REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE:	Italy
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Project Title:	Sensitivity experiments on decadal prediction

If this is a continuation of an existing project, please state the computer project account assigned previously.		
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2019	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2019-2021:
(To make changes to an existing project please submit an amended version of the original form.)

		2019	2020	2021
High Performance Computing Facility	(SBU)	9,500,000	9,500,000	9,500,000
Accumulated data storage (total archive volume)[2]	(GB)	15,000	30,000	45,000

Continue overleaf

1 The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

2 If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Extended abstract

Overview

In this special project we plan to explore the role of the ocean decadal variability on global climate. We will focus on two modes of decadal variability of the ocean: the Atlantic Multidecadal Variability and the Pacific Decadal Variability. In particular, we are interested in how the North Atlantic and North Pacific sea surface temperature modulate the global surface temperature trends and the regional climate variability in Europe. This work will be carried out with the EC-Earth Earth System Model (ESM) at its standard resolution, which is represented by a horizontal resolution of approximately 80 km in the atmosphere and 100 km in the ocean. In order to account for the large internal variability characteristic of mid-latitudes, a large number of ensemble members is needed. This is a key aspect for a reliable prediction, especially on decadal time scales.

Scientific context

Studying the present climate is essential to better predict and understand the changes in the upcoming years. Global Climate Models (GCMs) are a powerful tool for investigating the climate response to external forcing as the increase in greenhouse gas and aerosol concentrations. Indeed, in the past years, large efforts have been devoted to the simulations of long term scenarios aimed at providing an estimate of the climate change at the end of the 21st century. Moreover, the decadal prediction of climate became of increasing interest in the scientific community because of its likely role in modulating the future projections. For the first time, the potential for such prediction has been assessed by the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC AR5). The term *decadal prediction* encompasses predictions on annual to decadal timescales and the approach for studying it differs from the standard end-of-the-century climate scenario. In particular, it should be considered not merely as an externally forced numerical integration but as a combined initial and boundary-value problem (Corti et al., 2015).

There are mainly two modes of ocean decadal variability reported in literature that impact on global and regional climate. The Atlantic Multidecadal Variability (AMV) has been identified as a coherent mode of natural variability occurring in the North Atlantic Ocean with an estimated period of 60-80 years. North Atlantic sea surface temperature (SST) varies coherently on the basin scale (Sutton and Hodson, 2005; Knight et al., 2005; Dima and Lohmann, 2007). The AMV has an impact on weather and climate predominantly in the Northern Hemisphere (Steinman et al., 2015) and particularly on the North American and European climate (Sutton and Hodson, 2005; Nigam et al., 2011; Peings and Magnusdottir, 2014; Davini et al., 2015). On the other hand, the Pacific Decadal Variability (PDV) modulates the SST variability in the extra-tropical North Pacific. The SST pattern is characterized by same-signed anomalies in the central and western parts of the basin and opposite signed anomalies along the west coast of the United States and the Gulf of Alaska (Trenberth and Hurrell, 1994; Mantua et al., 1997; Zhang et al., 1997). This pattern exhibits decadal to multi-decadal variability together with interannual variability that is largely in tune with the tropical El Niño-Southern Oscillation (ENSO) phenomenon. The PDV appears to force atmospheric teleconnection patterns controlling climate variability in distant locations (Kumar et al., 2013; Pak et al., 2014; Watanabe and Yamazaki, 2014).

Within this special project we plan to perform a group of targeted simulations with the aim of investigating the origins, mechanisms and predictability of decadal variability in climate and their regional imprints. On the one hand, the experiments will help us to understand the climate response to the AMV and PDV. More specifically, we aim at evaluating to what extent the decadal climate variability at regional scales can be attributed to the patterns of AMV and PDV. On the other hand, our experiments will contribute to the assessment of the coupled model capability to reproduce decadal variability which is of great interest as they underpin the inherent predictability of the system that governs the forecast skill.

Methodology

We plan to apply the EC-Earth ESM (Hazeleger et al., 2010, 2012, http://www.ec-earth.org), version v3.2.2. EC-earth is developed by a large consortium of European research institutions and researchers. It includes state-of-the-art validated components for the atmosphere (ECMWF IFS), the ocean (NEMO; Madec, 2008), sea ice (LIM; Fichefet and Morales Maqueda, 1997) and land (Balsamo et al., 2008) and it is being worldwide applied (see for instance Hazeleger et al., 2010; 2012). In particular, version 3.2.2 includes IFS cy36r4, NEMO version 3.6 and an improved sea-ice scheme LIM3. The model consists of two separate (atmosphere and ocean models) highly-parallelized codes running in MPMD mode. It has been already successfully implemented and tested on different supercomputing platforms including CCA at ECMWF. This should minimize the time needed for the setup of the machine. We will apply the standard resolution according to CMIP6 project, denoted TL255L91-ORCA1. This model setup implies a horizontal resolution of approximately 80 km and 100 km for the atmosphere and ocean, respectively. In the vertical, the atmosphere is solved in 91 levels and the ocean in 75 levels. The integration period for each proposed simulation is 10 years.

