Barcelona Supercomputing Center
Centro Nacional de Supercomputación

RES
RED ESPAÑOLA DE SUPERCOMPUTACIÓN

TEMP-2019-2-0057 Influence of eddy-wind mechanical interactions in a very high-resolution coupled climate model

1. General Information

Activity Id
TEMP-2019-2-0057

a) Activity Title
Influence of eddy-wind mechanical interactions in a very high-resolution coupled climate model

b) Area
Astronomy, Space and Earth Sciences

2. Research Project Description

a) Is this a Test Activity?
No

b) Is this a Long Term Activity that will extend over two application periods?
No

c) Brief description of the Project
Global high resolution climate models have demonstrated that coarse horizontal atmospheric and oceanic resolution from typical climate models is a limiting factor to correctly reproduce climate mean state and variability, and recent publications highlight the need for increasing resolution for better simulating climatic processes such as El Nino Southern Oscillation (ENSO) (Masson et al., 2012), Tropical instability waves (Roberts et al., 2009), the Gulf Stream and its interactions with the atmosphere (Kuwano-Yoshida et al., 2010, Ma 2016) or monsoon rainfalls (Seo, 2017) among many others. The Earth Science department of the Barcelona Supercomputing Center (BSC) has recently developed a coupled version of the EC-Earth 3.2 climate model at a groundbreaking resolution of about 15 km (EC-Earth3.2 UHR) for all the climate system components.
EC-Earth3.2 comprises three major components: the atmospheric model IFS (Integrated Forecasting System) Cy36r4, the ocean model NEMO 3.6, which also includes the LIM3 sea-ice model, and OASIS3 that couples the main components. IFS is an operational global meteorological forecasting model

developed and maintained by the European Centre of Medium-Range Weather Forecasts (ECMWF). NEMO is a state-of-the-art modelling framework for the ocean used for oceanographic research, operational oceanography, seasonal forecasting and climate research studies. The resolution of EC-Earth3.2 UHR has ~2M horizontal grid points points with 91 vertical levels for the atmospheric component (T1279L91) and ~13M horizontal points with 75 vertical levels for the oceanic model (ORCA12L75). Compared to standard climate simulations, the increase in horizontal and vertical resolution as well as a reduced time-step leads to an increase in computing resources by two orders of magnitude. In a previous RES project (AECT-2018-3-0006), we proposed to run this EC-Earth UHR configuration in the framework of the Sixth Phase of the Coupled Model Intercomparison Project (CMIP6, HighResMIP coordinated exercise (Haarsma et al., 2016)). It offers a framework for building a large multi-model ensemble of high-resolution simulations with a low resolution counterpart. The production and analysis of this simulation is also defined as a deliverable of the PRIMAVERA European project (H2020).
Although generally much weaker than winds, surface oceanic currents effect on atmospheric stress influences both the atmosphere and the ocean (“current feedback”, referred as CFB, e.g., Duhaut and Straub (2006)). By reducing the energy input from the atmosphere to the ocean, the current feedback slows down the mean oceanic currents (Luo et al., 2012; Renault et al., 2016). It also induces a dampening of the mesoscale activity by roughly 30% via an "eddy killing", i.e., a sink of energy from eddies to the atmosphere (e.g. Renault et al. (2017)). It has been shown that such an interaction partly controls the dynamic of the Western Boundary Currents. Historically, CFB effect was generally not implemented in climate models because of the coarse resolution used. However, in the case of this EC-Earth UHR configuration, where oceanic mesoscale activity is explicitly reproduced, this hypothesis has to be revisited. We propose in this project to study the role of the current-feedback on the global scale oceanic circulation and energy budget, as well as on atmospheric response, and on time long scale to stress its influence on climate indices. We propose to run a twin simulation of the EC-Earth UHR configuration that has already run in the framework of the RES AECT-2018-3-0006 project, including the effect of the current-feedback.

