Hacia una nueva generación de sistemas de predicción estacional

Towards a new generation of seasonal forecasting systems

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RESUMEN
Los sistemas de predicción estacional – y su extensión a predicción decadal – son cruciales en el desarrollo de estrategias para la adaptación al cambio climático. Sin embargo, a pesar de los importantes avances en este área, las predicciones solo alcanzan niveles significativos de calidad en las regiones cuyo clima esta claramente influenciado por ENSO (*El Niño -South Oscillation*). El Met-Office ha desarrollado un nuevo sistema de predicción estacional (GloSea4) con la intención de mejorar la calidad de las predicciones estacionales y decadales a nivel regional. El nuevo sistema ha sido diseñado con el objetivo de crear un sistema más flexible y fácil de desarrollar, mejor integrado con la estructura de desarrollo de modelos del Met-Office. Los resultados preliminares de GloSea4 son positivos, mostrando un aumento significativo en la calidad de las previsiones en la región de El Niño.
Palabras clave: Predicción por conjuntos; predicción estacional; clima; desarrollo de modelos.

ABSTRACT
Seasonal forecasting systems – and their extension to decadal timescales – are crucial in the development of adaptation strategies to climate change. However, despite important achievements in this area, significant levels of skill are only generally found over regions strongly connected with the El Nino-Southern Oscillation. With the aim of improving the skill of regional climate predictions at seasonal and decadal timescales, a new Met Office seasonal forecasting system (GloSea4) has been developed. The new system has been designed to be a flexible and easy-to-upgrade system, fully integrated within the Met Office model development infrastructure. Preliminary results from GloSea4 are positive, showing a significant increase in the skill of the forecasts over the El Niño regions.
Key words: Ensemble prediction; seasonal forecasting; climate; model development.

1. INTRODUCTION

Seasonal predictions using comprehensive coupled dynamical models of the atmosphere, oceans and land surface have now been operational for near a decade. These predictions have been shown to exhibit significant skill for certain regions and seasons (Graham et al., 2005) and many important socio-economic benefits are derived from them in areas such as food production, health and transport and energy management (Morse et al., 2005; Challinor et al., 2005). On top of this, seasonal forecasts systems – and their extension to decadal timescales – are crucial in the development of adaptation strategies to climate change. To put it simply, there is no better way of adapting to climate change tomorrow than adapting to climate variability today.

Despite these important achievements in the area of seasonal forecasting, significant levels of skill are only generally found over regions strongly connected with the El Niño-Southern Oscillation. The forecast skill over mid-latitude regions, such as Europe, is much lower. One of the reasons for this is that, over mid-latitudes, a higher fraction of the atmospheric seasonal mean variability is related to internal variability than to boundary conditions' forcings (Kumar et al., 2007). Therefore, the seasonal atmospheric predictability will be always higher over tropical regions than over extra-tropical regions.

However, there are important processes that give raise to predictability over mid-latitudes that are poorly represented in the current generation of models and seasonal forecasting systems (e.g. land surface or stratospheric processes). Therefore, there is scope to improve the skill of seasonal forecasts over mid-latitudes. With this aim, the new Met Office seasonal forecasting system (GloSea4) has been designed to be a flexible and easy-to-upgrade system, fully integrated within the Met Office model development infrastructure. GloSea4 is expected to become operational in August 2009.

The paper is organised as follows: Section 2 includes a description of GloSea4 and its links with model development. Verification results are presented in Section 3 and conclusions in Section 4.

2. DESCRIPTION OF GLOSEA4, THE NEW MET OFFICE SEASONAL FORECASTING ENSEMBLE PREDICTION SYSTEM

GloSea4 is an ensemble prediction system built around HadGEM3_AO_r1.1, the version 1.1 of the Met Office Hadley Centre coupled climate model as in May 2009.

As any seasonal prediction system, GloSea4 has two components: the forecast itself and an associated set of hindcast, also called historical re-forecasts, used for calibration purposes and for skill assessment. In the case of GloSea4 the hindcast covers the period 1989–2002. Both, forecast and hindcast, are performed using the same GloSea4 ensemble prediction system but, obviously, with different initial conditions.

The coupled model used in GloSea4 is HadGEM3_AO_r1.1. This model is part of the HadGEM3 family of models, a group of models sharing the same physical and dynamical schemes at different resolutions, which can be used for regional and seasonal to decadal predictions.

