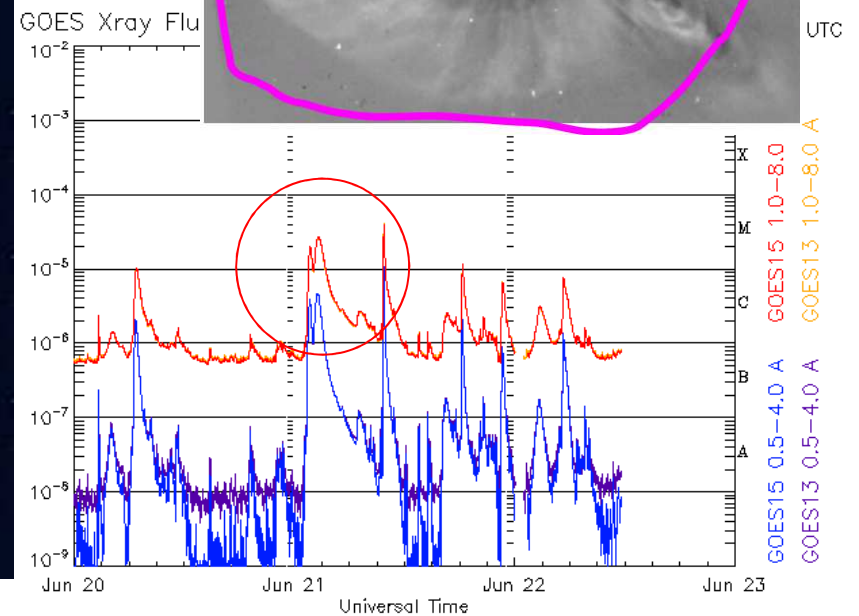
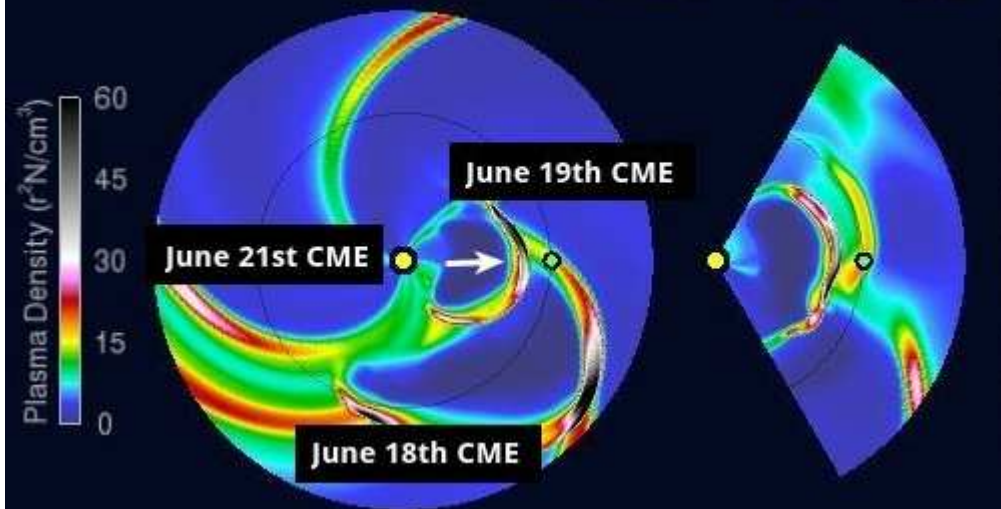
A full-halo CME was launched at 21 JUN 02:30 by an M-class flare from active region 2371 which is now near disc centre. We expect this 21 JUN CME to arrive during the 1st forecast interval.

Two glancing CME blow shocks arrived at 21 JUN 15:45 and 22 JUN 04:45: these were from CMEs launched 18 JUN and 19 JUN.

The magnetosphere is already in a somewhat disturbed state due to the arrival of the shocks in the last 24 hours. We expect STORM periods of up to G3 with the arrival of the 3rd CME. Outlook for intervals 2 and 3 is for more possible STORM periods as CME effects slowly decline.



2015-06-22



:Product: 0621RSGA.txt
 :Issued: 2015 Jun 21 2200 UTC
 # Prepared jointly by the U.S. Dept. of Commerce, NOAA,
 # Space Weather Prediction Center and the U.S. Air Force.

