Estimating GIC from a single observatory at high and mid latitudes

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IAGA 2017, Cape Town, South Africa, Session A26 [Thu @ 14.15]

Background

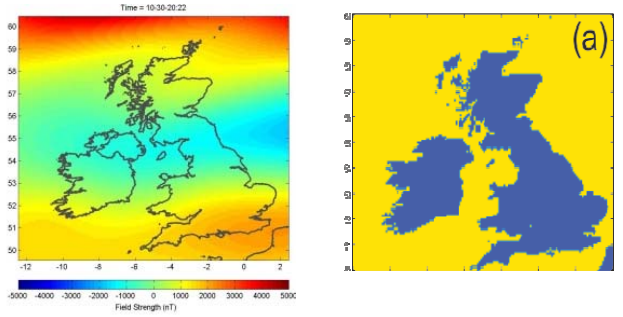
- GICs are hazardous to high-voltage (HV) power systems, particularly transformers
- Real-time estimates of GIC can be made from observatory magnetic data (and other direct or indirect measurements)
- How does magnetic field extrapolation affect GIC estimates?
- How far can an observatory be from an HV network to be ‘useful’?

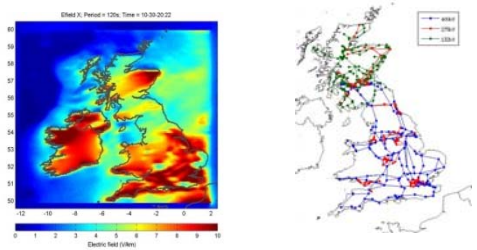
Thin-sheet modelling

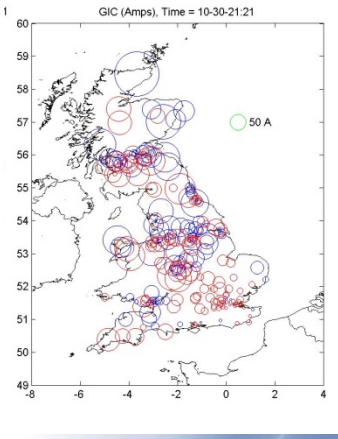
- Time-varying magnetic field + surface + 1D conductivity model → geo-electric field

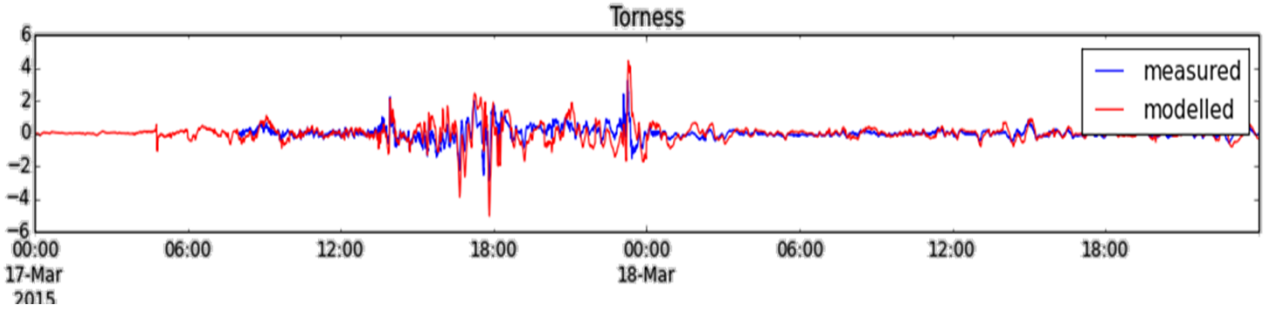
- Geo-electric field + High voltage network model → GIC

- Validation of method over many years e.g. Torness, UK: 17-Mar-2015 (Kp8)