Duhaut, T. H. et al., (2006). Wind stress dependence on ocean surface velocity: Implications for mechanical energy input to ocean circulation. JPO, 36(2), 202–211
Haarsma, R. J., et al. (2016). High resolution model intercomparison project (HighResMIP v1. 0) for CMIP6. GMD, 9(1), 4185-4208.
Kuwano-Yoshida, A.,(2010). Precipitation response to the Gulf Stream in an atmospheric GCM. Journal of Climate, 23(13), 3676-3698.
Luo, G., et al. (2012). Impact of intra-daily SST variability on ENSO characteristics in a coupled model. Clim. Dyn., 39(3-4), 681-707.
Ma, X., et al., (2016). Western boundary currents regulated by interaction between ocean eddies and the atmosphere. Nature, 535(7613), 533– 537.
Masson, S., et al. (2012). Impact of intra-daily SST variability on ENSO characteristics in a coupled model. Climate dynamics, 39(3-4), 681-707.
Renault, L., et al. (2016). Modulation of Wind Work by Oceanic Current Interaction with the Atmosphere. JPO, 46(6), 1685–1704
Renault, L., et al. (2017). Modulation of the Agulhas Current retroflection and leakage by oceanic current interaction with the atmosphere in coupled simulations. JPO, 47(8), 2077-2100.
Roberts, M. J., (2009). Impact of resolution on the tropical Pacific circulation in a matrix of coupled

models. Journal of Climate, 22(10), 2541-2556.
Seo, H., (2017): Distinct Influence of Air–Sea Interactions Mediated by Mesoscale Sea Surface Temperature and Surface Current in the Arabian Sea. JoClim., 30(20), 8061–8080.

d) Grants and funded projects related to this activity

Reference code
H2020 GA 641727

Project title
PRIMAVERA

Starting date
2015-11-01

Ending date
2019-10-31

Total financing (in EUR)
14.967.970,00

Financing source
European

e) Brief description of the Project (if this Activity takes place in the context of a Technology or Industrial Project)

f) Specific Activity proposed

Implementation of CFB is far from being the state-of-the-art in climate models. However, with the increasing resolution of standard configurations, and the preparation of next generation of high-resolution models, the question of the influence of CFB on ocean dynamics and climate becomes critical. Indeed, the increase in meso-scale structures explicitly resolved will lead to a potential stronger effect of CFB, mainly via the “eddy-killing” effect.
EC-Earth3.2 configurations, by default, do not include the CFB. We propose here is a 20 years long simulation of the EC-Earth UHR configuration that includes the CFB.
This simulation, in addition to its counterpart without including the CFB effect that already run in RES AECT-2018-3-0006 program, represents a very unique potential to tackle the issue of the CFB effect in global high-resolution models over a long time frame, in addition of preparing the next version of EC-Earth.
Based on scalability tests and previous simulation of the EC-Earth UHR configuration, one month of simulation has an approximate cost of 20,000 core-hours. The final estimate for a 20 years simulation is thus a total request of 5 million core-hours. This includes an extra ~2% to account for some software issues (numerical instabilities).
The simulation that will be carried on within this project will be divided into separate monthly chunks, each one dependent on the previous iteration. To handle the complexity that involves running the 240 chunks and ensuring failure tolerance, we will use the Autosubmit workflow management system. Autosubmit is able to create, manage and monitor experiments by using remote resources as

Computing Clusters or HPC systems remotely via ssh.
Simulation proposed here would be an additional input to the set of HighResMIP control simulation, i.e. using a constant forcing of 1950 constant forcing. If proven successful (i.e. taking into account CFB significantly improves the quality of the simulation), simulation will be continued to follow HighResMIP protocol within the framework of a PRACE call. These 2 UHR simulations, as well as lower resolution counterparts already available, will be a direct contribution to PRIMAVERA H2020 project (WP4 : Frontiers of Climate Modelling). This set of global coupled simulations ensemble would make a unique tool of to tackle the role of numerical resolution as well as the role of the CFB, and would provide keys contributions on how to improve climate simulations. The potential for publications is very high as impacts are likely to affect several key climatic regions (western boundary currents, southern ocean, tropical zones) but also all the components (ocean, atmosphere, ice).
CFB in the EC-Earth UHR configuration has already been implemented and validated over a short period by our group, and has lead to the recent submission of a publication (Renault et al., (submitted)).

