Recent advances and validation of GIC modelling in the UK

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Modelling GIC

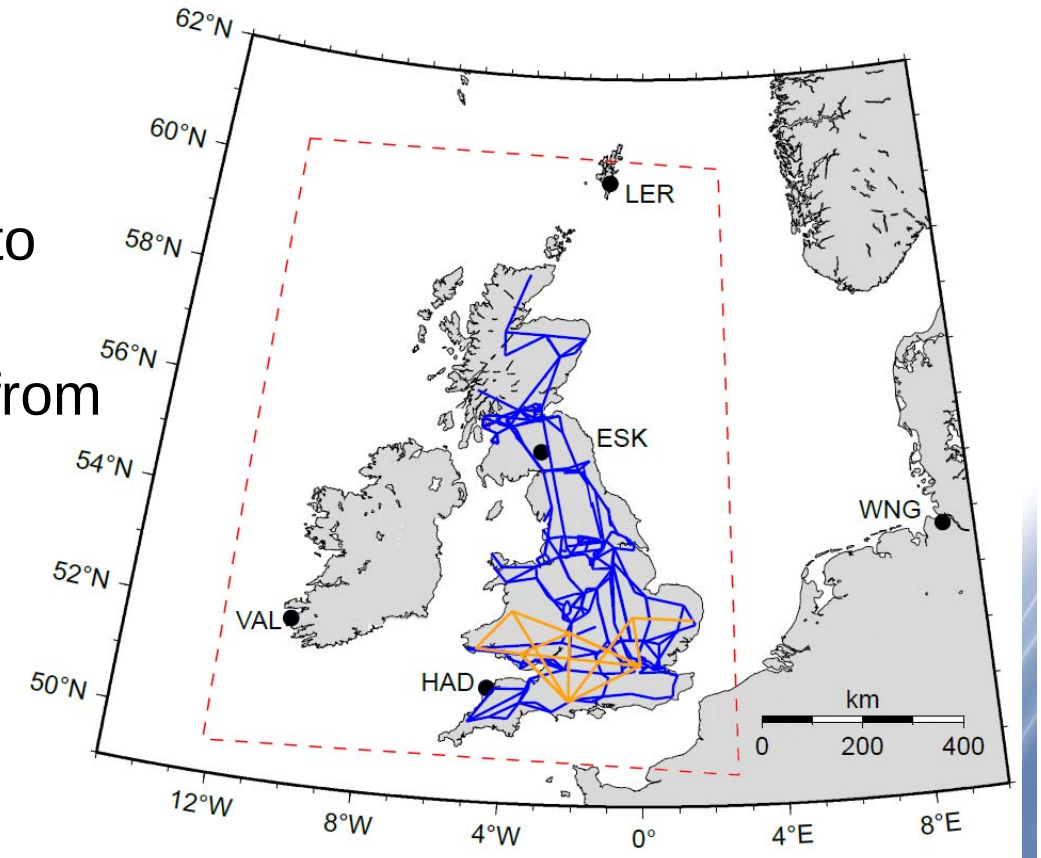
Models of geomagnetically induced currents (GIC) require:

- Input geomagnetic field
- Electric field calculation (including ground conductivity model)
- Estimation of GICs in the network

We have recently been upgrading our network and trying to validate each step in the process

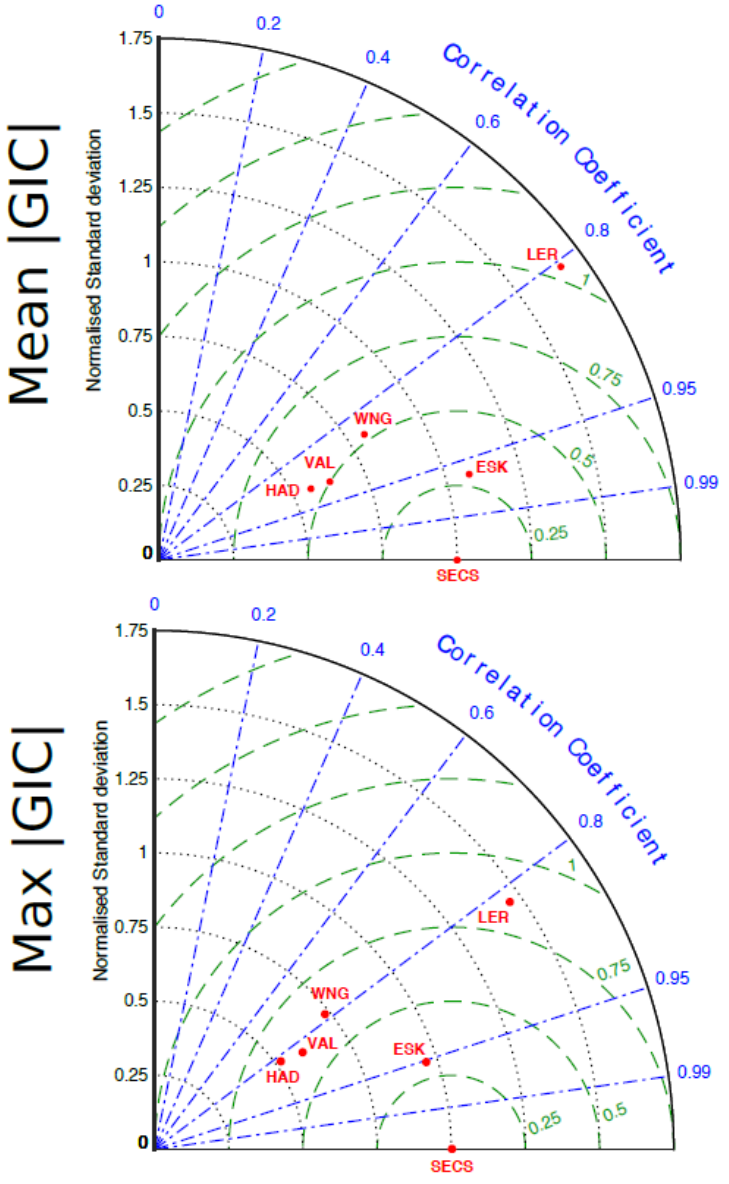
Input geomagnetic field

- How does distance from observatory affects GIC estimates?
- Use Spherical Elementary Current Systems (SECS) to interpolate magnetic field
- Compare with using data from individual observatories across the whole grid



