High resolution and seasonal forecast scores with CNRM-CM5

Michel Déqué[1], Jean-Philippe Piedelievre[1] and Eric Maisonnave[2]
[1]Centre National de Recherches Météorologiques (CNRS/GAME), Météo-France.
42 avenue Coriolis F-31057 Toulouse Cédex 1, France, michel.deque@meteo.fr
[2]Centre Européen de Recherche et Formation Avancée en Calcul Scientifique (CNRS/SUC)
42 avenue Coriolis F-31057 Toulouse Cédex 1, France

Atmospheric and oceanic horizontal resolutions are a key parameter for the realism of the representation of the natural complex system by a set of equations, because the horizontal derivatives are calculated with a better accuracy, and because important forcings like orography, bathymetry or land/sea distribution involve scales from 1000 to less than 1 km. In short-range prediction, high resolution is essential, because the initial state of the system is observed at high resolution, and because time and space accuracy is required for the forecasts. From the 1970s to today, increases in resolution have been quasi-systematically followed by increases in forecast quality. In seasonal prediction, the target concerns continental scales. In addition, past experience has shown that a good representation of physical processes and large ensembles were essential for seasonal skill: the computation cost implied thus restrictions on horizontal resolution. In this study we explore the role of horizontal resolution in both the atmosphere and the ocean on the predictability of two major phenomena at seasonal scale: ENSO and NAO.

We used here the CNRM-CM5 model (Voldoire et al, 2013). In its reference version the horizontal resolution is 1.5° for the atmosphere and 1° for the ocean. This version will be referred to as LR in the following. A high resolution (referred to as HROA) uses 0.5° in the atmosphere and 0.25° in the ocean. We will also consider a high resolution atmosphere-only version (referred to as HRA) with 0.5° in the atmosphere and 1° in the ocean. These three versions have been used to re-forecast the 1993-2009 period. There are four hindcasts per year, starting at the beginning of February, May, August and November, and ending seven months later. Each hindcast is based on 60 members, generated by small initial perturbations of the atmospheric state.

The ENSO phenomenon is measured by the mean monthly sea surface temperature in the 5°S-5°N by 170°W-120°W rectangle (Nino3.4 box). Figure 1 shows the time correlation, based on 17 observed-predicted pairs, as a function of the lag for the 4 seasons. The impact of higher resolution is far from systematic, according to the season, with an improvement in Autumn, and a degradation in Spring.

The NAO is another large-scale phenomenon, but, contrary to ENSO, it has many temporal scales from the week to the decade. Here it is defined as the first EOF of the daily geopotential height over the rectangle 90W-30E 20N-80N for a given season. We address here the seasonal scale, by averaging months 2 to 4 of the forecasts. Only the DJF mean index exhibits a significant correlation between observation and forecast. Another difference with ENSO is that NAO is a chaotic phenomenon: within an ensemble, some members have a positive mean NAO, some have a negative one. So the NAO index within a season can be characterized by its pdf rather than by a single value. According to the limit central theorem, the mean NAO of a large ensemble (here 60 members) has a Gaussian pdf. One can therefore generate many NAO sequences for the 17 winters and calculate many NAO scores. We obtain thus a pdf for the NAO time correlation taking into account the sampling uncertainty of the ensemble. Figure 2 shows the pdf for the three versions. The mean correlation is 0.46 for LR, 0.51 for HROA, and 0.36 for HRA. The only significant difference is between HRA and HROA.

Additional experiments with 71 vertical levels instead of 31 in the atmosphere, with 3h coupling frequency instead of 24 h indicate that the absence of systematic jump in the forecast scores with high horizontal resolution is a robust characteristics of the model. These results, together with other forecast scores, which confirm this last feature, are available on SPECS Technical Report 1, which can be downloaded at:
http://www.specs-fp7.eu/SPECS/Technical_notes.html

Acknowledgements : We acknowledge that the results in this paper have been achieved using the PRACE Research Infrastructure resource Curie based in France at TGCC (project ID 2012060982). Scientific analyses and additional experiments have been carried in the framework of the FP7-SPECS project of the European Commission

