Process-based Modeling Approaches for Attribution Science: Challenges and Opportunities

Panel 2: "Small scale/local" modeling needs and opportunities for attribution science

NAESM Information Gathering Session, 11 March 2025

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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Three opportunities/challenges

1. CANARI Large Ensemble and regional modelling
2. Blocking in GCMs
3. Extreme/very extreme heatwaves

CANARI: Climate Change in the Arctic-North Atlantic Region and Impacts on the UK

PI: Len Shaffrey

A NERC NC Multi-Centre Science Programme

- CANARI PI: Len Shaffrey (NCAS)
- Apr 2022 – Mar 2027
- Further info: canari.ac.uk

Aim: Advance understanding of the impacts on the UK arising from climate variability and change in the Arctic-North Atlantic region, with a focus on extreme weather and the potential for rapid and disruptive change.

- Inland flooding
- High temperatures and health
- Drought and water supply
- Extreme winds and wind damage
- Changes in UK Shelf Seas

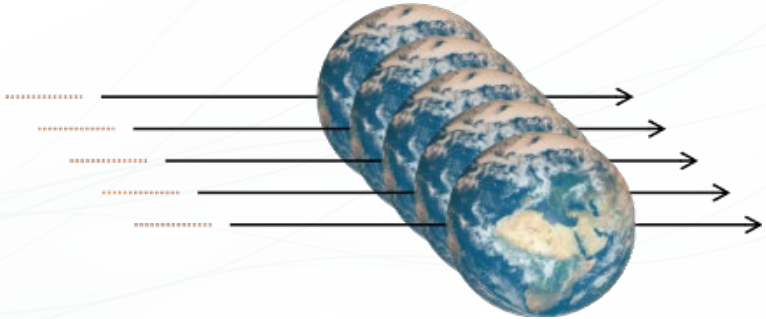
National Centre for Atmospheric Science NATURAL ENVIRONMENT RESEARCH COUNCIL
UK Centre for Ecology & Hydrology
National Oceanography Centre
BGS British Geological Survey
National Centre for Earth Observation NATURAL ENVIRONMENT RESEARCH COUNCIL
British Antarctic Survey NATURAL ENVIRONMENT RESEARCH COUNCIL
cpom Centre for Polar Observation and Modelling Natural Environment Research Council
Met Office
UKRI Natural Environment Research Council

CANARI Large Ensemble

Model
- HadGEM3-GC3.1 (the UK Met Office CMIP6 model)
- N216-ORCA0.25 (~60 km atmosphere, ¼° ocean)

Experiments
- CMIP6 historical (1950 – 2014)
- CMIP6 SSP3-7.0 scenario (2015 – 2100)

40 members
- Hybrid initialisation
- 8 macro ICs x 5 micro perturbations



Output
- 6000 years – "CMIP-like"
- RCM boundary conditions for a wide range of CORDEX-like domains

Production completed Dec 2024:
https://canari.ac.uk/resources_new/tools

CANARI Regional Model: Experimental Design

Identify the most extreme UK storms in the CANARI Large Ensemble

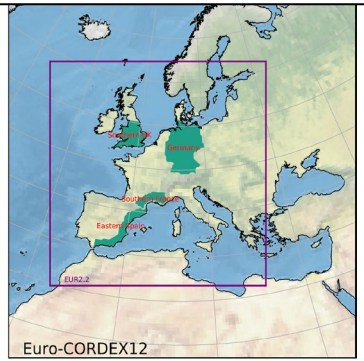
Downscale with the Met Office 2.2km regional model (atmosphere only, within a 12km nested domain)

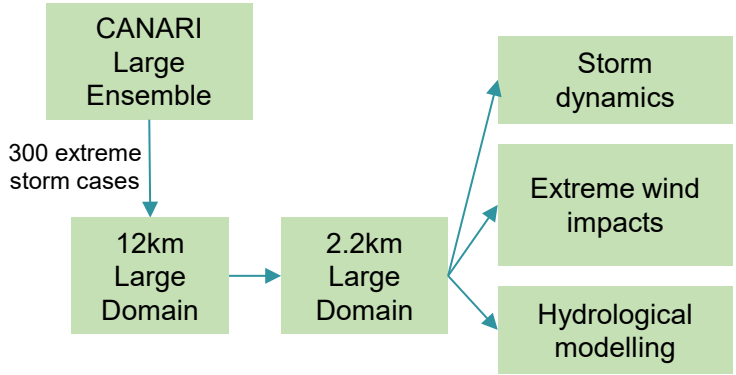
- Start from recent monthly start dump; drive with 6 hourly LBCs, daily SST and sea ice
- Include scenario-based GHGs, ozone, veg fraction, aerosols