Input geomagnetic field

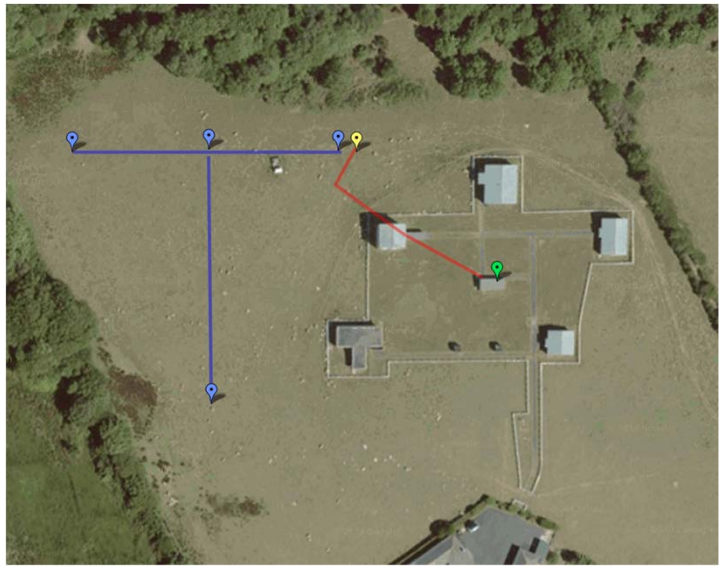
- Results shown for October 2003 storm
- Observatories within the network, or on the same geomagnetic latitude within 400km gave estimates within 25% on average with correlation >0.8
- More distant observatories become less reliable, for example experiencing max GIC at different times



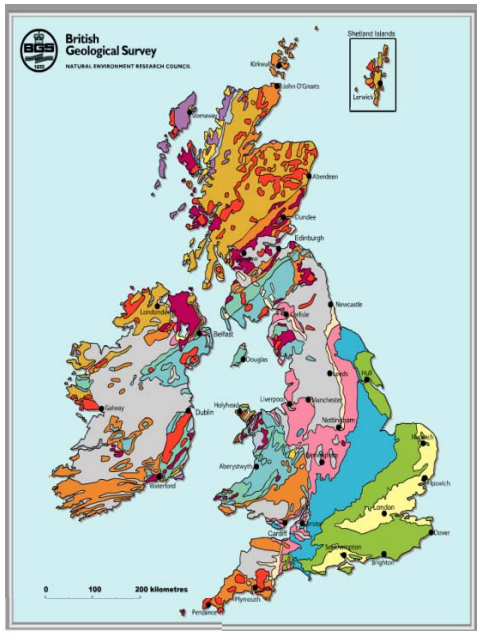
Electric field calculation

Measurements

- We have electric field measurements at the three UK observatories
  - 10Hz
  - Probes ~100m apart in NS and EW directions

