GIC at mid-latitudes under extreme Dst scenarios

Gemma Kelly[1], Ari Viljanen[2], Ciaran Beggan[1], Alan Thomson[1], Alexis Ruffenach[3]

1 British Geological Survey, Natural Environment Research Council

2 Finnish Meteorological Institute

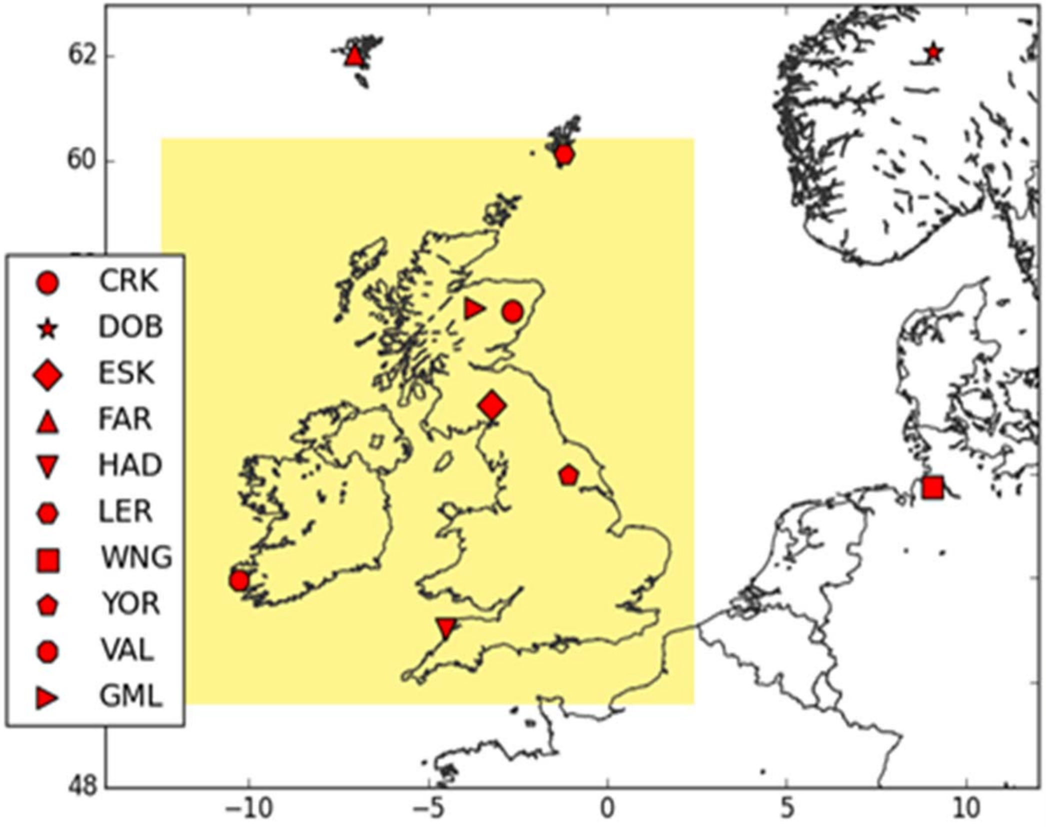
3 EDF Energy

Introduction

- Study of GIC in Europe
- Higher profile of Space Weather at government level
- Initial investigation of GIC in the UK and French power grids
- Building on previous work as part of the EURISGIC project and work with National Grid
- Range of hypothetical electrojet and historical scenarios simulating extreme events

Study Methodology

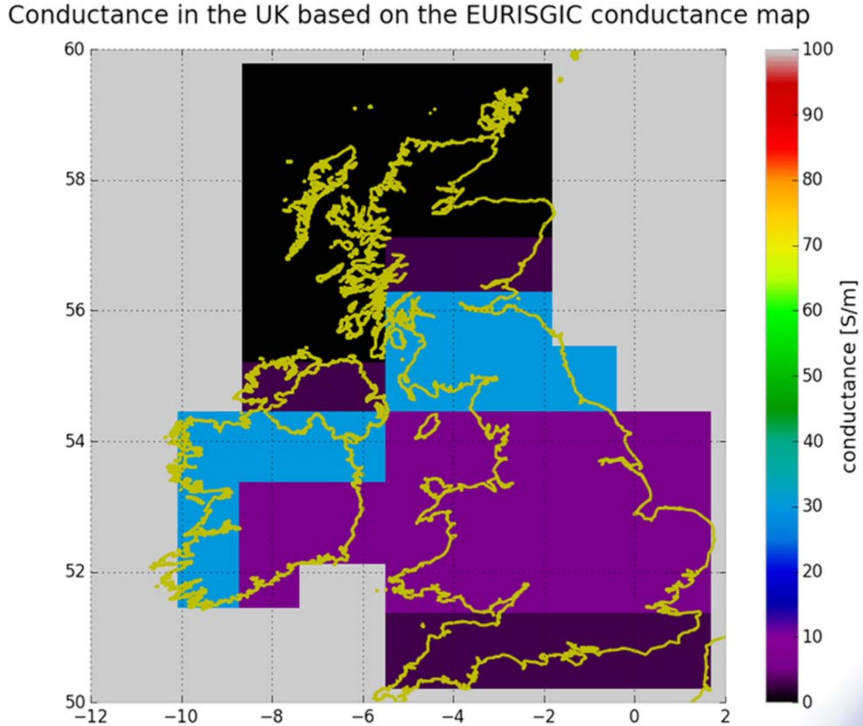
- Constructed models of
  - Magnetic field variations across each country
  - Sub-surface electrical conductivity
  - Surface electric field ('thin sheet model')
  - Transmission system electrical properties (line and earth resistances)

