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Analysis and causes of non-stationary teleconnections impacting on West African Monsoon rainfall

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West Africa rainfall is influenced by several teleconnections and physical mechanisms. Known teleconnections are linked to the El Niño-Southern Oscillation (ENSO), the sea surface temperatures (SSTs) of major ocean basins, the Atlantic Meridional Mode (AMM) and/or the Atlantic Multidecadal Oscillation (AMO), and the Indian Monsoon. The decadal-scale SST variability might have modulated the impact of ENSO on West Africa rainfall; thus the ENSO teleconnection is known to vary over decades. In the present study, we use a large and high quality West African rainfall data set, covering the period 1921–2009 for three homogenous regions. The main goal of this study is to revisit teleconnections (e.g. ENSO, SST, AMM-AMO, Indian Monsoon) with a focus on the non-stationarity, on the percent variance explained using multiple linear regression, and on potential physical mechanisms that may explain the non-stationarities. Several ENSO and precipitation indices from West Africa (5-20°N; 17°W-25°E), divided into namely the West Sahel (WS: accumulated precipitation from June to September), Central Sahel (CS: accumulated precipitation from June to September), and Guinea Coast (GC: annual precipitation, rainfall for the two rainy and dry seasons), are first used in a (lagged) linear correlation analysis to investigate the long-term, multi-decadal, and seasonal evolutions (variations) of their ENSO-rainfall relationship. Simultaneous correlations show a significant correlation between ENSO, and WS and CS indices. Regarding the correlation coefficients between ENSO and GC precipitation indices, it seems that the impact of ENSO on GC rainfall is not statistically significant. A moving window of 31 years in term of the correlation between ENSO indices and the rainfall of all selected zones of West Africa, confirm the non-stationarity of the correlation coefficients. Three eras are detected for WS and CS, two maxima (1935-1952 and 1980-1993) and a minimum (1953-1979) of the moving correlation coefficients. Lagged correlation analysis show the strongest relation for simultaneous four-month periods.

Secondly, we have investigated the evolution of the relationship between the AMM, the AMO and the above-mentioned precipitation indices in West Africa. Simultaneous correlation shows some small, though statistically significant, impacts of AMM and AMO on WS precipitation and a smaller impact on CS. However the relationship between AMO (detrended before calculation) and precipitation indices, using the 31-year moving window, is variable. This relationship is negligible for the first part of the 20th century but since the 1950s, there is a stronger relationship (with correlation coefficients between 0.5-0.6 near the 1990s).

The evolution of the coefficient correlations between monthly SST of three oceans basins (namely the Indian ocean (IO: 50-90°E;10°S-30°N), the eastern Mediterranean Sea (MO: 10-36°E; 32- 36°N), and the Gulf of Guinea (GG: 17°W-12°E; 5°S-6°N)) and the precipitation indices in West Africa (used above) are also evaluated. Concurrent long-term correlation coefficients show an impact of the Indian Ocean on rainfall in WS and CS. SSTs in the eastern Mediterranean Sea seem to have a stronger influence on CS than WS. The moving windows approach for the Indian Ocean and the Mediterranean Sea show near stationary correlation coefficients from 1935 to 1965. Simultaneous and lagged correlation analysis shows a negligible impact of SST in the Gulf of Guinea on the first and stronger rainy season at the Guinean Coast. However, there is a strong (weak) impact on the strength of the little dry season (second rainy season) at the Guinean Coast zone.