REQUEST FOR A SPECIAL PROJECT 2026–2028

MEMBER STATE: GB

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Project Title: Alternative schemes to advance seamless weather prediction

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**GBMONG	
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]	95000000	95000000	95000000
Accumulated data storage (total archive volume)[2]	[GB]	25,000	45,000	50,000

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

[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.

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Extended abstract

Motivation and Project description

The new generation of Earth System Models (ESMs) required to answer pressing questions on weather extremes under climate change needs to be developed in ways that allow seamless prediction across a wide range of resolutions and timescales.

This requires a range of processes from different elements of the Earth System that influence surface weather to be realistically included in models. This often means parameterizing processes that cannot be resolved in current models, using approximated approaches. It sometimes also means that emerging key processes are not so promptly included in models, slowing down our ability to address new questions.

Processes on relatively long timescales, like stratospheric processes, are being increasingly recognized as a potential source of predictability for surface weather on multiple timescales from days to decades (e.g. Scaife et al., 2022). How to efficiently incorporate appropriate descriptions of stratospheric processes, including stratospheric composition, in new ESMs is still an open question. Such descriptions need to exhibit the right compromise of realism and computational cost to be able to adequately perform across all timescales.

Due to computational costs, full-chemistry descriptions for the stratosphere are still mainly reserved for coarser resolutions than operational numerical weather prediction (NWP) models typically require, and such full-chemistry descriptions are not yet affordable for multi-ensemble long-range weather simulations. Therefore, alternative stratospheric descriptions that are both realistic and affordable for all timescales and resolutions are key needs for emerging seamless NWP systems.

With the increasing complexity in the number and variety of processes that future ESMs will include, from the high atmosphere to the deep ocean, from chemistry to clouds microphysics, from industrial emissions to vegetation processes, reducing the computational costs for the simulation of some of these elements will also allow for a wider constellation of processes to be included, and therefore for more comprehensive and realistic ESMs.

In this project we plan to assess the feasibility and performance of alternative fast approaches for stratospheric key radiative species that can be implemented in an ESM at low computational cost, while providing quality comparable to key chemical fields from widely used full-chemistry models. We will assess their impact on meteorological fields and atmospheric patterns.

From our group at the University of Oxford we are developing new alternative approaches to simulate stratospheric composition, options that allow interaction with atmospheric radiation and dynamics in ESMs without the high costs of full-chemistry modules.

The project will also assess the impact of different stratospheric processes, with particular focus on stratospheric composition, including sensitivity experiments for the assimilation of selected instrument datasets in both NWP and CAMS settings. The value of the Microwave Limb Sounder (MLS) data for key stratospheric species has been recently highlighted for ozone (Monge-Sanz et al., 2025) and for humidity (Semane and Bonavita, 2025), and this project will contribute to expand on this line of research.

In collaboration with colleagues at ECMWF and international institutes (see additional researchers named in this document), we plan to assess the performance of these alternative approaches and configurations within the IFS system, with planned experiments both on medium-range and long-range timescales.

In previous published work, we demonstrated how an improved description of stratospheric ozone improved meteorological fields and diagnostics in ECMWF experiments at different timescales (Monge-Sanz et al., 2022). For this, a fast linear ozone model was used (Monge-Sanz et al. 2011) that represented a significant advance over other existing linear descriptions. We are continuing and expanding this line of research to include not only stratospheric ozone but also other species and processes key for stratospheric variability and evolution; for instance, promising results were presented for water vapour and methane by Monge-Sanz et al. (2013) and collaborations in this project will also allow for assessment of corresponding meteorological impacts.

Assessment of impact on temperature and dynamics diagnostics will be performed to quantify potential improvements in prediction skill for meteorological events with stratospheric links. Validation of results will typically be done against operational analyses and reanalyses for meteorological variables and against additional independent observations, providing a quantification of impacts on radiative gases distributions and meteorological fields in the different model configurations.

New approaches we are developing in our group in Oxford are not limited to linear models but are also incorporating non-linear approaches and machine learning (ML) emulators. Thus, the implementation and assessment of our approaches in the ECMWF model would also contribute to the ECMWF machine-learning strategy and to evaluate the feasibility and performance of ML-based descriptions to accelerate weather forecasting and ESM development (Dueben and Bauer, 2018) incorporating new elements into the system.

For the implementation of linear fast models, we will build upon the experience and collaborations developed from previous work (Monge-Sanz et al., 2022). While for the implementation of ML-based models we will build upon the experience and coupling tools developed in the Model Section at ECMWF.

Our research will not only increase knowledge of stratospheric impacts on weather and climate prediction, showing potential ways to improve forecasts and predictability, it will also contribute to sustainable strategies to increase the complexity of processes included in the ECMWF model and guide model developments in other operational centres.

An additional benefit of implementing fast realistic approaches for key stratospheric species, is that we can then identify feedbacks and potential compensation errors that need to be addressed so that the ECMWF system is better prepared for an eventual operational use of interactive full chemistry across different timescales.

While the focus of the main part of the project will be on stratospheric processes, we anticipate that later parts of the project will start to investigate other elements. Our research will therefore expand into other parameterization schemes contributing to a comprehensive development of Earth System Models at reduced computational cost compared to traditional approaches.

Experimental plan and justification of resources

Sets of experiments will be conducted with the ECMWF IFS model under different configurations and timescales, including forecast and analysis experiments using the latest ECMWF operational IFS cycle version (49r1). This will aim to assess the impact of the different schemes and observation datasets on weather and circulation patterns, with initial focus on the Northern Hemisphere. We will run experiments for deterministic medium-range forecasts and for ensemble prediction runs on longer timescales. ECMWF analysis experiments will also be performed using the latest ECMWF operational IFS cycle version (49r1) and CAMS chemistry settings.

An assessment of diagnostics similar to that in Monge-Sanz et al (2022) will be performed, providing a quantification of impacts on stratospheric ozone distributions and meteorological fields in the different experiments and model configurations. Diagnostic metrics to assess impacts on meteorological fields will include differences and correlation for meteorological variables from IFS experiments compared to operational (re)analyses; changes in error and evolution with lead time for meteorological variables, especially temperature and wind fields, at stratospheric and tropospheric levels. As well as changes in atmospheric circulation patterns and stratospheric-tropospheric coupling proxies, like the polar vortex, the Quasi-Biennial oscillation and the North Atlantic Oscillation which is also a major proxy for winter/spring weather over Eurasia.

Based on test experiments and experiments run in previous years of the special project:

For resolution TCo399 and L137, the estimated cost of 10-day forecasts covering 1-year period is 140,000 System Billing Units (SBUs).

For a seasonal run with 2 start dates and 10 ensemble members covering 14 simulation months, the estimated cost is 800,000 SBUs.

Analysis experiments run with 49r1 CAMS settings and resolution T511 L137 have an estimated cost of 5.2m SBUs per simulation month.

The HPC budget we propose of 95,000,000 SBUs per year, would allow us to carry out up to four simulation years of medium-range experiments, as well as seasonal experiments covering up to 30-year periods and up to 12 months of analysis experiments each year with the above configurations. We allow for an additional 10% SBUs to account for tests and spin-up periods.

Our existing knowledge of IFS and of the ECMWF supercomputing facilities ensures we can start these simulations from the first year and keep an analogous request of SBUs for the second and third years of the project.

References:

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