REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: United Kingdom

Principal Investigator[1]: Christopher O'Reilly

Affiliation: University of Reading

Address: Department of Meteorology, Earley Gate, University of Reading, Reading, UK.

Other researchers: Scott Osprey (U. Oxford), Tim Woollings (U. Oxford), Antje Weisheimer (U. Oxford), Jon Robson (U. Reading), Kristian Strommen (U. Oxford)

Project Title: **Interrogating sources of predictable circulation signals in seasonal forecasts**

If this is a continuation of an existing project, please state the computer project account assigned previously.	N/A	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2026	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2026**	**2027**	**2028**
High Performance Computing Facility	[SBU]	260 million	260 million	200 million
Accumulated data storage (total archive volume)[2]	[GB]	190Tb	380Tb	440Tb

EWC resources required for project year:		**2026**	**2027**	**2028**
Number of vCPUs	[#]	N/A	N/A	N/A
Total memory	[GB]	N/A	N/A	N/A
Storage	[GB]	N/A	N/A	N/A
Number of vGPUs[3]	[#]	N/A	N/A	N/A

[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.
[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

Principal Investigator: Christopher O'Reilly

Project Title: **Interrogating sources of predictable circulation signals in seasonal forecasts**

Extended abstract

A. Scientific plan

Previous studies suggest that large-scale teleconnection responses to predictable drivers are underestimated in seasonal forecasts (e.g. O'Reilly, 2025; Weisheimer et al., 2024). Multiple factors may contribute to the weak circulation signals and therefore the signal-to-noise errors seen in many seasonal forecasts. However, direct assessment of individual predictability drivers from existing hindcasts is difficult due to short hindcast periods and complex driver interactions. This project will address this problem by explicitly probing sources of predictable circulation signals through targeted denial and isolation experiments using ECMWF seasonal forecasting system (SEAS5/6) that systematically move away from full seasonal hindcasts. By comparing these experiments with the operational hindcasts, we can evaluate the linearity of different sources of predictable signals and reveal how individual and collective dynamical driving mechanisms contribute to the signal-to-noise paradox (SNP).

This work is part of an upcoming NERC-funded AUSPICE project (a 4-year project beginning Oct-2025) and parallel experiments to those outlined below will be performed as part of the wider project are planned, using both the Met Office's seasonal forecasting system (i.e. "GloSea6") and the NCAR prediction system (i.e. the CESM2-based DPLE). These companion experiments that will be run as part of the project provide a unique opportunity to examine the mechanisms underlying seasonal signals in a controlled manner across multiple models.

Overall, this project will deliver a detailed quantitative understanding of the relative roles of different sources of predictability.

Task 1: Denial experiments.

We will systematically assess how specific initial state components affect predictable circulation signals in three leading forecasting systems (ECMWF, Met Office, NCAR). Using their operational hindcast setups, we will perform "denial experiments" where specific anomalies within the initial state are systematically removed. For example, to test the role of El Niño for a given year, we will alter the initial ocean state by nudging temperatures in the Tropical Pacific towards climatology and re-initialise the forecasts with these. Similar experiments will target the stratospheric circulation, extratropical SSTs, and Arctic sea ice. By comparing the denial experiments with the full seasonal hindcasts, we will identify the role of these different mechanisms in generating predictable circulation signals and their contribution to the SNP. Given the intermittency of the SNP, we will focus on key years with significant contributions to hindcast skill, the SNP, and the strength of the model circulation signals. To extract the clearest circulation signals, we will leverage large ensembles (see Table 1).

This task will deliver a quantitative understanding of the relative influences of different sources of predictability on midlatitude circulation signals.

Task 2: Isolation experiments.

To complement the denial experiments, "isolation experiments" will investigate the impact of each of the large-scale circulation drivers that were removed in the denial experiments in Task 1 in isolation. While the isolation experiments represent further idealisations away from operational seasonal hindcasts, they will clarify the role of the specific initial condition anomalies, and their relative interactions, in generating predictable circulation signals in operational models. To create initial conditions, all fields except the target anomalies will be nudged towards climatology. We will also run subsets of isolation experiments with higher resolution and with stratospheric nudging throughout the season, to bridge possible atmospheric pathways, explore ocean-atmosphere interactions and stratosphere-troposphere feedbacks. By comparing these isolation experiments with denial experiments and full hindcasts, we will evaluate the nonlinear interactions between sources of predictable signals.

