PREDICTABILITY OF THE INTRA-SEASONAL RAINFALL CHARACTERISTICS VARIABLES OVER SOUTH AFRICA

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Abstract

Aspects of seasonal forecast skill of the SCM and ECHAM4.5 general circulation model (GCMs) are assessed over South Africa. The GCMs output is configured to predict low and high number of rainfall days at South African Weather Service stations exceeding different threshold values for the summer rainy seasons and to predict the onset of the rainy seasons for eight homogeneous rainfall regions of South Africa. Using canonical correlation analysis as statistical downscaling tool the forecast skill levels of both the coupled and uncoupled models are determined through retro-actively generated hindcasts. Both approaches have skill in predicting low and high number of rainfall days exceeding different threshold values for the summer rainy seasons as well as the onset of the rainy seasons for the homogeneous rainfall regions.

Keywords: Retro-active validation, Forecast skill, Area-averaged ROC scores, Reliability diagrams.

Introduction

Southern Africa is a region of significant rainfall variability on a range of temporal and spacial scales and is prone to extreme droughts and floods events (Usman & Reason, 2004). Examples include, the devastating floods in northeast South Africa and southern Mozambique during February/March 2000 and severe droughts of 1991/92, 2002/03 and 2003/04 over northern South Africa and surrounding areas (Cook *et al*., 2004). Most of African countries depend significantly on rain fed agriculture, which is highly vulnerable to the amount and distribution of rainfall (Kijazi & Reason, 2005). According to Usman and Reason (2004) the occurrence of extreme dry (wet) conditions over southern Africa during the austral summer have been associated with high dry spell frequency (wet spell frequency). Previous studies showed that seasonal rainfall totals are predictable over South Africa (e.g. Landman *et al.* 2012). Very few studies of the predictability of the intra-seasonal rainfall characteristics variables such as onset of the rainy seasons over South Africa are documented. The purpose of this study is therefore to assess the skill of the state-of-the-art forecasting systems in predicting low and high number of summer seasons rainfall days exceeding different threshold values and the onset of the rainy seasons over South Africa.

Data and Methodology

The observed daily rainfall data from 563 stations over South Africa obtained from the South African Weather Service (SAWS) are used to calculate monthly and seasonal rainfall totals as well as indices of the number of rainfall days exceeding the threshold values of 1mm, 5mm, 10mm, 15mm, 20mm, 30mm, 40mm and 50mm for October to November (OND), November to January (NDJ), December to February (DJF) and January to March (JFM) summer rainy seasons over South Africa from 1982 to 2009. The predicted large-scale 850hPa geopotential heights for the above mentioned summer rainy seasons, which are taken from the hindcast simulations of the SAWS Coupled Model (SCM; Beraki *et al*., 2014) and ECHAM4.5 (Roeckner *et al*., 1996; Beraki *et al*., 2015) GCMs are used as predictors in a statistical downscaling system.

Using the Climate Predictability Tool (CPT) developed at the IRI the hindcast outputs of both the coupled and uncoupled GCMs are first statistically recalibrated and downscaled to seasonal rainfall totals, then to number of days exceeding different rainfall threshold values and finally to the onset of the rainy seasons over South Africa by using model output statistics (MOS). Forecast skill levels of both GCMs are evaluated using retro-actively generated hindcasts through canonical correlation analysis (CCA). Retro-active forecast validation is a robust method to assess forecast model performance and give unbiased skill levels (Landman *et al.*, 2001). Two attributes of the downscaled forecasts are to be tested, namely, discrimination and reliability. For the former relative operating characteristics (ROC) is used and for the latter the attributes or reliability diagram is used. A high ROC score (>0.5) indicates the models' ability to discriminate event from non-events. Furthermore, to test if the hindcasts are well calibrated the reliability diagrams is used to assess the extent to which forecast probabilities match observed frequencies. ROC and reliability plots are calculated for seasonal totals, rainfall thresholds and for seasonal onsets.

Results and Discussion

Firstly, the forecast skill of both the SCM and ECHAM4.5 GCMs are assessed in predicting the seasonal rainfall totals for OND, NDJ, DJF and JFM seasons over South Africa. The area-averaged ROC scores greater than 0.5 in Figure 2 indicate that the 850hPa geopotential height fields produced by GCM initialized at 0, 1, 2, 3 and 4 month lead-times of both forecast systems have skill in discriminating wet or dry seasons from the rest of the seasons when predicting seasonal rainfall totals for the seasons considered. The higher skill scores is mostly found during NDJ and DJF seasons and this findings are agreement with Landman *et al.* (2012).

