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The Effect of El-Niño Southern Oscillation (ENSO) on Ethiopian Seasonal Rainfall

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Abstract

Singular value decomposition (SVD) method is used to investigate the covariability between Ethiopian June to September (JJAS) rainfall anomalies and the anomalous sea surface temperature (SST) in Pacific Ocean based on precipitation and SST reanalysis data sets. Results show that significant coupled modes of variability exist, with the first dominant coupled mode explaining 68.31%. The spatial pattern shows a strong negative loading of SST in the central and eastern part of Pacific Ocean, and below (above) normal rainfall in southern part of Ethiopia. The findings from this study give insight into the influence of El-Niño Southern Oscillation (ENSO) events (Pacific Ocean) on Ethiopian JJAS rainfall.

Introduction

In the tropics where the domain of this study lies including Ethiopia, rainfall is the most important climate variable since the economies of most countries mainly rely on rain fed agriculture (Conway and Schipper, 2011; Bewket 2009; Cheung et al., 2008; Fraser, 2007; Korecha and Barnston 2007; Devereux 2000; Okoola 1999). The Greater Horn of African (GHA) countries including Ethiopia experience extreme climate events, especially drought throughout human history and million life losses and substantial economic damage are registered in the region (Camberlin and Okoola 2003; Berhan, et al., 2011). Recent studies (e.g. Ferris-Morris, 2003; Sarah, 2002; Tebaldi et al., 2006) present evidences suggesting that globally, there have been more flood/drought-inducing events, which are set to escalate in frequency and intensity. It is therefore vital to understand the variability of rainfall in the region.

Ethiopia, which is located within 3.30°-15°N, 33°- 48°E, Climatically, the region belongs to the sub-tropics and monsoon weather prevails throughout the year. The country experiences trimodal rainfall regime: June-September, October-January and February-May (Shanko and Camberlin 1998; Tsegay, 2001; Cheung et al., 2008). The June - September (JJAS) account approximately for 50%–80% of annual rainfall totals over the regions having high agricultural productivity (Gissila et al., 2004). The country's rainfall climatology is determined mainly by seasonal changes in large-scale circulation changes in macroscale pressure systems and monsoon flows (Nicholson 1989; Bekele 1997; Hastenrath, 1991).

A number of studies have been carried out in the GHA to investigate the significance of climate variability based on rainfall across the region (Camberlin and Okoola 2003; Korecha and Barnston 2007; Segeleet al., 2009). According to (Wolde-Georgis, 1997) the severe drought in Ethiopia is associated with El-Niño Southern Oscillation (ENSO) events. (Wolde-Georgis, 1997) explained that the scenario for long years indicates that the drought events existed at the same year with El-Niño year or one year later to El Niño year. During their investigation of predictability of JJAS rainfall in Ethiopia, a moderately strong teleconnective relationship between the northern summer ENSO state and concurrent JJAS Ethiopian seasonal rainfall is demonstrated, La-Niña (El-Niño) associating with enhanced summer rainfall across much of the country (e.g. Korecha and Barnston 2007; Diro et al., 2011).

The aim of this study was to investigate the effect of El-Niño Southern Oscillation (ENSO) events on Ethiopian JJAS seasonal rainfall. Sea Surface Temperature (SST) and precipitation were the main parameters analyzed. The findings of this study will help improve the accuracy of the JJAS seasonal rainfall forecast over Ethiopia. The JJAS seasonal rainfall is the main source of water and livelihood in the country.

Materials and Methods

The singular value decomposition (SVD) technique is one of the powerful and popularly applied methods in atmospheric sciences. The technique is the best in order to separate coupled patterns from two fields with identical temporal period, but may not necessarily be equal number of station or grids. In order to perform the mathematical framework of SVD technique on two space-time distributed data fields, two arbitrary scalars fields usually called the left and right fields with dimension of the number of stations (grids) for each field by the number of temporal period need to be computed. The details of mathematical expressions for SVD techniques can be found from (Bretherton et al., 1992; Wallace et al., 1992; Bjornsson and Venegas, 1997; Baker, 2005; Juneng and Tangang 2006; Hannachi et al., 2007).

Data

The precipitation (rainfall) dataset used in this study is the Global Precipitation Climatology Centre (GPCC) monthly precipitation dataset which is provided in their Web site at http://www.esrl.noaa.gov/psd/, and station data from National meteorology agency of Ethiopia from 1981-2010. In fact the station data is used for validity checking, because the African rain-gauge data has many spatial and temporal discontinuities over large sections of east Africa (Schreck and Semazzi, 2004).On the other hand the SST data used is the Extended Reconstructed Sea Surface Temperature (ERSST), from the National Oceanic and atmospheric Administration/National Climatic Data Center, which is available at: http://iridl.ldeo.columbia.edu/SOURCES/.NOAA/.NCDC/.ERSST/.version3b/.sst/. The study period spanned between 1961-2010, inclusive.

Results and Discussion

The mean JJAS seasonal rainfall over Ethiopia varies highly in space, the western parts of the country receives high rainfall while the eastern part experiences very low (Gebrehiwot and van der Veen 2013; Korecha and Barnston 2007). Smith (1979) and Slingo et al. (2005) attributed the observation to topography.

There exist significant coupled modes of variability between SST in Pacific Ocean and the mean JJAS rainfall over Ethiopia; the first dominant coupled mode shown to explain 68.31% (Figure 1) of the total covariance.