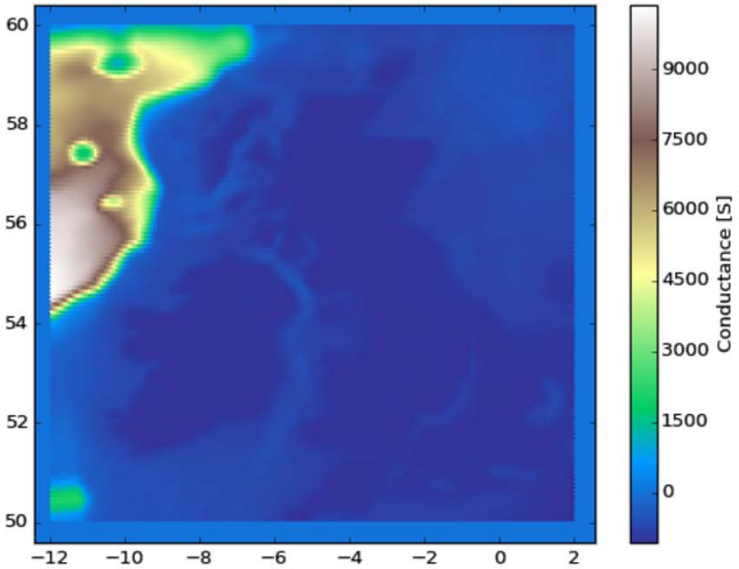


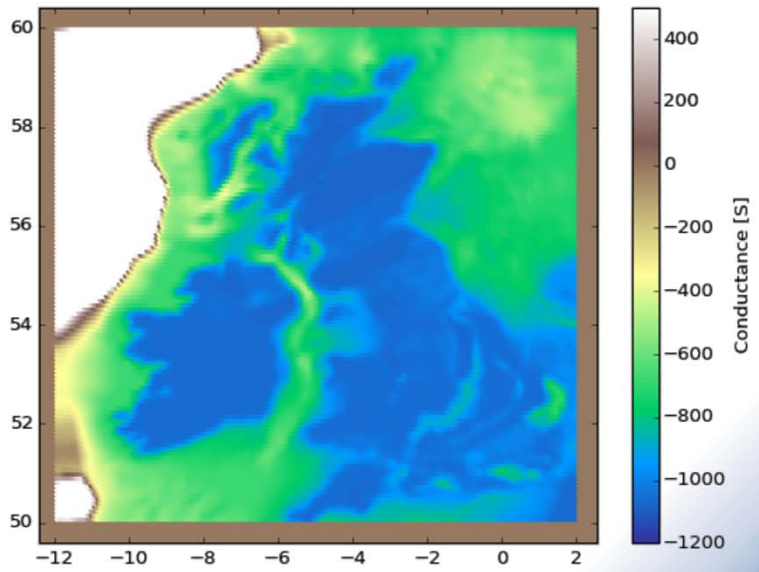
Electric field calculation



Model

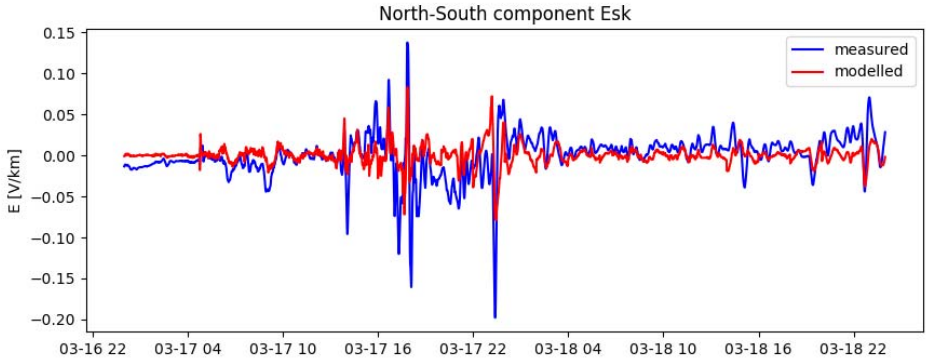
- Thin-sheet model
- The conductivity model of top 3km based on UK lithologies and bathymetry
- 10km grid