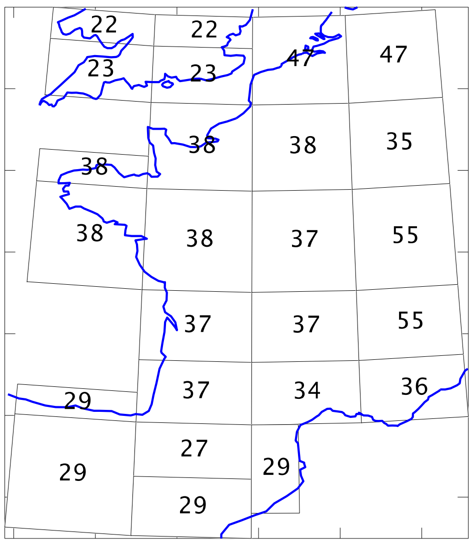


Interpolate magnetic fields using 'SECS' technique

Conductivity models

- Constant land and sea
- UK surface layer map based on EURISGIC
- EURISGIC conductivity model in Europe



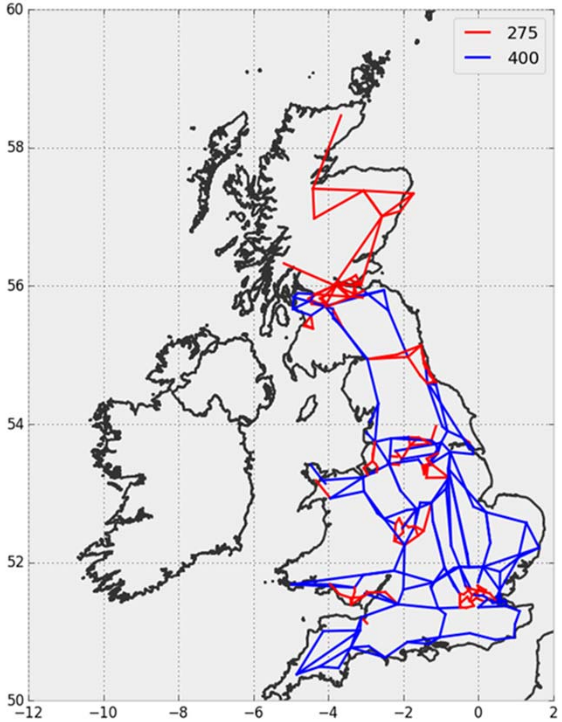


Block 37

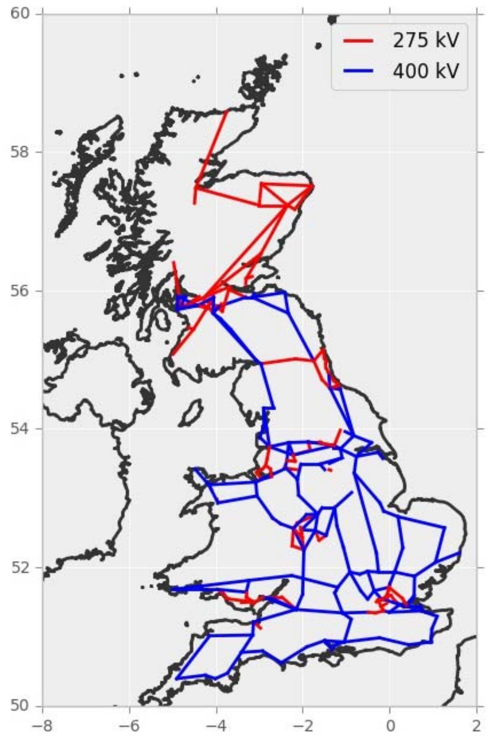
depth [km]	ρ [ohmm]
0–0.8	10
0.8–6.8	1500
6.8–14.8	70000
14.8–69.8	10000
69.8–	80

Network grids

- GB transmission system based on the 2008 system reports (SYS2008)
- EURISGIC grid

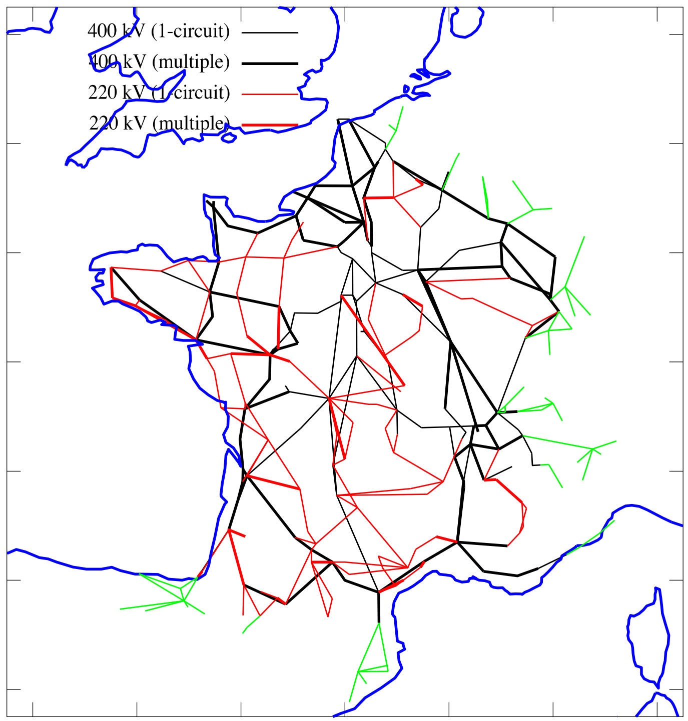


SYS2008



EURISGIC (UK)

