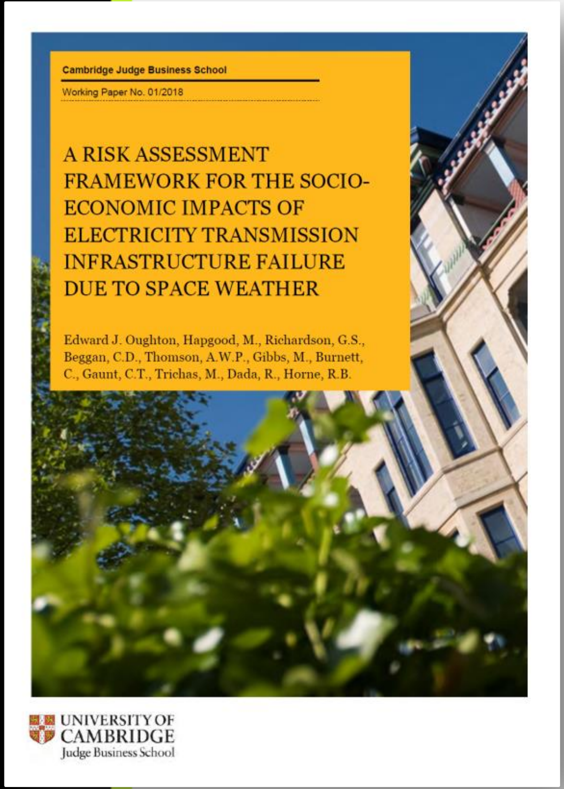
Testing Realistic Scenarios for Space Weather

The Economic Impacts of Electricity Transmission Infrastructure Failure in the UK

Mark Gibbs 17/4/2018

Met Office



Oughton, E.J., M. A. Hapgood, G.S. Richardson, C.D. Beggan, A.W.P. Thomson, M. Gibbs, C. Burnett, C.T. Gaunt, M. Trichas, R. Dada and R.B. Horne. 2018.

"A Risk Assessment Framework for the Socio-Economic Impacts of Electricity Transmission Infrastructure Failure Due to Space Weather."

Cambridge Judge Business School Working Paper No. 01/2018.

https://www.jbs.cam.ac.uk/faculty-research/publications/working-papers/working-papers-from-2018/

EPSRC Engineering and Physical Sciences Research Council

NERC SCIENCE OF THE ENVIRONMENT

Science & Technology Facilities Council

ITRC mistral multi-scale infrastructure systems analytics

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British Geological Survey NATURAL ENVIRONMENT RESEARCH COUNCIL

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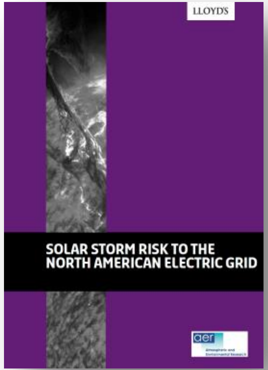
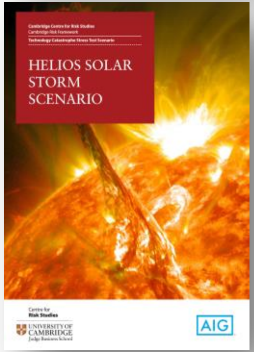
Literature review

