Initial results of pipeline modelling in Great Britain

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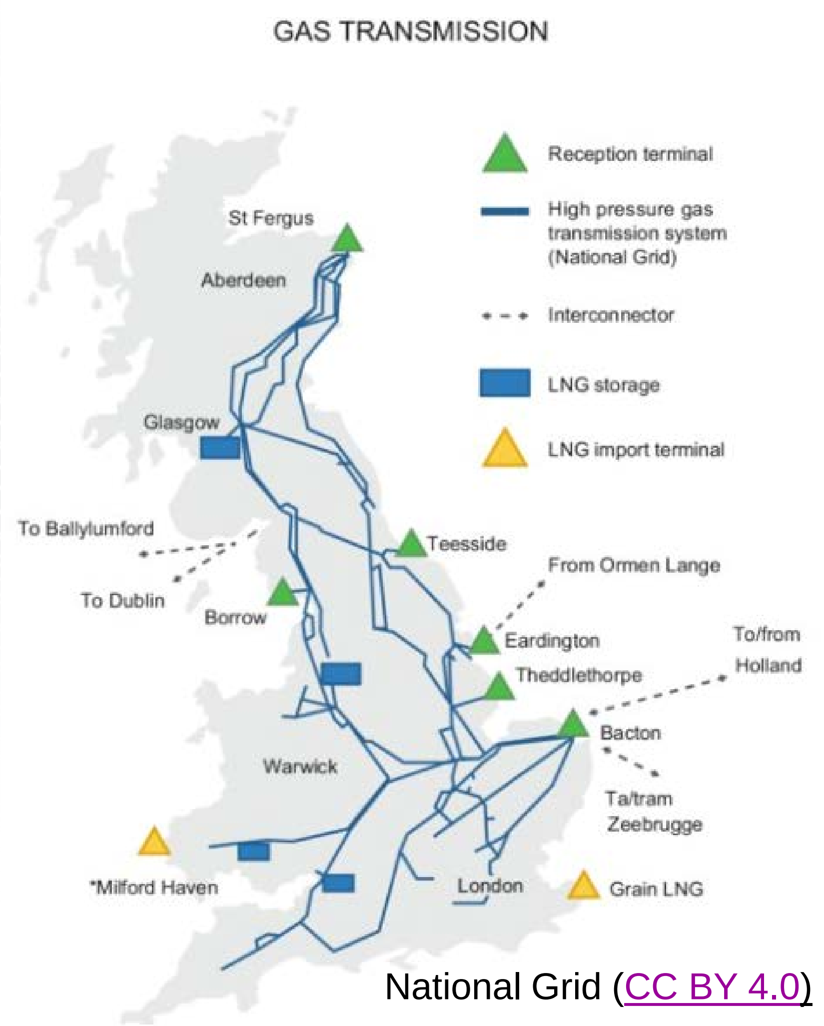
Space weather effect on Pipelines

- Pipelines are coated in a low conductance material and maintained at a slightly negative potential in relation to the Earth to minimise corrosion (“cathodic protection”)
- But during geomagnetic storms, induced electric currents can cause an increase of this potential beyond the desired range
- Not an instantaneous failure of the system – more of a cumulative effect

Rosemary Oakeshott - *Gas pipeline internment*

GB pipeline modelling

- Not previously been investigated in UK
- UK has extensive Gas transmission network (run by National Grid Gas)
- 7,600km of pipelines which transport gas from coastal terminals and storage facilities to exit offtake points (to 8 Distribution networks and power stations and large industrial consumers)
- Similar to modelling GIC in a power network but with some subtle differences ("continuously earthed")



National Grid (CC BY 4.0)

SWIGS

- *Space Weather Impact on Ground-based Systems*
- A 4-year UK Natural Environment Research Council grant-funded project - £3.75M (€4.20M)
- 10 partner institutes
- Started 1st May 2017
- 4 main Work packages
  - WP4: Infrastructure impact of GIC
    - Impact on rail and pipeline infrastructure

Establishing the method

- Following method of Boteler 2013 (*Space Weather*)
- Spilt the pipeline up into sections that are short enough that the electric field can be considered constant in each section
- Develop equivalent-pi circuit to describe induction in the pipeline
- Combine equivalent-pi circuits for each section into a nodal admittance network

