GCRF AFRICAN SWIFT
SCIENCE FOR WEATHER INFORMATION AND FORECASTING TECHNIQUES

Potential impact of the Madden Julian Oscillation on monsoon onset over West Africa

Coumba Niang[1], Linda Hirons[2], Steven Woolnough[2], Abdou L. Dieng[1], Dahirou Wane[1], Amadou T. Gaye[1]

[1]LPAOSF (Laboratoire de Physique de l'Atmosphere et de l'Océan Siméon Fongang, UCAD)

[2]NCAS (National Centre for Atmospheric Science-Climate, Leeds, UK)

Plan

- Monsoon onset over West Africa remains the most important concern for farmers and regional stakeholders (Ingram et al., 2002)
- Many definitions of monsoon onset over WA using different scales and metrics (Sultan and Janicot, 2003; Marteau et al., 2009; Sivakumar et al., 1988; Diallo et al., 2014)
- Some studies have explored the effect of some local drivers such as the Saharan Heat Low (Lavaysse et al., 2009), AEW (Berry and Thorncroft 2005; Bain et al., 2014), SST (Caniaux et al. 2011; Rowell 2013)
- Few works have analysed the impact of large-scale drivers (MJO) on monsoon onset and the mechanisms through which these divers affect West African local monsoon onset is not clearly understood so needs to be evaluated

Aims of the work

Evaluate the potential relationship between West African monsoon onset and MJO and analyze the associated mechanisms

Specific Objectives:

- Analysis of the relationship between onset dates and MJO phasing
- Explore environmental differences between Early/Late onset years during active/weakening MJO events
- Investigate the mechanisms associated to the relationship between large-scale modes and WAM onset

Data

Variables	*Period*	*Resolution (°)*
OLR	*Daily (1979-2018)*	*1x1*
CHIRPS Rainfall	*Daily (1981-2018)*	*0.5x0.5*
200 and 850hpa zonal wind (ECMWF)	*Daily (1979-2018)*	*0.25x0.25*
Specific humidity (ECMWF)	*Daily (1979-2018)*	*0.25x0.25*

Methodology

- Onset metrics

References	Onset definitions
Marteau et al., (2009)	The onset date (OD hereafter) is defined here as the first wet day of 1 or 2 consecutive days receiving at least 20 mm without any 7-day dry spell receiving less than 5 mm during the following 20 days counted from the onset. We computed it from May, 1st over the all regions.
Sivakumar et al., (1988)	The onset date is the first date when the total precipitation of three (3) consecutives days exceeds 20 mm with no seven-day dry spell in the following thirty days after 1 May.
Sultan and Janicot, (2003)	Date at which 10-day time smoothed, zonal averaged (10°W-10°E) precipitation time series at 5°N decreases simultaneous with precipitation increase at 10°N and 15°N.
Diallo et al., (2014)	The onset occurs during the first pentad rainfall in which the Sahelian Index is greater than the Guinean Index for at least 5 consecutive pentads. Sahelian Index is defined as the standardized 5-day means of rainfall averaged over 10°W-10°E and 7.5°N-20°N while Guinean Index is the one over 10°W-10°E and 0°-7.5°N.

Methodology

- Study period categorized into early and late onset years and analyze large-scale conditions associated to those years
- Approach similar to Wheeler and Hendon (2004): 20-90-day band-pass filter and CEOF analysis (Venegas, 2001) performed on the zonal winds at 850 and 200hPa and OLR.
- Wavenumber frequency filtering method (Wheeler and Kiladis, 1999) is used then OLR and zonal wind powers are finally averaged over time segments and then summed over latitudinal band of the tropics

