Influence of Equatorial Pacific and South Atlantic large-scale forcings on precipitations extremes in the West African Monsoon system

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BACKGROUNDS

The West African Monsoon is a significant component of the global monsoon system, delivering the majority of annual precipitation for the west Africa and varying on timescales from seasons to decades and beyond. Much of the internal variability of this system is driven by sea surface temperature (SST) anomalies and their resulting atmospheric teleconnections linking oceanic changes to land-based precipitation. A 38-year record (1981–2018) of gridded data covering West Africa was used to investigate these anomalies between precipitation over West Africa and SST in key tropical areas, as depicted by the Niño 3.4 and South Atlantic indices used in this study. Three annual indices of daily rainfall were calculated over the period 1981 to 2018 during MJJAS season, examining changes to both the entire distribution as well as the extremes. The results show that there is a link between temperatures in the Pacific and the Atlantic as explained by several authors in the literature. Indeed, the events taking place during the warming in the Pacific are also observed at the level of the South Atlantic (TAS), except that the difference is in the fact that one observes a zonal displacement of the total and extreme rains in TAS.

DATA AND METHODOLOGY

Data

- CHIRPS v2 (rainfall data), developed by the US Geological Survey (USGS) scientists, in collaboration with the University of Santa Barbara, California;
- Kaplan SST (Sea Surface Temperature dataset) V2 data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA;
- At three (925, 700 and 200 hPa) pressure levels, we use only zonal component of wind speed atmospheric data from the NCEP Reanalysis Derived data provided by the NOAA/OAR/ESRL PSD, Boulder, Colorado, USA.

Methodology

First, we compute the six ETCCDI climate indices described, over each grid point and for each year and we selected years of temperatures indices (TSA cold and warm ; El Nino and la Nina) during the period 1981-2018.

List of tested remote or teleconnection indices in controlling extreme precipitation indices in West Africa.

Location Indices	Full Name	Reference
NINO.3.4 (5° S–5° N; 120°–170° W)	El Niño 3.4 index	Kevin et al. (2001)
TSA (0°–20° S and 10° E–30° W)	Tropical Southern Atlantic Index	Enfield et al. (1999)

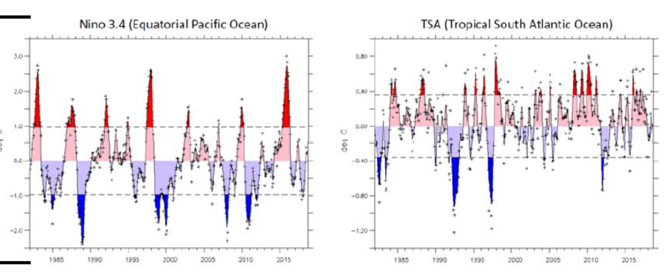
Then, we conduct 3 types of analysis :

1) we compute the regional mean for each MJJAS season ETCCDI extreme climate indices over each grid point and for each year over the selected period 1981-2018 ;

2) we selected years (see table) and compute the regional mean of these annual temperatures indices over each grid point and for each year selected referred time period ;

