REQUEST FOR A SPECIAL PROJECT 2014–2016

MEMBER STATE: ……………………….…ITALY…………………………………… …..…

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Project Title: …Sensitivity of multi-annual forecasts to model resolution………………………………………………………. ……

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

Computer resources required for 2014-2016: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2016.)		**2014**	**2015**	**2016**
High Performance Computing Facility	(units)	23 million	28 million	19 million
Data storage capacity (total archive volume)	(gigabytes)	50000	50000	50000

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): ………………30/06/2013…………… ……………

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.

Principal Investigator: ………Susanna Corti………………………………………………

Project Title: … Sensitivity of multi-annual forecasts to model resolution ………………………………………………………………………

Extended abstract

It is expected that Special Projects requesting large amounts of computing resources (500,000 SBU or more) should provide a more detailed abstract/project description (3-5 pages) including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used. The Scientific Advisory Committee and the Technical Advisory Committee review the scientific and technical aspects of each Special Project application. The review process takes into account the resources available, the quality of the scientific and technical proposals, the use of ECMWF software and data infrastructure, and their relevance to ECMWF's objectives. - Descriptions of all accepted projects will be published on the ECMWF website.

Introduction and motivations.

A set of multi-year forecasts have been carried out in the last five years using different versions of the ECMWF coupled system (Doblas-Reyes et al. 2011, Corti et al. 2012, Magnusson et al. 2012) as part of the EU-projects ENSEMBLES, THOR and COMBINE. All these integrations were preformed at T159L91 (~125km) atmospheric resolution. The ocean component was integrated at an average resolution of 1˚ with 42 levels. This is the standard horizontal resolution of most of the models involved in decadal predictions within the CMIP5 framework (e.g. Meehl et al. 2013). However, it has been shown (e.g. van Oldenborgh e al. 2012) that at this resolution forecasts systems have pervasive systematic errors which impact both on the mean state of the system and on the (mis)representation of the non-gaussian probability distribution associated with the climatology of quasi-persistent weather regimes (Dawson et al. 2012). In this latter study it is shown that a low-resolution atmospheric model at T159, is not capable of simulating the statistically significant regimes seen in reanalysis, yet a higher resolution configuration of the same model at T1279 simulates regimes realistically.

The relevance of the study of Dawson et al. 2012 for multi-year predictions is limited by the fact that they consider AMIP-like integrations (i.e. the models studied used observed SSTs for boundary conditions). Because of the errors in the ocean model and the two-way interactions between the atmospheric and oceanic model components, it seems unlikely that one would see such a large improvement moving from T159 to T1279 in a coupled scenario. The coupling process often involves a certain amount of model parameter tuning, which may also decrease the impact of improved atmospheric resolution noted in this study. However, there is evidence that with modest improvements to oceanic resolution one can reduce some of the large SST biases that affect the global circulation (Scaife et al., 2011), suggesting improved atmospheric resolution may still provide considerable benefits. Furthermore, while the ocean provides the primary source of predictability on seasonal to decadal time scales, the response of the atmosphere to sea surface temperature anomalies often determines the impact of these anomalies in remote regions via atmospheric teleconnections. Forecast quality may therefore be particularly sensitive to the resolution of the atmospheric component of the coupled system.
On the other hand increasing the ocean model resolution generally improves the representation of key ocean processes and therefore it should in principle increase the realism of ocean variability which in turn should lead to a decrease of the systematic errors in ocean sea surface temperatures and therefore leading to a potential improvement in the simulation of the ocean-atmosphere coupled variability.

In the light of the above considerations, this proposal aims to investigate the sensitivity of multi-year forecasts to model resolution. During the first project year it is planned to assess the sensitivity to the atmospheric model resolution. In the following project years, depending on the results of the experiments carried out during the first year, we will assess (or not) the sensitivity to the ocean model resolution (see the experimental set up below). Such sensitivity will be assessed by a set of integrations with suitable versions of the ECMWF coupled system (including the Sea-Ice interactive module LIM2) where ocean resolution is kept at the standard ~1˚ or increased to ~0.25˚, while atmospheric resolution is increased from T255 (~80 km) to T511 (~40km). Despite the fact that this latter resolution might be considered nowadays a coarse resolution for a weather prediction system, this is an extremely high resolution for a global climate model and so far few experiments of multi-year predictions have been carried out with such a high resolution for the atmospheric component.

Experimental set up

First year

During the first year of the project we plan to perform the following three experiments.

1) The first experiment (CTL 10-3-5) will consist of a control series of hindcasts with the atmospheric model integrated at T255 (~80km) with 91 levels in vertical (this is the current resolution of the ECMWF System4 coupled model for seasonal predictions). The ocean resolution will be the standard NEMO-ORCA1 (~1˚). We will consider 10 starting dates and we will perform 3-year long hindcasts with 5 ensemble members.

