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Dynamical and statistical downscaling of seasonal temperature forecasts in Europe: Added value for user applications

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ABSTRACT

This work describes the results of a comprehensive intercomparison experiment of dynamical and statistical downscaling methods performed in the framework of the SPECS (http://www.specs-fp7.eu) and EUPORIAS (http://www.euporias.eu) projects for seasonal forecasting over Europe, a region which exhibits low-to-moderate seasonal forecast skill. We considered a 15-member hindcast provided by the EC-EARTH global model (similar to ECMWF System 4, but using bias corrected SST) for the period 1991–2012. In particular, we focus on summer mean temperature and evaluate the added value of downscaling for representation of the local climatology (mean values and extremes), improvement of model skill and performance in particular heatwave episodes. Whereas the suitability of dynamical downscaling for reducing the orographic biases of the global model depends on the region and model considered, statistical downscaling can systematically reduce errors in different order moments, from the mean to the extremes (as represented by the 95th percentile here). However, both dynamical and statistical methods lead to similar skill patterns with about the same overall performance as the global model, which shows higher values in south-eastern Europe. Therefore, no relevant added value is found in terms of model skill improvement. Finally, when focusing on the heatwaves of 2003, 2006, 2010 and 2012, the limitations of the global model to detect these hot episodes are inherited by all dynamical and statistical downscaling methods so no added value is neither found in this aspect. This work provides, to our knowledge, the largest and most comprehensive intercomparison of statistical and dynamical downscaling for seasonal forecasting over Europe.

Practical Implications

Dynamical and statistical downscaling methods allow transferring the coarse biased seasonal predictions from global ocean–atmosphere coupled models to the regional/local spatial scales required in impact studies, providing thus actionable products which properly represent the local features of interest. However, whereas both approaches have been extensively used and critically assessed in climate change studies, their added value for seasonal forecasting is not well understood yet, and comprehensive intercomparison studies over Europe are still lacking.

In this work we focus on this problem and consider several representative dynamical and statistical methods—which have been used in the framework of the SPECS (http://www.specs-fp7.eu) and EUPORIAS (http://www.euporias.eu) projects—to downscale the seasonal forecasts of summer temperature over Europe from a state-of-the-art global model. We evaluate the (possible) added value of downscaling, both dynamical and statistical, in terms of representativeness of the local climatology (mean values and extremes), improvement of model skill and performance in particular extreme episodes (2003, 2006, 2012 and 2012 heatwaves). This comprehensive intercomparison provides therefore key information for European stakeholders focused on different socio-economic sectors.

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Our results show that, whereas the suitability of dynamical downscaling for reducing the orographic biases of the global model depends on the region and model considered, statistical downscaling can systematically reduce errors in different order moments, from the mean to the extremes (as represented by the 95th percentile here), providing thus more realistic climate information than global models do. This can have important practical implications for different user applications in a range of sectors such as agriculture, energy, health or tourism, for which the use of realistic seasonal forecasts is increasingly growing. For the case of dynamical downscaling, it is worth to mention that sophisticated quantile mapping techniques have been recently applied to regional models so that they match the local observation's statistics grid box by grid box. This approach (dynamical downscaling followed by bias adjustment) has become a common practice in different user applications—particularly in the context of multi-decadal climate change, where regional climate projections are readily available—and it is preferable to the direct bias adjustment of the global model outputs, particularly when local (point-wise) information is required.

Differently, no relevant added value is found in terms of model skill improvement, neither for dynamical nor for statistical methods. Both downscaling approaches lead to similar skill patterns (evaluated by means of the ROC Skill Score here) with about the same overall performance as the global model, which shows low-to-moderate skill over most of the continent—the highest skill being located over south-eastern Europe and for cold events. Similar conclusions have been also reported in Nikulin et al. (2017) for East Africa, a region with different skill and climate characteristics. Nevertheless, note that the ROC Skill Score (ROCSS) is not sensitive to mean errors and thus, other bias-dependent performance measures such as the Root Mean Square Error (RMSE) or the Continuous Ranked Probability Skill Score (CRPSS) could still indicate that some added value may be obtained from downscaling. As for the ROCSS, no added value is found here in terms of reliability, neither for dynamical nor for statistical methods, all of them yielding similar results, overall comparable to the ones provided by the global model. This suggests that other strategies rather than downscaling, such as the use of probability calibration techniques (Primo et al., 2009), might be needed to improve the reliability of the global seasonal forecasts over Europe. However, since they work based on interannual probabilities, these techniques require long hindcasts (over 30 years) for proper calibration and validation. This should be taken into account when defining the hindcasts feeding climate services such as Copernicus (http://www.copernicus.eu).

