Forecast-based attribution

Nick Leach, Shirin Ermis, Antje Weisheimer, Tim Palmer, Myles Allen (and others)

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NATURAL ENVIRONMENT RESEARCH COUNCIL

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The **why**

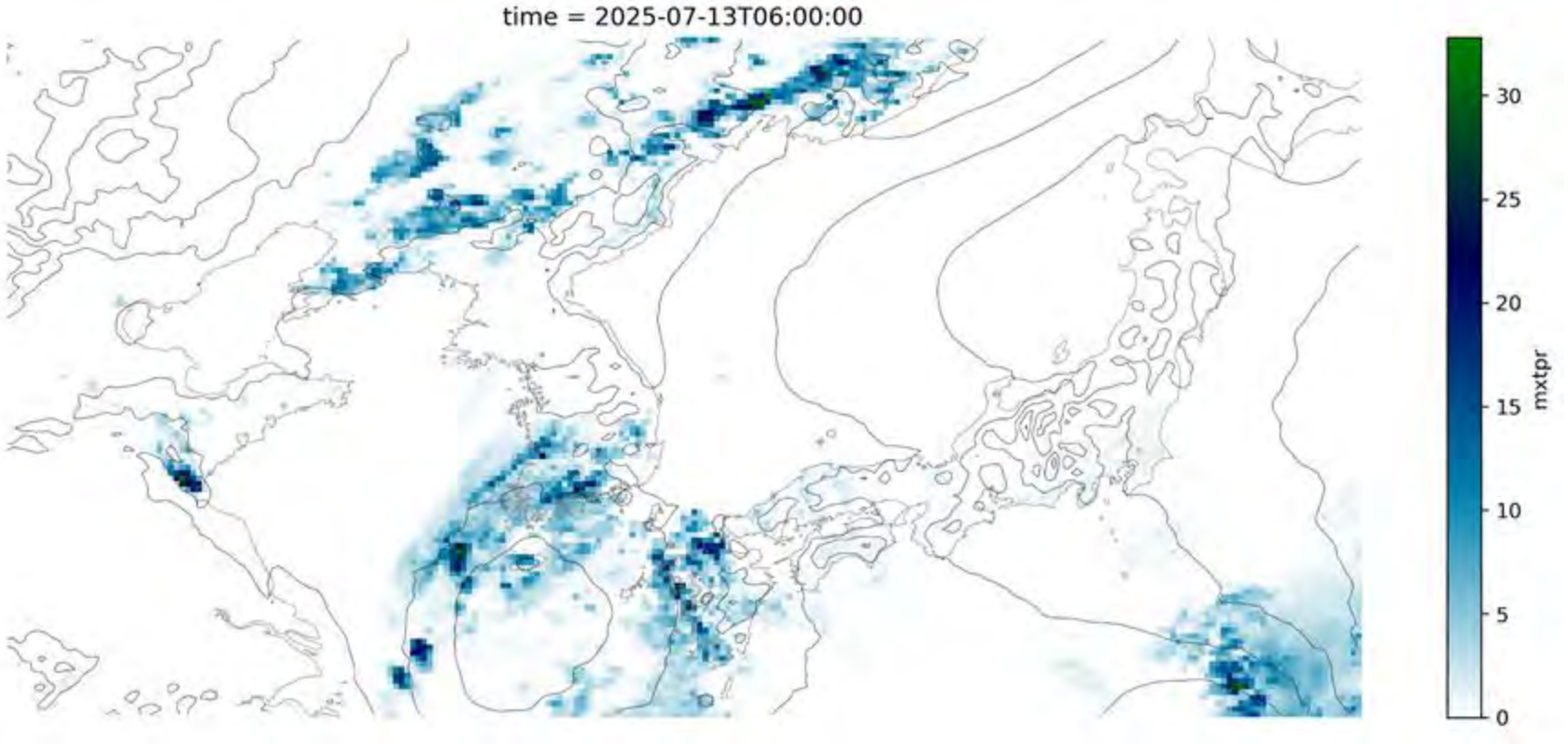
Why use operational forecasts for extreme weather attribution?

- Put the **weather** first
  - Predictability
- Model understanding
  - **Reliability**
- Process understanding
- Impacts
- HiRes transient runs aren’t there yet
- (Operational attribution?)

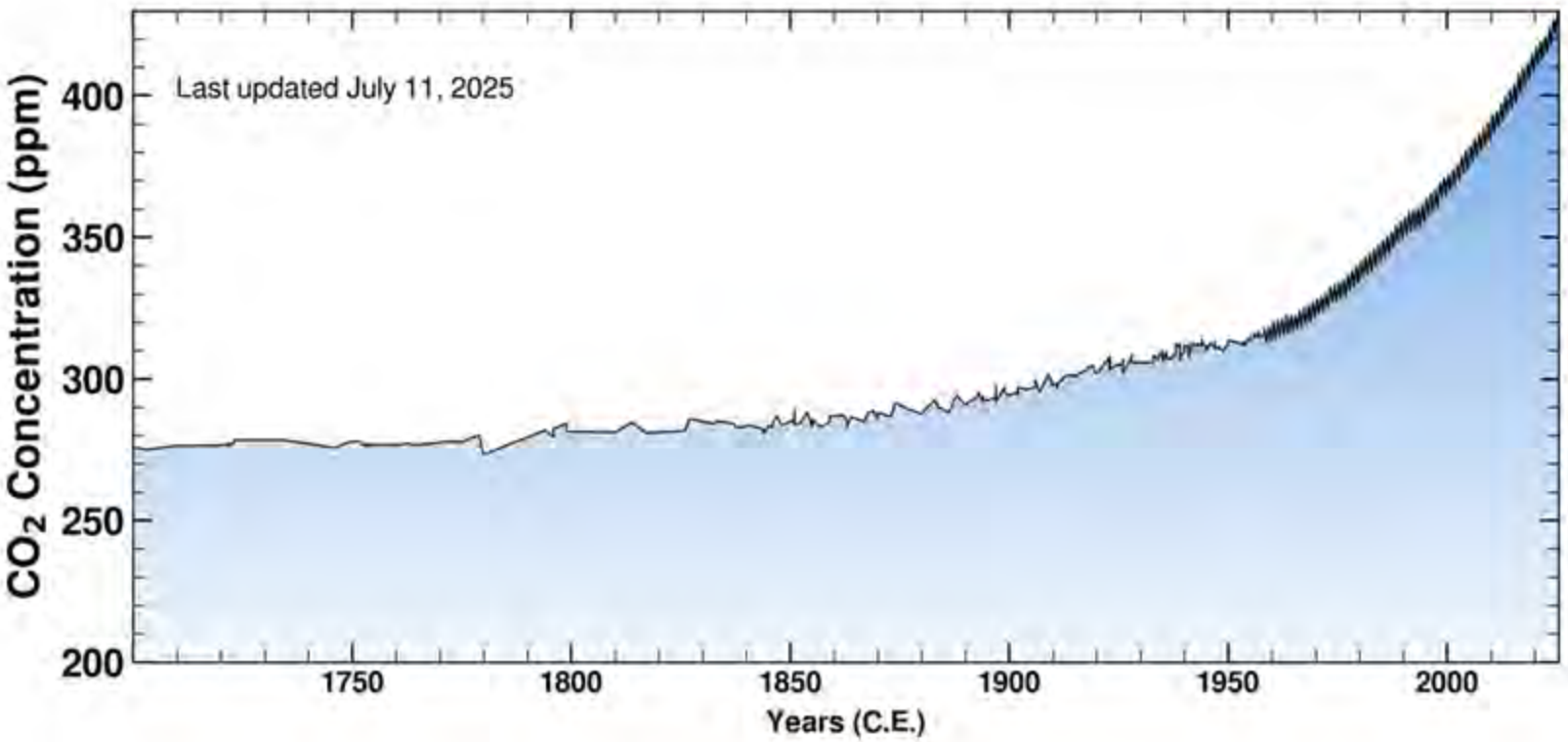
The **what**

What's the *current* experiment design?

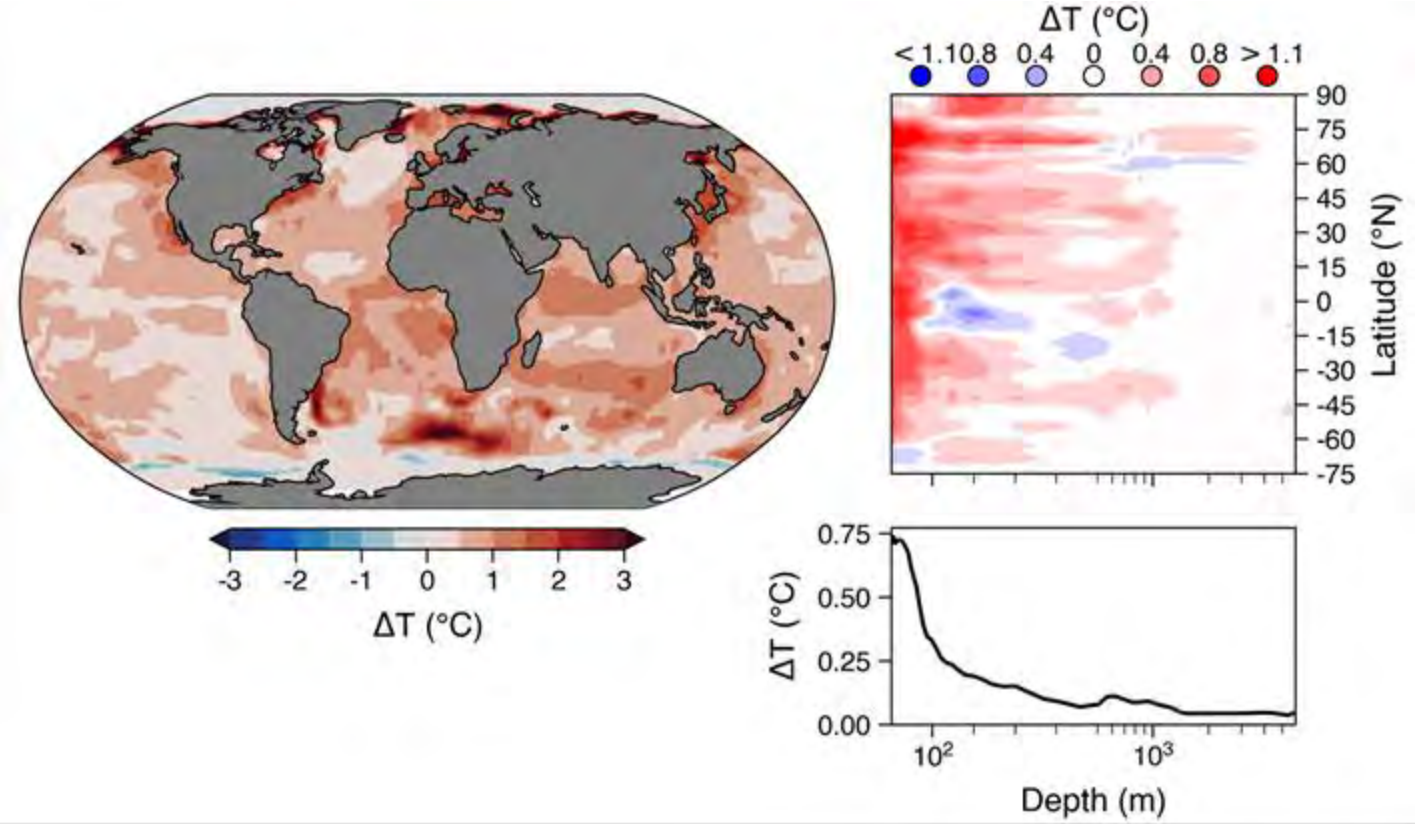
- Operational NWP model
- Perturbed IC / BC counterfactuals