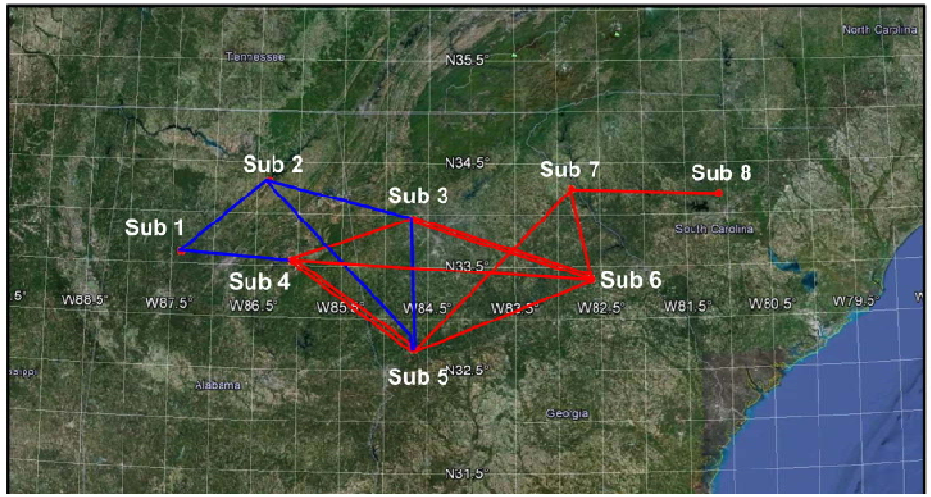








Horton *et al.* (2012) benchmark grid



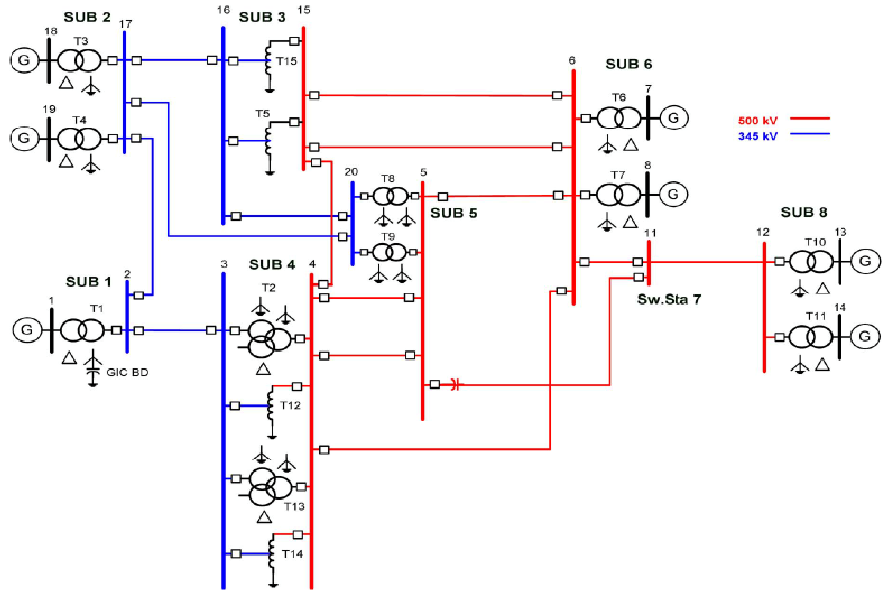


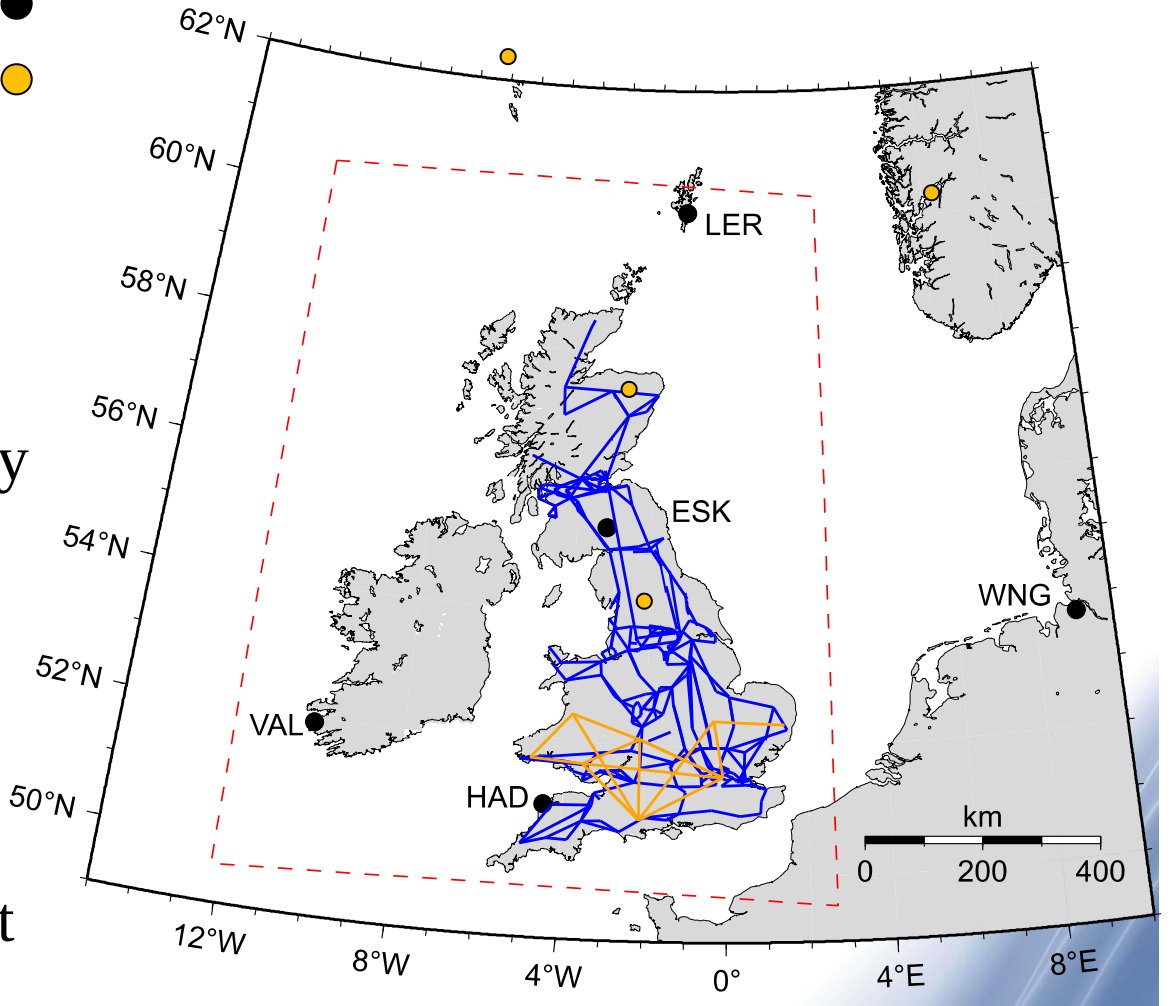
Fig. 1. Single-line diagram of benchmark test case.

- 8 substations
- 15 transformers
- 15 lines
- 2 GIC blocking devices
- 1 line split

	Horton et al. (2012)		BGS Python code	
	North	*East*	*North*	*East*
Sub1	*0.00*	*0.00*	*0.00*	*0.00*
Sub2	115.6	-189.3	114.3	-189.8
Sub3	139.8	-109.5	137.9	-109.8
Sub4	20.0	-124.6	19.2	-124.6
Sub5	-279.1	-65.5	-280.55	-63.9
Sub6	-57.3	354.5	-53.24	354.0
Sub7	*0.00*	*0.00*	*0.00*	*0.00*
Sub8	60.9	134.3	62.45	134.1

