REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: United Kingdom……………………………..…

Principal Investigator[1]: Nicholas Leach…………………………….……

Affiliation: University of Oxford……………….……

Address: St Cross College, 61 St Giles……

Oxford……………………………………………….……

OX1 3LZ…………………………………………….……

Other researchers: Antje Weisheimer…………………………….……

Myles Allen…………………………………….……

Tim Palmer…………………………………….……

Project Title:

The influence of CO_2 on an individual extreme event - the high February temperatures in the UK 2019

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** __________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2020-2022: (To make changes to an existing project please submit an amended version of the original form.)		**2020**	**2021**	**2022**
High Performance Computing Facility	(SBU)	6,500,000	-	-
Accumulated data storage (total archive volume)[2]	(GB)	8,000	-	-

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Extended abstract

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific Advisory Committee. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages). Large requests asking for 10,000,000 SBUs or more might receive a detailed review by members of the Scientific Advisory Committee.

Introduction

In 2019, maximum February temperature records were broken throughout the UK. The spell of exceptional warm weather lasted for approximately one week, between the 21st and 27th. This event broke February maximum temperature records for over 200 stations - the majority of the real-time network - and set a new winter maximum temperature record of 21.2 degrees in Kew Gardens, London on the 26th February; 1.5 degrees higher than the previous 1998 record. On the same day, anomalies over almost all of England and Wales were 10 degrees higher than the 1981-2010 long term average.

This event was characterised by high levels of sunshine (February 2019 was the second sunniest February since at least 1929) and a large diurnal temperature range of around 20 degrees over much of the UK, suggesting that the warmth during the day is mostly attributable to local radiative heating rather than warm air flows from the south. However, although the flows may have an insignificant direct contribution to the heat, it is likely that a significant fraction of the heat is attributable to the circulation pattern: an area of high pressure across the near continent, which contributed to the extremely low cloud cover throughout the event.[2]

This event was in general well predicted by the high-resolution operational mid-range ensemble forecasting system at ECMWF, at a lead time of 7 days. The skill of these forecasting simulations will allow us to explore the climatic drivers behind the hot February temperatures, and quantify the relative importance of the circulation pattern compared to local radiative heating in causing this event. Our main focus will be performing an attribution-style experiment where we compare a real-world (factual) high resolution forecast ensemble to an identical ensemble initialized from the same conditions, but with no atmospheric CO_2 burden above pre-industrial conditions.

Direct event attribution to CO_2 burden

In general, attribution studies interested in the impact of CO_2 on climate investigate long-term trends in events such as heatwaves and extreme precipitation, and attempt to quantify the probability of a particular event in the real-world and compare it to a natural world without CO_2 forcing to determine the impact of climate change on the likelihood of these events. Such attribution studies intrinsically determine the changes in likelihood due to global warming, which is in itself caused by an increased CO_2 burden. However, a recent paper by Baker et al (2018) investigating the direct local radiative forcing impacts of increased CO_2 concentrations on climate extremes in a 1.5 degree warmer world, found that increased CO_2 concentrations do have a direct influence - independent of global temperature change - on the frequency of temperature extremes observed, particularly in the Northern Hemisphere. We are proposing a conceptually similar experiment, though will be attempting to quantify the change in likelihood of a single event from direct CO_2 influence.

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[2] Analysis from the UK MET office Hadley Centre, Accessed from https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/uk-past-events/interesting/2019/2019_002_february_warmspell.pdf

Finally, we propose to use these simulations to carry out a multi-dimensional event attribution study, similar to the work of Hannart et al (2015), in which we characterise the event using an index calculated from several relevant climatic variables (such as temperature, precipitation, and circulation pattern index). We will investigate the impact on both the real-world event probability density and probability ratio (ratio of event likelihood with and without CO_2) of applying different weights to each variable, visualising the changes in probability density in the multi-dimensional space of chosen climate variables.

One additional use for these simulations would be to compare them with the new OpenIFS@home distributed computing project which can run large ensembles of a low-resolution implementation of OpenIFS. This event, and these simulations from the operational medium-range ensemble system would provide a good test of the OpenIFS@home predictive skill of an unusual event. The OpenIFS@home team are very supportive about running a forecast of the February heat in their distributed set-up.

Summary of proposed research questions:

1. What were the physical drivers behind the extreme UK February temperatures in 2019?
2. To what extent were the temperatures forecast by IFS attributable to the direct radiative forcing influence of increased CO_2 concentrations?
3. How does the event probability density change when quantified by a multi-variate index combining several climate variables (characterizing an extreme events in a more holistic sense)?

Experimental Details

This project will consist of a single phase, since we only require data from two ensembles of the same medium-range forecast.

We will run two ensembles with 50 ensemble members of the operational medium-range ensemble system, both initialized from the real-time initial conditions, one with CO2 concentrations as in the real-time forecasts, and one with pre-industrial CO2 concentrations. We will run five different start dates, centered around the 21st February, in order to assess the predictability time-scale of the event in this set-up.

We will then use the real-world ensemble to determine the influence of the various potential physical drivers on the event as it happened. A comparison of the two ensembles will allow us to determine the contribution of the direct CO2 forcing impact on the likelihood of the event. Finally, the two ensembles will allow us to determine the impact of using different variable weights in a multi-dimensional attribution study of the event.

Technical Requirements

The project is not especially computationally expensive, due to the constraint to a single event, but we will require a large ensemble size to provide reliable results, especially for the multi-dimensional aspect of the study. We plan to run two 50 member ensembles (current CO2 / pre-industrial CO2) of 10-day coupled forecasts from 5 different start days at T_co639L91 resolution, using IFS cycle 45r3 - the operational cycle at the time of the event. A single 10-day member run in this set-up costs 12,000 billing units, so we will require 12,000 x 2 x 50 x 5 = 6,000,000 BU, plus 500,000 BU to test the set-up and ensure that the simulations are run exactly as required.

We will require a limited amount of storage for the simulations, no more than 8,000GB.

References

Baker, H. S. et al. Higher CO2 concentrations increase extreme event risk in a 1.5 °C world. Nat. Clim. Chang. 8, 604–608 (2018).

Hannart, A. et al. DADA: Data Assimilation for the Detection and Attribution of Weather- and Climate-related Events. (2015).