Operational forecast model - ECMWF IFS



Perturbed CO_2

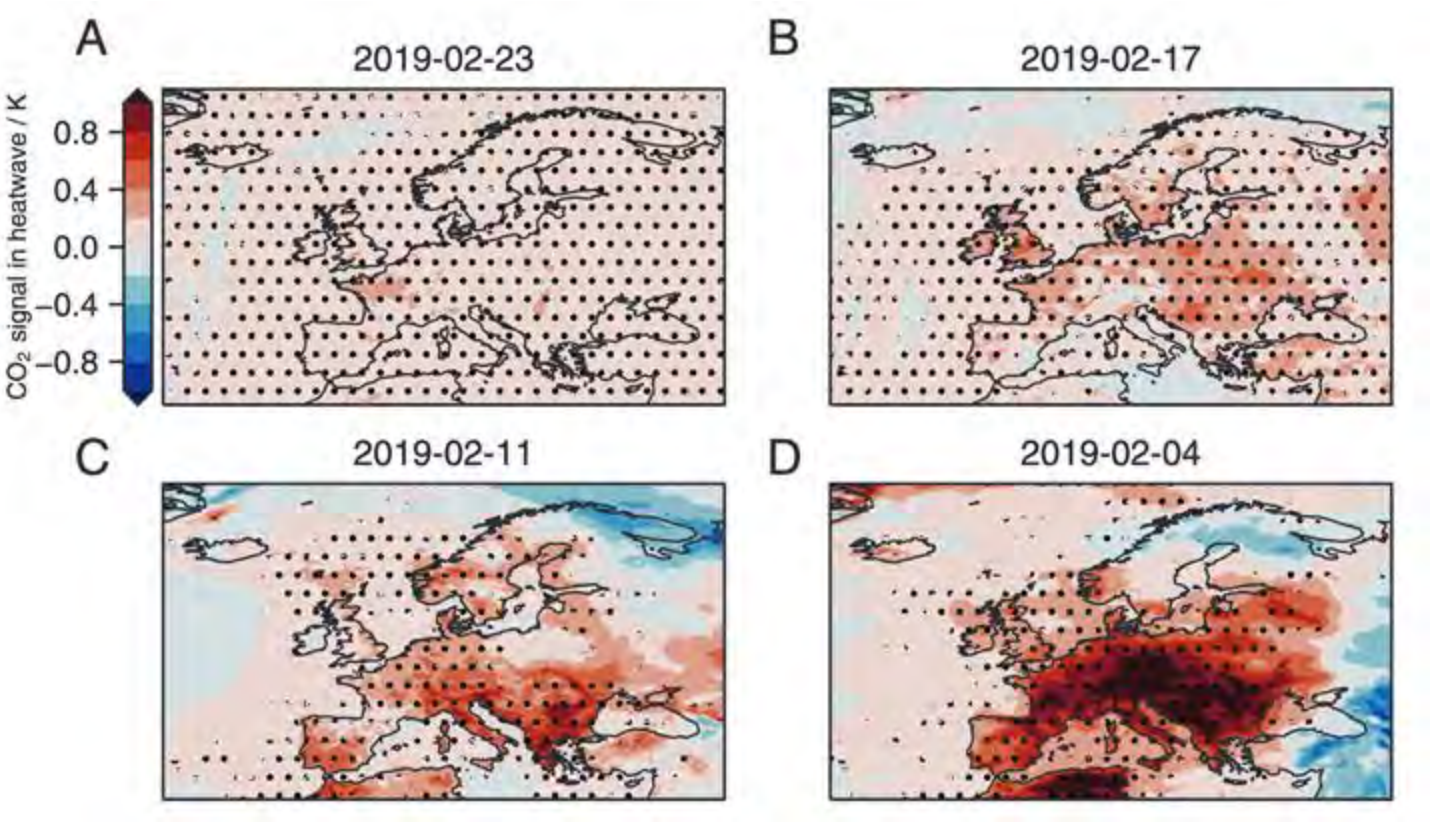


Adjusting the ocean state

Case studies

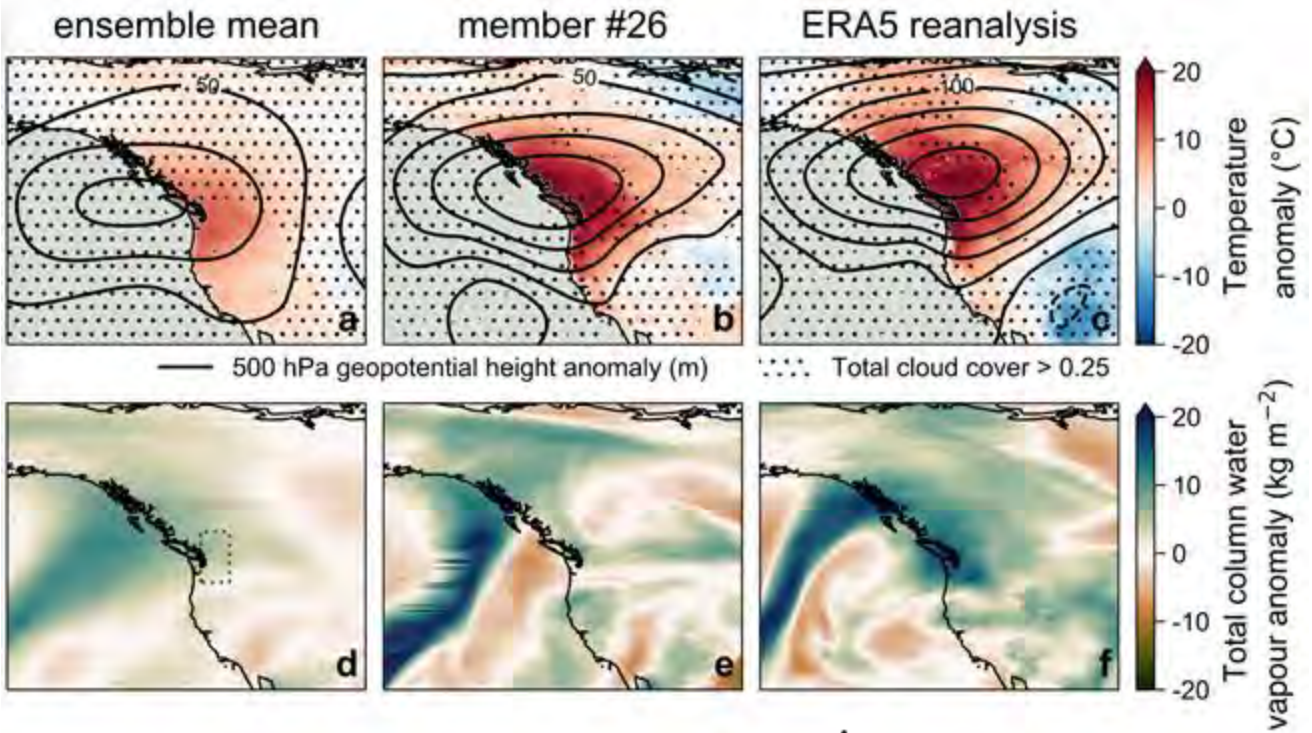
Events of opportunity

- UK winter heatwave (direct CO2)
- PNW heatwave
- UK storm
- Pakistan flooding



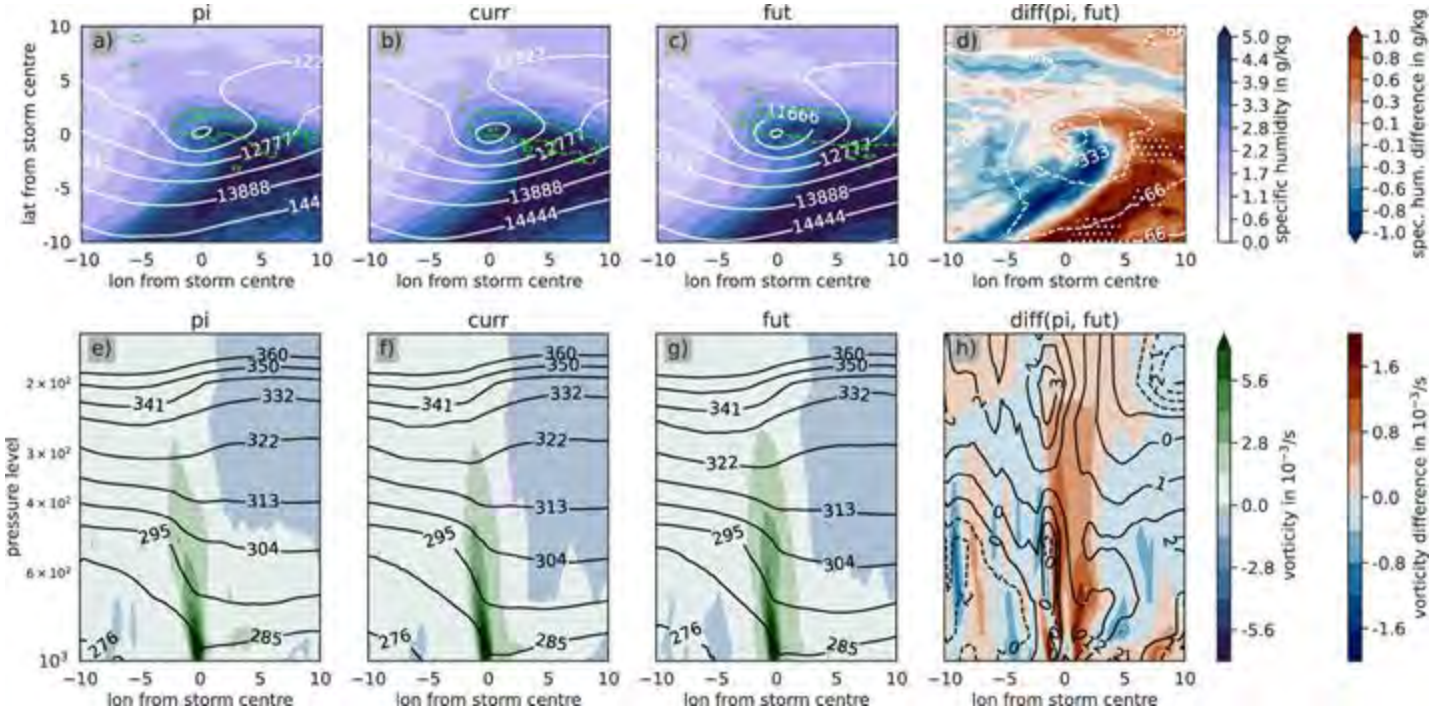
Where we started...

Leach, Nicholas J., Antje Weisheimer, Myles R. Allen, and Tim Palmer. 'Forecast-Based Attribution of a Winter Heatwave within the Limit of Predictability'. Proceedings of the National Academy of Sciences 118, no. 49 (7 December 2021): e2112087118. https://doi.org/10.1073/pnas.2112087118.



Not *another* PNW Heatwave study

