Trend and variability in western and central Africa streamflow and its relation to climate variability between 1950 and 2005

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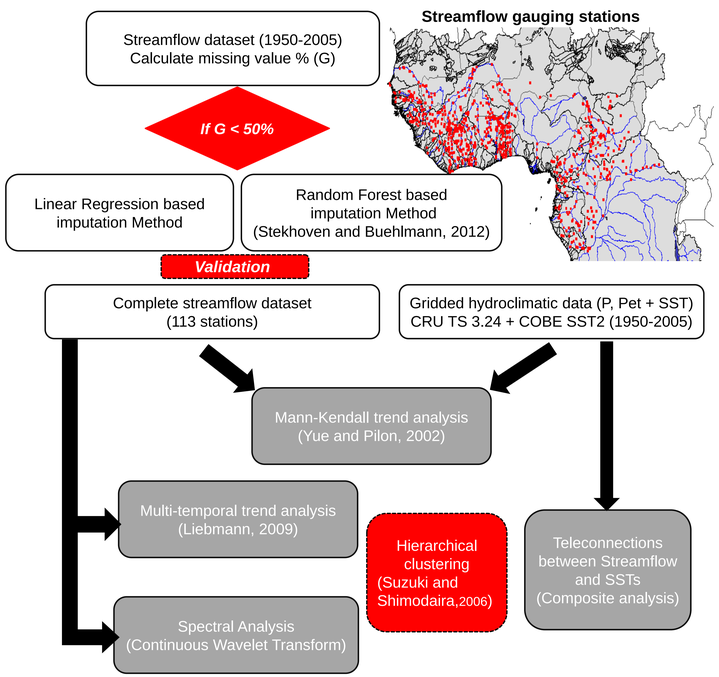
1. Background & Objectives

- Over the last 60 years, the Sahel has experienced two decades of persistent excessive rainfall in the 1950s-60s, followed by two decades of rainfall deficits. Recently, a partial recovery in annual rainfall amounts, particularly pronounced over the Central Sahel, has been discussed (Lebel and Ali, 2009).
- Several studies have investigated the impacts of climate changes on hydrological systems, but are mostly limited to the catchment scale. Here, we aim at better understanding how climate fluctuations and changes impact hydrological systems at the regional scale.
- Such studies are particularly important to reduce the uncertainties in developing future river-flow scenarios and for large-scale water resource development.

This study can be depicted in three parts :

- Generate the first large-scale river flow database for West and Central Africa;
- Quantify and compare trends in annual effective precipitation and river flow over West and Central Africa;
- Investigate the relative contribution of fluctuations and trends in streamflow variability (interannual and decadal), and define the associated teleconnections with large scale climate variability, e.g. Global sea surface temperature (SST) anomalies.

