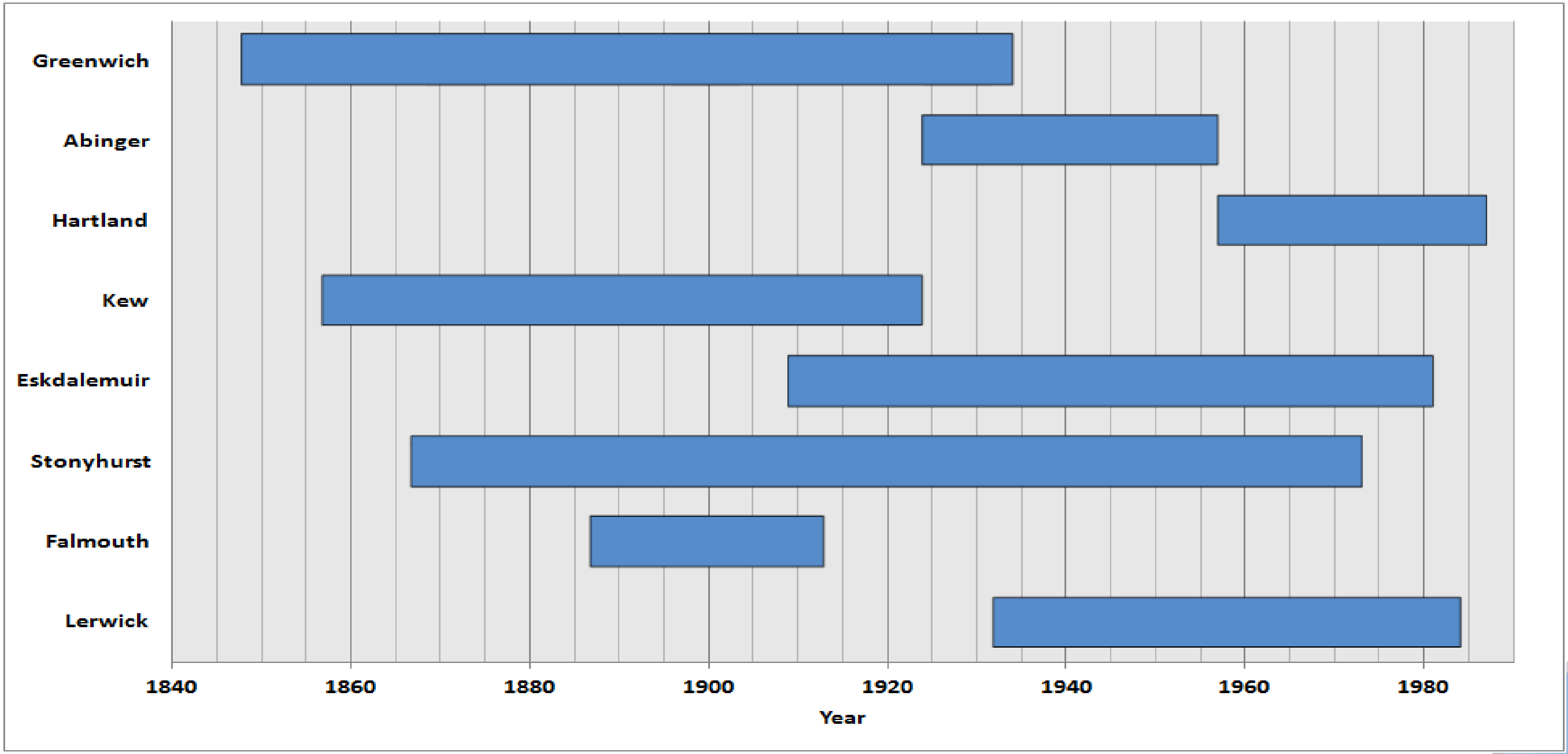
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Recent BGS activities: digitising and modelling with historical data and telluric measurements and analysis

