THE PERFORMANCE OF EUROBRISA SEASONAL PRECIPITATION FORECASTS OVER NORTHEAST BRAZIL DURING THE RAINY SEASON OF THE LAST 4 YEARS

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RESUMO: O DESEMPENHO DAS PREVISÕES SAZONAIS DE PRECIPITAÇÃO DO EUROBRISA SOBRE A REGIÃO NORDESTE DO BRAZIL DURANTE A ESTAÇÃO CHUVOSA DOS ÚLTIMOS 4 ANOS

Este trabalho apresenta uma avaliação das previsões climáticas sazonais híbridas (empírico-dinâmicas) de precipitação sobre a América do Sul para o período Março-Abril-Maio (MAM) produzidas no mês de Fevereiro anterior (ou seja, previsões com um mês de defasagem), com ênfase na região nordeste do Brasil durante os últimos 4 anos (2008-2011). Estas previsões foram produzidas pelo Centro de Previsão de Tempo e Estudos Climáticos (CPTEC) no contexto do EUROBRISA (Uma Iniciativa Euro-Brasileira para a melhoria das previsões sazonais para a América do Sul). A porção norte da região nordeste do Brasil tipicamente recebe a maior parte da precipitação anual durante o período MAM, definindo a estação úmida (chuvosa) da região. Previsões antecipadas sobre a possibilidade de excessos ou déficits de precipitação durante a estação chuvosa são de grande relevância para vários setores que dependem das chuvas para suas atividades (por exemplo, agricultura, recursos hídricos e turismo). A avaliação comparativa das previsões probabilísticas tercílicas de precipitação para as categorias acima da normal, normal e abaixo da normal produzidas pelo sistema híbrido do EUROBRISA com as observações indicaram em geral notável consistência entre as previsões e as observações, demonstrando que o sistema de previsão produziu boas indicações para as condições esperadas de precipitação durante a estação chuvosa dos últimos 4 anos.

ABSTRACT: This study presents an assessment of empirical-dynamical (hybrid) March-April-May (MAM) precipitation seasonal forecasts for South America issued in the previous February (i.e. 1-month lead), with particular attention devoted to forecasts over the northeast region of Brazil during the last 4 years (2008-2011). These forecasts were issued by the Centre for Weather Forecasts and Climate Studies (CPTEC) as part of EUROBRISA: A EURO-BRazilian Initiative for improving South American seasonal forecasts. During MAM the northern part of the Brazilian northeast region usually receives most of its annual precipitation, defining the wet (rainy) season. Forecasting in advance the possibilities of precipitation excesses or deficits during the rainy season is of great relevance for a number of sectors that depend on rainfall for their activities (e.g. agriculture, water resource management and tourism). The comparative assessment of forecast probabilities for the most likely precipitation tercile categories (above normal, normal and below normal) produced by the EUROBRISA hybrid system with the observed precipitation indicates generally noticeable consistency between the forecasts and observations, demonstrating that the forecasting system has been producing good indication for the expected conditions during the rainy season of the last 4 years.

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

1. INTRODUCTION

The northern part of the Brazilian northeast region has a well defined wet (rainy) season during March-April-May (MAM). Advanced predictive information about the expected seasonal rainfall amount during the wet MAM period is of great relevance for several economical sectors (e.g. agriculture, water resource management and tourism). These sectors are particularly interested to learn well in advance if an excessively wet or dry season (i.e. opposite extreme events) is likely to occur. However, northeast Brazil seasonal rainfall predictions are challenging due to a combination of factors affecting the regional climate. Among these factors one can highlight: the behavior of equatorial Pacific and Atlantic sea surface temperatures (SSTs), the position of the inter-tropical convergence zone (ITCZ), and the manifestation of so-called intra-seasonal oscillations and easterly waves within the rainy season. Identifying which of these factors will dominate or how they will interact is the major challenge for the production of good quality seasonal rainfall predictions for the northeast region in Brazil.