SIDC

#-----#
 # DAILY BULLETIN ON SOLAR AND GEOMAGNETIC ACTIVITY from the SIDC
 # (RWC Belgium) #
 #-----#

SIDC URSIGRAM 50621
 SIDC SOLAR BULLETIN 21 Jun 2015, 1230UT
 SIDC FORECAST (valid from 1230UT, 21 Jun 2015 until 23 Jun 2015)
 SOLAR FLARES : M-class flares expected (probability >=50%)
 GEOMAGNETISM : Minor storm expected (A>=30 or K=5)
 SOLAR PROTONS : Warning condition (activity levels expected to increase, but no numeric forecast given)
 PREDICTIONS FOR 21 Jun 2015 10CM FLUX: 135 / AP: 027
 PREDICTIONS FOR 22 Jun 2015 10CM FLUX: 133 / AP: 071
 PREDICTIONS FOR 23 Jun 2015 10CM FLUX: 131 / AP: 063
 COMMENT: Solar flaring activity was moderate with an M4.0 flare from
 Solar wind conditions are expected to become perturbed later today by a
 glancing blow from the June 18 CME, followed by the arrival of another
 glancing blow from the June 19 CME and the arrival of the June 21 CME from
 the afternoon of June 22 onwards.

Minor to moderate geomagnetic storms may occur later today and tomorrow
 with possibly major to severe storms late June 22 and June 23 associated to
 the arrival of the June 21 CME.

 Joint USAF/NOAA Solar Geophysical Activity Report and Forecast
 SDF Number 172 Issued at 2200Z on 21 Jun 2015

IA. Analysis of Solar Active Regions and Activity from 20/2100Z to 21/2100Z: Solar activity has been at moderate levels for the past 24 hours. The largest solar event of the period was a M3 event observed at 21/0944Z from Region 2367 (S18W64). There are currently 2 numbered sunspot regions on the disk.
 IB. Solar Activity Forecast: Solar activity is expected to be moderate with a slight chance for an X-class flare on days one, two, and three (22 Jun, 23 Jun, 24 Jun).

IIA. Geophysical Activity Summary 20/2100Z to 21/2100Z: The geomagnetic field has been at quiet to active levels for the past 24 hours. Solar wind speed, as measured by the ACE spacecraft, reached a peak speed of 370 km/s at 21/2055Z. Total IMF reached 11 nT at 21/1853Z. The maximum southward component of Bz reached -6 nT at 21/1912Z. Protons greater than 10 MeV at geosynchronous orbit reached a peak level of 14 pfu at 21/2055Z. Electrons greater than 2 MeV at geosynchronous orbit reached a peak level of 1877 pfu.

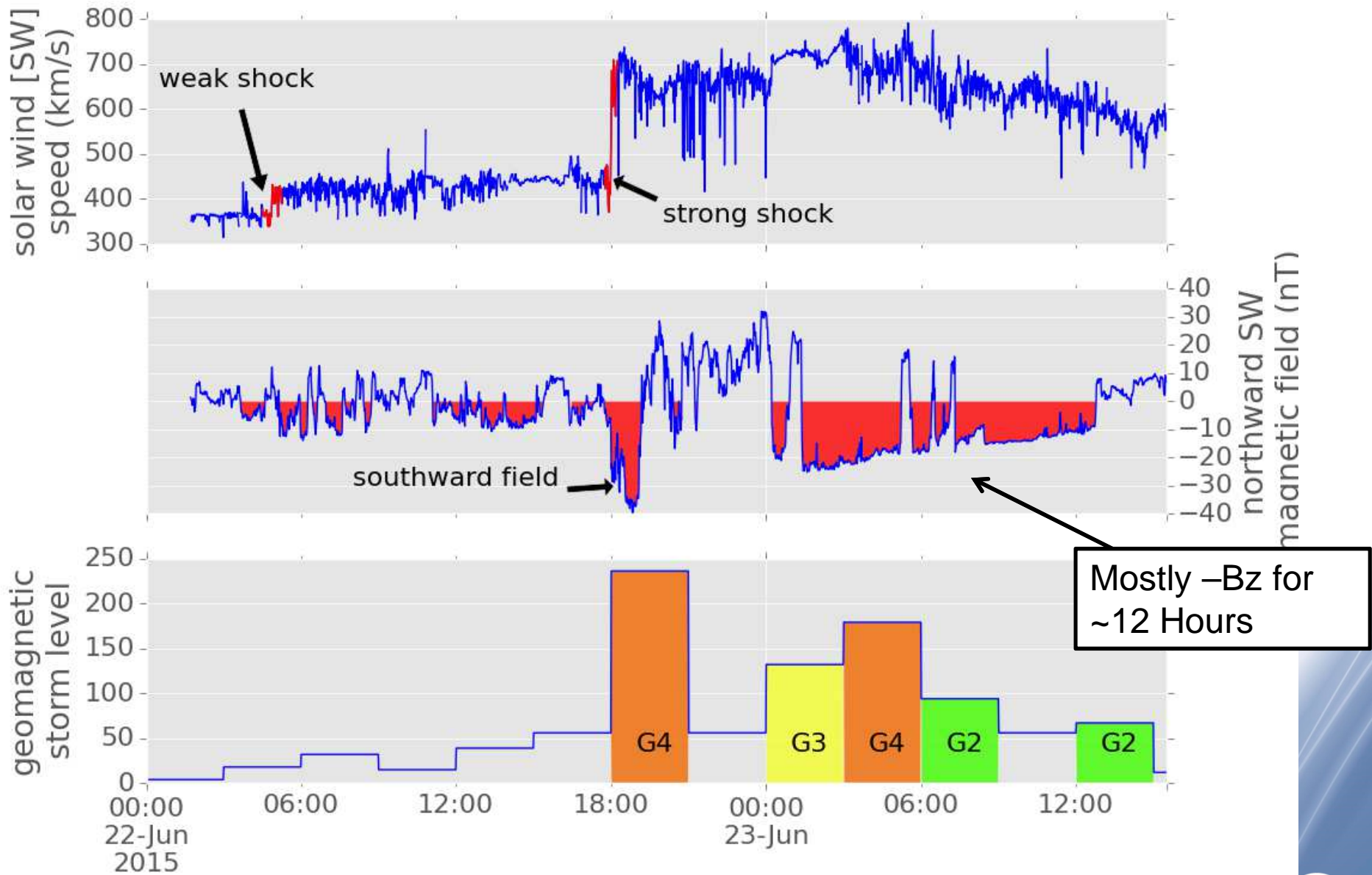
IIB. Geophysical Activity Forecast: The geomagnetic field is expected to be at unsettled to severe storm levels on day one (22 Jun), unsettled to major storm levels on day two (23 Jun) and quiet to active levels on day three (24 Jun). Protons are expected to cross threshold on day one (22 Jun), are expected to cross threshold on day two (23 Jun) and are likely to cross threshold on day three (24 Jun).

