

Prediction of Short Rains over Equatorial East Africa Using Multi-Model Ensemble

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1. Introduction

In this study the performance of dynamical seasonal forecast systems is evaluated for the prediction of short rain anomalies over equatorial East Africa. The evaluation is based on observational data and the Asia-Pacific Climate Center (APCC) Ocean-Atmosphere coupled Multi-Model Ensemble (MME) hindcasts. The ensembles of individual models and their MME mean are evaluated. Hindcasts initialized on 1st August for 24 years covering 1982-2005 periods alone are considered, as these are the most relevant to short rain predictions. This study is motivated by the desire to use the output of best seasonal forecasts over East Africa.

The climate of equatorial Eastern Africa is dominated by March to May (long rains) and September to November (short rains). Interannual variability of short rains over equatorial East Africa is dominated by changes on the large-scale with a clear link to tropical ocean-atmosphere variability. The Indian Ocean Dipole (IOD) and its influence on climate variability over surrounding regions have been reported by Saji *et al.* (1999). After the discovery of this mode, several studies focused on the Indian Ocean to understand variability of the short rains over East Africa (Black *et al.* 2003; Behera *et al.* 2005; Ummenhofer *et al.* 2009; Bahaga *et al.* 2013). These studies indicated that SON rainfall over East Africa (Indonesia) is increased (decreased) during positive IOD events.

2. Data, models and evaluation methods

2.1 Verification data

The observed rainfall data used in this study are derived from Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) (Xie and Arkin 1996). The observational SST data are obtained from

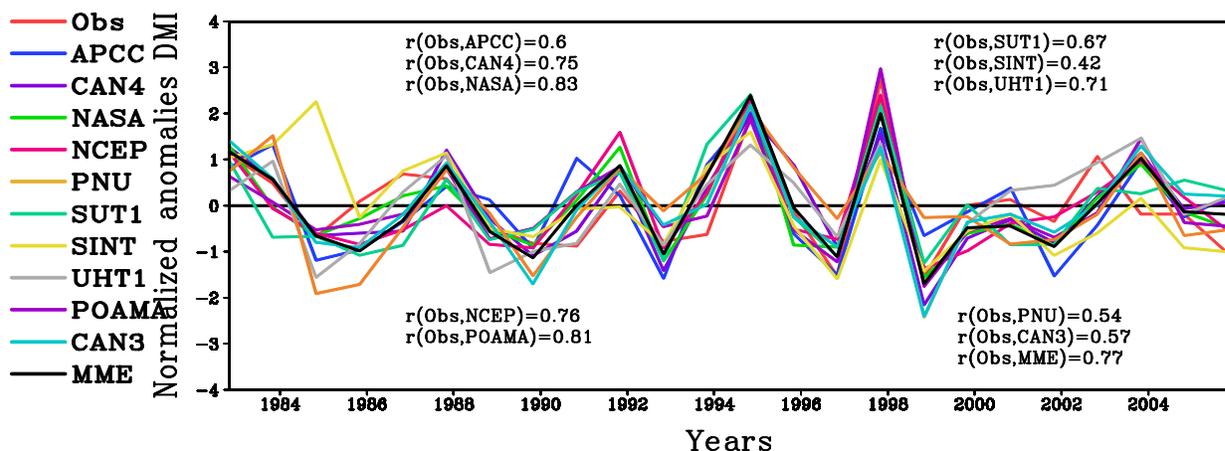


Fig. 1 Year-to-year variation of IOD derived from observation, Individual coupled models ensemble mean and MME mean hindcast SST anomalies normalized by standard deviation along with their correlation coefficient with respect to verification data.

improved Extended Reconstruction SST (ERSSTv3b, which includes satellite data) of Smith *et al.* (2006). This data was downloaded from <http://www.ncdc.noaa.gov/ersst/> and is available from 1871 to present.

2.2 Coupled forecast models

The coupled models that are examined in this study are ten state-of-the-art fully coupled atmosphere-ocean-land seasonal prediction systems and are obtained from operational seasonal prediction models participating in the APCC MME seasonal forecast (Sohn *et al.* 2012).

2.3 Forecast quality measures

To measure the quality of a deterministic forecast, MME mean prediction was constructed using the simple average of ten models ensemble means. The metrics used to measure and evaluate prediction skill of individual coupled models ensemble mean and MME mean forecasts includes the spatial map of anomaly correlation coefficient (ACC) and simple correlations. Calculation of these quantities is standard (*e.g.*, Wilks 1995) and uses anomaly data, whereby the observed seasonal cycle and the hindcast climatology are removed from the observations and forecasts, respectively.

3. Results

3.1 IOD prediction in coupled models and MME

Bahaga *et al.* (2013) has shown that the IOD in the SST dipole mode index has high prediction skill for the variations of short rains. Here we consider SON mean SST anomalies for hindcast verification, which is the peak season in the evolution of IOD. In addition, IOD and equatorial East Africa short rains have strong contemporaneous relations at this time of the year.

