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
2020

Project Title:
State- and forcing-dependence of Equilibrium Climate Sensitivity in EC-Earth

Computer Project Account:
spitfabi

Principal Investigator(s):
Federico Fabiano
(S. Corti, P. Davini, J. von Hardenberg)

Affiliation:
ISAC-CNR (Bologna)

Name of ECMWF scientist(s) collaborating to the project
(if applicable)
-

Start date of the project:
01/01/2020

Expected end date:
31/12/2022

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)	NA	NA	9,600,000	0
Data storage capacity	(Gbytes)	NA	NA	17,000	0

Summary of project objectives (10 lines max)

The aim of this project is to explore how the Equilibrium Climate Sensitivity (ECS) of a climate model (i.e. the mean global temperature increase in response to a CO_2 doubling with respect to preindustrial levels) might depend on the model tuning and mean state. Thus we are going to perform a set of coupled climate simulations with EC-Earth, applying different tuning parameters.
In the second part of the project we will analyze the role of the warming patterns in modifying the climate feedbacks and ECS.

Summary of problems encountered (10 lines max)

The planned activities have been delayed due to the lockdown measures.

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

The plan for the next months is to perturb the tuning parameters of the model using a "tuning simulator" to obtain an equilibrated version of the model with a different mean state. Three different "worlds" will be obtained in this way and a preindustrial control run will be performed for each model version. In the meanwhile, the calculation of climate feedbacks through radiative kernels will be explored and applied to the simulations.

List of publications/reports from the project with complete references

No publication is available for this project yet.

Summary of results

1. Code installed and tested on cca

As a first step, the new EC-Earth 3.3.3 version has been installed on the machine. The code has been compiled and a first test has been successfully run.

2. Analysis of ECS in previous EC-Earth versions

Since the project aims at evaluating the impact of the model tuning on the ECS, we first started analyzing how ECS is related to the model mean state in a set of EC-Earth runs available for the Climate SPHINX project (Davini et al., 2017). In that case, EC-Earth is run in two different configurations: one adopting a Stochastic Parametrization (namely the SPPT scheme) in the atmospheric model (stoc) and one with the nominal deterministic parametrization (base).
Figure 1 shows a Gregory plot (i.e. a scatterplot which compares the time evolution of net TOA fluxes vs. global surface temperature) for the two spinup runs in the different configurations. Although the Gregory plot is most informative on the 4xCO2 runs, also the spinup gives a hint of which is the model climate sensitivity. The green lines, which fit the 10-year averages of the yearly net global mean radiation at TOA and the global mean temperature, show a slightly different slope in the two experiments, which correspond to ECS estimates of 5.90 +/- 0.65 K (base) and 6.65 +/- 1.07 K (stoc). The difference between the projected temperature increase in the Climate SPHINX scenario runs has been analyzed in Strommen et al. (2019) and extended up to year 2160 in Meccia et al. (2020). In particular, the latter showed that the situation is more complex than might appear from a linear framework and the climate feedbacks may vary in different ways in the two versions with increasing global temperature.

