SPECIAL PROJECT PROGRESS REPORT

Progress Reports should be 2 to 10 pages in length, depending on importance of the project. All the following mandatory information needs to be provided.

Reporting year ……………………2015……………………………….……

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

Computer Project Account: ………………SPITCORT………………………………

Principal Investigator(s): …………Susanna Corti……………………………..……

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Affiliation: Institute of Atmospheric Science and Climate (ISAC) of the Italian National Research Council (CNR)………

Name of ECMWF scientist(s) collaborating to the project
(if applicable)
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Start date of the project: ………………01-01-2014…………………….……

Expected end date: ……………31-12-2016…………………………..……

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	23 millions	23 millions	28 millions	0
Data storage capacity	(Gbytes)	50000 Gb		50000 Gb	

Summary of project objectives

(10 lines max)

This is a three-year project, which 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 the sensitivity to the ocean model resolution. Such sensitivity will be assessed by a set of integrations with a 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).

Summary of problems encountered (if any)

(20 lines max)

The third experiment planned for the first project year was a set of three-year long integrations using a complete high-resolution coupled system (HRCTL 10-3-1: 10 starting dates, 3-year long, 1 ensemble member). The configuration chosen consists of IFS Cycle 40R1 integrated at T511L91 coupled with the ocean model NEMO ORCA025 (0.25˚). In this configuration we were supposed to repeat the same hindcasts as in the control (CTL 10-3-5; i.e. IFS at T255L91 coupled with NEMO ORCA1) and in the atmospheric high resolution experiments (HRA 10-3-5; i.e. IFS at T511L91 coupled with NEMO ORCA1).

However, due to some issues in finding an acceptable configuration for NEMO ORCA025 coupled with T511L91, both in terms of computing time efficiency and in terms of stability of the configuration, we decided to postpone the HRCTL 10-3-1 experiments. The computer time was used to increase the number of starting dates (from 10 to 22) for both control (CTL 22-3-5) and atmospheric high resolution (HRA 22-3-5) experiments.

Summary of results of the current year (from July 2014 to June 2015)

During the current year project we carried out the following experiments:

1) The first experiment (CTL 22-3-5) consists 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 is the standard NEMO-ORCA1 (~1˚). It was initially planned to consider 10 starting dates and perform 3-year long hindcasts with 5 ensemble members. However, as mentioned in the section “Summary of problem encountered” we decided to increase the number of starting dates to 22. The simulations were started on the 1st of November, once every year over the period 1988 to 2009.

2) The set up of the second experiment is the same as the first one, but the atmospheric component of the coupled system is integrated at T511L91 (HRA 22-3-5)

Both experiments 1) and 2) use IFS cycle 40R1 for the atmosphere, NEMO_V3.0 for the oceanic component (Medec 2008) and the LIM2 sea-ice dynamical component (Goosse and Fichefet 1999). All the simulations were initialized with a full initialization procedure (Magnusson et al. 2013) with NEMOVAR-ORAS4 ECMWF operational analysis (Mogensen et al. 2011). The atmosphere is initialised with ERA Interim (Dee et al. 2011). The sea ice initial conditions have been obtained forcing from a 5-member sea ice reconstruction described in Guemas et al. 2014. The external forcing is based on the CMIP5 recommended historical datasets (Taylor et al. 2012).

In this report we will show the impact of increased atmospheric resolution on model mean state and forecast quality at different lead times, from one season to one year ahead.

Near-surface air temperature from ERA Interim (Dee et al., 2011) are used to evaluate the hindcasts. The reference climatology is taken to be the average of the entire period from 1988 to 2009. To take into account the model systematic error, forecast anomalies for each experiment are calculated as: $X'_{j\tau} = X_{j\tau} - \bar{X}_{k\tau}$ where j is the starting year (j = 1, n), τ is the forecast month (τ = 1,120) and $\bar{X}_{k\tau} = \frac{1}{n-1}\sum_{j\neq k}^{n-1} X_{j\tau}$ is the forecast average estimated in cross-validation mode (i.e., estimated removing the model climate for the specific forecast period, see Doblas-Reyes et al. 2011 for more details).
Observation anomalies are estimated using the average on the period for which both observations and hindcasts are available (per=pairs selection of the years, Garcia-Serrano and Doblas Reyes, 2012), i.e., as: $O'_{j\tau} = O_{j\tau} - \bar{O}_{\tau}$.