This study presents an assessment of empirical-dynamical (hybrid) March-April-May (MAM) precipitation seasonal forecasts for South America issued in the previous February (i.e. 1-month lead), with particular attention devoted to forecasts over the northeast region of Brazil during the last 4 years (2008-2011). These forecasts were issued by the Centre for Weather Forecasts and Climate Studies (CPTEC) as part of EUROBRISA: A EURO-BRazilian Initiative for improving South American seasonal forecasts (http://eurobrisa.cptec.inpe.br). This initiative uses state-of-the-art knowledge in both statistical post-processing for the calibration and combination of dynamical and empirical models forecasts and coupled ocean-atmosphere climate prediction, which are designed to represent physical climate processes and factors as highlighted in the previous paragraph, to produce good quality probabilistic season precipitation forecasts for South America.

2. METHODOLOGY

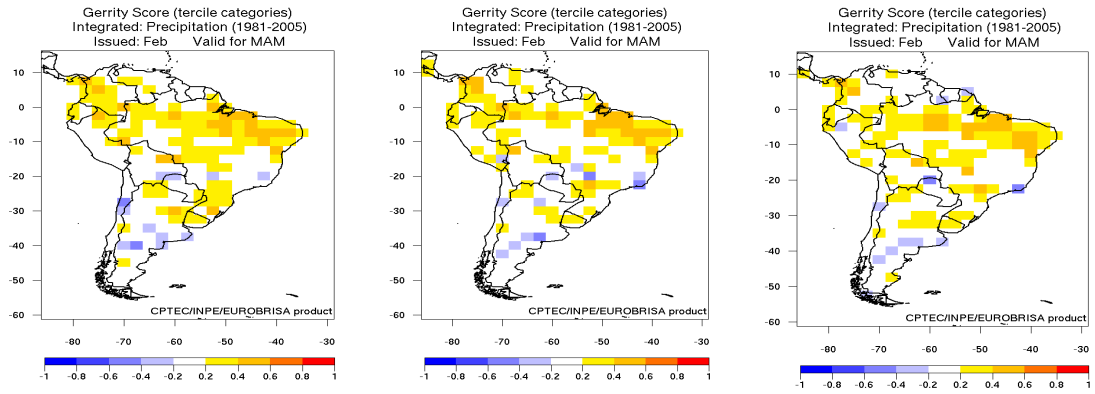
The EUROBRISA hybrid (empirical-dynamical) forecasting system is composed by 5 models all issuing 1-month lead (1-month in advance) seasonal precipitation forecasts for South America. The empirical component of the system is a model that uses Pacific and Atlantic sea surface temperatures as predictor variables for precipitation over South America (Coelho et al. 2006). For example, the observed sea surface temperature in the previous January is used as predictor for precipitation in the following MAM. This model is based on maximum convariance analysis (MCA), also known as singular value decomposition (SVD), of the cross-covariance matrix between sea surface temperature and precipitation. Three leading modes of this cross-covariance matrix are used to produce empirical forecasts. Retrospective empirical forecasts for the period 1987-2001 are produced in cross-validation (leave-one-out) mode (Wilks 1995). The dynamical components of the forecasting system are four coupled ocean-atmosphere models: ECMWF [Anderson et al. 2007 (System 3) and Molteni et al. 2011 (System 4)], the UK Met Office (UKMO, known as GloSea 4 (Arribas et al. 2011), which is an improved version of the previous UKMO model (Graham *et al.* 2005), Méteo-France which is an improved version of the previous Méteo-France model (Gueremy et al. 2005) and CPTEC (Nobre et al. 2009). The forecast output from ECMWF, UKMO and Méteo-France models is coordinated at ECMWF as part of the European Seasonal to Inter-annual Prediction project (EUROSIP). In the assessment presented here all five models issued forecasts for MAM in the previous February (1-month lead forecasts).