Renault, L., et al. (submitted to Ocean Modelling). On the Implementation and Consequences of the Oceanic Currents Feedback in Ocean-Atmosphere Coupled Models.

g) Computational algorithms and codes outline

EC-Earth3.2 comprises three major components: IFS (atmospheric component), NEMO (oceanic component), and OASIS3 (coupler). It is essential to configure and build separate executable for each one of them. IFS and NEMO fully support a parallel environment, while OASIS3 supports a pseudo-parallel environment. IFS generates the output in GRIB format and NEMO in NetCDF, while OASIS3 does not generate any output. At the end of a simulation the three components always generate restarts separately (IFS in binary, and NEMO and OASIS3 in NetCDF format).
For configuring and building the model executable, GNU make 3.81 or 3.81+, FORTRAN 77/90/95 complaint compiler with preprocessing capabilities and NetCDF4 deployed with HDF5 and SZIP are needed. A newly designed tool for automatic build configuration called "ec-conf" can be used. This useful tool requires Python 2.4.3+ (although it does not work yet with Python 3.0+). For NEMO, FCM, bash and perl are essential, and the GRIB_API I/O 1.9.9 or 1.9.9+ and GRIBEX 370 are required for IFS. GNU date (64-bit) is also required for executing the model with the run scripts.
EC-Earth3.2 supports several configurations which have already been tested on various supercomputing platforms, Marenostrum4 among them. In this activity we will use only the ultra-high resolution configuration of the model : T1279-ORCA12. Resolution of both atmospheric and oceanic components is approximately 15km (compared to ~100km and ~50km resolution for standard and high resolution configurations, respectively). Because of the multi-models interplay, a complete scalability study can be done in two different ways. The first one is to do a separate analysis for each component and then choose the best combination by taking into account the load balance between components, as explained in Acosta et al. (2016). The second is more comprehensive and involves a complete test running all the combinations for each total number of processes and then work further on refining the most efficient one. The second approach, which constitutes the most reliable measure of scalability of this configuration in a state-of-the-art HPC system has been used in our case. We performed a series of 20 tests with different load for all the components of the model, and best performances are obtained with 4512 cores (2976 for NEMO, 1584 ofr IFS, 65 for the I/O server XIOS). For better efficiency on memory usage, we have to distribute efficiently the processors on the nodes (i.e. one processor for XIOS associated with 47 processors for NEMO on each node). We run the model with chunks of 1 month and use restarts to run the following chunk. Also, the configuration now runs in the production workflow Auto-EcEarth developped in our group at BSC. All these previous tests and

work for running and managing the simulation indicate that the configuration is optimized for production in MN4 and the simulation is ready to run as soon as the project starts and the hours are available.

Acosta, M.C., et al. (2016). Performance analysis of EC-Earth 3.2: Coupling. BSC-CES Technical Memorandum 2016-006, 38 pp.

3. Software and Numerical Libraries

Software components that the project team requires for the activity.

a) Applications + Libraries

BLAS, HDF5, LAPACK, NETCDF, R, SCALAPACK, OPENMPI, UDUNITS, NCO, MKL, INTELMPI

b) Compilers and Development Tools

GCC, TOTALVIEW, INTEL, MVAPICH2

c) Utilities + Parallel Debuggers and Performance Analysis Tools

CMAKE, PERL, PYTHON, NCVIEW, AUTOCONF

d) Other requested software

e) Proprietary software

GRIB_API, GRIBEX, CDO, CDFTOOLS

4. Research Team Description

a) Personal Data

Name of Team Leader	Thomas Arsouze
Gender	Male
Institution	Barcelona Supercomputing Center
e-mail	thomas.arsouze@bsc.es
Phone	+34665899021
Nationality	France

b) The employment contract of the activity leader with the research organisation is valid at least 3 months after the end of the allocation period.

Yes

c) Curriculum Vitae of the Team Leader

The scientist responsible of this proposal is Dr. Thomas Arsouze. He is a research scientist at the Climate Prediction Group led by Dr. Pablo Ortega and Dr. Markus Donat, within the Earth Sciences department led by Prof. Doblas-Reyes of the Barcelona Supercomputing Center.
Dr. Thomas Arsouze graduated in Climate sciences from the University Toulouse III (France) in 2008 (Laboratory: LEGOS). He worked between 2009 and 2010 at Columbia University / LDEO (NY, USA) as a postdoctoral researcher. From 2011 to 2017, he has been a research scientist at ENSTA-ParisTech (Paris, France), within the IPSL group. Since early 2018, he is conducting postdoctoral researches at BSC.
He has 35 published and 3 submitted articles in international Q1 peer-reviewed journals. He has a total of more than 1150 citations, with an h-index of 17 and an i10-index of 24 (sources: Google Scholar). He gave 33 presentations (22 oral presentations, and 11 poster presentations) in international conferences and
workshops. He has led 3 French national projects (Simed : coordination of the french community on modeling the Mediterranean Sea, AGRIF-MED and IVASMED: modeling the Mediterranean Sea at high resolution using a nesting approach), contributed to 4 national scientific projects (french ANR projects REMEMBER, DYNED-Atlas, AMEDA, ASICS-MED) and 1 European projects (PRIMAVERA). He was also for 4 years the technical and scientific coordinator for a modeling team for accessing french supercomputing resources (DARI projects). Lastly, he was the team leader for AECT-2018-3-0006 RES project.
He acquired a strong background in regional modeling of the Mediterranean, with a focus on the influence of oceanic small scale structures on oceanic transport on one part, and on ocean-atmosphere interactions on the other part.

