EUROBRISA: A EURO-BRAZILIAN INITIATIVE FOR IMPROVING SOUTH AMERICAN SEASONAL FORECASTS

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RESUMO: EUROBRISA: UMA INICIATIVA EURO-BRASILEIRA PARA A MELHORIA DAS PREVISÕES SAZONAIS PARA A AMÉRICA DO SUL

Este estudo ilustra como previsões sazonais de precipitação empíricas (estatísticas) e de modelos dinâmicos acoplados vem atualmente sendo integradas (ou seja, combinadas e calibradas) para produzir previsões híbridas (previsão empírica-dinâmica) para a América do Sul. Este sistema operacional híbrido de previsões, o primeiro a ser implementado na América do Sul, foi desenvolvido no contexto do EUROBRISA (Uma Iniciativa Euro-Brasileira para a melhoria das previsões sazonais para a América do Sul) – uma iniciativa de cooperação multi-institucional entre instituições Brasileiras e Européias. O modelo empírico utiliza temperatura da superfície do mar observada sobre os oceanos Pacífico e Atlântico como variável preditora para precipitação. As previsões dos modelos dinâmicos acoplados são provenientes das versões operacionais do Centro Europeu para Previsões de Tempo de Médio Prazo (ECMWF) e do Serviço Meteorológico do Reino Unido (UK Met Office). Para a calibração e combinação das previsões do modelo empírico com as previsões dos modelos dinâmicos acoplados para produzir previsões integradas (híbridas) aplica-se uma metodologia Bayesiana denominada assimilação de previsões. A destreza das previsões para o verão (Dezembro-Janeiro-Fevereiro) desde 1987 até 2001 produzidas em Novembro (ou seja, com um mês de antecedência) é avaliada e discutida. Finalmente apresenta-se a previsão operacional em tempo real para o verão 2007/2008 produzida por esse novo sistema em Novembro de 2007.

ABSTRACT: This study illustrates how empirical (statistical) and dynamical coupled model precipitation seasonal forecasts are currently being integrated (i.e. combined and calibrated) to produce hybrid (empirical-dynamical) forecasts for South America. Such a hybrid operational forecasting system, the first to be implemented in South America, has been developed by EUROBRISA (A EURO-BRazilian Initiative for improving South American seasonal forecasts) – a multi-institutional cooperation initiative between Brazilian and European institutions. The empirical model uses Pacific and Atlantic sea surface temperature as predictor variable for precipitation. Coupled dynamical model precipitation forecasts are from the operational versions of the European Centre for Medium-Range Weather Forecasts (ECMWF) and the United Kingdom Met Office (UKMO). A Bayesian approach knows as forecast assimilation is used to combined and calibrate empirical and dynamical coupled model forecasts and produce the so-called integrated (hybrid) forecast. The skill of one month lead 1987-2001 austral summer (December-January-February) forecasts is asseesed and discussed. To illustrate an operational real time forecast, the most recent austral summer 2007/2008 forecast issued by this system in early November 2007 is presented.

Key-words: Seasonal forecasts, South America precipitation, empirical and coupled model dynamical forecasts, Bayesian forecast assimilation, forecast calibration, combination and verification.

1. INTRODUCTION

Seasonal climate forecasts are forecasts of the expected climatic conditions in the forthcoming 3-6 months. Improvement in seasonal climate forecasts is a key issue for helping countries reduce losses due to weather and climate risks. In South America, seasonal climate forecasts already benefit governmental decision-making in several key areas such as energy production, agriculture, and water resources planning to minimize human and economical losses caused by extreme climate events (e.g. droughts and excessive rainy periods). For example, seasonal forecasts of precipitation are used for decision-making in hydropower electricity production in South America. Hydropower accounts for the major source of electricity production in several South American countries: 60% in Bolivia, Brazil, Colombia, Paraguay and Uruguay; and 40% in Argentina, Chile, Ecuador, Peru and Suriname. Improved seasonal precipitation forecasts can help South American governments to better manage these carbon-friendly electricity production programmes – a strategic element in the reduction of global greenhouse gas emissions. In addition, the economies of South American countries also depend heavily on agriculture, an activity which can also benefit from higher quality seasonal climate forecasts. Improved seasonal climate forecasts can thereby clearly benefit the 370 million people who live in South America.