2B. MAGNETIC FORECAST

Date	Ap	Conditions
22 Jun	50	Storm Levels
23 Jun	50	Storm Levels
24 Jun	30	Active to Minor Storm

Geo-Magnetic Storm	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	N	70	60	15
Strong	G3	M	40	30	5
Severe	G4	N	20	15	1
Extreme	G5	N	7	5	1

COMMENT: IPS Geomagnetic Warning 23 was issued on 19 June and is current for 21-22 Jun. In the IPS magnetometer data for 21 Jun, a weak (19nT) impulse was observed at 1646UT. This was due to the first of the three CMEs forecast to impact the Earth. The IMF Bz has been predominantly northward so far with this CME and the effects have been relatively mild so far. The other two CMEs are forecast to impact the Earth later in the UT day of 22 June with more significant effects. Mostly unsettled to active levels are expected during the first half of the UT day of 22 June with minor storm periods possible for high latitudes. Major to severe storm levels are possible with the arrival of the two other CMEs forecast to arrive in the latter half of the UT day of 22 June. Storm levels are expected to continue into 23 June.



Monday PM

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
22 JUN-23 JUN	STORM G1	STORM G4
23 JUN-24 JUN	ACTIVE	STORM G2
24 JUN-25 JUN	ACTIVE	STORM G2

Upgraded a G3 forecast made at 11:20 to G4 at 19:36

For more information about the forecast and activity categories see www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 72 hours

Global				Local (UK)		
Date	Average	Max	At time (UT)	Average	Max	At time (UT)
19 JUN-20 JUN	QUIET	QUIET	12:00-15:00	QUIET	QUIET	03:00-06:00
		QUIET	09:00-12:00			
20 JUN-21 JUN	QUIET	QUIET	00:00-03:00	QUIET	QUIET	00:00-09:00
		QUIET	09:00-12:00			
21 JUN-22 JUN	QUIET	ACTIVE	15:00-18:00	QUIET	ACTIVE	15:00-18:00
		ACTIVE	06:00-09:00		ACTIVE	06:00-09:00

Additional Comments

BGS Global Geomagnetic Activity Forecast for Met Office

Tuesday

Forecast period (noon-to-noon GMT)	Forecast Global Activity level	
	Average	Max
23 JUN-24 JUN	STORM G2	STORM G3
24 JUN-25 JUN	ACTIVE	STORM G3
25 JUN-26 JUN	STORM G1	STORM G3

For more information about the forecast and activity categories see
www.geomag.bgs.ac.uk/education/activitylevels.html

Activity during last 24 hours

Date	Global			Local (UK)		
	Average	Max	At time (UT)	Average	Max	At time (UT)
22 JUN-23 JUN	STORM G3	STORM G4	18:00-21:00	STORM G3	STORM G4	18:00-21:00

Additional Comments

An hour-long period of strong southward IMF around 19:00 UT on 22 JUN produced a peak in activity at STORM G4 level before dropping.