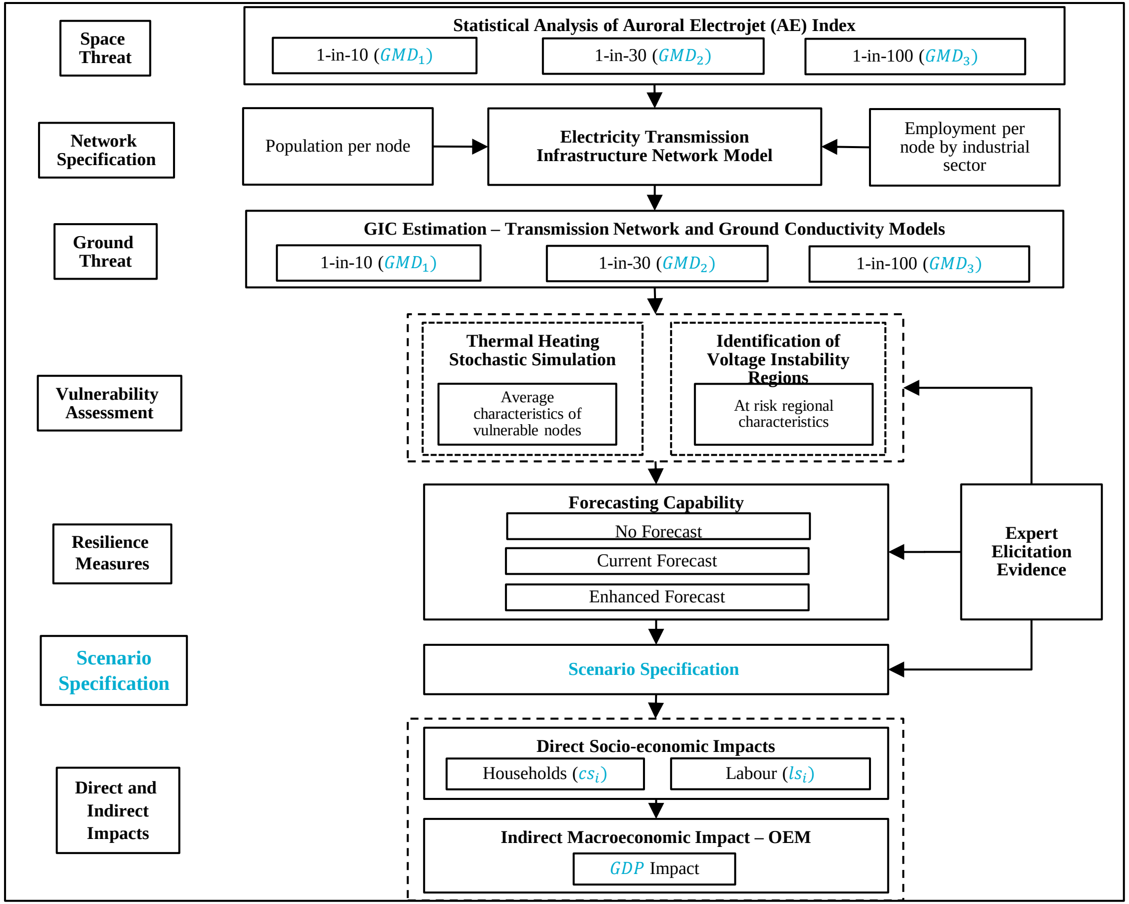




Research questions

- What is the probability of the UK being affected by substorms?
- How vulnerable are infrastructure network assets and nodes to GIC exposure?
- What are the potential socio-economic impacts of CNI failure due to space weather, under different forecasting capabilities?
  - No Forecast
  - Current Forecast
  - Enhanced Forecast

Methodology



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Space weather threat

1-in-10 case:

- **October 2003**

1-in-30:

- **March 1989**

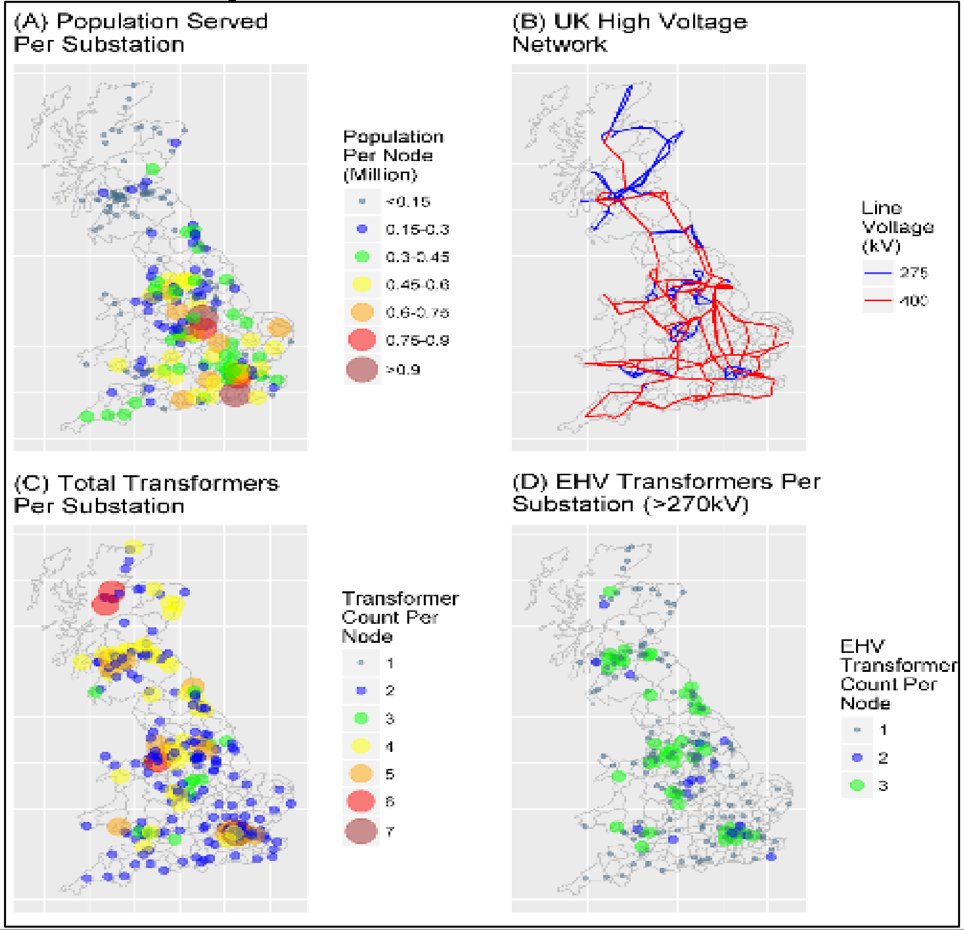
1-in-100 case:

- **1859 (Carrington) storms**, adapting the 1989 substorm timeline

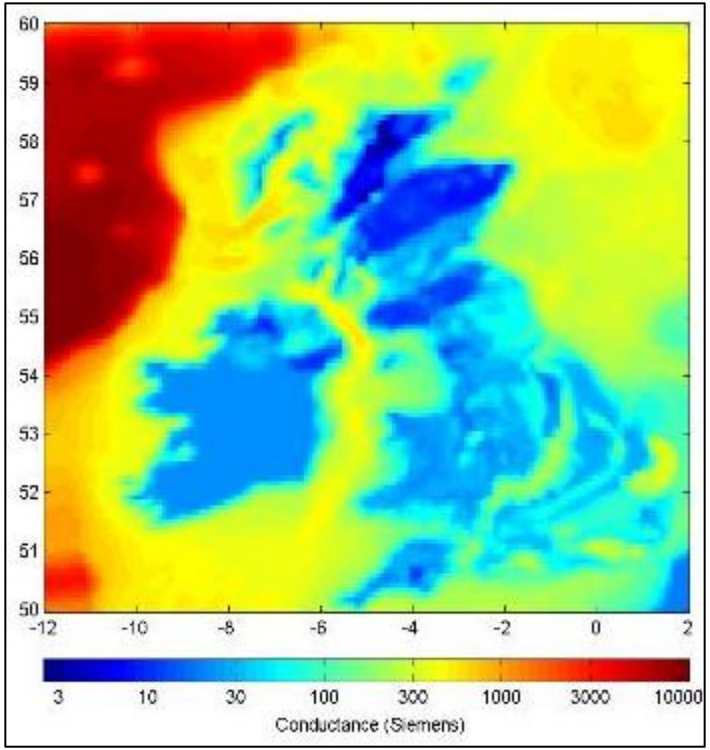
Risk-level	Number of very intense substorms over UK			Total cases
	0	1	2	
1-in-10-year	22 (92%)	2 (8%)	0 (0%)	24
1-in-30-year	20 (83%)	4 (17%)	0 (0%)	24
1-in-100-year	7 (29%)	12 (50%)	5 (21%)	24

