REQUEST FOR A SPECIAL PROJECT 2025–2027

MEMBER STATE: ...Italy.....

Principal Investigator[1]: ...Federico Serva.....

Affiliation: ...Consiglio Nazionale delle Ricerche.....

Address: ...Via Fosso del Cavaliere 100, 00133, Rome, Italy

.....
.....
.....

Other researchers: .....

.....
.....

Project Title: ...Investigating the origin of model biases in the representation of the stratosphere.....

.....
.....

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** ITSERV	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2025	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2025**	**2026**	**2027**
High Performance Computing Facility	[SBU]	8 000 000		
Accumulated data storage (total archive volume)[2]	[GB]	10 000		

EWC resources required for project year:		**2025**	**2026**	**2027**
Number of vCPUs	[#]	0	0	0
Total memory	[GB]	0	0	0

[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.

Storage	[GB]	0	0	0
Number of vGPUs[3]	[#]	0	0	0

Continue overleaf.

Principal Investigator: ...Federico Serva.....

Project Title: ...Investigating the origin of model biases in the representation of the stratosphere .....

Extended abstract

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

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the 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 exceeding 10,000,000 SBU should be more detailed (3-5 pages).

A realistic simulation of stratospheric processes in weather and climate models have long been demonstrated to matter for reliable extended range predictions. Considering for example the last phase of the Coupled Model Intercomparison Project (CMIP6), an increasingly larger number of models are now able to realistically simulate the stratosphere thanks to extended vertical domains and increased resolution. However, the representation of key processes such as the quasi-biennial oscillation (QBO) remains difficult.

A frequently used approach to correct atmospheric model biases is to nudge simulations towards specified states (e.g., observations), at least for some key parameters. This procedure also allows us to diagnose model biases, e.g. the response of different parameterized physics schemes to prescribed background states. As illustrated in Fig. 1, this can be done in different ways depending on the application of interest: for example, the SNAPSI protocol (Hitchcock et al., 2022) focused on ensemble subseasonal forecasts, where nudging was applied with a fast temporal scale and a throughout the stratosphere. Conversely the QBOi Phase 2 approach limited the prescription of the background to the inner tropics and the height range where the QBO is the dominant source of variability.

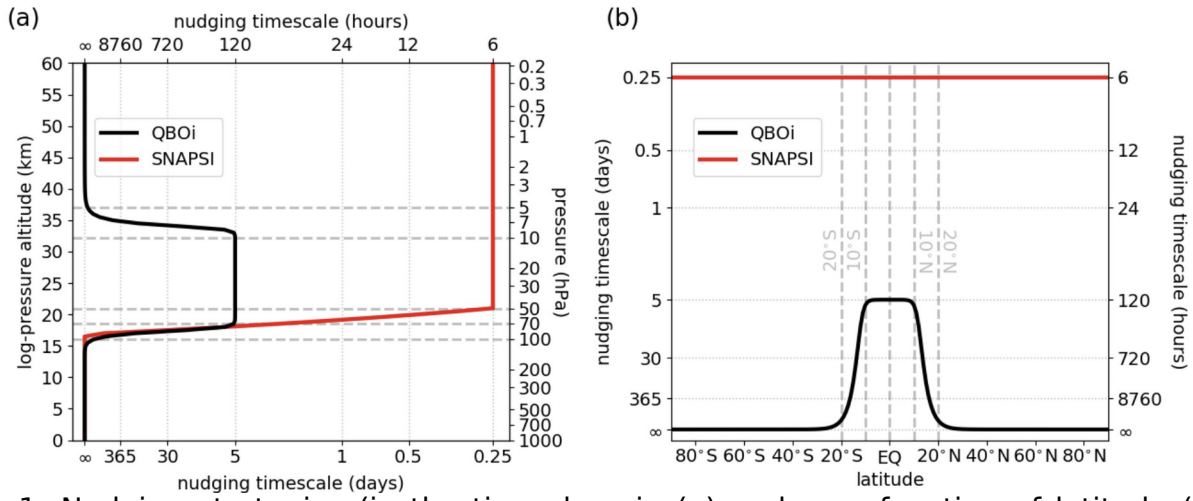

Fig. 1: Nudging strategies (in the time domain (a) and as a function of latitude (b)) adopted for the SNAPSI and the QBOi Phase 2 simulations. Reproduced from Anstey et al., in preparation.