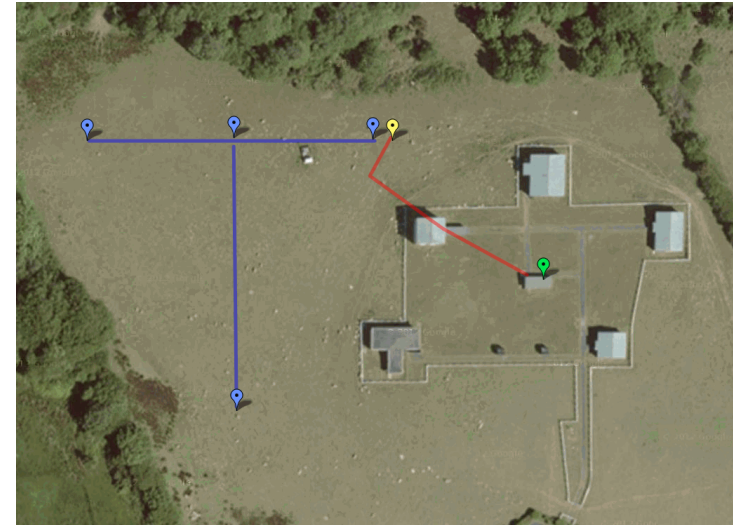
A second increase in activity has followed another sustained period of southward IMF starting around midnight on 22 JUN. The southward IMF and high solar wind speed persist and high levels of geomagnetic activity are expected to continue over the first forecast period.

Activity is expected to decline in the second period but should increase again with the arrival of a second CME, associated with the M6 flare from AR2371, yesterday. Periods of strong geomagnetic activity are therefore expected in the second half of the second forecast period. This activity is expected to continue into the third period.

