Composite meteorological structure of flood events over the eastern mountains of South Africa

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Abstract

This study examines composite meteorological features of intense wet spells over the eastern mountains of South Africa during summer. Weather data for 14 Five-day periods (pentads) with rainfall exceeding 50 mm were composited during the period October to March, 1980 to 1991. Historical summer means were subtracted from pentad composite maps to evaluate anomalies. A subtropical low is located over the western plateau of Southern Africa during flood events. Tropical moisture is converged and the South Atlantic High ridges south of the continent. Upper levels are dominated by south-eastward outflow around an anticyclonic anomaly to the east. Vertical uplift is most vigorous in the 700 to 500 hPa layer. A case study pertaining to peak flooding is analysed and a budget analysis of various influences demonstrates a mixed tropical - temperate character.

Introduction

Motivation

Southern Africa, within the southern subtropical belt of high pressure, is subject to large fluctuations in rainfall. Droughts and floods are common and skew the rainfall distribution. The background circulation is characterised by weak subsidence in the mid-troposphere and the region is regarded as arid (Tyson, 1986; Levey, 1993). However, the subcontinent's eastern flank next to the warm Indian Ocean is subject to increased rainfall (Harrison, 1986). KwaZulu-Natal and the adjacent mountain escarpment are susceptible to frequent flooding (Kovacs, 1988). This area supplies about 80% of the water resources of South Africa and runoff rates are over 20% (Schulze, 1982). The variability of streamflow is critical to the region's economy. Floods experienced in the eastern mountains of South Africa during the summer of 1995/96 prompted this study of contributing factors.

Background

The rainfall over Southern Africa has been analysed with respect to predictability of wet or dry seasons using precursors such as sea surface temperatures (Lindesay and Mason, 1989) and tropospheric winds (Jury, 1996). Other studies have focused on fluctuations in rainfall associated with changes in the frequency and type of circulation regimes (Tyson, 1986) or their composite anomalies (Jury and Pathack, 1993). Walker (1990) suggests that during wet spells the Indian Ocean Anticyclone is displaced south-west of its mean summer position, bringing the Inter-Tropical Convergence Zone polewards. There is also a relative increase in easterly winds in the western Indian Ocean. The increase in onshore winds accompanied by warmer, moister air masses results in increased convergence over the eastern mountains of South Africa which rise to 2 000 m in places.

Hurry and Van Heerden (1982) attribute good summer rains to an easterly wave regime supported by a ridge of high pressure south of Africa linking the Atlantic and Indian Ocean anticyclones. A strong pressure gradient over the eastern interior brings warm moist air from the Mozambique Channel. Over the eastern mountains it converges with cooler air flowing around a mid-latitude high. At the 500 hPa level a cut-off low may be situated over the south-western Cape, a trough to the north extends southward over the central interior towards this cut-off low. Convection to the east of the trough may result in flooding.

Harrison (1986) described cloud bands extending south-eastward from SW Zambia along the leading edge of a westerly wave as the major cause of rain events over Southern Africa. In truncated cases the cloud band contained a subtropical cold cored vortex embedded in deep easterly flow. These could take the form of cut-off lows during transition seasons (Taljaard, 1982).

The eastern seaboard of South Africa experiences more frequent flooding (Tyson et al., 1976) due to a combination of moist, unstable air from the warm Indian Ocean and orographic uplift. Due to their high frequency, Natal floods are well documented (Badenhorst, 1989; Van Heerden, 1989; Terblanche, 1989; Lindesay et al.., 1989). At the local scale summer thunderstorms are the largest contributor to rainfall over the eastern escarpment and occur in the mid- to late-afternoon about 100 days each year (Schulze, 1972). The storms are classified in two groups; large-scale squall-lines which move to the north-east and those that result from local slope convection along the escarpment (Tyson et al., 1976).

Scope

The aim of this study is to highlight meteorological features of flood events over the eastern mountains of South Africa. Common aspects of rain-producing systems are composite averaged to elucidate the convective dynamics. The hypothesis to be tested is that these flood events result from orographic uplift of tropical and Agulhas air into a deep low which tilts westward over the interior. It is expected that convergence and cyclonic vorticity at the lower level will be compensated by divergence and anticycionic vorticity at upper tropospheric levels.

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