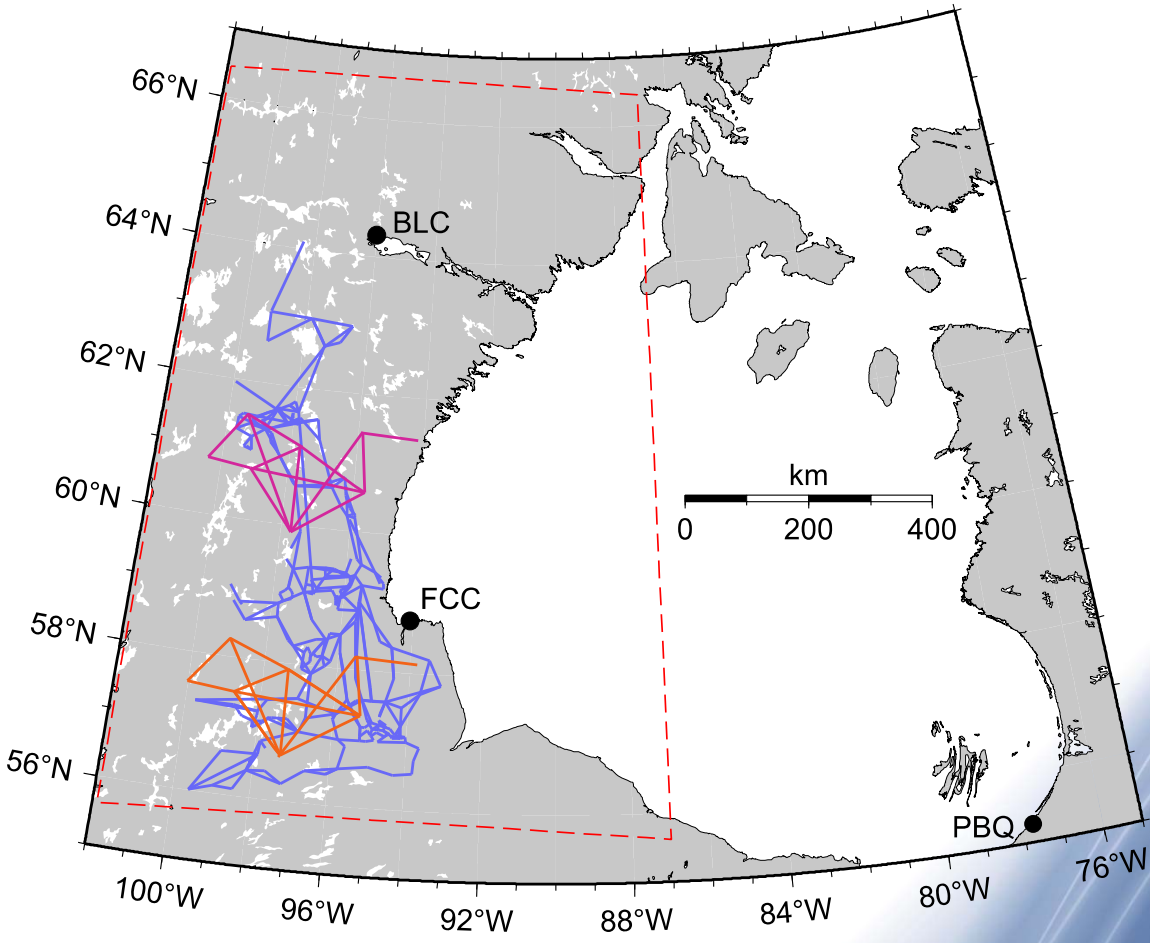
Area #1: Island of Great Britain

- 5 INTERMAGNET obs ●
  4 variometers (in 2003) ●
- UK grid: 252 nodes, 379 line connections
- Use Spherical Elementary Current Systems (SECS) to interpolate magnetic field
- Compute electric field in red dashed box (constant conductivity land/sea model)