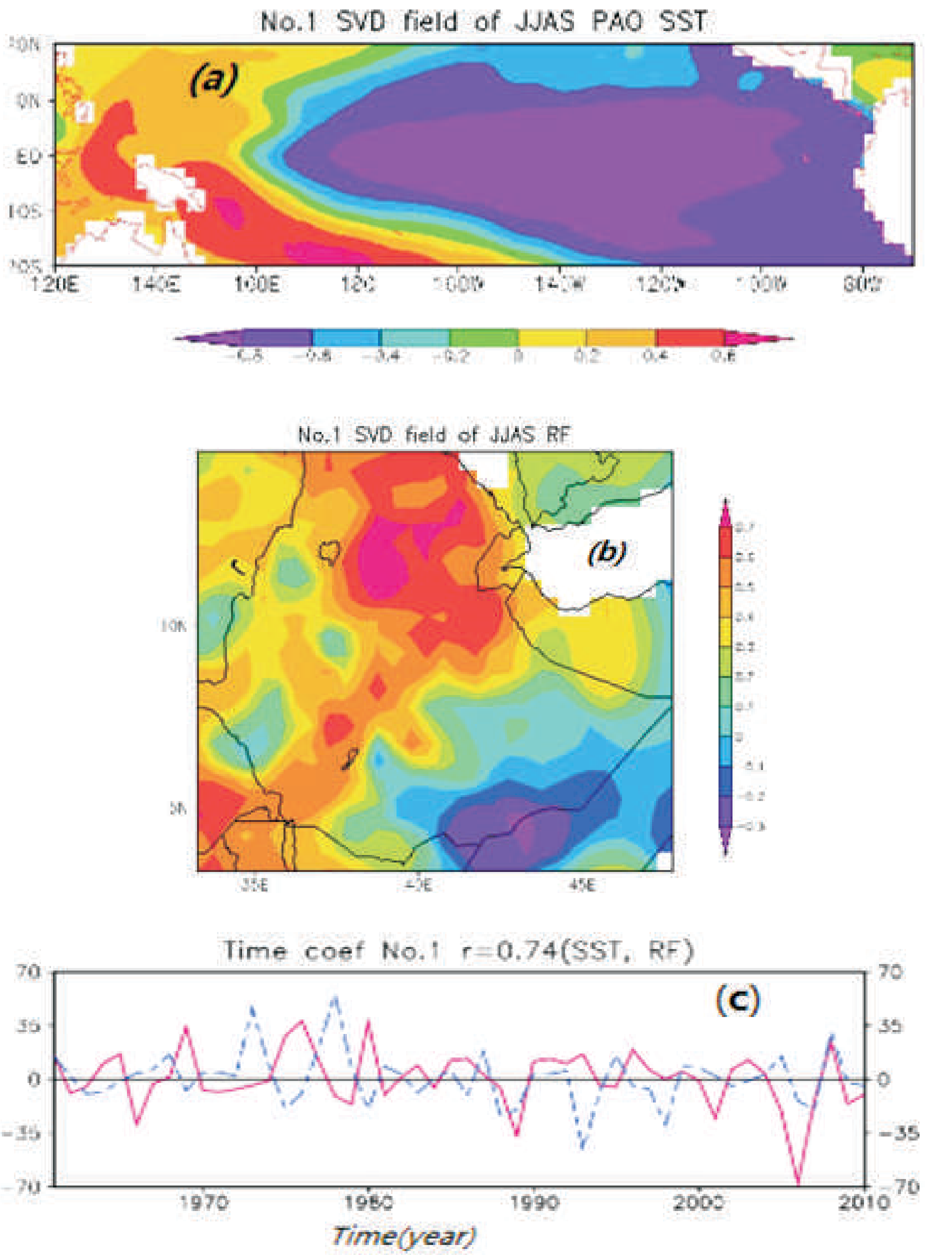

Figure 1: The homogeneous map of the first mode of SVD for the (a) Left field (SST) (b) Right field (Rainfall, RF) and (c) The corresponding extension coefficients

Results further show that the spatial pattern of the first dominant mode displays a strong negative loading of SST from central to most areas of eastern region of Pacific Ocean, and below (above) normal rainfall in southern (northern) region of Ethiopia. This is in agreement with earlier studies (Wolde-Georgis, 1997) the severe drought in Ethiopia, especially in northern region of the country is associated with El-Niño Southern Oscillation (ENSO) events. For instance, Jury (2010) highlighted the role of the Atlantic Multi decadal Oscillation for rainfall over northern Ethiopia. On the contrary, the Pacific Decadal Oscillation and the southern meridional overturning circulation affected the southern regions where rainy seasons are autumn and spring.

Conclusion

The study examined the covariability between SST over Pacific Ocean and the Ethiopian mean JJAS rainfall, based on SVD technique. Results reveal that significant coupled modes of covariability exist. The first dominant coupled mode was found to explain 68.31%.

The spatial pattern of the first dominant mode shows a strong negative loading of SST in the central and eastern part of Pacific Ocean, and below (above) normal rainfall in southern (northern) region of Ethiopia. This is associated with earlier studies (Wolde-Georgis, 1997) the severe drought in Ethiopia, especially in northern region of the country is associated with El-Niño Southern Oscillation (ENSO) events.

In general, the dominant coupled modes were able to show the effect of pacific Ocean, specificallly the El-Niño Southern Oscillation (ENSO) events on Ethiopian rainfall. Changes of SST in central, western and most of eastern Pacific Ocean causes anomaly in the rainfall distribution over Ethiopia especially the northern regions which are the areas with many agricultural activities, and usually victims of the extreme climate events.

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