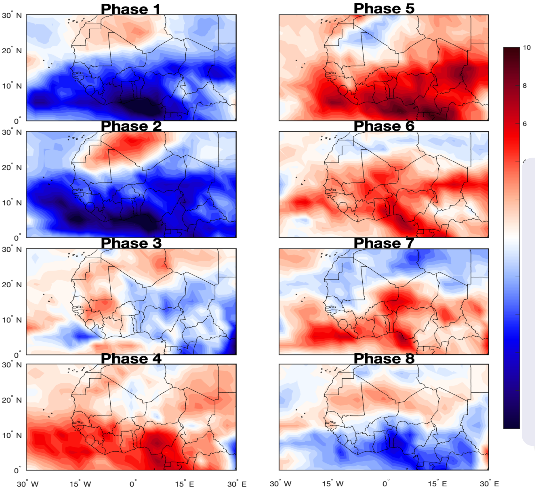


Figure 1: ***Summer composites of OLR (W/m) anomalies according to the eight phases associated with the MJO from 1979 to 2018***

- Two main modes: negative OLR anomalies during phases 8, 1 and 2 and positive anomalies during phases 4, 5 and 6
- Phases 8, 1, and 2 clearly represent the convectively active phase of MJO while phases 5 and 6 as the suppressed ones

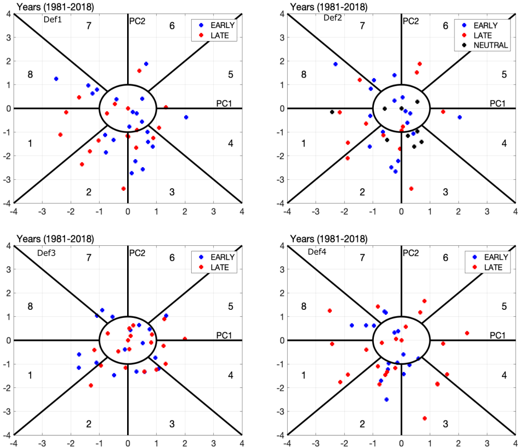


Figure 2: ***Phase diagram of onset dates using local (Def1 and Def2) and regional (Def3 and Def4) definitions with regard to MJO phases.***

- WAM onset occurring during wet phases of MJO: most of onset dates (more than 20 out of 38 years for each) likely to occur from phases 8 and 3
- Categories: nearly 60% of early as well as late onset years occur during phases 8-3 during active MJO events
- Regional Def3: OD lies between phases 1 and 3 for active MJO events while many onset dates occurs during weekening events
- Def4 show similar pattern to local definitions with most of dates lying between phases 8-3.

3. Analysis of large scales conditions associated with Early/Late onset years

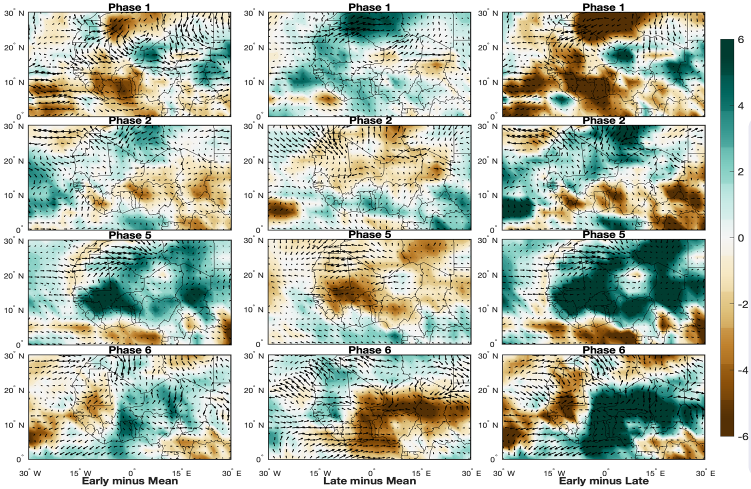


Figure 3: ***Composite difference of OLR (shaded) and 850hPa wind (vectors) anomalies: (left): Early minus Mean, (middle): Late minus Mean and (right): Early minus Late during active and weakening MJO events***