d) Names of other researchers involved in this activity

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Lionel Renault (lionel.renault@ird.fr)

e) Relevant publications

Acosta, M.C., X. Yepes-Arbós, S. Valcke, E. Maisonnave, K. Serradell, O. Mula-Valls and F.J. Doblas-Reyes (2016). Performance analysis of EC-Earth 3.2: Coupling BSC-CES Technical Memorandum 2016-006, 38 pp.

Brossier, C.L., Arsouze, T., Béranger, K., Bouin, M.N., Bresson, E., Ducrocq, V., Giordani, H., Nuret, M., Rainaud, R. and Taupier-Letage, I., (2014). Ocean Mixed Layer responses to intense meteorological events during HyMeX-SOP1 from a high-resolution ocean simulation. Ocean Modelling, 84, pp.84-103.

Léger, F., Lebeaupin Brossier, C., Giordani, H., Arsouze, T., Beuvier, J., Bouin, M.N., Bresson, É., Ducrocq, V., Fourrié, N. and Nuret, M., (2016). Dense water formation in the north-western Mediterranean area during HyMeX-SOP2 in 1/36° ocean simulations: Sensitivity to initial conditions. Journal of Geophysical Research: Oceans, 121(8), pp.5549-5569.

Tintó Prims, O., M. Castrillo, K. Serradell , O. Mula-Valls and F.J. Doblas-Reyes (2015). Optimization of an ocean model using performance tools. BSC-CES Technical Memorandum No. 2, 16 pp.

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 (2016) Geoscientific Model Development, 9, 4185-4208, doi:10.5194/gmd-9-4185-2016.

5. Resources

a) Estimated resources required for the Activity for the current Application Period

Requested machine	MareNostrum 4 ((Intel(R) Xeon(R) Platinum 8160, 2.10GHz with Intel(R) Omni-Path / 165888 cores)
Interprocess communication	Tightly Coupled

Typical Job Run	
Number of processors needed for each job	4512.00
Estimated number of jobs to submit	240.00
Average job durations (hours) per job	5.00
Total memory used by the job (GBytes)	1000.00
Largest Job Run	
Number of processors needed for each job	4512.00
Estimated number of jobs to submit	240.00
Average job durations (hours) per job	5.00
Total memory used by the job (GBytes)	1000.00

Total disk space (Gigabytes)	**Minimum**	1000.00	**Desirable**	1000.00
Total scratch space (Gigabytes)	**Minimum**	25000.00	**Desirable**	40000.00
Total tape space (Gigabytes) (*)	**Minimum**	0.00	**Desirable**	0.00
Total Requested time (Thousands of hours)		5000.00		

If this activity is asking for more than 10Million CPU hours, you need to justify the amount of resources requested for the activity. (max 1000 characters)

INFORMATION: The estimated cost of the requested hours, considering only the electricity cost, is 5350 euros.

The architectures selected for the requested resources are only a suggestion. If no hours in this machine/these machines are available, please grant resources in any other similar architecture where the codes used for the application may run efficiently.
** this option implies that if no hours in this machine/these machines are available, the acces committee will allocate the activity in any other similar machine.

6. Abstract for publication

We propose in this project to produce a climatic simulation at a meso-scale resolving resolution. That will come in addition to an already existing twin simulation counterpart, and will document first the first time on a global scale and over a long time frame the influence of the mechanical feedback between oceanic surface currents and wind stress. Studying this effect, so far neglected in the vast majority of climate simulations, will be an unprecedented contribution to describe the physical and dynamical processes in play, both on the atmospheric and oceanic side, and for the climate modeling community to prepare the next generation of high resolution climatic models.

7. Contact with CURES during last year

Information about the RES Users Committee (CURES).

a) User has contacted the CURES during last year

Yes

Yes

Usage Terms & Conditions

- The Usage Terms & Conditions have been already accepted.