Predictability Of Seasonal Sahel Rainfall Using GCMs And Lead-Time Improvements Through A Coupled Model

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MOTIVATION

The Sahel region of West Africa has a well known short rainy season from June to September followed by a long dry season. The rainy season itself is marked by strong interannual variability embedded in low frequency multidecadal variability. A forecast of the rainy season is crucial to the population in the Sahel for climate risk management spanning many issues such as agriculture, diseases, livestock etc. A good seasonal forecast would provide for a better preparedness within the region's limited economic resources. Thus we are interested in understanding and predicting Sahel rainfall variability. Our objective is to find the best way of using a dynamical model as a forecast tool (comprehensive representation of ocean influence on large-scale atmospheric patterns), while overcoming difficulties of representing the detailed rainfall process over the Sahel.

GCM EXPERIMENTS AND THE MODEL OUTPUT STATISTICS APPROACH

When driven with observed sea-surface temperature (SST), most atmospheric general circulation models (AGCMs) have poor skill in simulating interannual Sahel rainfall variations. Yet diagnostic work has shown a strong predictive relationship between SST patterns (regional, near-global) and Sahel seasonal rainfall totals.

An Empirical Orthogonal Function (EOF) analysis is applied to July-September (JAS) low-level AGCM zonal wind over the tropical Atlantic basin. The time series of the leading EOFs are then used as candidate predictors (regression model) for an index of observed JAS seasonal Sahelian rainfall. This is a Model Output Statistics (MOS) approach to predicting the seasonal rainfall.

The MOS extracts good predictive skill from all 8 AGCMs that are analyzed, in most cases, using just a single EOF. However, skill is lost (not shown) when the AGCMs are driven with SST anomalies observed before the rainy season (especially before June).

Therefore, coupled ocean-atmosphere GCM (CGCM) seasonal prediction experiments are analyzed. The NCEP CFS illustrates the potential of CGCMs, initialized several months (up to 6 months) ahead of the rainy season, to capture the evolution of ocean-atmosphere teleconnections and express them in the regional tropical Atlantic circulation that permits accurate specification of Sahel seasonal rainfall.

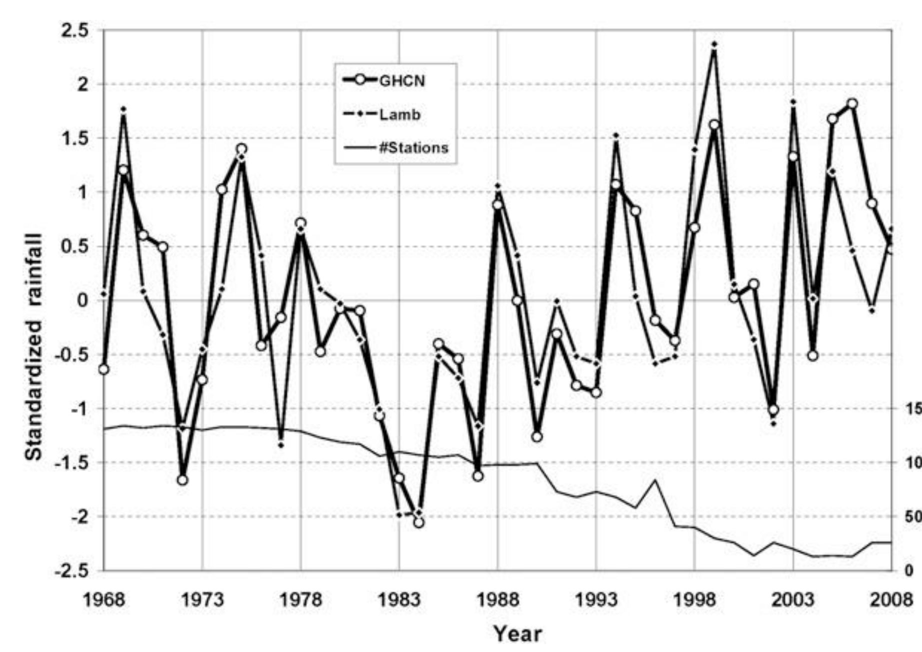
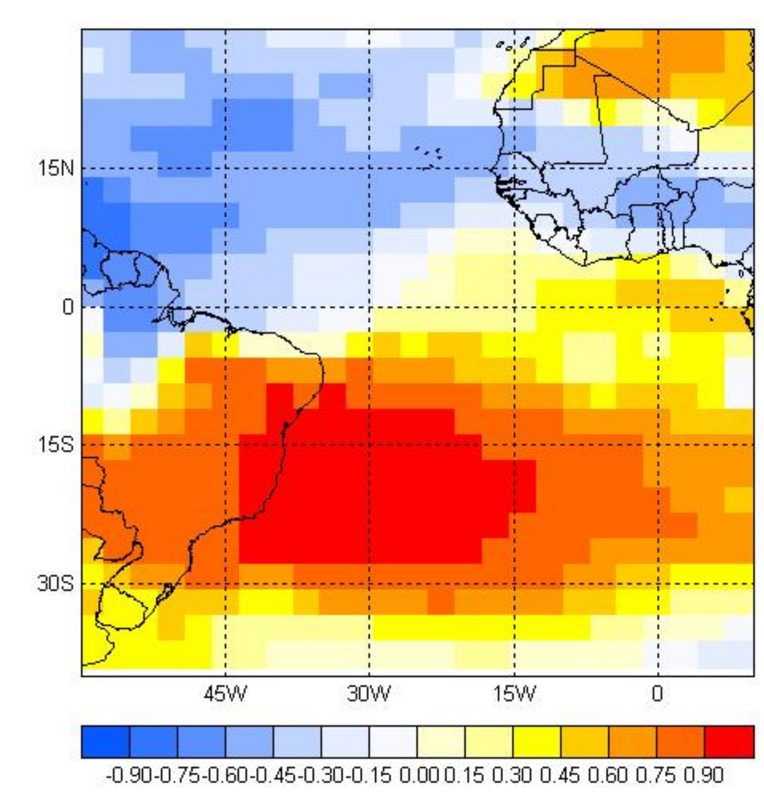