Figure 1 show the forecast of interannual variation of SON season mean Dipole mode index (DMI) normalized by the corresponding standard deviation and derived from ten coupled models ensemble mean and MME mean hindcast initialized on the 1st of August. It is seen from Figure 1 that there is a large skill of IOD predictions for almost all models and their MME mean, as reflected in the large significant correlation of predicted SST anomalies with observation.

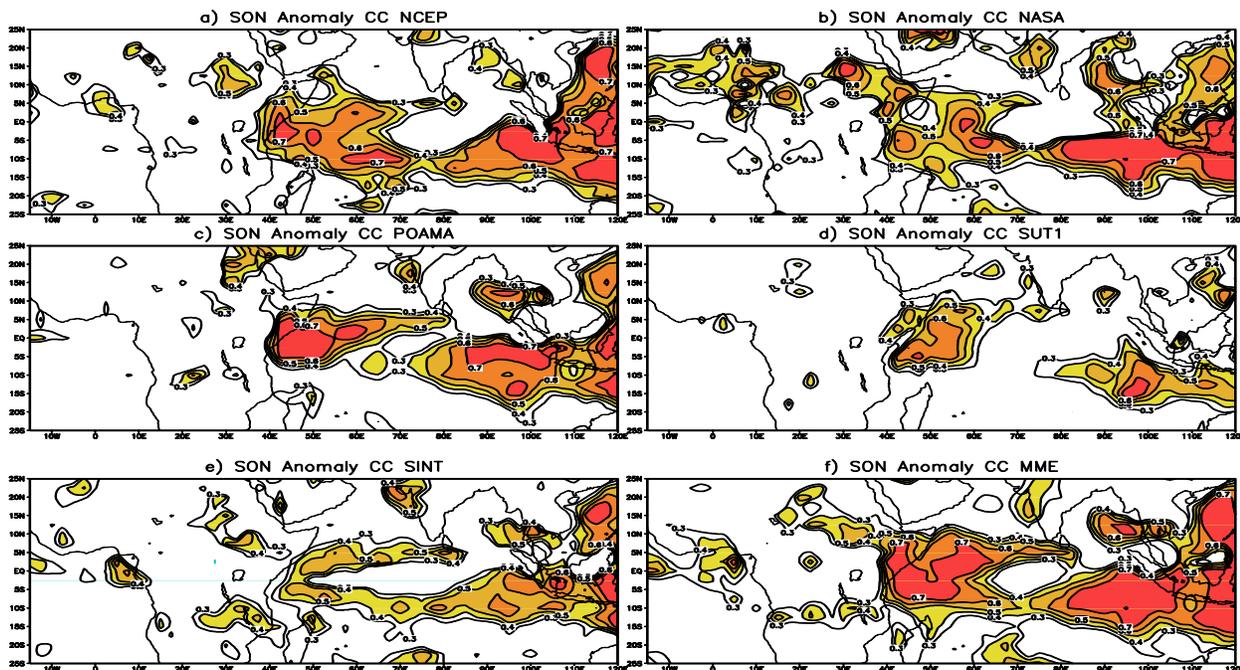


Fig. 2 Anomaly correlation coefficient (ACC) between SON observed rainfall and forecast rainfall derived from coupled models ensemble and MME mean during the period of 1982-2005 with a) NCEP, (b) NASA, (c) POAMA, (d) SUT1, (e) SINT, and (f) MME. Shaded positive values are significant at 95% confidence level.

The forecast skill for the SST anomalies in almost all models exhibits skill greater than 0.5 and also highly significant above 99.9% level, except for the SINT model (with a correlation of only 0.42). Models with high DMI forecast skill are NCEP, NASA, POAMA ensemble mean and MME mean. On the other hand, SUT1, PNU, and CANCM3 are characterized by relatively lower correlation. Moreover, DMI prediction shows very good skills with the major positive IOD events like 1982, 1994 and 1997 captured well in nearly all forecasts (Figure 1). In general, it can be concluded that the APCC coupled models and MME mean initialized on 1st August produce excellent predictions of the temporal behavior of the SST anomalies over the Indian Ocean.

3.2 Equatorial East Africa short rain prediction

Previous studies have demonstrated that IOD is the source of predictability for East African short rains (Behera *et al.* 2005; Bahaga *et al.* 2013). The skill of SON rainfall anomaly forecast is evaluated based on the Anomaly Correlation Coefficient (ACC) between the observation and coupled models forecast over Indian Ocean basin (Figure 2). Overall there is little or no skill found over most of land points, with the exception of the coast of East Africa and countries east of tropical Indian Ocean region where significant skill can be identified. A similar lack of rainfall predictability over most land regions has also been reported by Wang *et al.* (2009). On the other hand, most coupled models and MME mean show significant skill over ocean points in the south eastern Indian Ocean and western Indian Ocean (Figure 2a-f).