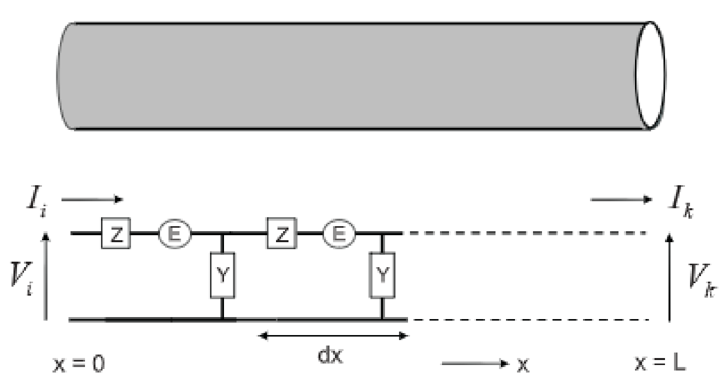


Figure 1. Pipeline and its transmission line model.

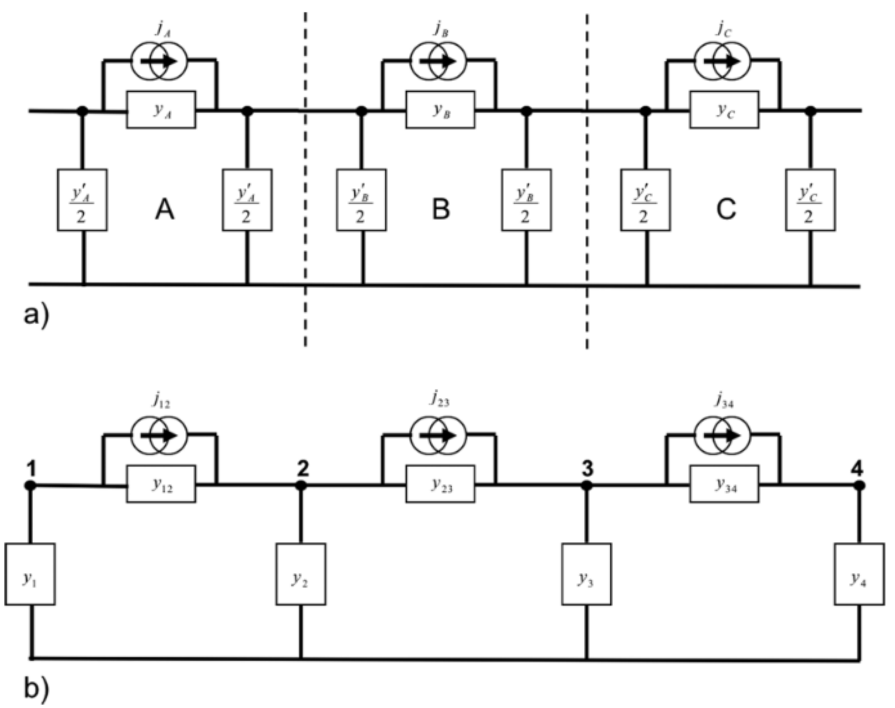
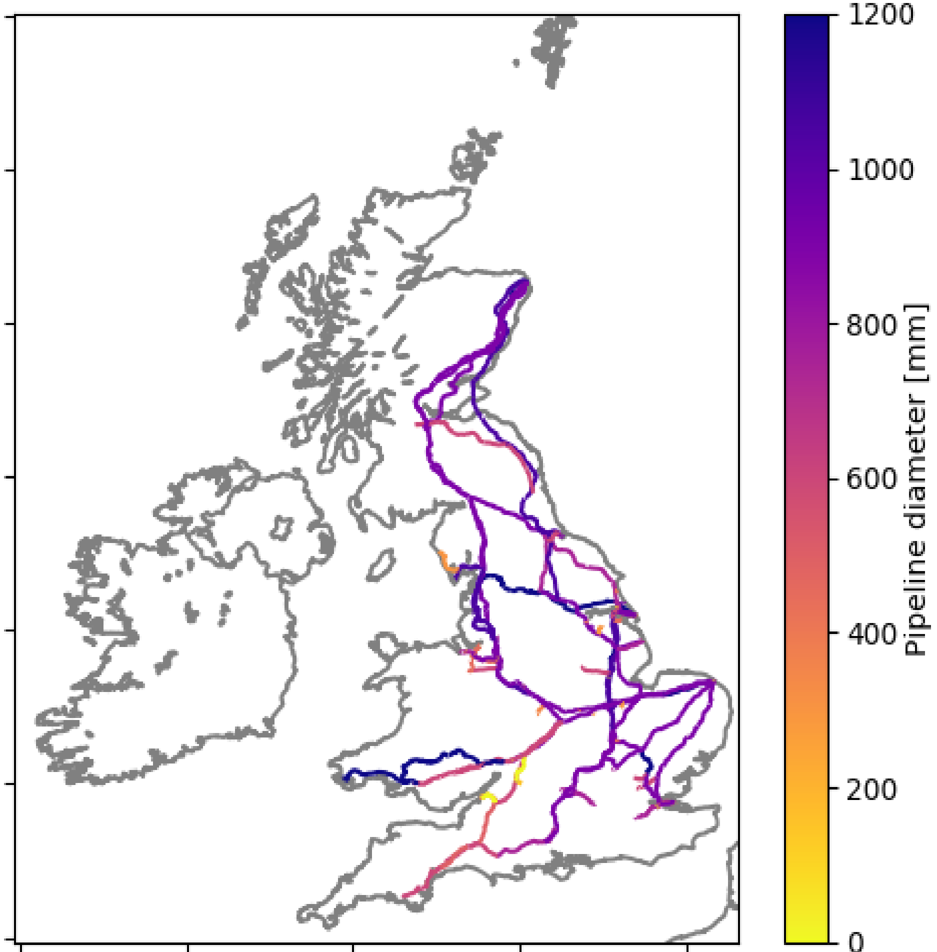