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 (hybrid) 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) to produce hybrid forecasts at the Centre for Weather Forecasts and Climate Studies (CPTEC). Such a hybrid operational forecasting system, the first to be implemented in South America, has been developed by EUROBRISA (A EURO-BRazilian Initiative for improving South American seasonal forecasts, http://www6.cptec.inpe.br/eurobrisa) – a multi-institutional cooperation initiative between CPTEC, the European Centre for Medium-Range Weather Forecasts (ECMWF), the United Kingdom Met Office (UKMO), Météo-France, the Brazilian National Institute of Meteorology (INMET), the University of São Paulo (USP), Federal University of Paraná (UFPR), the Paraná State Meteorological Institute of Technology (SIMEPAR) and the University of Exeter. The skill of one month lead austral summer (December-January-February) forecasts is asseesed and discussed. To illustrate an operational real time forecast the most recent austral summer 2007/2008 forecast produced by this system is presented.

2. METHODOLOGY

One of the simplest empirical approaches to produce one-month lead austral summer (December-January-February) South America precipitation forecasts use as predictor variable Pacific and Atlantic sea surface temperatures observed in the previous October. 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 summer (December-January-February) 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 (i.e. hybrid) 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).

3. 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 also skilful over the south of Brazil, Uruguay and southeast Argentina with correlation coefficient between 0.2 and 0.8. 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). However, over parts of central-east Brazil, where the three individual models present nearly null skill (Fig. 1a-c), integrated forecasts present poor skill (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 scores that evaluate the skill of probabilistic forecasts. Here we examine relative operating characteristic (ROC) skill score maps for the event positive or negative precipitation anomaly (Figs 1e-h). ROC measures the ability of the forecasting system in detecting a particular event. In other words, it measures the ability of the forecasting system in discriminating between different forecast probabilities for a particular event that is being forecast. This ability is known in the forecast verification literarure as *forecast resolution*. The ROC skill score is defined as ROCSS = 2A − 1, where A is the area under the ROC curve for forecast probabilities of the event positive or negative precipitation anomaly. A comprehensive review about ROC and other forecast verification scores is found in the book by Jolliffee and Stephenson (2003). No skill forecasts have area A under the ROC curve equals to 0.5 (i.e. null ROCSS). Large positive values of ROCSS indicate increasing ability of the forecasting system in forecasting different forecast probabilities for the event that is being forecast (i.e. increased forecast resolution). Conversely, large negative values of ROCSS indicate increasing inability of the forecasting system in forecasting different forecast probabilities for the event that is being forecast (i.e. poor forecast resolution). 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.