Probability of UK impact derived from each scenario based on CME arrival at a random time of day

Network specification



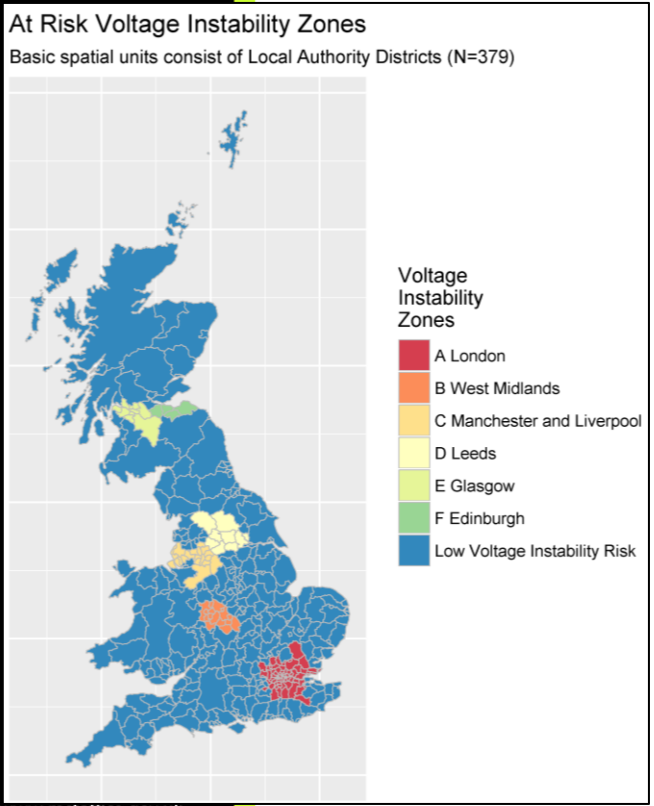
Ground threat



Modelling the topology, location and resistance characteristics of the high voltage grid. This is placed onto the geoelectric field map to deduce the GIC (see Beggan *et al.*, 2013).

Folllowing Lehtinen & Pirjola (1985): $\boldsymbol{I} = (1 + \boldsymbol{Y} \cdot \boldsymbol{Z})^{-1} \cdot \boldsymbol{J}$

Vulnerability assessment

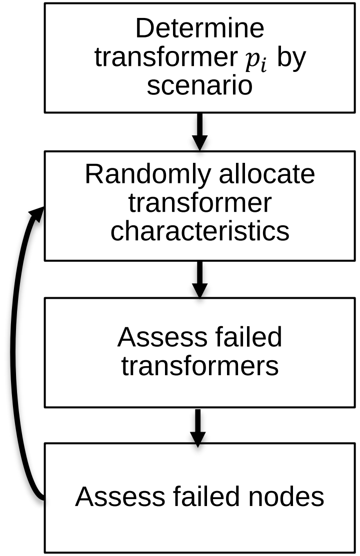


Thermal heating

The probability of failure p_i for the *i* th transformer dependent on:

- Size of the geomagnetic disturbance $(GMD_1, \dots, GMD_z)$
- GIC estimated at each n node
- Different transformer design characteristics $(c_1, \dots, c_z)$