Figure 4. Combining equivalent-Pi circuits into a nodal network.

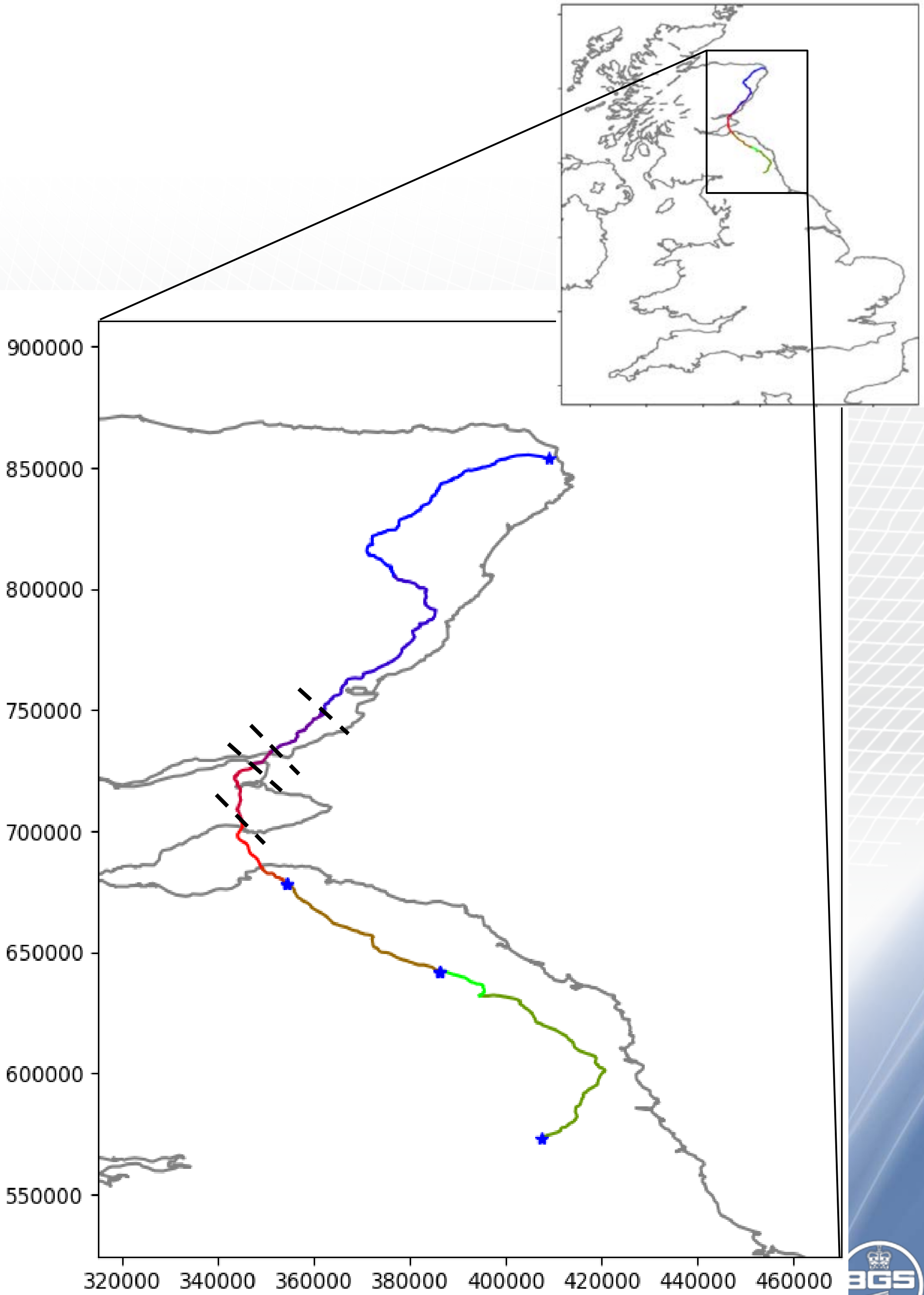
Constructing a “Real” network

- On the National Grid website there are shapefiles which detail the pipeline network
- Include the following info:
  - Pipe name
  - Diameter
  - Path of each line
- “Missing” info
  - Thickness
  - Pipe resistivity: 0.18×10^{-3} Ωm
  - Coating conductance: 5×10^{-6} Sm^{-2}