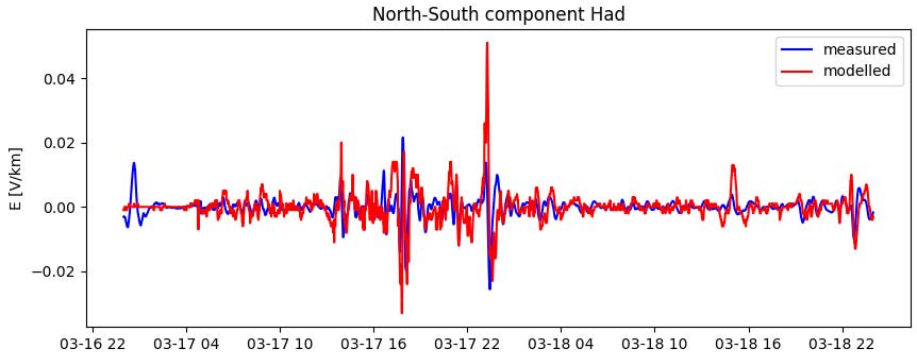


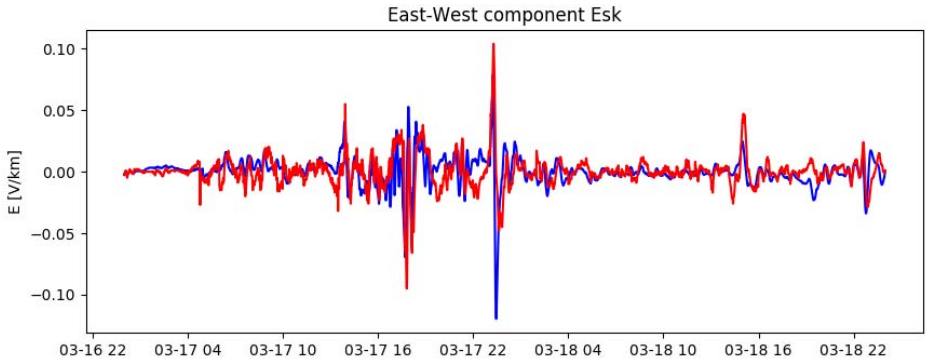


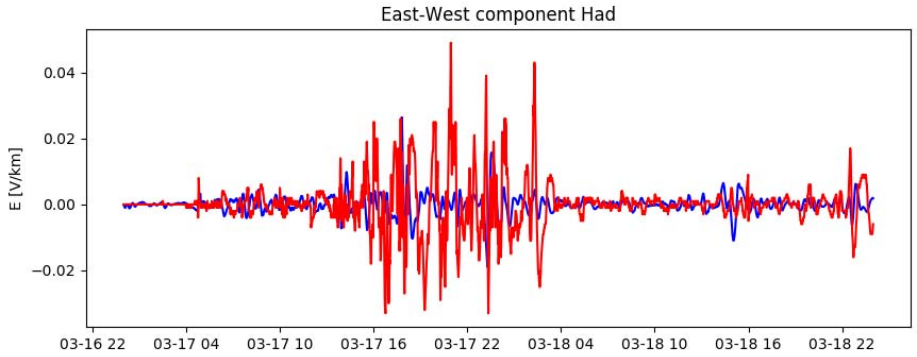
Electric field

- Measured (blue) and modelled (red) E at 1 minute resolution









Correlation NS : 0.43
EW : 0.43

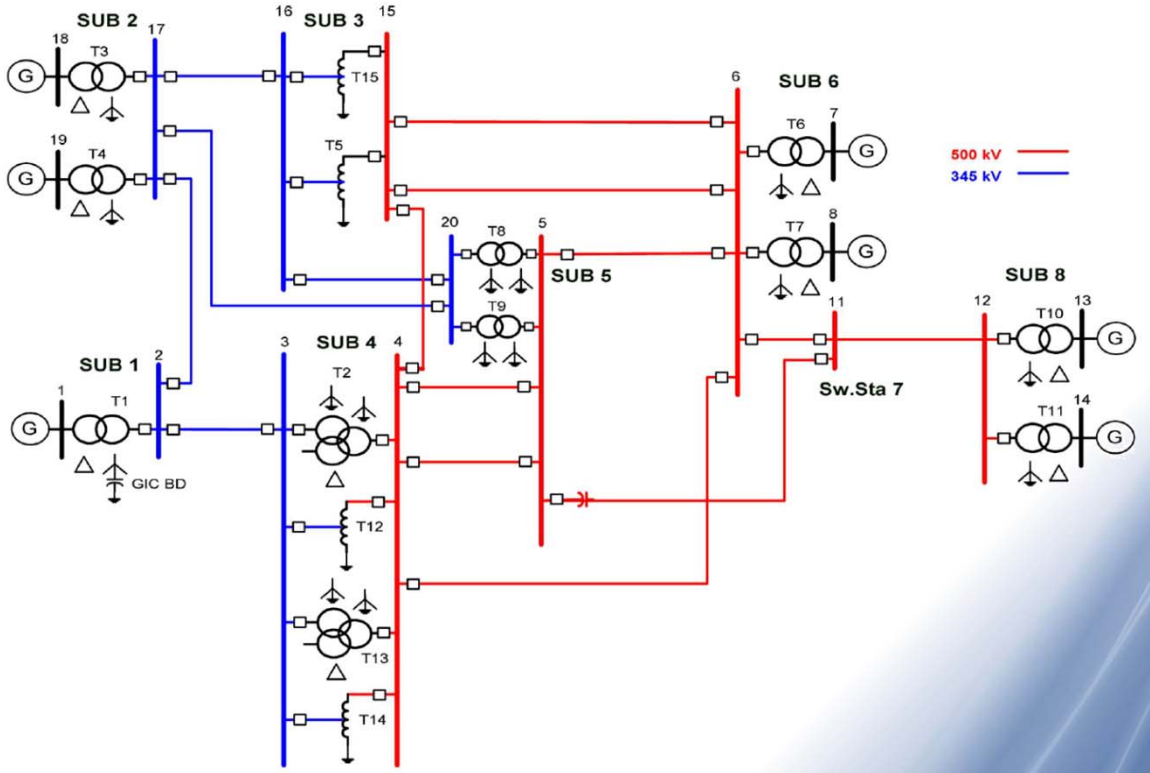
Correlation NS : 0.04
EW : 0.29

Electric field

- We need to account for local effects better, e.g. galvanic distortion, tidal signals, local conductivity etc. (see poster 5 – Baillie et al.)
- More storms will help
- During the SWIGS project (see Poster 4 – Thomson et al.) we will measure E-fields at more sites in the UK so we can also test the model away from the observatories

GIC calculation