In a previous special project, simulations were carried out with a CMIP6 class model (EC-Earth3, Doescher et al., 2020) which has an improved representation of the stratosphere, as discussed by Serva et al. (2024). In that project, simulations were carried out by nudging to prescribed states the winds in the inner tropics, where the QBO is dominant at interannual timescales.

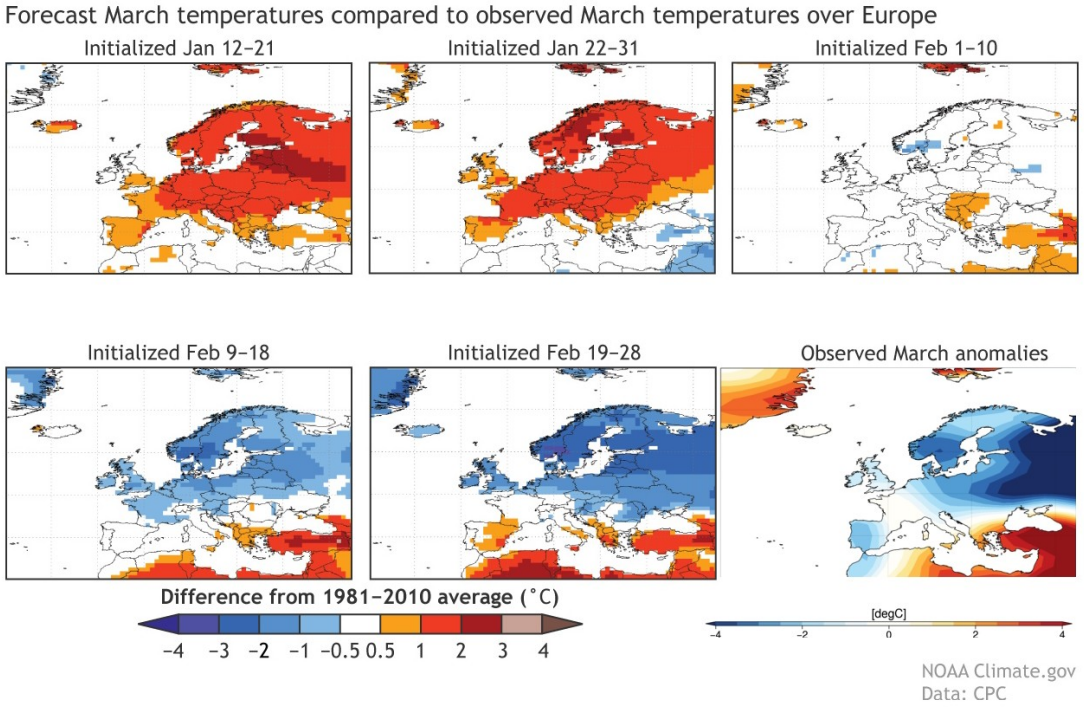

Fig. 2: Forecast and observed monthly averaged temperature anomalies in March 2018. Forecasts are from NCEP CFSv2, averaged over a total of 40 ensemble members, 4 of which are initialized on each date in the range of initial dates given in the captions. Observations are from the NCEP/NCAR reanalysis. Reproduced from Hitchock et al., 2022.

On shorter timescales (days to weeks), the state of the stratosphere is known to influence the predictability of surface weather conditions (Fig. 2). Different nudging strategies as well as the use of different models can help

understanding the reason for model biases and ultimately improving the simulation fidelity.

The objectives of this Special Project proposal are aligned with those pursued in previous ones, since one major component of the simulations will be carried out by following additional simulations currently under discussion within the QBOi Phase 2 initiative. While these are under definition, these could include simulations with different ozone specifications, as it is known to be important for the representation of the QBO characteristics (Butchart et al., 2023, see Fig. 3) but also include nudging to different parameters or regions of the atmosphere. For example, altering only equatorial winds has not proven sufficient to properly represent the interaction between the stratosphere and intraseasonal rainfall patterns (Martin et al., 2023), and this could be tackled by correcting other fields such as moisture or temperature profiles in the troposphere.