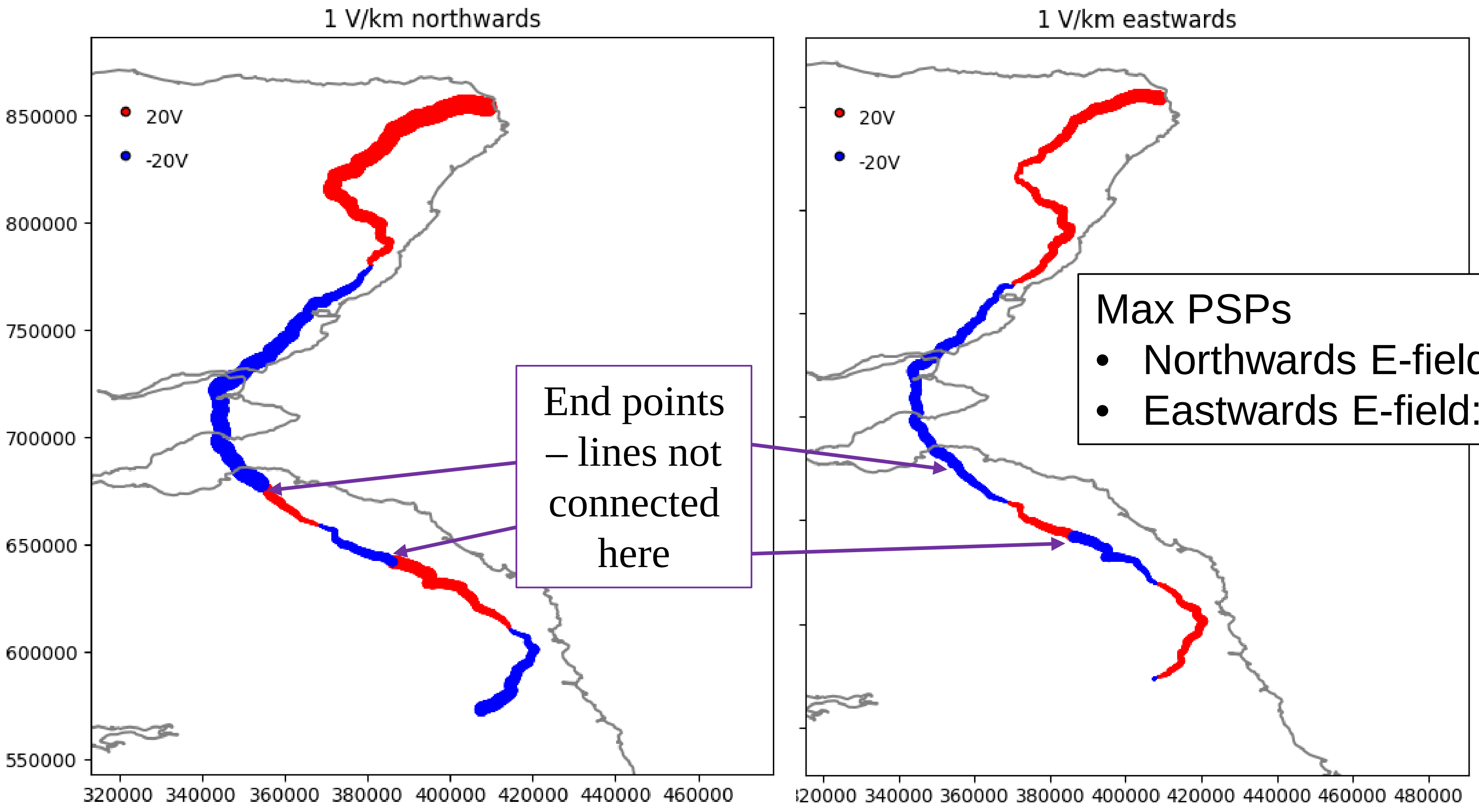


Scottish example

- Started with a set of connected lines from Aberdeen to Corbridge
- Stars indicate ends of lines (i.e. lines either side are not connected)
- Each long pipe is broken up into sections between each set of coordinates along the line
- These sections are short enough to be able to consider the E-field uniform using our E-field model (10km grid spacing)



