SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	Investigating the stratospheric dynamics of high-top climate model configurations
Computer Project Account:	SPITSERV
Start Year - End Year :	2022 - 2024
Principal Investigator(s)	Federico Serva
Affiliation/Address:	CNR-ISMAR Via del Fosso del Cavaliere, 100 00133 Rome, Italy
Other Researchers (Name/Affiliation):	

The following should cover the entire project duration.

Summary of project objectives

(10 lines max)

The objectives of the project are to study the characteristics of the stratosphere in free-running simulations carried out with a high-top climate model and verify how correcting the model biases via nudging to observational datasets can help improving the representation of the upper atmosphere and its remote and surface connections. The simulations are performed following protocols defined fro multi-model initiative, so to put results in a wider context.……

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Summary of problems encountered

(If you encountered any problems of a more technical nature, please describe them here.)

No specific problem was encountered. The allocated resources initially requested were not sufficient to complete a set of additional nudged experiments, requiring a larger (10) number of ensemble members are required to analyse tropospheric processes. A colleague working with the same model requested the Special Project team to provide access to their project (SPITDAV) resources, and it was therefore possible to complete the experiments as foreseen.

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Experience with the Special Project framework

(Please let us know about your experience with administrative aspects like the application procedure, progress reporting etc.)

The experience was very positive. The support team quickly helped with clarifications on the resource assignment and reporting procedures, when needed……

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Summary of results

(This section should comprise up to 10 pages, reflecting the complexity and duration of the project, and can be replaced by a short summary plus an existing scientific report on the project.)

The project allowed to execute a number of free-running, atmosphere-only simulations with the EC-Earth3.3 model, generally run at a T255L91 configuration, with a model top around 80 km. Thanks to the presence of physical parameterizations for unresolved drag processes, the model has an improved representation of the upper atmosphere. A first set of experiments was done following the Coupled Model Intercomparison project – phase 6 (CMIP6) protocol, and results compared with simulations done in the previous phase. The evolution of the model is shown in Fig. 1 below, reproduced from one of the publications originating from the project. Showing the tropical upper atmospheric winds, it shows a much more realistic variability. The project also enabled to increase the diagnostic outputs, which are key to understand model biases and perform process-oriented evaluation.

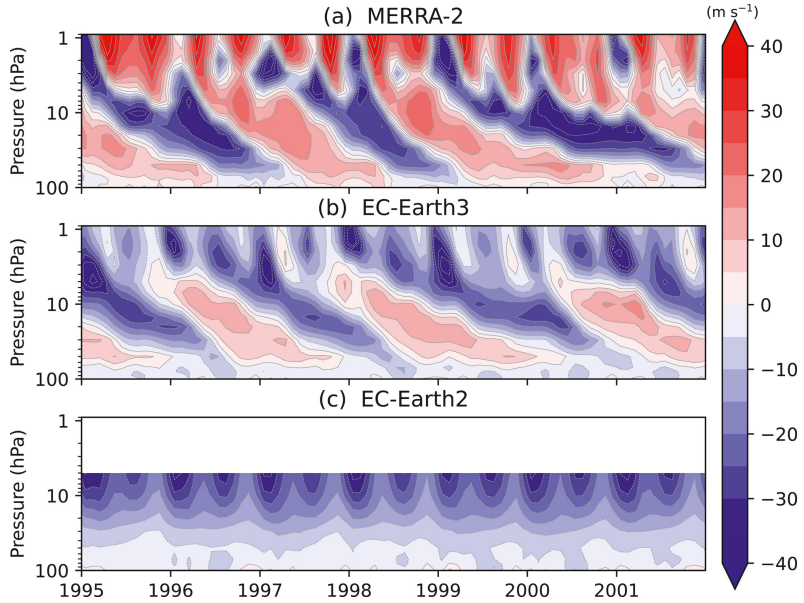

Fig. 1: Zonal mean zonal wind in the equatorial stratosphere as a function of time and pressure for (a) MERRA-2, (b) EC-Earth3 and (c) EC-Earth2.

