The annual cycle of African climate and its variability

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Abstract

A statistical analysis of African rainfall and temperature, and surface wind components and sea level pressure over the tropical Atlantic and Indian Oceans is done in the period 1965 to 1995. The annual cycle is found to be the dominant mode, exhibiting a subtropical north - south dipole with a cycle period of 12 months. The second mode is equatorial with 6-month oscillations prevalent. Annual cycle variance is of the order of 40%, compared with ~ 10% for the interannual residual. The north-south alternation of winds over the adjacent oceans accounts for 92% of north-south rainfall oscillations over the African continent. The annual cycle varies coherently over periods of 3 to 8 years. Years of high (low) annual cycle correspond with La Nina (El Nino) and increased (decreased) inter-annual fluctuations of the African climate. A composite analysis shows that the South Atlantic Hadley cell and standing waves in the subtropical jet may connect annual and interannual signals.

Keywords: annual cycle, African monsoon, climate diagnostics

Introduction

The annual cycle of the earth's climate is forced by solar insolation and corresponding surface fluxes that vary from summer to winter. There is a surplus of heat energy in the tropical zone that is exported pole-ward in both the ocean and atmosphere. These features may conspire to produce monsoon circulations, wherein the atmospheric Hadley cells are amplified in certain regions according to land-sea temperature contrasts. If various sources of forcing for the annual cycle could be distinguished, then it may be easier to contextualize long-term variability such as intra-decadal oscillations in climate. The separation of short- and long-term cycles is possible through statistical time series analysis, as reported here. However, the separation of local and remote forcing in the spatial domain is more difficult.

Biasutti et al. (2003) analysed the annual cycle around the tropical Atlantic, where it is known to be large relative to interannual fluctuations of sea surface temperature (SST). They found the role of SST in the annual cycle of air temperature and precipitation to be large over the Atlantic Ocean, the Guinea coast of Africa and north-east Brazil. The role of insolation is large over the highlands of Africa and the sub-tropics of South America. The interaction between these two forcings is small in their numerical model results and impacts of the Indian Ocean monsoon were not considered.

The African continent straddles the equator (Fig. 1) and its convection is a significant source of atmospheric heat. It has an extended plateau, two large deserts, and borders two tropical oceans of markedly different character. Energy released over equatorial Africa is exported through tropical/extra-tropical interactions, causing feedback with the global circulation and regional monsoons. The annual cycle of African rainfall is particularly strong and is expected to follow the pattern of the meridional flow set-up by the Hadley cell and its association with land-surface characteristics and the surrounding oceans.

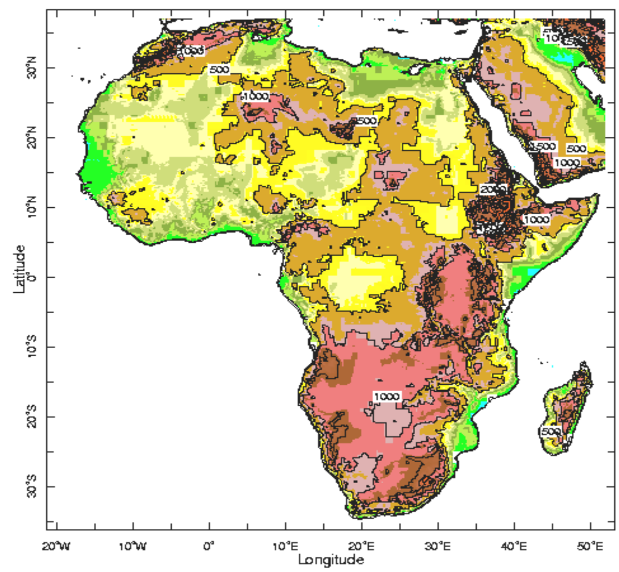

Figure 1
Topographic map of Africa distinguishing the southern highlands / northern lowlands. Many of the following PCA patterns conform to these features.

The monsoon circulation over Africa and its adjacent oceans undergoes shifts: In austral summer a convective trough extends from the Congo to Madagascar (Mulenga, 1998; Nassor and Jury 1998), in boreal summer a trough extends west-ward along the Guinea coast. Both features link with oceanic inter-tropical convergence zones (ITCZ); Jury et al., 1994). Heat and moisture are transported by cross-equatorial flows, comprising the lower limb of the Hadley overturning circulation. The NE monsoon of the Indian Ocean and SW monsoon of the Atlantic both provide essential inflows that depend on land-sea thermal contrasts. Heating over the subtropical deserts helps trigger the African monsoon, yet

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