<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2022–2024

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

Principal Investigator[1]**:** Dr Matthew Patterson…..…………………………………….……

Affiliation: Atmospheric, Oceanic and Planetary Physics, University of Oxford

Address: ……………………………………………………………….……

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Other researchers: Dr Chris O'Reilly (University of Reading)

Dr Antje Weisheimer (ECMWF)

Project Title: Drivers of the successful 2022 European summer seasonal forecast …………………………………………………….……

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ___N/A_______________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2022	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for the years: (To make changes to an existing project please submit an amended version of the original form.)		**2022**	**2023**	**2024**
High Performance Computing Facility	(SBU)	34.5	X	X
Accumulated data storage (total archive volume)[2]	(GB)	15000	X	X

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 an annual progress report of the project's activities, etc.
[2] 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.

Principal Investigator: Dr Matthew Patterson………………………………………………

Project Title: Drivers of the successful 2022 European summer seasonal forecast

Extended abstract

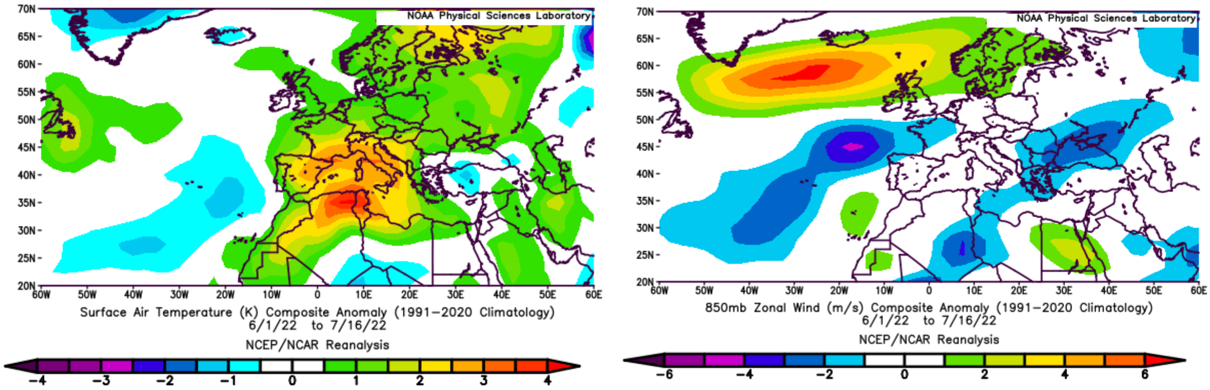

Figure 1: Observed (left) 2m temperature and (right) 850hPa zonal wind anomalies for the first half of the 2022 European summer season (1st June-16th July) from NCEP/NCAR reanalysis.

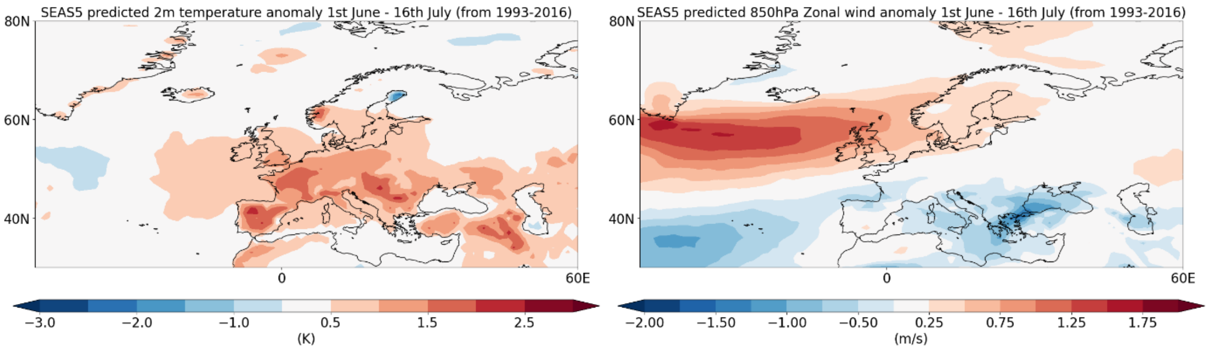

Figure 2: Ensemble-mean prediction of (left) 2m temperature and (right) 850hPa zonal wind anomalies for 1st June to -16th July from the ECMWF system 5 model initialised on 1st May (51 ensemble members).

