High-Resolution Decadal Prediction - Impacts on the predictability of the Pacific variability

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I. Extended Abstract

Decadal prediction is a relatively recent field of research, attracting growing interest beyond the scientific community due to its strong potential to provide key information for decision making in economic sectors (e.g. energy production, agriculture, insurance) in a context of pressing danger of climate change. Decadal climate prediction (DCP) skill can arise from two major sources. The first is related to the external radiative forcings (such as volcanic eruptions, solar activity or the anthropogenic greenhouse gases), whose past variations have caused important climate trends in recent decades. And the second is the internal low-frequency variability, usually associated with oceanic processes operating at decadal and multi-decadal timescales. The premise of DCP is that such internal variability processes, when adequately modelled and initialized, can improve our predictive capacity not only on the oceans but also over the surrounding land areas, such as in the North Atlantic region [1].

However, one major limitation common to current DCP systems is the little skill that they present over the continents, which appears to be connected to an incorrect representation of the teleconnection mechanisms that, mediated via the atmosphere, connect the ocean with the neighbouring continents. There are several indications that the current generation of models at standard resolution misrepresents those key teleconnections, and that higher resolution versions might improve them, decreasing common biases of global models and improving some regional seasonal prediction skills, e.g. in tropical sea surface temperature [2]. For decadal prediction, it is still unclear if similar improvements can be achieved through increased resolution, as these systems involve many more simulation years than the seasonal ones, which have made them computationally unaffordable until now.

In this study, we explore how the forecast skill of the DCP can be improved by increasing the spatial resolution of the model. A specific focus on ENSO predictive skill and its associated climate teleconnections will be given to investigate the predictability of the Pacific Ocean, given the promising results of the resolution of oceanic eddies and therefore their effect on the ocean variability [3].

A. Climate model

The experiments will be run with the coupled global climate model EC-Earth v3.3, using its HR configuration [4].

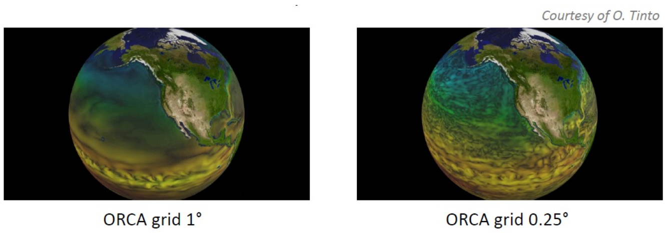

Fig. 1. Different representation of the oceanic circulation depending on the resolution of the model with (left) ORCA 1 degree, (right) ORCA 0.25 degree.

The specific atmosphere-ocean grids are T511-ORCA025, which corresponds to a resolution of approximately 39 km in the atmosphere and 25 km in the ocean. As mentioned above, increasing the horizontal resolution of the model leads to a better representation of previously unresolved processes (e.g. ocean eddies) that are important for ocean-atmosphere interaction (Figure 1). We can expect to better reproduce both the climate mean state and its variability.

B. Methodolody

The ability of climate models to make accurate predictions is usually tested by performing retrospective predictions or hindcasts. These are ensembles of predictions with forecast horizons from months to up to ten years that are started from different past initial states (or start dates). The set of initial states is equi-probable and aim to represent best estimates of the observational uncertainty. The ensemble of past initial conditions is generated by introducing random perturbations in the temperature fields of both the ocean and the atmospheric initial conditions This process is repeated with start dates that sample different years (ideally all years if computing resources allow for it) covering the last few decades until present. By comparing these with observations from the same period, we can then produce an assessment of the forecast quality at different forecast horizons.

Each retrospective forecast will consist of 10 ensemble members, each of them 10-year long, initialised once every 5 years, on the 1st of November over the period 1960-2010 (the last initialised ensemble will start in 2010 and will last 10 years to cover the recent decade of observations), which corresponds to 550 years of simulations.

C. Results

One particularly interesting feature of this HR model version is the improvement in the simulation of the deep

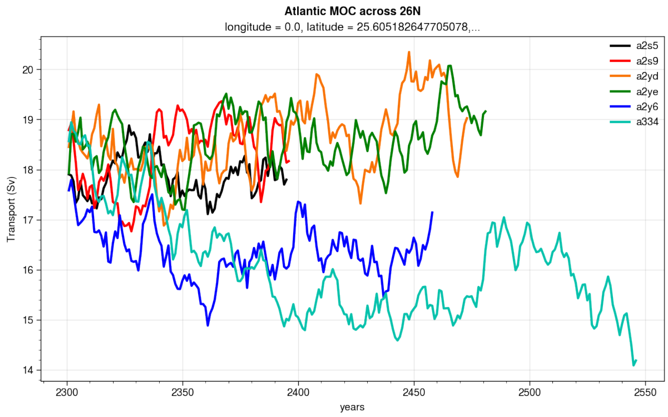

Fig. 2. Strength of the AMOC at 26N for different tuning experiments at HR compared to the SR simulation (light blue line).

convection in the Labrador Sea and the Atlantic Meridional Overturning Circulation (AMOC), compared to the standard resolution version (SR, of approximately 100 kms in both the atmosphere and the ocean). In a decadal prediction system based on EC-Earth3.3-SR, all start dates show a consistent collapse of the Labrador Sea convection [5]. This collapse is caused by the model drift towards its preferred mean state, a drift that induces a quick decrease in the predictive skill in the Subpolar North Atlantic, a source region of decadal variability and predictability [6]. Some initial tests show that this problem is not present in EC-Earth3.3-HR, for which the Labrador Sea convection remains active and stable all along the simulations, directly impacting the strength of the AMOC (Figure 2).

D. Conclusion and perspectives

Different tests are currently being conducted, both on the observation products used to represent the initial state for the hindcast initialisation and on the tuning of the HR version of the model. Further efforts are also required for performing the HR decadal prediction system, computationally expensive, to save CPU hours via an optimal energy-to-solution configuration of the different components of the model.

The analysis of skill (evaluation against observations) and reliability (characterization of uncertainty) of the HR DCP system will then be performed to (1) assess the impact of the increase of the horizontal resolution on the prediction quality of the model and (2) investigate the predictability of the Pacific Ocean.

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Aude Carréric was born in Hennebont, France, in 1984. She received an engineering diploma in Hydraulics and Fluid Mechanics from Toulouse INP-ENSEEIHT (France) in 2007. She subsequently completed her M.Sc degree in Climate Sciences in 2015 and received her PhD in Oceanography in 2019 from the University of Toulouse III - Paul Sabatier (France). She is currently working at the Barcelona Supercomputing Center (BSC), within the Climate Prediction (CP) Group of the Earth Sciences Department.