Enhancing electricity network Resilience to extreme windstorms in the UK

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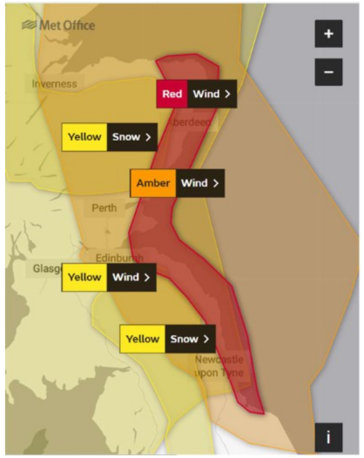
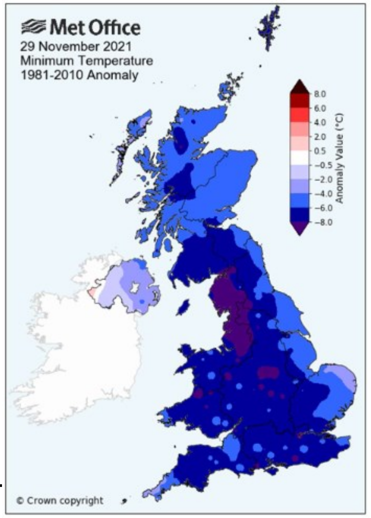
CS-NOW
Climate services for a net zero resilient world

Storm Arwen: Large impact on Electricity Networks

Extreme Winds from Northeast

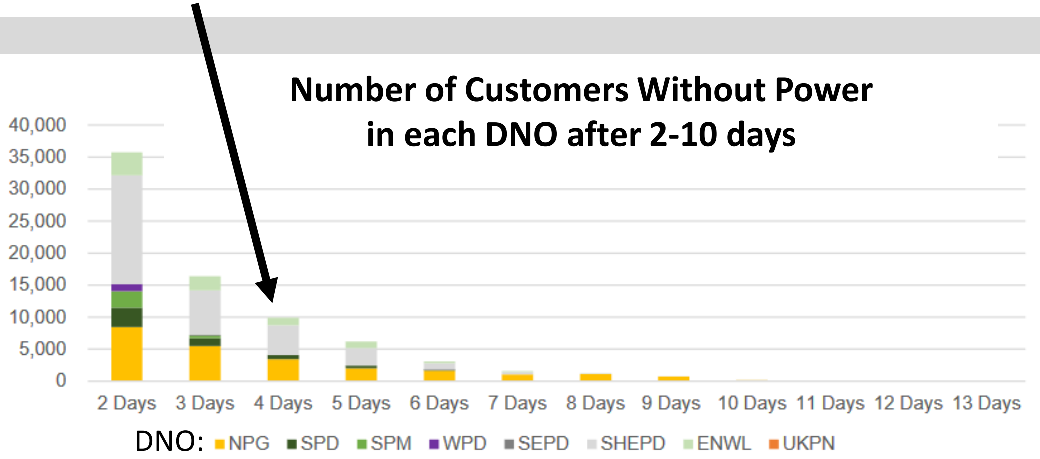


Extremely Cold Conditions

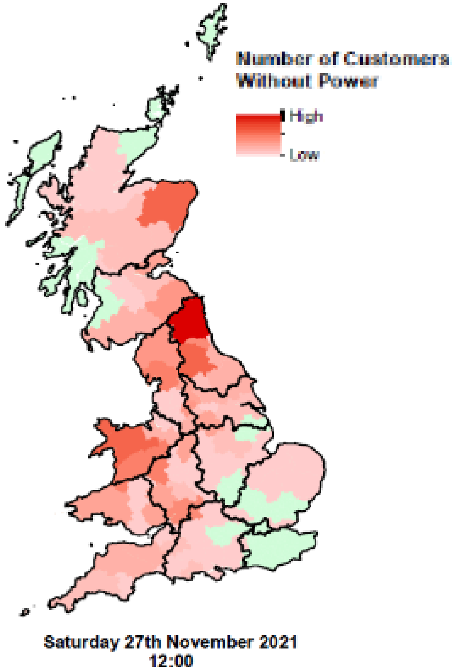


Credit: Met Office

- **> 1 million customers lost power across the UK**
  - > 40 thousand for more 4 days in freezing conditions



