SPECIAL PROJECT FINAL REPORT

All the following mandatory information needs to be provided.

Project Title:	REsolved orography impact on the mid-latitude FlOw with ECEarth (REFOrgE)
Computer Project Account:	Spitdav2
Start Year - End Year:	2019 - 2021
Principal Investigator(s)	Paolo Davini
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Other Researchers (Name/Affiliation):	Irina Sandu (ECMWF) Federico Fabiano (CNR-ISAC)

Summary of project objectives

Within REFORGE we aim at exploring the impact that resolved and sub-grid orography has on the flow using the EC-Earth3 global climate model. Making use of a set of atmosphere-only integrations at three different horizontal resolutions (~80 km, ~40 km and ~25 km) we will 1) explore the effect of resolved orography on the mid-latitude climate – with a special regard to recurrent weather patterns as atmospheric blocking –2) assess to what extent the current parametrizations of sub-grid orographic effects (which are unresolved at a standard climate model resolution, i.e. ~80 km) are able to reproduce the effects of the resolved orography, 3) explore ways of improving the simulation of circulation patterns in climate simulations improving the representation of the unresolved orography.

Summary of problems encountered

Nothing to report in the last 6 month of the projecgt

Experience with the Special Project framework

Overall, the experience was positive. However, the absence of a reminder for the final report did not help in reporting the final progress on time

Summary of results

REFORGE simulations allowed to demonstrate the fundamental role of mean orography in the quality of the simulated climate and its variability in the Northern Hemisphere: this led to one peer-review publication, Davini et al (2023) publisedh in Weather and Climate Dynamics. As suggested by the ECMWF guidelines, we will report only a short summary of the result achieved and will send for the manuscript for further details on the achievements.

REFORGE set of simulations run without any orographic parametrization at different horizontal (TL255, TL511 and TL799) resolutions highlighted how horizontal resolution is key – at least in EC-Earth3 - to improve the representation of many aspects of North Atlantic climate, including very complex phenomena as atmospheric blocking.

However, making a specific simulations where high-resolution mesh was associated with lower resolution mean orography (e.g. TL799/TL511 runs with TL255 orography), it was possible to demonstrate how most of the improvements in most fields (as the ones shown by the radar chart in Figure 1) was consequence simply of the level of detail of the orography rather than some dynamically-induced improvements in the representation of eddies of air-sea interaction. More refined orography implies a much better resolved mean flow and this has a wide set of implications for jet stream dynamics.

Further details can be found in the relative peer-reviewed paper Davini et al. (2023) published on Weather and Climate Dynamics.

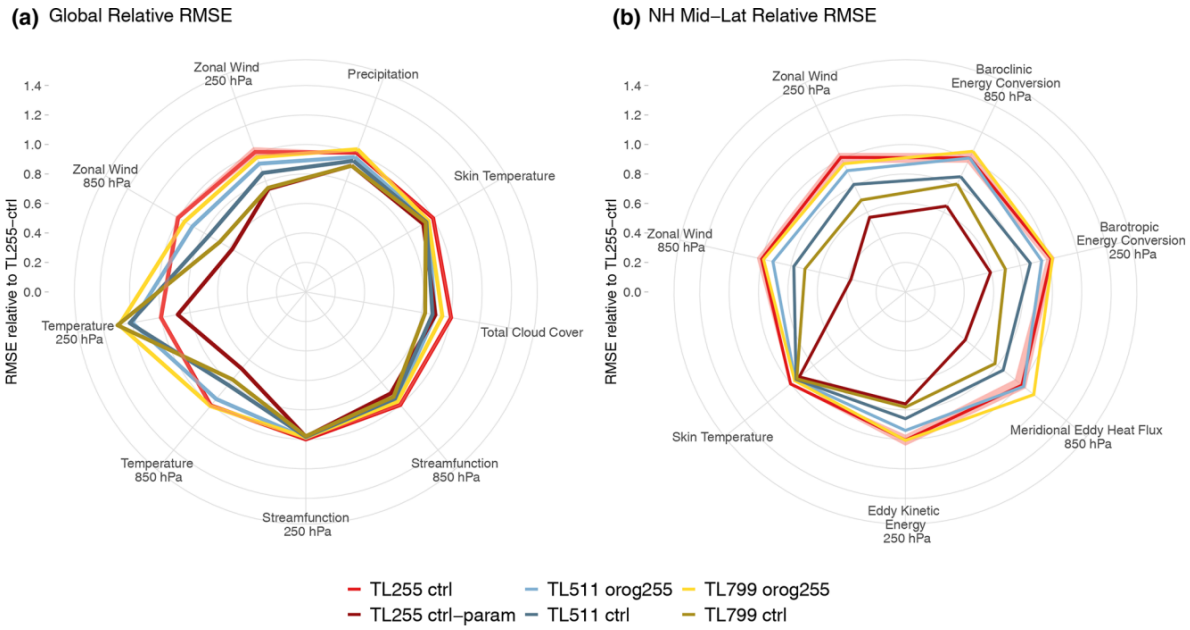

Figure 1: Radar chart showing the December-to-March Root-Mean-Square-Error (RMSE) against ERA5 relative to the EC-Earth3 TL255-ctrl experiment for (a) a set of globally averaged fields and (b) a set of Northern Hemisphere mid-latitude (30–75◦ N) fields. Since the TL255-ctrl experiment is the reference (red), its values are always 1. TL511 is shown in blue and TL799 in yellow, with lighter colours indicating orog255 experiments. For the TL255-ctrl run the three integrations available are shown, with the ensemble mean in bold. Values closer to the centre of the plot imply smaller RMSE. Please note that (a) and (b) include different variables. From Davini et al. 2023.

Other experiments have been run in the last months of the project to try to improve the quality of the Lott and Miller (1997) parametrizations, by assessing a set of sensitivity test on a series of tuning knob of the parametrization playing in the plausible range. A minimization strategy aiming at reducing the RMSE of zonal wind at three different levels (850hPa, 300hPa and 10hPa). Despite some positive results during the sensitivity analysis, done with a Sobol matrix approach to sample the sensitivity to 4 critical parameters of the parametrizations (namely GFRCRIT, GKDRAG, ZTOFD, GKWAKE), we will not be able to conclude a final robust approach to be replicated and therefore we will not plan to produce a specific publication on the topic in the short term.

List of publications/reports from the project with complete references

Davini, P., Fabiano, F., and Sandu, I.: Orographic resolution driving the improvements associated with horizontal resolution increase in the Northern Hemisphere winter mid-latitudes, Weather Clim. Dynam., 3, 535–553, https://doi.org/10.5194/wcd-3-535-2022, 2022.

Future plans

Despite the topic is most the intriguing, there are no current ideas for future applications.