2) The set up of the second experiment will be the same as the first one, but the atmospheric component of the coupled system will be integrated at T511L91 (HRA 10-3-5)

3) In the third experiment a high-resolution coupled system will be considered. The atmospheric component will be integrated at T511L91 and the resolution of the ocean model will be increased to the configuration ORCA025 (0.25˚). The number of vertical levels will be kept the same. In this configuration we will repeat the same hindcasts as in 1) and 2), but, due to the considerable computer time required by coupled high resolution integrations, we will run only 1 ensemble member (HRCTL 10-3-1 experiment).

The model will be initialised using the ECMWF NEMOVAR reanalysis dataset (Balmaseda et al. 2012). Four out of ten starting dates will be chosen in the late period of the observed record (1995-2010) to investigate the ability of the model to reproduce the warming slow-down in the period 2000-2010 (Meehl et al. 2011, Guemas et al. 2013) and to take advantage of the ARGO observing system in the reanalysis. The remaining six starting dates will be chosen in a period of strong trend (for example during the 1980s) and in a period of modest trend (the 1960s). However, other choices are also possible. ISAC-CNR is an affiliated partner in the EU-funded project SPECS (Seasonal to decadal Predictions towards Climate Services). The proposed integrations will contribute to WP41 (Impact of increased horizontal resolution) and the final decision on the starting dates will be taken in agreement with the other partners contributing to this work-package.

By comparing CTL 10-3-5 and HRA 10-3-5 we will estimate the impact of the increased atmospheric horizontal resolution on the forecast quality (and more generally on the simulation of key climate processes) over multi-annual time scale. By comparing CTL and HRA integrations with the HRCTL single member hindcasts we will give a first estimate of the potential gains in forecast quality of a high resolution coupled system against an equivalent low resolution system (CTL) and an atmosphere only high resolution (HRA) coupled system.

Second year

Depending on the improvements arising from the experiments carried out during the first year of the project, two different sets of hindcasts will be performed during the second year:

a) If the comparison between HRA and HRCTL will show that the gain in performing a coupled high resolution system is modest, it is planned to extend the experiments CTL and HRA to consider ten more starting dates in different decades in order to assess the sensitivity to different initial conditions and external forcings.

b) If instead the comparison between HRCTL and HRA will show a considerable improvement in terms of model error and forecast quality when a coupled high resolution system is considered, then it is planned to perform a new set of experiments (HRO 10-3-5) in which we will use the same set up as in CTL 10-3-5, but the horizontal resolution of the ocean model will be increased to ~0.25˚ (ORCA025). The HRO experiments will aim to estimate how much the improvement of the key ocean processes, such as for example ocean convection and the representation of ocean currents, impacts the ability of the models to simulate important modes of variability (for example ENSO and the Atlantic Meridional Overturning Circulation), which in turn influence the extended range predictability over remote continental regions (via teleconnections). Furthermore, in order to have a more robust estimate of the forecast quality it is planned to add two more ensemble members to the HRCTL experiments performed during year 1.

Third year

The set of experiments planned during the third year of the project will depend on the results of the first 2 years. If we had followed solution a), then we will continue the extension of the HRA 10-3-5 experiments adding additional starting dates or (in case of very good forecast quality) extending the hindcasts to 6-year length. If we had followed solution b), then we will have the following two possibilities:

ba) If the comparison between HRO and HRCTL will show that the gain in performing a coupled high resolution system (compared to an ocean only high resolution) is modest, it is planned to extend the experiments CTL and HRO to consider ten more starting dates in different decades in order to assess the sensitivity to different initial conditions and external forcings.

bb) If instead the experiments will show that the improvement of HRCTL is considerable, then we will extend the HRCTL experiment adding ten more starting dates in different decades performing 3-year long hindcasts with 3 ensemble members. In this case we will have at the end of the third year a set of high-resolution 3-year long hindcasts with 20 starting dates and 3 ensemble members.

Technical Characteristics

The following figures have been estimated on the basis of four-month long integrations of the ECMWF coupled system at CTL resolution carried out in collaboration with ECMWF.

First year: In order to perform the CTL 10-3-5 experiment it will requires ~0.975 million SBUs. The atmosphere high-resolution companion experiment (HRA 10-3-5) it will need ~15.6 million SBUs. The HRCTL 10-3-1 will need ~6.24 million SBUs. This sums up to 22.8 million SBUs.

Second year: We will need 16.6 million SBUs in case a) and 28.1 million SBUs in case b).

Third year: We will need 16.6 million SBUs in case a) or ba) and 19 million SBUs in case bb)

The data storage volume required per year is 50000 gigabytes.

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