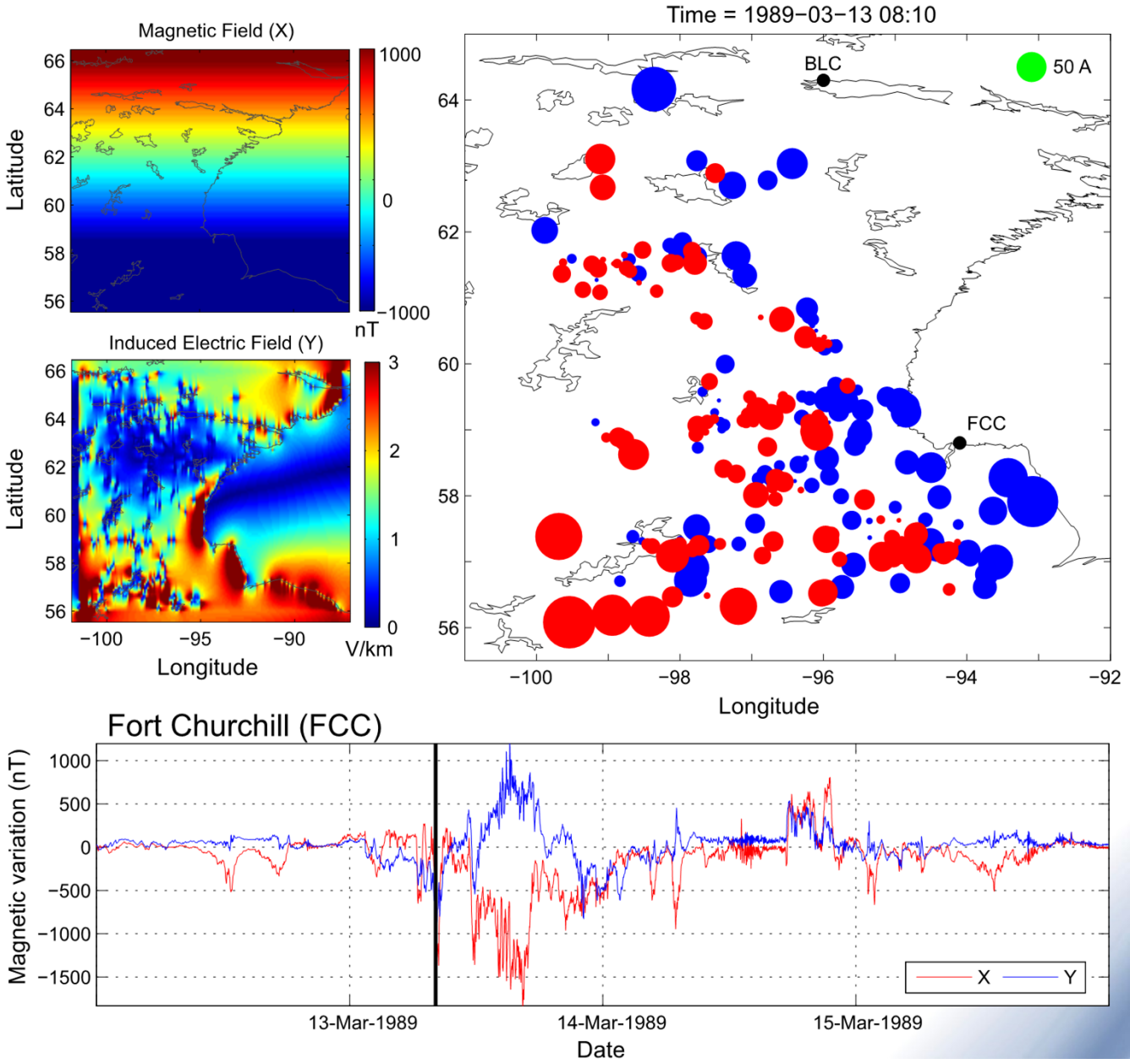


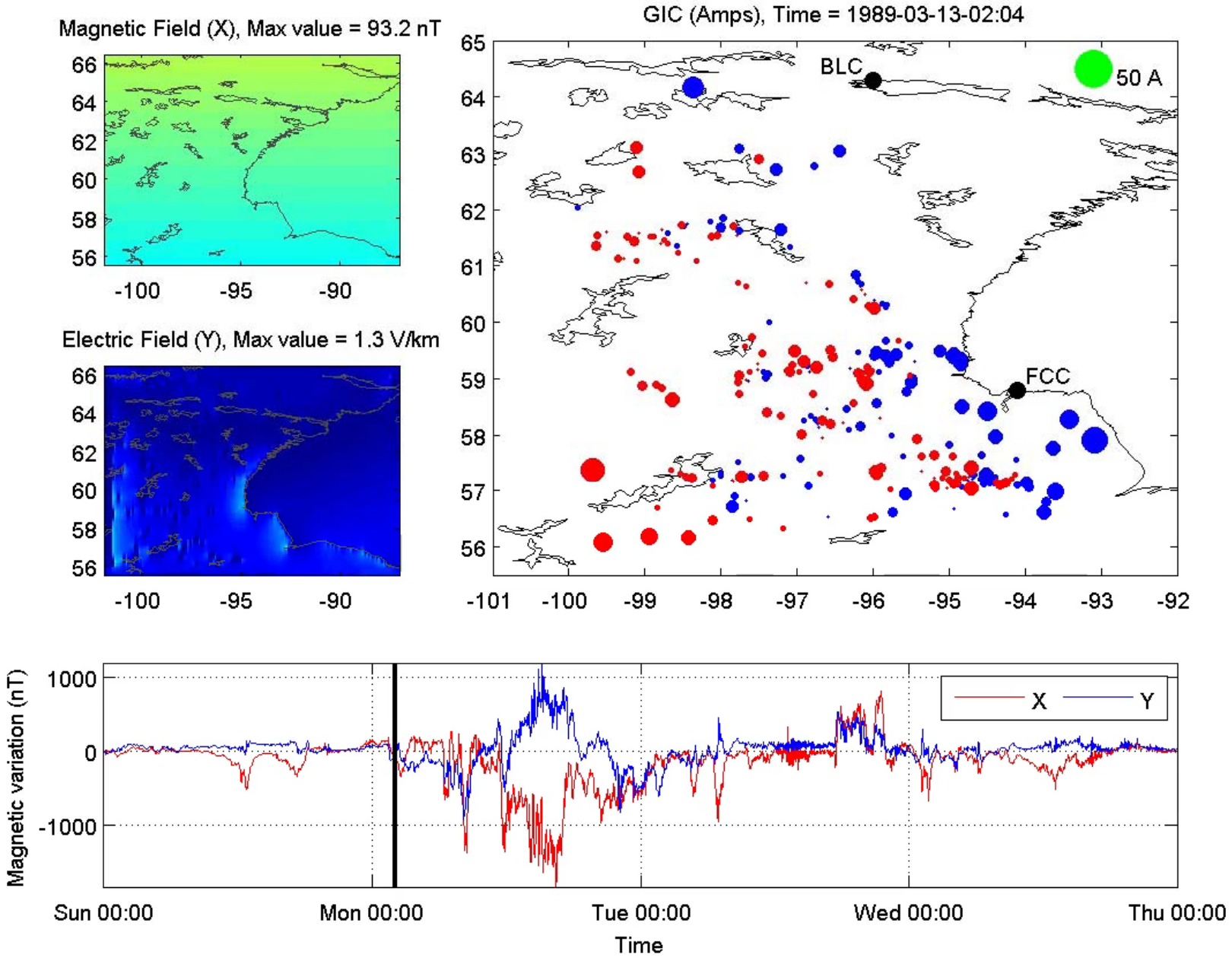
Area #2: Hudson Bay

- 3 INTERMAGNET obs (PBQ no longer in use)
- 1 x UK grid;
  2 x Horton grids
  (North and South of FCC)
- Use linear interpolation between stations to interpolate magnetic field
- Compute electric field in red dashed box (constant conductivity land/sea model)