Early years

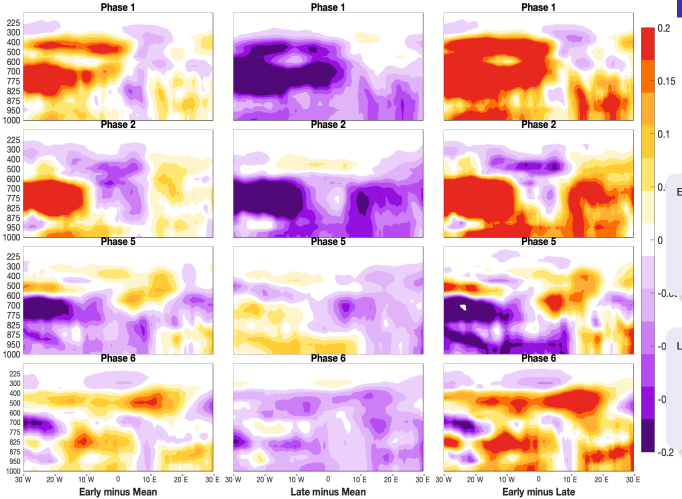
- Active: Stronger convection associated with westerly wind anomalies then shift eastward which is consistent with MJO moving
- Weakening: less convection than the mean which move eastward at phase 6 and relatively weak westward propagation of wind anomalies

Late years

- Active: weaker conditions than mean associated with very weak anomalous westerly winds while negatives ones during weakening events and are associated with low-level westerly flow

More convection for Early than Late years and changes in circulation for both categories: enhanced convection with anomalous westerly winds during active and suppressed convective envelope with pronounced easterlies wind anomalies

MJO activity and Specific humidity pattern during Early/Late onset years



Early years

- Stronger anomalies than mean state throughout the troposphere associated with MJO convective envelope during active MJO with southwesterlies anomalies moving along the equator while Weakening favor weaker conditions

Late years

- Drier anomalies in the entire troposphere column than the mean while weakening events favor positive specific humidity anomalies over lower troposphere associated with the convective envelope core which then decreases

Figure 4: ***Summer composites of the difference of specific humidity anomalies (g/kg): (left): Early minus Mean, (middle): Late minus Mean and (right): Early minus Late for active and weakening MJO events***

- Active MJO events: more humid conditions during Early Onset with moistening pronounced over GG favor to MJO activity
- Weakening events: less tropospheric specific humidity in both categories

4. Mechanism through which MJO impact monsoon onset

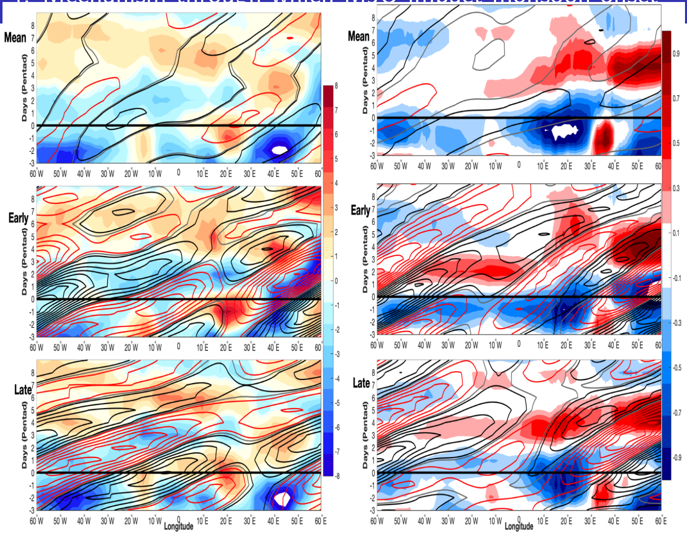


Figure 5: ***Hovmoller diagram of the OLR (left panel) and 850hPa wind (right panel) anomalies filtered between 20 and 90days band pass (shaded) and the ones obtained by filtering over the MJO component***

