British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Verifying GIC Nowcast Models with Geo-electric Field Measurements

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EURISGIC

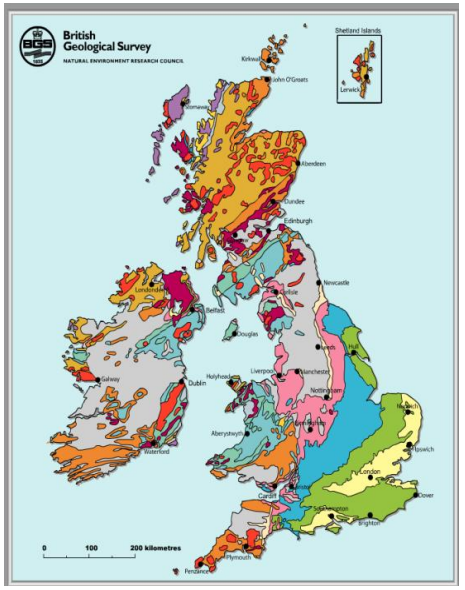
GIC calculation

a) Ground **conductivity** (geology)

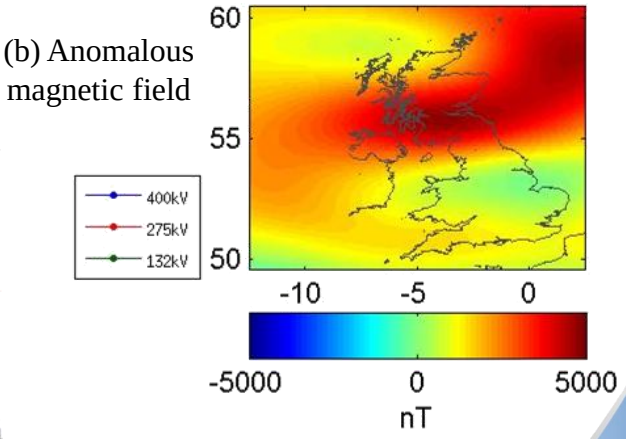
b) Anomalous **magnetic field** which induces electric field

- 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



(a) Geology of UK and Ireland



(b) Anomalous magnetic field

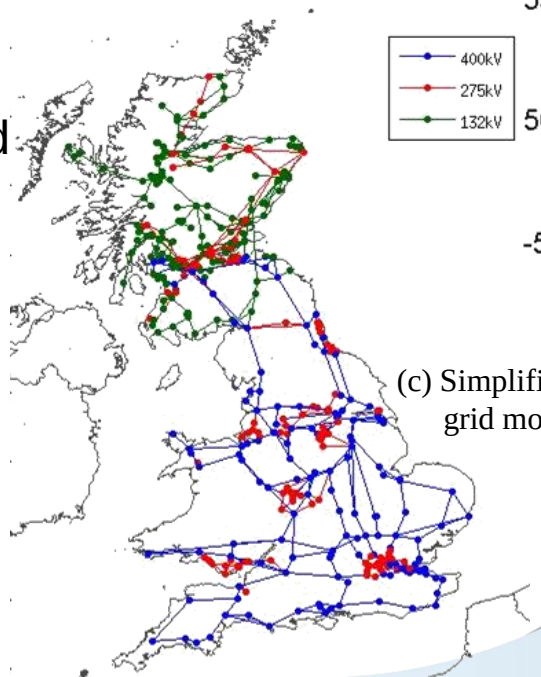
GIC calculated through integration of line resistances along line length divided by network topology matrices i.e.

$$\text{GIC: } I = (1+Y.Z)^{-1} \cdot J$$

network admittance matrix

impedance matrix

geo-voltage between nodes



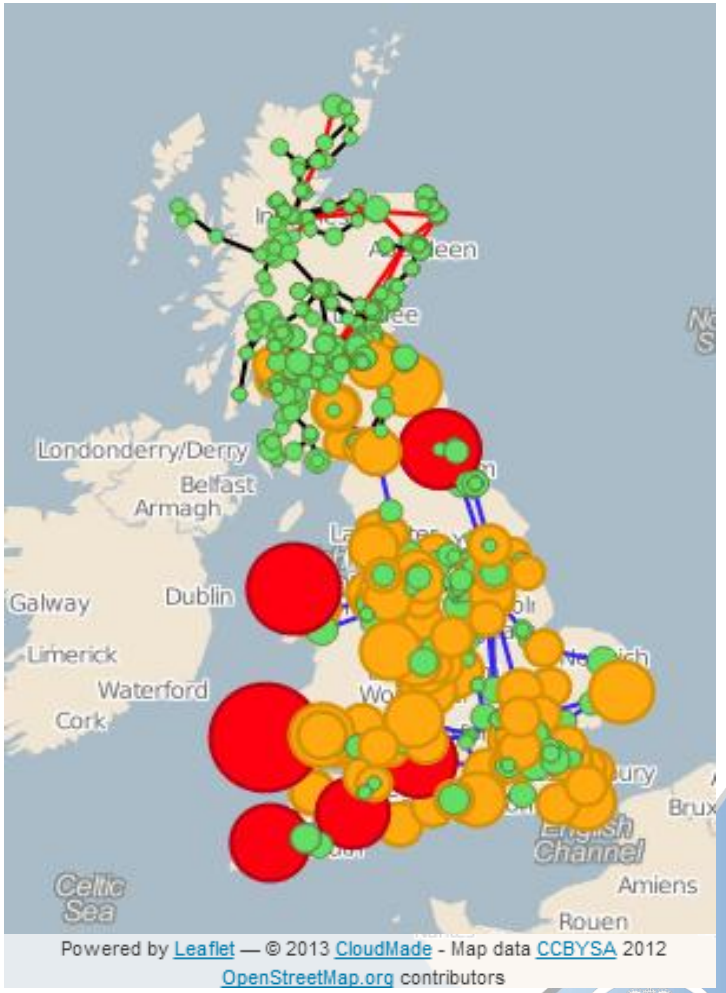
(c) Simplified UK grid model

GIC nowcast model

- Estimates of GIC provided as the 3 phases summed at each node
- Delivered to National Grid in near real time through a web tool

But....

- We had no electric field measurements for the UK and very few GIC measurements, so we have been unable to verify our models