PSPs with a uniform E-field



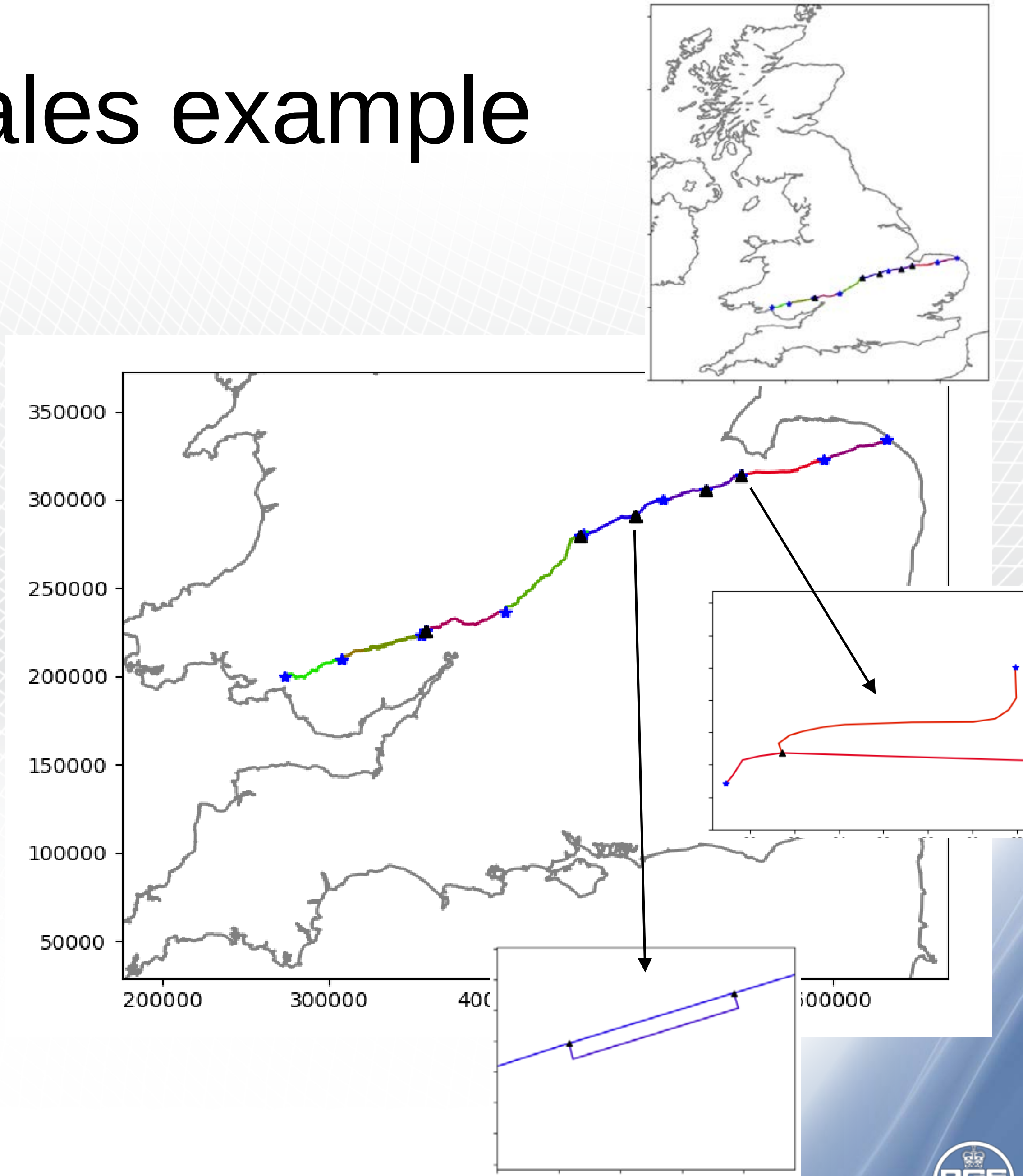
Max PSPs

- Northwards E-field : 75.6 V
- Eastwards E-field: 38.9 V

Marker size scaled by area

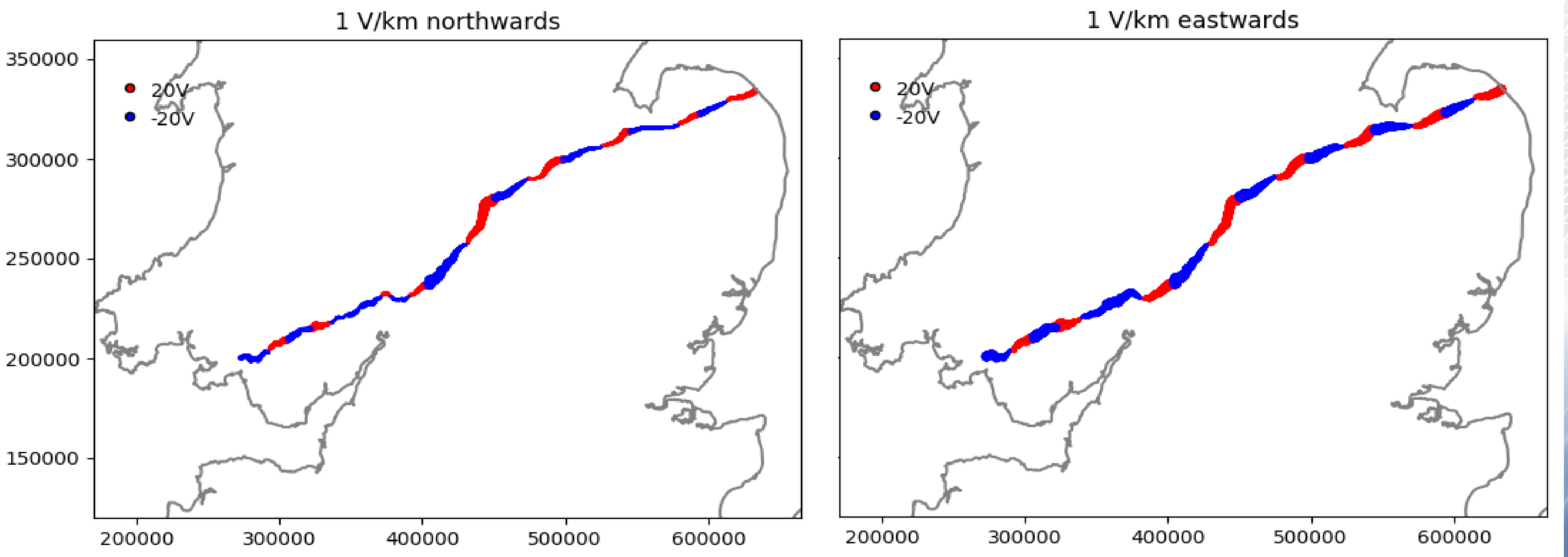
England/Wales example

- Long ~E-W lines
- Stars indicate ends of lines
- Black triangles are junctions in the line