Years selected for calculation

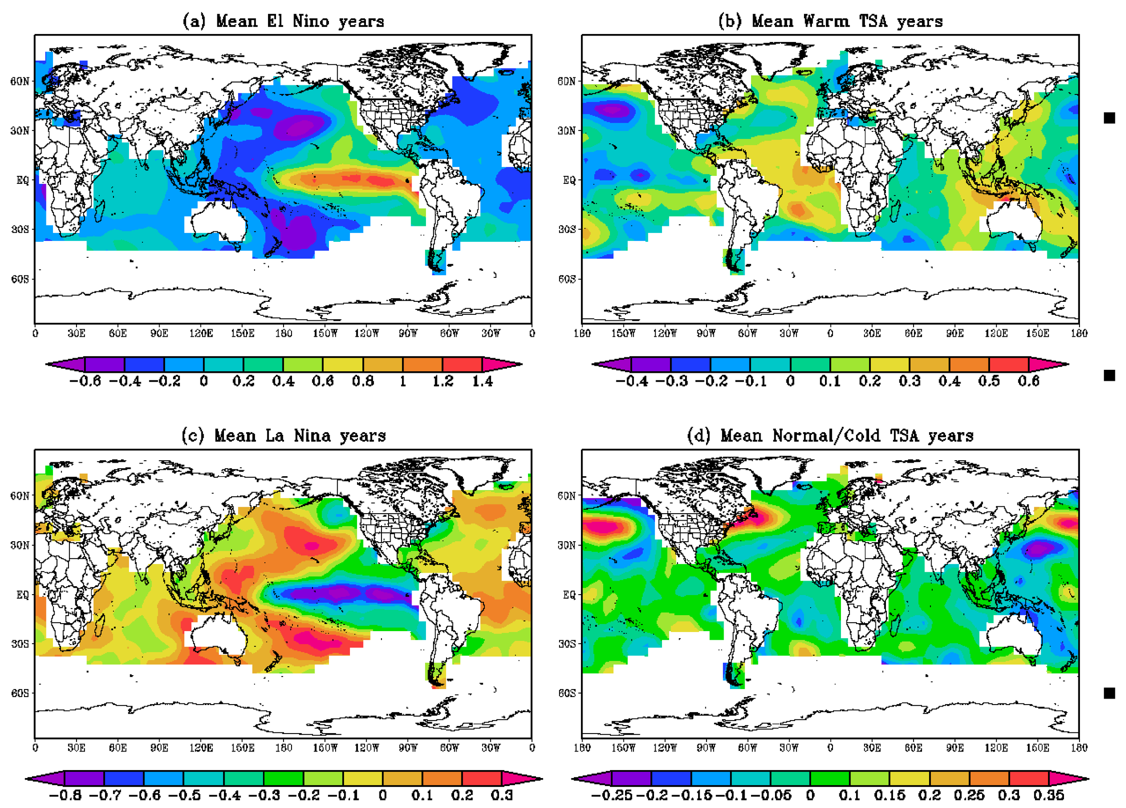
El Nino	La Nina	TSA Warm	TSA Normal
1982	1988	1984	1990
1987	1989	1995	1993
1992	1996	1998	2006
1997	2007	2010	2012
2015	2011	2016	2013



3) we compare the extremes precipitations in West Africa with anomalous in the South Atlantic Ocean (TSA warm and Normal) and with both Pacific El Niño/La Niña SST indices over each grid point.

RESULTS AND DISCUSSION

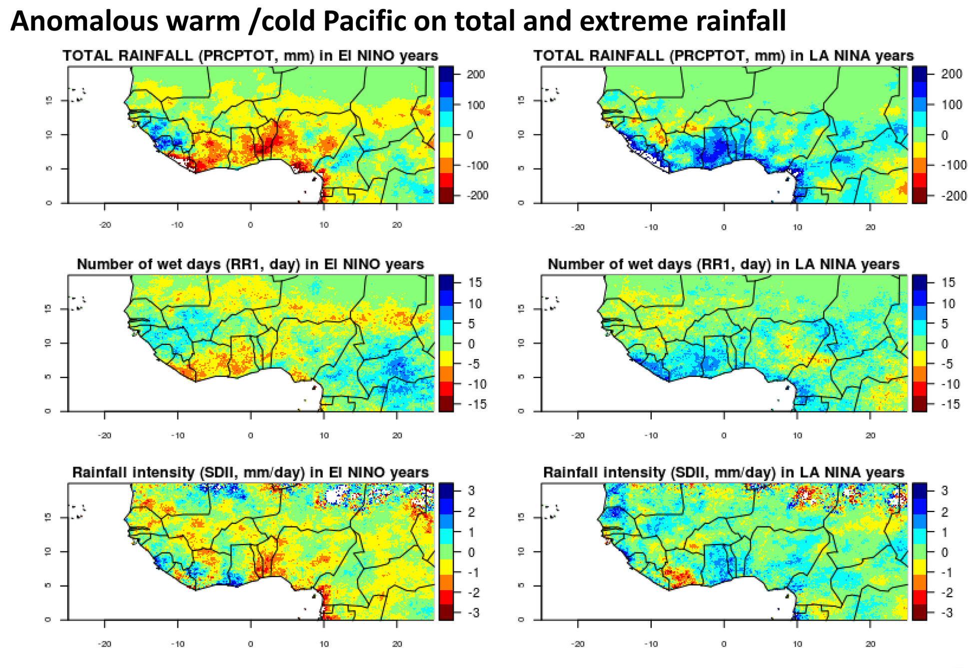
Anomaly index with selection years in Equatorial Pacific and South Atlantic



Anomaly Sea Surface Temperature (SST) map of the equatorial pacific and Tropical South Atlantic during (a) El Niño, (b) Warm TSA, (c) La Nina and (d) Normal TSA years

- El Nino and la Nina years correspond to 1982, 1987, 1992, 1997, 2015 and 1988, 1989, 1996, 2007 and 2011 during which the index is > 1 and < -0.6, respectively.
- Warm and Normal TSA correspond to 1984, 1995, 1998, 2010, 2016 and 1990, 1993, 2006, 2012 and 2013 during which the index is < 0.4 and < -0.1, respectively.
- For the 5 selected years, the averaged SST anomaly has largely reaches the mean in the equatorial Pacific and Tropical South Atlantic as shown in Joly & Voldoire, 2009, which is significant in regard to the high variability of SST in that region .