Targets: 50 present-day and 50 future storms for each of

- Extreme winds
- Extreme precipitation associated with
  - Extratropical cyclones (winter frontal rainfall)
  - Slow-moving cut-off lows (summer convective rainfall)

Domains for nested 12km and 2.2km models (Chan et al. 2020)





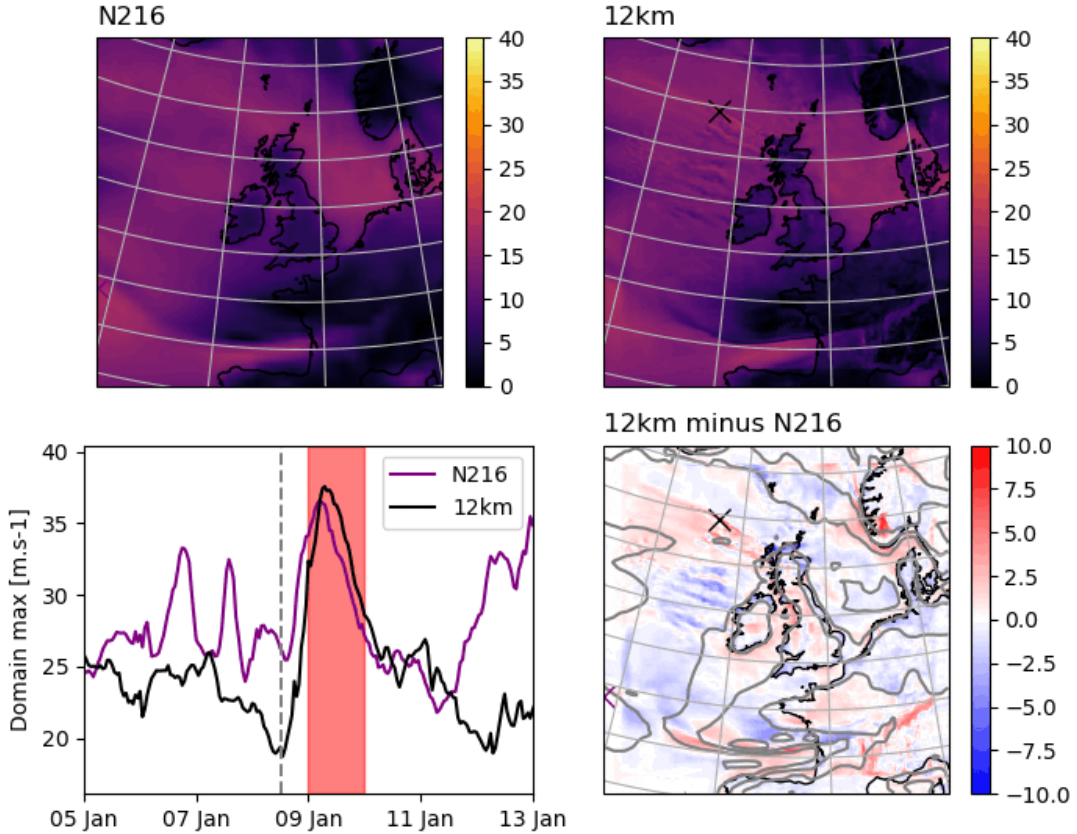
Ben Harvey, Oscar Martínez-Alvarado

Illustration

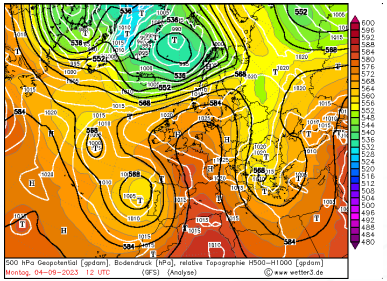
- The most intense UK windstorm in 2,600 years of LE data simulation
- Cold conveyor belt is more intense and sharper in the 12km RCM than the GCM

Choice of domain will be made from a sample of test cases:

- Balance between faithfully reproducing the storm track/intensity and capturing as much of the storm development at high resolution as possible



Atmospheric blocking in GCMs: Are we getting “there”?