Ellen Clarke, Gemma Kelly & Ciaran Beggan

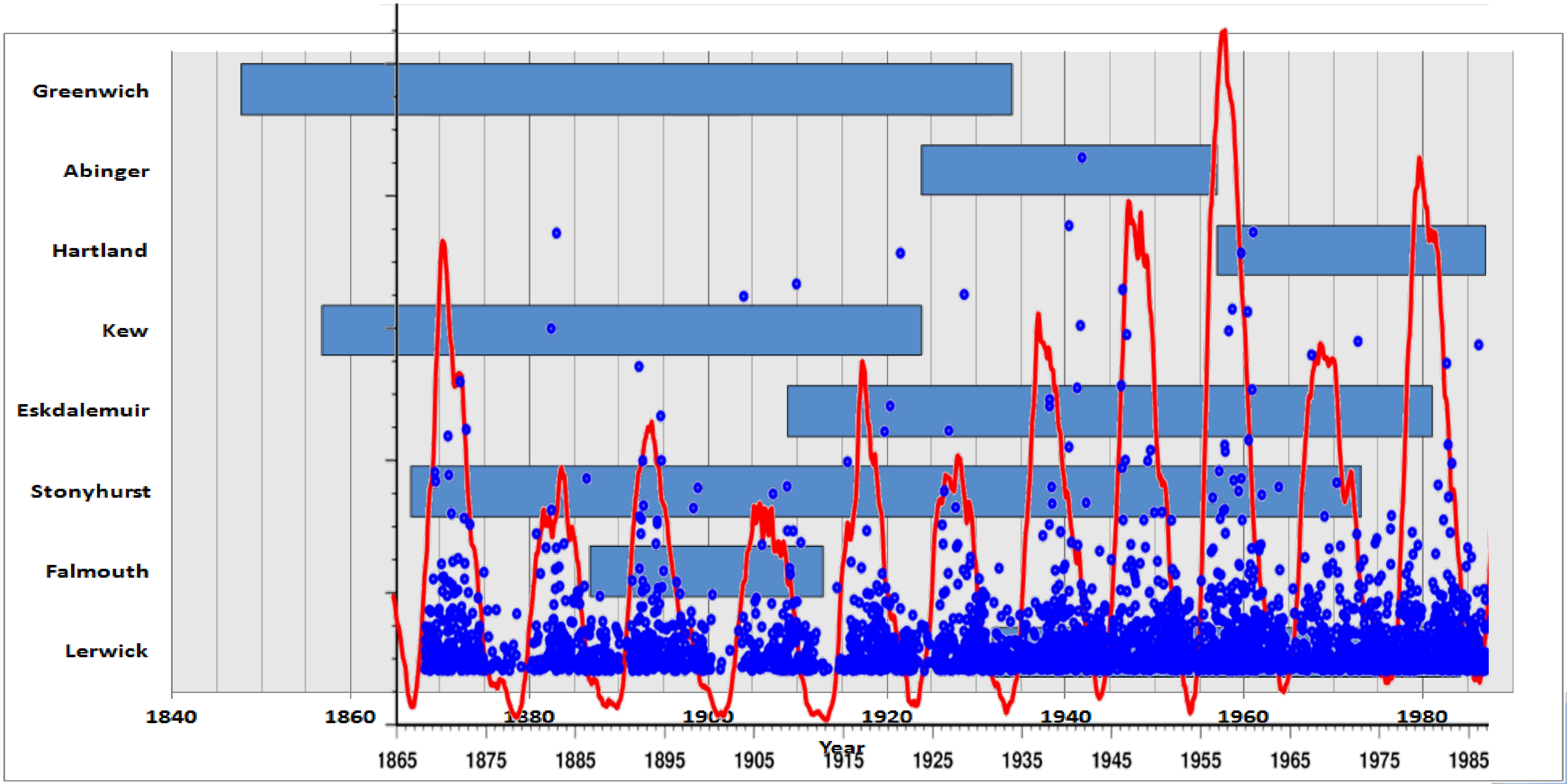
Digital Capture of Magnetograms



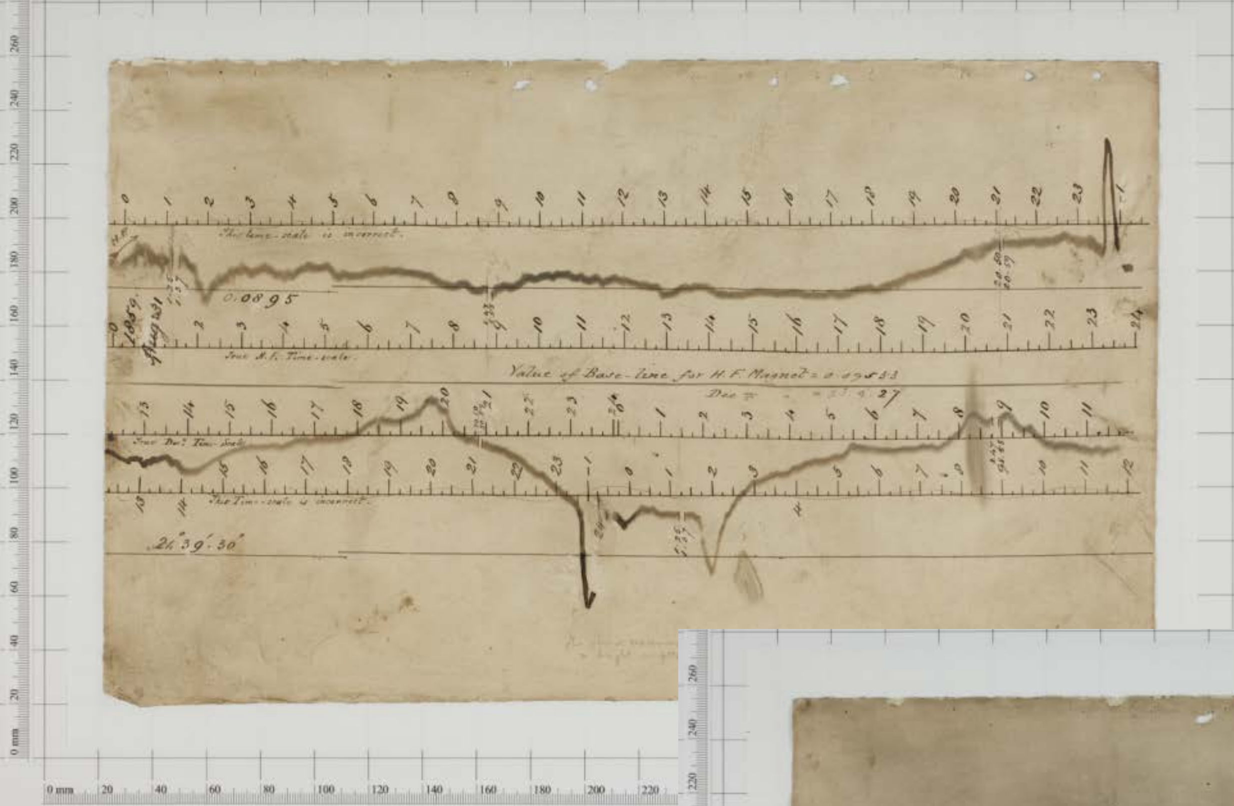
Total of 472 years and >350000 magnetograms