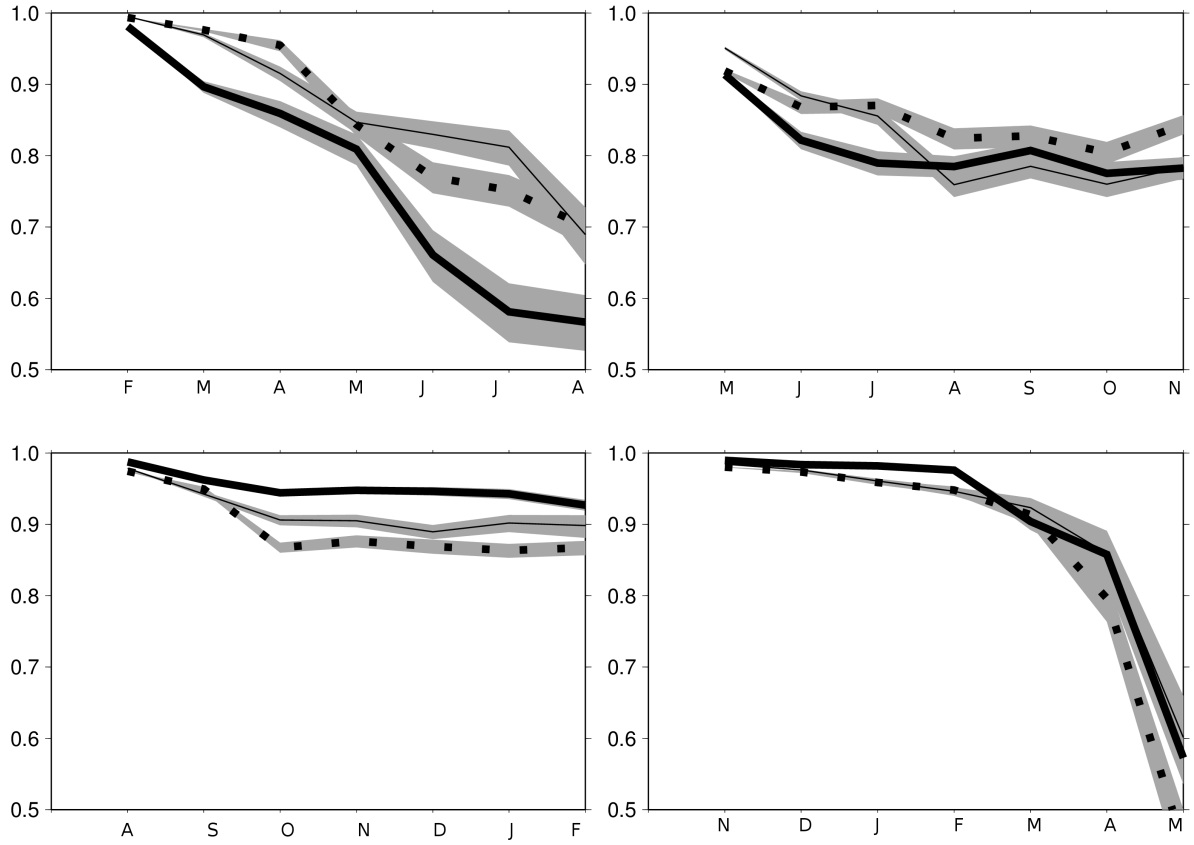

Figure 1: ENSO scores for the 4 seasons with LR (thin line), HROA (thick solid line) and HRA (thick dotted line). Shading for the 95% confidence intervals.

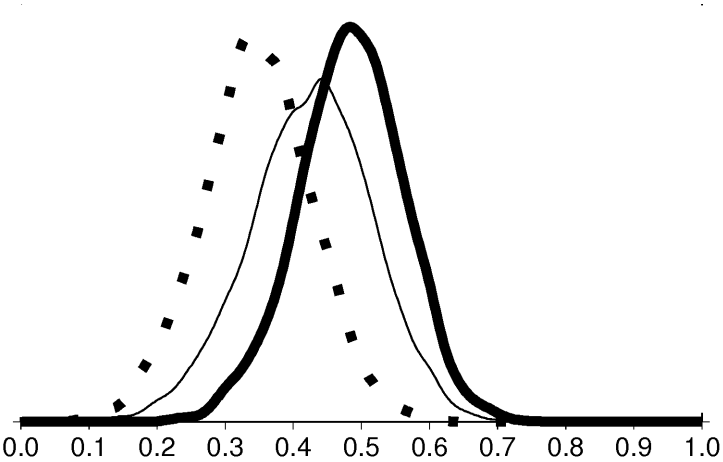

Figure 2: Probability density function for the NAO correlation coefficient in DJF: LR (thin line), HROA (thick solid line) and HRA (thick dotted line).

References:

Voldoire, A. E. Sanchez-Gomez, D. Salas y Mélia, B. Decharme, C. Cassou, S.Sénési, S. Valcke, I. Beau, A. Alias, M. Chevallier, M. Déqué, J. Deshayes, H. Douville, E. Fernandez, G. Madec, E. Maisonnave , M.-P. Moine, S. Planton, D. Saint-Martin, S. Szopa, S. Tyteca, R. Alkama, S. Belamari, A. Braun, L. Coquart, F. Chauvin., 2013, The CNRM-CM5.1 global climate model : description and basic evaluation , Clim. Dyn., DOI:10.1007/s00382-011-1259-y, online.