To produce empirical-dynamical (i.e. hybrid) multi-model integrated probabilistic forecasts, a Bayesian procedure, known as forecast assimilation (Stephenson *et al.* 2005), is applied. This procedure allows the spatial calibration and combination of forecasts produced by each individual model. In the first version of the EUROBRISA hybrid system implemented in 2007, only precipitation forecasts over South America (30^{o}W, 90^{o}W, 60^{o}S, 15 ^{o}N) were used in the forecast assimilation (calibration and combination) procedure. In the updated version of the EURORISA hybrid system implemented in 2009, for which the forecasts are presented in this study, the forecast assimilation procedure uses dynamical coupled model precipitation forecasts over the Pacific and South America (30^{o}W, 100^{o}E, 60^{o}S, 15 ^{o}N). The reason for using forecasts over the ocean in addition to forecasts over South America is based on the fact that coupled models generally produce forecasts in better agreement with the observations over the oceans compared to forecasts over land. There is therefore scope for improving forecast quality over land by spatially calibrating the forecasts produced by coupled models taking advantage of forecast information over the ocean. The skill of integrated forecasts obtained with forecast assimilation is assessed over the hindcasts period 1981-2005 because the updated implementation of the forecast assimilation procedure allows the calibration and combination of forecasts produced by different models with distinct hindcast periods. All results were obtained using the cross-validation leave-one-year-out 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 1 shows Gerrity score maps of tercile probability precipitation hybrid forecasts for the EUROBRISA system configuration used during 2008 and 2009, which was composed by empirical, ECMWF System 3, UK Met Office Glosea 3, Météo-France and CPTEC coupled models (panel a), for the EUROBRISA system configuration used during 2010, which was composed by empirical, ECMWF System 3, UK Met Office Glosea 4, Météo-France and CPTEC coupled models (panel b), and for the EUROBRISA system configuration used during 2011, which was composed by empirical, ECMWF System 3, the updated

version of UK Met Office Glosea 4, Météo-France and CPTEC coupled models (panel c). Positive Gerrity score values indicate regions where there good agreement between the category forecast as most likely and the observed category. The comparison of panels a, b and c in figure 1 shows that the northeast region of Brazil consistently maintains a reasonable level of skill despite the modifications in the EUROBRISA forecasting system with the update of UK Met Office from Glosea 3 to Glosea 4, suggesting good ability to indicate possible seasonal precipitation excesses or deficits over the northern part of the Brazilian northeast region.

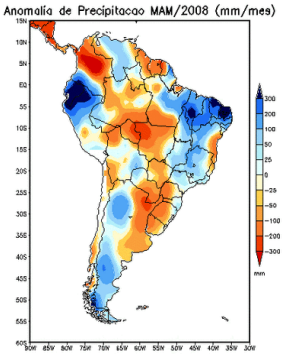


(a) (b) (c)

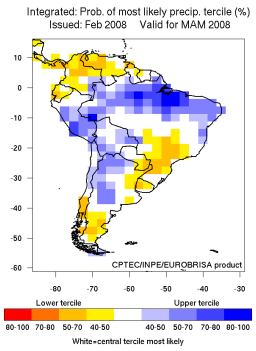
Figure 1: Gerrity score for tercile categories (below normal, normal and above normal) for EUROBRISA empirical-dynamical (hybrid) probabilistic seasonal precipitation forecasts for MAM produced in the previous February (i.e. 1-month lead forecasts). The verification period is 1981-2005. a) Skill map for the EUROBRISA system configuration during 2008 and 2009 composed by empirical, ECMWF System 3, UK Met Office Glosea 3, Météo-France and CPTEC. b) Skill map for the EUROBRISA system configuration during 2010 composed by empirical, ECMWF System 3, UK Met Office Glosea 4, Météo-France and CPTEC. c) Skill map for the EUROBRISA system configuration during 2011 composed by empirical, ECMWF System 3, the updated version of UK Met Office Glosea 4, Météo-France and CPTEC.

Figures 2 and 3 (panel a and c) show the observed precipitation anomalies (mm) in MAM 2008 (Figure 2a), MAM 2009 (Figure 2c), MAM 2010 (Figure 3a) and MAM 2011 (Figure 3c). During this season in 2008 La Niña conditions were observed in the Pacific and in 2009 a negative dipole pattern developed in the tropical Atlantic, with colder than normal conditions in the north tropical Atlantic and warmer than normal conditions in the south tropical Atlantic. These oceanic conditions were favorable for the observed above normal precipitation in northern northeast Brazil in 2008 (Figure 2a) and 2009 (Figure 2c) in association with the ITCZ located to the south of its climatological position. The forecasts issued by the EUROBRISA empirical-dynamical (hybrid) system indicated high probabilities for precipitation in the above normal category (upper tercile) as illustrated in Figure 2b for MAM 2008 and Figure 2d for MAM 2009. The consistency between the forecasts and the observations shows that the EUROBRISA forecasting system was capable of providing good indications for the observed precipitation excesses in northern northeast Brazil in these two years.