The design of the experiments will follow the indication of the Decadal Climate Prediction Project (Boer et al., 2016). It consists of a series of idealized coupled atmosphere-ocean model simulations described in Ruprich-Robert et al. (2017) with some minor adaptations. Basically, the SST of a selected regional domain is relaxed to a known anomalous state, while the rest of the coupled system is left free to drift. To study the system response to the AMV and PDV, we will implement the above-mentioned strategy to the North Atlantic and the North Pacific regions. SST will be relaxed to both, positive and negative phases of the AMV and PDV. Such anomaly patterns are provided by the DCPP-C protocol (Boer et al, 2016) and derived from the difference between observations and the ensemble mean of coupled model historical simulations (Ting et al., 2009). They can be considered as an estimate of the unforced climate internal variability. So far, we plan 4 sets of coupled 10-years runs: 2 in which the North Atlantic SST is relaxed to the signal associated to the positive and negative phases of the AMV, and 2 in which the North Pacific SST is relaxed to the anomalies associated to both phases of the PDV. Additionally, we propose two extra experiments in which the Atlantic SSTs are relaxed to the positive and negative phases of the AMV but only between 0° and 30° N. The results of these runs will allow the assessment of the contribution of the tropics in influencing the regional climate. These two extra experiments are motivated by previous studies that emphasize the role of the Tropical Atlantic SST in influencing the Euro-Atlantic climate (Okumura et al., 2001; Terray and Cassou, 2002; Peng et al., 2005; Sutton and Hodson, 2007; Davini et al., 2015).

Finally, because the internal variability is extremely large at mid-latitude (Deser et al., 2012) it is necessary to run a large number of ensemble members in order to obtain reliable results. We propose 25 ensemble members for each of the 6 sets of runs.

The spun-up state will be provided by the PRIMAVERA H2020 project (https://www.primavera-h2020.eu/) with fixed forcing for the year 1950. Initial conditions will be built sampling the spin-up simulation at time intervals of 5 years. For all the simulations, external forcings (i.e. GHGs, volcanic aerosol, etc.) and boundary conditions will be in line with CMIP6 requirements for the year 1950-1959. Because the sensitivity analysis will be performed by comparing results from the experiment forced with the positive and negative phases, no control experiments are needed. Still, the last part of the spin-up simulation could be used as a neutral configuration to assess the presence of non-linear climate responses.

In summary the planned simulations are the following ones:

- 25 ensemble members (each of 10 years) in which the SST in the North Atlantic is relaxed to the positive phase of AMV;
- 25 ensemble members (each of 10 years) in which the SST in the North Atlantic is relaxed to the negative phase of AMV;
- 25 ensemble members (each of 10 years) in which the SST in the North Pacific is relaxed to the positive phase of PDV;
- 25 ensemble members (each of 10 years) in which the SST in the North Atlantic is relaxed to the negative phase of PDV;
- 25 ensemble members (each of 10 years) in which the SST in the Atlantic between 0° and 30° N is relaxed to the positive phase of AMV;
- 25 ensemble members (each of 10 years) in which the SST in the Atlantic between 0° and 30° N is relaxed to the negative phase of AMV;

The post-processing and data storing will be performed simultaneously with the model running. Our group has acquired expertise in this field thanks to the experience in the Climate SPHINX PRACE project (Davini et al., 2017).

Justification of the computer resources requested

We propose a total of 150 experiments (25 ensemble members per each of the 6 configurations) of 10 years. This sum up to 1500 modeled years.

Scaling tests performed on CCA at ECMWF in the framework of the SPITDAVI project have determined that the optimal configuration for the EC-earth standard resolution (TL255L91-ORCA1) is obtain with 286 cores for IFS and 108 cores for NEMO, with one core each for the runoff mapper and the XIOS server. One year of integration with the above-mentioned conditions is completed in about 19,000 SBU. This number can be increased or reduced if at the moment of need we will be concerned or not by the wall time of the simulations. Following our estimations, we will need 28.5 million SBU for the whole project. We divide this amount in three years. We plan to run the experiments associated to the North Atlantic SST anomalies (AMV) during the first year, those associated to the North Pacific (PDV) during the second year, and the extra simulations associated to the Atlantic SST anomalies in the tropics during the third year of the project.

Considering 6-hourly output for IFS and monthly means for NEMO, the requirements for the storage are around 30 GB/model-year. Consequently, the total amount of required space at the end of the project is around 45 TB. Storage resources will be split in equal parts between the three years.

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