Digital Capture of Magnetograms

Selection of Extreme Storms

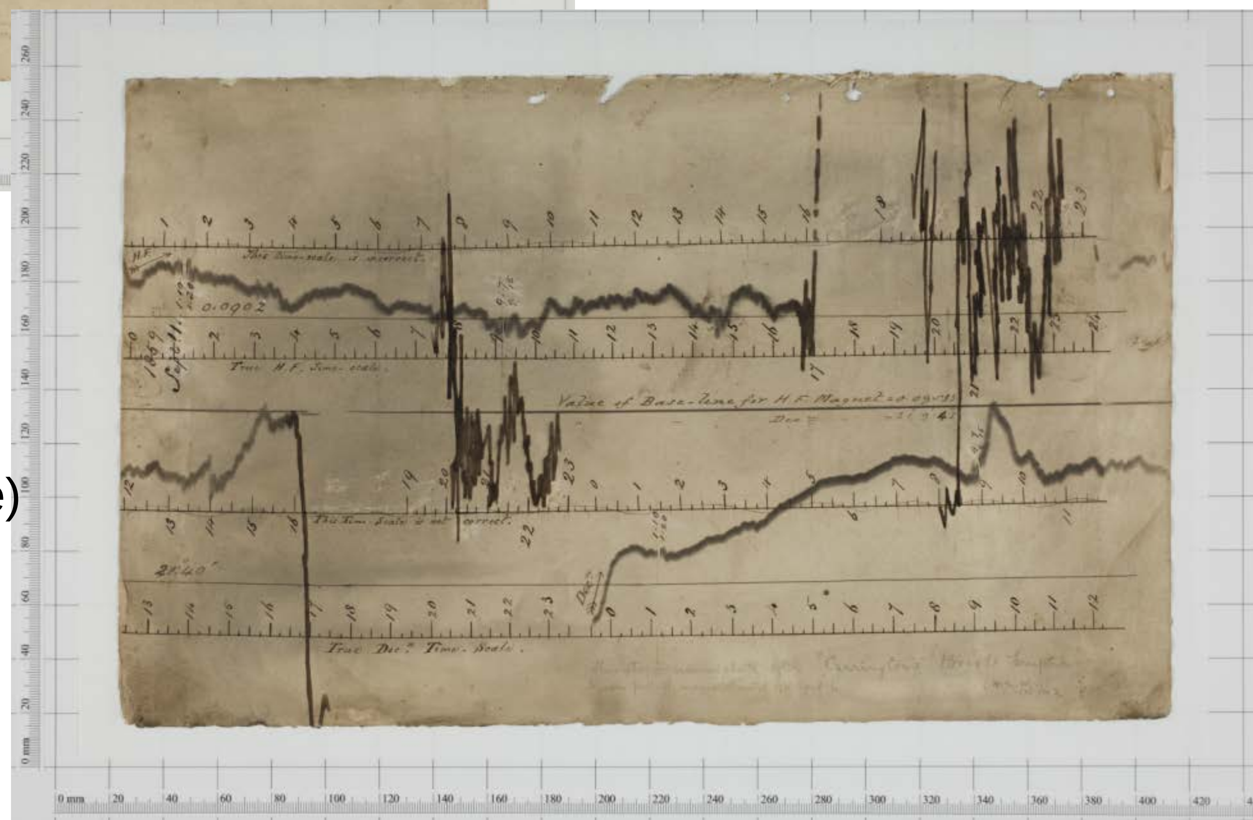


Total of 472 years and >350000 magnetograms



Greenwich Magnetograms

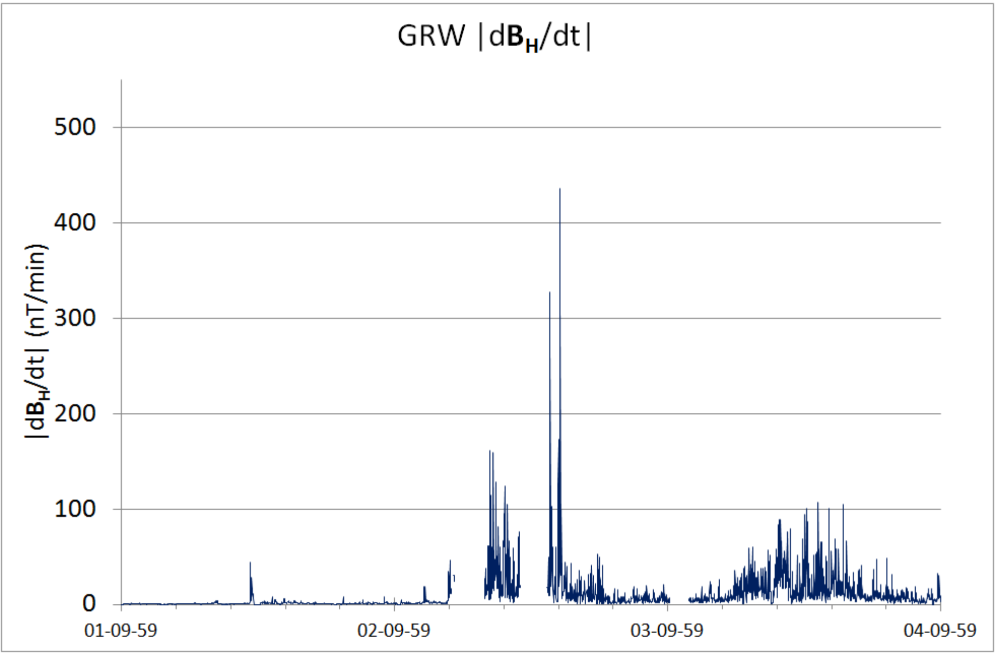
(Carrington Storm)

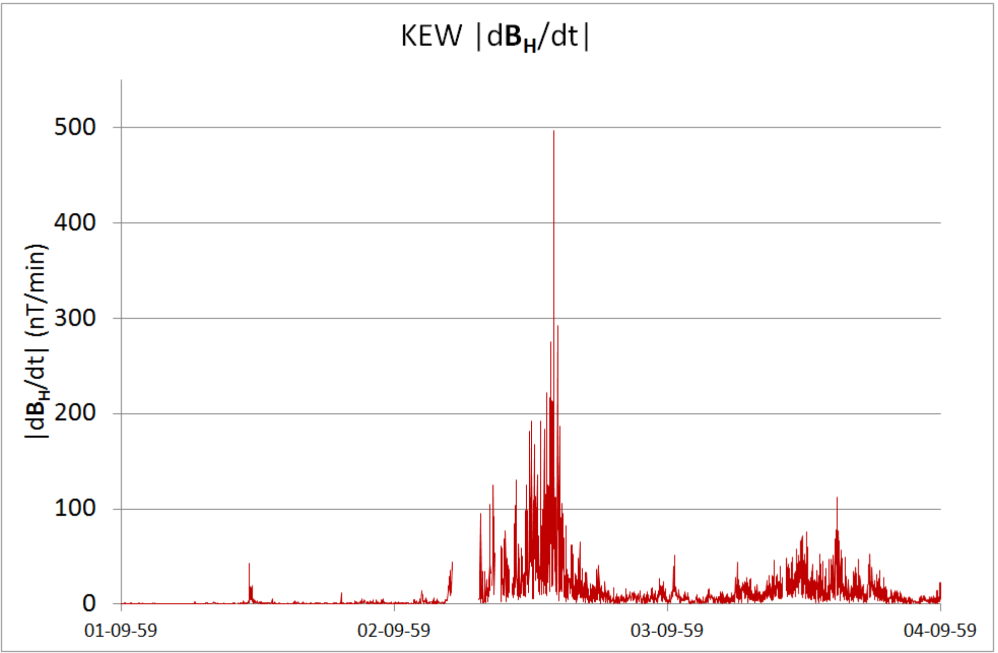


Above: 31 – 1st Sep 1859
Right: 1st – 2nd Sep 1859

Horizontal Intensity (top trace)
Declination (bottom trace)

Carrington Storm d**B**$_H$/dt at GRW and KEW





- Results are still provisional
- Good agreement between KEW and GRW
- Estimate |d**B**$_h$/dt| reached at least 500 nT/min
- Compare this to the maximum for the March 1989 storm of 327 nT/min in South England
- Study on worst case scenarios (Thomson *et al*) estimates the 100 and 200 year return level for |dH/dt| at this location to be ~600 and ~800 nT/min respectively

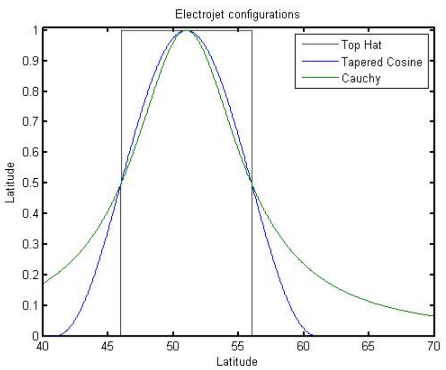
Modelling the Carrington event

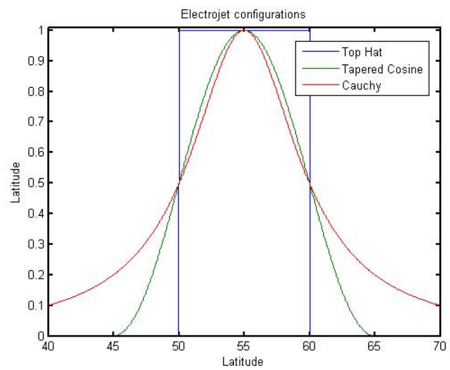
- UK time-series at one location (London)
  - has peak **dB_H/dt > 550 nT/min** (c.f. Ellen's slide earlier)
- How do we infer B and E across the UK?