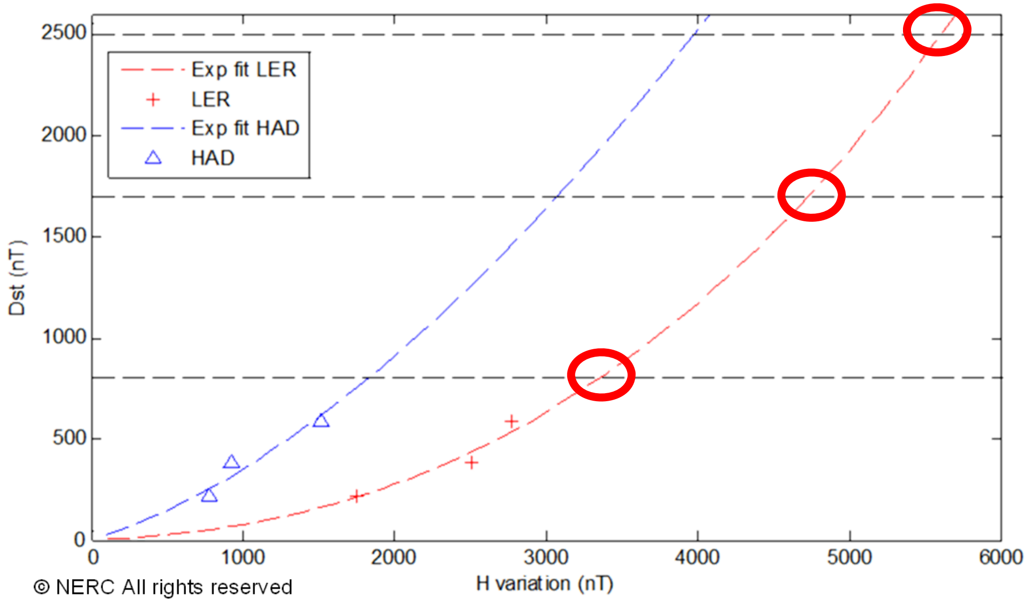
249 nodes, 351 lines



EURISGIC (France)

Dst - Establishing hypothetical scenarios

- Estimated H component at UK observatories for 3 hypothetical Dst Values: -800nT, -1700nT and -2500nT (Siscoe et al. 2006, Vasyliunas 2011)
- 2 methods:
  - Extrapolation from the three largest storms in digital record



Dst	H component variation (nT)	
	Hartland	Lerwick
-800	1900	3350
-1700	3000	4750
-2500	3900	5600

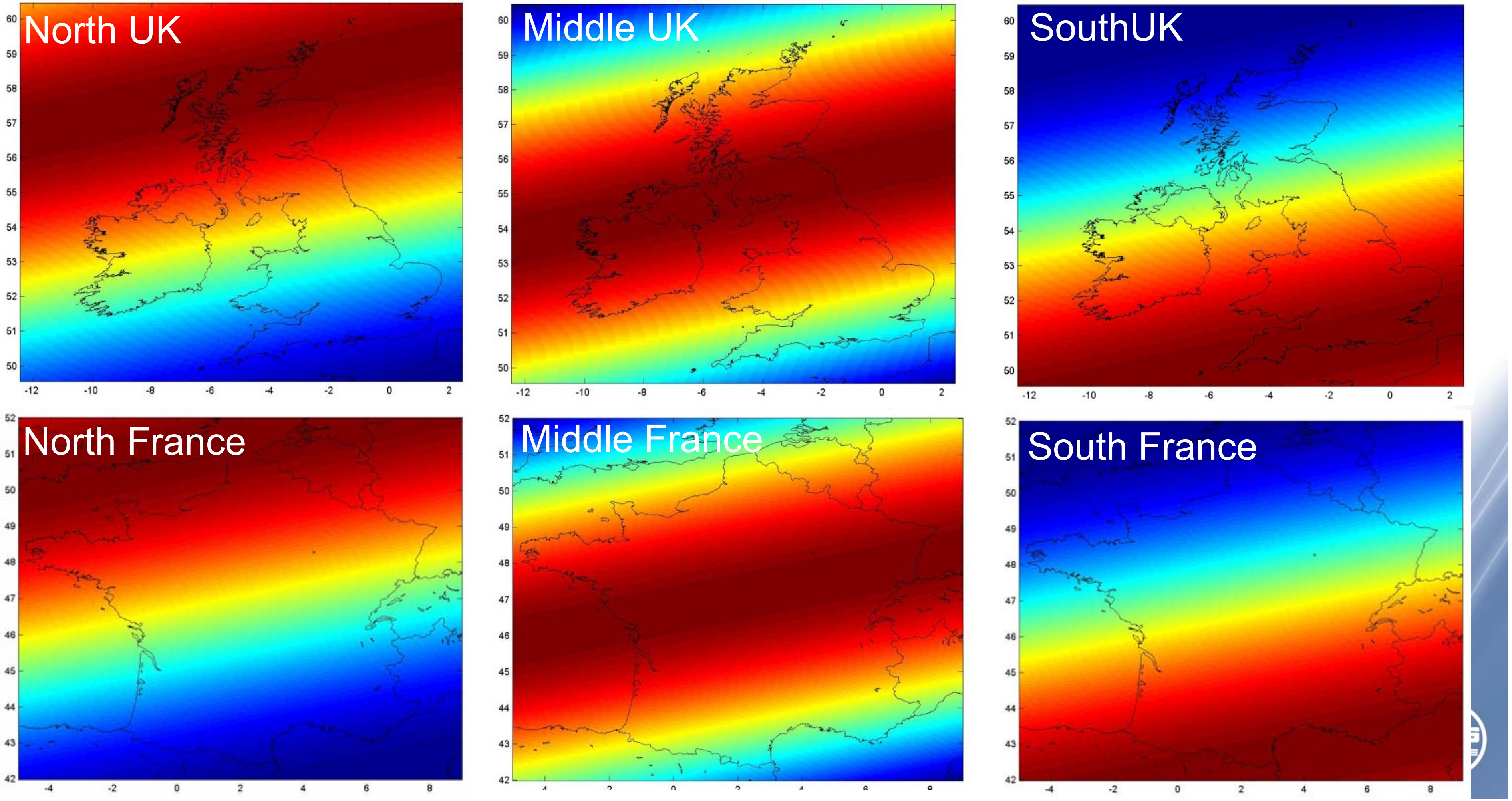
Dst - Establishing hypothetical scenarios

- Estimated H component at UK observatories for 3 hypothetical Dst Values: -800nT, -1700nT and -2500nT
- Two methods:
  1. Extrapolation from the three largest storms in digital record
  2. Use simple ring current model
     - Assuming ring current contributes ~10% of total H at Lerwick.

