SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2024
Project Title:	AddRessing iMpact of lArGe- and small-scale biases of North Atlantic SSTs on the mid-latitude Circulation (ARMAGNAC)
Computer Project Account:	spitdav2
Principal Investigator(s):	Paolo Davini
Affiliation:	Istituto di Scienza dell'Atmosfera e del Clima, Consiglio Nazionale delle Ricerche (CNR-ISAC)
Name of ECMWF scientist(s) collaborating to the project (if applicable)	
Start date of the project:	01/01/2022
Expected end date:	31/12/2024

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	26 millions	4.5 millions	32 millions	16 millions
Data storage capacity	(Gbytes)	20,000	0	42,000	10,000

Summary of project objectives (10 lines max)

Within ARMAGNAC we aim at exploring the impact that different patterns and biases of North Atlantic sea surface temperatures (SSTs) - at different spatial and temporal scales - have on the mid-latitude circulation, using the newly developed version 4 of the EC-Earth Global Climate Model (GCM). Making use of a set of atmosphere-only integrations at three different horizontal resolutions (~100 km, ~50 km and ~25 km) we will 1) explore the effect of the most common large-scale SST bias featured by GCMs, such as the ones participating to the CMIP6 effort, 2) assess to what extent spatial and temporal resolution of the SST boundary forcing are relevant for a high resolution atmosphere, and 3) explore what are the impacts of different topologies of the Gulf Stream front, comparing *elongated* (non-meandering) vs. *convoluted* (meandering) Gulf Stream configurations on the local and downstream atmospheric circulation. Overall, ARMAGNAC aims at providing a deeper understanding of the influence that North Atlantic SST biases exert on the mid-latitude circulation dynamics, providing insightful indications for future pathways of bias reduction and model development.

Summary of problems encountered (10 lines max)

The project has been significantly slowed down this year due to two concurrent issues 1) Delays in the development of EC-Earth4, which resulted – among others - in a model that included the CMIP6 forcing only in the initial part of 2024 2) Further difficulties in hiring the staff that was expected to work on the ARMAGNAC project: despite having tried multiple times to find qualified postdoc to develop the project, the lack of manpower caused the most important delays. Therefore, even if some work has been done with EC-Earth4 in the first part of ARMAGNAC - given such limitations - we decided to divert the computing resources toward a failure-proof but slightly different goal. We thus aimed at extending some of the simulations done within the *spitfabi* (State- and forcing-dependence of Equilibrium Climate Sensitivity in EC-Earth) special project to address some of the issues raised there (see below)

Summary of plans for the continuation of the project (10 lines max)

Within the *spitfabi* special project the EC-Earth3 model has been tuned to investigate the possibility of having a pair of configurations where we maximize and minimized climate sensitivity by simply playing with some well-established tuning knobs. However, due to an error in the original setup of the tuning strategy we ended up with a configuration with one of the configuration (specifically the one with reduced climate sensitivity) which was not achieving the expected results. In the first part of this year, we ran a few extra sensitivity integrations to verify the properties of the tuning emulator and we tested the reliability of EC-Earth3 on Atos HPC. We plan in the last part of this year to run a new integration which is now expected to have a substantially reduced climate sensitivity to be compared with the older one.

List of publications/reports from the project with complete references

None

Summary of results

Our work in this reporting period – mostly in the second half of 2023 - has been initially directed toward trying to obtain a robust working version of EC-Earth4. We have been able to perform a set of simulations that have been helpful to support EC-Earth4 development. In this sense, the new configuration has been tested on Atos at both TL159L91-eORCA1 and at TL63L31-ORCA2 configuration. Unfortunately, a lot of manual intervention has been necessary to modify the code and to adapt it to multiple resolution support. Thanks to this effort, to this date also higher resolution configuration as Tco319 and Tco399 can be run, although with a computational cost larger than expected. Scientific concerns also emerged associated to the adoption of cubic octaheadral grids, which produces marked wiggles around sharp orographic gradient even at all resolution, very strong at Tco95 but still worrying at Tco199 resolution. For this reasons, EC-Earth4 community is likely opting for using TL configuration instead. A detailed scaling and testing have been thus possible – especially for the lower configuration resolution - and an example of the results obtained is reported in Figure 1.

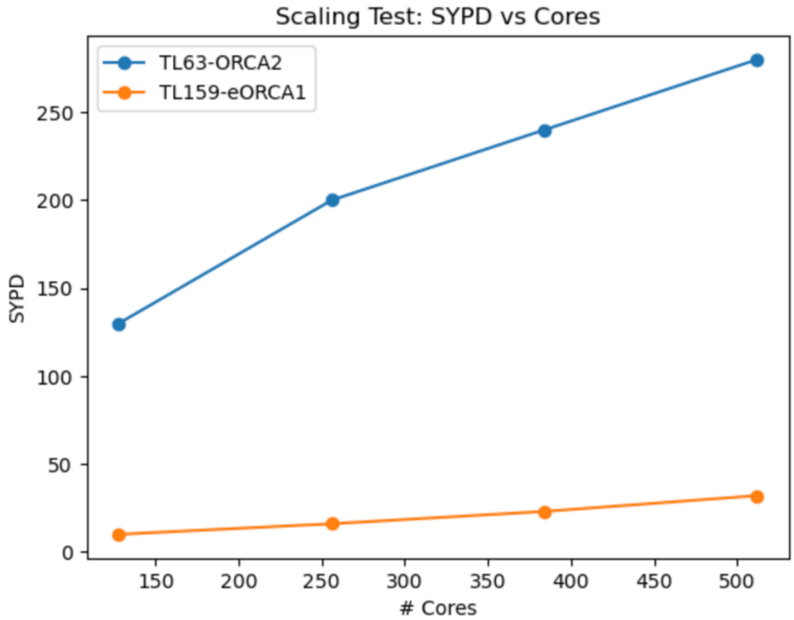

Fig.1: Scalability test for EC-Earth4 low resolution TL63L31-ORCA2Z31 configuration compared with a higher resolution TL159L91-eORCA1Z75, showing simulated years per day (SYPD) vs number of cores.