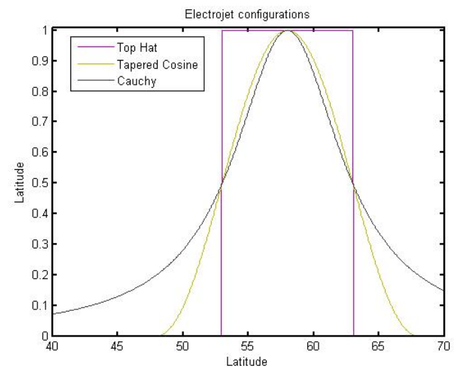
- Model tests:
  - Auroral electrojet *shape* [TopHat, Tapered Cos, Cauchy]
  - Auroral electrojet *width* [10°, 20°, > 20° latitude]
    - moves down the UK over time
  - also test **700 nT/min** (Stewart, 1859) and **1000 nT/min**
    - has a period of 2 and 10 minutes

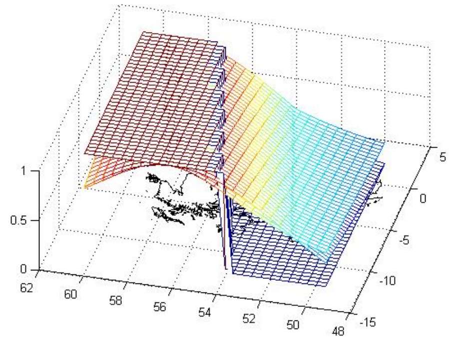
- Compute Electric field using BGS2012 Conductivity model
- Compute GIC using NG2012 network model (v7)

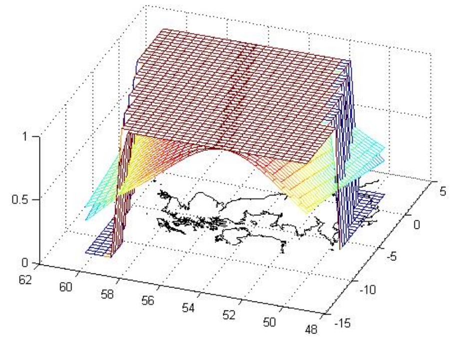
Electrojet shape & position

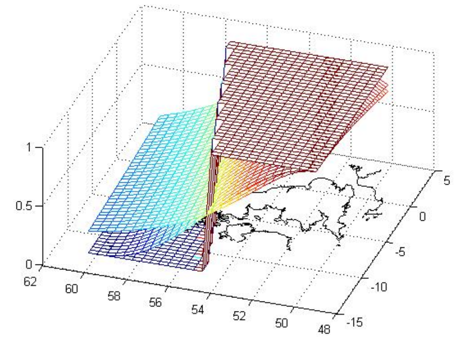






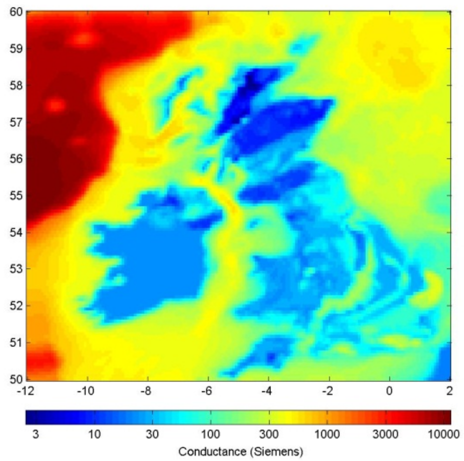


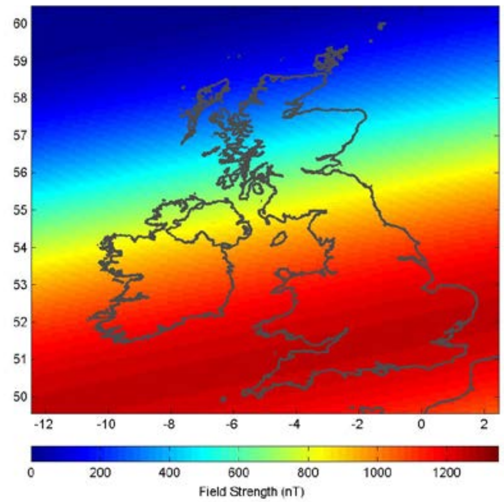


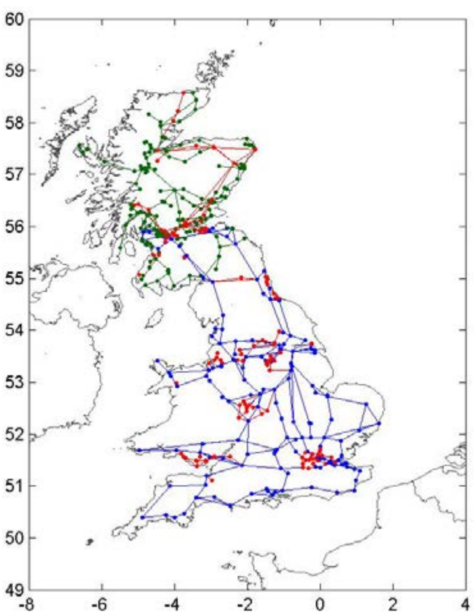


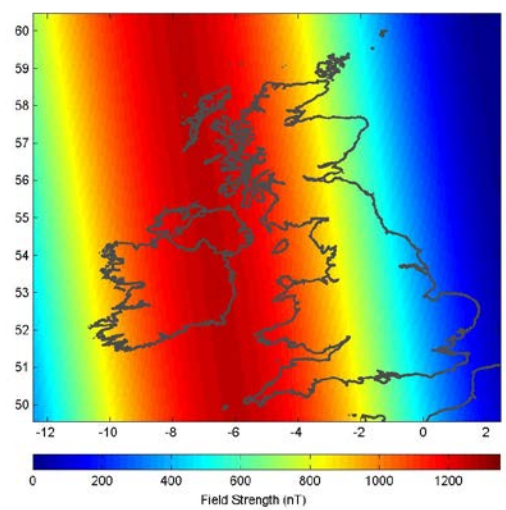
Time

Inputs









Scaling of electrojets:

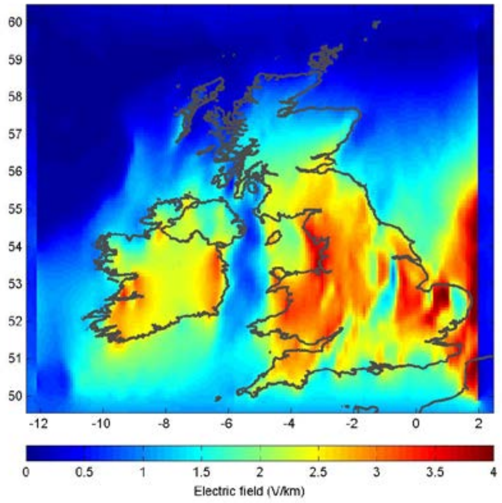
$$H_0 = (dB_H/dt) * Period / (\sqrt{2} * \pi)$$