Background and motivation

The 2022 European summer season has thus far been marked by extremely high temperatures over southern and western areas of Europe (figure 1, left panel) resulting in severe wildfires, heat-related deaths and general disruption to western European societies. These anomalous temperatures coincided with a negative summer North Atlantic Oscillation (NAO; Folland et al 2009), which is associated with a northward-shifted jet stream (Figure 1, right panel).

Interestingly, the atmospheric circulation and near-surface temperature anomalies for the first half of the summer season were generally well predicted by the operational ECMWF seasonal forecasting system (SEAS5) initialised on 1st May (compares figures 1 and 2). This is notable given that current operational seasonal forecasting systems generally show low skill in variables such as 2m temperature for European summers (figure 3a; MacLachan et al 2015, Johnson et al 2019). This is partly due to a lack of skill in atmospheric circulation in summer (Dunstone et al 2018) with a multi-model mean of current systems even showing negative correlation with observations to the west of the UK (Figure 3b; Patterson et al, under review).

The 2022 European Summer seasonal forecast therefore provides an interesting case-study in a successful prediction of summer atmospheric circulation and surface weather. In the proposed investigation, we would seek to identify the specific initial conditions that acted as drivers of the forecast. Identifying such drivers may help to establish whether this season was more predictable than usual and whether this could have been known ahead of time.

Moreover, in spite of the lack of summer circulation skill in the North Atlantic and European region in current models there are indications from studies of reanalysis data that the circulation may be predictable. For example, potential predictors of North Atlantic circulation include tropical SSTs and rainfall (Wulff et al 2017, O'Reilly et al 2017) and North Atlantic SSTs (Ossó et al 2018), while local soil moisture anomalies may amplify circulation patterns over Europe (Fischer et al 2007). Furthermore, Dunstone et al (2022) and Wang and Ting (2022) suggested that the state of the stratosphere may act as a predictor of the summer NAO.

It is possible that one of or a combination of these factors may have contributed to the prediction of the first half of the summer 2022 circulation. For example, in the Tropical Pacific there were significant SST anomalies due to a redeveloping La Nina event and also significant anomalies in the North Atlantic leading into the summer season. The spring season was anomalously dry across most of Northern and Western Europe which could also have contributed to the forecast signal (e.g. https://climate.copernicus.eu/precipitation-relative-humidity-and-soil-moisture-may-2022).

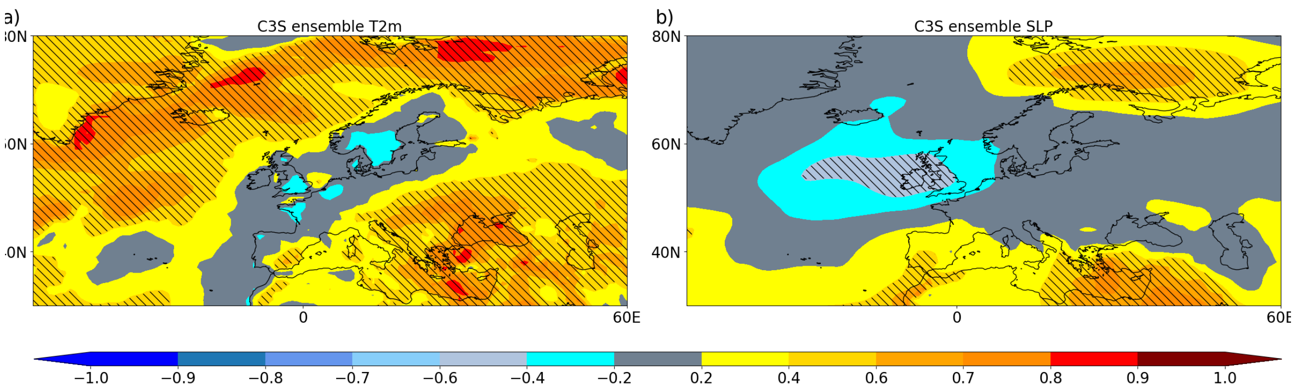

Figure 3: (left) 2m temperature and (right) sea level pressure anomaly correlation skill for a multi-model mean of five operational seasonal forecasting systems (ECWMF system 5, CMCC SPS3, DWD GCFSv2, Met Office GloSea6 and Meteo-France system 7) for runs initialised on 1st May with reference to ERA5 reanalysis for June-July-August 1993-2016. Note that the colourbar is non-linear. Hatching indicates statistically significant correlations at the 95% level following a t-test. Adapted from Patterson et al (under review, Environmental Research Letters).