Credit: DESNZ



Credit: Ofgem

- **Persistent strong winds and cold conditions hampered recovery**
  - Unsafe weather conditions for event response teams
  - Roads blocked/icy, preventing access to remote sites

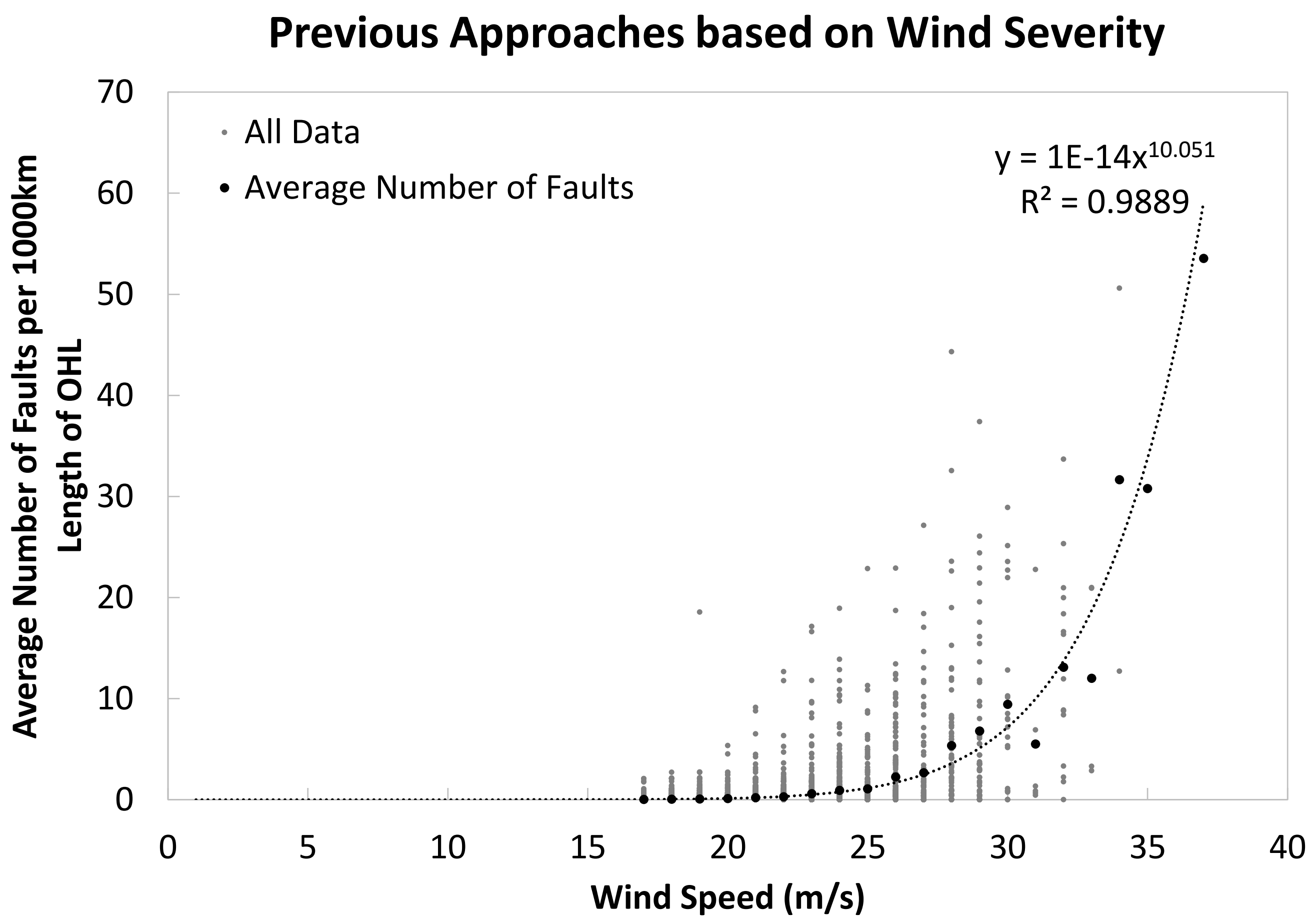
How do we mitigate risk from storms like Arwen?

