REQUEST FOR A SPECIAL PROJECT 2018–2020

MEMBER STATE: Italy

Principal Investigator[1]**:** Chunxue Yang

Affiliation: Institute of Atmospheric Sciences and Climate, National Research Council (ISAC-CNR), Italy

Address: Via Gobetti 101, Bologna, Italy 40129

E-mail: c.yang@isac.cnr.it

Other researchers: Susanna Corti, Jost von Hardenberg, Irene Mavilia, Paolo Davini

Project Title: Impact of model Resolution on Ocean Dynamics (IROD)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2018	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2018-2019: (To make changes to an existing project please submit an amended version of the original form.)		**2018**	**2019**	**2020**
High Performance Computing Facility	(SBU)	29.5 millions	29.5 millions	
Accumulated data storage (total archive volume)[2]	(GB)	80,000	100,000	

An electronic copy of this form must be sent via e-mail to: *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date):
…………29/06/2017……………

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 an annual progress report 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.

Principal Investigator: Chunxue Yang

Project Title: Impact of model Resolution on Ocean Dynamics (IROD)

Extended abstract

Objective

The objective of this special project is to investigate the impact of model resolution (both atmosphere and ocean resolution) on the ocean dynamics in the tropical Pacific and North Atlantic Oceans, which are two essential regions affecting the global climate. To this aim we will perform both high (T511L91 ORCA025L75) and standard (T255L91 ORCA1L75) resolution coupled simulations with the EC-EARTH coupled climate model (Hazeleger et al. 2010) following the HighResMIP protocol (Haarsma et al. 2016).

Introduction

Our research interests mainly focus on the ocean dynamics in the tropical Pacific and North Atlantic Oceans. In the tropical Pacific Ocean, the El Nino Southern Oscillation (ENSO) is the most dominant interannual mode and the effects of ENSO not only significantly locally, for example, in South America (Sarachik and Cane, 2010), but also global scale through teleconnections (Philander 1990), such as effects on the precipitation in the Indian monsoon (Ropelewski and Halpert 1996). The importance of the North Atlantic Ocean to the global climate is also highlighted in several studies (Sutton and Dong, 2012; Dong et al, 2013; Burt and Howden, 2013).

However, the representation of key processes, such as, the ENSO phenomenon (Yang and Giese, 2013), the Atlantic Meridional Overturning circulation (AMOC) (Wang et al., 2014) is still biased in the coupled climate models. Recent studies have shown that high-resolution climate models are significantly improve the representation of important atmospheric and oceanic physical processes, such as the Atlantic meridional circulations (AMOC) (Stepanov, et al, 2015), the ENSO (Shaffrey etl al., 2009), and the tropical Pacific circulations (Roberts, et al., 2009). The improvement due to high resolution is also shown in the global water cycle (Demory et al., 2014), as well as relevant features of the large-scale atmospheric circulation such as the jet stream (Lu et al., 2015), the Euro-Atlantic blocking (Davini et al. 2017a) the Madden–Julian Oscillation (Peatman et al., 2015), tropical cyclones (Jin et al., 2014).

The difficulties we face to have high resolutions simulations for studying climate science come from the high cost of computing time. Due to the expensive computing resources there are currently few simulations that cover a time scale long enough to allow the investigation of the impact of high resolution on the simulation of the main feature of climate variability. The High Resolution Model Intercomparison Project (HighResMIP) (Haarsma et al. 2016) applies, for the first time, a multi-model approach to the systematic investigation of the impact of horizontal resolution. It consists of a coordinated set of experiments designed to assess both a standard and an enhanced horizontal-resolution simulation in the atmosphere and ocean. The H2020 European Project PRIMAVERA is the framework in which many European Institutions carry out the climate simulations prescribed by HighResMIP. In PRIMAVERA 10 major research institutes, including AWI, CERFACS, CMCC, ECMWF, MetOffice, MPI and those part of the EC-Earth consortium (i.e. BSC, CNR, KNMI, SMHI) are committed to realize a multi-model ensemble of high resolutions simulations to assess

This form is available at:
http://www.ecmwf.int/en/computing/access-computing-facilities/forms

the impact of increased horizontal resolution on the simulation of the European climate for the recent historical period and the near future (1950-2050).