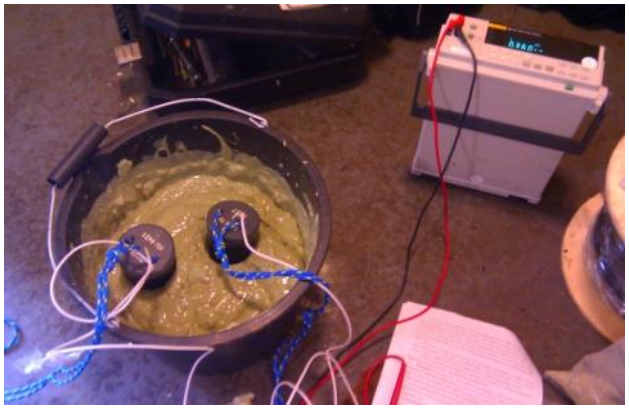
Snapshot from a test dataset

Electric Field Measurements

- 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

Geo-electric Field Monitoring - Details

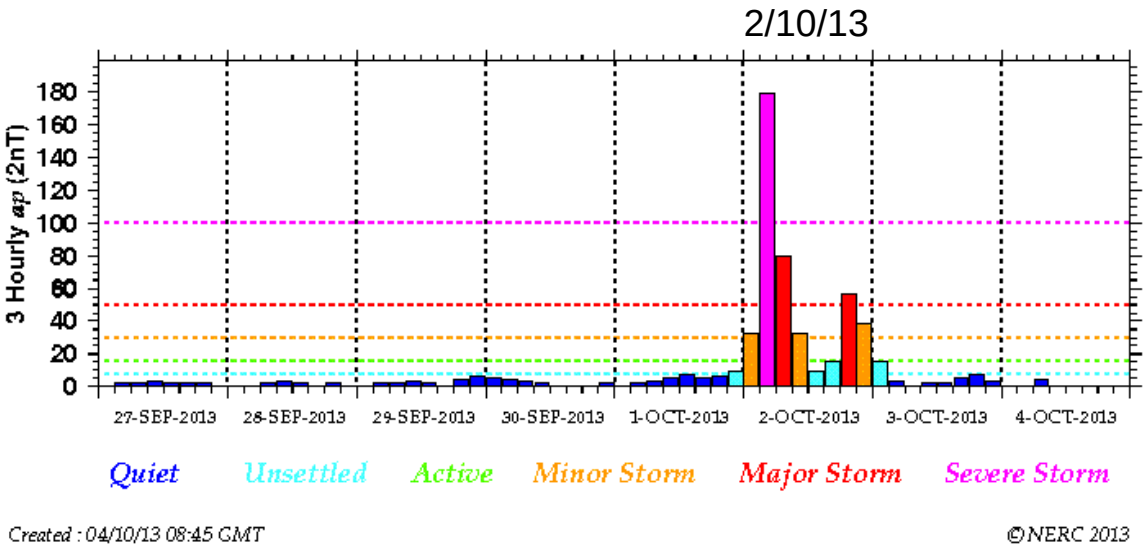
- Electrodes maintained in a ‘neutral’ Cu-CuSO4 clay mixture to prevent polarisation/self potential effects
- Transient resistance between electrodes checked before & after installation (< 5 KΩ)
- Buried in pits ~ 0.6m deep (helps minimise temperature variation)
- Electrode pairs separated by about 80-100 m
- Shielded cable to minimise pick-up of noise on signal line



How do the models compare?

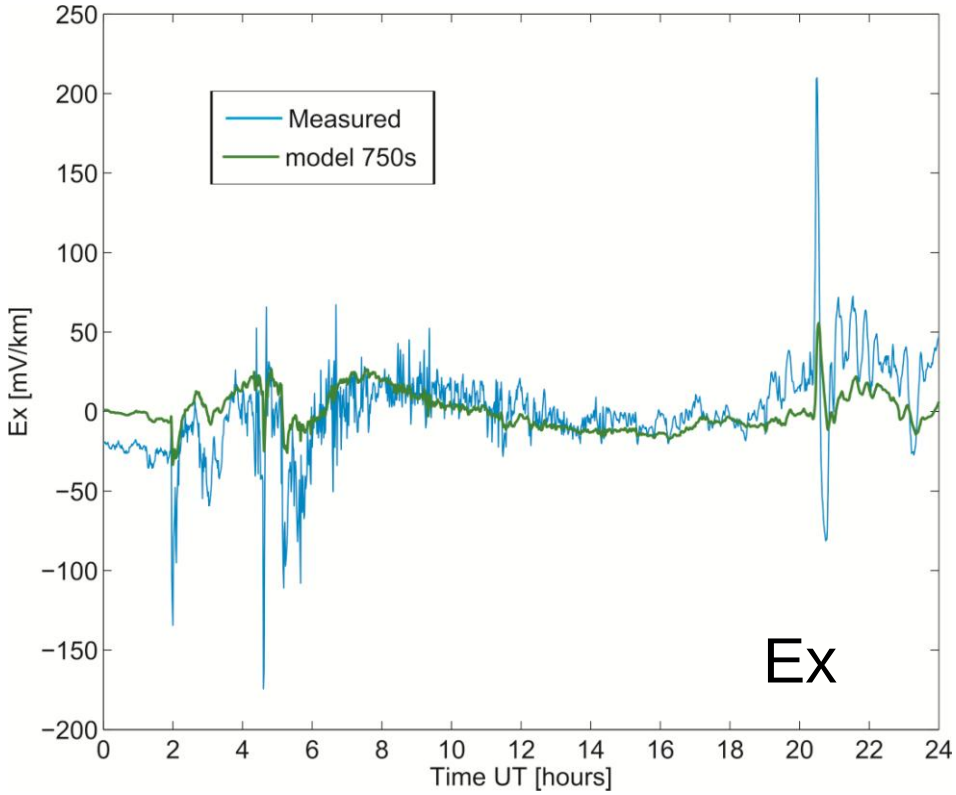
- Example: Storm on 2nd October 2013
  - Kp ≥ 5+ for first 9 hours of day
  - Kp reached 8- between 3.00-6.00 UT

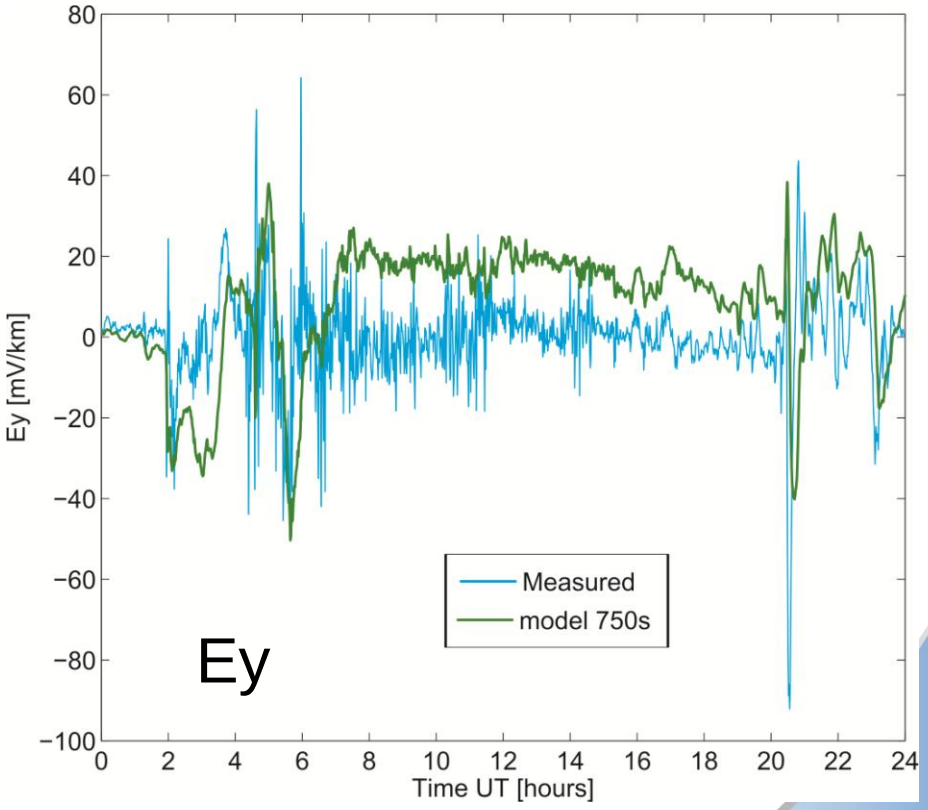
3-hour *ap* estimate with thresholds of activity