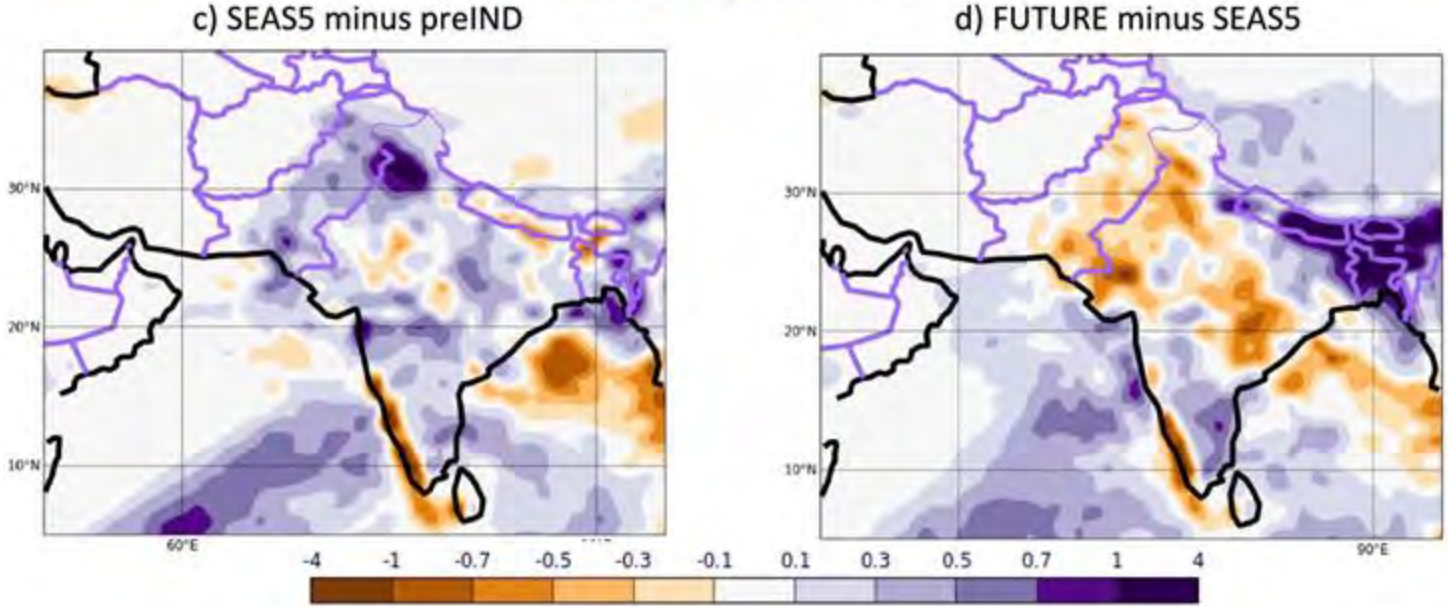
Leach, Nicholas J., Christopher D. Roberts, Matthias Aengenheyster, Daniel Heathcote, Dann M. Mitchell, Vikki Thompson, Tim Palmer, Antje Weisheimer, and Myles R. Allen. 'Heatwave Attribution Based on Reliable Operational Weather Forecasts'. Nature Communications 15, no. 1 (30 May 2024): 4530.



Something a bit more ~~interesting~~ dynamical?

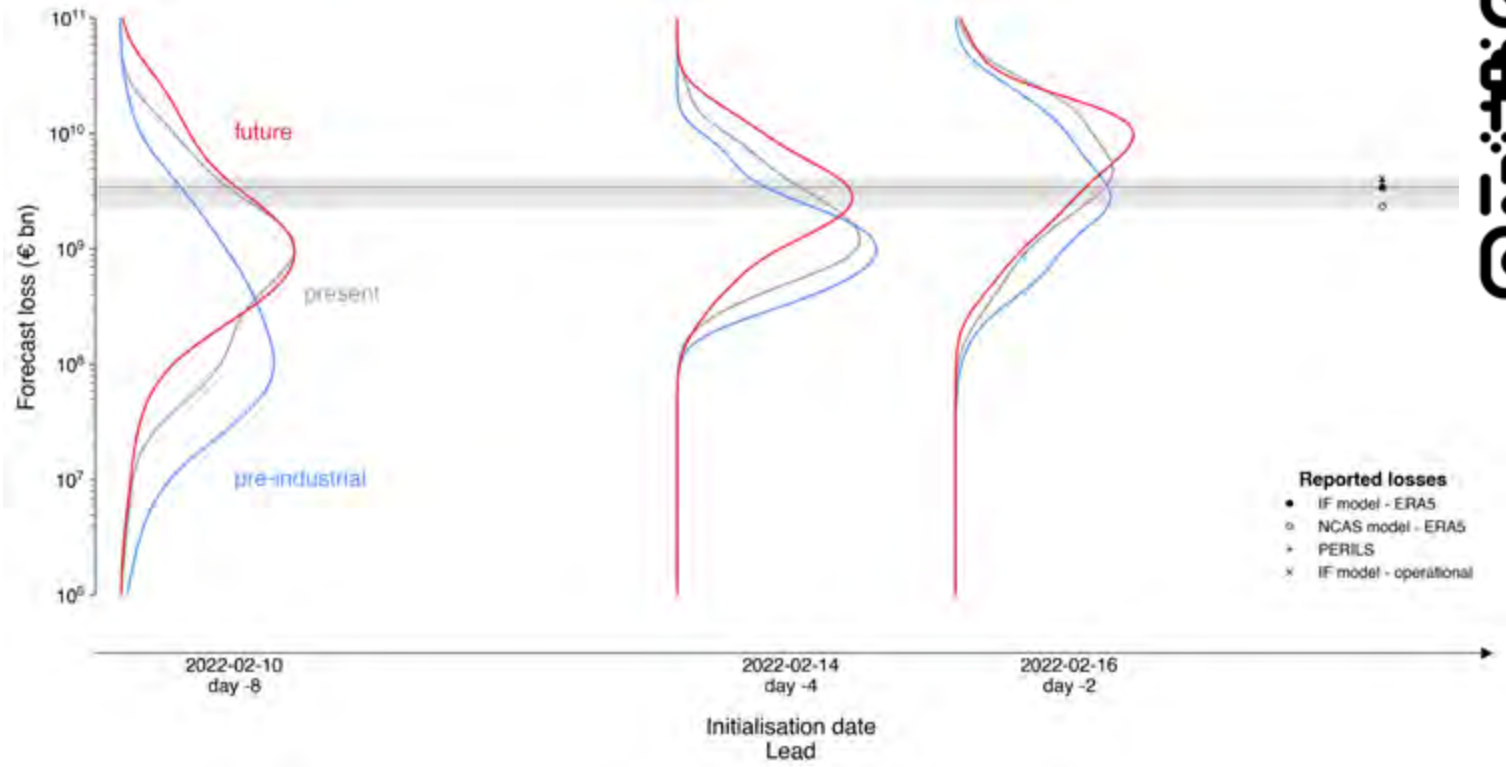
Ermis, Shirin, Nicholas J Leach, Fraser Charles Lott, Sarah Naomi Sparrow, and Antje Weisheimer. 'Event Attribution of a Midlatitude Windstorm Using Ensemble Weather Forecasts'. Environmental Research: Climate, 2024. https://doi.org/10.1088/2752-5295/ad4200.