Geomagnetic and geoelectric monitoring in the UK



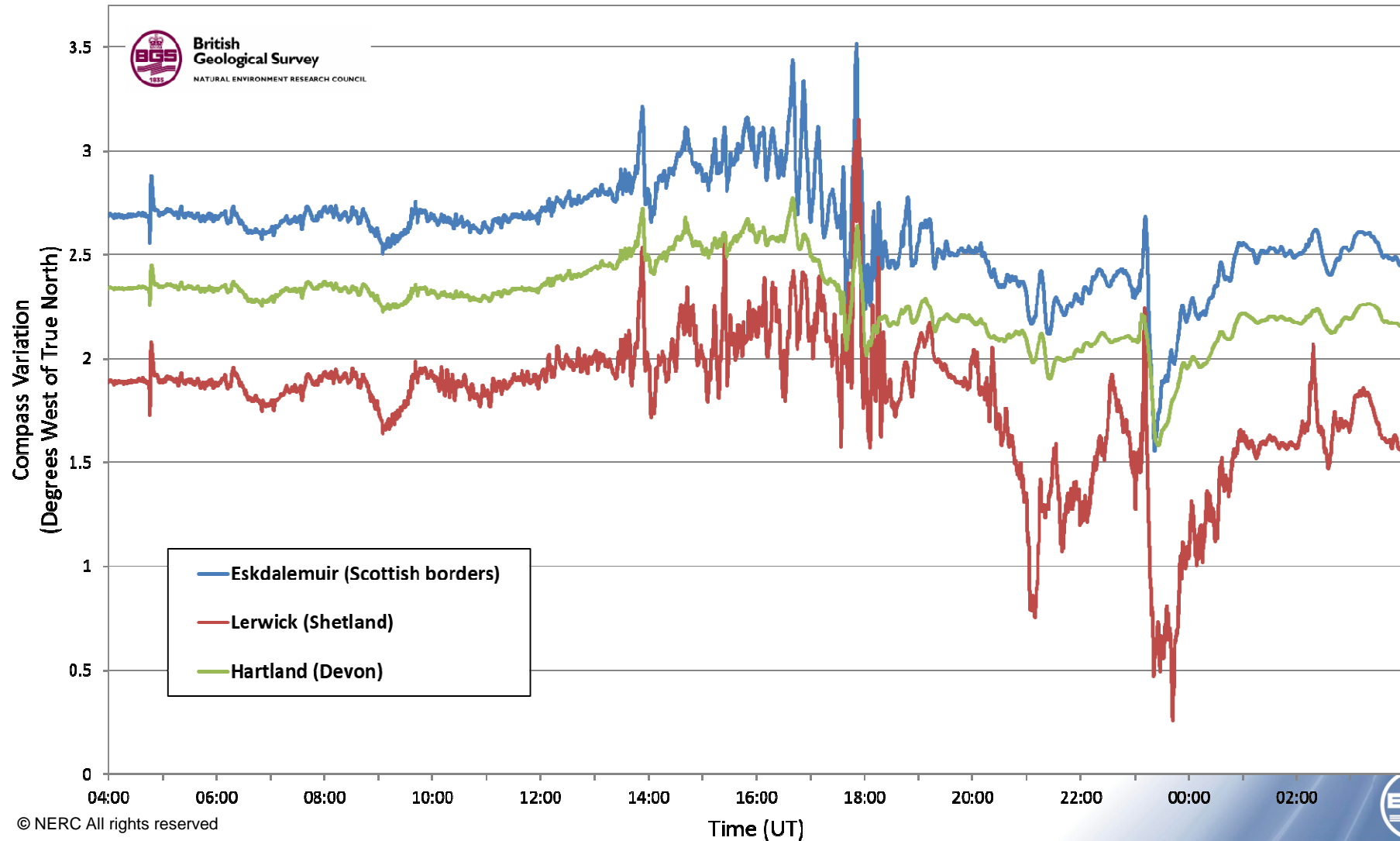
Magnetometers



Electrodes

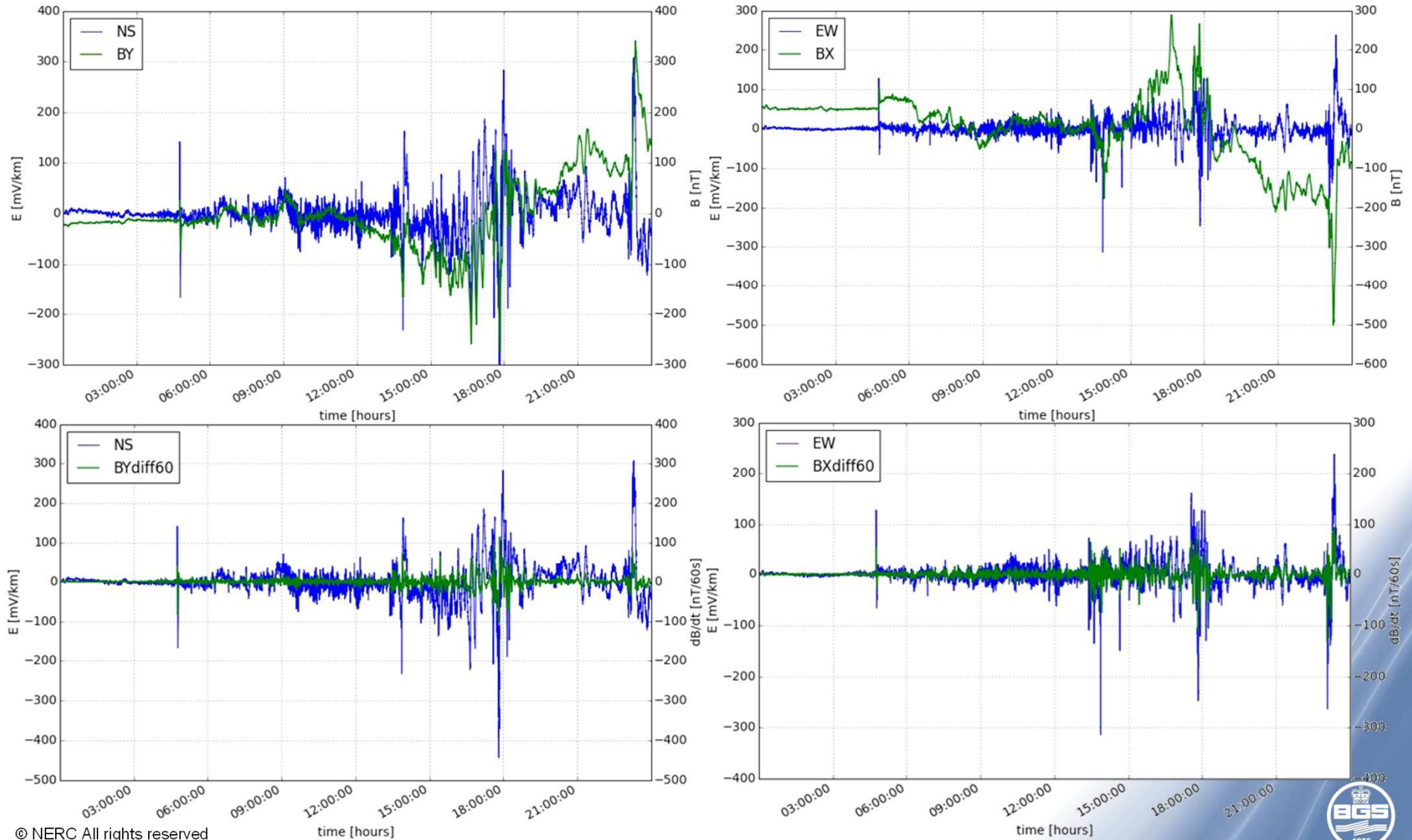
St Patricks' Day storm - Geomagnetic

Magnetic Compass Variations at UK Magnetic Observatories during the Geomagnetic Storm of 17th-18th March 2015