CNR has been using the EC-Earth model for climate simulations within the CMIP5 protocol and, more recently, has conducted the coordinated experiment Climate SPHINX (Stochastic Physics HIgh resolutioN eXperiments), a comprehensive set of forced (atmosphere only) ensemble simulations aimed at evaluating the sensitivity of present and future climate to model resolution and stochastic parameterization (Davini et al. 2017b; Watson et al. 2017). Climate SPHINX was granted by 20.4 millions of core hours from PRACE (the Partnership for Advanced Computing in Europe).

These simulations will help us to understand the impact of ocean and atmosphere resolution on the above mentioned phenomena and on other physical processes. Moreover, they will provide us tools to investigate the change of these processes and mechanisms due to both internal and external climate variability. Our simulations, which will be part of the ensemble carried out by the different partners of the EC-EARTH consortium will not only benefit to other partners that are involved in the project but also in a broad scale to all the climate scientists who are interested in high resolution climate coupled models.

Experimental setup

The experimental protocol follows the recommendation given in the HighResMip (Haarsma at al. 2016). In particular, all the integrations will start from “observed” datasets.

The initial condition for the ocean component of spin up comes from version 4 of the Met Office Hadley Centre “EN” series of datasets of global quality controlled ocean temperature and salinity profiles and monthly objective analyses (EN4, Good et al., 2013) over an average period of 1950–1954.

The initial condition for the atmospheric component is from ERA-20C (January 1950) from ECMWF.

The forcing includes the most recent CMIP recommendations (see table 1 in Haarsma at al. 2016).

Since all the integrations start from “observed” fields, i.e. outside the model attractor, a 30-50 years of spin up (with constant forcing) are needed in order to reach a “quasi-equilibrium” before initiating the experiments. These spin-ups simulations (performed elsewhere) will be used to initialize the coupled simulations listed below.

1950-CONST: Coupled CTRL historical (standard and high resolution): control experiments with 1950 constant forcing, covering the period 1950-2050 for both standard (T211L91 ORCA1L75) and high resolution (T511L91 ORCA025L75).

1950-2014-TRANSIENT: Coupled EXP historical (standard and high resolution): The forcing of coupled EXP experiments is transient forcing from 1950 to 2014 for both standard and high resolution like coupled CTRL.

2015-2050-FUTURE: Coupled EXP future (standard and high resolution): Coupled EXP future is a continuation of Coupled EXP historical, forced with transient future scenario forcing RCP8.5 in the period 2015-2050.

Justification of the computer resources

The detailed simulations we are going to perform and the computing time we need are shown in Table 1. For year 2018 we will have about 100 years of both high and standard resolution coupled simulations. scaling tests on the ECMWF machine CCA show that for high resolution coupled integrations the model needs 250,000 SBU per year, while the same integrations at standard resolution require 30,000 SBU per year. Before starting productions we would need to perform some test and "soft" tuning, thus we ask for 5% more computing time to make sure we can safely complete the whole integrations. The same requirements will apply also to 2019. The total number of SBU we ask for is 59 millions SBU.

One year of high resolution will require 1.2TB for storage, depending on the chosen output frequency and on specific variables to be saved in the CMIP6 output protocols. One year of standard resolution will require 76GB. Therefore, in total we would need 127.6TB per year for the final outputs. However, we plan to transfer data to our local storage place during the production, meaning that we will ask for 80TB output storage for the year 2018, and 100TB for the year 2019.

Table 1 Planned simulations and needed computing resources.