Climate change signals: Precipitation



A change in timescale

Weisheimer, Antje, Tim N. Palmer, Nicholas J. Leach, Myles R. Allen, Christopher D. Roberts, and Muhammad Adnan Abid. 'CO2-Induced Climate Change Assessment for the Extreme 2022 Pakistan Rainfall Using Seasonal Forecasts'. Npj Climate and Atmospheric Science 8, no. 1 (9 July 2025): 262. https://doi.org/10.1038/s41612-025-



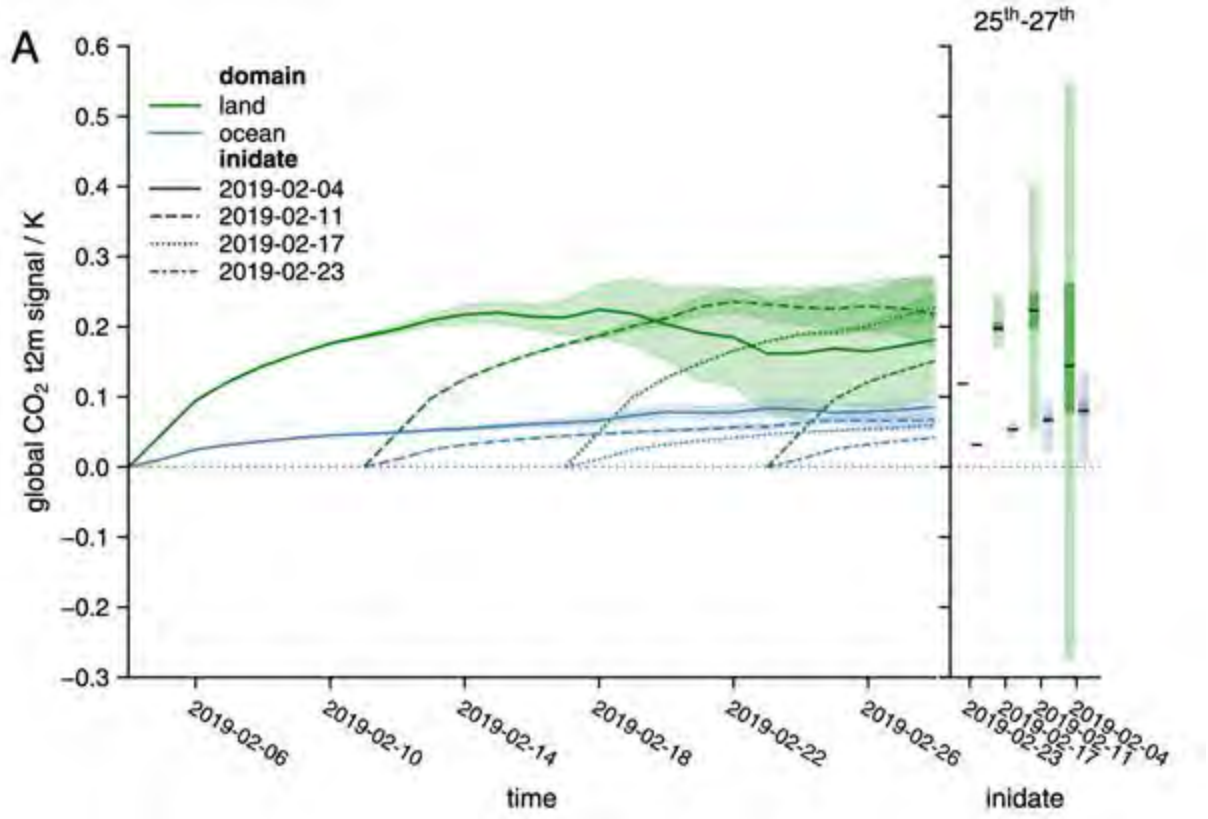
Impact attribution

Nicholas J. Leach, Shirin Ermis, Aidan Brocklehurst, et al. The perfect storm: human influence on the loss potential of Eunice-like cyclones. ESS Open Archive . June 26, 2025.

Limitations

Or future work, whichever you prefer

- Adjustment
- Forcings
- Model error
- Interpretation



Perturbing the atmosphere: it's complicated

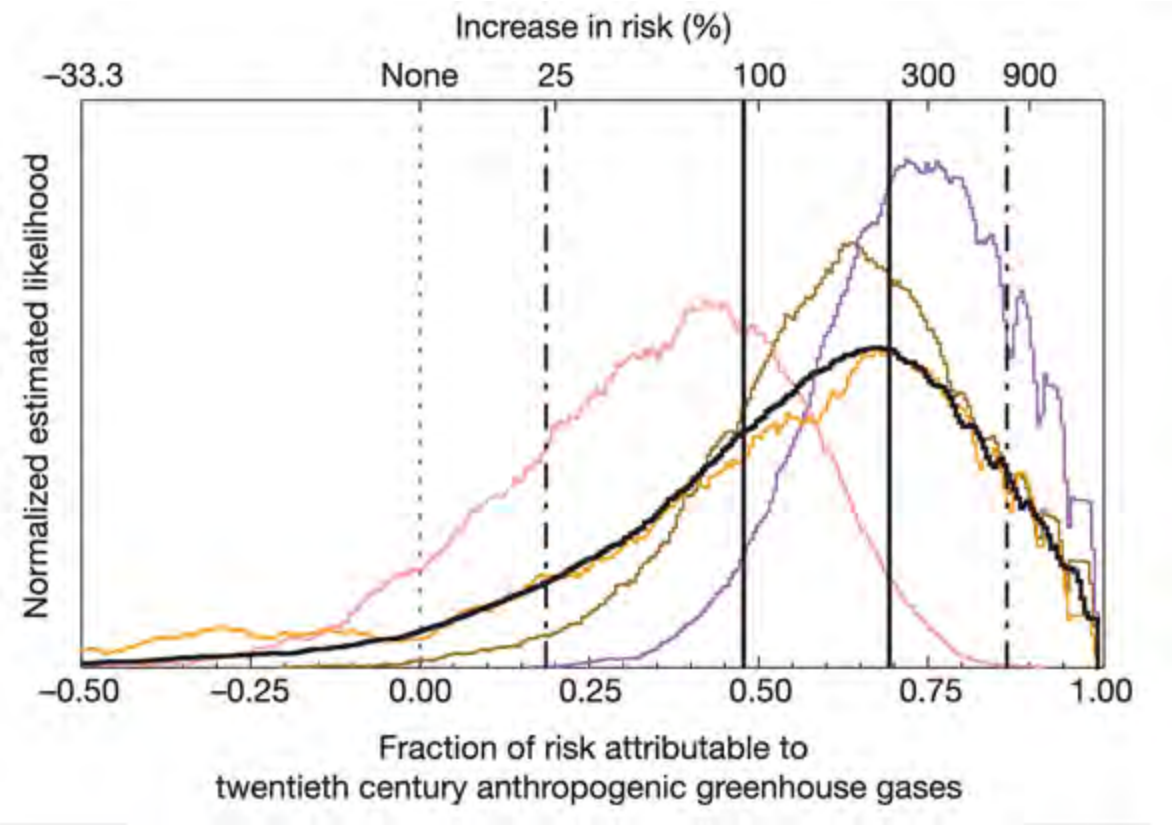
Aerosols must be included in climate risk assessments

Estimates of impending risk ignore a big player in regional change and climate extremes.

By Geeta G. Persad, Bjørn H. Samset & Laura J. Wilcox

Is CO_2 enough?

Persad, Geeta G., Bjørn H. Samset, and Laura J. Wilcox. 'Aerosols Must Be Included in Climate Risk Assessments'. Nature 611, no. 7937 (November 2022): 662–64. https://doi.org/10.1038/d41586-022-03763-9.



The need for multi-model

Pall, Pardeep, Tolu Aina, Dáithí A. Stone, Peter A. Stott, Toru Nozawa, Arno G. J. Hilberts, Dag Lohmann, and Myles R. Allen. 'Anthropogenic Greenhouse Gas Contribution to Flood Risk in England and Wales in Autumn 2000'. *Nature* 470, no. 7334 (February 2011): 382–85. https://doi.org/10.1038/nature09762.

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attribution methodology is conditioned on the component of the event that was predictable at forecast initialization, we show how

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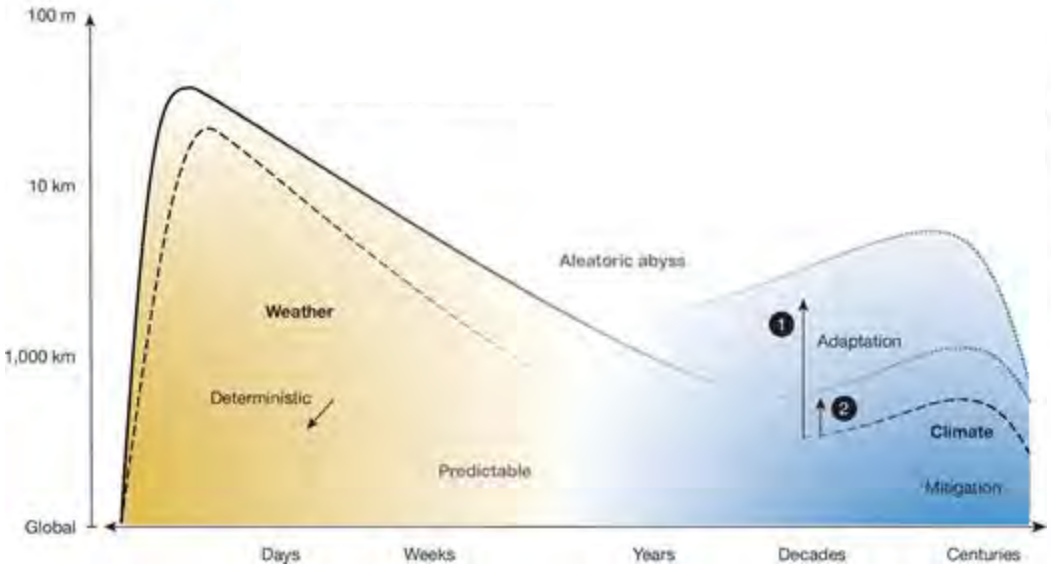
How to interpret results?

