Integrated seasonal climate forecasts for South America

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INTRODUCTION

South America seasonal climate forecasts are currently produced using empirical (statistical) and dynamical (physical) models. Given the availability of these two modelling approaches one might question the feasibility of producing a single and well calibrated integrated forecast that gather all available information at the time the forecast is issued. This study illustrates how empirical and dynamical coupled model precipitation seasonal forecasts for South America are currently being integrated (i.e. combined and calibrated) in EUROBRISA (A EURO-BRazilian Initiative for improving South American seasonal forecasts, http://www.cptec.inpe.br/~caio/EUROBRISA). The skill of one month lead austral winter (June-July-August) forecasts is asseesed and discussed.

METHODOLOGY

One of the simplest empirical approaches to produce one-month lead austral winter (June-July-August) South America precipitation forecasts use as predictor variable Pacific and Atlantic sea surface temperatures observed in the previous April. This multivariate regression model (Coelho *et al.* 2006) is used here to produce empirical precipitation forecasts for South America.

The dynamical systems used in this study to produce one-month lead precipitation forecasts for June-July-August are the coupled ocean-atmosphere seasonal prediction models of ECMWF (Anderson *et al.* 2007), known as System 3, and the UK Met Office (UKMO; Graham *et al.* 2005), known as GloSea. The forecast output from these models is coordinated at ECMWF as part of the European Seasonal to Inter-annual Prediction project (EUROSIP).

To produce empirical-dynamical multi-model integrated probabilistic forecasts we apply a Bayesian procedure, known as forecast assimilation (Stephenson *et al.* 2005). This procedure allows the spatial calibration and combination of forecasts produced by each individual model. The skill of empirical, ECMWF, UKMO and integrated forecasts obtained with forecast assimilation is assessed and compared over the common hindcasts period 1987-2001. All results were obtained using the cross-validation method (Wilks 1995). Forecast verification is performed using the version 2 Global Precipitation Climatology Project (GPCP) monthly precipitation analysis (Adler *et al.* 2003).

RESULTS AND DISCUSSION

Figure 1a-d shows correlation maps of ECMWF, UKMO, empirical and integrated precipitation anomaly forecasts for the period 1987–2001. Correlation maps show the correlation between observed and mean forecast anomalies at each grid point. Both ECMWF and UKMO forecasts are bias corrected because we are dealing with ensemble mean forecast anomalies with respect to each model climatology. The three individual models show high skill with correlation coefficient generally between 0.4 and 0.8 in tropical South America. ECMWF, UKMO and empirical forecasts are moderately skilful over the south of Brazil and southeast Argentina with correlation coefficient between 0.2 and 0.6. Empirical forecasts also show moderate skill over Bolivia with correlation coefficient between 0.4 and 0.6. When the forecasts of the three individual models was combined and calibrated to produce integrated forecasts, improved skill was obtained over tropical and southeast South America (Fig. 1d).

Correlation is a deterministic measure of skill that indicates how well associated is the forecast with the corresponding observed anomaly. Correlation, however, only assesses the mean forecast value. In order to assess how well estimated is forecast uncertainty one needs for example to examine probabilistic scores. Here we examine Gerrity (1992) score maps for tercile probability categories (Figs 1e-h). Tercile categories are defined as below normal, normal and above normal according to the climatological June-July-August precipitation distribution. Large values of Gerrity score indicate increasing correspondence between the category that was forecast as most likely and the category that was observed. In accordance with the correlation map (Fig 1d), integrated forecasts (Fig 1h) have improved (higher) skill in tropical and southeast South America when compared to the three individual forecasts (Figs. 1e-g). This result indicates that not only the estimate of the mean forecast value is improved by calibration and combination of empirical and coupled model forecasts. Uncertainty estimates are also improved by calibration and combination.

Figure 2 shows austral winter 1987–2001 precipitation anomaly forecasts for a grid point in southeast South America (longitude 297.5^{o}; latitude -37.5^{o}) produced by ECMWF, UKMO, empirical and integrated (combined and calibrated) with forecast assimilation. The 95% prediction interval (grey shading) is given by the mean forecast value plus or minus 1.96 times the forecast standard deviation. ECMWF and UKMO forecast standard deviation (i.e. the spread) is computed as the standard deviation of the ensemble members of each model. Empirical and integrated forecast standard deviation is computed as described in Coelho *et al.* (2006) and Stephenson *et al.* (2005), respectively, and posteriorly re-scaled to match the mean forecast error. Figure 2 shows that all four forecasting approaches produce reliable forecast uncertainty estimates, with most observations falling inside the 95% prediction intervals. ECMWF and UKMO have larger 95% prediction intervals than empirical and integrated forecasts. Integrated forecasts are well calibrated showing the best agreement between the mean forecast value and the observed anomalies (Fig 2d). Integrated forecasts have the largest amount of interannual variability. This is also reflected in the highest correlation between integrated forecast and observed anomalies. The correlation coefficients between forecast and observed anomalies for ECMWF, UKMO, empirical and integrated forecasts are 0.42, 0.44, 0.56 and 0.65, respectively.