2nd October 2013

Eskdalemuir

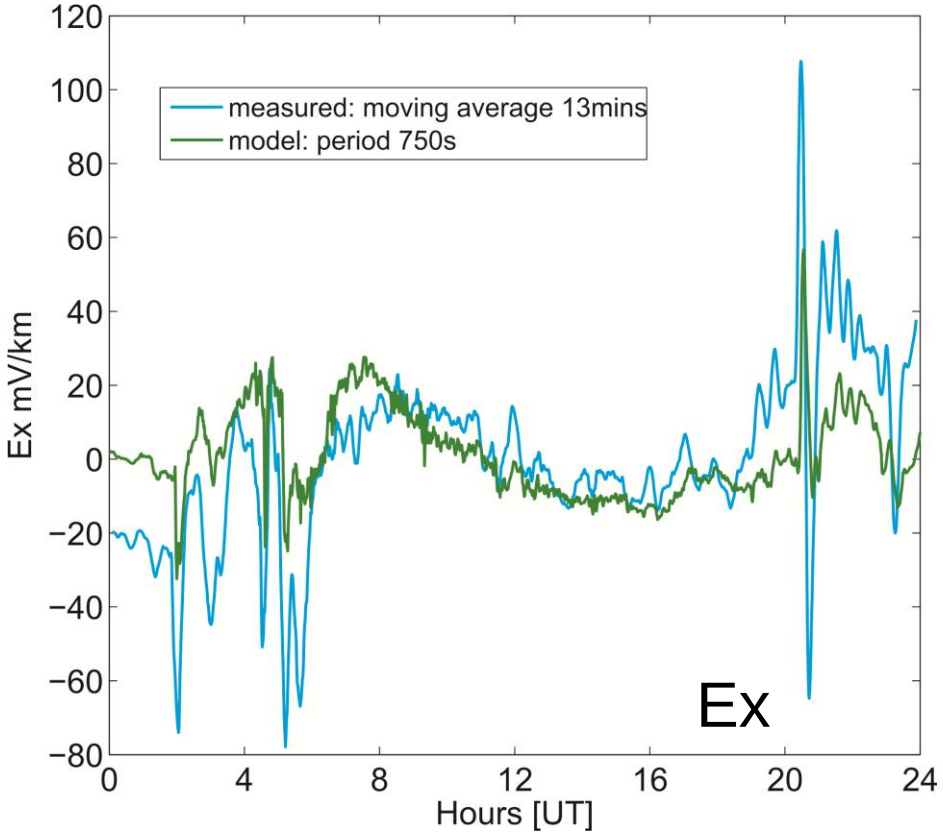


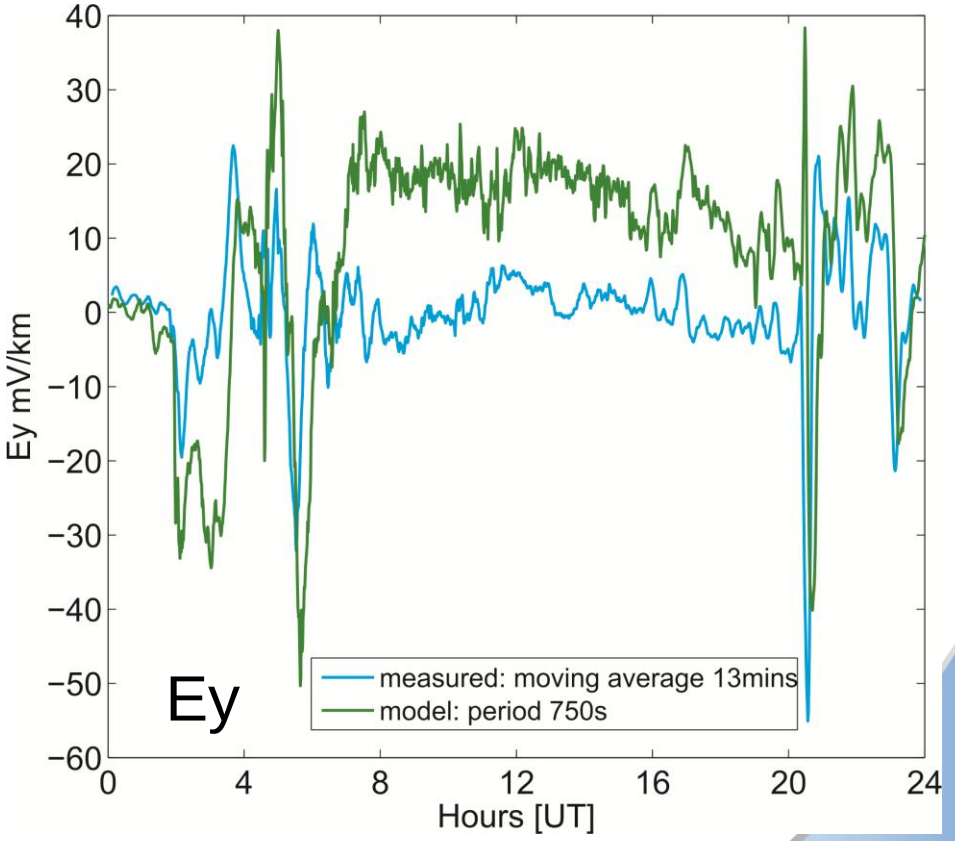


The models and measured data have had a mean subtracted to remove the bias

2nd October 2013

Eskdalemuir



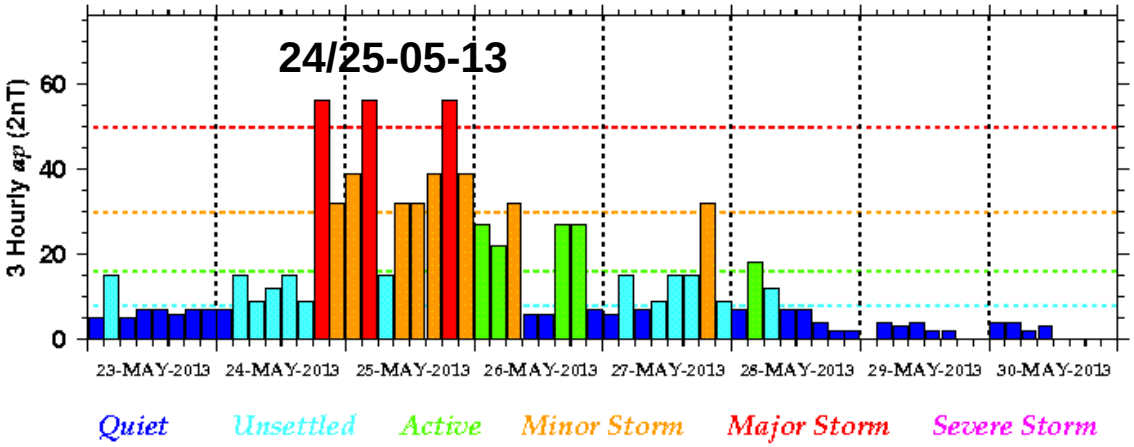


Removed the short period ‘noise’ using a moving average

How do the models compare?

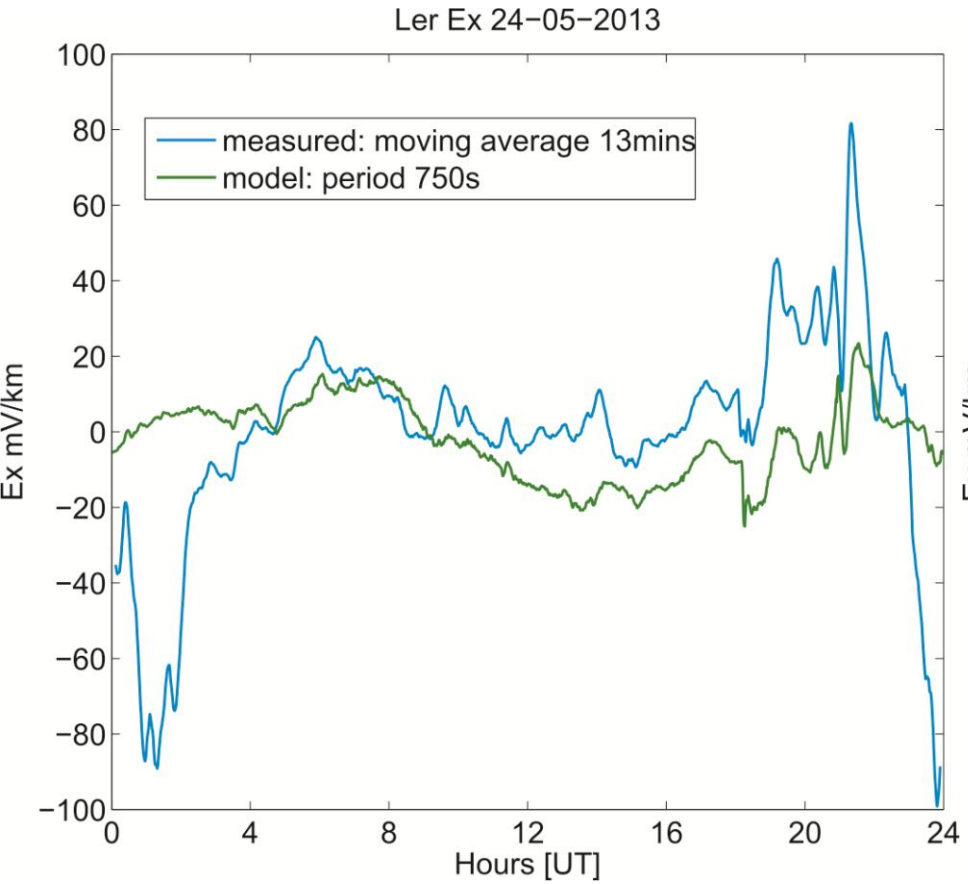
- What about a smaller storm?
- Example: 24th-25th May 2013
  - Storm not as big as 2nd Oct but longer lasting
  - Kp only reached 6-