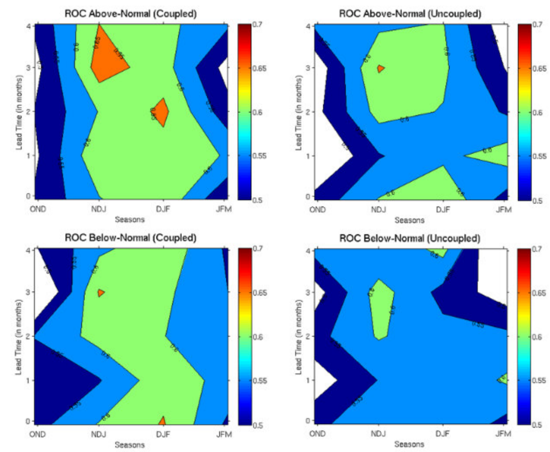

Figure 2. Area-averaged ROC scores of both the coupled and uncoupled GCMs in predicting OND, NDJ, DJF and JFM seasonal rainfall totals over South Africa from 1982 to 2009.

The forecast systems are also reliable in predicting seasonal rainfall totals. Reliability diagrams in Figure 3 shows that the 1-month lead-time hindcasts of both coupled and uncoupled forecasting systems possesses some reliability in predicting dry and wet conditions during DJF seasons. Although close to perfect reliability is obtained when the coupled system predicts wet conditions, both forecasting systems are overconfident in predicting dry seasons.

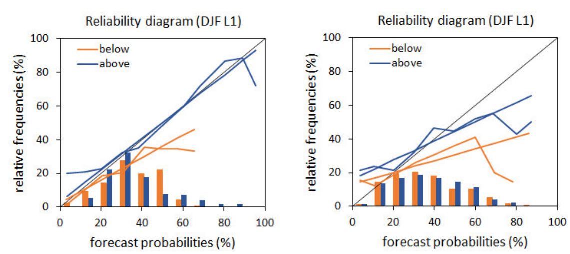

Figure 3. Reliability diagrams of both the coupled (left) and uncoupled (right) GCMs in predicting seasonal rainfall totals for DJF seasons from 1982 to 2009.

Secondly, the forecast skill of both sets (coupled and uncoupled) 850hPa geopotential heights at a 1-month lead-time is evaluated in predicting low and high number of rainfall days exceeding different threshold values for summer rainfall seasons over South Africa. The area-averaged ROC scores greater than 0.5 in Figure 4 indicate the models' ability to discriminate between a low and a high number of rainfall days exceeding the different threshold values for the OND, NDJ, DJF and JFM summer seasons. The forecast skill of predicting low (high) number of rainfall days is however increasing (decreasing) with the higher rainfall threshold values.

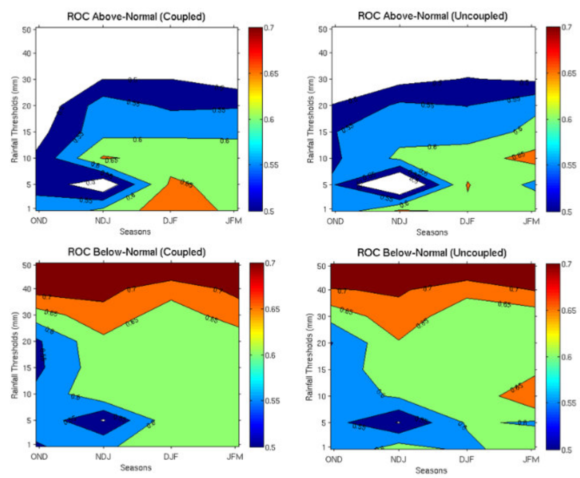

Figure 4. Area-averaged ROC scores of both the coupled and uncoupled GCMs in predicting high (Above-Normal) and low (Below-Normal) number of days exceeding different rainfall threshold values for the OND, NDJ, DJF and JFM seasons over South Africa from 1982 to 2009.

The forecast systems of both GCMs have some degree of reliability in predicting high and low numbers of rainfall days exceeding certain thresholds. The reliability diagrams in Figure 5 show good reliability for both systems, especially for the coupled model. However, for both models forecasts tend to be over-confident for high probability forecasts.