- Horton et al 2012 (*IEEE Transactions on power delivery*, 27) provides a test grid and calculated GIC for a uniform electric field
- Mix of transformer types, single and parallel connections and blocking devices



Comparison

- Despite some differences in the method we get results which are consistent with the Horton paper

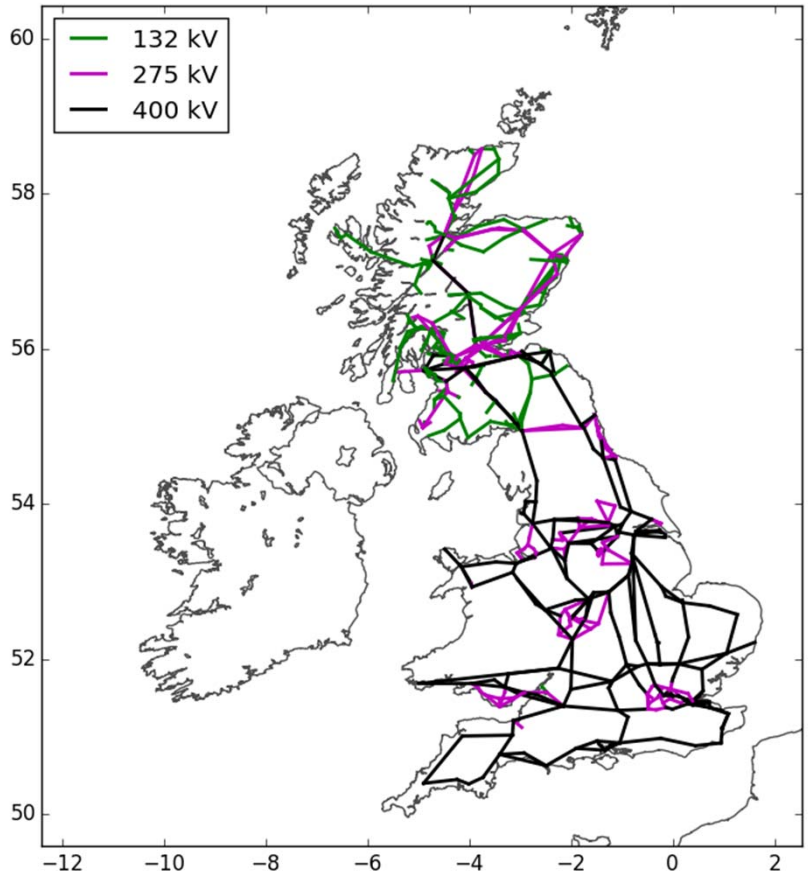
	Horton et al. (2012)		BGS	
	North	East	North	East
Sub1	0.00	0.00	0.00	0.00
Sub2	115.63	-189.29	114.25	-189.77
Sub3	139.85	-109.49	137.87	-109.79
Sub4	19.98	-124.58	19.22	-124.63
Sub5	-279.08	-65.46	-280.55	-63.94
Sub6	-57.29	354.52	-53.24	353.99
Sub7	0.00	0.00	0.00	0.00
Sub8	60.90	134.30	62.45	134.14

