Title: European weather and climate extremes in a net-zero world

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The Paris Agreement, adopted by 196 parties at COP21 in 2015, sets out the goal to limit global warming to no more than 2°C, and pursue efforts to limit warming to 1.5°C. Many countries across the world now have declared net-zero targets, and the UK's commitment to net-zero by 2050 is written into law.

Understanding the climate of a world where the net-zero emission targets have been met, and global temperatures are stabilising, is an important and developing area of research. Evidence is emerging that regional temperature and precipitation trajectories can be substantially different in a stabilised climate, compared to the rapidly warming world we currently experience. For example, recent work suggests that the projected summer rainfall decline in the Mediterranean in a warming climate could be halted or even reversed if emissions of greenhouse gases were reduced to netzero (Figure 1, also Dittus et al. 2023, in revision).

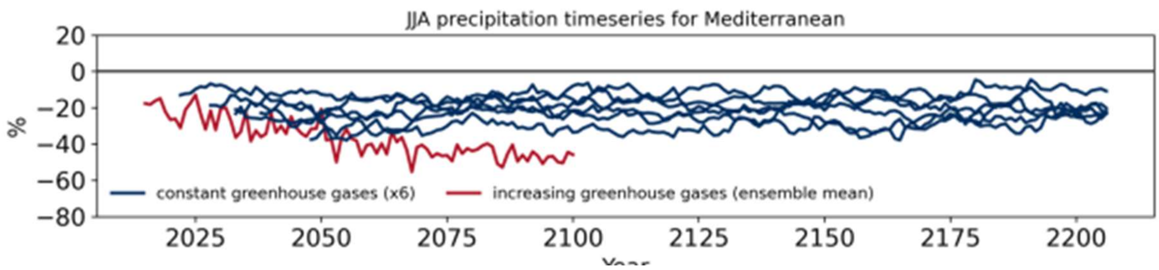

Figure 1 Precipitation projections with the UK Earth System Model 1 for summer (June, July, August) across the Mediterranean in simulations with continuing increases in greenhouse gas concentrations (red line, average across 16 simulations) and 6 stabilisation experiments with no further increases in greenhouse gas concentrations (blue lines, six simulations with 16-year smoothing applied)

This PhD project will focus on understanding how weather and climate extremes across Europe and the UK are projected to change in a world with net-zero emissions of greenhouse gases. Existing research suggests that differences in sea-surface temperature patterns and associated atmospheric circulation changes are important factors in explaining the differences between transient climate change projections and stabilised warming scenarios. This project will leverage novel methods to answer the following overarching science questions: How will European extreme weather events and their drivers be different in a net-zero world? Can the most damaging extreme precipitation events be avoided under net-zero emissions of greenhouse gases?

Building on existing climate model simulations, this project will run an ensemble of medium resolution, atmosphere-only climate model simulations with two different sets of sea-surface temperature patterns: one representing a rapidly warming world, and another representing the sea-surface temperature patterns post-net-zero emissions, both at the same level of globally averaged temperatures (e.g., 2 or 3°C of warming). Using this approach, atmospheric circulation changes associated with differences in the sea-surface temperature patterns between both sets of ensembles will be identified and analysed.

The second part of the project will focus on understanding changes in weather extremes across the European domain, initially broadly including multiple types of extreme events across the ensemble, then focussing on one type of extreme weather event specifically such as large-scale extreme precipitation events.

By definition, extreme weather events are rare, and extremely large ensembles of simulations are needed to sample the range of physically plausible events (to the extent that models are able to simulate them). To address this issue and explore the range of physically plausible events in a warming world beyond the observed range, a novel ensemble boosting method has been developed in co-supervisor Fischer's group. This approach has been highly successful in identifying physically plausible, but unseen heatwaves and extreme precipitation events (Gessner et al. 2021, 2022, 2023). In this part of the project, a small number of case studies will be selected to be 'boosted': a specific event will be re-run many times, re-running the same event by adding a very small perturbation to the atmospheric initial conditions 15-20 days before the event occurs. This approach will identify how extreme such an event could get if the weather trajectory had been slightly different. Such an approach has not yet been used in the context of a 'net-zero' stabilised climate.

Weather extremes in a warming world are often highly damaging, endangering lives, livelihoods and infrastructure. Understanding how the characteristics of such extremes will be different in a world where global temperatures have stabilised is important for preparing for future weather and climate extremes. This PhD project will use and develop novel methods to provide important new insights into extreme weather risk in a future world where global temperatures have stabilised.

Training opportunities:

Additional funding for one international research visit to work with Prof. Fischer at ETH Zurich, Switzerland will be made available over the course of this project.

Reference

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Gessner, C., Fischer, E. M., Beyerle, U., & Knutti, R. (2023). Developing Low-Likelihood Climate Storylines for Extreme Precipitation Over Central Europe. Earth's Future, 11(9),e2023EF003628. https://doi.org/10.1029/2023EF003628

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