Finally, when focusing on particular heatwaves (2003, 2006, 2010 and 2012), dynamical and statistical methods are shown to inherit the limitations of the global model, which fails in detecting these anomalously hot episodes, both in magnitude (much lower than observed) and location. Despite this, recent works have found that models can reach some skill for prediction of these events if soil moisture is properly initialized. Yet, further research is still needed in order to assess the performance of raw and downscaled seasonal climate data to forecast extreme indicators such as hot/cold spells, which may be relevant for different practical applications.

In summary, beyond the reduction of global model biases, our results indicate that there is no clear signal of added value for downscaling, neither dynamical nor statistical, for seasonal forecasts of summer temperature over Europe. Moreover, in agreement with a previous intercomparison study performed in south-eastern USA (Schoof et al., 2009), there is no clear indication on which of the two approaches is preferable. In this regard, it is important to note the elevated requirements of dynamical downscaling (as compared to statistical one) in terms of computing resources and time. For instance, whereas the WRF model took on 190,000 core hours in the Altamira HPC facility—which is part of the Spanish Supercomputer Network (see acknowledgements),—the statistical methods considered required less than 6 core hours to downscale the whole experiment in a regular workstation. Therefore, dynamical downscaling experiments should be carefully designed in order to maximize the information gained from such expensive simulations. With respect to the statistical methods, we have considered in this work two daily Perfect Prognosis (PP) and one monthly Model Output Statistics (MOS) techniques. It is worth to highlight that, when applied under a leave-one-out cross-validation framework, the MOS technique was found to provide worse results than the PP ones for all validation aspects considered. However, if no cross-validation is performed, high artificial skill appears as a result of model overfitting, outperforming all other methods. This warns on the misuse of MOS methods for monthly/seasonal forecasting.

The results from this work constitute the most comprehensive to date intercomparison of dynamical and statistical downscaling for seasonal forecasts on a continental scale. However, it must be noticed that the conclusions drawn here are only for summer temperature over Europe, and may be not extensible to other variables, regions and seasons. Further investigation is still needed to provide a more conclusive overview on the merits and limitations of dynamical and statistical downscaling for seasonal forecasting.

Both the global and downscaled (dynamical and statistical) seasonal forecasts used in this work have been published for the ECOMS' community through the User Data Gateway (UDG: http://meteo.unican.es/udg-tds, *ecoms* catalog), which combines a THREDDS data server with web-services to manage datasets, catalogs, users and authorization protocols, leading to a practical tool to explore and access the available datasets (see Cofi·o et al., 2017, for details).

1. Introduction

Global ocean–atmosphere coupled models are the primary tool used nowadays to generate seasonal climate forecasts. However, these models suffer from substantial biases (when compared with surface observations) and are unable to provide useful information at the regional or local spatial scales required in a number of sectors such as agriculture, energy, health, tourism or insurance (see Doblas-Reyes et al., 2013, and references therein). Therefore, an increasing interest has been focused in downscaling methods, which can transfer these global predictions to the regional/local spatial scales, providing thus actionable products representing the local features of interest. There are two main approaches to downscale climate information: statistical and dynamical. The latter is computationally very expensive, particularly in the case of seasonal forecasting where several members and initializations have to be downscaled. Moreover, the few existing experiences with dynamical models in seasonal forecasting have been mostly focused on tropical regions with moderate-to-high skill (see, e.g. Chou et al., 2005; Diro et al., 2012; Yoon et al., 2012; Diro, 2016). Thus, downscaling of seasonal forecasts has mainly relied on statistical methods (see Gutiérrez et al., 2013a, for a review), and studies over Europe, the target region in this work, are very scarce (Díez et al., 2005; Frías et al., 2010; Díez et al., 2011; Patarčić and Branković, 2012).

In contrast to the tropics, seasonal predictability over Europe is still limited (see, e.g., Doblas-Reyes et al., 2013, and references therein). However, the recent advances made with regard to the predictability of the NAO (see, e.g., Scaife et al., 2014) and the new potential sources for seasonal skill such as global warming, stratosphere-troposphere interactions and soil processes (see, e.g., Koster et al., 2010; Cohen and Jones, 2011) pave the way for better seasonal forecasts. As a result, there is a growing interest for this type of predictions, which are being demanded by different

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