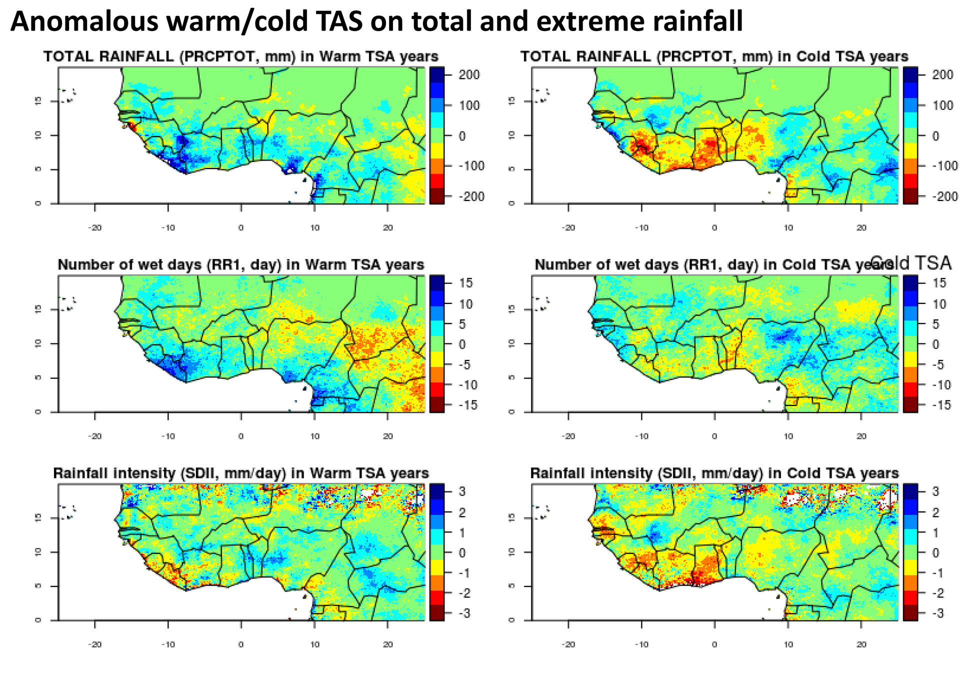
Anomalous warm /cold Pacific on total and extreme rainfall



Maps of the Annual total wet-day precipitation (top, prcptot), R1mm number of wet days (middle, rr1) and Simple daily intensity index (bottom, sdii) anomalies during El Niño (left) and La Nina (right) years.

- Decreased of PRCPTOT relatively all over west Africa but much more strengthened on the Guinean belt (between -100 to -150mm /yr) during El Nino year;
- Decreased of RR1 in the Guinean belt (between -5 to -10 days/yr) and around 15 ° north latitude during EL Nino years;
- SDII show an increasing in Gulf of Guinea like Côte d'Ivoire Ghana Sierra Leone and Guinee; and northern Mali and Niger (about 2mm/day/yr);
- We note that the positive SST anomalies over the Gulf of Guinea were associated with a dipole pattern of total and extreme precipitation anomalies consisting of negative values along the coast of Guinea and negative ones over the Sahel.