The root-mean-square differences is 2.3 A for the North direction and 0.7 A for the East direction

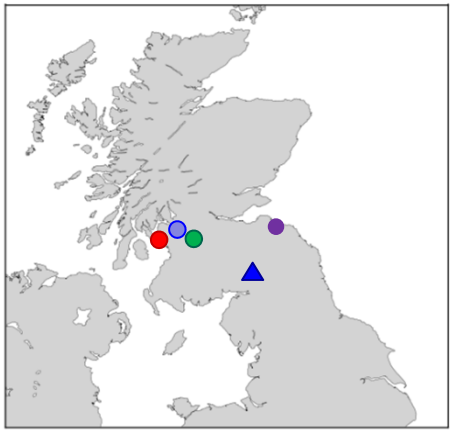
Per transformer we the difference was <1A per phase for all but 3 transformers and they were all <2A

Power network upgrade

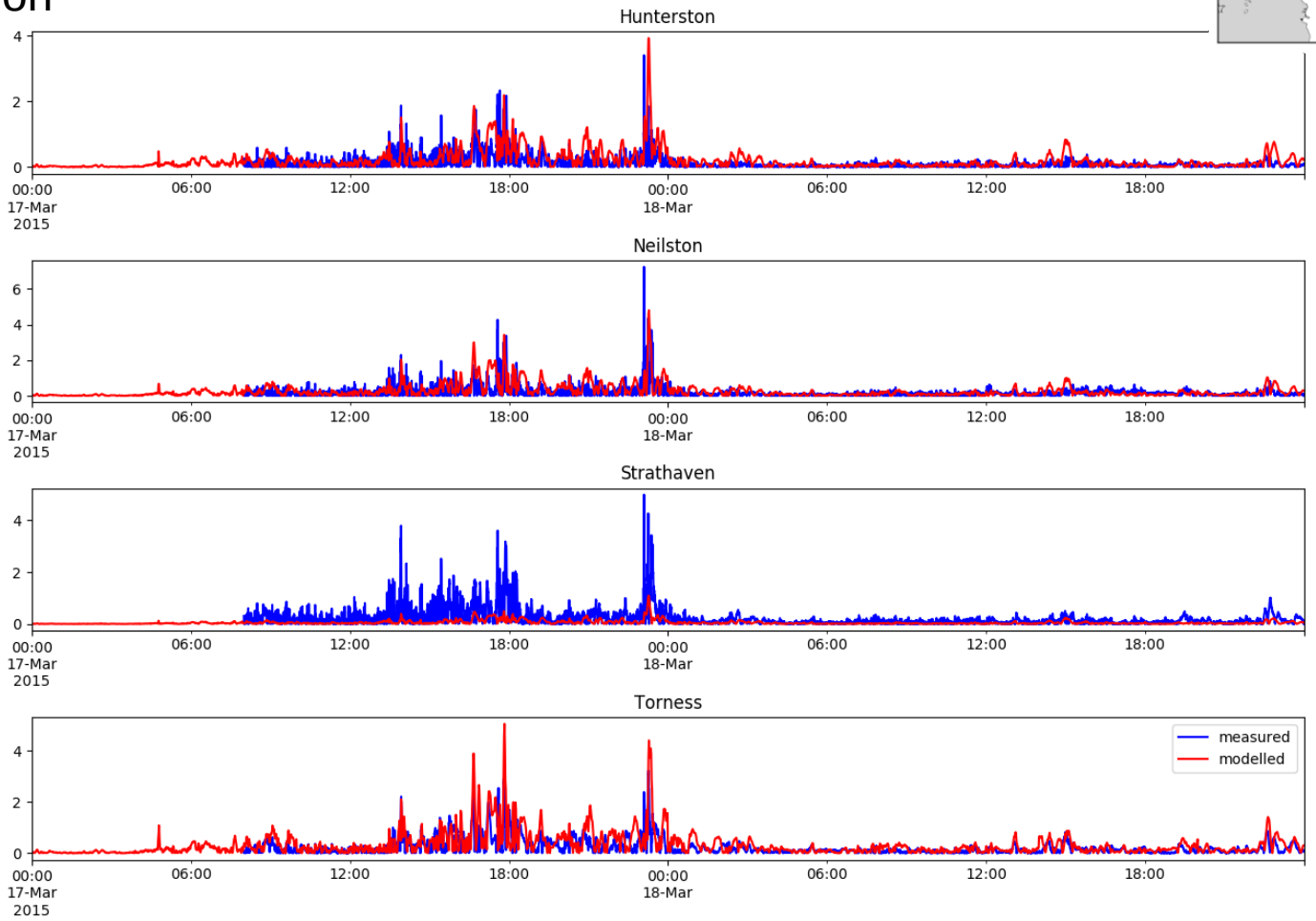
- Network upgrade using data from the 2016 Electricity Ten Year Statement
- Better representation of substation nodes
- Better inclusion of parallel lines