While the improvements between versions are clear, limitations documented in Serva et al. (2024) still persist. Building upon the developments of this phase of the project, a second part of the project focused on the impacts of correcting biases by using observations. This model version only supports full-field nudging, which is less flexible than e.g. spectral nudging approaches, which are possible in spectral-transform based models, such as this one. A set of simulations, which are currently being analyzed in the context of the last three works cited in the reference list in the next box (Anstey et al., Andrews et al., Huang et al.), required nudging to either the observed (ERA5) state or an idealized, climatological state of the tropical stratosphere. Preliminary results indicate an improvement of simulated teleconnections in the bias-corrected model, and fairly realistic surface influence of the QBO, likely due a high model resolution which gives a good variability of tropical precipitation.
A further set of simulations was dedicated to alternative nudging setups, in particular for the off-tropics conditions. An example of such simulations is shown in Fig. 2, illustrating how nudging only in the upper stratosphere (left) eliminates, as expected, the ensemble spread, but effects at lower levels, where no nudging is applied, vary between realizations. This setup can be helpful to better understand how the surface response is modelled under a ‘perfect’ upper atmospheric state.

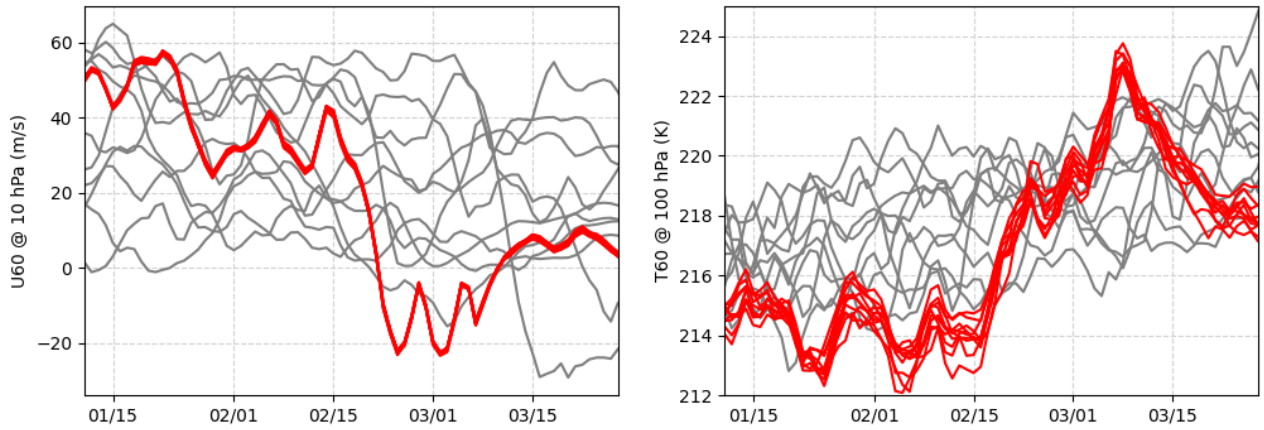

Fig. 2: Zonal mean zonal wind (left) and zonal mean temperature (right) for the alternate nudging simulations, for a sudden warming event in 2018. Red is nudged, grey is free-running.

This set of simulations required, as explained above, some additional resources, since a number of ensemble members are needed to better characterize rare events and their surface response. The analysis of this set of simulations is ongoing also in collaborations with other participants to the EC-Earth consortium, with some preliminary results presented in a scientific conference last spring.

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List of publications/reports from the project with complete references

Serva et al., Changes in Stratospheric Dynamics Simulated by the EC-Earth Model From CMIP5 to CMIP6, Journal Advances Modeling Earth Systems, 2024
Serva et al., Improving the simulation of the stratosphere in the EC-Earth model, poster presentation at QSQ workshop, Cambridge, 2025
Anstey et al, Experimental protocol for QBOi Phase 2, in preparation for Weather and Climate Dynamics
Andrews et al, Extratropical teleconnections in a multi-model ensemble nudged towards the observed QBO , in preparation for Weather and Climate Dynamics
Huang et al, The Missing QBO-MJO Connection in the QBOi Phase 2 Models with a Nudged Stratosphere, in preparation for Weather and Climate Dynamics

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Future plans

(Please let us know of any imminent plans regarding a continuation of this research activity, in particular if they are linked to another/new Special Project.)

The project has been continued in 2025, and the corresponding report to be submitted in the system. It is expected that some of the limitations of the model encountered in this project can be solved in the next ones, by using a more recent version of the IFS model.

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