Fig. 1. Sahel Rainfall Index for the Jul-Aug-Sep season from 1968 to 2008. GHCN stations (circle) and the index constructed by Lamb (diamond). The number of stations contributing to the GHCN index is indicated by the thin line (right Y axis). It is well known that the region undergoes strong decadal climate fluctuations. The period 1950-1970 was wetter than the 1970s and 1980s. An upward recovery phase in rainfall is then apparent.



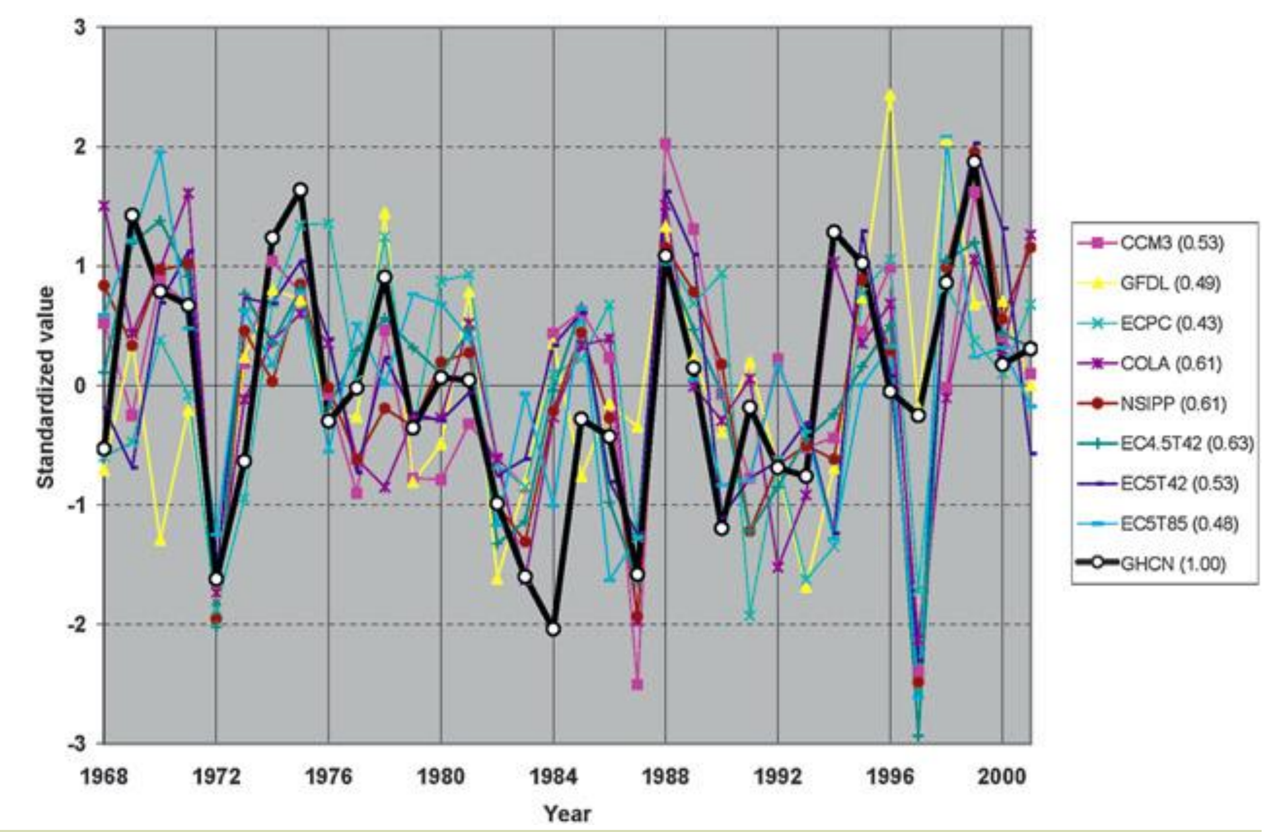
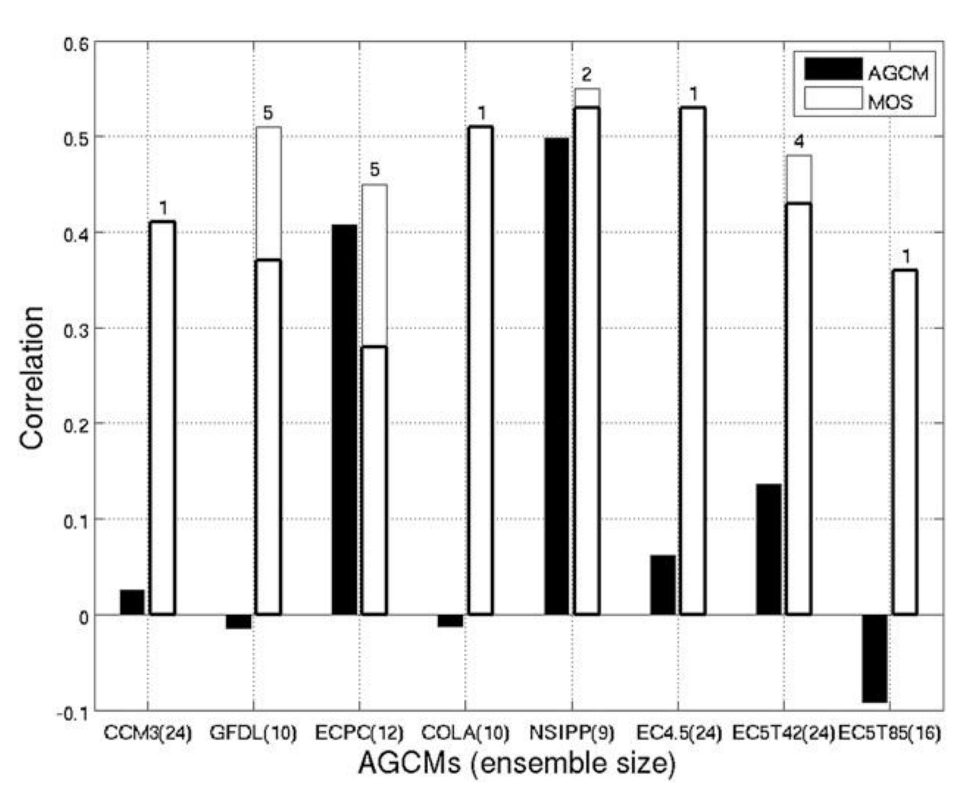
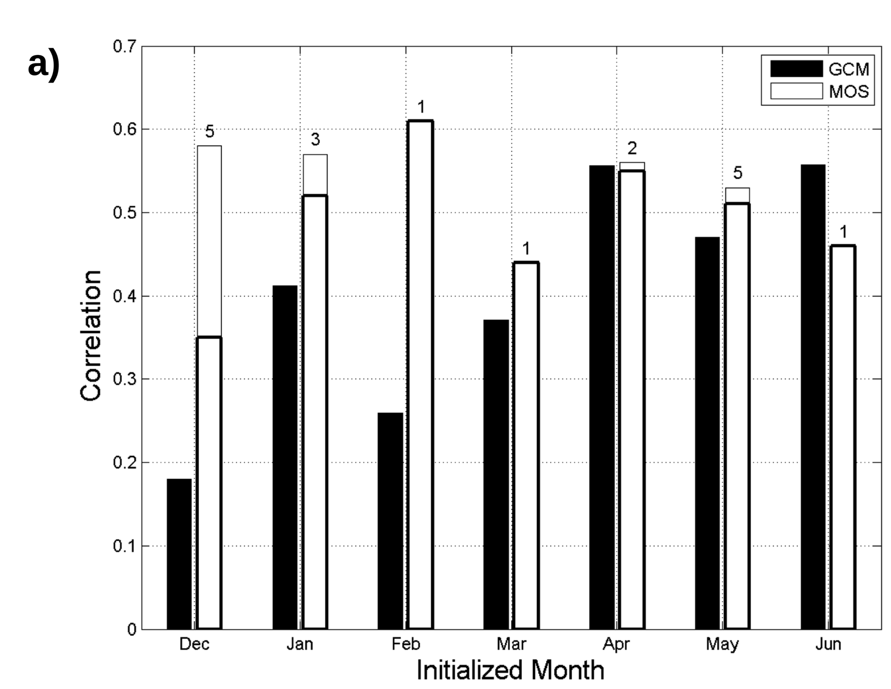