Enhancing resilience can be split into two approaches:

1. **Improved event response**
   - Can be aided by better forecasting of impacts
   - We have used NaFIRs data from National Grid to demonstrate this potential

2. **Physical interventions**
   - Many options with different barriers (e.g. cost/benefit)
   - We have identified best practice within one-to-one interviews with Distribution Network Operators (DNOs)

Improve Forecasting of Impacts



Large spread in number of faults that occur for a maximum wind speed in a windstorm

- Indication of other contributing factors

Reference:

Dunn, S., Wilkinson, S., Alderson, D., Fowler, H. & Galasso, C. (2017) "Fragility Curves for Assessing the Resilience of Electricity Networks, constructed from an Extensive Fault Database". Natural Hazards Review. DOI: 10.1061/(ASCE)NH.1527-6996.0000267.

Improve Forecasting of Impacts

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Trees falling (windthrow) on overhead lines accounted for 32% of faults in Storm Arwen

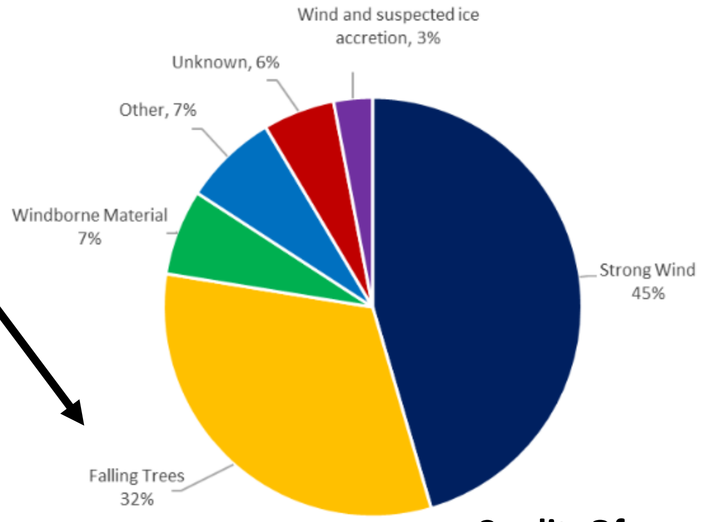
Improvements gained by considering 3 drivers of falling trees:

1. Rainfall preconditions (month prior to windstorm)
   - Trees uproot more easily in wet soils

2. Direction of strongest winds in storm
   - Trees are more vulnerable to strong winds from unusual direction as roots anchor against prevailing wind direction

3. Season a storm occurs within
   - Trees catch wind more when in leaf during Summer and Autumn

Cause of Faults during Arwen



Credit: Ofgem

Credit: DESNZ

Data & Windstorm Event Metrics

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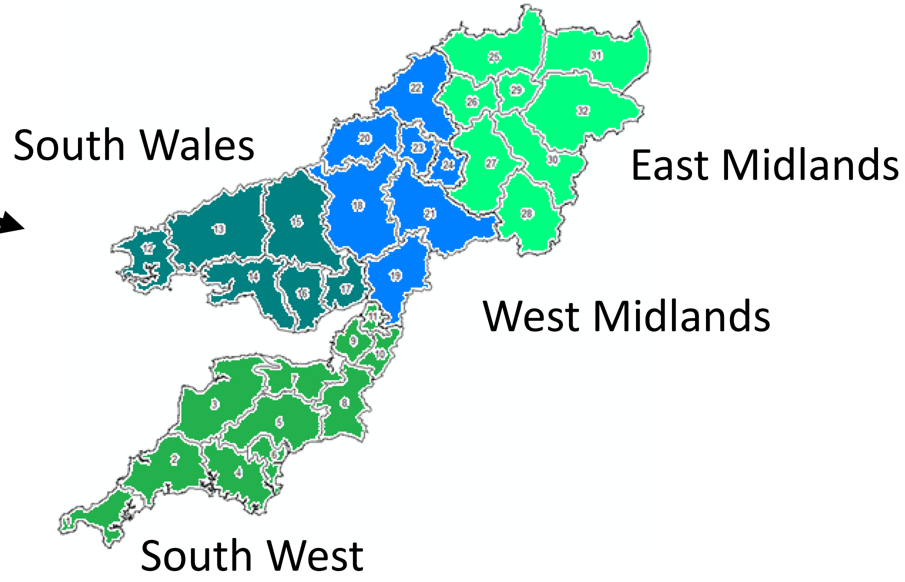
Data – Metrics extracted for individual windstorms (2005-2018):