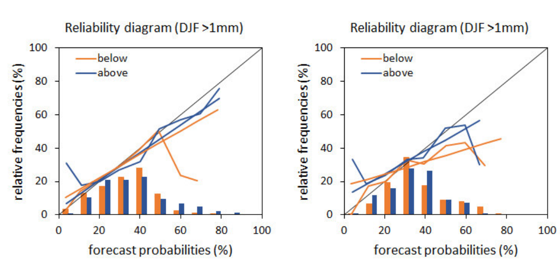

Figure 5. Reliability diagrams of both the coupled (left) and uncoupled (right) GCMs in predicting number of rainfall days exceeding 1mm for DJF seasons from 1982 to 2009.

Lastly, the skill of the 850hPa geopotential heights (1-month lead-time) of both coupled and uncoupled GCMs is tested in predicting the onset of the rainy seasons for all of the eight homogeneous rainfall regions of South Africa. The onset is defined here as the first month of a three month season on condition that the season consists of the wettest consecutive three months of the year as calculated over several decades (climatological values). According to our definition of onset, the onset month for region 1 is May, October for region 2 and 3, November for region 4, 5 and 6, December and January for region 7 and 8, respectively and are indicated with black arrows on the climatological annual circles in Figure 6.

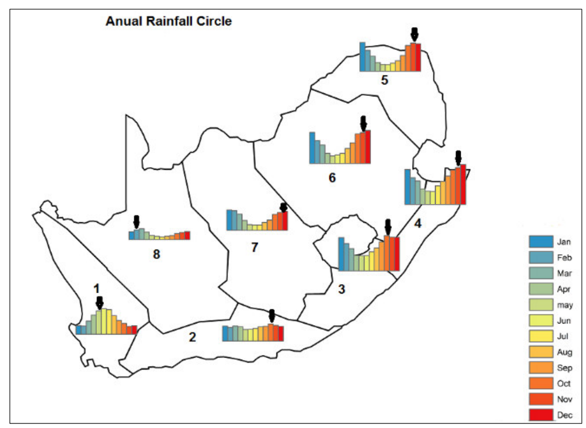

Figure 6. The eight homogeneous rainfall regions with their annual rainfall circle from 1982 to 2009.

Area-averaged ROC scores for both coupled and uncoupled GCMs have the skill scores above 0.5 for all the rainfall region's onset months (Figure 7), indicating the models ability to successfully discriminate between a good start (above-normal) and a poor start (below-normal) rainfall totals for the first month of the 3-month season. The skill level is however different from region to region.

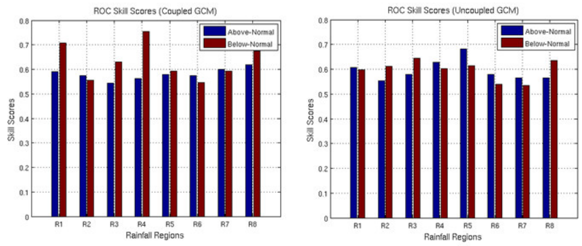

Figure 7. Area-averaged ROC scores of both coupled and uncoupled GCMs in predicting the onset of the rainy seasons for the 8 homogeneous rainfall regions of South Africa from 1982 to 2009.

The reliability diagrams in Figure 8 shows that the 850hPa geopotential height fields of both coupled and uncoupled forecasting systems are producing reliable downscaled onset forecasts for Region 1. As was found before, the below-normal cases are over-confident mostly for high probability forecasts.

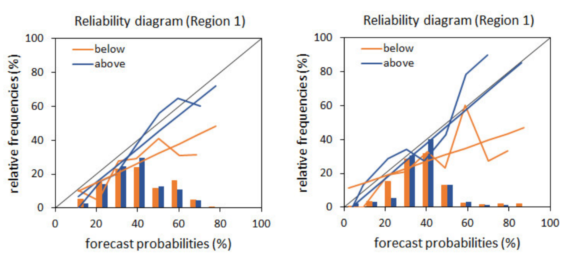

Figure 8. Reliability diagrams of both the coupled (left) and uncoupled (right) GCMs in predicting the onset of the rainy seasons for Region 1 from 1982 to 2009.

Conclusions

The forecast systems considered have the skill in terms of discrimination and reliability to predict for a range of seasonal rainfall characteristics over South Africa. These characteristics include seasonal rainfall totals, number of rainfall days exceeding certain thresholds, and seasonal onset of the rainy seasons as defined here.

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