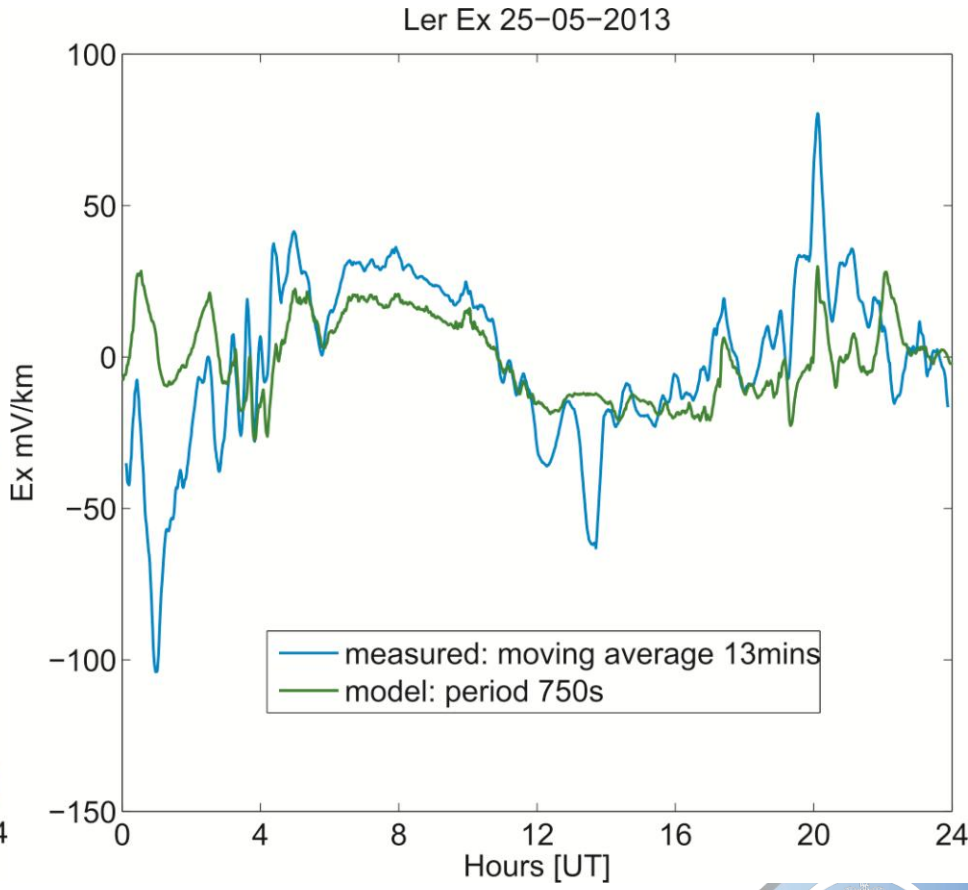
3-hour *ap* estimate with thresholds of activity



24th – 25th May 2013

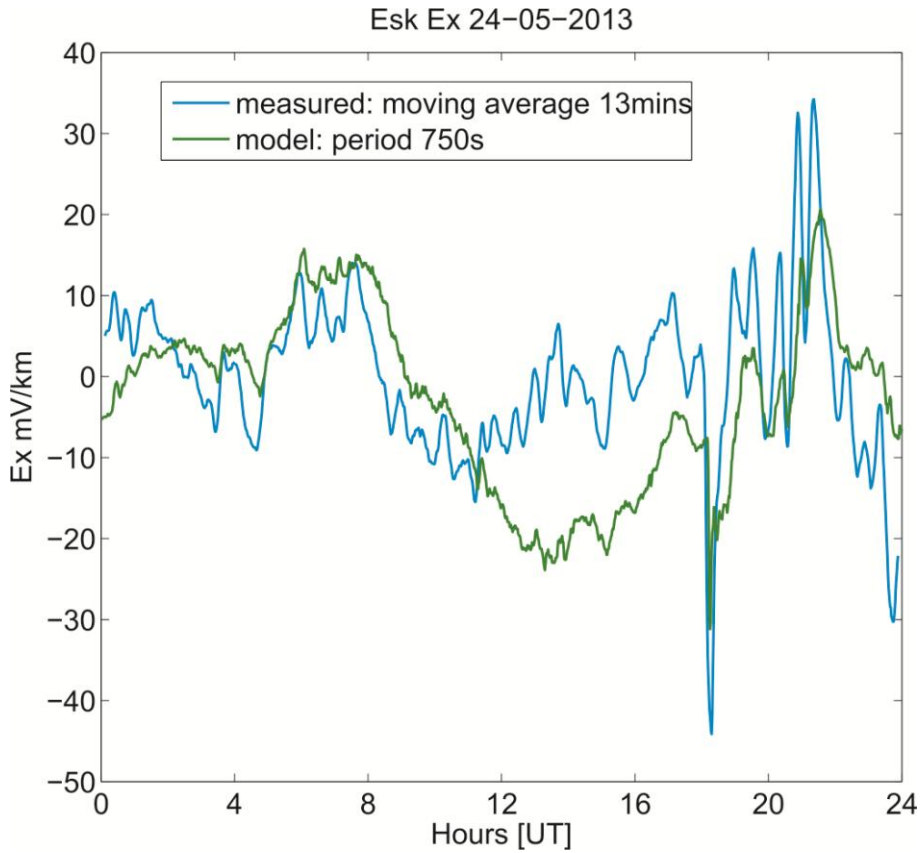
Lerwick - **Ex**

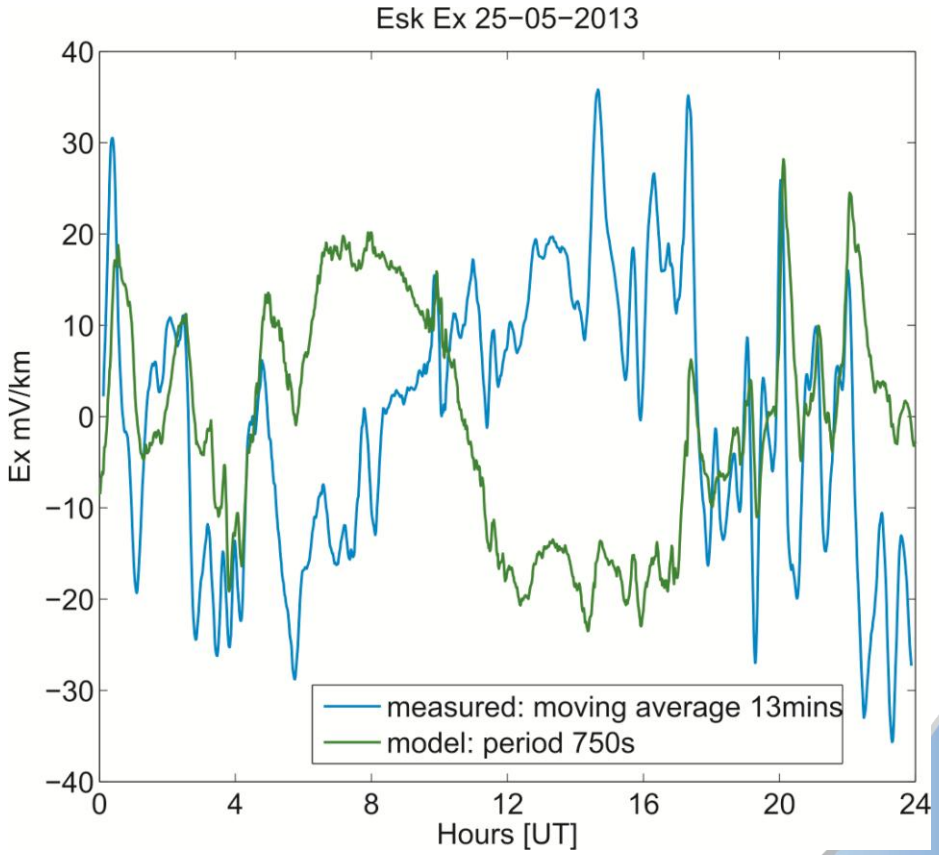




24th – 25th May 2013

Eskdalemuir - Ex





- The Sq current is not removed from the magnetic data
- For this smaller storm the signal from the Sq current is more obvious