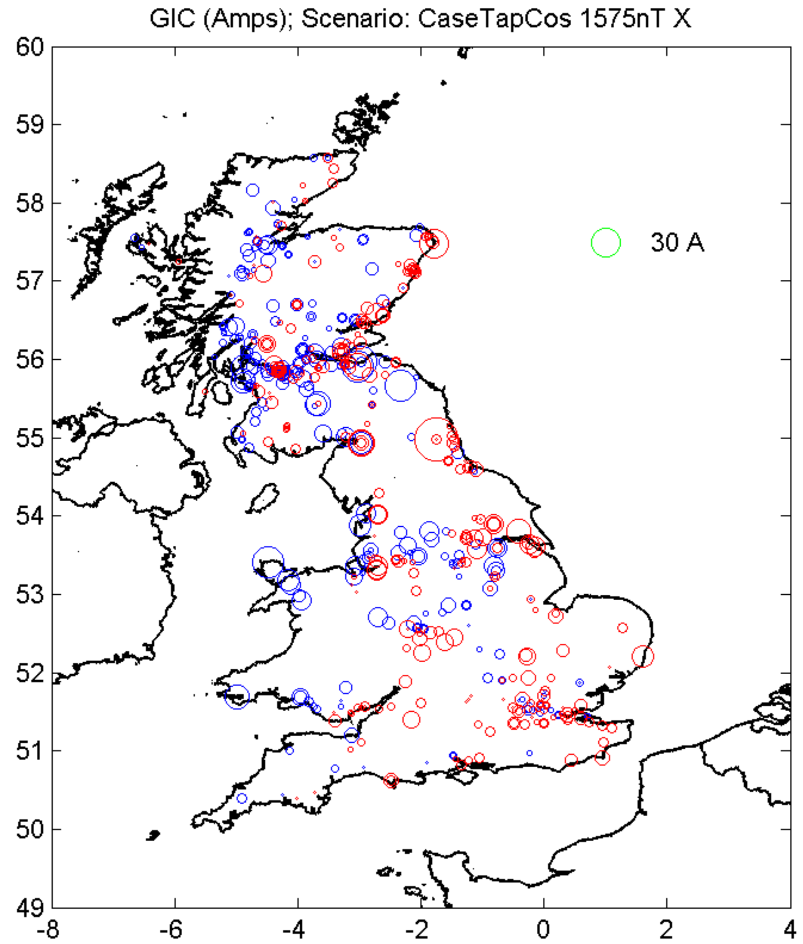
dB_H/dt nT/min	Period (min)	H_0 (nT)
550	2	250
550	10	1250
700	2	320
700	10	1575
1000	2	450
1000	10	2275

72 GIC scenarios :
2 x periods, 3 x electrojet shapes, 3 x scale factors [= 18]) x 3X + 1Y orientation

Resulting E-fields & GIC

Electrojet centred over London, Tapered Cosine shape, 20° wide; 700 nT/min @ 10 mins, X & Y





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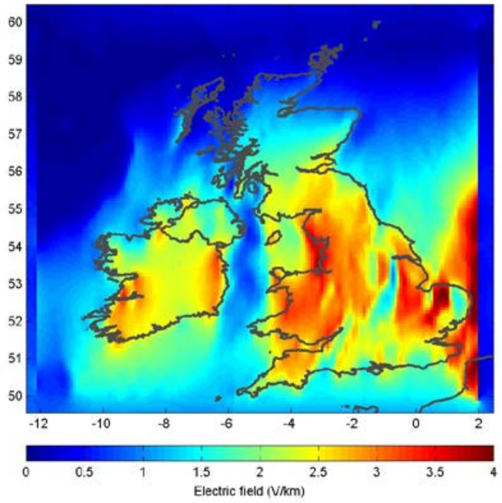
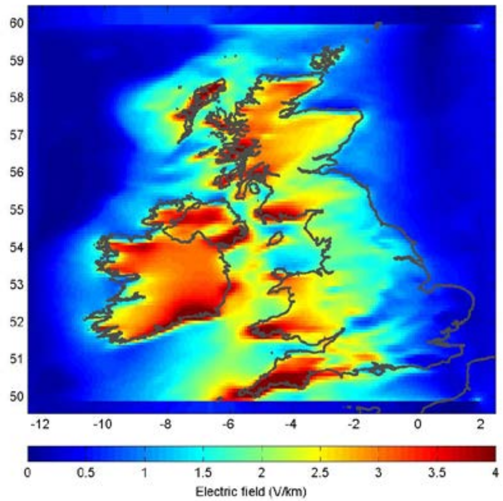
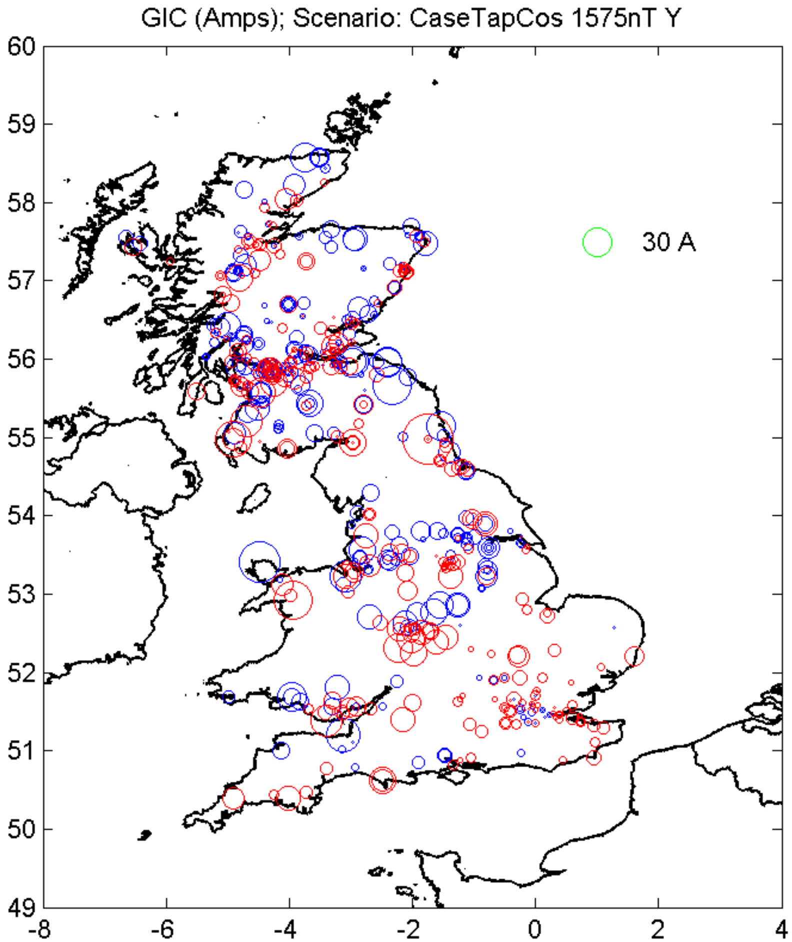






Largest peak GIC in London e-jet

dH/dt (nT/min)	Period (min)	H_0 (nT)	X orient (Amps)	Y orient (Amps)
550	2	250	16	29
550	10	1250	50	67
700	2	320	21	37
700	10	1575	63	85
1000	2	450	30	53
1000	10	2275	91	122

Electrojet Tapered Cosine shape; All three phases summed; Absolute value of GIC shown

