Characterizing vegetation response to rainfall at multiple temporal scales in the Sahel-Sudano-Guinean region using transfer function analysis

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Abstract

Rainfall is a key driver of terrestrial vegetation. Clarifying the response mechanism of vegetation to rainfall can advance the understanding of expected changes in ecosystems under projected rainfall scenarios. Besides the rainfall amount over a period of time, the frequency, duration and intensity are of importance in driving ecosystem domain to capture the response of vegetation to rainfall at multiple temporal scales. The TFA method determines coherence, gain, and phase to characterize the existence, strength, and time-lag, respectively, of the vegetation response to rainfall at different temporal scales. Specifically, the coherence measures the existence of the response and only with a significant response are the gain and phase values significant and valuable for further analysis. The gain measures the strength of the relationship between fluctuations in vegetation growth and fluctuations in rainfall, while the phase value (i.e. the time-lag) measures how fluctuations in vegetation growth lag (or lead) fluctuations in rainfall. The TFA method was applied to the 34-years (1982–2015) NDVI3g and CHIRPS precipitation dataset in the Sahel-Sudano-Guinean region (20°W ~ 60°E, 0–25°E). The Sahelian zone was characterized by a significant vegetation response to rainfall across all inter- and intra- annual time-scales, while the Sudano-Guinean zone was dominated by significant response at annual or 6-month scales. The negative phase lag indicated that rainfall variation normally led NDVI change for most areas and across timescales. However, a positive phase observed in part of the tropical rainforest area indicated that NDVI changes led rainfall variations, which may be caused by the strong vegetation-rainfall feedback through recycling of precipitation by evapotranspiration. In summary, these results suggested that the TFA method is a powerful tool to quantify the vegetation-rainfall response regime across a range of timescales, as conceptualized by the "pulsereserve" paradigm. Unraveling the response of fluctuations in vegetation growth to separate components of the forcing by precipitation might improve our understanding of environmental change in the past decades in the Sahel - Sudan - Guinean region.

Keywords:
Vegetation-rainfall response, Transfer function analysis, Cross spectral, Sahel, Time-lag, Remote sensing.