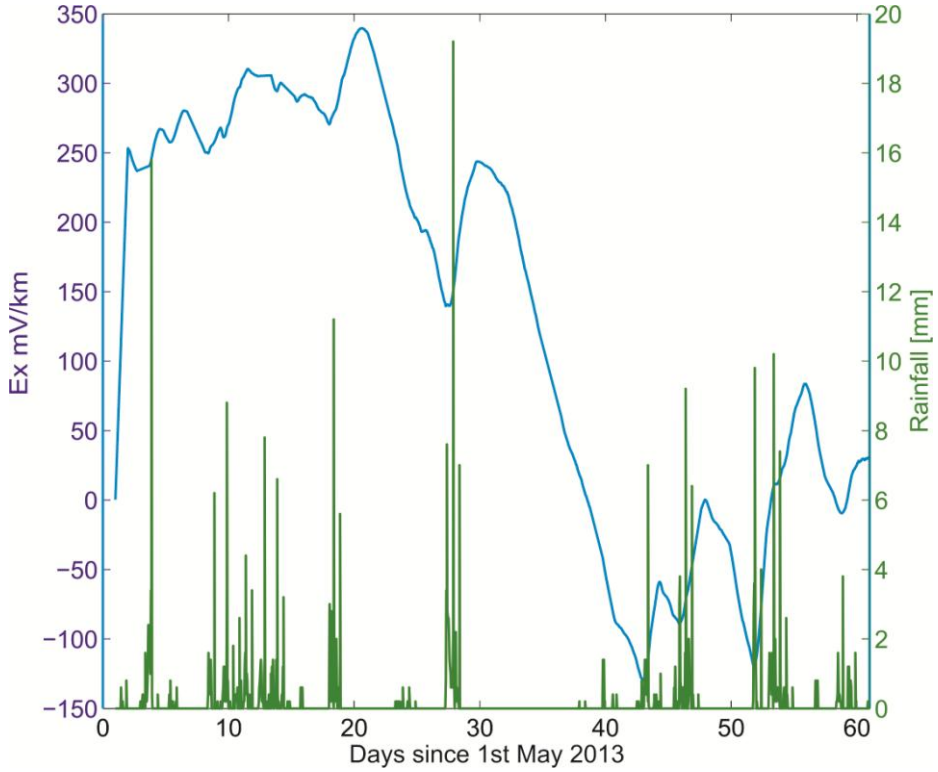
Problems

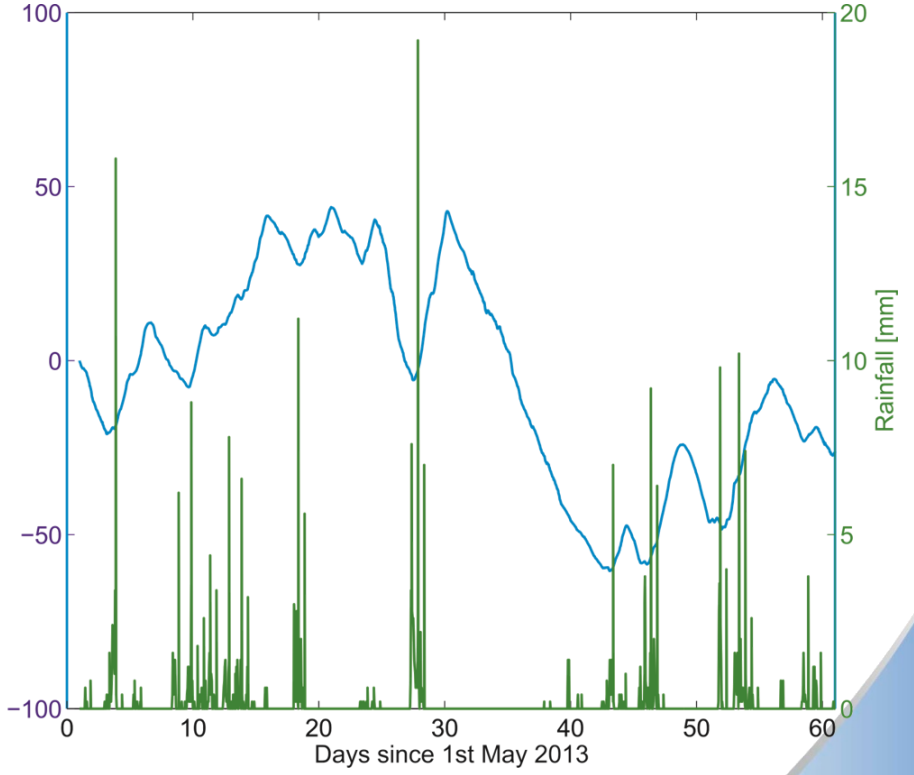
To be able to verify our models in a more comprehensive way we need to understand the other signals in the data e.g.:

- 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

Eskdalemuir May-June 2013



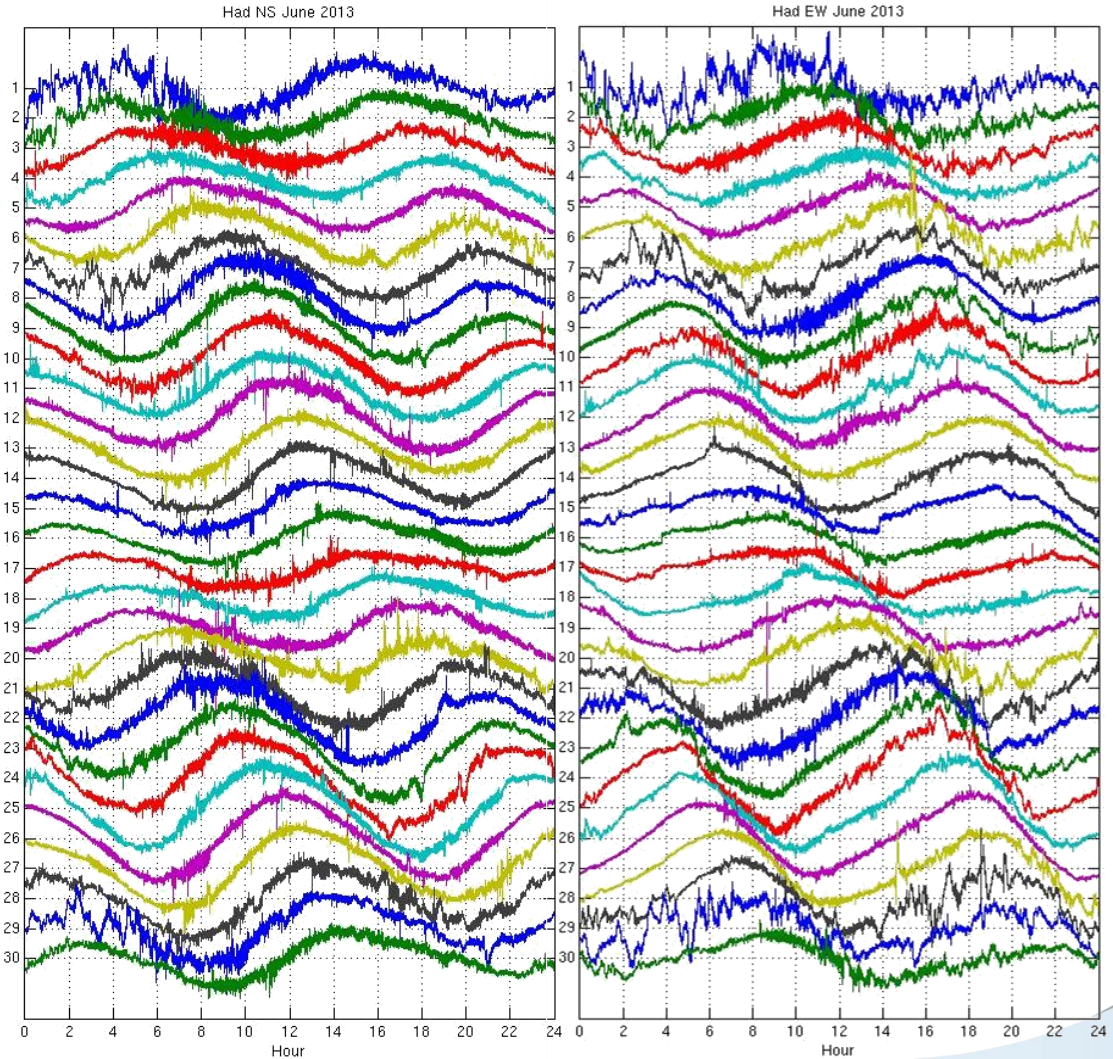


Data in blue smoothed using a moving average (length = 1 day)
Green is hourly rainfall in mm