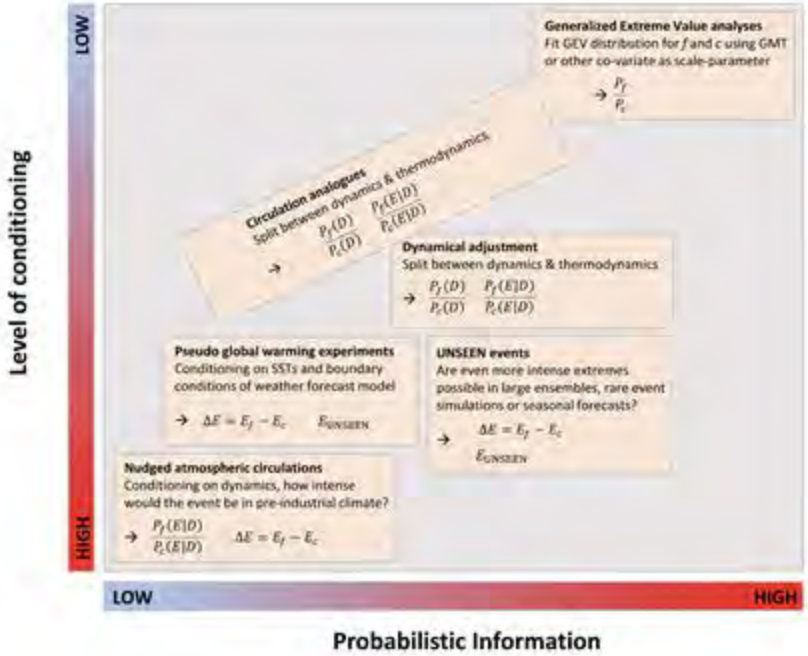
Leach, Nicholas J., Antje Weisheimer, Myles R. Allen, and Tim Palmer. 'Forecast-Based Attribution of a Winter Heatwave within the Limit of Predictability'. Proceedings of the National Academy of Sciences 118, no. 49 (7 December 2021): e2112087118. https://doi.org/10.1073/pnas.2112087118.

Opportunities

Or future work, whichever you prefer

- Knowing when you can’t
- Probabilistic-storyline synthesis
- Aerosols
- Impact attribution
- Tales of future weather
- Comparisons

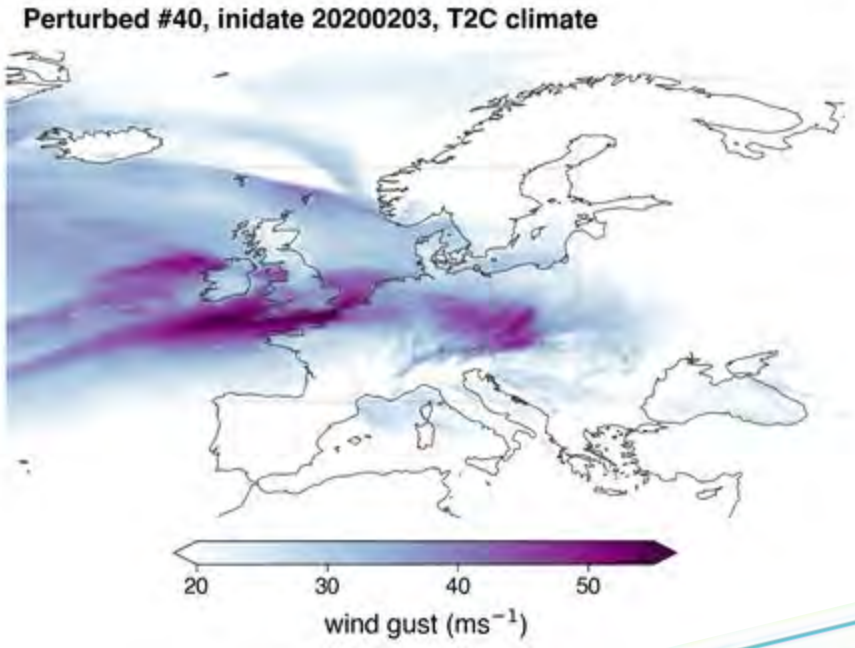


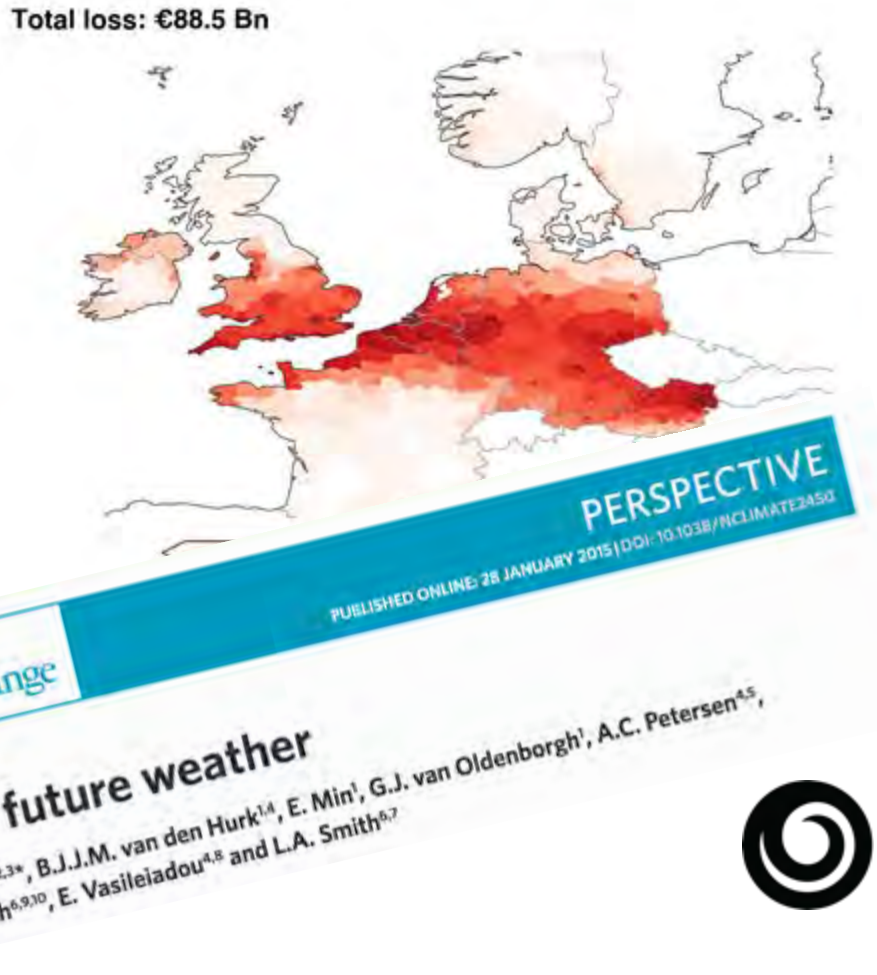


Bridging the “weather-climate schism” (or storyline-probabilistic schism)

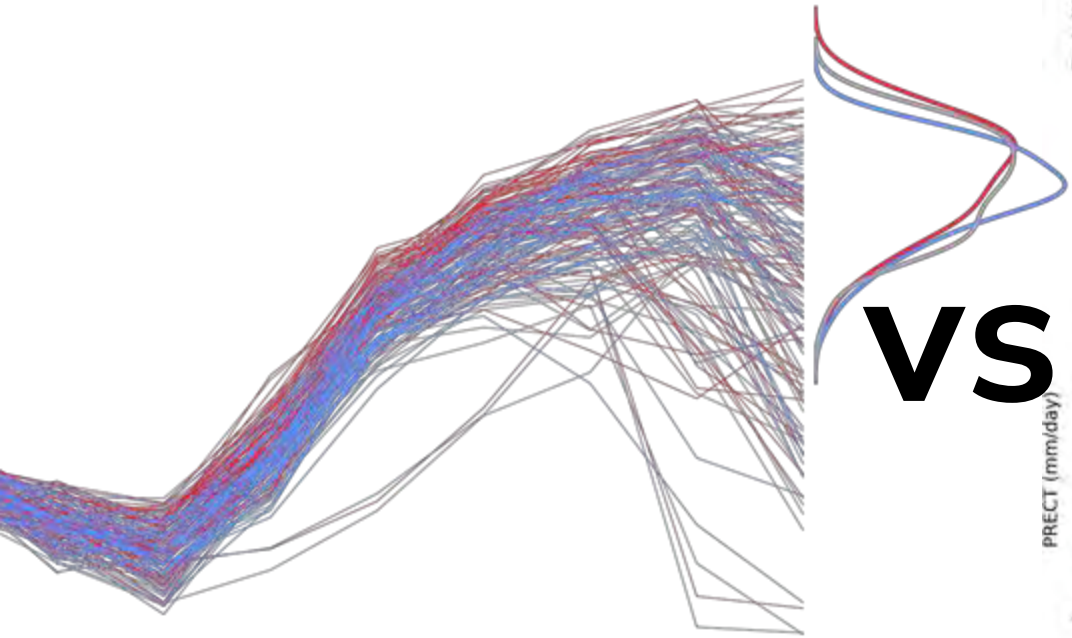
Shaw, Tiffany A., and Bjorn Stevens. ‘The Other Climate Crisis’. Nature 639, no. 8056 (March 2025): 877–87. https://doi.org/10.1038/s41586-025-08680-1.

Coumou, Dim, Paola A Arias, Ana Bastos, Charlotte Kendra Gotangco Gonzales, Gabriele C Hegerl, Pandora Hope, Christopher Jack, et al. ‘How Can Event Attribution Science Underpin Financial Decisions on Loss and Damage?’ PNAS Nexus 3, no. 8 (1 August 2024): pgae277. https://doi.org/10.1093/pnasnexus/pgae277.