CONCLUSIONS

This study has examined the skill of austral winter seasonal forecasts for South America produced by two coupled ocean-atmosphere models, an empirical model and integrated (i.e. combined and calibrated) forecasts. The main findings can be summarised as follows:

- forecast skill can be improved by calibration and combination;
- the availability of forecasts produced by both empirical and coupled models provide the opportunity to produce objectively integrated, in other words, combined and well calibrated probabilistic forecasts that gather all available information at the time the forecast is issued;
- austral winter precipitation forecasts produced by the empirical-dynamical multi-model integrated system presented here are skilful in tropical and southeast South America.
- integrated forecasts generally provide skill that is equal to or better than that of the best individual model

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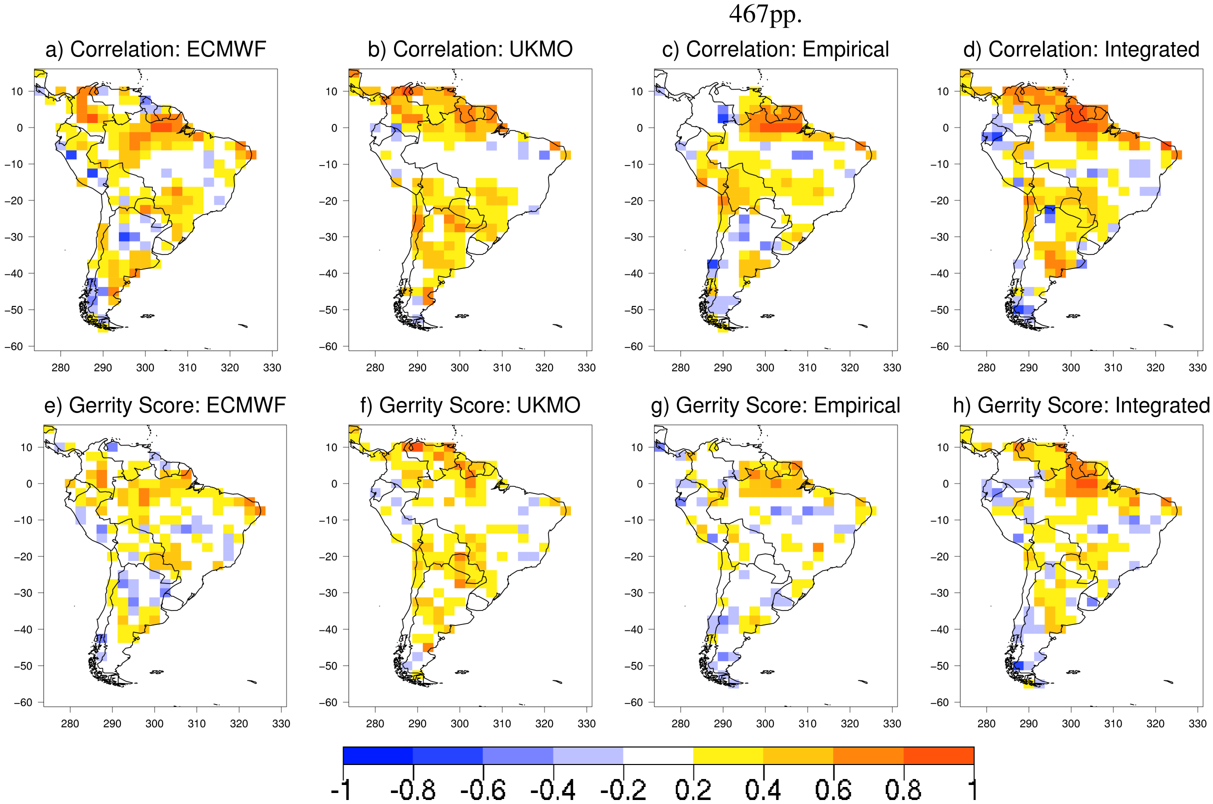

Figure 1: Correlation maps (panels a-d) and Gerrity score maps (panels e-h) of ECMWF, UKMO, empirical and integrated one month lead June-July-August precipitation forecasts for the period 1987–2001.

