REQUEST FOR A SPECIAL PROJECT 2019–2021

This form is available at:
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MEMBER STATE: ………Italy……...……………………………………………...…

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

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Other researchers:

……Chiara Cagnazzo (ISAC-CNR)…………………….……

Project Title:

….The dynamics of the stratosphere in the OpenIFS climate model…………………………………………………………….……

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.)	2019	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2019-2021:
(To make changes to an existing project please submit an amended version of the original form.)

		2019	2020	2021
High Performance Computing Facility	(SBU)	3 500 000	6 000 000	8 000 000
Accumulated data storage (total archive volume)[2]	(GB)	6 000	21 000	41 000

Continue overleaf

1The 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] 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.

Principal Investigator: ……Federico Serva………………………………

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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 and Technical Advisory Committees. 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 will receive a detailed review by members of the Scientific Advisory Committee.

The OpenIFS model is a simplified version of the Integrated Forecast System (IFS) model, developed and operational at the European Center for Medium-Range Weather Forecasts (ECMWF). This model is available to academic and research institutions, such as the Italian Institute for the Atmospheric Sciences and Climate (ISAC), and supports a wide range of configurations.

During this Special Project, we are willing to investigate the sensitivity of this model, performing a number of climate integrations. In particular, we want to study the sensitivity of the stratospheric dynamics to (i) the horizontal resolution, (ii) the number of vertical levels and (iii) changes in the imposed boundary conditions.

The resulting analyses are planned to aid the understanding of the dynamical processes affecting the variability of the stratosphere and their simulation, and the mechanisms behind the troposphere-stratosphere coupling. Moreover, the results of the experiments will be useful in view of the inclusion of this model as the atmospheric component of the EC-EARTH climate model.

Motivation and scientific aims

In the last two decades, many studies confirmed the strong implications that stratospheric anomalies for the weather and climate of the surface [*e.g., Baldwin and Dunkerton, 2001*]. Though the existence of the stratosphere-troposphere coupling is currently established, the understanding of the underlying processes is far from being complete, and there is no consensus on how the stratospheric dynamics might change in the future, due to changes in the atmospheric composition [*e.g., Simpson et al., 2018*].

While the understanding of the stratospheric processes has progressively improved in the last decades, the simulation of these phenomena in climate models remains difficult and computationally expensive. Small scale processes and phenomena occurring in the upper layers of the atmosphere are moreover difficult to observe, and thus their parameterization in models still presents unrealistic features [*Geller et al., 2013*]. Even the state-of-the-art climate models are affected by large thermal and dynamical biases, especially when it comes to the processes in the middle atmosphere [*Anstey et al., 2016, Geller et al., 2016, Politchtchouk et al., 2017*].

For the aforementioned reasons, a complete characterization of the stratospheric climate of a climate model is important also when the focus is on tropospheric climate, e.g. on the storm tracks or circulation [*Gerber and Manzini, 2016*]. For this project, we aim to perform a number of climate simulations using the OpenIFS climate model https://www.ecmwf.int/en/research/projects/openifs, which is available to the community for teaching and research purposes. Different configurations, e.g. vertical and horizontal resolutions, will be explored, and the realism of the stratosphere will be assessed comparing with reanalysis datasets. Specific parameterized processes, such as nonorographic gravity waves, will be another topic of interest for the planned simulations. The outcomes of the analyses will be beneficial for the community, also in view of the inclusion of OpenIFS in the comprehensive Earth system model EC-EARTH.

Plan of the experiments and related analyses

For the planned experiments, several model configurations will be considered. The OpenIFS model supports a wide range of configurations, both horizontal and vertical, and different combinations are possible.

Regarding the horizontal resolution, several values can be chosen starting at T21 (~ 600 km at the equator, typical of simplified models) up to T1279 (~ 10 km at the equator, comparable to that of weather prediction models). Values typical of climate models, around hundreds of kilometers, will be used for most experiments, in order to produce outputs compared to current climate models. However also coarse and high resolution will be employed, in order to study the changes in the resolved forcing of the stratosphere and in the vertical coupling.

In the vertical, different grids are available, starting from 19 up to 137 levels. The choice of the number of levels is particularly sensible for the simulation stratospheric processes, as it is well established that a realistic representation of the wave mean flow interaction (e.g., vertical wind shears and wave breaking) requires a fine resolution in that region. From experiments performed with other models (e.g., EC-EARTH), it is expected that 91 vertical levels are required for a realistic simulation of the stratosphere. Stratospheric processes and their teleconnections will be explored as the number of vertical levels is changed, in order to identify the relevant mechanisms and their sensitivity to the discretization.

Most of the experiments will be performed for the historical period (30 years in the late twentieth century), in order to compare with reanalysis assimilating satellites, and the boundary conditions (sea surface temperature and greenhouse gases) will be from observations. More idealized experiments (e.g., repeated annual cycle in the sea surface temperatures) will be performed in a later stage, also to study the response of the models to changes in the boundary conditions. For specific experiments, longer (multi-decadal or more) simulations will be carried out, in order to study the internal variability of the stratosphere, as in the case of the dynamics of the polar vortex.

The output of the experiments will be made available for research and teaching purposes upon request.

Summary of experiments and requested resources

As mentioned in the experimental plan, different simulations will be carried out, depending on the allocated resources. The following summary is valid if the allocation is accepted over the course of three years, otherwise it will be remodulated accordingly. The resource request is based on the results of atmosphere-only simulations of the EC-EARTH model, and might therefore be subject to further changes.

The first year will be dedicated to initial testing of the model, including the setup of the simulations and the postprocessing chain, including a preliminary evaluation of the model climate. For this, we estimate that the overall cost would be equivalent to a 400 years long simulation, or about 3.5 MSBU on cca. For the storage, archiving postprocessed files only, we estimate around 6 TB for the first year. The requests below might be amended depending on the results obtained.

Based on the results of the year one, during the second year different configurations of the model would be explored, for present-day boundary conditions. The length and number of simulations will be varied depending on the selected configurations, hence the computational load. We plan to perform standard 30-years experiments, exploring at least 5 horizontal grids, and 3 vertical discretizations, including coarse and high resolutions. Without a precise knowledge of the resources and based on EC-EARTH simulations, we estimate a cost of about 6 MSBU for running the experiments, and 15 TB for archival of postprocessed data (also for some of the output at a native resolution). Some additional experiments, e.g. for studying to sensitivity to parameterized processes, might be performed if resources are available.

For the third year, the sensitivity of the model to changed boundary conditions will be studied, again using different configurations (less than in the previous year, in order to perform more idealized experiments). For these experiments, we estimate a total of 8 MSBU on cca and 20 TB for archival needs. Possibly, longer integrations will be performed in order to focus on internal variability of the stratosphere.

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