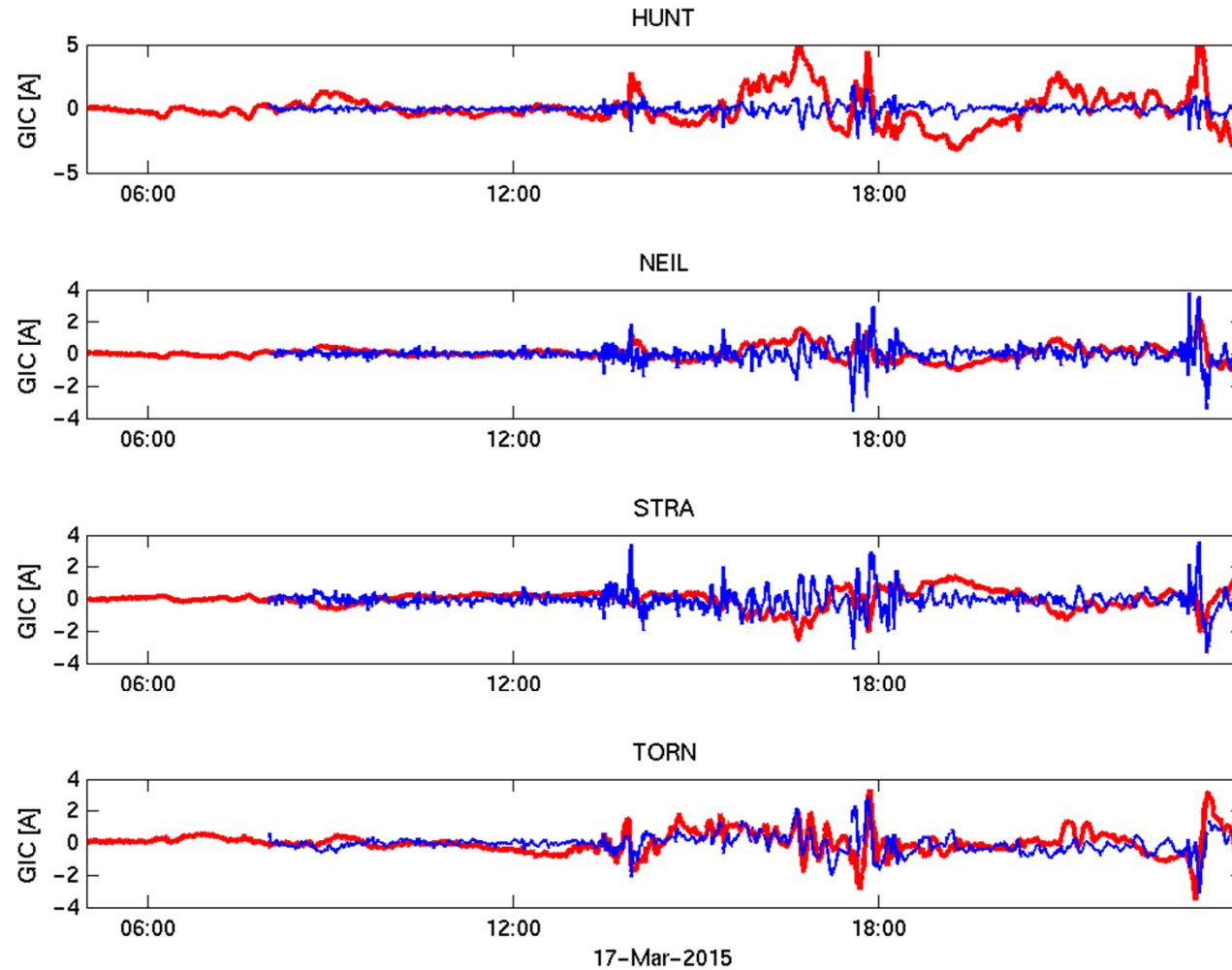


St. Patrick's Day storm - Geoelectric

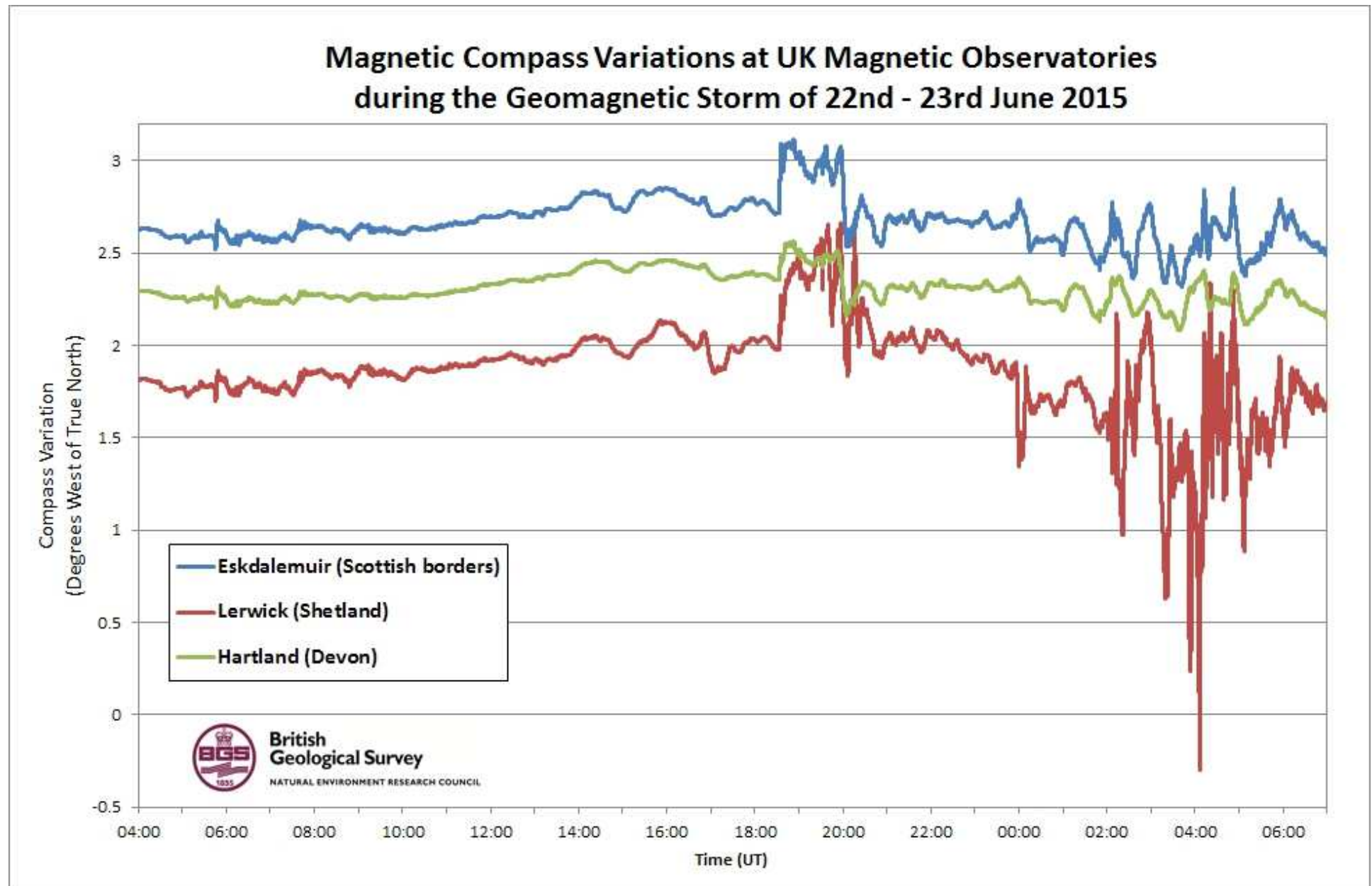
Eskdalemuir Observatory



GIC Modelling – 17th March 15