Dst	Contribution to H from Dst (nT)	Total H (nT)
-800	367	3700
-1700	781	7800
-2500	1150	11500

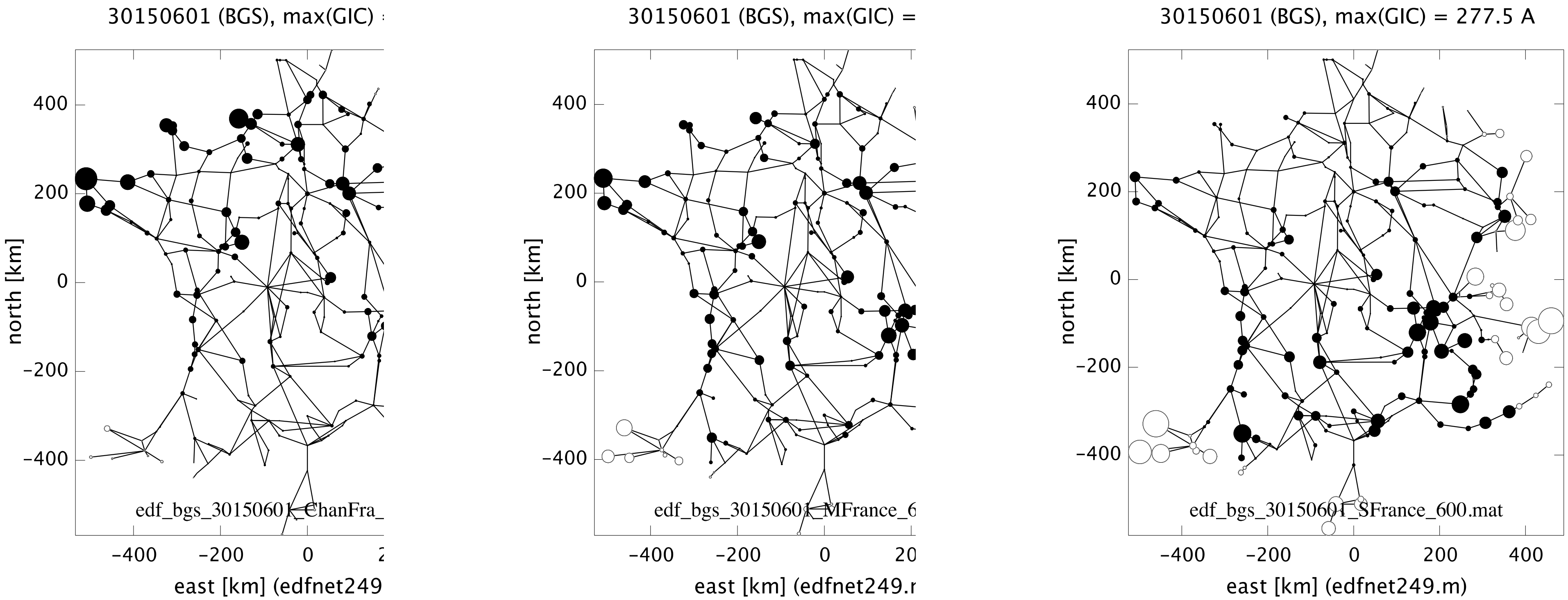
Establishing hypothetical scenarios

- Model with a tapered cosine in several locations



Hypothetical storms - France

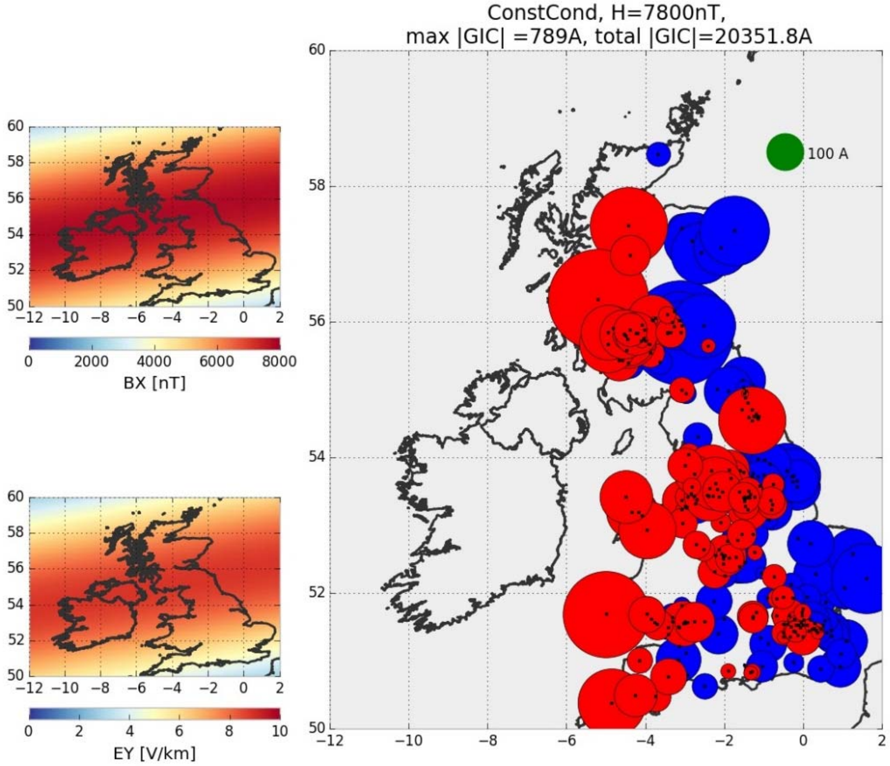
- Location of nodes with largest GIC moves with electrojet position

