The 1950-1998 warm ENSO events and regional implications to river flow variability in Southern Africa

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Abstract

The variability of annual river runoff and its possible association with the 1950-1998 seasonal El Niño/Southern Oscillation (ENSO) is investigated in 502 rivers gauged in 9 countries of the Southern African region. We found some evidence of possible links between available surface water resources in terms of mean annual runoff and warm ENSO events. This was revealed by the existence of strong and nearly-strong positive linear correlation between annual discharges and the warm seasonal ENSO indices explained by the sea level pressure (SLP) data. Of the 502 rivers we considered, 150 rivers exhibit strong positive correlation between the December to February quarter ENSO indices and the annual runoff – with 25% of the variance in annual runoff being accounted for by the warm ENSO events. A relatively weaker positive correlation also occurred in 174 rivers we considered. The strong positive correlation occurs in parts of Zambia, Namibia, Mozambique and the lowveld in South Africa. In these parts of Southern Africa, there is evidence of a general decline in annual runoff after the mid-1970s compared to the period before it. These revelations are explored and are found to be partly explained by the high frequency of drought-related warm ENSO phenomena that occurred during the same period.

Keywords: river flow variability, ENSO, correlation analysis, Southern Africa

Introduction

Significant correlations between large-scale regional precipitation patterns and ENSO episodes have been identified for several specific regions around the world (e.g., Jury, 2003; Chiew et al., 1998; Ropelewski and Halpert, 1987). On a seasonal time-scale, the ENSO phenomenon (Zhang et al., 1997) affects the atmospheric circulation outside the tropics (Philander, 1990), and south-eastern Africa tends to experience dry conditions during warm ENSO events (Jury, 2003; Ropelewski and Halpert, 1987). ENSO is an atmospheric phenomenon that has long been known to have a characteristic manifestation in Southern Africa whereby warm-phase episodes are associated with droughts while cold-phase episodes lead to wetter than normal conditions. Mechanisms linking above-normal sea-surface temperature (SST) anomalies over the central Indian Ocean with Southern African droughts have also been explored (Jury and Pathack, 1991; 1993; Landman, 1995; Jury et al., 1996; Tennant, 1996; Landman and Klopper, 1998; Rautenbach, 1998).

The ENSO phenomenon is one of the biggest players in the game of year-to-year climatic variability. As many researchers have now come to appreciate, these two phenomena typically occur in conjunction, about once every few years. The influence of ENSO events is profoundly felt outside the tropics as well (Jury, 2003; Rautenbach, 1998; Landman and Klopper, 1998). A predictive model for the December to March rainfall season simulation for South Africa that considers ENSO influence in a canonical correlation analysis is provided in Landman and Klopper (1998). Due to the heterogeneous nature of rainfall, a large number of measurement stations are required for accurate characterisation of rainfall patterns over large areas. River systems are comprehensive integrators of rainfall over large areas. Therefore, the ability to predict flow patterns in rivers will be highly enhanced if a strong relationship between river discharge and ENSO exists, and is quantified. Furthermore, understanding of large-scale global atmospheric dynamics will enhance our understanding of regional/local systems of rainfall occurrence, which could improve understanding of river flow characteristics.

In an attempt to address the relationship between ENSO and the natural variability in the flow of tropical rivers, Amaresekera et al. (1997) studied the Amazon, Congo, Parana and Nile Rivers. They investigated the existence of a stronger correlation between the annual discharges of these rivers and seasonal SST indices. A prevalence of below-normal rainfall occurrences in several regions of South Africa during El Niño years has been reported (e.g. Landman and Klopper, 1998; Rautenbach, 1998). Recent studies indicate that ENSO events can be accurately predicted one to two years in advance using a physical model of the coupled ocean-atmospheric system (Chen et al., 1995). Therefore, the motivation of this paper is to explore whether a relationship exists between river discharge and ENSO and to quantify the relationship in the Southern African river systems. Emphasis is given to the warm ENSO events to examine the possible link with the decline in runoff of this region in the period after the mid-1970s (Alemaw et al., 2001).

In this paper the relationship between seasonal quarter warm ENSO events in terms of the SLP anomalies data and annual discharge of the 502 rivers in the Southern African region is examined. The seasonal quarter ENSO indices are the three-month aggregate mean values of December to February (DJF), March to May (MAM), June to August (JJA) and September to November (SON). This analysis is specifically aimed at investigating the type and magnitude of possible correlations between warm ENSO events and the regional implications of the annual discharge of rivers over the Southern African region. Possible explanations are also presented for the possible link between the long-term ENSO patterns and trends in annual runoff pattern and the

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