	2018	**2019**
1950-CONST High resolution	~100 years 25 million SBU	
1950-2014-TRANSIENT **&** **2015-2050-FUTURE** High resolution		~100 years 25 million SBU
1950-CONST Standard resolution	~100 years 3 million SBU	
1950-2014-TRANSIENT **&** **2015-2050-FUTURE** Standard resolution		~100 years 3 million SBU
Test runs	1.5 million hours	1.5 million hours
Total	29.5 millions	29.5 millions

Technical characteristics of the code to be used

The EC-EARTH model is a global coupled climate model, that is composed with the atmospheric circulation model based on ECMWF's Integrated Forecasting System (IFS), ocean circulation model from the Nucleus for European Modelling of the ocean (NEMO; Madec 2008) version 3.6, and sea ice model from Louvain-la-Neuve Sea Ice model (LIM3; Fichefet and Morales Maqueda 1997). The coupler is based on OASIS3. The version we are going to use is based on EC-EARTH version 3.2.2. The configuration of standard resolution is ORCA1L75 for NEMO, which has horizontal resolution of 1degree and 75 vertical levels, and T255L91 for IFS, which is 80 km horizontal resolution. For high resolution the configuration is ORCA025L75, which has horizontal resolution of ¼ degree and 75 vertical levels, T511L91 for IFS, which is 40 km horizontal resolution.

HighResMIP output has a specific format which follows the CMIP6 protocol. During production, we will have post-process procedure for the output based on CMOR3. In the EC-EARTH consortium one of the partners (KNMI) has been working on the integration of CMOR with EC-EARTH, mainly based on with CDO, Python, NCO, NETCDF.

References:

Burt, T. P. and N. J. K. Howden (2013), North Atlantic Oscillation amplifies orographic precipitation and river flow in upland Britain, 49, 3504-3515.

Davini P., S. Corti, F. D'Andrea, G. Rivière, J. von Hardenberg (2017a) Improved winter European atmospheric blocking frequencies in high-resolution global climate simulations. *JAMES*, under review.

Davini, P., von Hardenberg, J., Corti, S., Christensen, H. M., Juricke, S., Subramanian, A., Watson, P. A. G., Weisheimer, A., and Palmer, T. N.: Climate SPHINX: evaluating the impact of resolution and stochastic physics parameterisations in the EC-Earth global climate model, Geosci. Model Dev., 10, 1383-1402, doi:10.5194/gmd-10-1383-2017, 2017b.

Dong, B. R. T. Sutton T. Woollings, and K. Hodges, (2013), Variablity of the North Atlantic summer storm track: mechanisms and impacts on European climate, 8, 034037

Demory, M.-E., Vidale, P. L., Roberts, M. J., Berrisford, P., Strachan, J., Schiemann, R., and Mizielinski, M.: The role of hori- zontal resolution in simulating drivers of the global hydrological cycle, Clim. Dynam., 42, 2201–2225, 2014.

Fichefet T and MA Morales Maqueda (1997) J. Geophys Res 102:12609-12646

Haarsma, R. J., Roberts, M. J., Vidale, P. L., Senior, C. A., Bellucci, A., Bao, Q., Chang, P., Corti, S., Fučkar, N. S., Guemas, V., von Hardenberg, J., Hazeleger, W., Kodama, C., Koenigk, T., Leung, L. R., Lu, J., Luo, J.- J., Mao, J., Mizielinski, M. S., Mizuta, R., Nobre, P., Satoh, M., Scoccimarro, E., Semmler, T., Small, J., and von Storch, J.-S.: High Resolution Model Intercomparison Project (HighResMIP v1.0) for CMIP6, Geosci. Model Dev., 9, 4185-4208, doi:10.5194/gmd-9-4185-2016, 2016.

Hazeleger, W., Severijns, C., Semmler, T., S ̧tefa ̆a ̆nescu, S., Yang, S., Wang, X., Wyser, K., Dutra, E., Baldasano, J. M., Bintanja, R., Bougeault, P., Caballero, R., Ekman, A., Christensen, J., van den Hurk, B., Jimenez, P., Jones, C., Kållberg, P., Koenigk, T., McGrath, R., Miranda, P., Van Noije, T., Palmer, T., Parodi, J., Schmith, T., Selten, F., Storelvmo, T., Sterl, A., Tapamo, H., Vancoppenolle, M., Viterbo, P., and

Willén, U.: EC-Earth: A Seamless Earth-System Prediction Approach in Action, B. Am. Meteorol. Soc., (2010) 91, 1357–1363, doi:10.1175/2010BAMS2877.1.