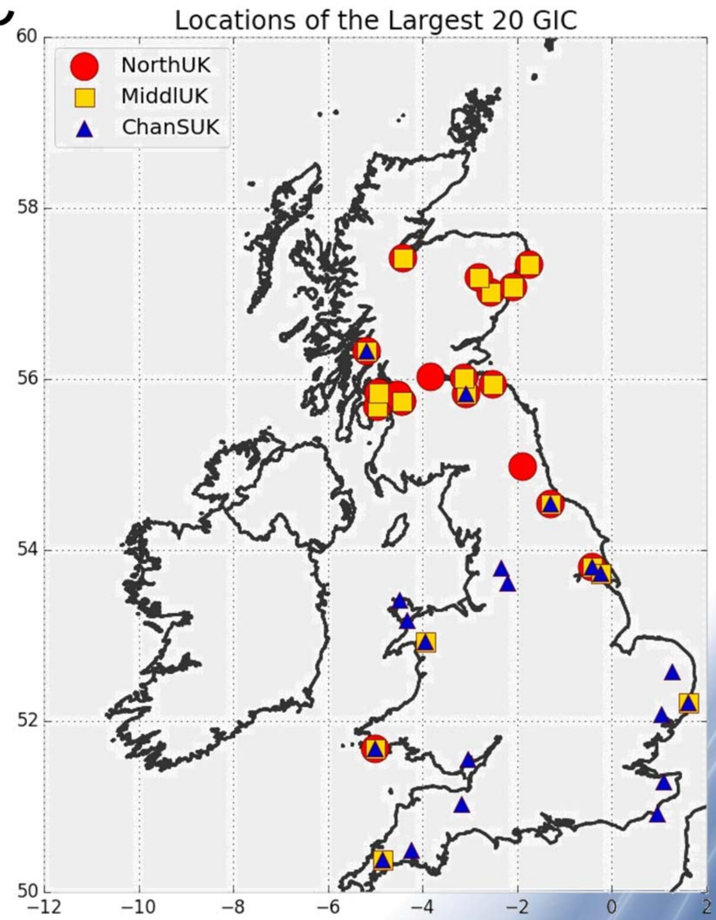


White circles indicate nodes outside of France

Hypothetical storms - UK

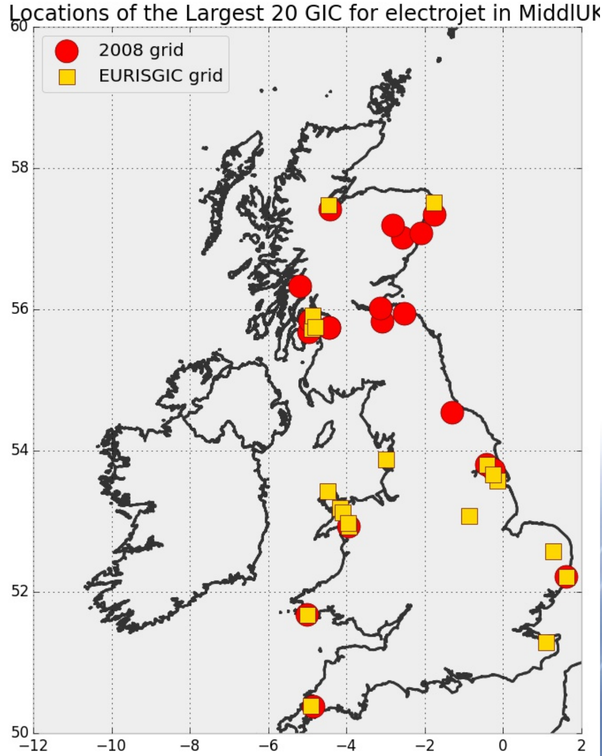
- Location of nodes with largest GIC moves with electrojet position





Sensitivity analysis - UK

- Conductivity:
  - Locations of most affected nodes change very little
  - ~1.5x change in total GIC
- Network Grid:
  - ~2x change in total GIC
  - Locations also quite different

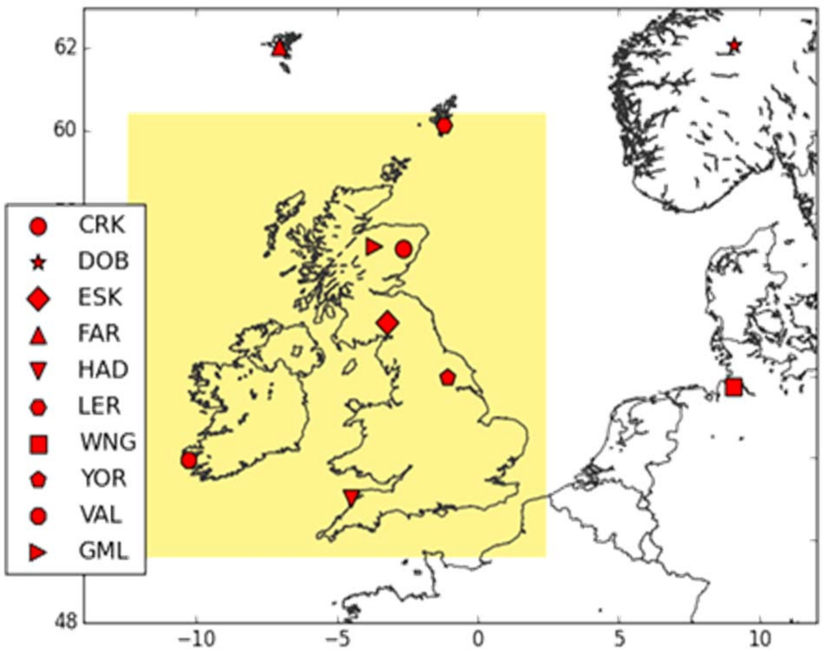


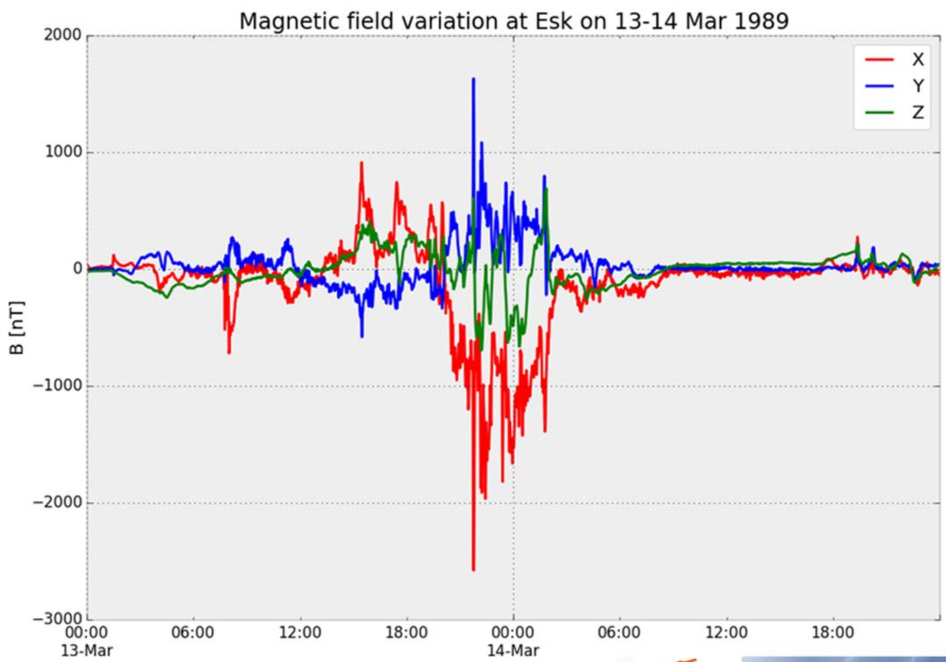
Conductivity model	Network grid model	Location of Electrojet		
		Channel UK	Middle UK	North UK
Constant land and sea	**2008 grid**	18341 (689)	27385 (1061)	12662 (720)
	EURISGIC	34314 (1349)	45606 (1412)	25684 (724)
EURISGIC	**2008 grid**	29118 (1093)	32310 (1252)	20101 (1144)
	EURISGIC	54475 (2143)	52392 (1551)	49047 (1791)