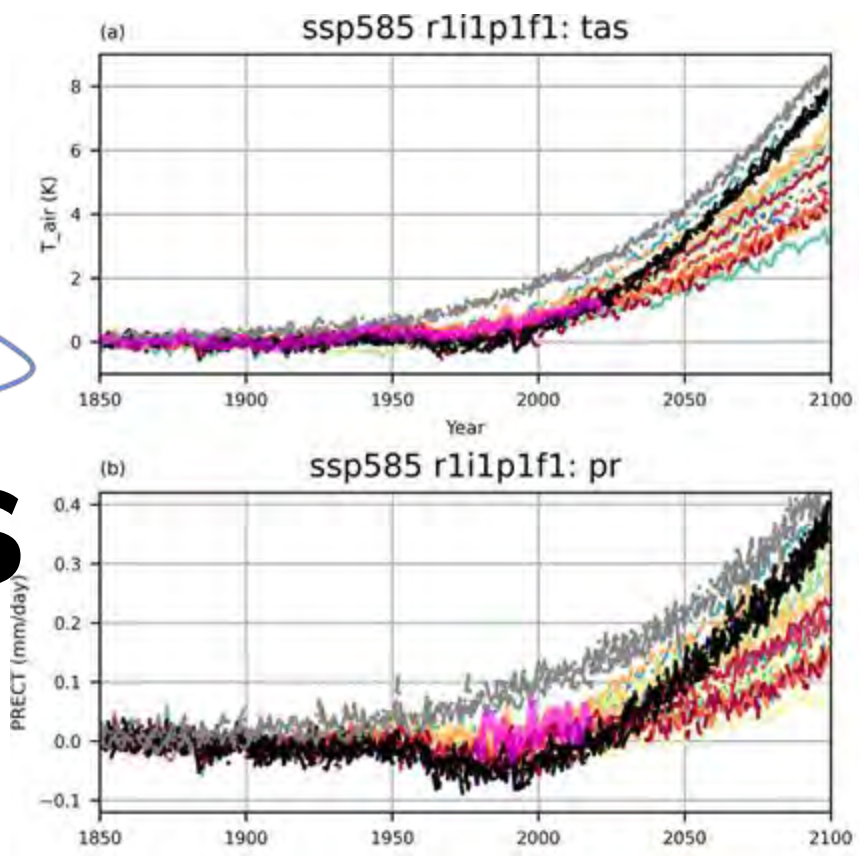




Tales of future weather



VS



Comparing initialised and transient responses

Please also talk to me about

- A season of counterfactual forecasts
  - Dec 2022 - Mar 2023
- Translation of EPESC / LEADER insights into user action
  - ie. for climate services

Connect with us!

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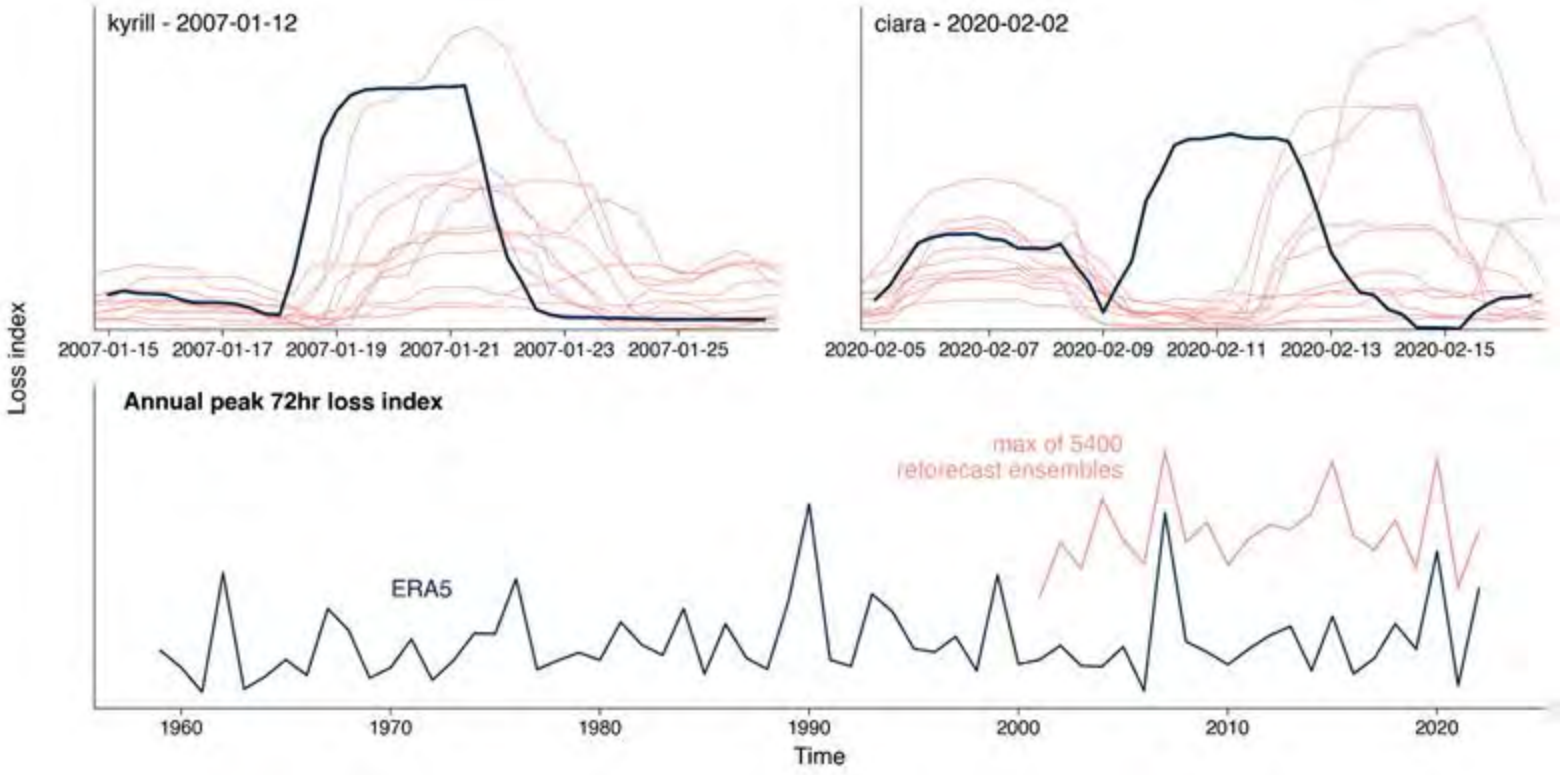
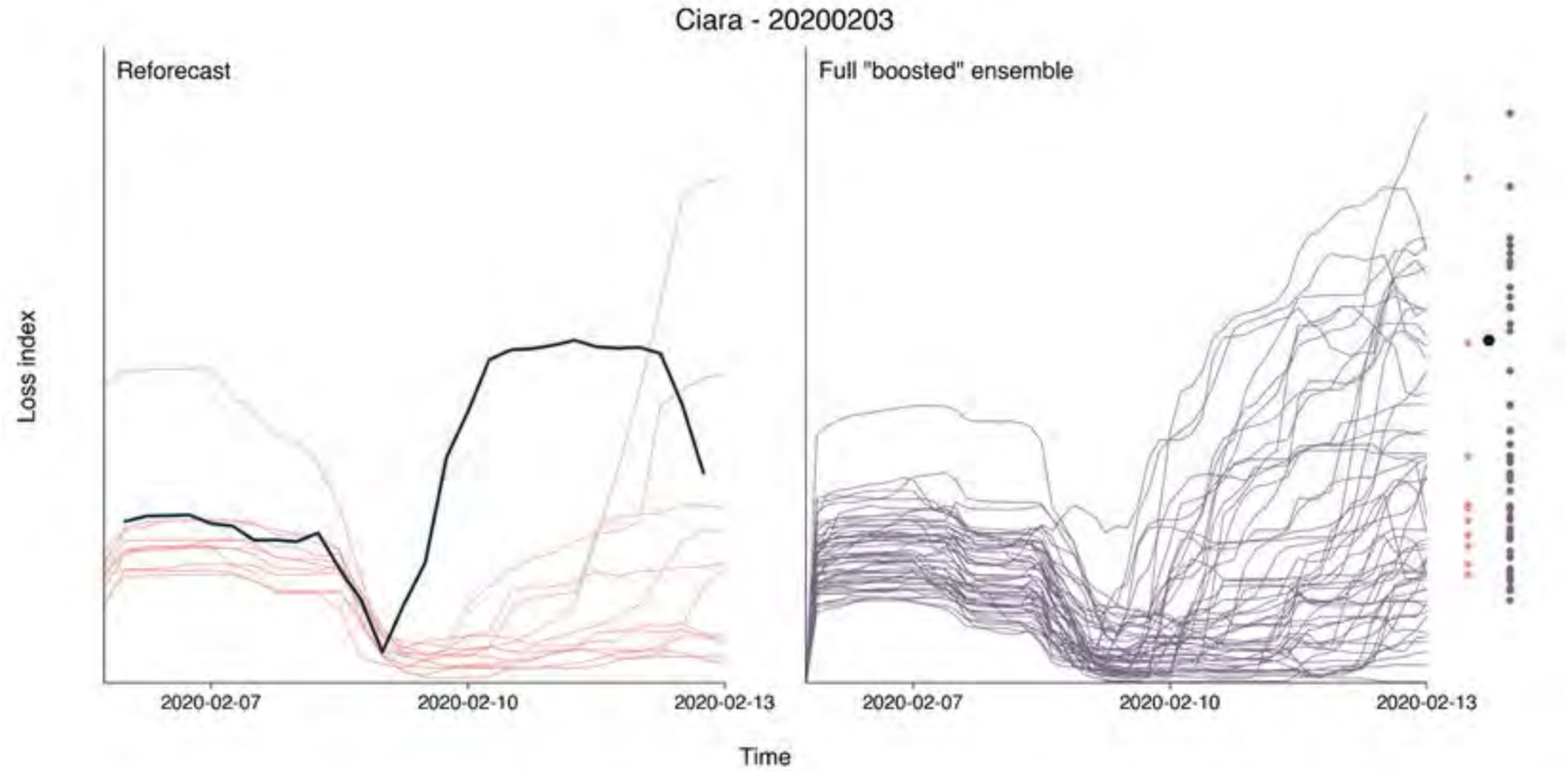
Extra slides: counterfactual^2