Proposed Experiments

As part of our investigation, we propose three sensitivity hindcast experiments of the 2022 summer season. Our approach will be to run modified simulations using the SEAS5 model setup, initialised on 1st May, in order to identify the drivers of the summer 2022 forecast.

Specifically, we intend to perturb soil moisture, SSTs and atmospheric circulation, motivated by studies showing these as predictors of North Atlantic and European circulation.

For each of the sensitivity experiments we will rerun the seasonal forecast using the setup as in the actual SEAS5 forecast but initialising only certain parts of the forecast from the analysis for May

2022. For the sensitivity experiments the initialisation of the different components will be performed using other years at random from the initialisation – this approach has previously been successfully applied to seasonal hindcasts performed with the IFS (e.g. O'Reilly et al., 2019; O'Reilly et al., 2021).

Each of the experiments will be run for 5 months from the 1st of May, with 200 ensemble members following the setup of the SEAS5 operational forecast. It should be noted that due to the supercomputer move to Bologna that we will need to run another *Control* experiment that will be performed using a model version that is equivalent to the operational SEAS5 setup. The proposed experiments are shown in Table 1.

	Initial conditions (observed conditions for 1st May 2022 unless stated)		
Experiment name	**Soil moisture**	**Atmospheric initial conditions**	**Ocean initial conditions**
Control *(SEAS5)*	As in SEAS5.	As in SEAS5.	As in SEAS5.
Soil-rand	Soil moisture initialisation for each member taken from another year (at random).	As in SEAS5.	As in SEAS5.
Atmos- IC- rand	As in SEAS5.	Atmospheric initial conditions for each member taken from another year (at random).	As in SEAS5.
SST-rand	As in SEAS5.	As in SEAS5.	Oceanic initial conditions for each member taken from another year (at random).

Table 1: A summary of proposed experiments.

Resources

To isolate the differences between the different experiments and achieve clear signals we will be performing 200 members for each of the 4 experiments. Each experiment will be run for 4 months from the 1st of May through the end of August.

The experiments are budgeted to cost 8250 SBU per month.

Therefore the total estimated cost of the experiments will be:

4 months * 4 experiments * 200 members = 26.4m SBU

As these will be performed on the new supercomputer in Bologna, the requested budget will be increased by 30% since we have been led to understand that the equivalent unit costs will increase on the new system.

Therefore we request 34.5m SBUs.

In terms of storage space, a total of 1,354 spatial fields per months will be archived. This includes a selection of 6-hourly and daily data together with monthly mean fields at the surface and selected pressure levels. With one field being of size 3.2 MB, this corresponds to 4.3 GB per month of simulations. Therefore we estimate that our experiments will require 15 Tb of storage in total.

References

Dunstone, N., Smith, D., Scaife, A., Hermanson, L., Fereday, D., O'Reilly, C., ... & Belcher, S. (2018). "Skilful seasonal predictions of summer European rainfall." *Geophysical Research Letters*, 45(7), 3246-3254.

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Fischer, E. M., Seneviratne, S. I., Vidale, P. L., Lüthi, D., & Schär, C. (2007). "Soil moisture–atmosphere interactions during the 2003 European summer heat wave." *Journal of Climate*, 20(20), 5081-5099. Folland, C. et al (2009)

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O'Reilly, C. H., Woollings, T., Zanna, L., & Weisheimer, A. (2018). "The impact of tropical precipitation on summertime Euro-Atlantic circulation via a circumglobal wave train." *Journal of Climate*, 31(16), 6481-6504.

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Wulff, C. O., Greatbatch, R. J., Domeisen, D. I., Gollan, G., & Hansen, F. (2017). Tropical forcing of the Summer East Atlantic pattern. Geophysical Research Letters, 44(21), 11-166.

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.

Requests asking for 3,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests the evaluation will be based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality,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.

All accepted project requests will be published on the ECMWF website.