Model inadequacy causes forecasts to drift away from the observed climate toward an imperfect-model climate. This drift, which can be understood as the evolving systematic error, depends on the forecast time, especially when using the full-initialization approach (Magnusson et al. 2013). Figure 1 displays the mean systematic error of near surface temperature for seasonal forecast (i.e for DJF), the first year forecast and for forecast period 1 to 3 years. Results from CTL and HRA experiments are shown on the left and right column respectively. The experiments have in general air temperatures cooler than the reference, however it is apparent an increase of the systematic error with forecast leading time and a general decrease in the systematic error with the increase of resolution. This is particularly obvious over the oceans, where the cooling is considerably alleviated in HRA, especially over the Pacific tropical band at forecast time longer than one year.

Figure 2 shows the ensemble mean correlation for near-surface temperature computed for seasonal forecast (i.e. average DJF, one month lead time) and for the forecast period 2 to 3 years. As in figure 1, results from the control experiment are on the left, while the HRA counterparts are on the right. Large areas with positive skill appear in all experiments, a consequence of both correctly projected climate change and forecast initialization. The regions where the impact of high resolution is more apparent are circled in blue. For the seasonal forecast, the most evident improvement is over Europe and Africa. It is interesting to note that high resolution shows a positive (even if not always significant) positive skill over Europe, a region with no skill in the CTL experiment. Indeed, the skill of seasonal predictions over Europe for near-surface temperature in forecasts starting in November is very modest, even when more ensemble members are used. The benefits of high resolution are evident also for the multi-annual forecasts. Figure 2 shows a clear improvement in the anomaly correlation coefficients over the Atlantic sub-polar gyre region, the North Pacific and the African continent. We found similar results (not shown) when other variables (for example the 500 hPa geopotential height and the mean sea level pressure) are considered.

Overall the increase in resolution of the atmospheric component lead to a general increase of the model systematic error at different lead time and to a better forecast quality over selected regions. In general the high resolution forecasts have a better skill over Europe and Africa on a seasonal time-scale and over the North Atlantic, Southern Europe and North Pacific for multi-year forecasts (i.e. year2-3). Some improvements have been also found for the seasonal prediction of precipitation over the Northeastern South-America.
Further analyses of these experiments are under way.