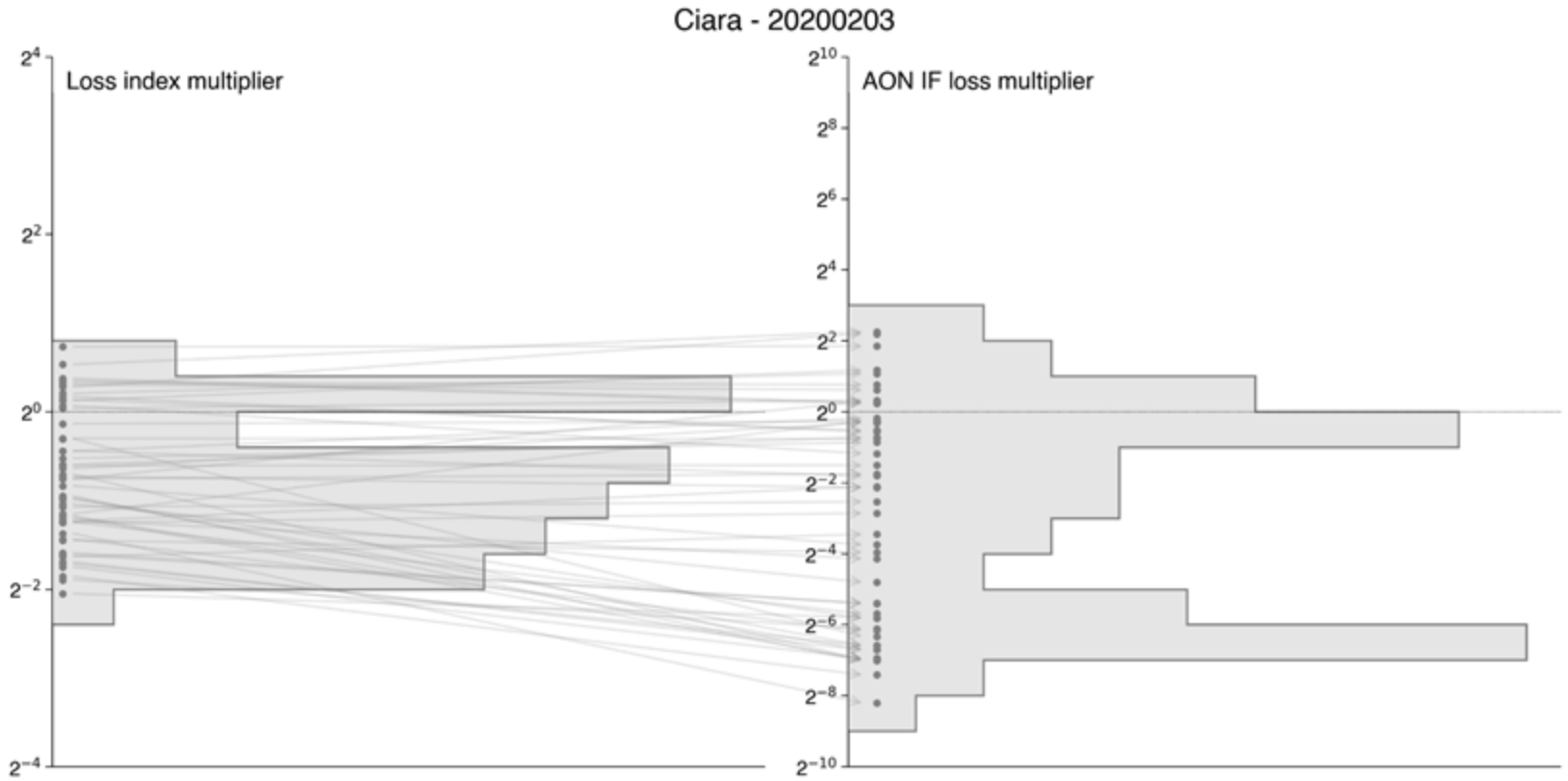
Downwards counterfactual reforecasts



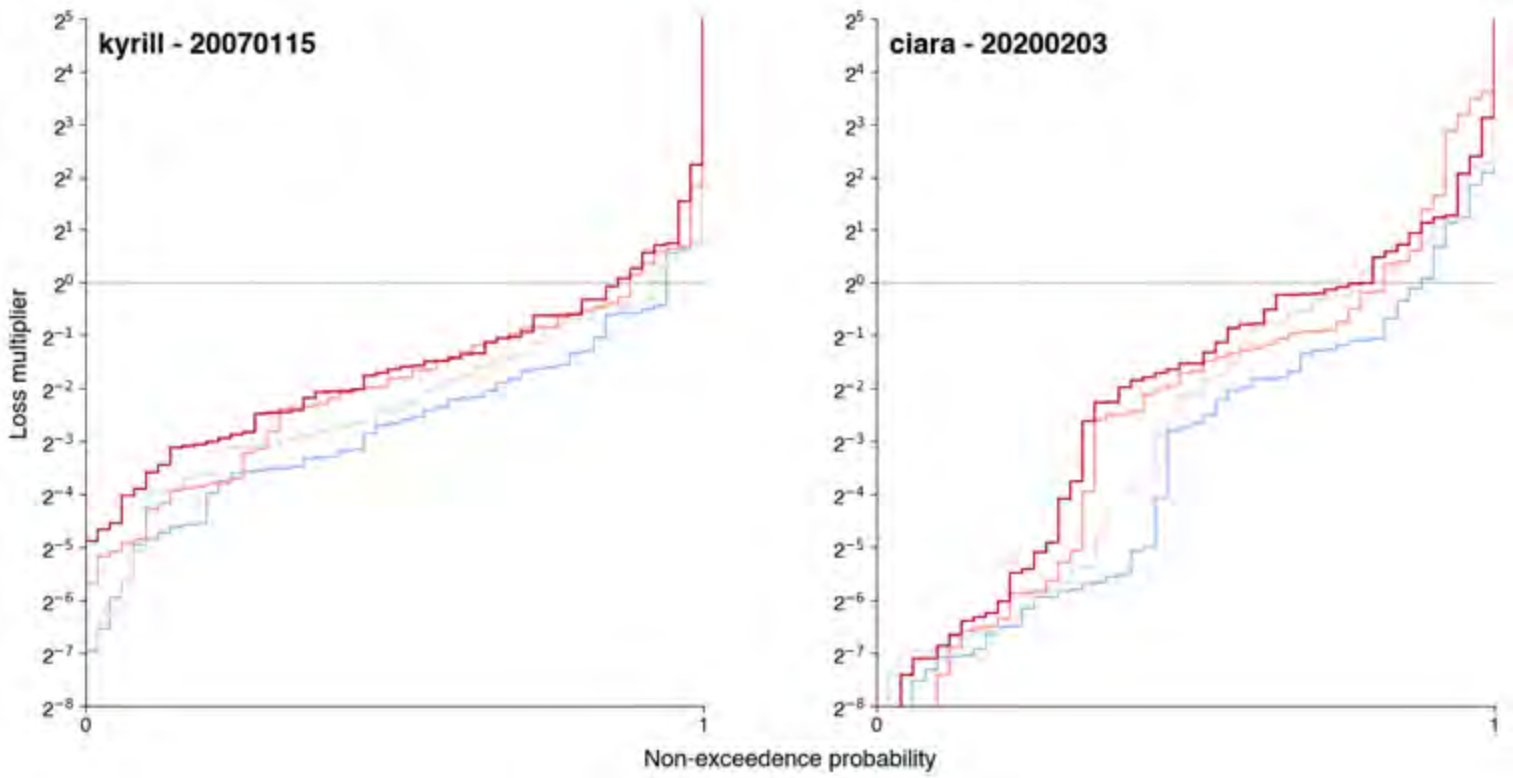
Boosting the reforecasts



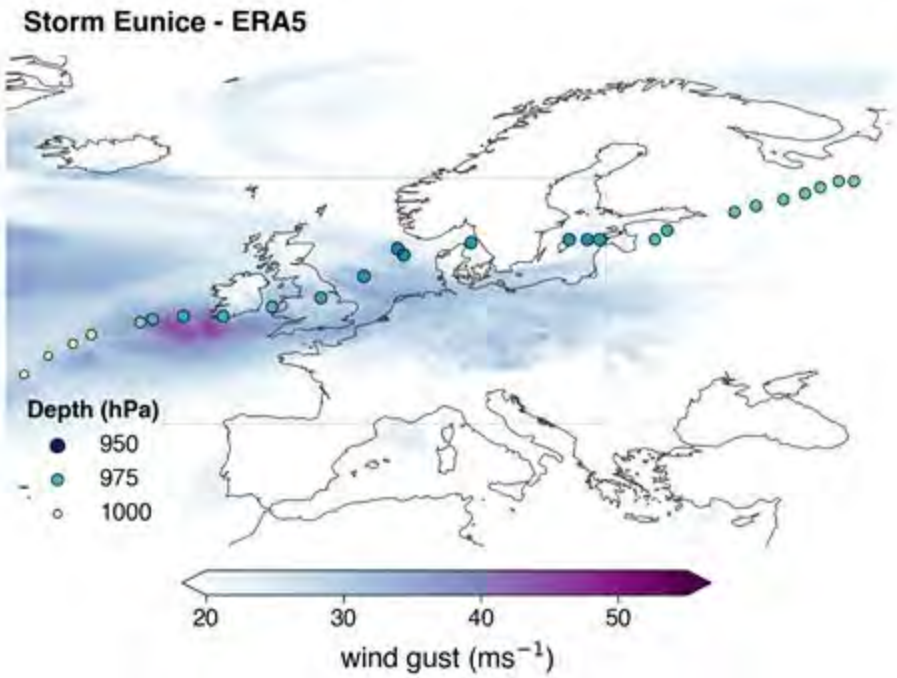
Loss distribution transform

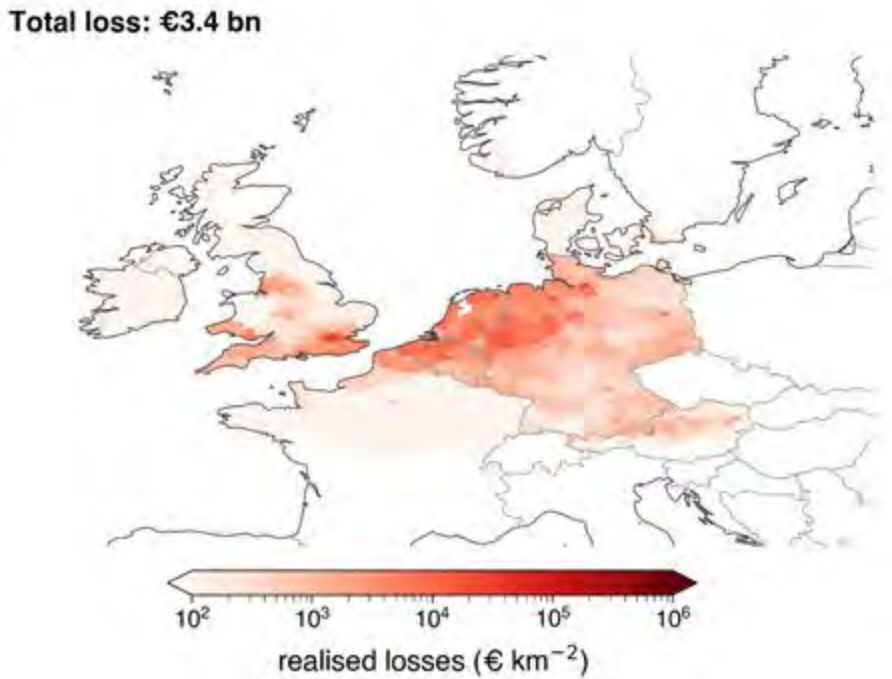