- Fault data from NaFIRs:
- Meteorological data from ERA5 Reanalysis
- Analysis carried out for 4 National grid regions

Windstorm metrics

- Impact metric:
  - Number of faults during storm across a region (e.g. South Wales)
- Meteorological metrics:
  - Maximum wind speed across region
  - Rainfall total from preceding 30 days (averaged across region)
  - Wind direction at time of maximum wind speed
  - Season storm occurred within

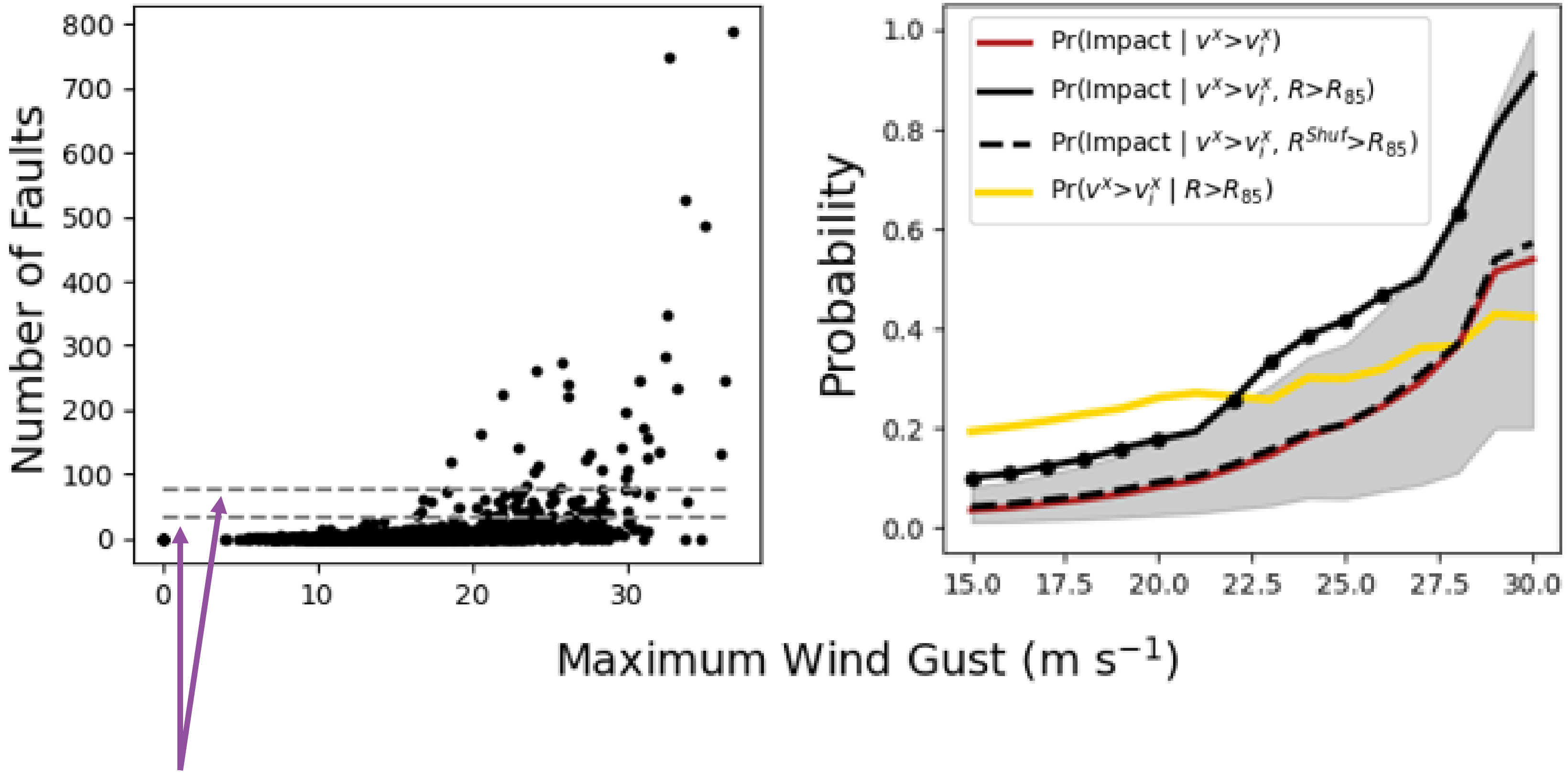
National Grid Management Areas



Influence of Rainfall Preconditioning (South West)

Wind Speed vs. # Faults

Prob. of Faults > 95th percentile