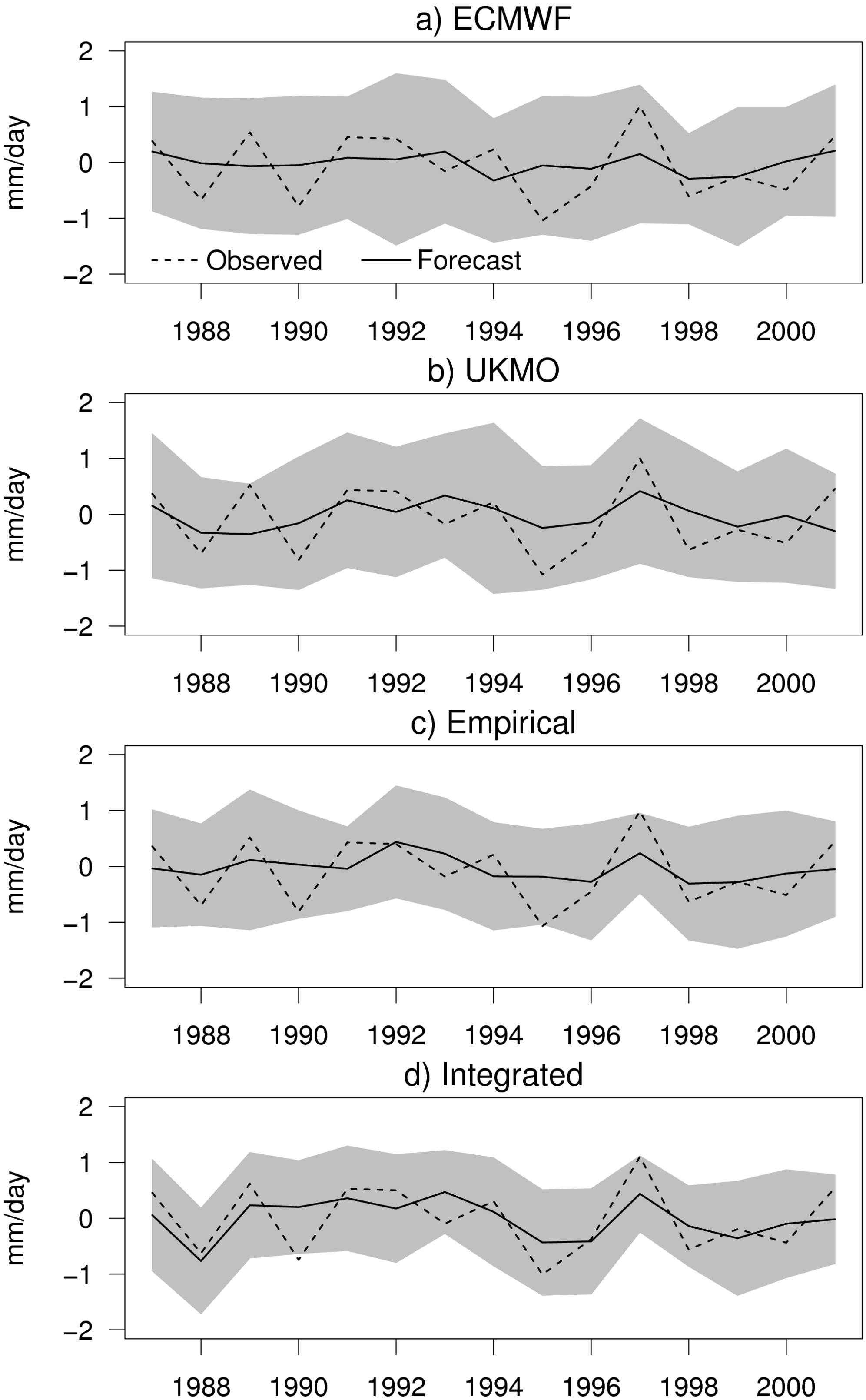

Figure 2: One-month lead June-July-August 1987–2001 precipitation anomaly forecasts (mm/day) for a grid point in southeast South America (longitude 297.5^{o}; latitude -37.5^{o}) produced by a) ECMWF coupled model, b)

UKMO coupled model, c) empirical model and d) integrated (combined and calibrated) with forecast assimilation. Observed values (dashed line), forecast (solid line), and the 95% prediction interval (grey shading).