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ORIGINAL PAPER

The effect of Indian Ocean on Ethiopian seasonal rainfall

Getachew Dubache[1,2] · Bob Alex Ogwang[3,4,5] · Victor Ongoma[3,6] · Abu Reza Md. Towfiqul Islam[3,7]

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Abstract
Singular value decomposition method is used to investigate the covariability between Ethiopian main rainy season [*Kiremt*, June to September (JJAS)] anomalies and the anomalous sea surface temperature (SST) in Indian Ocean based on precipitation and SST reanalysis datasets. Results show that significant coupled modes of variability exist, with the first dominant coupled mode explaining 49.3% and the second dominant coupled mode explains 12.6% of the total covariance. There is, however, higher correlation between the second dominant coupled modes than the first one. The spatial pattern of the first dominant mode shows a strong positive loading of SST in the central part of Indian Ocean, and below (above) normal rainfall in western (eastern) part of Ethiopia. The second dominant mode exhibits positive phase of Indian Ocean Dipole (IOD) event, with a strong positive (negative) SST anomaly in the western (southeastern) sector of Indian Ocean. This is associated with below (above) normal rainfall in northwestern (southeastern) region of Ethiopia. This is further affirmed by the correlation between the Dipole Mode Index of IOD and Ethiopian JJAS rainfall, which shows a negative (positive) correlation in the northwestern (southeastern) region. The analysis of the circulation anomalies associated with the pure positive (negative) IOD years are associated with anomalous easterly (westerly) winds over Ethiopia. Further analysis reveals that there is a widespread moisture divergence over Ethiopia and neighboring countries during negative phase of IOD as opposed to the positive phase of IOD which exhibits moisture convergence over the entire south and eastern Ethiopia, including parts of Uganda, Kenya, South Sudan, and western Somalia. The findings from this study give insight into the influence of Indian Ocean on Ethiopian JJAS rainfall.

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✉ Getachew Dubache
gechdubache@yahoo.com

[1] State Key Laboratory of Atmospheric Boundary Layer Physics and Atmospheric Chemistry, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

[2] College of Earth and Planetary Science, University of Chinese Academy of Sciences, Beijing 100049, China

[3] School of Atmospheric Sciences, Nanjing University of Information Science and Technology, Nanjing 210044, China

[4] Uganda National Meteorological Authority, P. O. Box 7025, Kampala, Uganda

[5] African Centre of Meteorological Applications for Development (ACMAD), Niamey, Niger

[6] School of Geography, Earth Science and Environment, The University of the South Pacific, Laucala Campus Private Bag, Suva, Fiji

[7] Department of Disaster Management, Begum Rokeya University, Rangpur 5400, Bangladesh

1 Introduction

In the tropics where the domain of this study lies, rainfall is the most important climate variable since the economies of most countries mainly rely on rain fed agriculture (Okoola 1999; Devereux 2000; Korecha and Barnston 2007; Fraser 2007; Cheung et al. 2008; Bewket 2009). Ethiopia's economy is no exception on overreliance on climate sensitive sectors such as agriculture, water and energy, thus, being very vulnerable to effects of climate variability and climate change (Conway et al. 2011; EPCC 2015). Weather and climate virtually affect all socio-economic sectors (IPCC 2007). The variability in timing and amounts of rainfall has always resulted into loss of life and property in Ethiopia. Most of the Great Horn of African (GHA) countries including Ethiopia have experienced extreme climate events, especially drought throughout human history resulting into loss of million lives and substantial economic damage (Camberlin and Okoola 2003; Berhan et al. 2011). Recent studies (e.g., Sarah 2002; Ferris-Morris 2003; Tebaldi et al. 2006; Ongoma et al. 2018) present evidences suggesting

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