Tides

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

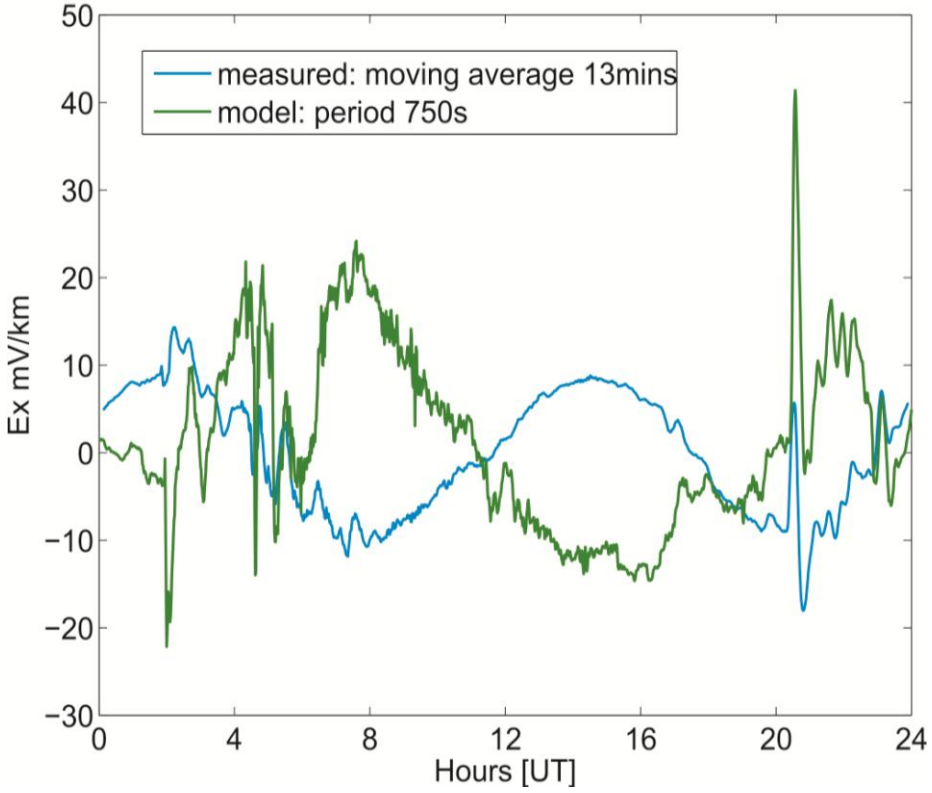
Ex

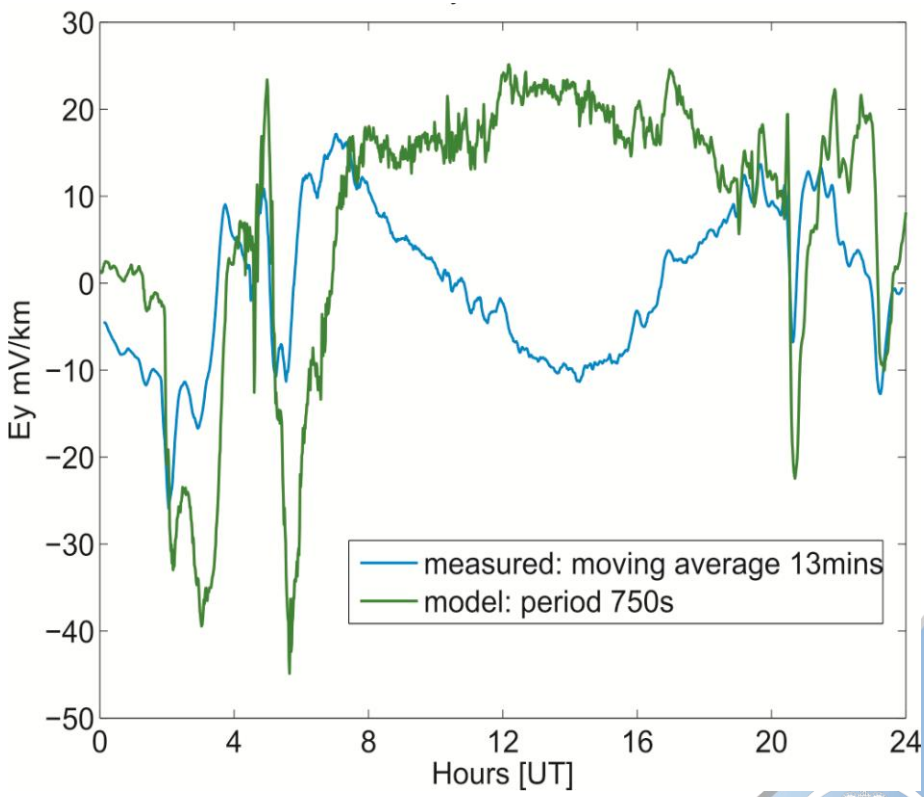


Ey

Hartland – 2nd October

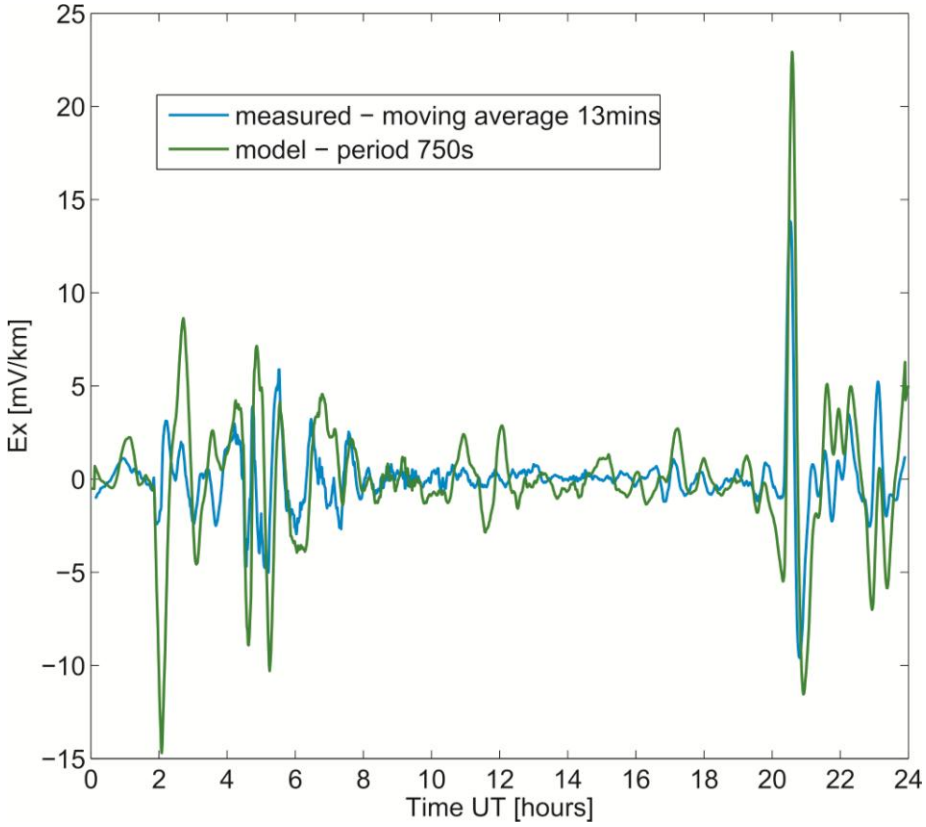
- The tidal signal in the measurements and the Sq signal in the model make it very difficult to compare