Total GIC (max GIC) in the grid for each scenario with H=7800nT

Historical scenarios

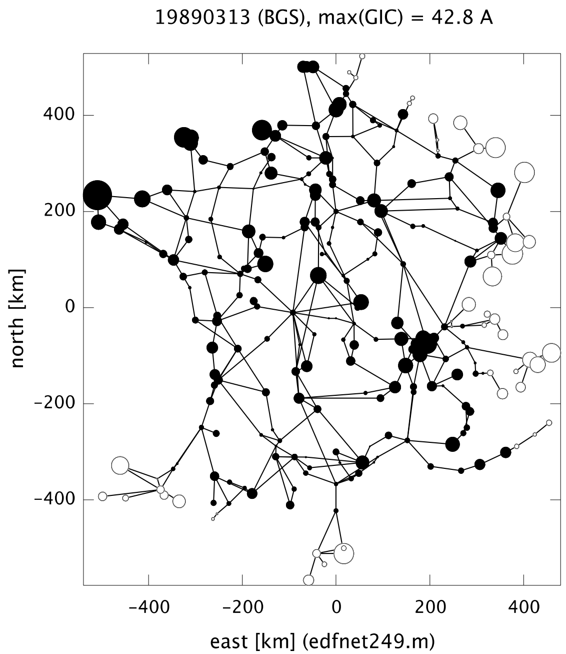
- Observatory measurements of historical storms interpolated using SECS (Amm, 1997; Amm & Viljanen, 1999)
  - 29th-31st Oct 2003 (Halloween)
  - 13th-14th March 1989
  - 20th Nov 2003



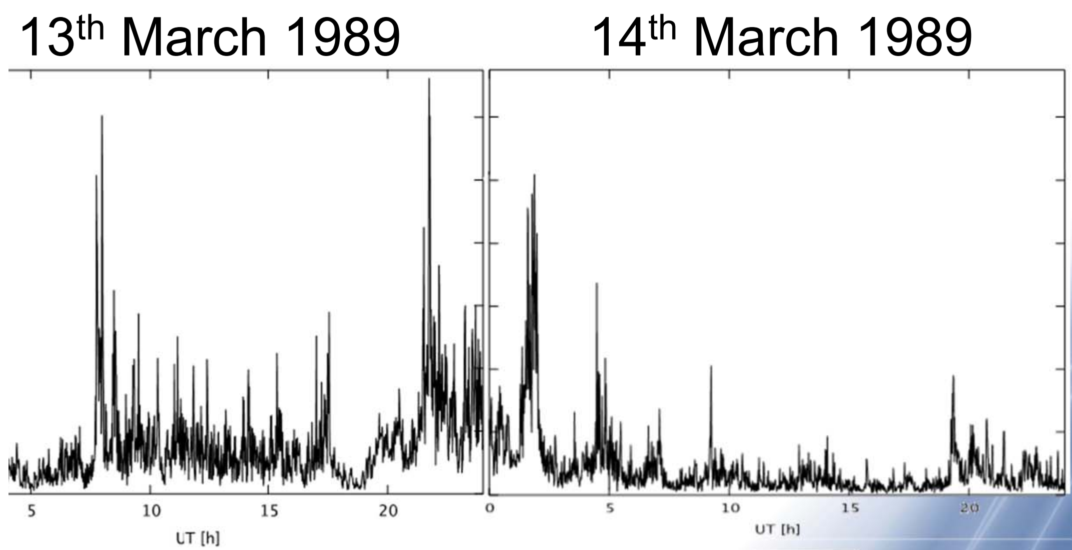


Historical scenarios - France

- Sum GIC for March 1989
- Largest GIC seen along the north coast and small area in the south-east.