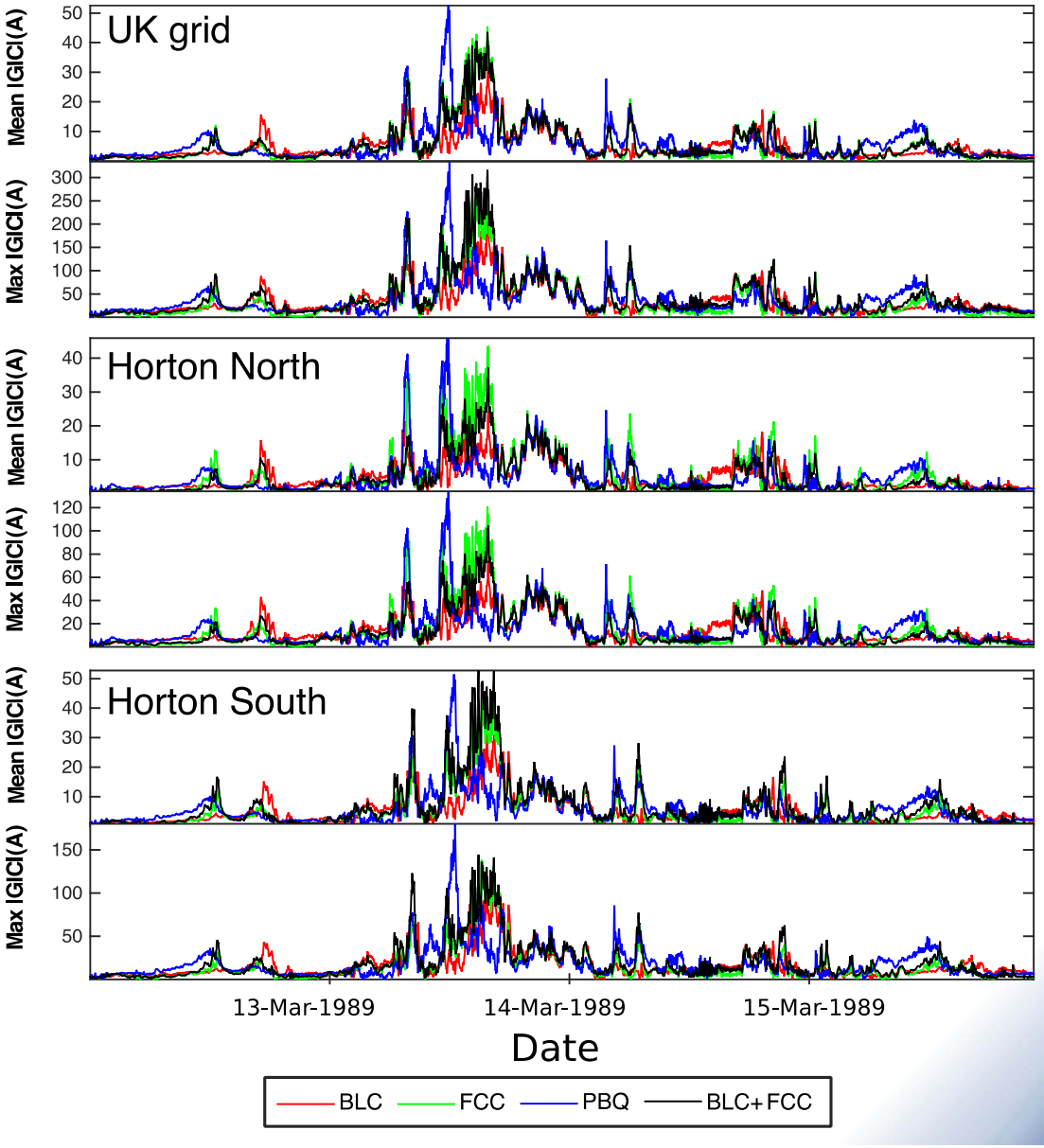


March 1989 storm: snapshot




Magnetic Field (X), Max value = 93.2 nT
66
64
62
60
58
56
-100
-95
-90
Electric Field (Y), Max value = 1.3 V/km
66
64
62
60
58
56
-100
-95
-90
GIC (Amps), Time = 1989-03-13-02:04
65
64
63
62
61
60
59
58
57
56
BLC
50 A
FCC
-101
-100
-99
-98
-97
-96
-95
-94
-93
-92
Magnetic variation (nT)
1000
0
-1000
X
Y
Sun 00:00
Mon 00:00
Tue 00:00
Wed 00:00
Thu 00:00
Time

March 1989 storm: time-series

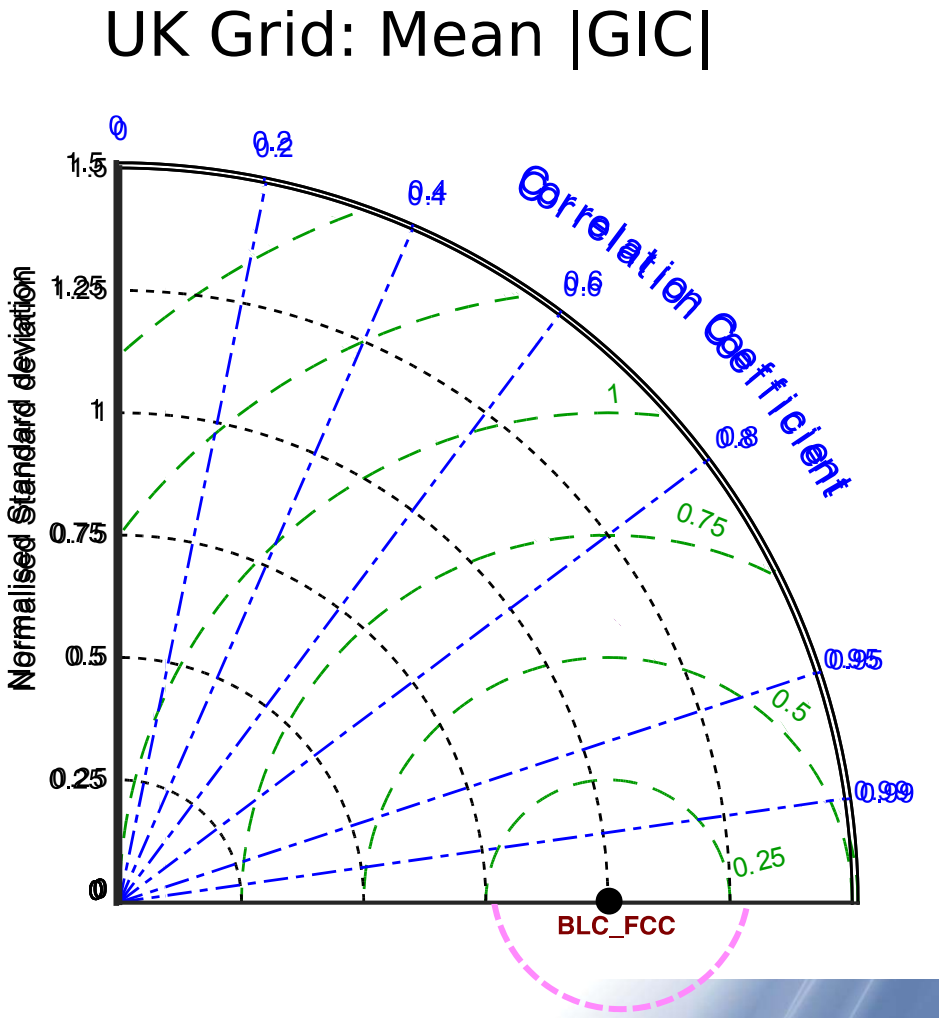


What are Taylor Plots?