We are getting there!

Over the last ~30 years, blocking performance in climate and weather models has slowly improved, due to parameterisation development and increases in resolution, in the atmosphere and ocean.

Some climate models are now ‘not so bad’.

Multi-model projections agree on a decline in blocking frequency, although it is fairly small compared to variability.

We are not there yet!

Models continue to underestimate blocking and intrinsic atmospheric biases remain important.

Spread between models is large. (Larger than the bias of the best models.)

Model performance is not always consistent (e.g. for winter and summer) and is difficult to engineer.

Model agreement vs. confidence …

Recording of this talk and many others at:
CLIVAR Workshop (March 2024): Blocking and Extreme Weather in a Changing Climate

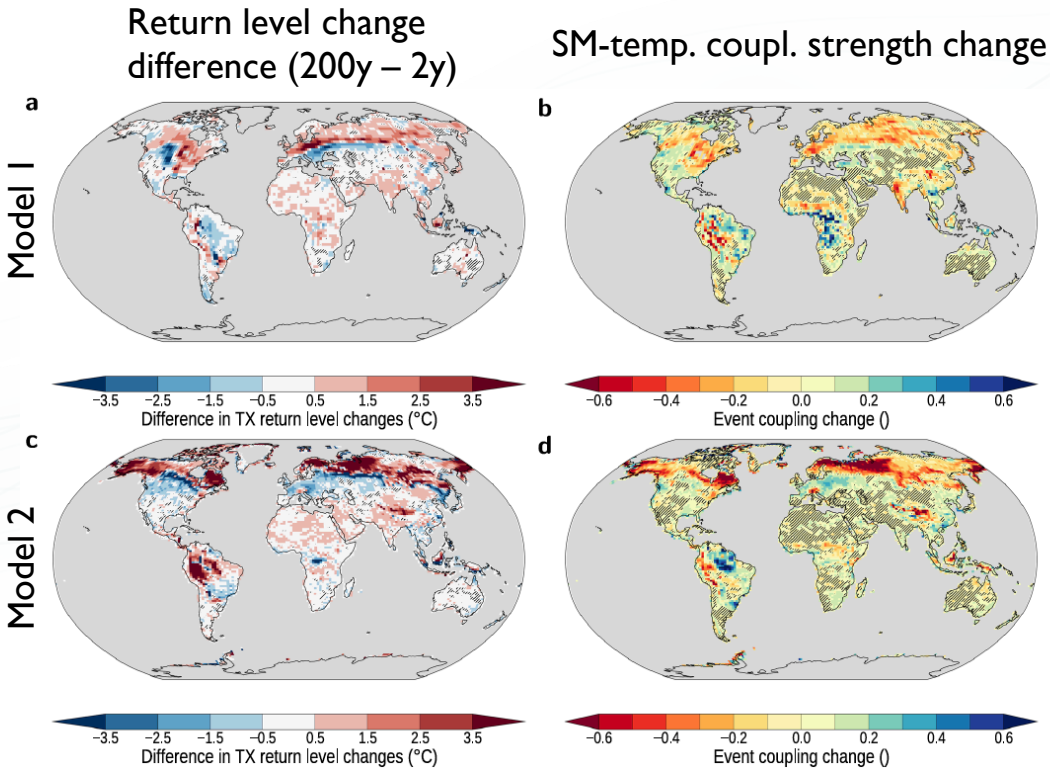
“Extreme” vs. “Very Extreme” heatwaves

Compare simulated change in daily max. temperature:

a) 2y return level change

b) 200y return level change

- These are different in many areas.
- Related to land-atmosphere interactions in the midlatitudes.
- Seen in different models, but patterns disagree between models.



Maraun et al., Nat. Commun., 2025