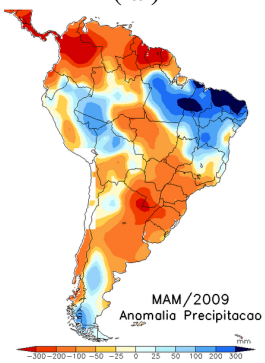
During MAM 2010 El Niño conditions were observed in the Pacific and warmer than normal conditions in the north tropical Atlantic. During MAM 2011 La Niña conditions were observed in the Pacific and slightly warmer than normal conditions were observed in the tropical Atlantic. These oceanic conditions were favorable for the observed below normal precipitation in northern northeast Brazil in 2010 (Figure 3a) and the observed above normal precipitation in northern northeast Brazil in 2011 (Figure 3c) in association with the ITCZ located to the north of its climatological position in 2010 and to the south of its climatological position in 2011. The forecasts issued by the EUROBRISA empirical-dynamical (hybrid) system indicated high probabilities for precipitation in the below normal category (lower tercile) as illustrated in Figure 3b for MAM 2010 and high probabilities for precipitation in the above normal category (upper tercile) as illustrated in Figure 3d for MAM 2011. The consistency between the forecasts and the observations shows that the EUROBRISA forecasting system was capable of providing good indications for the observed precipitation deficit in northern northeast Brazil in 2010 and the observed precipitation excess in this region in 2011.



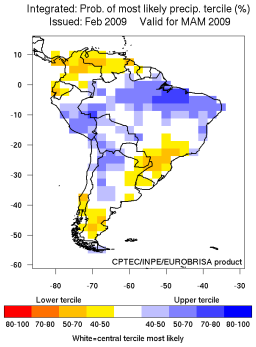
(a)



(b)

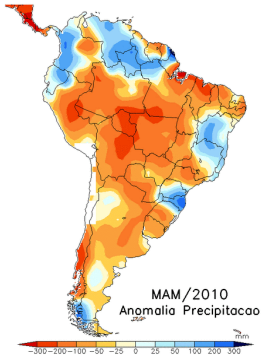


(c)

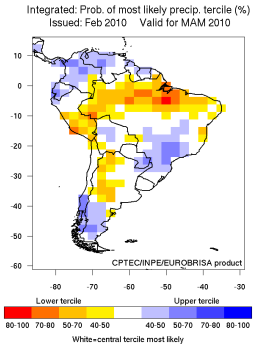


(d)

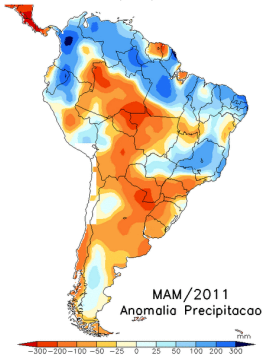
Figure 2: Observed precipitation anomalies (mm) in MAM 2008 (panel a) and MAM 2009 (panel c). One-month lead (i.e. produced in Frebuary) EUROBRISA empirical-dynamical (hybrid) most likely precipitation tercile forecasts for MAM 2008 (panel b) and MAM 2009 (panel d).



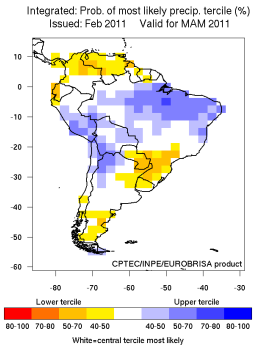
(a)



(b)



(c)



(d)

Figure 3: Observed precipitation anomalies (mm) in MAM 2010 (panel a) and MAM 2011 (panel c). One-month lead (i.e. produced in Frebuary) EUROBRISA empirical-dynamical (hybrid) most likely precipitation tercile forecasts for MAM 2010 (panel b) and MAM 2011 (panel d).

4. CONCLUSIONS

This study has assessed the performance of empirical-dynamical (hybrid) March-April-May (MAM) precipitation seasonal forecasts for South America issued in the previous February (i.e. 1-month lead), with particular attention devoted to forecasts over the northeast region of Brazil during the last 4 years (2008-2011). These forecasts for MAM issued by CPTEC as part of EUROBRISA have presented reasonable performance indicating high probabilities for an abnormally wet rainy season in 2008, 2009 and 2011 for the northern part of the northeast region of Brazil and an abnormally dry rainy season in 2010, which were all in good agreement with the observations.

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