Fig. 3. Left panel: Example of AGCM low-level wind EOF that is used in the MOS (the different models all have some version of the tropical Atlantic pattern, and have least consistency in their expression of the wind teleconnection into West Africa). Right Panel: For each model analyzed, time series of the leading explanatory EOF (colored lines), along with the Sahel rainfall index (black line). Numbers in brackets indicate the correlation skill with Sahel rainfall.



Fiig. 2. Sahel rainfall skill during 1968–2001 from various AGCMs forced with observed SST. Skill is shown for AGCM rainfall (shaded bars) and after applying a MOS to the 925-hPa tropical Atlantic wind field (open bars). The regional wind features are known to be important components related to the dynamics of Sahel rainfall (e.g., Fontaine et al. 1992).



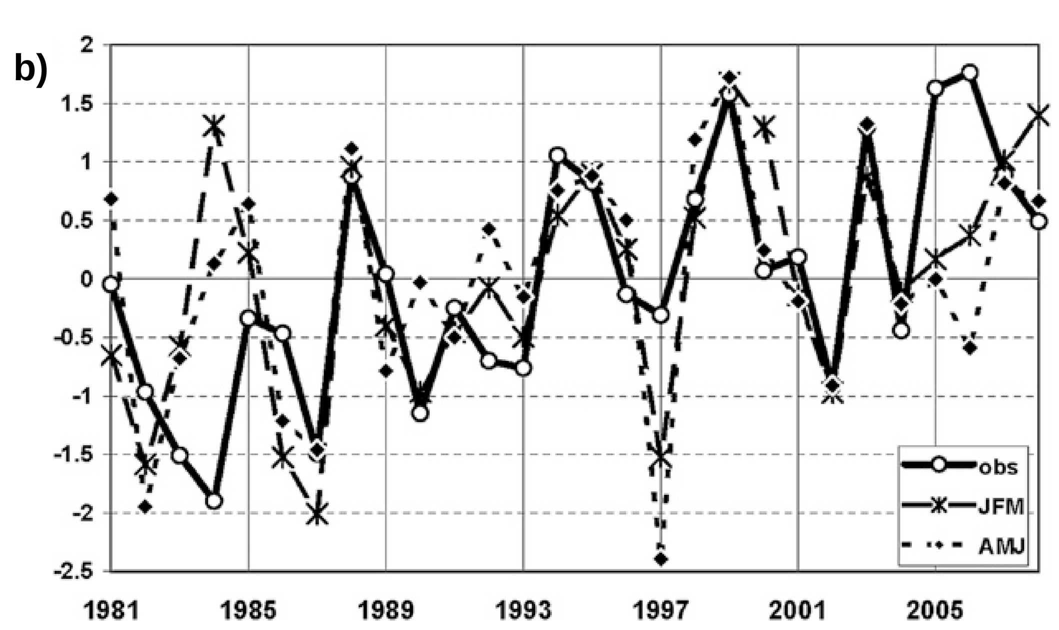


Fig. 4. Skill of a CGCM (NCEP CFS) for Sahel seasonal prediction. (a) Skill at increasing lead times, from June initialization (zero lead on the Sahel rainfall season) up to December initialization (6-month lead). Solid bar is skill of CGCM rainfall, open bar is skill after applying the MOS system. (b) Time series of observed and MOS predicted rainfall, based on the average of model initializations in Jan-Mar (long dash) and Apr-Jun (short dash). The plot reveals ability to track the upward trend (diagnostic analysis suggests association with a warming in the North Atlantic, relative to the South Atlantic), as well as some of the year-to-year interannual variations (diagnostic analysis suggests primary source in this period is the El Niño /Southern Oscillation).

Conclusions

Most AGCMs, when driven with the observed SST, still have difficulty in simulating the observed interannual variability of Sahel rainfall.
However, AGCMs are remarkably consistent in simulating the variations in the tropical Atlantic wind field that teleconnect to the observed July-September Sahel rainfall.
Assuming persistence of SST anomalies (at least before June) fails to allow AGCMs to predict the key circulation fields for Sahel rainfall.
CGCMs show potential in predicting the key tropical Atlantic wind fields at lead-times up to 6 months, offering the prospect of at least some long-lead predictability for seasonal Sahel rainfall.
Such an increase in lead-time has great potential societal benefit in a region so dependent on a single brief rainy season.

References

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