- Described by Taylor (2001) for atmospheric model data

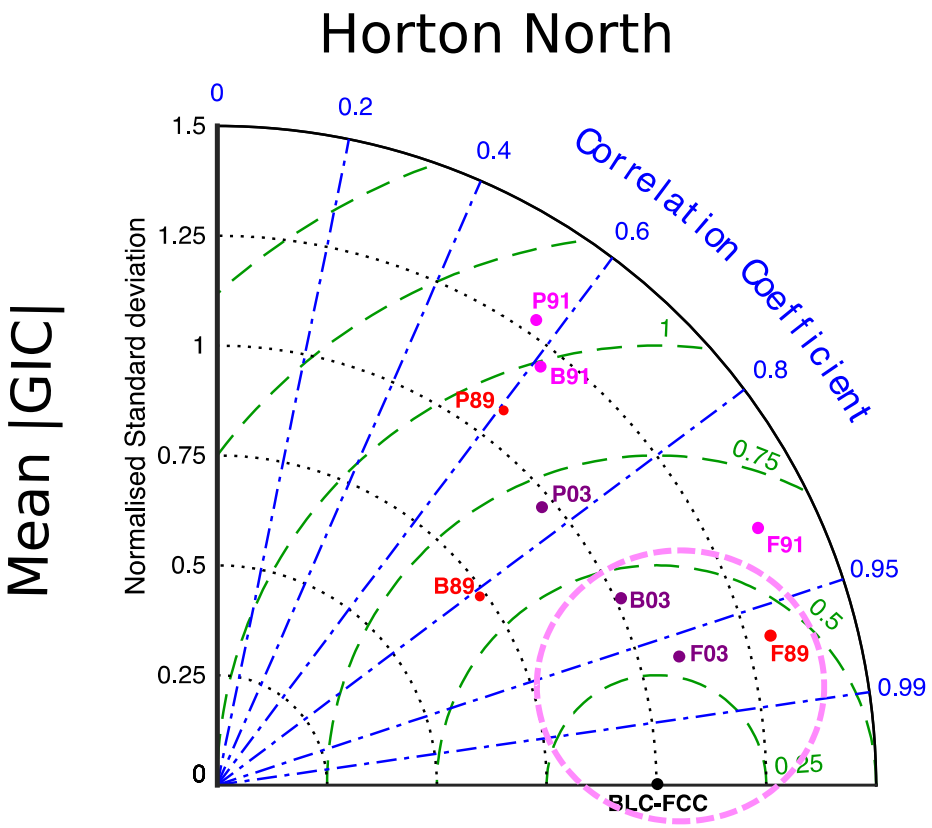
- Use for assessing similar-looking time-series
- Compare each time-series to a ‘baseline’
- Combine RMS difference, normalized standard deviation, and correlation onto one diagram
- Points *nearest* to [1,0,1] are better

- Use BLC_FCC as baseline?
  - Data from FCC are ‘best’

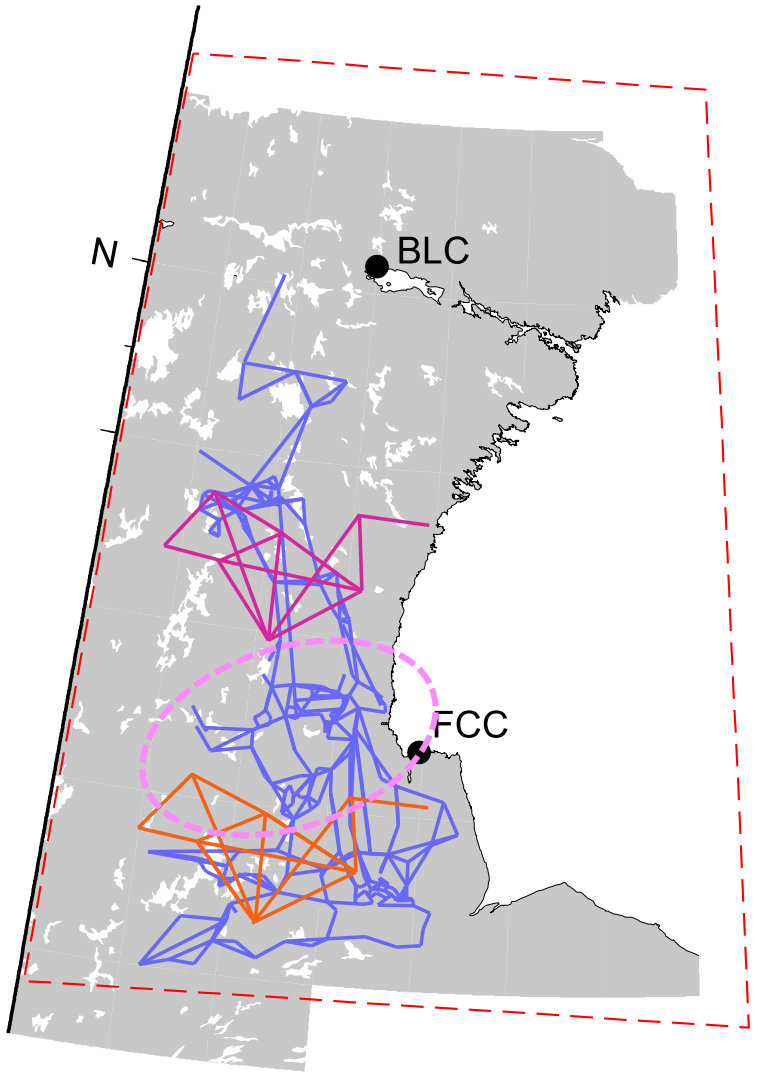


Taylor, K. E. (2001), Summarizing multiple aspects of model performance in a single diagram, Journal of Geophysical Research: Atmospheres, 106 (D7), 7183- 7192, doi: 10.1029/2000JD900719.