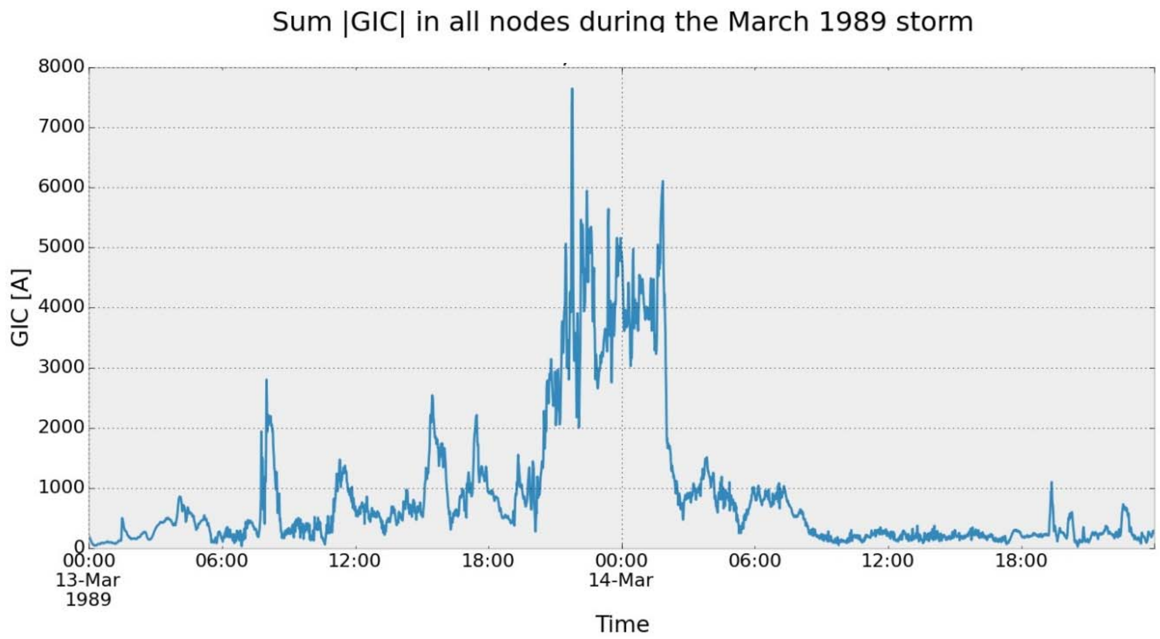
Max GIC at each node on 13th March

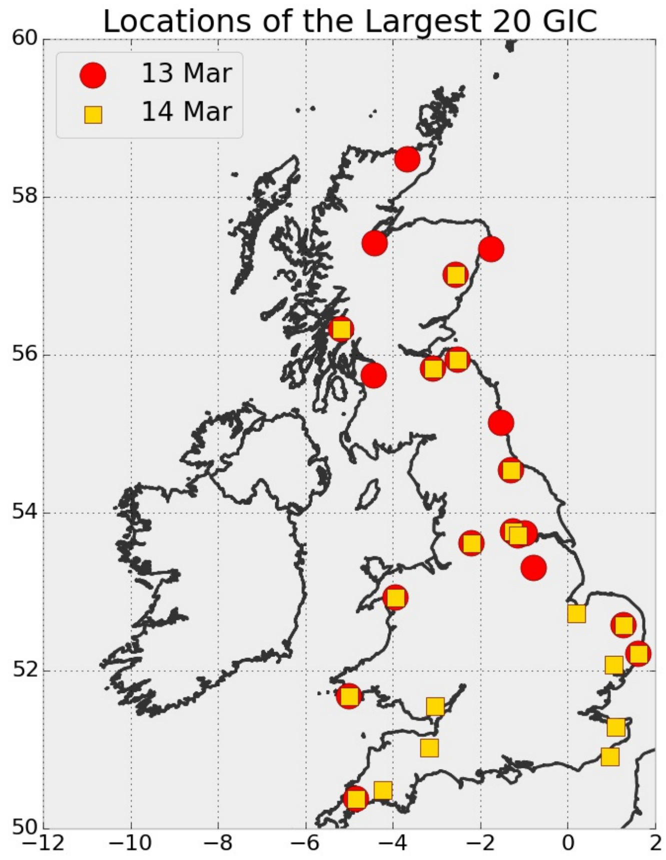


Total GIC throughout the storm

Historical scenarios - UK

- Sum GIC throughout the storm follows ΔB
- Affected nodes change over course of the storm