3.3 Short rain forecast skill

The interannual variation of equatorial East Africa rainfall index (EEARI) (5°S-5°N, 35-45°E) and the correlation between observed and each coupled models ensemble and MME mean is shown in Figure 3. The figure illustrates that five coupled models predict equatorial East Africa rainfall with statistically significant skill. NCEP prediction giving the strongest correlation of all and SUT1, UHT, POAMA and CANCM3 also show significant skill. The other models have relatively lower skill and are unable to produce significant correlations. Despite insignificant skill in some individual models, MME mean produce the fourth largest significant correlation at 95% confidence level.

3.4 MME mean forecast skill improvements by model selection

Finally we consider improvements of forecast skill in the MME mean hindcasts of SON equatorial East Africa rain-fall by selecting five good models according to their correlation skill in predicting the EEARI index (Figure 3). Only models that show at least 90% statistically significant correlations are selected. The resulting models are UHT1, NCEP, POAMA, SUT1 and CANCM3. Such a selection should be revisited once more hindcast data is available. The correlation between observed and ensemble mean of EEARI for the selected coupled models and their MME mean is shown in Figure 4. The 90% significant level is indicated by

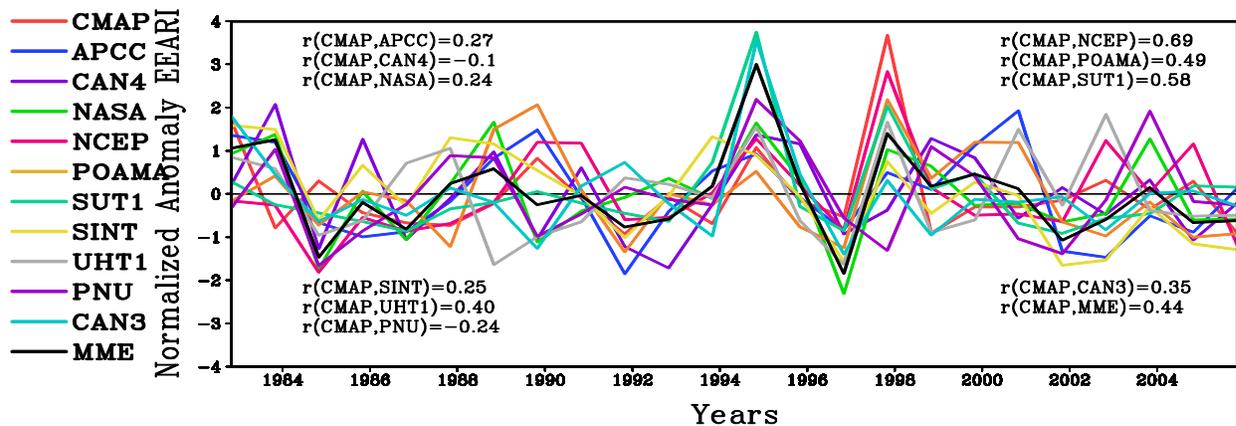


Fig. 3 Interannual variation of SON normalized anomaly over equatorial East Africa in APCC coupled models hindcast and MME mean verified against observation along with the spatial correlation between observed and predicted SON equatorial East Africa rainfall index (EEARI) (5°S-5°N, 35-45°E) for a period of 1982-2005.

the horizontal dashed line. Thus the skill of the MME based on this model selection improves its skill from 0.44 for all models to 0.67.

4. Conclusions

Hindcast experiments from 10 APCC coupled models ensemble mean and their MME mean were analyzed regarding their predictive skill of East African rainfall. Coupled model hindcast also evaluated for prediction of SST anomalies over tropical Indian Ocean. Nearly all models and MME mean shows statistically high significant skill in forecasting the peak phase of the IOD in the boreal autumn season, which is typically when the IOD is best defined and most climatically important. Furthermore, out of ten models five coupled models and MME mean show statistically significant skill in predicting equatorial East Africa short rains. The results of this study reveal an encouraging potential for real time forecasts of East African rainfall with about one month lead time. Such forecasts would be of substantial societal importance.

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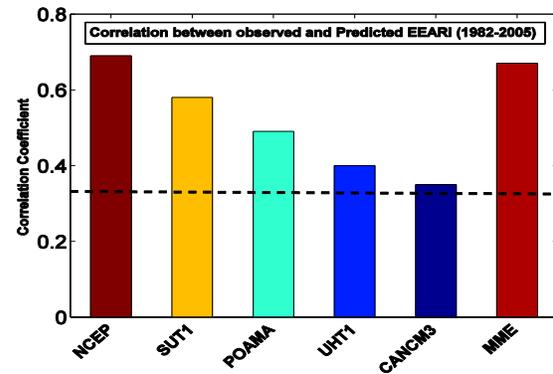


Fig. 4 Correlation between observed and predicted SON Equatorial East Africa rainfall for hindcasts in APCC coupled models dataset for a period 1982-2005, the correlation is calculated for the same index.