Largest GIC – NE England + NE Scotland regions

N Scotland/N England

dH/dt (nT/min)	Period (min)	H_0 (nT)	N Scotland X (Amps)	N England X (Amps)
550	2	250	25	21
550	10	1250	33	27
700	2	320	46	39
700	10	1575	60	63
1000	2	450	75	79
1000	10	2275	109	114

Largest GIC: Wales for NScotland; Newcastle for NEngland

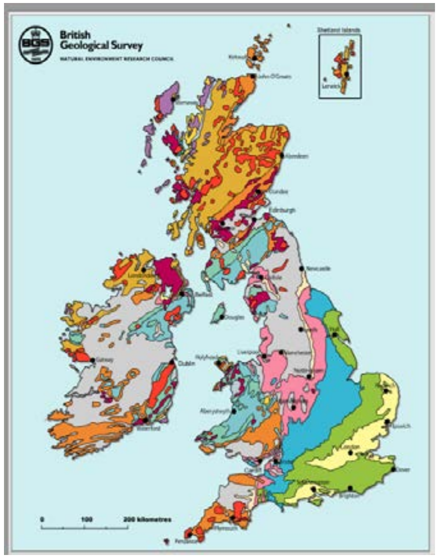
GIC calculation

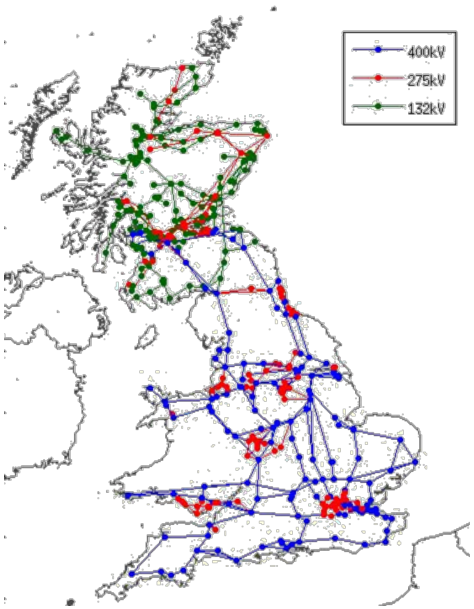
a) Ground **conductivity** (geology)

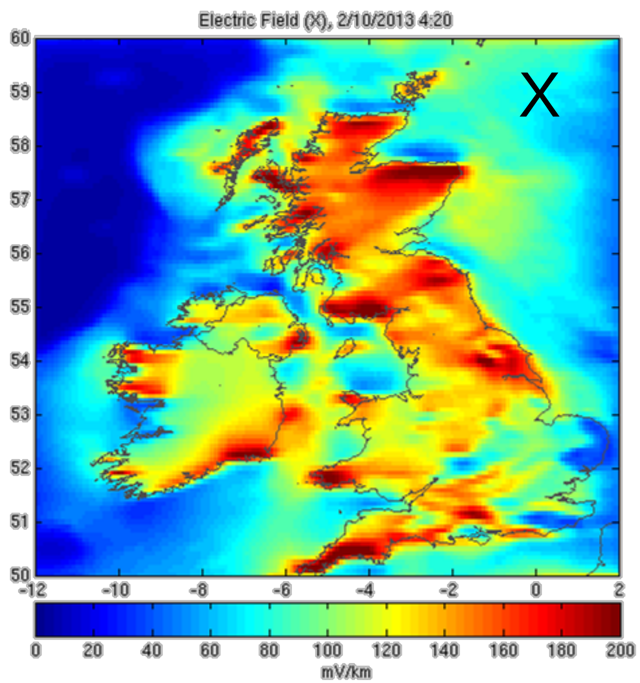
b) Anomalous **magnetic field** which induces electric field

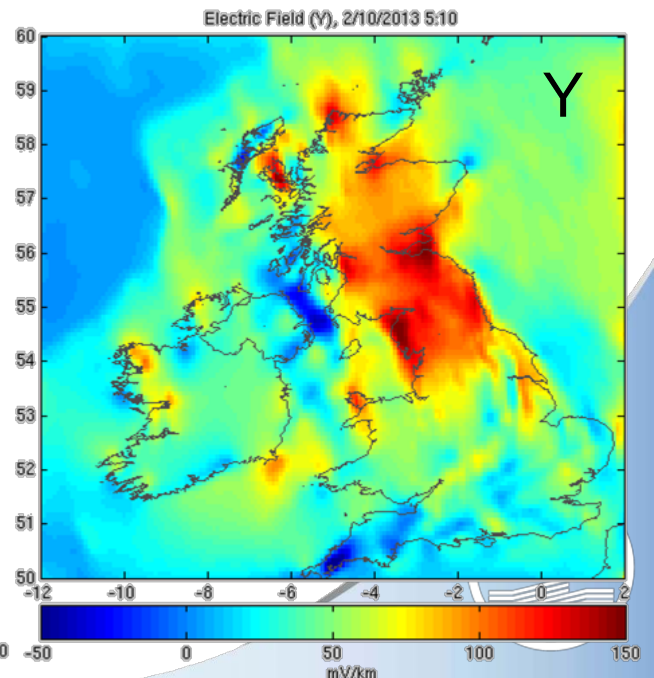
- Measured in real time and interpolated across the UK and Ireland
- 'Thin Sheet' modelling used to convert magnetic field changes to **electric field** induced in the ground

c) Grid topology & characteristics



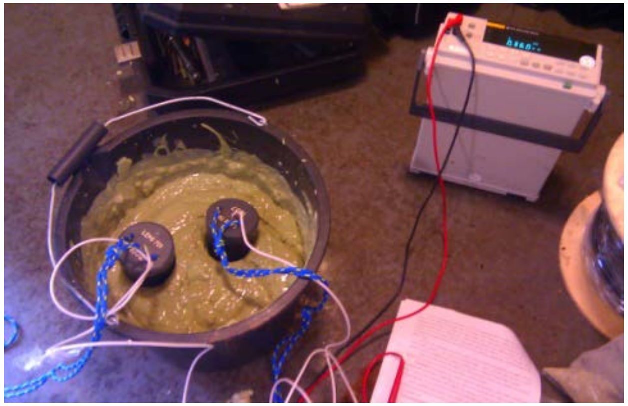






Geo-electric field monitoring

- Installations:
  - Eskdalemuir in Nov 2012
  - Lerwick in March 2013
  - Hartland in May 2013
- Instrumentation:
  - Two pairs of probes at each site, aligned EW and NS ~100m apart
  - Delivers 1Hz measurements