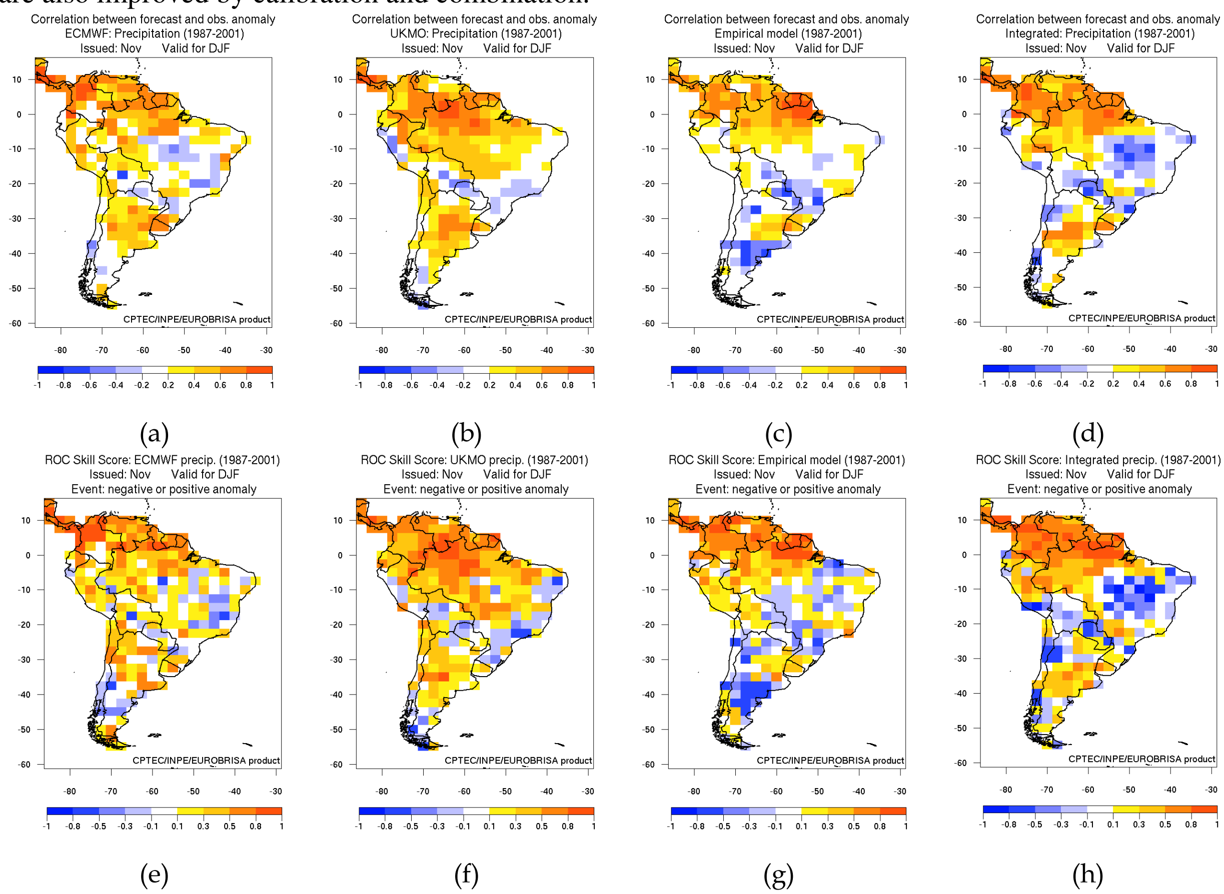
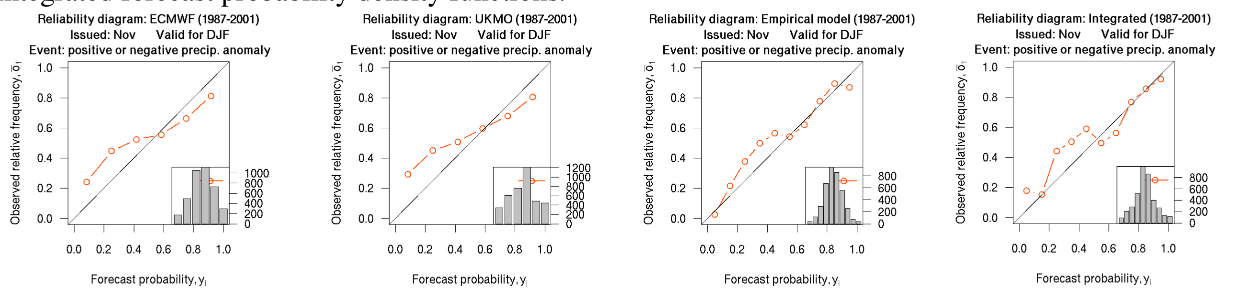


Figure 1: Correlation maps (panels a-d) and ROC skill score maps for the event negative or positive anomaly (panels e-h) of ECMWF, UKMO, empirical and integrated one month lead December-January-February precipitation forecasts for the period 1987–2001.