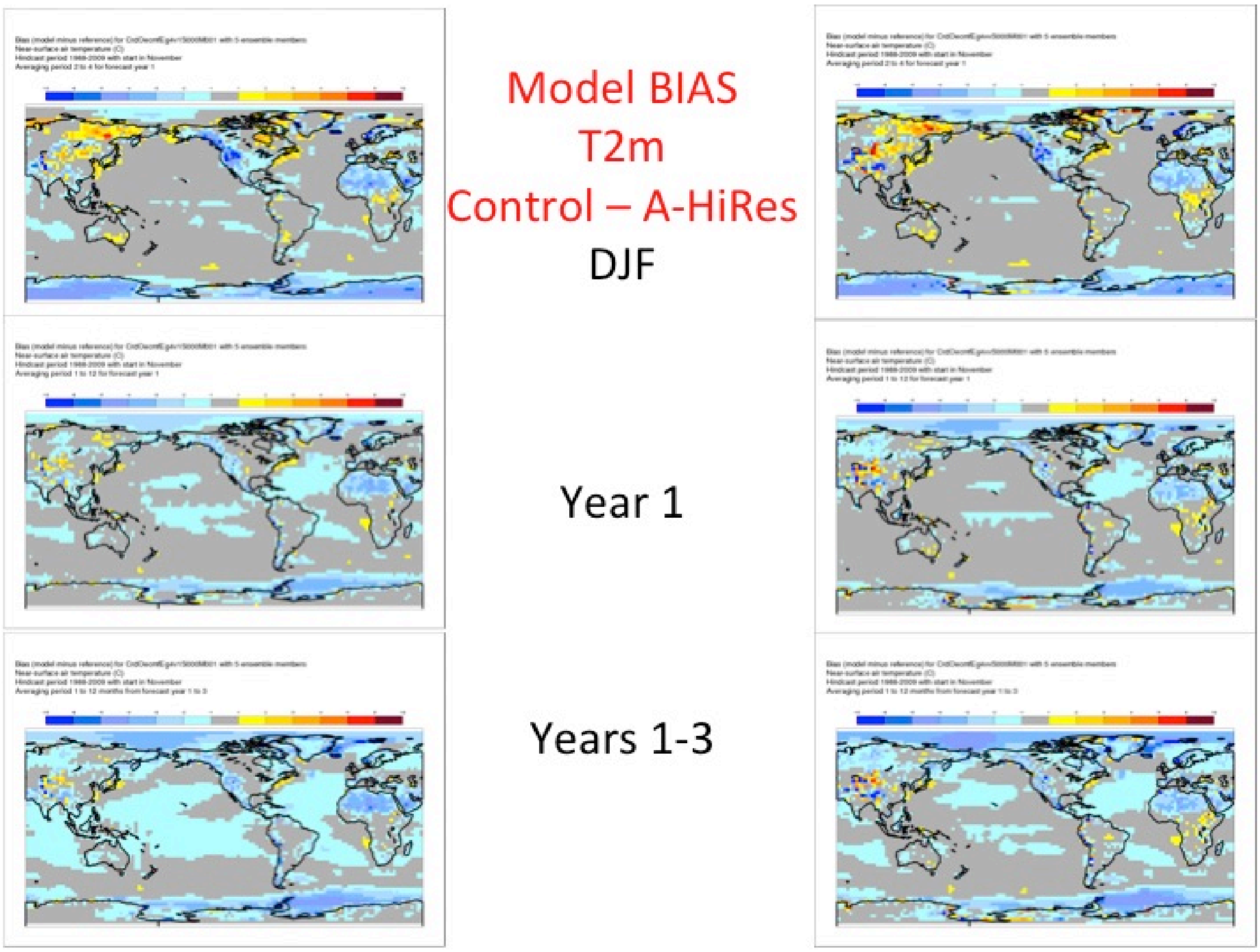

Figure 1. Near-surface air temperature (K) systematic error over the forecast period seasonal (DJF, top row), annual (middle row) and 1 to 3 years (bottom row) of the CTL (on the left) and HRA (on the right) experiments. The systematic error has been estimated with respect to the ERA-Interim dataset. Five-member ensemble reforecasts for the period 1988–2009 have been used.