Type	Proportion	Amp exposure	Failure threshold
Type 1	50%	200A	300A
Type 2	25%	100A	200A
Type 3	12.5%	50A	150A
Type 4	12.5%	25A	125A



Assumption: More than half the transformers at a node must fail to lose the node

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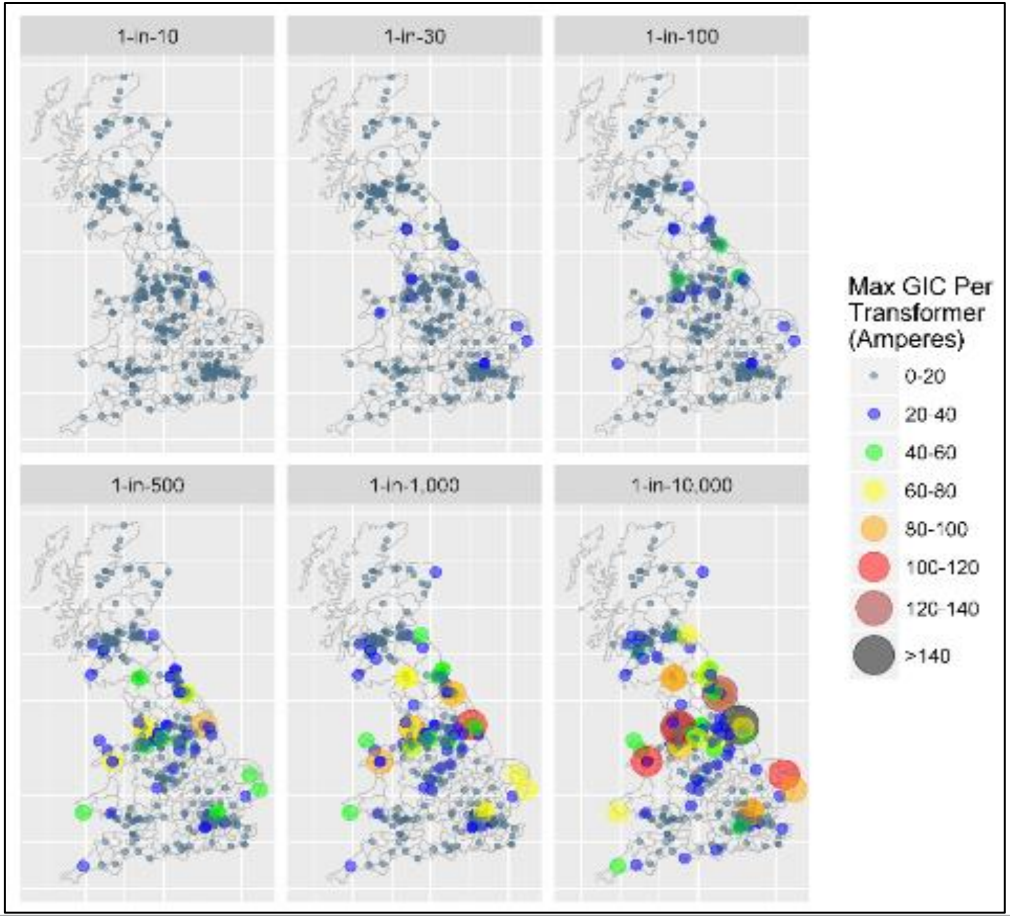
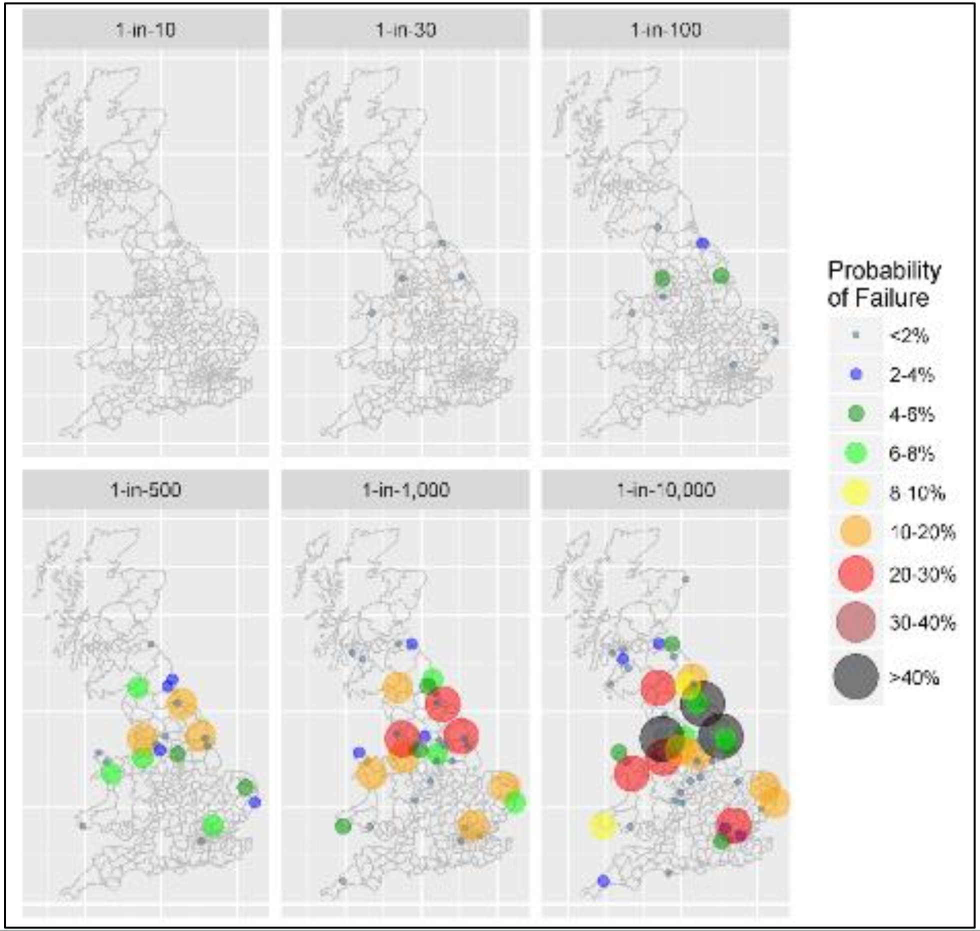
Scenario specification