95th and 98th percentiles of # Faults in Windstorm

Prob. of impacts given **wind > 25ms^{-1} increases from 0.18 (wind only)** to **0.4 when windstorm follows wet conditions**

Increased probability cannot be achieved by random chance

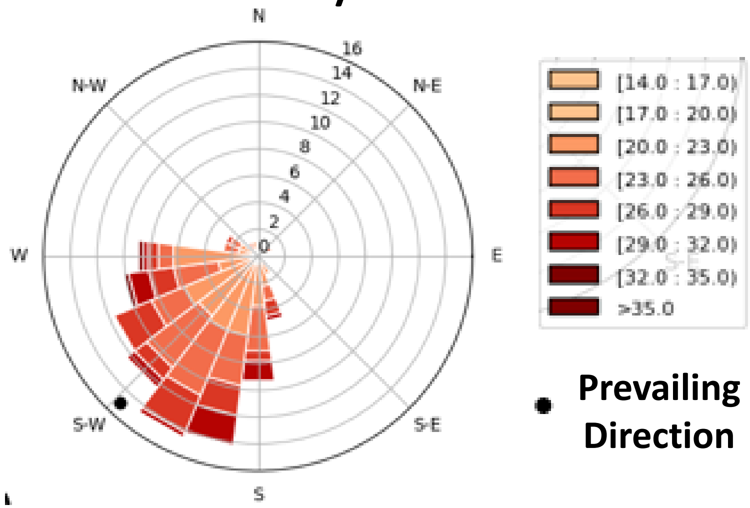
- Black line outside uncertainty interval (shaded region) constructing by bootstrapping (randomly shuffling of precip in annual blocks)

Positive dependence between wind and rainfall may also contribute to increased probability

- Potential confounding factor

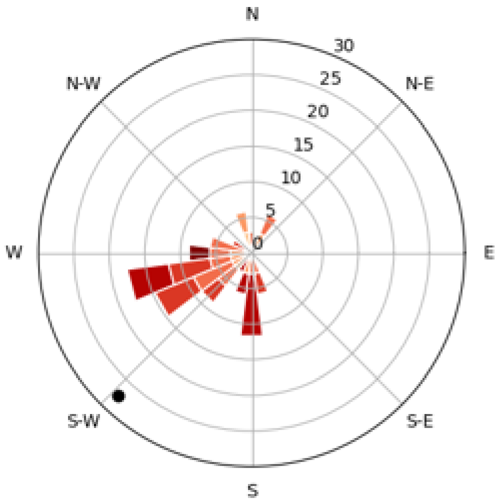
Influence of Wind Direction (West Midlands)