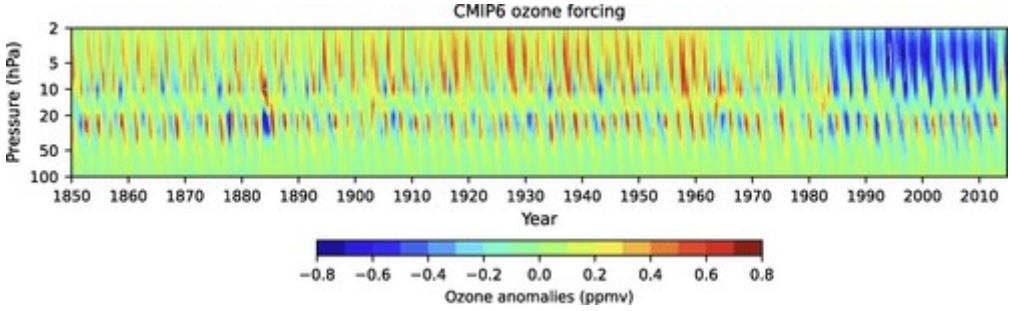

Fig. 3: CMIP6 zonal mean anomalies of equatorial ozone data after removing the mean annual cycle. Solar cycle and long-term trends are not removed. Reproduced from Butchart et al., 2023.

Beyond the EC-Earth3 model, the aim is to perform runs also with the GLOBO model (Malguzzi et al., 2011, Mastrangelo and Malguzzi, 2019), which was used for the SNAPSI initiative and is currently ongoing development. For example, the model has lower resolution and does not produce an internal QBO, therefore can be used as an alternative to the more computationally expensive EC-Earth3 model. The model is currently being developed to improve its performances for climate experiments, as it has mostly used for weather or subseasonal predictions for now.

Since details of the experimental protocol are at the moment under definition, request is made for a single year Special Project, where mostly model setup and sensitivity experiments would be carried out.

In terms of resources, these are estimated following the experience with the previous Special Project and they should suffice to perform both multidecadal simulations and shorter runs (dedicated to model development and testing).

As found in previous projects, it is unfeasible to store all the raw (i.e. 6-hourly and at full resolution) data in the ECFS archive, therefore only processed files (e.g. daily on a subset of vertical levels) will be archived. Consequently, the request is similar to the previous Special Project, consisting of 10 TB of space.

References

Butchart, N., Martin B. Andrews, Chris D. Jones: QBO Phase Synchronization in CMIP6 Historical Simulations Attributed to Ozone Forcing, https://doi.org/10.1029/2023GL104401, 2023

Doescher, R., and coauthors: The EC-Earth3 Earth system model for the Coupled Model Intercomparison Project 6, https://doi.org/10.5194/gmd-15-2973-2022, 2022

Hitchcock, P., and coauthors: Stratospheric Nudging And Predictable Surface Impacts (SNAPSI): a protocol for investigating the role of stratospheric polar vortex disturbances in subseasonal to seasonal forecasts, https://doi.org/10.5194/gmd-15-5073-2022, 2022

Malguzzi, P., Buzzi, A., and Drofa, O.: The Meteorological Global Model GLOBO at the ISAC-CNR of Italy Assessment of 1.5 Yr of experimental Use for Medium-Range Weather Forecasts, Weather Forecast., 26, 1045–1055, https://doi.org/10.1175/WAF-D-11-00027.1, 2011

Martin, Z. K, and coauthors: The Lack of a QBO-MJO Connection in Climate Models With a Nudged Stratosphere, https://doi.org/10.1029/2023JD038722, 2023

Mastrangelo, D. and Malguzzi, P.: Verification of Two Years of CNR-ISAC Subseasonal Forecasts, Weather and Forecasting, 34, 331–344, https://doi.org/10.1175/WAF-D-18-0091.1, 2019

Serva, F., B. Christiansen, P. Davini, J. von Hardenberg, G. van den Oord, T. J. Reerink, K. Wyser, S. Yang: Changes in Stratospheric Dynamics Simulated by the EC-Earth Model From CMIP5 to CMIP6, https://doi.org/10.1029/2023MS003756, 2024