Comparsion with GIC measurements



Correlation

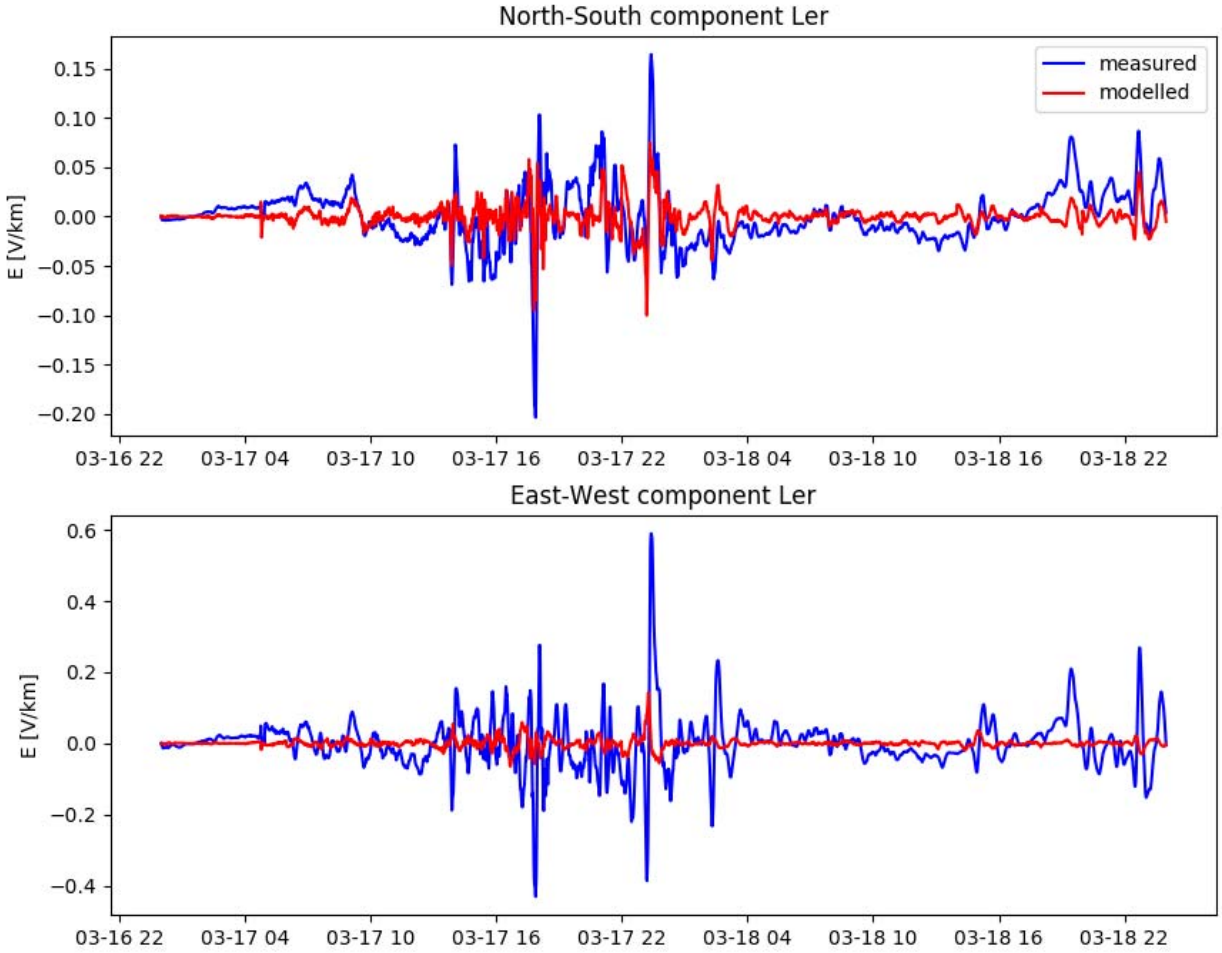


Summary

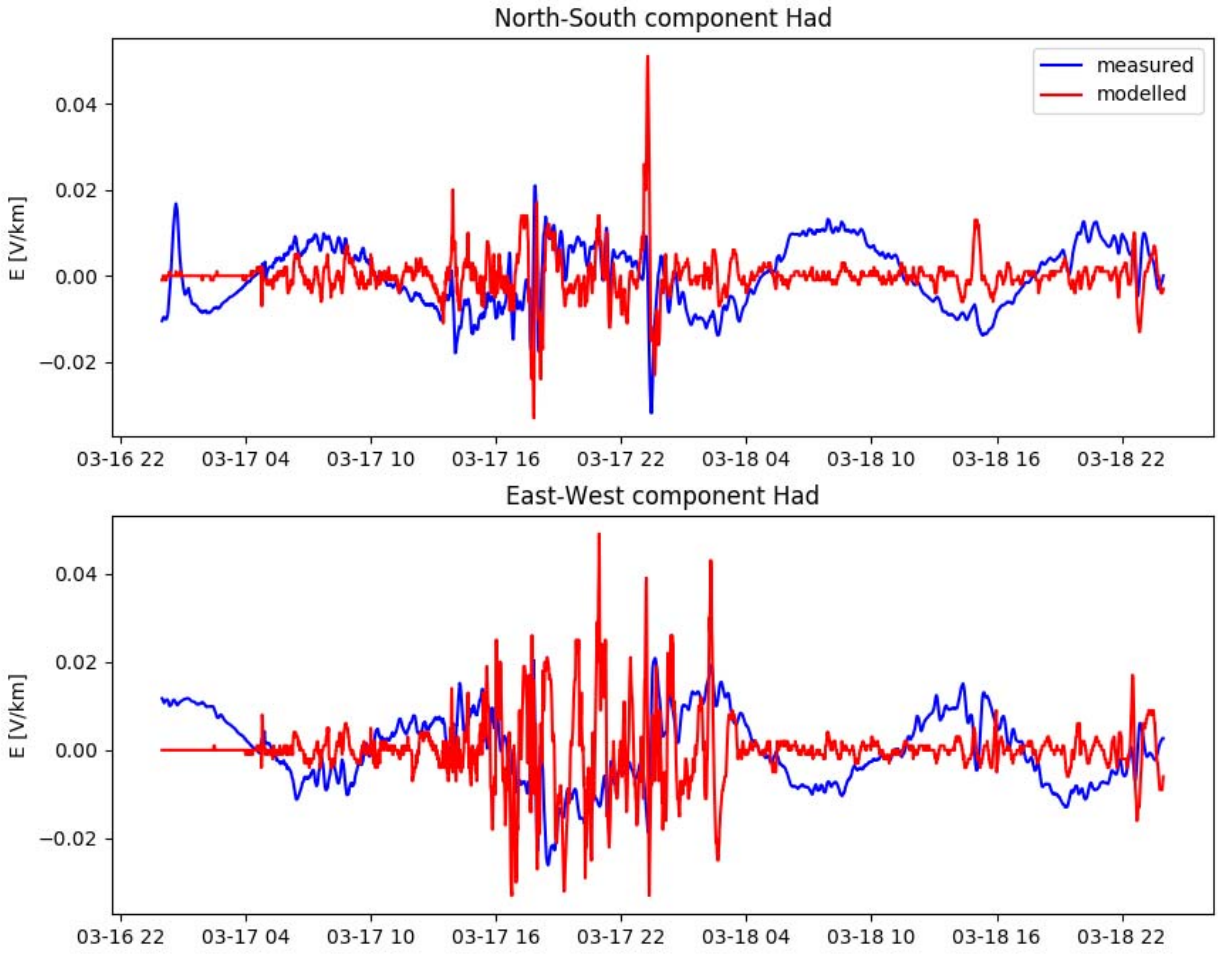
- Electric field
  - on a broad scale we capture the storm
  - need to account for local effects better to truly compare the model and measured data
  - Future work will help with validation across the UK
- Validated GIC calculation
- Full GIC calculation
  - Getting the size and timing of GIC largely correct although these are relatively small GIC measurements

- SWIGS project will really help with validation – providing more measurements of both E and GIC

