APPLICATION FORM
DECI 15 call

Type of proposal	DECI-15 PROJECT

SEnsitivity of Very high-resolution coupled climate model to Eddy-Wind mechanical Interactions (SEVEWI)

1 Scientific objectives

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)[1], 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 PRACE project (**Glob-15km** project, end in october 2019), 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

1 References can be found in the dedicated "bibliography references" section of the online application form.

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 **20 years long simulation of the EC-Earth UHR configuration** already running in the framework of the Glob15km project, **including the effect of the current-feedback.**

2 Scientific and technical innovation potential

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. The simulation proposed here, in addition to its counterpart EC-Earth3.2 UHR without including the CFB effect ran in Glob15km PRACE project, represents a very unique potential to tackle this issue.

CFB in the EC-Earth UHR configuration has already been implemented and validated, and has lead to the recent submission of a publication (Renault et al., (submitted)).

3 Code performance

EC-Earth3.2 comprises three major components: IFS, NEMO and XIOS. Because of that, 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.

As a communitary model, EC-Earth3.2 has been deployed in many HPC systems with different architectures across Europe, including Intel-OmniPath based ones, as MareNostrumIV, or Cray Systems, as the ECMWF cluster or Beskow. EC-Earth 3.2 UHR is already deployed and running in the MareNostrum IV (Glob15km PRACE project). Before starting the production, a scalability test was done on this platform by using the second approach of the two introduced above. This constitutes the most reliable measure of scalability of this configuration in a state-of-the-art HPC system.

As shown in Figure 1, EC-Earth3.2 UHR can use 4,512 processes efficiently, devoting 1,584 cores to IFS, 2,736 to NEMO and 191 cores for the I/O server XIOS, plus one for the element known as runoff mapper, which uses a separate binary, all in a single job. This number might change slightly once the model is installed for the experiment production because the model performance changes with the level of I/O selected and also the machine. One month of simulation would have an approximate cost of 20,484 core-hours. This is the factor used in the preparation of Table 2.

The final estimate is for a total request of **5 million core-hours**, which includes the numbers described in Table 2 plus a buffer of ~2% to account for small tests at the deployment stage and repeated jobs due to hardware (a problem whose chances grow with the number of nodes and the bigger exposure to marginal issues) and software (numerical instabilities).

#Procs	Wallclock hours (1 month sim.)	SYPD
1,632	20	0.1
2,592	7.27	0.27
3,552	5.56	0.36
4,512	4.5	0.44
5,472	4.11	0.49
6,432	3.95	0.51
7,392	3.70	0.54
8,352	3.56	0.56
9,312	3.46	0.58
10,272	3.46	0.58

Table 1: EC-Earth3.2 UHR model performance. The model speed is expressed in simulated years per day (SYPD) and wallclock time (in hours). The tests have been performed on MareNostrum4 with samples of five one-month runs for each processor combination, the average of which is shown in the figure. The numbers provided do not include the time for initialisation and finalisation of the job.

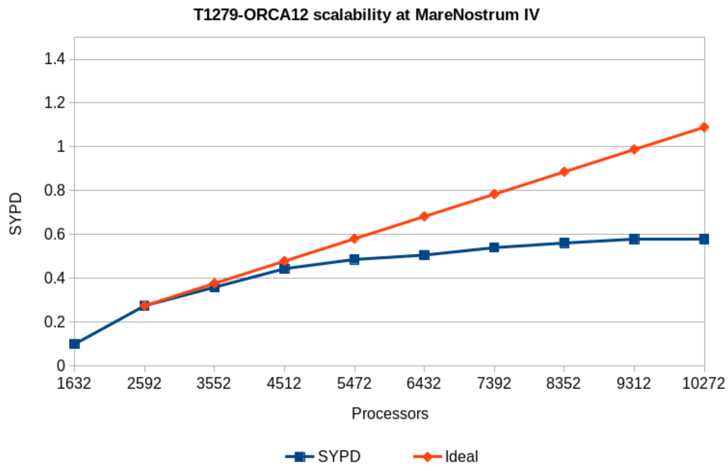

Figure 1: EC-Earth 3.2 (blue) and ideal (red) scalability. The throughput is expressed in simulated years per day (SYPD) of wallclock time, an efficiency measure typically used in climate studies as a function of the number of processes used for each main model component. The tests have been performed on MareNostrum4 with samples of five one-month runs for each processor combination, the average of which is shown in the figure. The ideal is computed over the 2,592 case to avoid showing a "false" superscaling behavior as a result of the poor performance of the base case. The horizontal axis corresponds to the number of cores used.

Run type	# Runs	# Steps/Run	Walltime/Step	#CPU cores	**Total core hours**
Control	1	240	4.54h	4,512	**4,916,275**

Table 2. Computational cost of simulation scheduled within the framework of SEVEWI project: one 20 years simulations performed in chunks of one month. One chunk is expected to require a wallclock time of 4.54 hours using 4,512 cores, following the benchmark performed on MareNostrum4 described in the previous section.

Table 2 does not include the cost of the data management on the HPC platform because its cost is marginal compared to performing the simulations (the workflow contains jobs dedicated performing this task at the end of each model chunk). Each one of these jobs uses a handful of cores.

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.

4 Specific benefits expected from PRACE

Simulation scheduled in SEVEWI project 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 another 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).

5 Project plan

To monitor the resource management and set targets for the dissemination of the results, a number of milestones have been considered and added to Table 3:

- **M1**: Deployment and small load balance tests of the coupled model in the target system
- **M2**: First analysis and initiate data transfer to BSC and JASMIN machines
- **M3**: End of production of the simulation
- **M4**: Documentation of the influence of CFB effect in EC-Earth simulations as a BSC technical memorandum prior to submission to peer-review journals and final report. Publication of the full simulation onto JASMIN data management system at ECMWF.

Months since start	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Deployment and tests			**M1**									
Historical run								**M3**				
Analysis and data dissemination						**M2**						**M4**

Table 3. Schedule of the activities to be undertaken.

6 Summary

We propose in this project to produce a climatic simulation at a meso-scale resolving resolution that will come in addition to its already existing twin simulation counterpart. This will document first the first time on a global scale and over such 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 the community to prepare the next generation of high resolution climatic models.