Winds > 15 m/s



● **Prevailing Direction**

 # Faults > 98th percentile

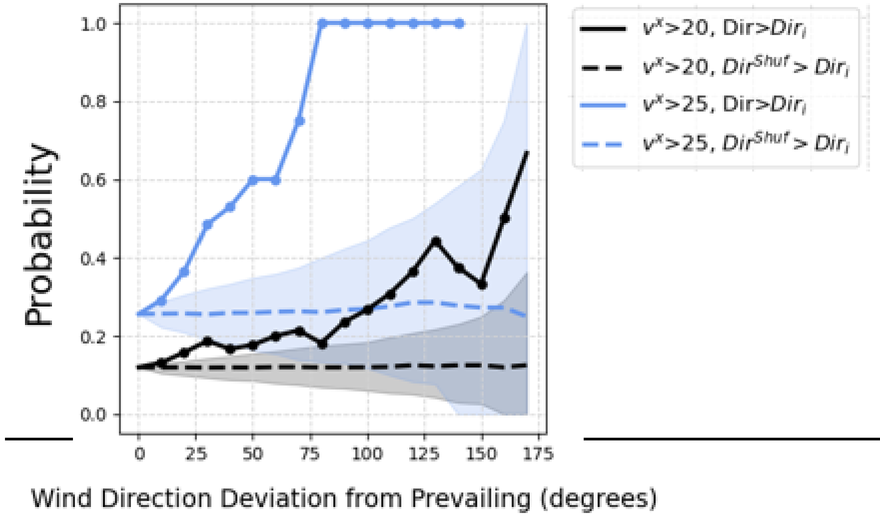


Prevailing winds are south westerly

Disproportionately high frequency of impactful events from west, south and northeast

- Very few impactful events from prevailing direction

Prob. of Faults > 98th percentile | wind > 20ms^{-1} , wind > 25 ms^{-1}



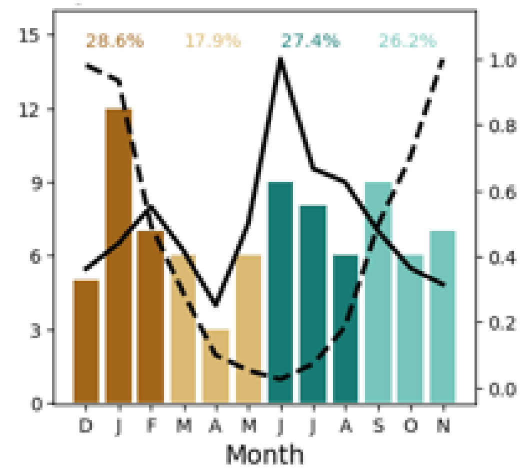
Probability of impact increases as wind direction deviates from prevailing direction

- Highest probability for winds from northeast direction

Increased probabilities cannot be achieved by random chance (solid lines outside shaded regions)

Influence of Season (East Midlands)

Seasonality of Events with # Faults > 95th Percentile

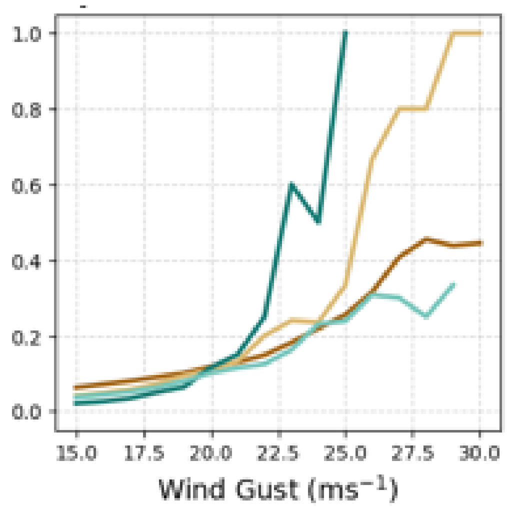


Opposite seasonality in probabilities (wind vs impact)

- Probability of wind > 25 ms^{-1} (dashed line) peaks in winter months
- Probability of impact when wind > 25 ms^{-1} (solid line) peaks in summer months

High frequency of high fault events in summer/late autumn potentially due to leaf cover

Seasonality of Probability for all wind speeds



Probabilities increase with increasing wind speed in all seasons, though rate of increase is highest in summer when trees are in leaf

Note: size of impact is generally smaller in summer due to smaller windstorm footprints

Longer growing seasons due to rising temperatures may increase wind-related risk in future