2. Methods

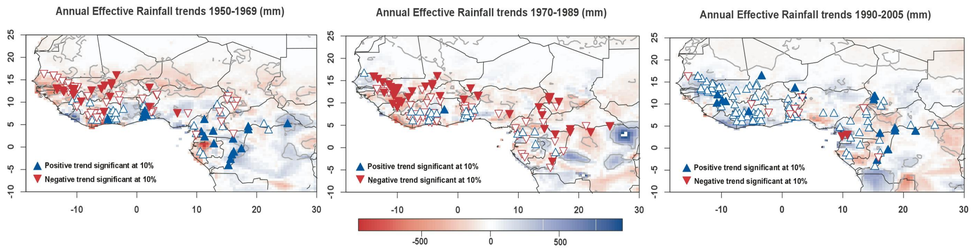


A summary of key steps in this study

3. Trend vs. variability in rainfall and streamflow

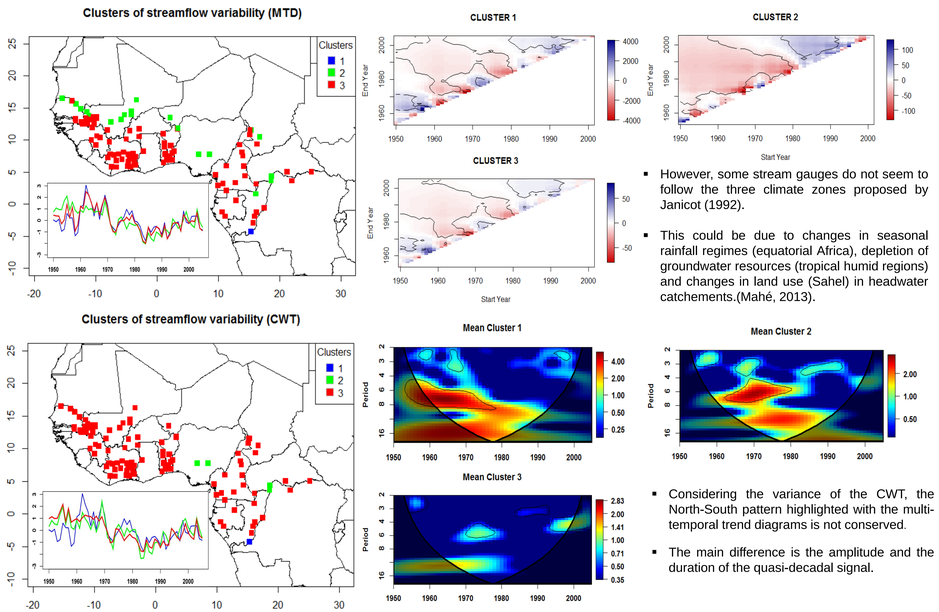
❑ Historical Trend analysis

- **Effective rainfall** The period 1950-69 is mostly characterized by a significant and spatially coherent drying trend over the Sahel regions. This drying trend then extends to the Gulf of Guinea costal regions in the 1970s and 1980s. We also note a partial recovery in effective rainfall during the last 2 decades, which is particularly pronounced in the westernmost and central Sahel regions.
- For most of the regions**, long-term trends in streamflow are mainly consistent with trends in effective rainfall**. The recent partial recovery in Sahelian effective rainfall could therefore have impacted river flows (in particular, the Senegal and Niger rivers).



❑ Multi-temporal trend analysis and Continuous Wavelet Transform (CWT)

- Multi-temporal trend analysis is used to examine the relative contributions of trends vs. variability, while CWT is used to detect the dominant modes of variability.
- Hierachical clustering applied to multi-temporal trend diagrams (MTD) and CWT power spectra highlighted three regional clusters. These three clusters, which are broadly consistent with three climatic regions defined by Janicot (1992), are related to the end of the 1950/60s wet conditions, intensity of a short wet-spell in the mid-1970s and of the post-1990s streamflow recovery.



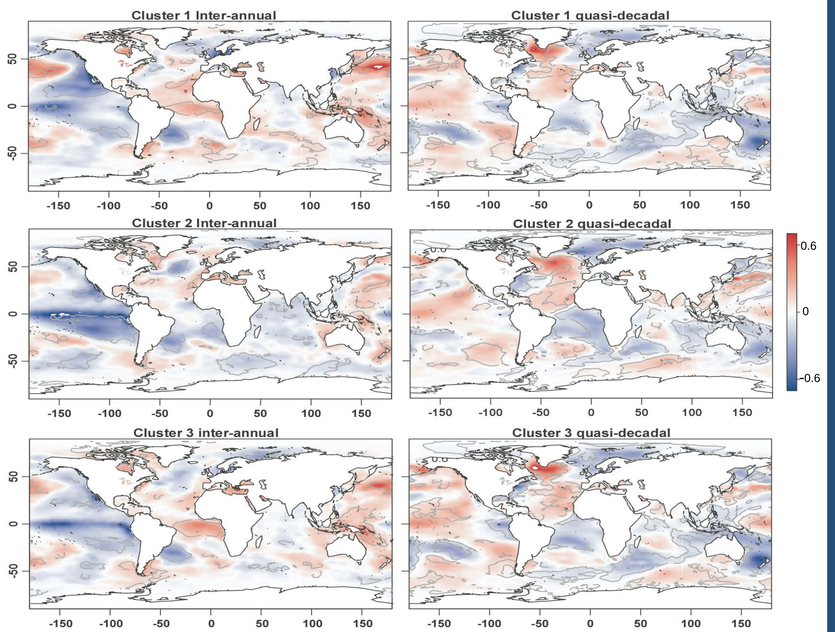
- However, some stream gauges do not seem to follow the three climate zones proposed by Janicot (1992).
- This could be due to changes in seasonal rainfall regimes (equatorial Africa), depletion of groundwater resources (tropical humid regions) and changes in land use (Sahel) in headwater catchements.(Mahé, 2013).
- Considering the variance of the CWT, the North-South pattern highlighted with the multi-temporal trend diagrams is not conserved.
- The main difference is the amplitude and the duration of the quasi-decadal signal.

4. Teleconnections with global SST anomalies

❑ Composite Analysis

At the interannual time scale, streamflow variability is primarily associated to SSTs anomalies in the tropical Atlantic, *i.e.* ENSO, but differences between sahelian and equatorial regions are related to cold and warm SST anomalies in the tropical South Atlantic.

At the decadal time scale, streamflow variability is related to the Atlantic Multidecadal Oscillation (AMO) pattern, Pacific Decadal Oscillation (PDO) patterns. This is consistent with previous studies investigating rainfall variability, *e.g.* Balas et al. (2007), Mohino et al., (2010),Dieppois et al., (2015).



5. Summary & discussions

- West African hydroclimate was characterized by a succession of wet and dry periods, which have significantly impacted streamflow regimes, over the last 60 years.
- Even though the rainfall recovery is only modestly significant in the Sahel catchments, it has triggered an increasing trend in streamflow. Changes in land use (*e.g.* Increase of cultivated areas) could also have influenced this recent trend in streamflow (Diello et al., 2006; Mahé, 2013).
- Despite the post-1990s rainfall recovery, some areas in Cameroon, Ghana and Senegal show a decreasing trend in streamflow, which might be explained by the significant depletion of groundwater ressources (Bricquet et al., 1997; Mahé, 2009).
- Decadal fluctuations, such as described in Dieppois *et al.* (2013), strongly influence streamflow in western and central Africa. The coherence between Rainfall-SSTs and Streamflow-SSTs teleconnections underline the importance of climatic variables in driving streamflow variability.