England/Wales example

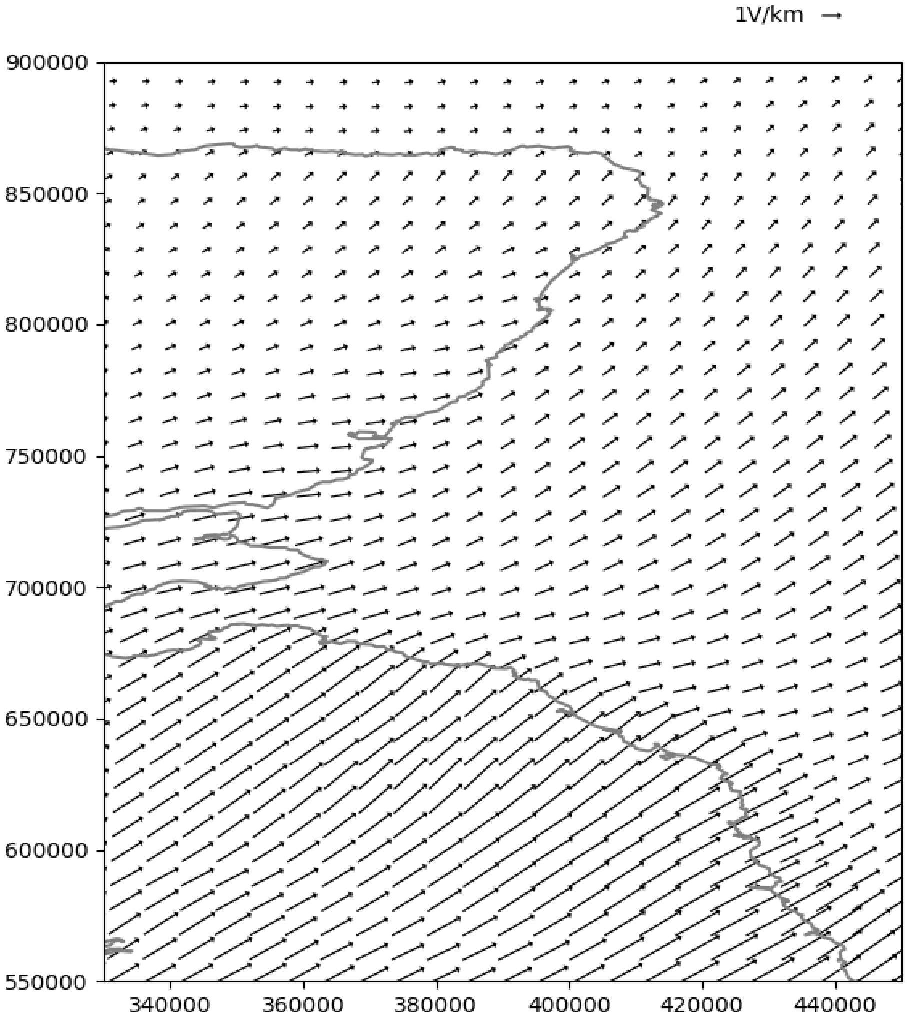
Eastward |max|: 24.65 V
Northwards |max|: 22.45 V