Another desirable property of a good probabilistic seasonal forecasting system is *forecats reliability* – a measure of how well calibrated are the forecast probabilities produced by the forecasting system. Forecast reliability can be assessed using the so-called reliability diagram, which is a graph of forecast probabilities against observed relative frequencies of the event being forecast. A well calibrated forecasting system must have its forecast probabilities closely matching the observed relative frequency of the event being forecast. In other words, in a sample of N forecast probabilities for a particular event (for example, occurrence of positive or negative precipitation anomaly), each forecat probability for this event must match the observed frequency n/N, where n is the number of occasions when the event of interest was observed. For example, for a forecast probability of 70% for the event occurence of positive or negative precipitation anomaly, one should observe the occurence of this event in 70% out of the total number N of events forecast. If such correspondence between forecast probabilities and observed frequencies is noted for all forecast probabilities the forecasting system is said to be well calibrated presenting good reliability.

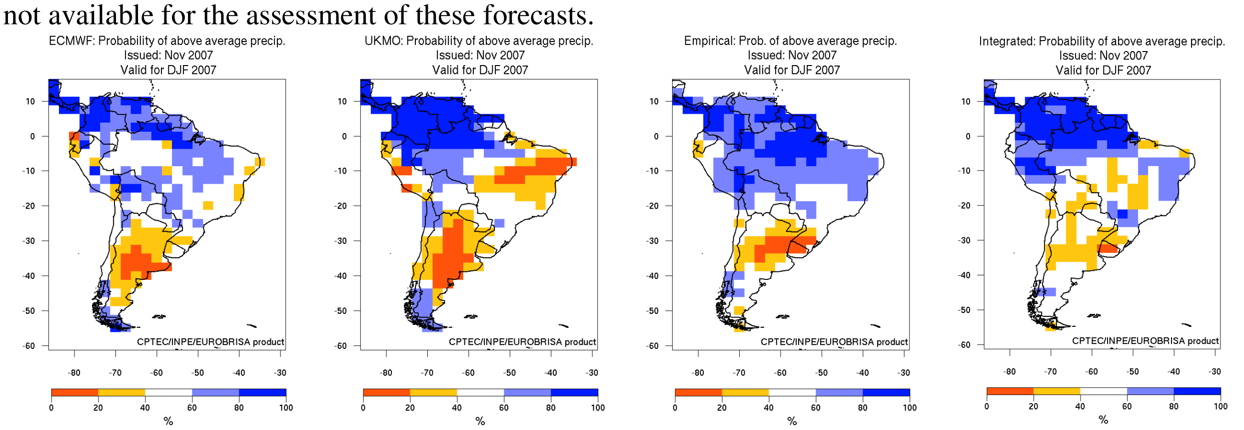
Figure 2 shows reliability diagrams for the event positive or negative precipitation anomaly for all South America land grid points for the three individual forecasts (Figs. 2a-c) and integrated forecasts (Fig. 2d) over the period 1987-2001. Perfectly reliable forecasts should have a reliability diagram represented by a diagonal (45^o) line. The reliability diagrams for ECMWF and UKMO (Figs. 2a-b) show a typical signature of overconfident forecasting systems, with high probabilities being forecast more frequently than observed and low probabilities being forecast less frequently than observed. Empirical and integrated forecasts (Figs. 2c-d) show a signature of well calibrated forecasts with good reliability, which can be noted by the superposition of the red curve and the diagonal black line. The histograms on the bottom right corner of each reliability diagram show the frequencies of each forecast probability. Figure 2 shows that these histograms peak close to the climatological frequency of the event being forecasts (i.e. 50% for the event positive or negative precipitation anomaly). Empirical and integrated forecasts have better reliability than ECMWF and UKMO forecasts because their forecasts probability density functions are better calibrated. ECMWF and UKMO have overconfident (narrower) forecast probability density functions when compared to empirical and integrated forecast probability density functions.