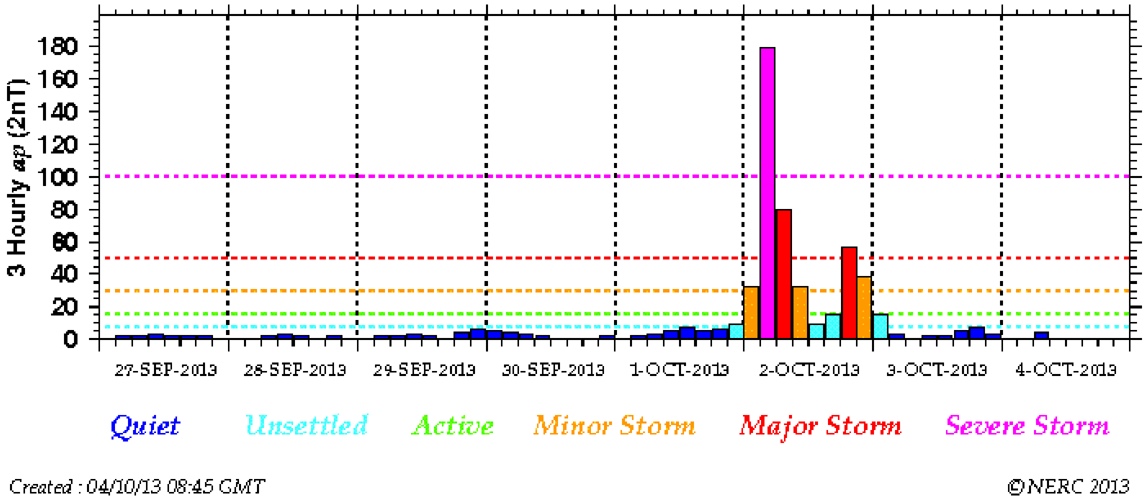


How do the models compare?

- Example: Storm on 2nd October 2013
  - Kp ≥ 5+ for first 9 hours of day
  - Kp reached 8- between 3.00-6.00 UT

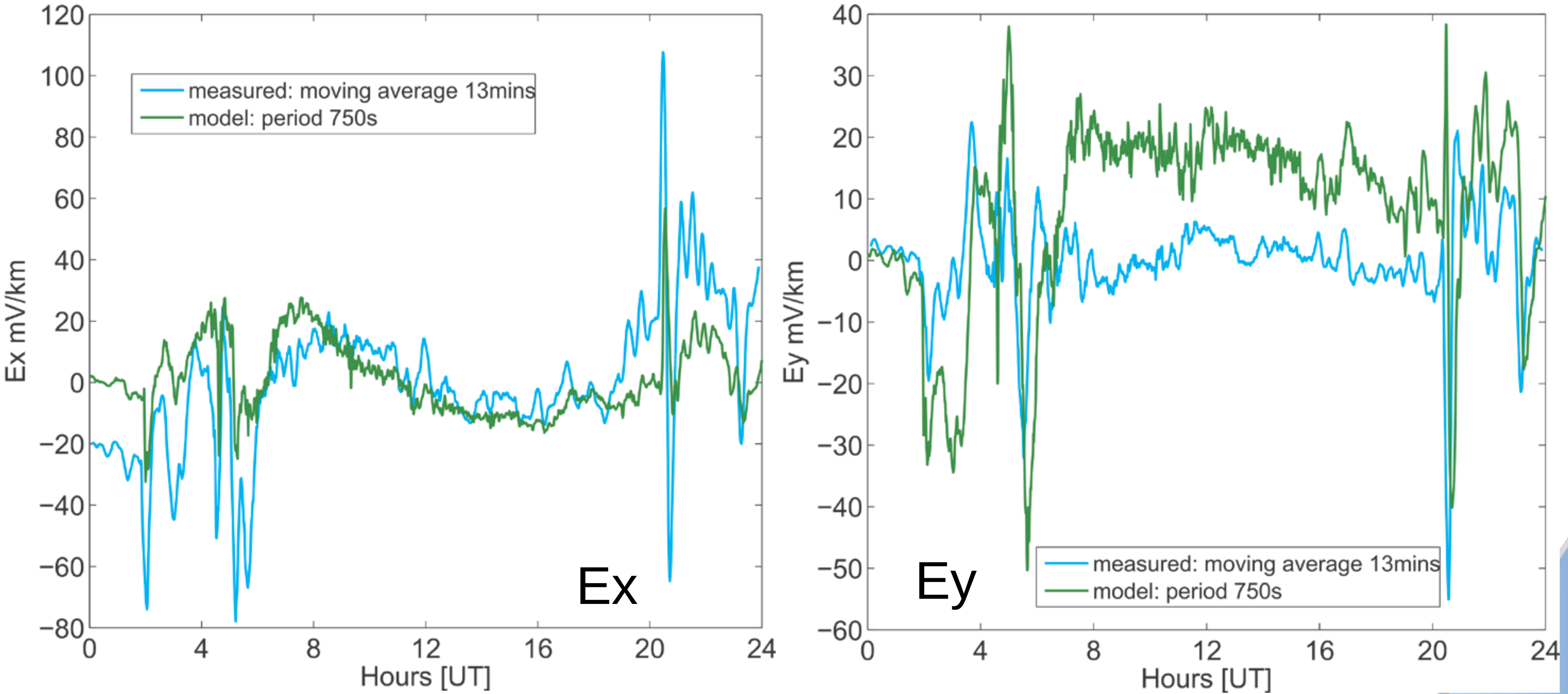
3-hour *ap* estimate with thresholds of activity

2/10/13



2nd October 2013

Eskdalemuir



Removed the short period ‘noise’ using a moving average

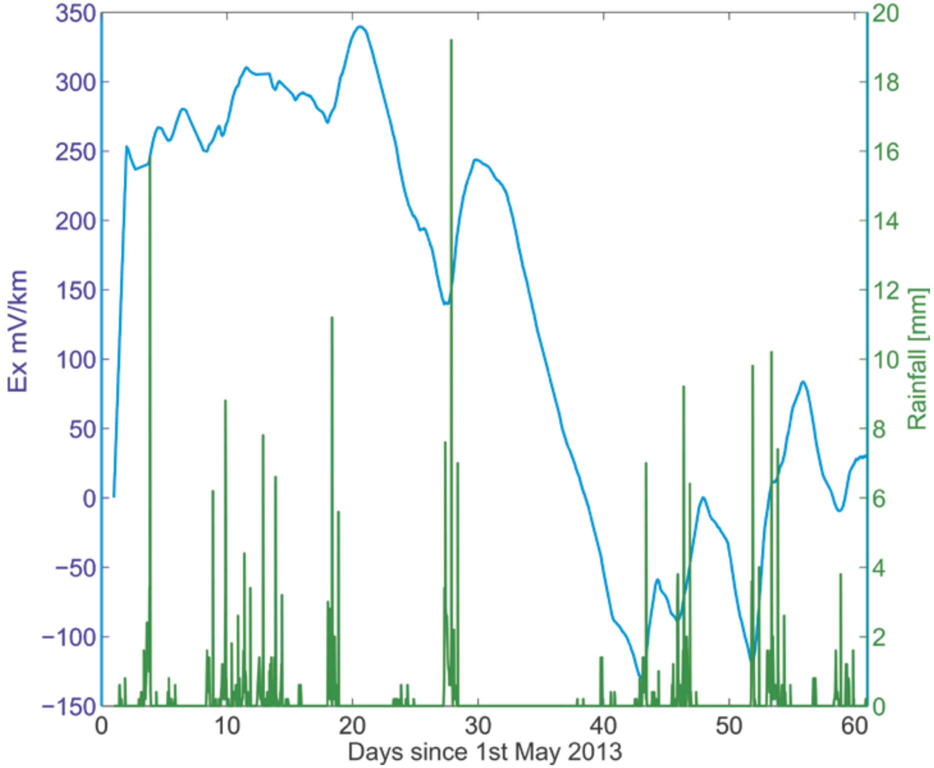
Problems

To be able to verify our models in a more comprehensive way we need to understand the other signals in the data e.g.:

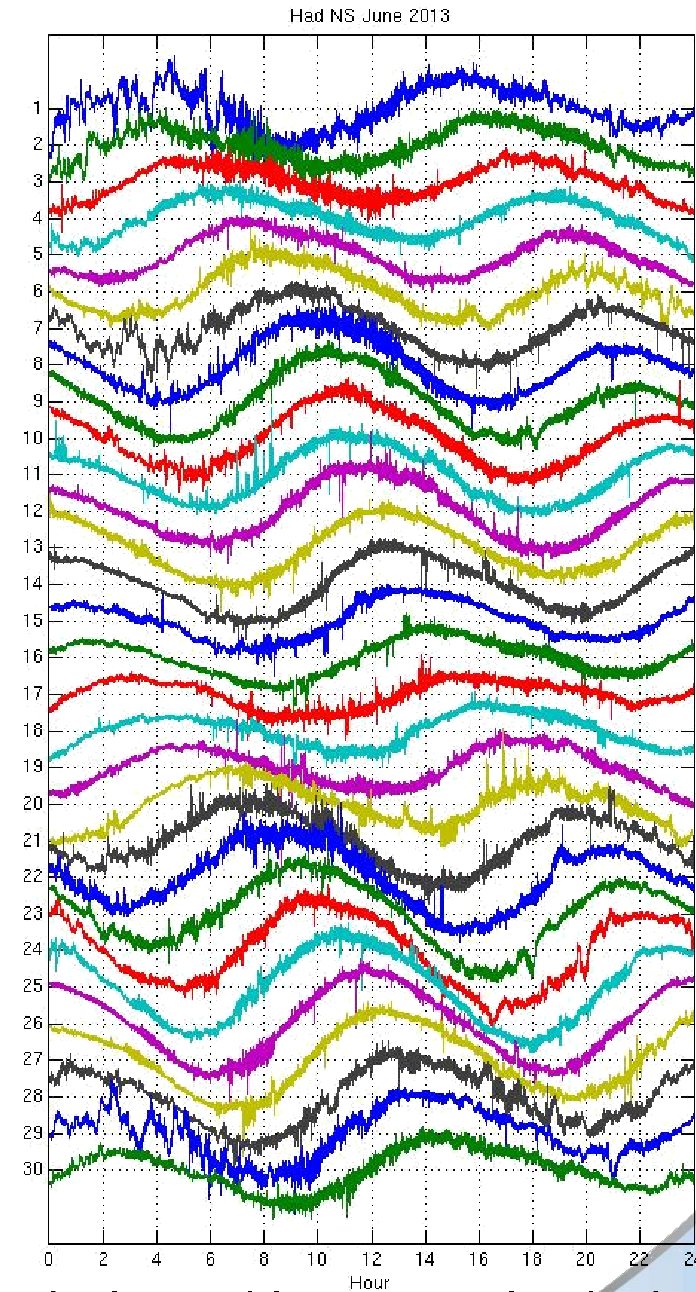
- Baseline shifts and spikes
- Signal due to induction from magnetic field is largest during storms – at quiet times local signals dominate
- Weather and tides....

Rainfall & tides

Eskdalemuir May-June 2013



Data in blue smoothed using a moving average (length = 1 day)
Green is hourly rainfall in mm

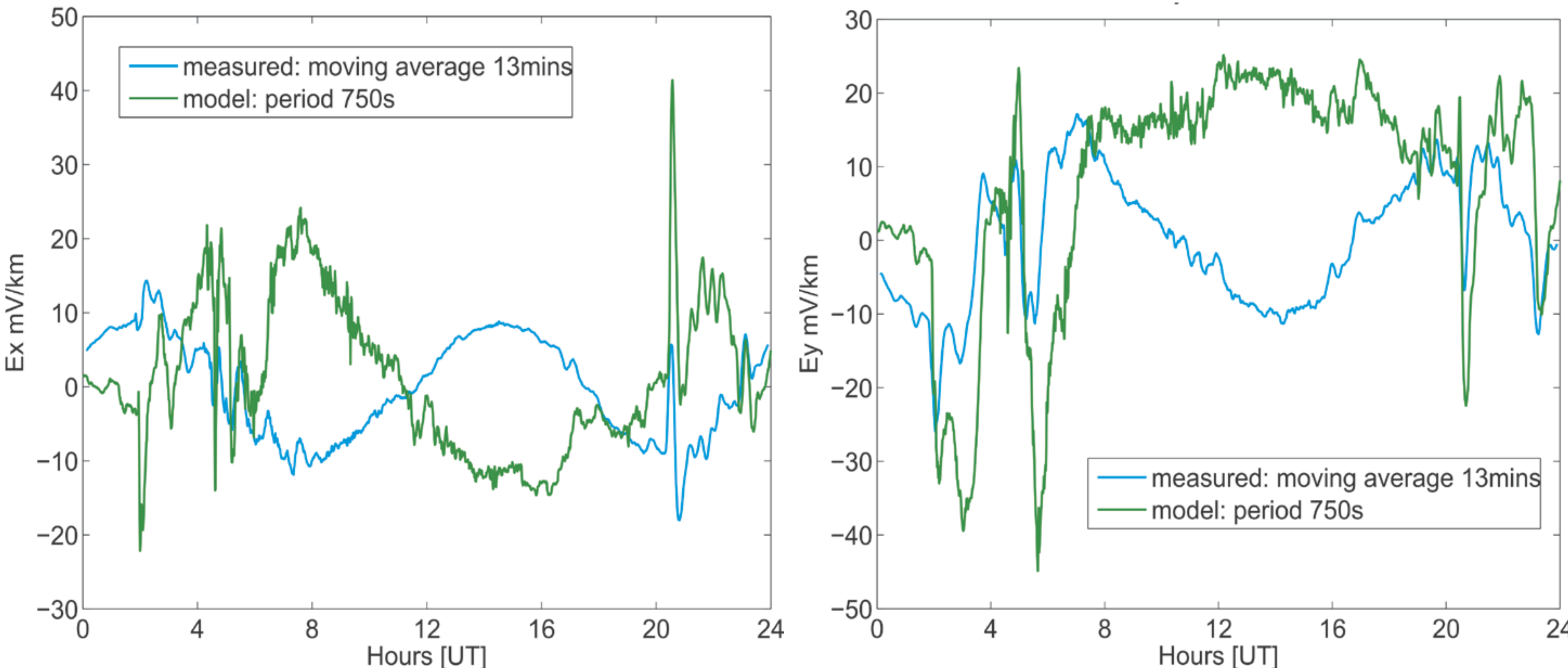


Ex

Particular problem at Hartland – but some tidal signal in all 3 locations

Hartland – 2nd October

- The tidal signal in the measurements and the Sq signal in the model make it very difficult to compare



Hartland – 2nd October

- Subtracted hourly mean curve to remove tidal and Sq signals