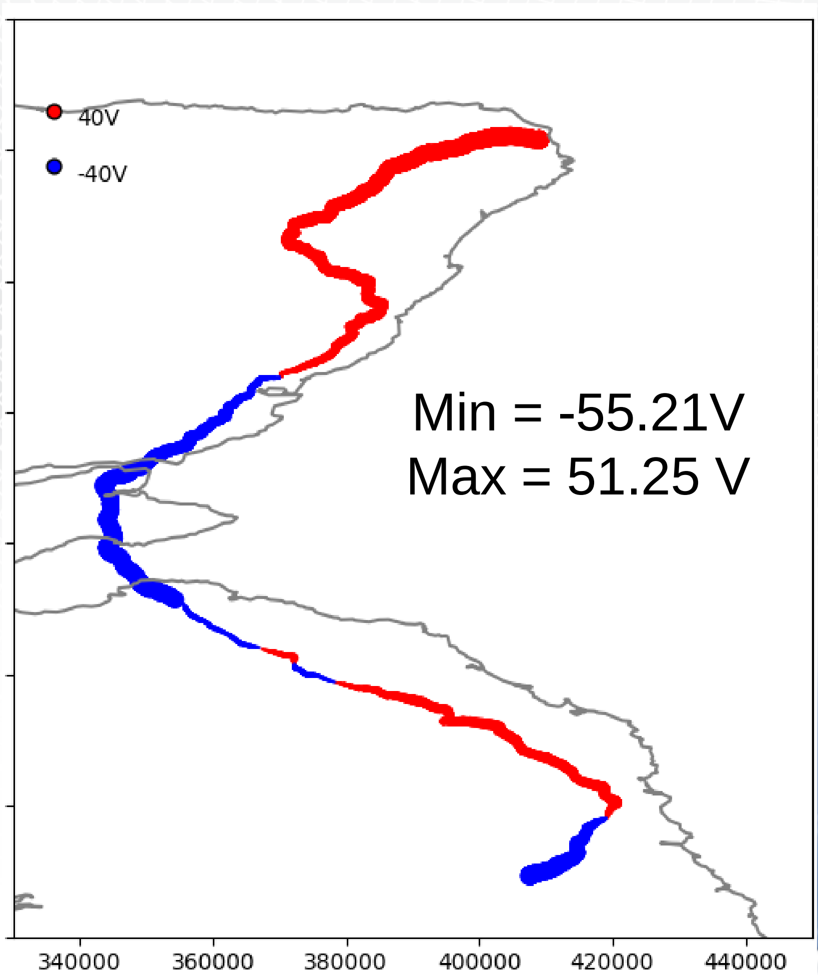


Marker size scaled by area

More realistic E-field - Scotland

- Snapshot during the March 1989 storm – 21:46 on 13th March





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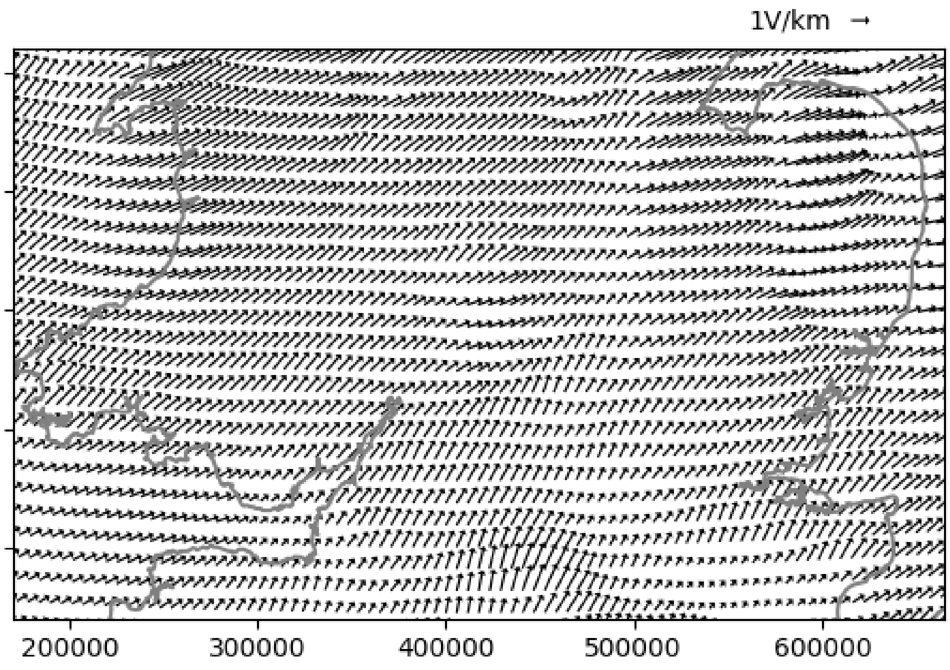

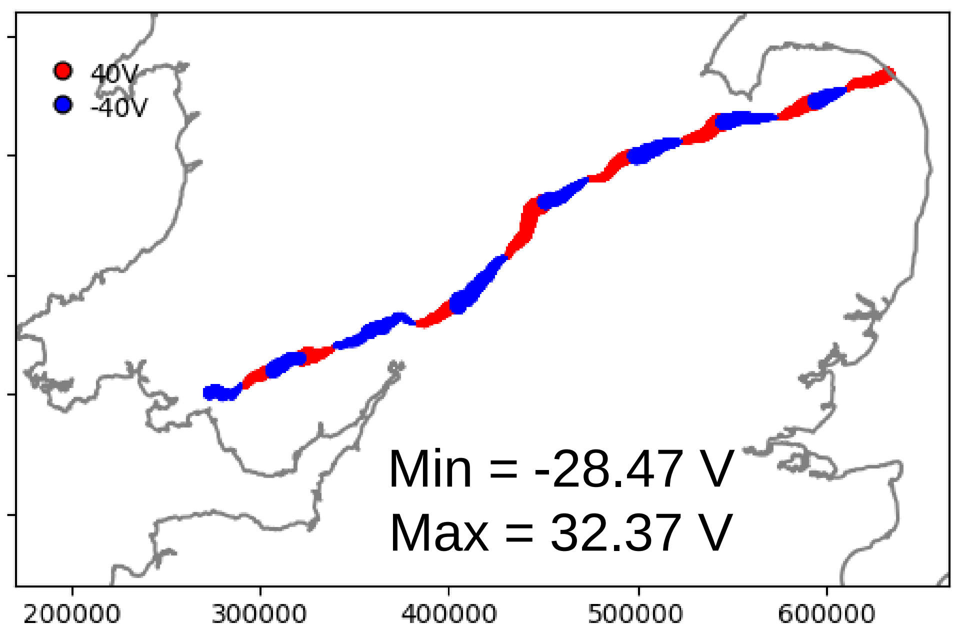

Summary

- Now have capability to model Pipe-to-soil potentials in the UK
- Still missing some important information
  - Pipeline resistivity
  - Coating conductance
  - Pipe thickness
  - How/whether sections of pipe are electrically connected
- Next steps
  - Complete the network
  - Simulate a full storm
  - Test the assumptions
  - Go to National Grid with this demonstration