counterfactual^2 distributions

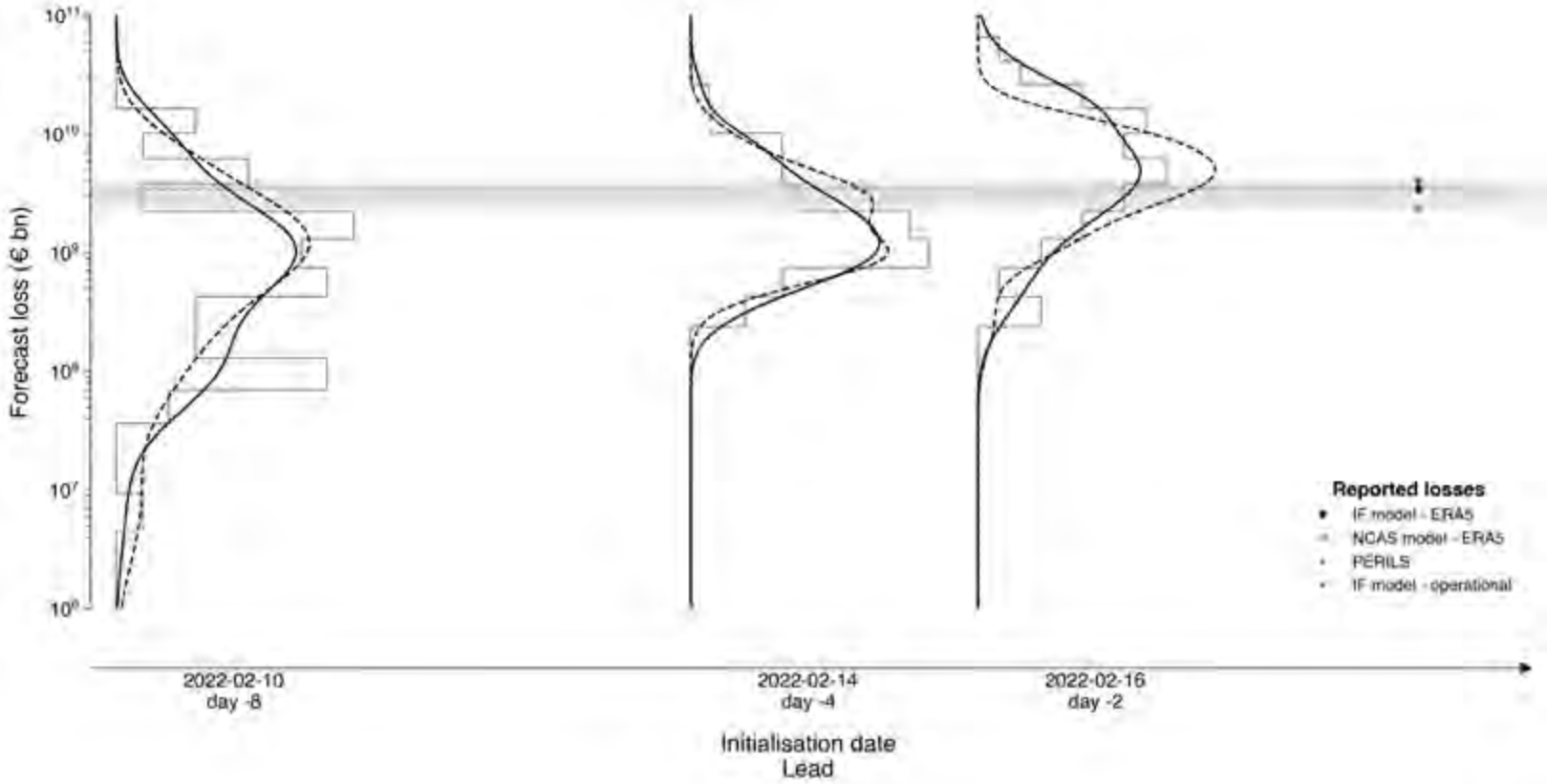


Extra slides: Eunice impact attribution

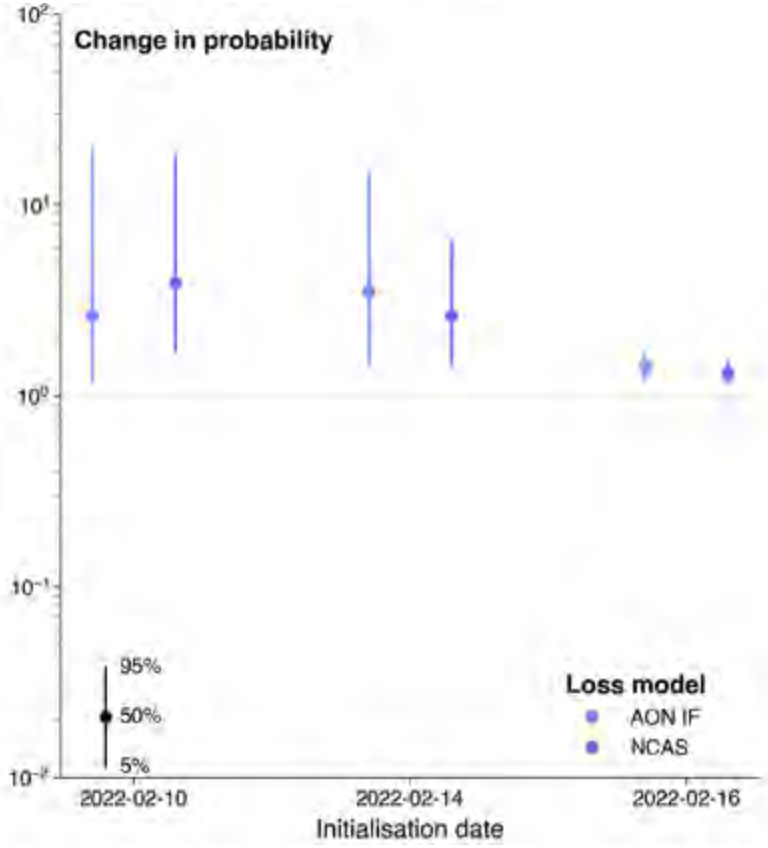


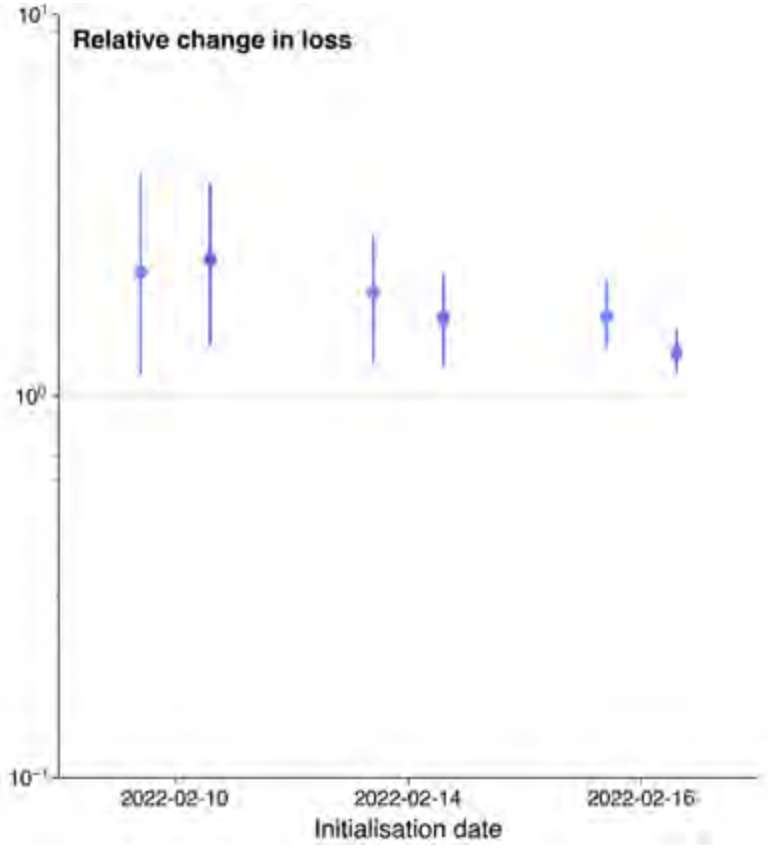


Storm Eunice



Impact forecasts





Conditional impact attribution