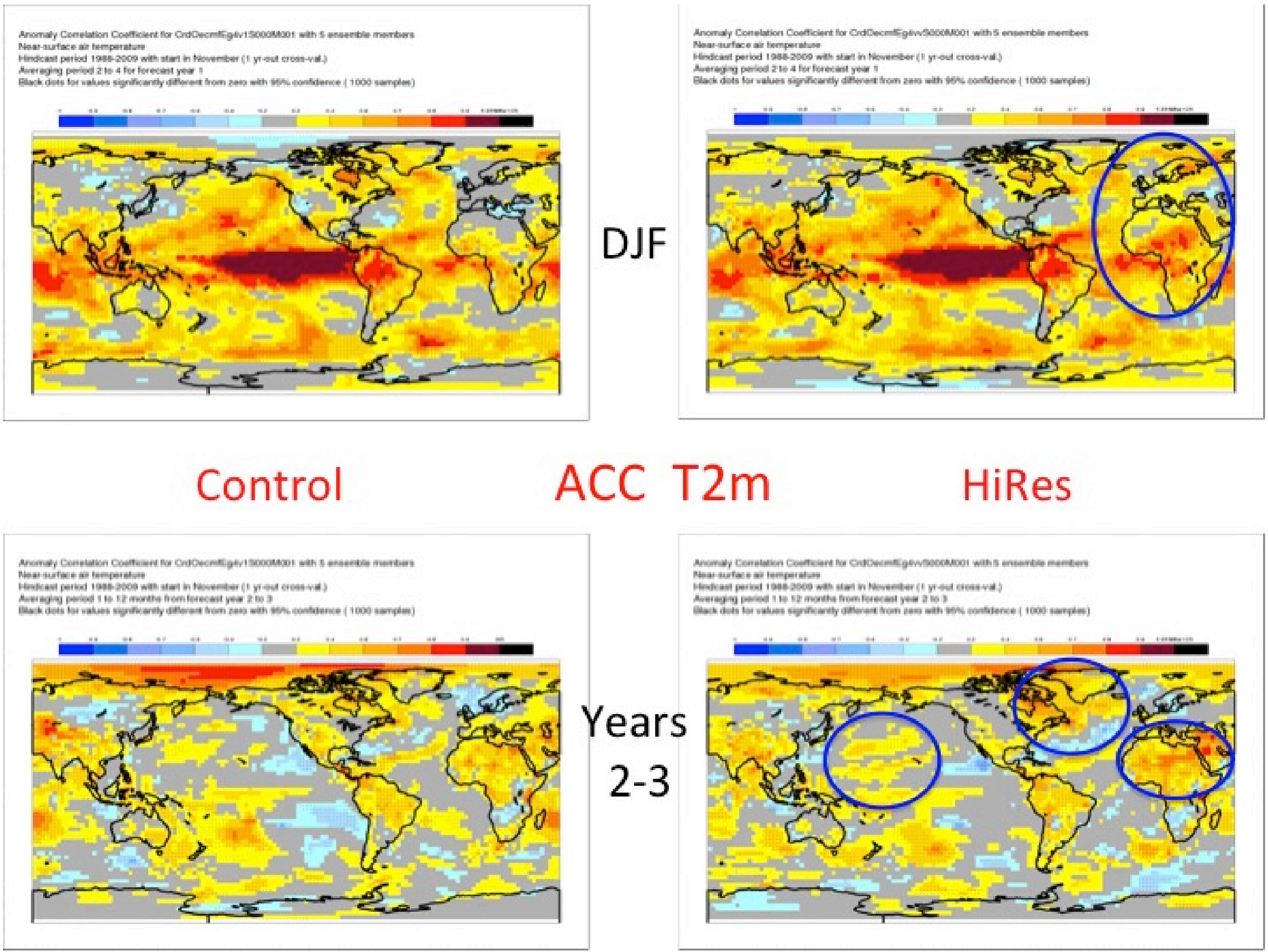

Figure 2. Ensemble mean correlation for near-surface air temperature with respect to the ERA Interim data set over the forecast periods 1 season (DJF top row) and 2 to 3 years of the CTL (left column) and HRA (right column). Five-member ensemble reforecasts for the period 1988–2009 have been used. The black dots depict the grid points where the correlation is significantly different from zero with 95% confidence. Blue circles highlight regions where the impact of resolution is more apparent.

References

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Madec, G., 2008: NEMO reference manual, ocean dynamics component: NEMO-OPA. Note du Pole de Modelisation 27, Institut Pierre-Simon Laplace (IPSL), France.

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Mogensen, K., M.A. Balmaseda, A. Weaver (2012), The NEMOVAR ocean data assimilation system as implemented in the ECMWF ocean analysis for system 4. ECMWF Technical Memorandum 668.

Taylor, Karl E., Ronald J. Stouffer, Gerald A. Meehl, 2012: An Overview of CMIP5 and the Experiment Design. Bull. Amer. Meteor. Soc., 93, 485–498.

List of publications/reports from the project with complete references

The first results of the project have been presented at the Joint MiKlip/SPECS Meeting on Decadal Climate Prediction held in Offenbach the 23-26 February 2015.
http://www.fona-miklip.de/_media/MiKlipSPECS_workshop_leaflet_final_for_web.pdf
A publication based on that presentation is in preparation.

Summary of plans for the continuation of the project

We have been discussing with ECMWF staff in the Predictability Division how to proceed with the experiments planned for the second project year. In principle it was planned to perform a new set of experiments (HRO 22-3-5) in which we use the same set up as in CTL 22-3-5, but the horizontal resolution of the ocean model will be increased to ~0.25” (ORCA025). The HRO experiments 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 turns influence the extended range predictability over remote continental regions (via teleconnections). The technical set up of these experiments is still under discussion, however they will be carried out during the second half of 2015 and should be completed by the end of the year.