(a) (b) (c) (d)

Figure 2: Reliability diagrams for the event negative or positive anomaly of ECMWF, UKMO, empirical and integrated one month lead December-January-February precipitation forecasts for the period 1987–2001.

Figure 3 shows maps of one-month lead forecast probabilities for the event December-January-February 2007/2008 precipitation above average (i.e. positive precipitation anomaly). These forecasts were issued in early November 2007 when a well defined La Niña event was configured in the equatorial Pacific. Consistently with typical La Niña conditions, all three individual models (Figs. 3a-c) and integrated forecasts (Fig. 3d) indicate high probabilities for above average precipitation in northern South American and low probability of above average precipitation in southeastern South America (i.e. high probability of below average precipitation in southeastern South America). Jointly examining the forecasts of Fig. 3 and the verification maps of Fig. 1 that indicate the regions where the forecasts have better quality the seasonal forecast for austral summer 2007/2008 issued in November 2007 is for above average precipitation in northwestern South America and below average precipitation in parts of Uruguay and parts of south Brazil. At the time this article is being written the observed December-January-February precipitation data is still not available for the assessment of these forecasts.



(a) (b) (c) (d)

Figure 3: One-month lead December-January-February 2007/2008 real time ECMWF, UKMO, empirical and integrated probability forecast for the event above average precipitation.

4. CONCLUSIONS

This study has illustrated how empirical and dynamical coupled model precipitation seasonal forecasts are currently combined and calibrated in EUROBRISA to produce integrated forecasts for South America. The skill of austral summer precipitation forecasts produced by two coupled ocean-atmosphere models, an empirical model and integrated (i.e. combined and calibrated) forecasts has been assessed and discussed. 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 (i.e. hybrid empirical-dynamical forecasts);
- austral summer 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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5. REFERENCES

ADLER, R.F.; HUFFMAN, G.J.; CHANG, A.; FERRARO. R.; XIE, P.; JANOWIAK, J.; RUDOLF. B.; SCHNEIDER, U.; CURTIS, S.; BOLVIN, D.; GRUBER, A.; SUSSKIND, J.; ARKIN, P. The Version 2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present). J. Hydrometeor., 4, 1147-1167, 2003.

ANDERSON, D.; STOCKDALE. T.; BALMASEDA, M.; FERRANTI, L.; VITART, F.; MOLTENI, F.; DOBLAS-REYES, F. J.; MOGENSEN, K.; VIDARD, A. Development of the ECMWF seasonal forecast System 3. ECMWF Technical Memorandum, 503, 2007, 56p.
Available from http://www.ecmwf.int/publications/library/do/references/show?id=87744

COELHO, C.A.S.; STEPHENSON, D. B.; BALMASEDA, M.; DOBLAS-REYES, F. J.; OLDENBORGH, G. J. VAN. Towards an integrated seasonal forecasting system for South America. J. Climate, 19, 3704-3721, 2006.

GRAHAM, R.J.; GORDON, M.; MCLEAN, P. J.; INESON, S.; HUDDLESTON, M. R.; DAVEY, M. K.; BROOKSHAW, A.; BARNES, R.T.H. A performance comparison of coupled and uncoupled versions of the Met Office seasonal prediction General Circulation Model. Tellus, 57A, 320-339, 2005.

JOLLIFFE, I. T.; STEPHENSON, D. B. Forecast verification: A Practitioner's Guide in Atmospheric Science, Wiley, 2003, 240p.

STEPHENSON, D. B.; COELHO, C. A. S.; DOBLAS-REYES, F.J.; BALMASEDA, M. Forecast Assimilation: A Unified Framework for the Combination of Multi-Model Weather and Climate Predictions. Tellus, 57A, 253-264, 2005.

WILKS, D. S. Statistical methods in atmospheric sciences: An introduction. 1st Edition. Academic Press, 1995, 467p.