However, given the above-mentioned difficulties with EC-Earth4, we decided to start running the EC-Earth3 configuration to extend some of the integrations originally planned within the *spitfabi* project. Although this can be considered as partially different task from the original ARMAGNAC goal, the computing time used has been possible to show some interesting features and to integrate some of the previous results. Indeed, the walltime required to run the ARMAGNAC integration was likely exceeding the remaining duration of the project.

An example of what has been achieved can be shown by two integrations where a couple of modified set of parameters involves a change to RPRCON (rate of conversion of cloud water to rain) and ENTRORG (organized entrainment in deep convection) has been run. Specifically, two simulations are reported here:

- pic9, with a lower value of RPRCON (-30%) and ENTRORG (-20%);
- pi9r, with the opposite changes, RPRCON (+30%) and ENTRORG (+20%).

The two parameters, the first affecting the rate of conversion of precipitable water and the second the entrainment in organized convection, are key elements in any EC-Earth (or better IFS) tuning strategy. Those parameters mostly affect the tropical cloud cover and precipitation, but this translates to an impact on the large-scale circulation at global scale. Most importantly, they result in opposite effect on the climate sensitivity.

The global radiative budget is almost conserved in the new configurations, but the climate experiences a strong drift, mostly in the North Atlantic region and related to sea-ice extent. Figure 2 shows the difference in the annual mean temperature of the last 40 years of the simulations (pic9-pi9r), highlighting the warming of the subpolar gyre and North Sea region.

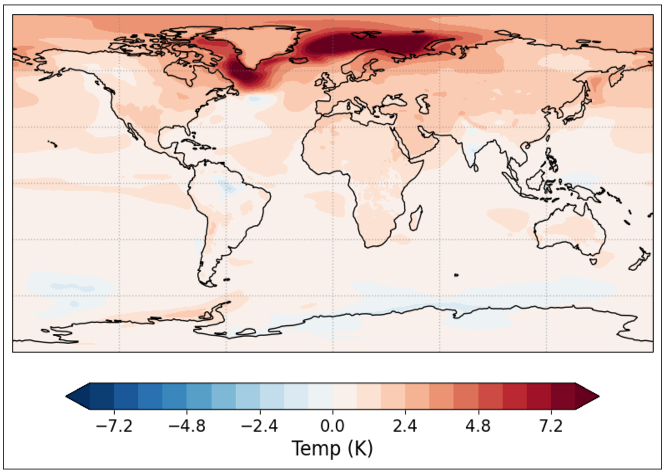

Figure 2. Annual mean surface air temperature difference between the two simulations (pic9-pi9r).

The different climate also determines changes in the atmospheric circulation. We focus here briefly on the wintertime circulation in the Northern mid-latitudes. For example, the mean geopotential height at 500 hPa during winter (not shown) is characterized a strong high geopotential anomaly is observed over the northern part of North Atlantic, over the Atlantic-Arctic gateway, and similarly in the Pacific, just south of the Bering strait. The geopotential height anomaly has a significant impact on the zonal wind in the lower troposphere (850 hPa), which is shown in Figure 3: a dipolar pattern is observed in the Atlantic, with a decrease of the wind over centre-south Europe and a slight increase in the north.

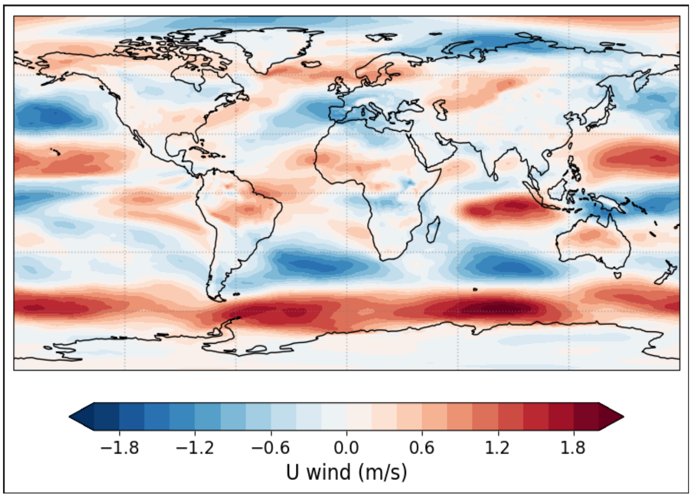

Figure 3. Difference (pic9-pi9r) of the mean zonal wind at 850 hPa during boreal winter (DJF).

More detailed analysis and results are expected by the end of the project where the new run with reduced climate sensitivity will be available so that we will finally able to compare to configuration of the same model with two substantially different climate sensitivity.