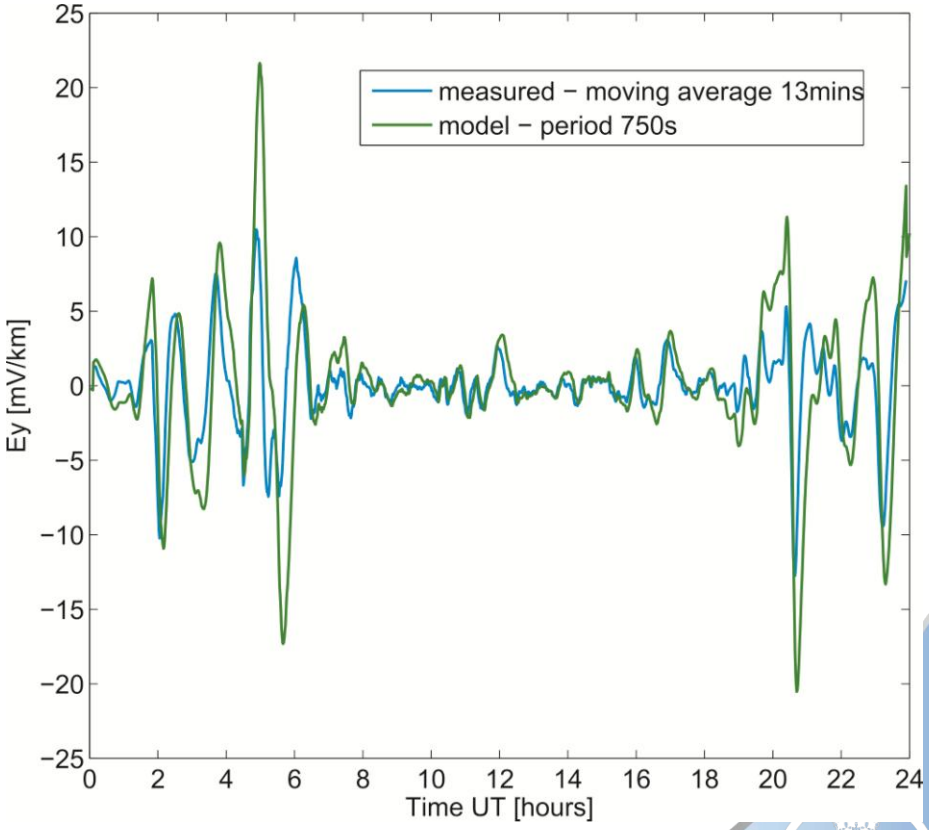




Hartland – 2nd October

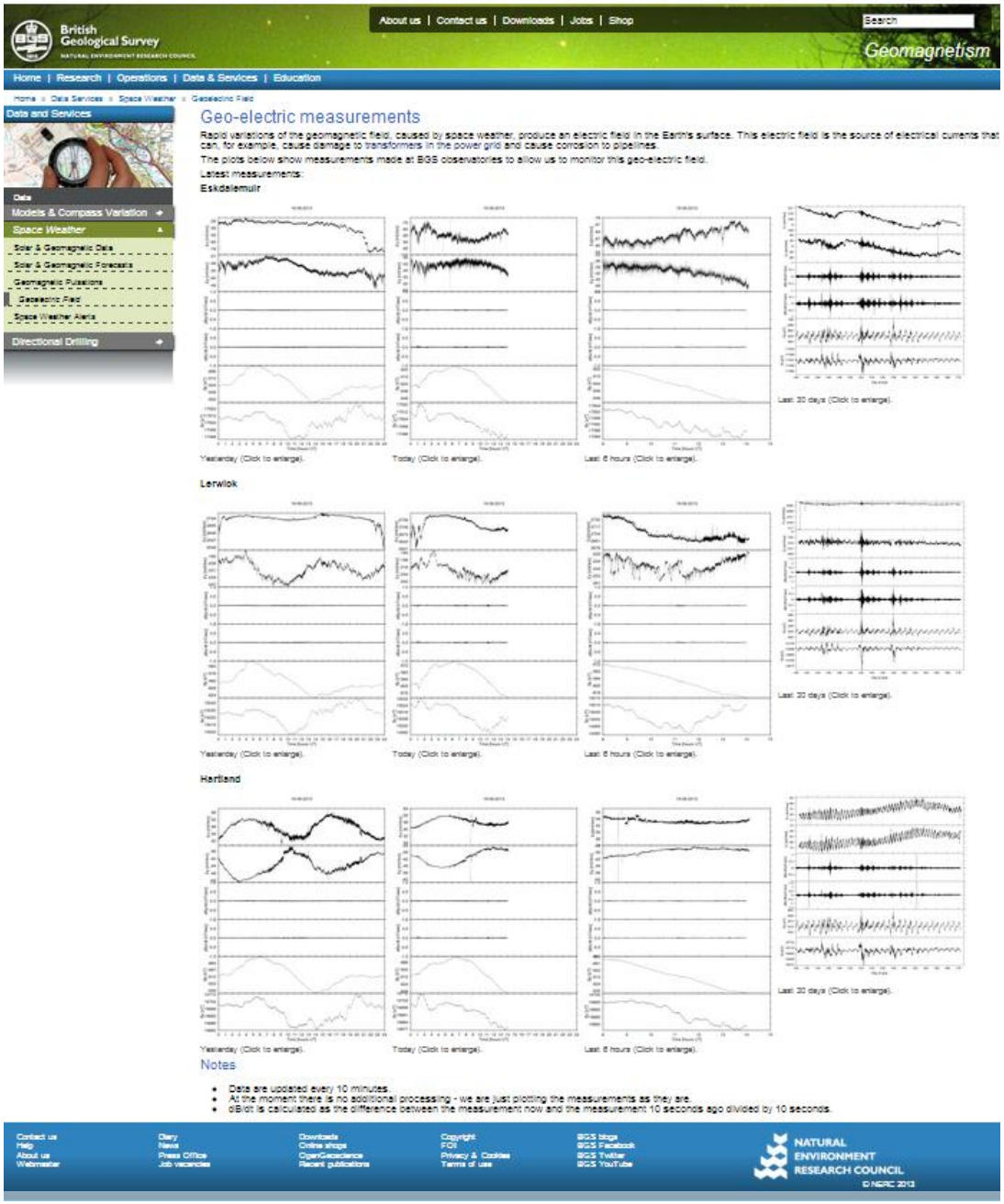
- Subtracted hourly mean curve to remove tidal and Sq signals