HadGEM3_AO_r1.1 is formed by the following components: UM (Met Office Unified Model atmosphere; NEMO (Nucleus for European Modelling of the Ocean) ocean; CICE (Los Alamos Sea-ice Model) sea-ice; and MOSES (Met Office Surface Exchange Scheme) land surface. The model resolution – as used in GloSea4 – is N96 (approximately 120 km. horizontal resolution in mid-latitudes) and 38 levels in the vertical for the atmosphere, and the ORCA1 grid (1 degree ocean with 1/3 of a degree refinement between 20S and 20N) and 42 levels in the vertical for the ocean.

Technically, GloSea4 has been designed to be more flexible and better integrated within the rest of the Met Office systems than its predecessor was. Therefore, all GloSea4 components run on Met Office's supercomputer and all input data for the forecasts (not the hindcast which are initialised using ERA-interim reanalysis data for the atmosphere) comes from Met Office systems. Crucially, both, hindcast and forecast simulations, are completed on real time in order to allow model and system changes to be introduced easily and facilitate model development.

Scientifically, apart from using an improved coupled model (HadGEM3_AO_r1.1), the representation of uncertainties – for both, initial conditions and model – has changed completely from GloSea3.

In the case of the initial conditions, no perturbations are added to the analysis. A lagged initialization approach, with all simulations being initialised weekly (every Monday in the case of the forecast and on fix calendar dates, 1st, 9th, 17th and 25th, for the hindcast) is followed to represent the uncertainties in the initial conditions. For the purposes of seasonal forecasting, and depending on the number of ensemble members we consider necessary, every week we can pull together all forecast available from the last few weeks. It needs to be noted that all simulations initialised on a particular start date will have exactly the same initial conditions and they will differ only because of the stochastic physics schemes used to represent model uncertainties.

In terms of number of ensemble members and hindcast years, the GloSea4 forecast has 14-members per week (initialised on Mondays), the GloSea4 hindcast has 3-members per start-date (fixed calendar dates: 1st, 9th, 17th and 25th) and 14-yrs (1989 to 2002).

There are two main reasons for choosing this approach over what was done for GloSea3 (SST and wind stress perturbation of a central analysis) or at others centres such as ECMWF and MeteoFrance: First, perturbing a central analysis degrades the initial conditions (as demonstrated in Bowler et al. 2008a); Second, perturbations to SST and wind stress are only relevant for the tropics.

The representation of model uncertainties is done in GloSea4 by including two schemes: RP (Random Parameters) and SKEB2 (Stochastic Kinetic Energy Backscatter version2.0). The RP scheme aims to represent the structural uncertainty arising from subjective parameters in physical parameterizations.

SKEB2 aims to represent the sub-grid scale uncertainty arising from advection and numerical dissipation.

Both schemes are currently used in the operational Met Office short- and medium-range ensemble systems (MOGREPS). Additional information can be found in Bowler et al. (2008b) and Shutts (2005).

Finally, all climate forcings (aerosols, methane and CO_2 concentrations, etc) are set to observed values for the period 1960-2000 and follow the scenario A1B afterwards. Ozone is fixed to observed climatological values and includes a seasonal cycle.

2.1 Links with model development

The use of shared codes across the Met Office models facilitates the efficiency of model development activities. In particular, having a more flexible infrastructure, the HadGEM3 family of models is intended to be the basis of all Met Office coupled modelling work for regional, seasonal to decadal prediction as well as Earth System modelling at different resolutions.

A crucial point is that, while previous Met Office Hadley Centre climate models were developed with centennial prediction in mind, requiring further development before being incorporated in the seasonal forecasting system, the first intended use of HadGEM3-AO is in the seasonal forecasting setting as part of GloSea4.

In fact, the development of GloSea4 and HadGEM3 are intrinsically linked: First, all interim coupled model versions are tested using the GloSea4 framework and not only long-climate integrations. Second, the seasonal forecasting system will use the latest HadGEM3 model version available at the highest resolution affordable. Therefore, providing important information and feedback for further model development.

3. RESULTS

GloSea4 will become the operational Met Office seasonal forecasting system in August 2009 and only a limited set of simulations are available at the time of writing this paper.

Given that the highest levels of skill are found over the tropical Pacific, we will focus the analysis of the system over this region. Figure 1 shows the temporal evolution of the monthly mean root-mean square error (RMSE) and the ensemble spread for the Niño3 Sea Surface Temperatures (SST). The hindcast data used to produce this figure is 1989–1999 (i.e. an 11 year period).