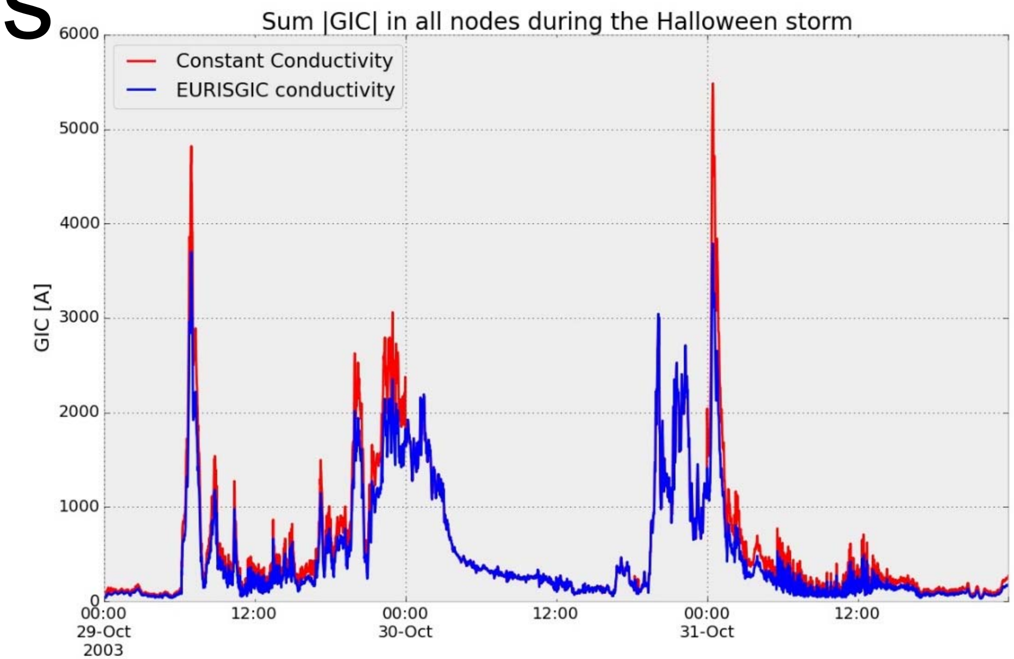
Historical events

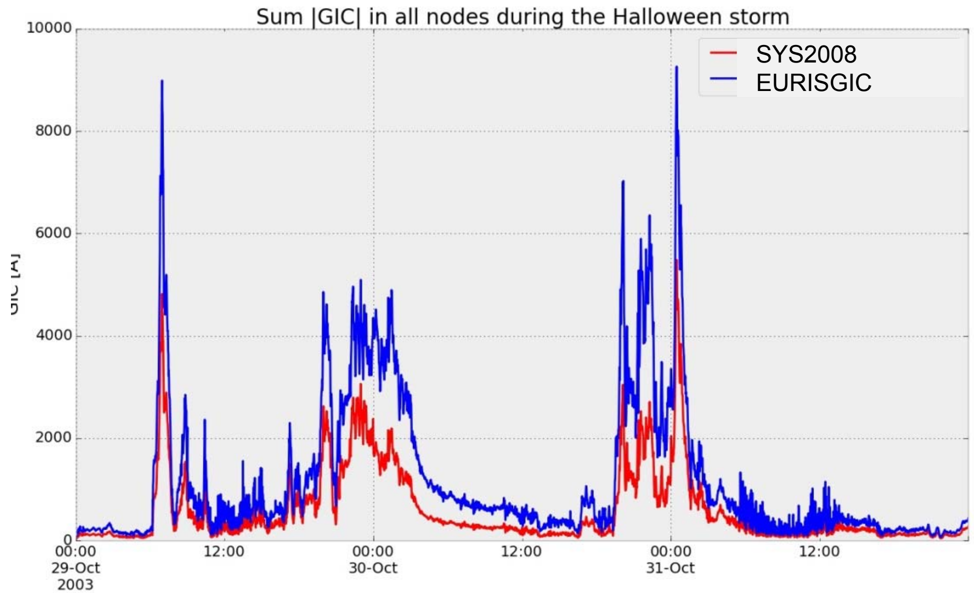
- GIC peaks at ~43A in France (March 1989) and ~212A in the UK (March1989)
- Assuming a linear scaling based on Dst then extreme values would be:

Extreme Dst (nT)	Max Dst in historical data	Scale factor	Max GIC for extreme Dst value	
			43 (Fra)	(UK)
-800	-589	1.4	60	297
-1700	-589	2.9	125	615
-2500	-589	4.2	181	890

Sensitivity analysis

- Conductivity model:
  - Constant conductivity slightly bigger at peak
- Network grid:
  - EURISGIC ~2x bigger (as for electrojet scenarios)
- Source field model:
  - No change in top 20 nodes
  - Fine scale details of total GIC very similar





Summary

- Coastal substations generally more susceptible to GIC
- Geomagnetic variations are typically largest to the north, therefore northern substations are more regularly susceptible, but total GIC across a grid can be larger for more central electrojets
- Hypothetical electrojets: GIC peaks of many hundreds (>1000 in UK) of Amps possible at many sites for extreme scenarios
- Historical events: GIC peaks in hundreds of Amps, and locations of max GIC changes throughout the storm.
- Conductivity model and network configuration make a notable difference (~2x) to GIC – important to take this into account

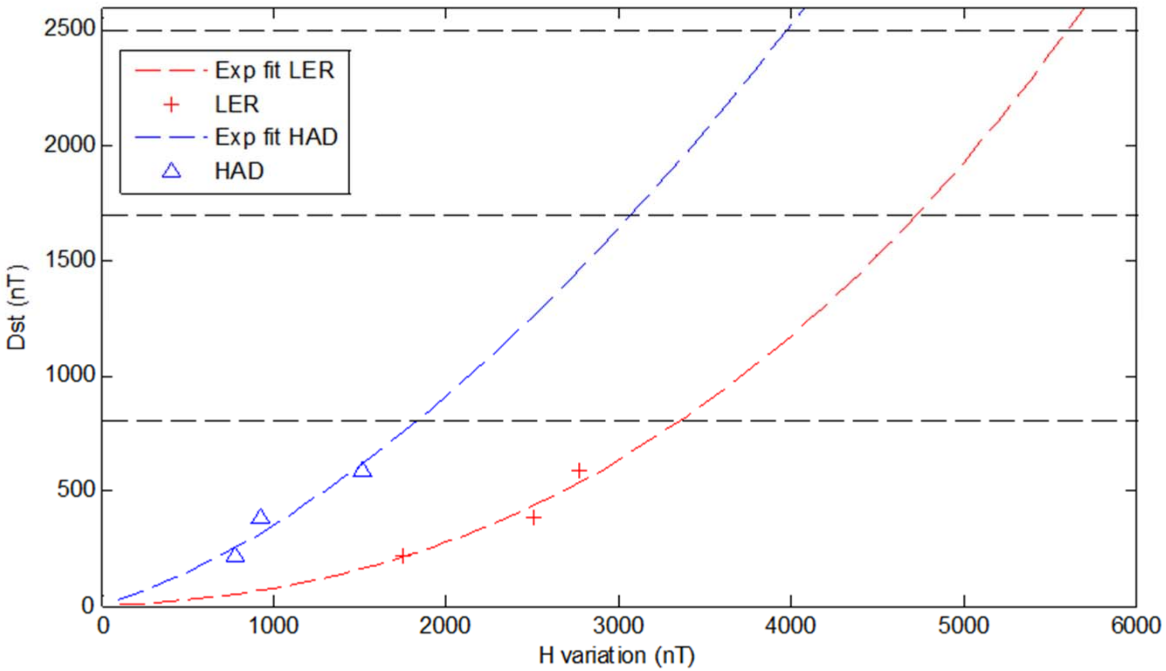
Extras

Summary

- Historical data (*real* data)
  - GIC peaks at ~43A (La Martyre, March 1989)
  - But need to apply Dst scale factors: 1.4 to 6.5
    - Leads to Hundreds of Amps possible at many sites for extreme space weather events (i.e. Dst>800)
- Hypothetical data
  - GIC peaks in the many hundreds of Amps (300-800A)

Extreme Event Scenarios (1)

- Exponential scaling model – hypothetical electrojet



Dst (nT)	H component variation (nT)	
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800	1900	3350
1700	3000	4750
2500	3900	5600

Extreme Event Scenarios (1)

- Ring-current scaling model

Dst (nT)	H component variation (nT)					
	Hartland			Lerwick		
	Measured	RC model	Ratio (%)	Measured	RC model	Ratio (%)
589	1510	350	23	2800	285	10
383	920	230	25	2500	185	7.4
220	780	130	16	1750	105	6

Dst value	H component from Dst at Lerwick (nT)	H component in total at Lerwick (nT)
800	367	3700
1700	781	7800
2500	1150	11500

Sensitivity analysis

- Removing top 5 to 10 nodes
  - Large scale picture relatively unaffected (total GIC)
  - Locations which see largest GIC move