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Complex Networks Dynamics Based on Events-Phase Synchronization and Intensity Correlation Applied to The Anomaly Patterns and Extremes in The Tropical African Climate System

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The African continent lie almost entirely within the tropics and as such its (tropical) climate systems are predominantly governed by the heterogeneous, spatial and temporal variability of the Hadley and Walker circulations. The variabilities in these meridional and zonal circulations lead to intensification or suppression of the intensities, durations and frequencies of the Inter-tropical Convergence Zone (ICTZ) migration, trade winds and subtropical high-pressure regions and the continental monsoons. The above features play a central role in determining the African rainfall spatial and temporal variability patterns. The current understanding of these climate features and their influence on the rainfall patterns is not sufficiently understood. Like many real-world systems, atmospheric-oceanic processes exhibit non-linear properties that can be better explored using non-linear (NL) methods of time-series analysis.

Over the recent years, the complex network approach has evolved as a powerful new player in understanding spatio-temporal dynamics and evolution of complex systems. Together with NL techniques, it is continuing to find new applications in many areas of science and technology including climate research. We would like to use these two powerful methods to understand the spatial structure and dynamics of African rainfall anomaly patterns and extremes. The method of event synchronization (ES) developed by Quiroga et al., 2002 and first applied to climate networks by Malik et al., 2011 looks at correlations with a dynamic time lag and as such, it is a more intuitive way to correlate a complex and heterogeneous system like climate networks than a fixed time delay most commonly used. On the other hand, the short comings of ES is its lack of vigorous test statistics for the significance level of the correlations, and the fact that only the events' time indices are synchronized while all information about how the relative intensities propagate within network framework is lost.

The new method we present is motivated by the ES and borrows ideas from signal processing where a signal is represented by its intensity and frequency. Even though the anomaly signals are not periodic, the idea of phase synchronization is not far fetched. It brings into one umbrella, the traditionally known linear Intensity correlation methods like Pearson correlation, spear-man's rank or non-linear ones like mutual information with the ES for non-linear temporal synchronization. The intensity correlation is only performed where there is a temporal synchronization. The former just measures how constant the intensity differences are. In other words, how monotonic are the two functions. The overall measure of correlation and synchronization is the product of the two coefficients. Complex networks constructed by this technique has all the advantages inherent in each of the techniques it borrows. But, it is more superior and able to uncover many known and unknown dynamical features in rainfall field or any variable of interest. The main aim of this work is to develop a method that can identify the footprints of coherent or incoherent structures within the ICTZ, the African and the Indian monsoons and the ENSO signal on the tropical African continent and their temporal evolution.