Three systems are compared: GloSea3; ECMWF-System3 and GloSea4. GloSea3 has 15 members, ECMWF-System3 9 members and GloSea4 6 members. GloSea3 and ECMWF-System3 have been initialized on the 1^{st} of May. GloSea4 members have been initialized on the 25^{th} of April, 1^{st} of May and 9^{th} of May (2-members per start-date) which corresponds to a central point on the 2^{nd} of May.

As can be seen, GloSea4 has the smallest errors. Also, in a perfect ensemble system and over a large number of ensemble forecast, the RMSE of the ensemble mean should be equal to the ensemble spread (Palmer et al., 2004). Generally, ensemble prediction systems at seasonal timescales are underdispersive (i.e. their spread is smaller than the RMSE of their ensemble mean). Although this is still the case for GloSea4, its mean errors and spread are in better agreement than in any of the other two systems.

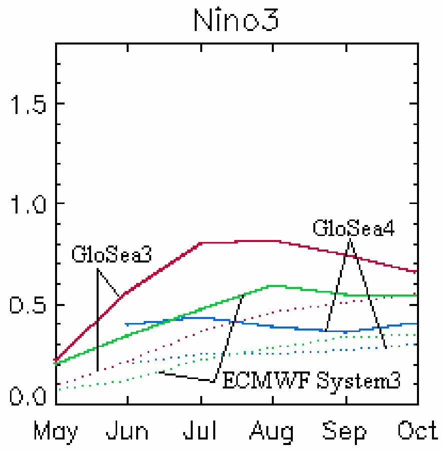

Figure 1. Root-mean square error (solid lines) and spread (dotted lines) for GloSea3, ECMWF-System3 and GloSea4 over the period 1989 – 1999.

Besides the ensemble mean errors, it is also necessary to analyse the ability of the ensemble prediction system to forecast different outcomes. Scatter plots of observations and GloSea4 forecast (initialised around the 1st of May) for Niño3 SST at lead times of 1 and 6 months are shown in Figure 2. GloSea4 has anomaly correlations above 0.8 at 6-month lead time.

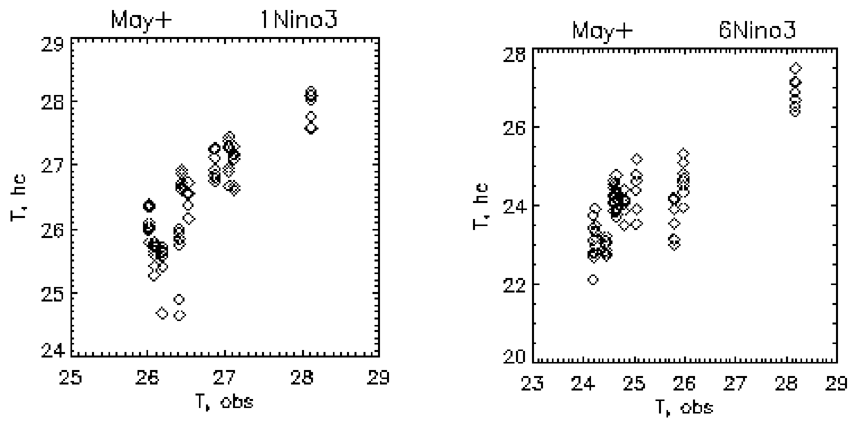

Figure 2. Scatter plots of observations vs GloSea4 forecast values for Niño3 SSTs at 1-month lead time (left) and 6-month lead time (right).

4. SUMMARY AND CONCLUSIONS

GloSea4 is the new Met Office seasonal ensemble prediction system. It is expected to become operational in August 2009.

Apart from the obvious aim of improving seasonal forecasts, there are two high-level objectives behind the development of GloSea4: First, to facilitate model development by helping to bridge modelling work between Numerical Weather Prediction and Climate Research at the Met Office. Second, to help adaptation to climate change by allowing extension to decadal timescales and providing relevant information for end-users.

To achieve these objectives, GloSea4 has been designed to be a more flexible system, better integrated with other Met Office systems (e.g. atmospheric data assimilation) than its predecessor was. A crucial technical change is the ability to run forecast and hindcast simulations on real-time which allow us to upgrade the model and system easily.

Preliminary results are positive, showing that the skill of GloSea4 forecasts over the tropical pacific is higher than its predecessor.

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