Hudson Bay

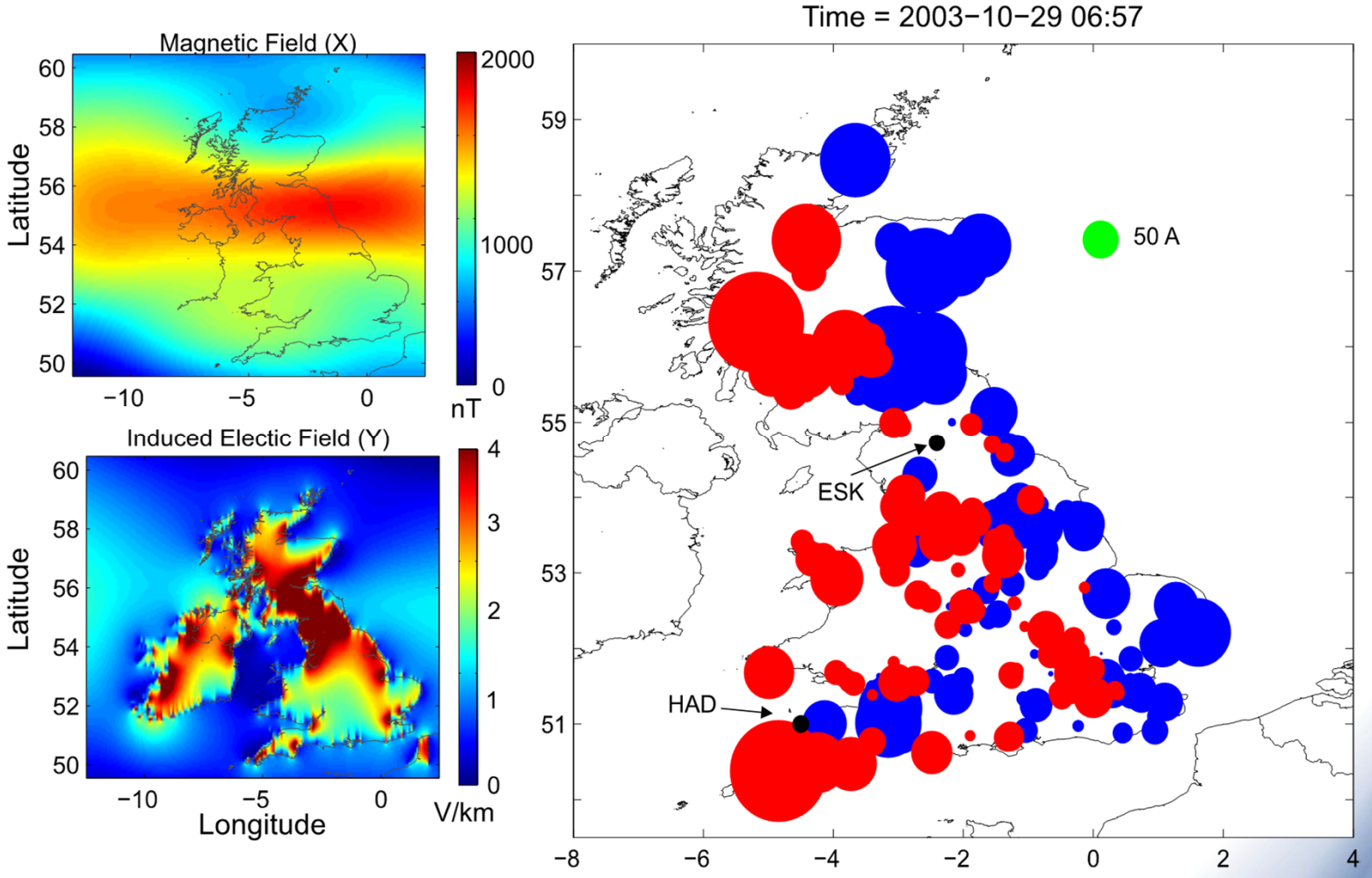


Depending on storm
BCC or FCC are better.
PBQ not very useful

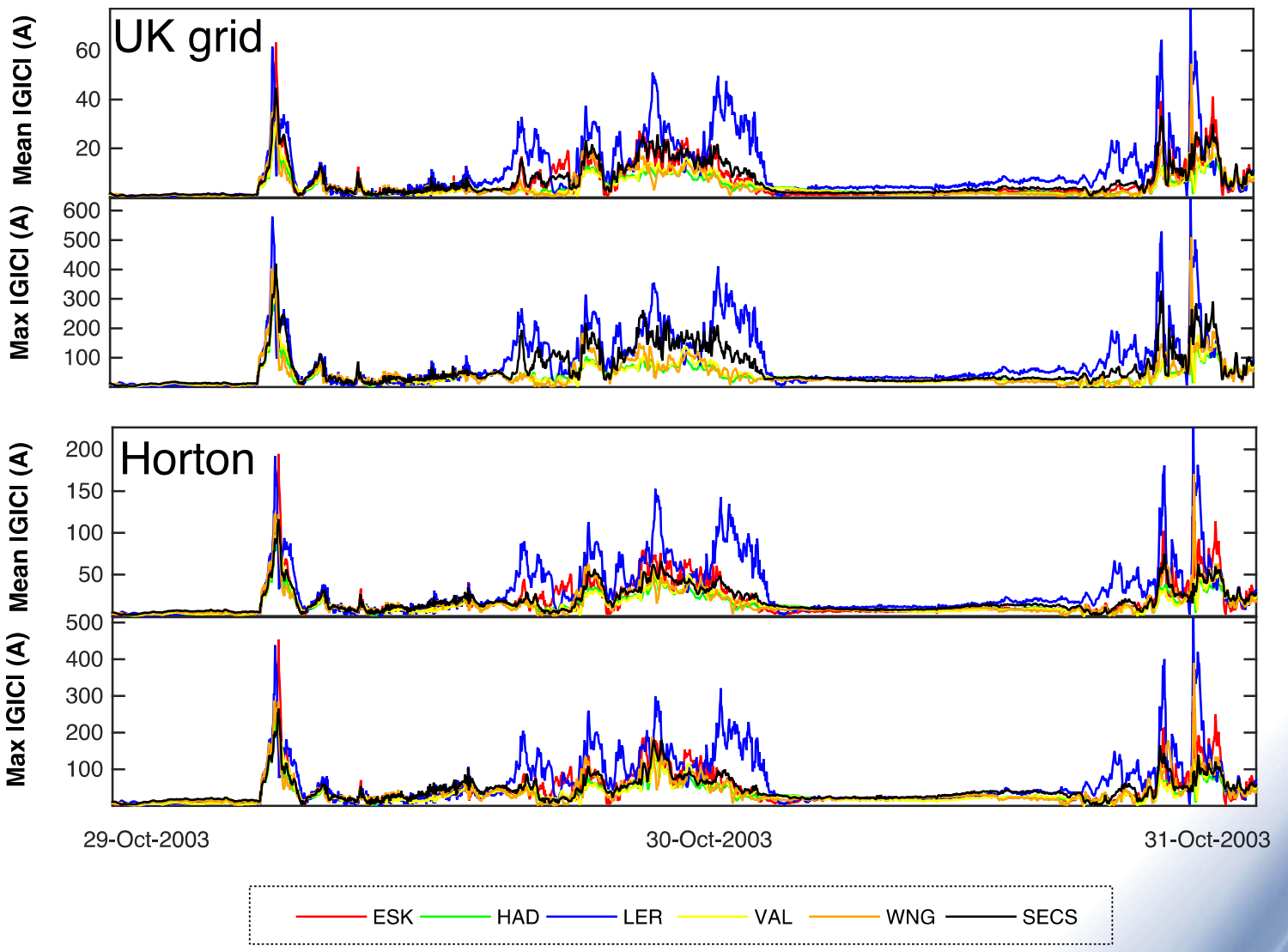


FCC is best
but BLC and PBQ are similar

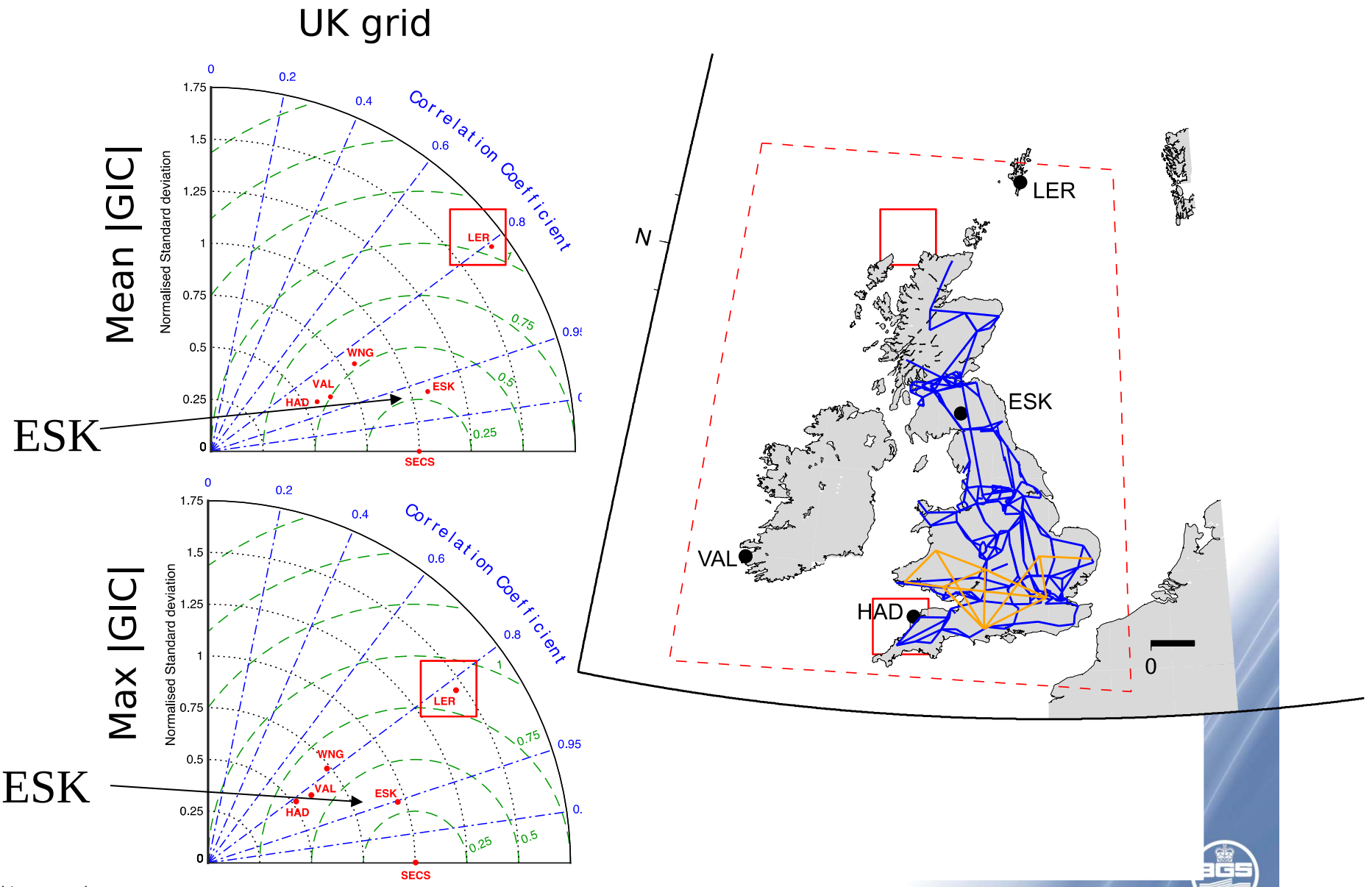
Great Britain: Halloween 2003 snapshot



Great Britain: 2003 time series



2003 Taylor Plots



Conclusions

- GIC estimates are very good when single observatory is:
  - Within the grid
  - Along similar geomagnetic latitude < 500 km

- Estimates are not so useful if:
  - Observatories > 600 km at similar geomagnetic latitude
  - Observatory is located far to the north of the grid

- More observatories are better (with the caveat of being too far north)

- Will also depend on the dynamics of a particular storm

Thank you for listening

Questions/comments?