

Easterly flow in the tropical Indian Ocean and climate variability over south-east Africa

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Abstract

The relationship between African rainfall and zonal wind anomalies in the adjacent tropical Indian Ocean is investigated. Comparisons are made using a December to March rainfall index for Africa south of 20°S and east of 25°E. Cases are selected when the zonal 850 hPa wind anomaly in the area 5° to 20°S, 40 to 90°E exceeds ± 1 standard deviation. During wet (dry) summers, low-level winds are more easterly (westerly). The easterly flows surge at certain times, bringing intra-seasonal 'pulses' of convection from the tropical Indian Ocean to south-east (SE) Africa during austral summer. National Center for Environmental Prediction (NCEP) reanalysis composites are constructed and structural features are analysed by subtracting the dry westerly cases from the wet easterly cases. Composite differences of zonal easterly flow extend through the troposphere in the 5° to 20°S band. Convection is reduced over the tropical South Indian Ocean whilst increased over SE Africa. Differences between east and west regimes are evident in the velocity potential and outgoing longwave radiation (OLR), indicating a convective sink near 15°S, 75°E over the South Indian Ocean. Composite sea surface temperatures (SST) are significantly above normal in the latitude band 25° to 35°S, and below normal in the tropics to the north. Precursor patterns are investigated to determine the origins of this climate mode.

Introduction

Much of the summer rainfall over Africa south of the Zambezi River ($\sim 15^\circ\text{S}$) is produced by quasi-stationary troughs (Harrison, 1986; Levey and Jury, 1996). The convection is often focused along a NW-SE oriented band by a Rossby wave in the subtropical upper westerly flow. Prior to the convective event, a period of low-level easterly flow from the tropical Indian Ocean is necessary to build up moisture as illustrated in Fig. 1 (D'Abreton and Lindsay, 1993; D'Abreton and Tyson, 1995). Widespread rainfall occurs over many days at near-monthly intervals during the November to March season (Makarau, 1995; Levey and Jury, 1996). Each convective spell brings ~ 100 mm of rainfall and contributes about 20% of the seasonal total, so an understanding of their coupling to the surrounding monsoon circulations would be useful.

A number of studies have described the meteorological structure of multi-day rainfall events (Taljaard, 1987; Matarira and Jury, 1990; Lindsay and Jury, 1991; Lyons, 1991; D'Abreton and Lindsay, 1993; Jury et al., 1993) based on statistical inferences from model-interpolated weather data. Across south-eastern (SE) Africa and the south-western (SW) Indian Ocean the wet spells appear to be pulsed at frequencies which are consistent with the passage of tropical waves during austral summer (Hayashi and Golder, 1992). Transient waves of the tropical Indian Ocean were studied by Jury et al. (1991) through homomoller analysis of satellite imagery in the 10° to 20°S band over the period 1970 to 1984. 50% of years between 1971 and 1984 exhibited westward moving convective disturbances with a mean speed of $2 \text{ m}\cdot\text{s}^{-1}$ and wavelength of 3 500 km giving an average period of 20 d. Other years had quasi-stationary or eastward-moving disturbances. Characteristics of the background circulation with respect to the potential for easterly waves have not been investigated. Here we look specifically at this issue. We investigate whether tropical easterly inflows

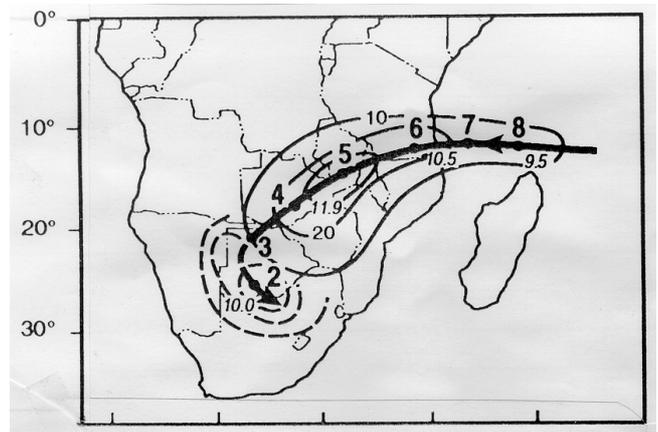


Figure 1

Mean water vapour trajectory for rainy spells over the interior of SE Africa from D'Abreton and Tyson (1996)

are sourced from a divergent centre in the Indian Ocean and analyse the regional structure and ocean-atmosphere environment.

Data and methods

Our study considers the principal components analysis of Mulenga (1998) on gridded summer rainfall departures (Hulme and Jones, 1993). In that work, areas with common fluctuations were identified over the period 1950 to 1992. A significant mode (PC4) occurs over Africa south of 20°S and east of 25°E. This area is agriculturally productive and yields a substantial food grain reserve following wet seasons (Lindsay, 1990). Seasonal rainfall extremes were noted and related to differences in the atmospheric circulation over the west Indian Ocean. Two common circulation patterns were identified based on the NCEP reanalysis zonal 850 hPa wind anomaly in the area 5° to 20°S, 45° to 85°E north-east of Madagascar exceeding ± 1 standard deviation. East flow years include:

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