Jin, H., M. S. Peng, Y. Jin, and J. D. Doyle, (2014), An evaluation of the impact of horizontal resolution on tropical cyclone prediction using COAMPS-TC, Weather and Forecasting, 29, 252-270.

Lu, J. G. Chen, L. R. Leung, D. A. Burrows, Q. Yang, K. Sakaguchi, and S. Hagos, (2015), Towards the dynamical convergence on the jet stream in Aquaplanet GCMs, J. Climate, 28, 6763-6782.

Madec G (2008) NEMO ocean engine. Note du Pole de modelisation, Institut Pierre- Simon Laplace (IPSL), France, No 27 ISSN No 1288-1619

Peatman, S. C., Matthews, A. J., and Stevens, D. P.: Propagation of the Madden–Julian Oscillation and scale interaction with the diurnal cycle in a high-resolution GCM, (2015) Clim. Dynam., 45, 2901– 2918, doi:10.1007/s00382-015-2513-5.

Philander, S. G. H., 1990: El Niño, La Niña, and the Southern Oscillation. Academic Press, 293 pp.

Roberts, M. J., A. Clayton, M. E. Demory, J. Donners, P. L. Vidale, W. Norton, L. Shaffery, D. P. Stevens, I. Stevens, R. A. Wood and J. Slingo, (2009), Impact of resolution on the Tropical Pacific Circulation in a Matrix of coupled models, (2009), J. Climate, 22, 2541-2556.

Ropelewski, C. F., and M. S. Halpert, 1996: Quantifying Southern Oscillation– precipitation relationships. J. Climate, 9, 1043–1059,

Sarachik, E. S., and M. A. Cane, 2010: The El Niño–Southern Oscillation Phenomenon. Cambridge University Press, 384 pp.

Shaffrey, L. C., Stevens, I., Norton, W. A., Roberts, M. J., Vidale, P. L., Harle, J. D., Jrrar, A., Stevens, D. P., Woodage, M. J., De- mory, M. E., Donners, J., Clark, D. B., Clayton, A., Cole, J. W., Wilson, S. S., Connolley, W. M., Davies, T. M., Iwi, A., M., John, T., C., King, J. C., New, A. L., Slingo, J. M., Slingo, A., Steenman-Clark, L., and Martin, M.: U.K. HiGEM: the new U.K. High-Resolution Global Environment Model-model description and basic evaluation, J. Climate, 22, 1861–1896, 2009.

Stepanov, V. N., D. Iovino, S. Masina, A. Storto and A. Cipollone, (2015), the impact of horizontal resolution of density field on the calculation of the Atlantic meridional overturning circulation at 34S. J. Geophys, Res. –Oceans, 121, 4324-4340.

Sutton, R. T. and B. Dong (2012), Atlantic Ocean influence on a shift in European climate in the 1990s, Nature. Geoscience, 5, 788-792.

Wang, C. L. Zhang, S-K. Lee, L. WU and C. R. Mechoso, (2014), A global perspective on CMIP5 climate model biases, Nature climate change, 4, 201-205.

Watson, P. A. G., Berner, J., Corti, S., Davini, P., von Hardenburg, J., Sanchez, C., Weisheimer, A., & Palmer, T. N. (2017). The impact of stochastic physics on tropical rainfall variability in global climate models on daily to weekly timescales. *Journal of Geophysical Research: Atmospheres*. https://doi.org/10.1002/2016JD026386

Yang, C. and B. Giese (2013), El Niño Southern Oscillation in an ensemble ocean reanalysis and coupled climate models, J. Geophys, Res. Oceans, 118, 4052-4071.