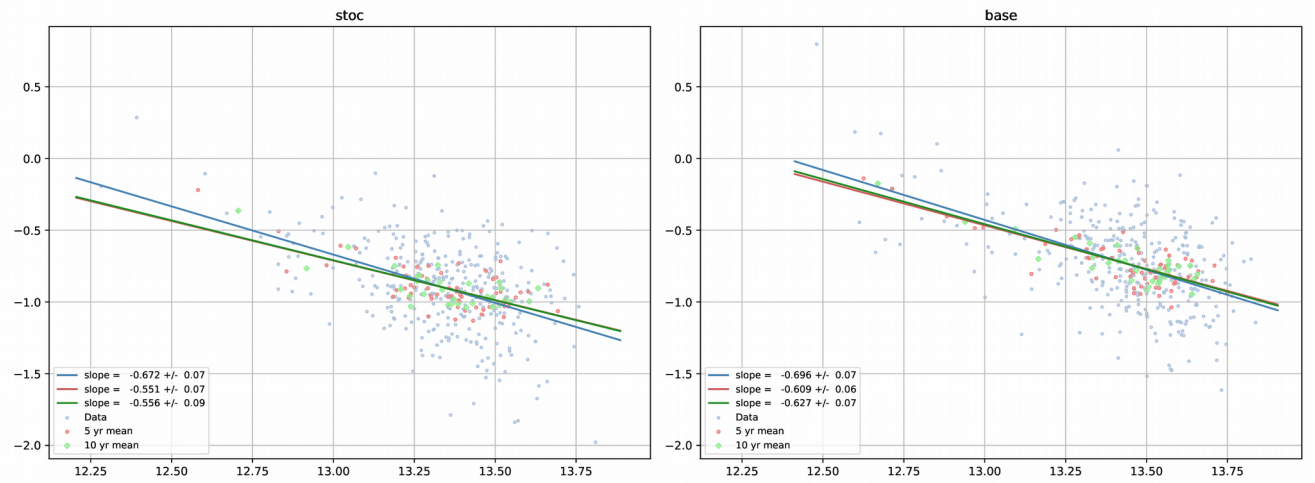

Figure 1. Estimates of ECS in two different version of the EC-Earth model. On the left the model with stochastic physics, on the right the version without. Data from the spinup runs performed under the Climate SPHINX project (Davini et al., 2017).

Also, the warming pattern in the historical run differs in the two model versions. This is shown in Figure 2, which shows the difference between the warming patterns in the stoc and base runs during the period 1900-2005.

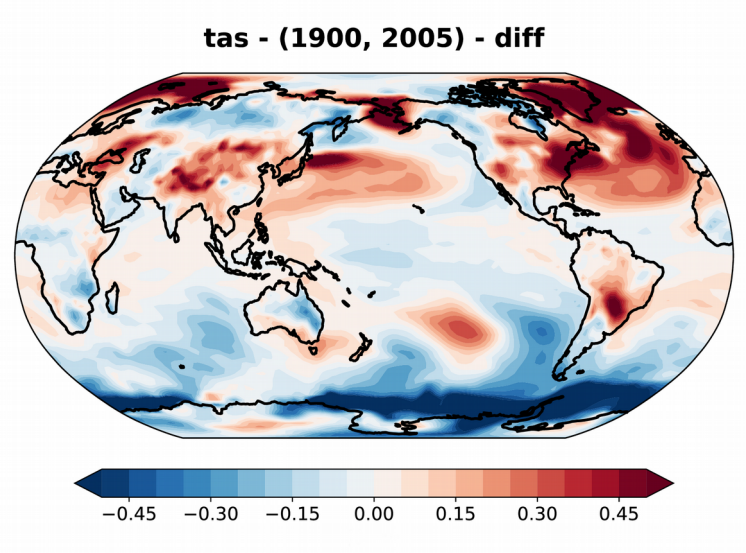

Figure 2. Difference in the warming trend during the historical period (1900-2005) between the stoc and base version of EC-Earth. The colorbar units are K/century. Large differences are seen in the North-Atlantic, North-Pacific and Southern ocean.

These differences suggest that the different mean climate produced by the stochastic physics parametrization also affects the model climate feedbacks. We are further exploring this hypothesis analyzing the spinup and scenario runs performed with EC-Earth3 and EC-Earth3-HR under CMIP6.

3. Model tuning

The work done by the EC-Earth community for the CMIP6 model tuning has allowed to have a clearer picture of the effects of various tuning parameter on the model state. In particular, a “tuning simulator” has been developed that gives an estimate of the global mean temperature and radiative

fluxes obtained for a given set of parameters. We are now using the simulator to find suitable combinations of the parameters to build two different model versions with different climate states.

References

Davini, Paolo, et al. "Climate SPHINX: Evaluating the impact of resolution and stochastic physics parameterisations in climate simulations." *Geoscientific Model Development* 10 (2017).

Meccia, Virna L., et al. "Stochastic parameterizations and the climate response to external forcing: An experiment with EC-Earth." *Geophysical Research Letters* 47.3 (2020): e2019GL085951.

Strommen, Kristian, P. A. G. Watson, and T. N. Palmer. "The impact of a stochastic parameterization scheme on climate sensitivity in EC-Earth." *Journal of Geophysical Research: Atmospheres* 124.23 (2019): 12726-12740.