Ler – Mar 2015

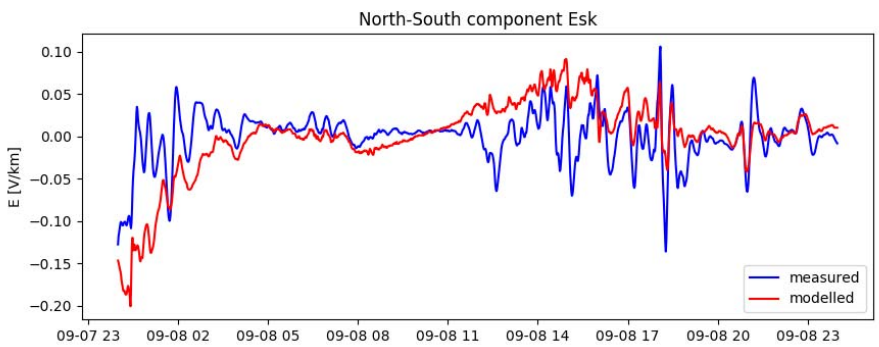


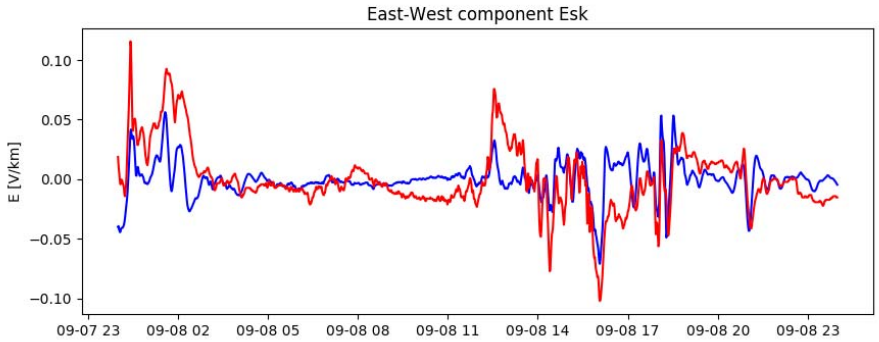
Had - unfiltered

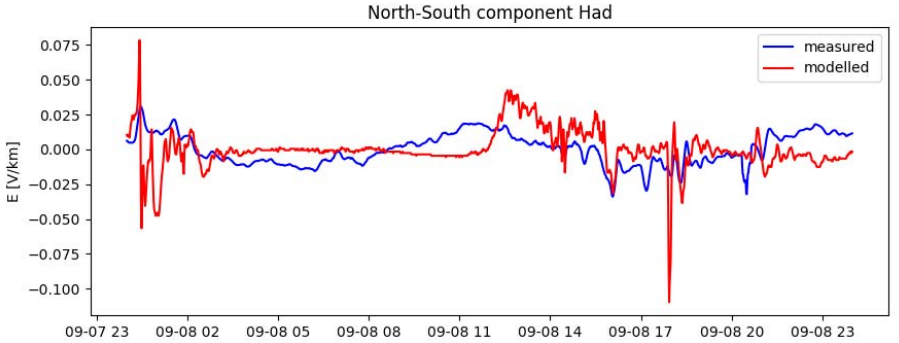


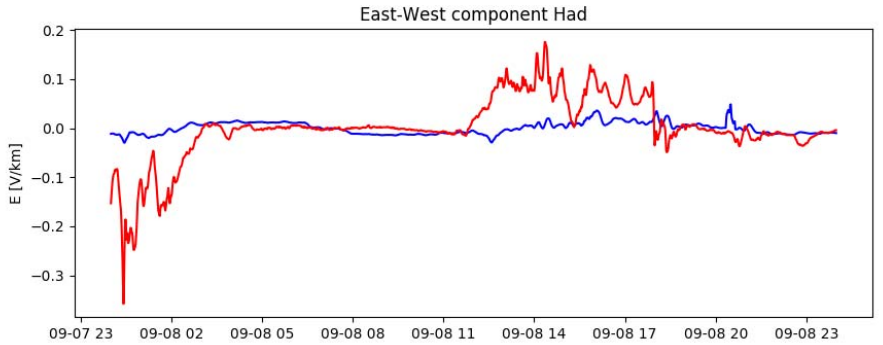
- 0.1406
- 0.0314

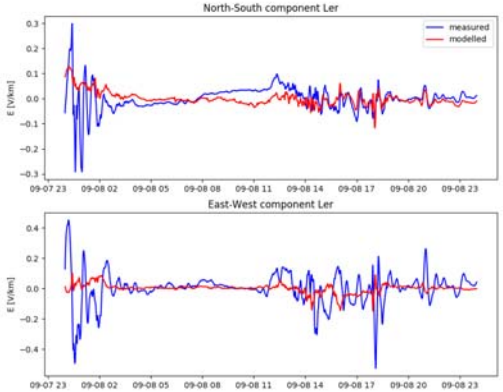
Sep 2017 – E-field





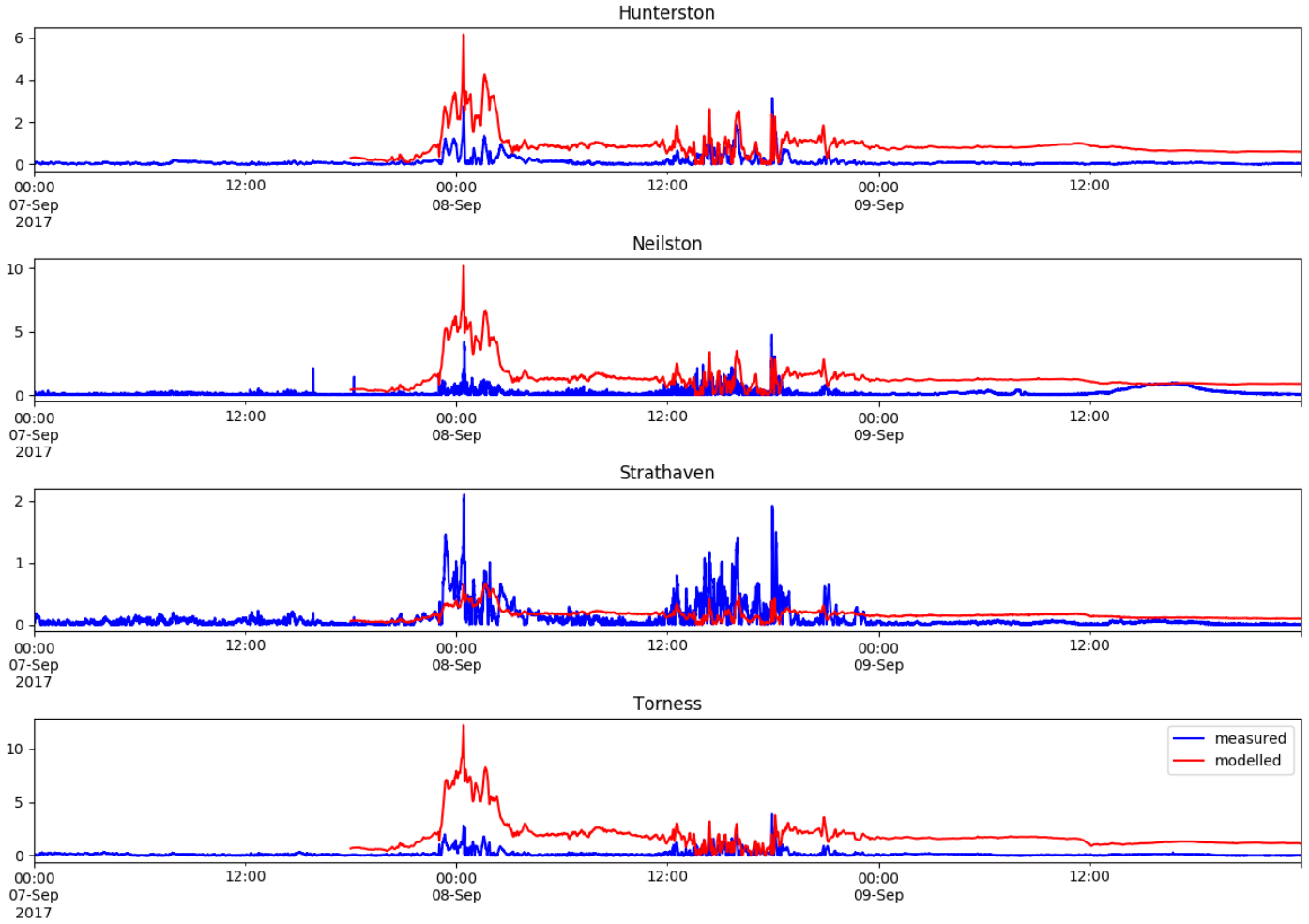






Sep 2017 - GIC

correlation HUNT 0.5343286546782464
correlation NEIL 0.1842394052155707
correlation STRA 0.438831398654849
correlation TORN 0.4891124941799598



Mar2015 resampled to 1min means