Improved predictability (result from West Midlands)

Predictability assessed using a logistic regression model in a cross-validation framework:

- When predicting the prob. of events in a given year, those events are excluded when fitting the model

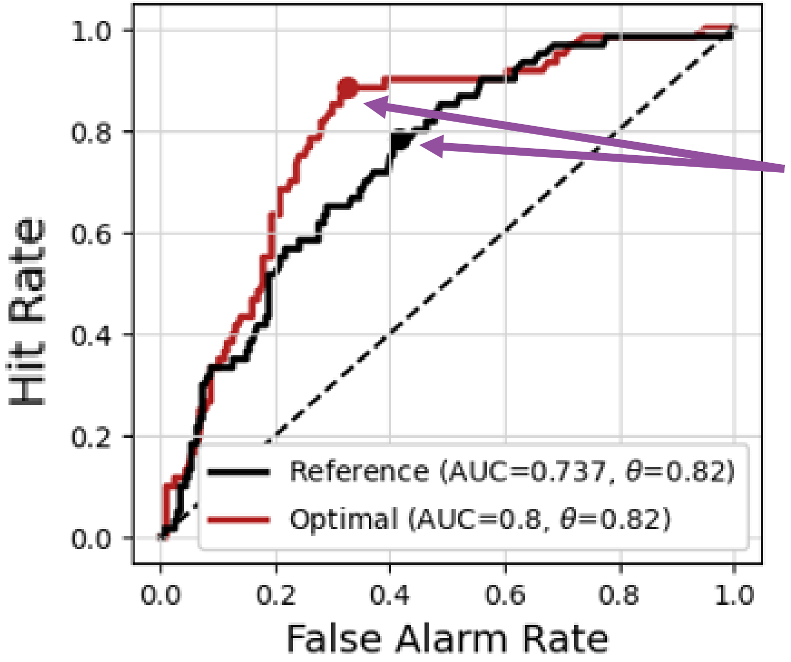
Performance assessed using ROC curves and area under curve (AUC) statistic:

- Model predicts prob. of event having # Faults > 95th percentile

Model with additional variables improves prediction compared to **model based on wind alone:**

- AUC increases from **0.737** to **0.8**
- Given a threshold probability to predict event:
  - Increased hit rate from **0.78** to **0.88**
  - Decreased false alarm rate from **0.43** to **0.33**

ROC curves (Predicting



Threshold probability that maximises difference between hit rate and false alarm rate

Black line: model based on wind only

Red line: model based on wind along with the additional variables

Summary of Improved Predictability

Predictability of extreme impacts can be improved with inclusion of variables that influence windthrow

- Improvements found in all four regions, but magnitude of improvement varies region to region
- Further improvements may be obtained from different model types (e.g. machine learning approaches)
- Improved predictability may help guide event response teams in extreme events (e.g. positioning responders in ideal locations prior to impact), particularly if similar results may be obtained on a local scale
- Results highlight need for climate risk assessments to include such additional variables when assessing wind risk (not currently done)

Improving resilience may be obtained via improve event response alongside other physical interventions

Climate Resilience Strategies identified with DNOs

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Resilience planning is carried out within a synergistic approach:

- Considered within overall investment strategy of the company
- Must optimise across multiple drivers of investment:
    - Increasing capacity to manage higher demands
    - Health, condition and age of assets
    - Criticality of asset - how many people would lose power if the asset failed?
    - Risk of asset to different types of extreme weather in current/future climate
        - e.g. flooding risk for one substation serving > 10,000 customers may be greater than wind risk to one area of overhead line network serving 100s
    - Cost/benefit

Options for enhancing resilience to extreme wind:

- Vegetation management (very expensive, sometimes controversial to cut down trees)
- Undergrounding of cables (extremely expensive and less beneficial compared to building flood defences)
- Building redundancy into network (e.g. rerouting electricity along alternative line if one fails)
- **Fixing asset relatively quickly in an extreme event:** Improved event response may be a better option to a physical intervention that is very costly and less beneficial

Thanks for your attention

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Questions?

- Please feel free to email Colin Manning (colin.manning@newcastle.ac.uk)