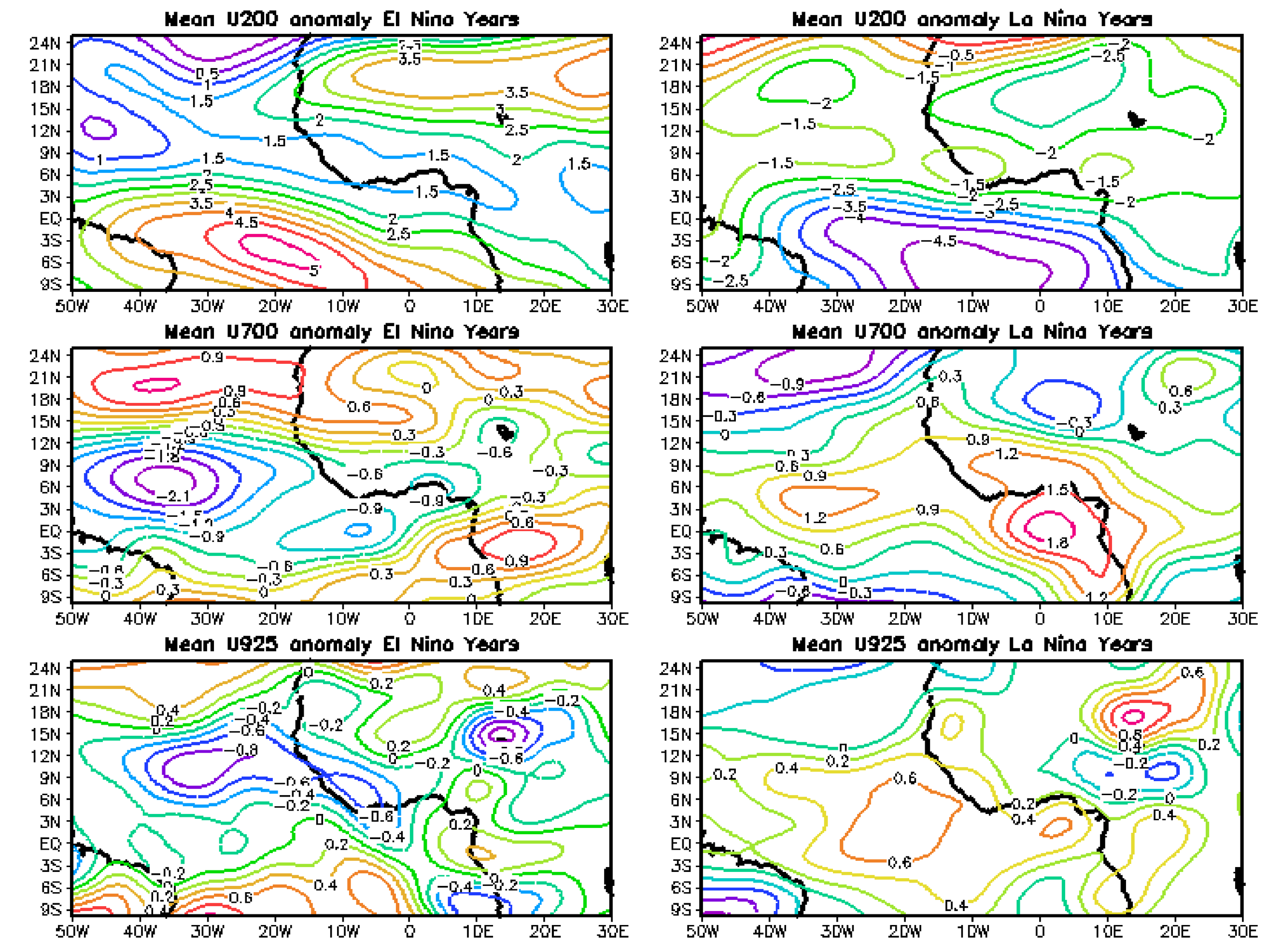
Anomalous warm/cold TAS on total and extreme rainfall



Maps Mean Anomalies warm TSA years (warm south Atlantic on the left and cold on the right) for the indices on total rain (prcptot), R1mm number of rainy days (rr1) and intensity of the rain (sdii)

- During Warm TSA, an increasing of PRCPTOT along the Guinean coast (up to the limit of 10 ° north latitude) between 100 to 150 mm/yr, the opposite effects are observed during cooling or normal TSA;
- Increasing of RR1 over the Gulf of Guinea (between 5 to 10 days/yr) during Warm TSA (up to the limit of 10 ° north latitude), the opposite effects are observed during cooling or normal TSA;
- Regarding the sdii index, there is a strong spatial variability (1-2.5 mm / day) marked by a negative anomaly in the Gulf of Guinea during the colding of Atlantic. The same effects are observed during warming TSA but weaker.
- We note that a warming of the South Atlantic results in total and extreme precipitation increased in Golf of Guinea

Atmospheric circulation on El Nino/La Nina years



zonal wind anomalies over West Africa: difference between the average MJJAS of the El Nino and La Nina years, at 925 hPa; 700 hPa and 200 hPa.

- At 200 hPa, an increase of the Tropical Easterly Jet (TEJ) is noted during El Nino years over west Africa but strong over the whole Sahel;
- At 700 hPa, an increase in the magnitude of the African Easterly Jet (AEJ) over the whole Sahel band during El Nino years;
- Decrease of the monsoon flow over the Guinea Coast and over the whole Sahel region during EL Nino years (925 hPa).

CONCLUSION AND PERSPECTIVES

- This work reveals that the South Atlantic dipole has a good connection with Guinea Coast precipitation anomalies ;
- while the Pacific tropical has a good connection with precipitation anomalies over the whole Sahel band and the Guinea Coast.
- During El Nino/La Nina years, the AEJ tends to be weaker (stronger) than normal and is located more northward (southward);
- while the TEJ and the low-level monsoon flow tend to be stronger (weaker). Warm years lead to dryer Sahel conditions.

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