This task will deliver a complementary assessment to Task 1 of how various drivers contribute to predictable circulation signals and the SNP.

B. Technical plan and justification of resources

We plan to run experiments using the ECMWF seasonal forecasting system SEAS6. The numbers below use costs of running the model at different resolutions based on the ongoing testing for SEAS6 from colleagues at ECMWF.

Our plan is to perform experiments mainly in two configurations – the operational "SEAS6" resolution (TCo319 coupled to a 0.25-degree ocean) and the lower resolution version developed and tested at ECMWF, "SEAS6-lowres" (TCo199 coupled to a 1-degree ocean). The benefit of the lower-res model is it is relatively efficient computationally but is very comparable with typical resolutions that contribute to operational multi-model seasonal/decadal forecasts (e.g. C3S and DCPP). This will provide useful insight into the importance of resolution through comparison with the operational resolution.

Horiz. resolution (atmos | ocean)	System name	Seasonal hindcasts	Mechanism denial expts (Task 1)	Mechanism isolation expts (Task 2)	Cost per month (SBU)	Cost per season (SBU)	Total cost (SBU)
TCo199 (50km) | 1 x 1 ocean	SEAS5(/6)-lowres	1981-2023 (51 members)	10200 seasons	2000 seasons	1500	7500	9.61E+07
TCo319 (36km) | 1/4 x 1/4 ocean	SEAS5(/6)	1981-2023 (51 members)	10200 seasons	2000 seasons	9000	45000	5.76E+08
TCo639 (18km) | 1/4 x 1/4 ocean	N/A			750 seasons	21000	105000	8.27E+07
						Total (SBU)	7.55E+08

Table 1: Summary of estimated costs and calculations (cells in blue indicate experiments planned as part of this Special Project, with the seasonal hindcasts already run or planned by ECMWF).

The indicative computations costs below are estimated for 5 different "denial" hindcasts (Task 1), running 51 members for a 40-year hindcast (for 5-month seasons) - further details are summarised in Table 1. For the "isolation" experiments (Task 2), we plan to run with 10 members for 40 years of the sampled "observed" variability from 5 different drivers used in Task 1. In addition, we will perform as smaller number of the isolation experiments at a higher atmospheric resolution (TCo639) to allow us to explore how the behaviour varies with resolution.

These simulations are 7500 SBU per season for the SEASS6-lowres setup and 45000 SBU per season for the SEAS6 setup. The TCo639 resolution runs are estimated to cost 105000 SBU per season.

Multiplying the estimated costs by the number of planned seasons, and adding 5% for pre/postprocessing costs and potential margin of error on the “cost per month” estimates, gives the total units for the runs planned as ~760 million SBU spread across three years, as follows:

Year 1: 280 million SBU
Year 2: 280 million SBU
Year 3: 200 million SBU
Total: 760 million SBU

The work plan will be to do the main bulk of the denial and isolation experiments in the first two years of the project, with the third year being the higher resolution isolations experiments and additional complementary isolation experiments using the operational resolution.

In agreement with the reduced archiving settings of standard seasonal forecast research experiments at ECMWF, 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 for the standard SEAS6 resolution. We then scale this figure for the appropriate resolution, multiply by the number of forecast months, ensemble members and start years to get the total number of GB required.

The total accumulated storage over the three years is estimated as 440 Tb, achieved as follows:

Year 1 (accumulated): 190 Tb
Year 2 (accumulated): 380 Tb
Year 3 (accumulated): 440 Tb

References

O'Reilly, C.H., 2025. Signal-to-noise errors in early winter Euro-Atlantic predictions linked to weak ENSO teleconnections and pervasive jet biases. *Quarterly Journal of the Royal Meteorological Society*, p.e4952.

Weisheimer, A., Baker, L.H., Bröcker, J., Garfinkel, C.I., Hardiman, S.C., Hodson, D.L., Palmer, T.N., Robson, J.I., Scaife, A.A., Screen, J.A. and Shepherd, T.G., 2024. The signal-to-noise paradox in climate forecasts: revisiting our understanding and identifying future priorities. *Bulletin of the American Meteorological Society*, *105*(3), pp.E651-E659.