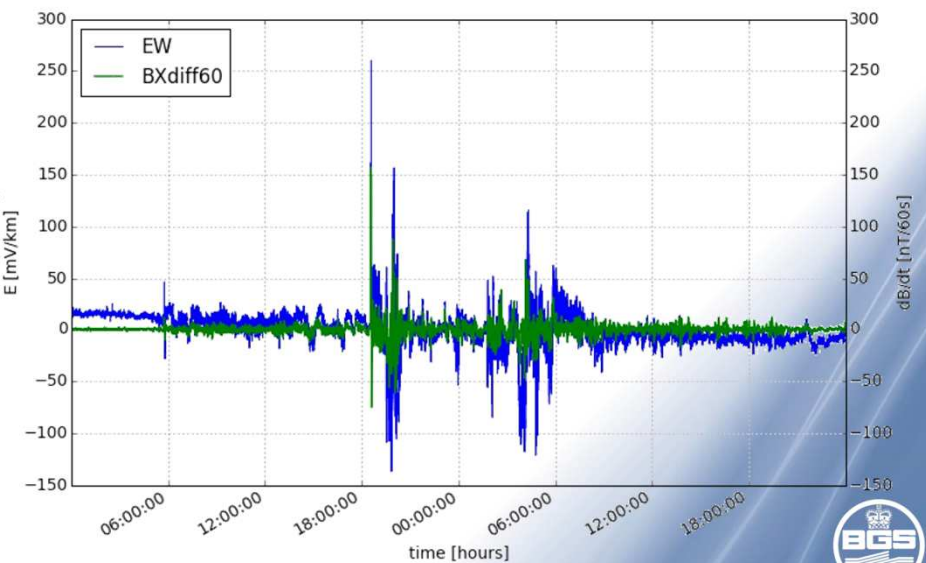
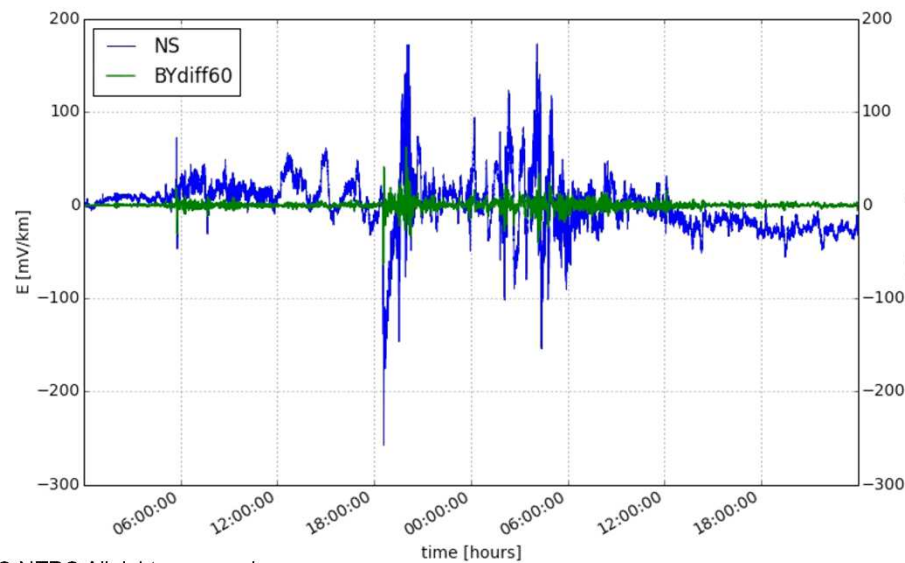
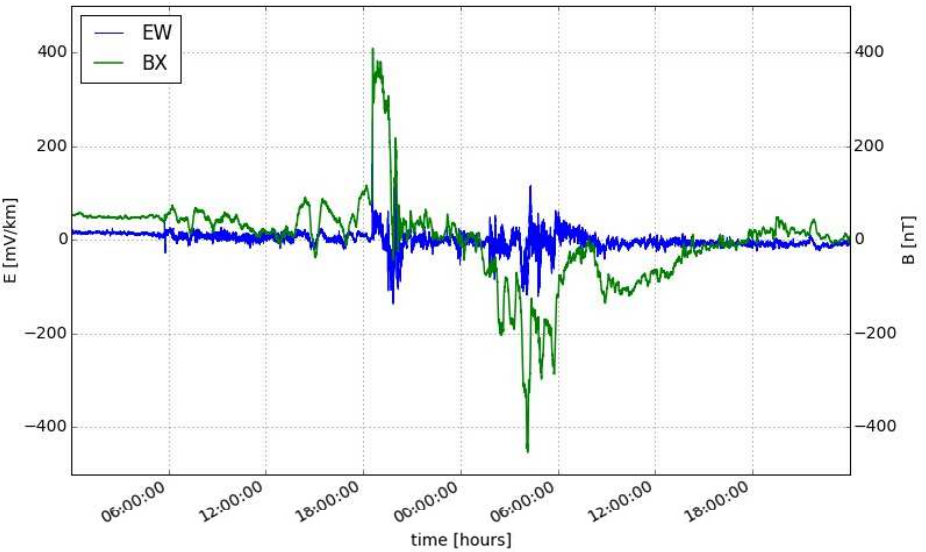
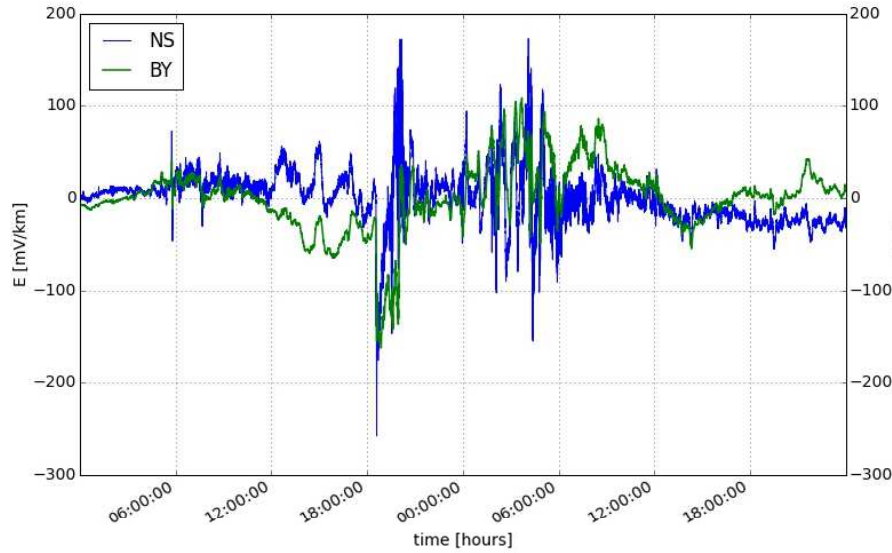


Summer Solstice storm - Geomagnetic



Summer Solstice storm – Geoelectric

Eskdalemuir Observatory



Thank You

See our latest forecast at:

www.geomag.bgs.ac.uk/data_service/space_weather/3dforecast.html