Event	Damage Type	Dimension	No Forecast	Current Forecast	Enhanced Forecast
1-in-100-years	Voltage collapse	Spatial	National grid collapse	3 voltage instability regions (Yorkshire, Manchester/NW and Birmingham/West Mids)	1 voltage instability region (Birmingham)
		Temporal	5 days	2 days	1 day
	Thermal heating	Spatial	2 nodes	2 nodes	1 node
		Temporal	10 weeks (extended off-site transformer replacement)	6 weeks (off-site transformer replacement)	4 weeks (expedient off-site transformer replacement)
1-in-30-years	Voltage collapse	Spatial	2 voltage instability regions (Manchester/NW and Birmingham/West Midlands)	1 voltage instability regions (Manchester/NW)	-
		Temporal	2 days	1 day	-
	Thermal heating	Spatial	1 node	-	-
		Temporal	6 weeks	-	-
1-in-10-years	Voltage collapse	Spatial	1 voltage instability region (Manchester/NW)	-	-
		Temporal	12 hours	-	-
	Thermal heating	Spatial	-	-	-
		Temporal	-	-	-

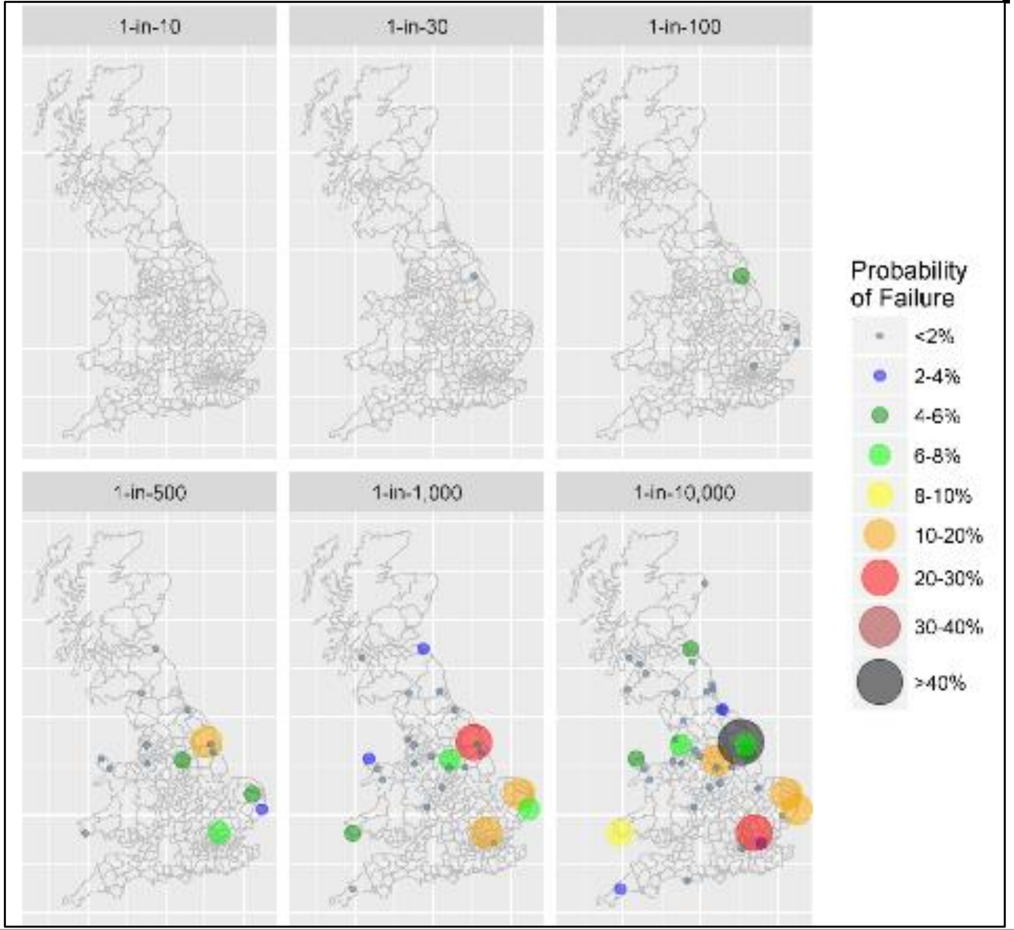
Max GIC per EHV transformer



Simulated transformer failure frequency



Simulated substation failure frequency



Differences between scenario specification & simulations

Possibly due to random allocation of transformer types?

Newer more resilient transformers focussed on urban areas?

Discussion

1. *What is the probability of being affected by substorms?*
   - UK unlucky in 1989 (only 17% likelihood)
   - Carrington-class: 71% chance of at least one intense substorm, and 21% chance of two
2. *How vulnerable are infrastructure network assets and nodes to GIC exposure?*
   - Number of EHV transformers per substation matters
3. *What are the potential socio-economic impacts of CNI failure due to space weather, under different forecasting capabilities?*

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Conclusions

	No Forecast	Current forecast	Enhanced forecast
1-in-100 year	£16 bn	£3.0 bn	£0.8 bn
1-in-30 year	£2.0 bn	£0.4 bn	-
1-in-10 year	£0.4 bn	-	-

SWFO & L5 missions are required to stop a reduction of forecasting capability

Thank you
and questions?