Summary

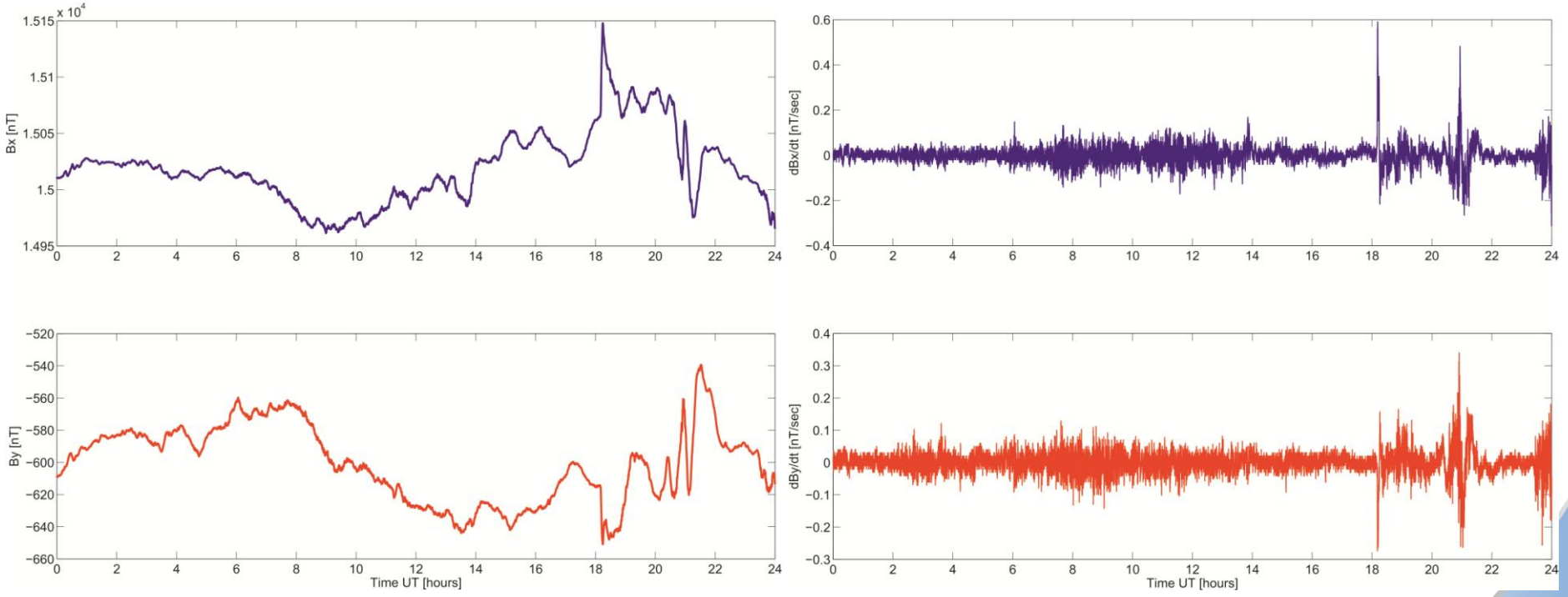
- Electric field measurements are helping us to understand the models better (and vice versa!)
  - Rainfall and tidal signals need careful handling
  - Sq needs to be included in our models
  - Unexplained baseline shifts and spikes are a problem
- These new measurements are a vast improvement in terms of validation compared to what we had before (i.e. nothing)
- We can now have confidence that our conductivity and electric field models are doing the right thing
- The electric field data can be viewed on our website www.geomag.bgs.ac.uk



http://www.geomag.bgs.ac.uk/data_service/space_weather/geoelectric.html

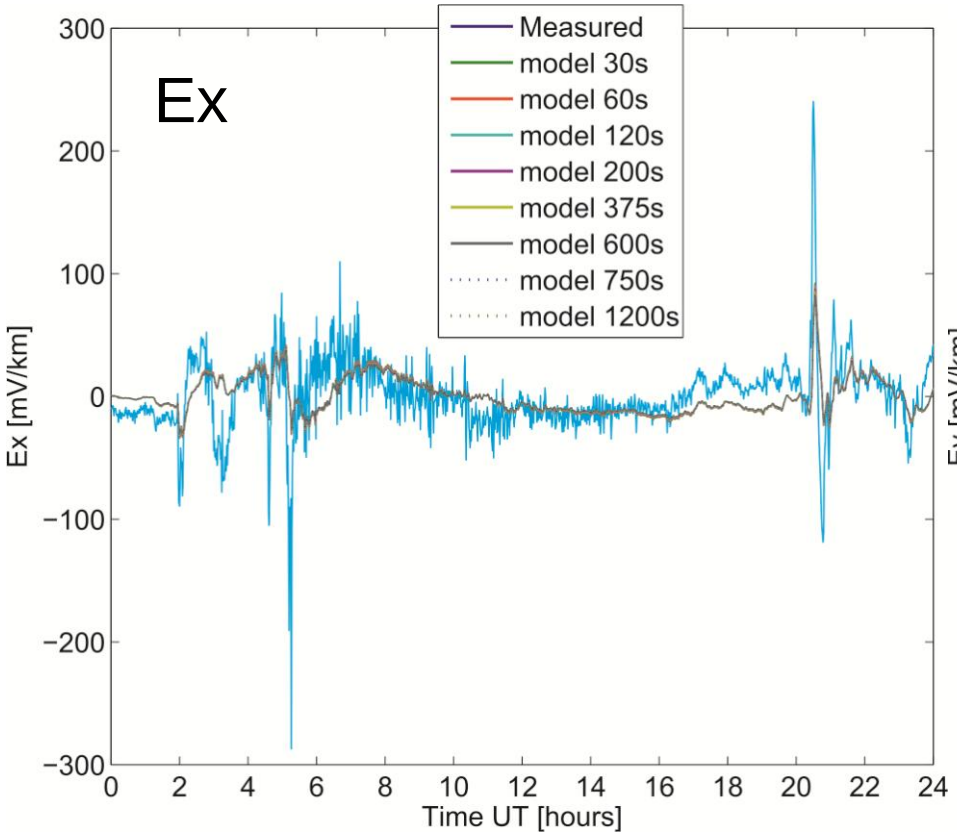
Extras

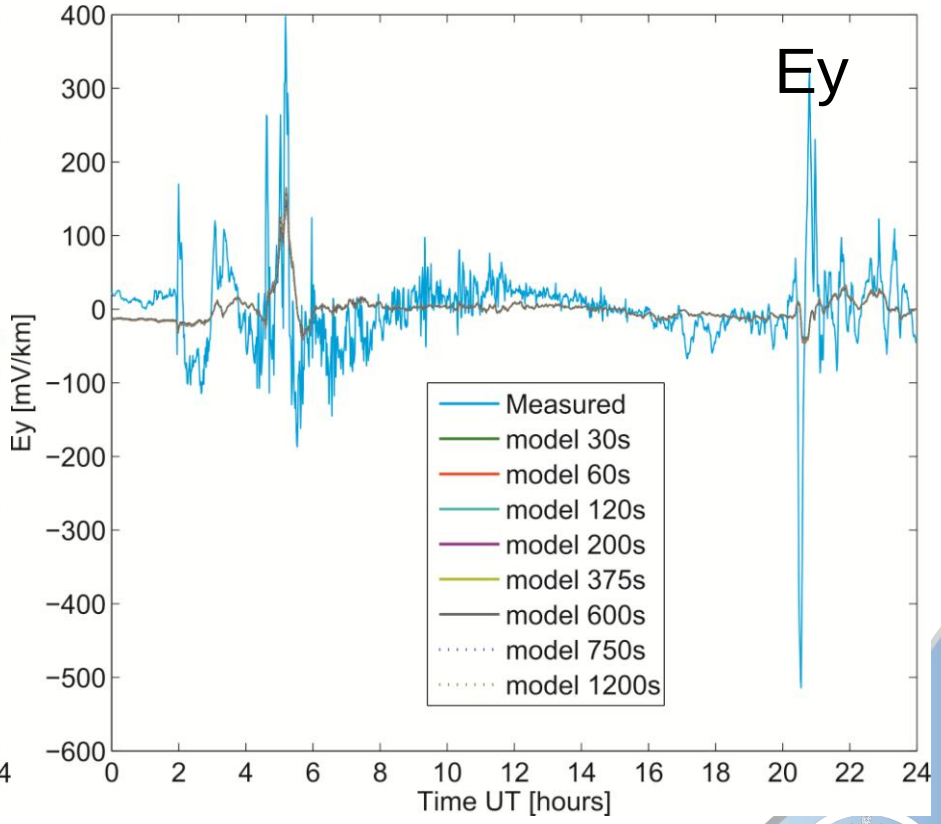
B 24th May Lerwick



How do the models compare?

Lerwick – 2nd October





Rotation

The table shows the correlation between the electric field and dB/dt (70 seconds) for a range of rotations. In Esk Ex rotation does not improve the correlation, in Ey the correlation is improved slightly with a rotation of 10 degrees. For Lerwick both the X and Y components are improved with an anti-clockwise rotation

θ	Esk		Ler	
	Ex	Ey	Ex	Ey
-40	0. 4691	-0.3590	0.5649	0.6626
-30	0.5050	-0.4236	0.5710	0.6032
-20	0.5252	-0.4961	0.5666	0.5459
-10	0.5363	-0.5747	0.5407	0.4914
0	0.6301	-0.6516	0.5407	0.4914
10	0.5426	-0.6724	0.3391	0.3867
20	0.5400	-0.6131	0.1500	0.3329
30	0.5338	-0.4837	-0.0377	0.2755
40	0.5232	-0.3419	-0.1827	0.2113