Early onset

- Clearer eastward signal associated with neg OLR anomalies propagating from West Atlantic basin to WA regions then reaches more or less two pentads prior mean OD with similar pattern in the MJO-filtered OLR component
- Easterlies anomalies over WA prior to the mean onset and are converted to westerlies at the time of OD mean which could be associated to strong MJO-filtered components

Late onset

- Similar pattern in OLR anomalies associated with the presence of easterlies before and during OD mean
- Transition from easterlies to westerlies occurs two pentads after the mean onset which is consistent with the weaker MJO-filtered components

Presence of Eastward-moving MJO signal could favours the occurrence of monsoon onset

4. Mechanism through which MJO impact monsoon onset

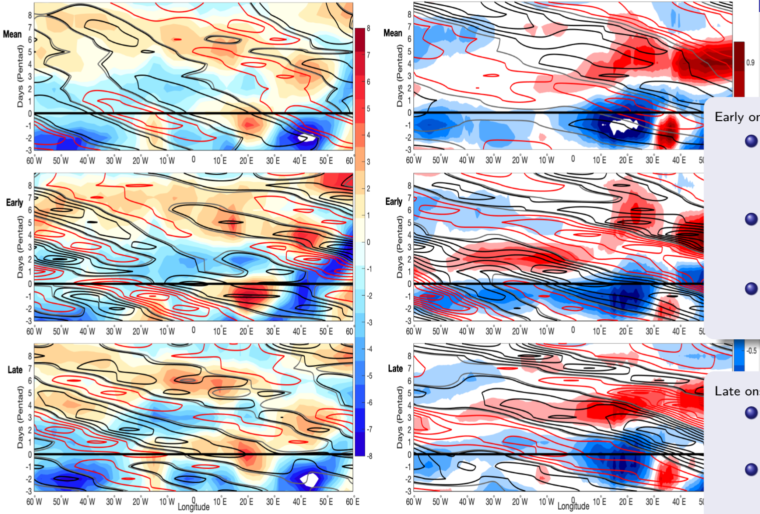


Figure 6: ***Hovmoller diagram of the OLR (left panel) and 850hPa wind (right panel) anomalies filtered between 20 and 90days band pass (shaded) and the ones obtained by filtering over Rossby component***

Early onset

- Strong neg OLR anomalies three pentads prior the OD mean and are associated with easterly winds at 850 hPa three pentads prior over the convectively active region of WA
- Transition from easterly to westerly wind anomalies occur at the time of the mean OD which is consistent with the signature of CCEWs Rossby wave
- These anomalies drive Rossby waves which propagate westward then reach and are centered over WA during the onset date

Late onset

- neg OLR are weakening and located more westward associated with convection envelope over the Atlantic before OD mean
- Westward propagating convective signal originate from the east side and reach WA at the time of the OD delaying the transition of easterly to westerly wind anomalies just after

In association with the MJO mode over WA, presence of Rossby anomalies pattern at the time of the OD tends to favor westerly moisture advection inland and the development of the enhanced convection envelope over WA

Conclusions

- WAM onset is favored to occur during the wet phases of the MJO propagating over West Africa (more clear using local definitions)
- Occurrence of monsoon onset could be related to the strength of the MJO events across the regions
- Anomaly differences in OLR and low-level wind pattern show high pattern in exhibiting the environmental differences between Early and Late monsoon onset years
- Active MJO events are associated with more moisture over WA throughout the troposphere during Early onset years than during Late ones (moistening is more pronounced over the Atlantic Ocean and over the Gulf of Guinea which favours more MJO activity over the regions)
- Presence of MJO can support the development of lower tropospheric westerlies that help initiate the monsoon onset processes
- In addition it require the presence of CCEWs westward Roosby anomalies which tends to enhance westerly moisture advection inland, and to the development of the enhanced convection envelope over West Africa associated with the MJO mode

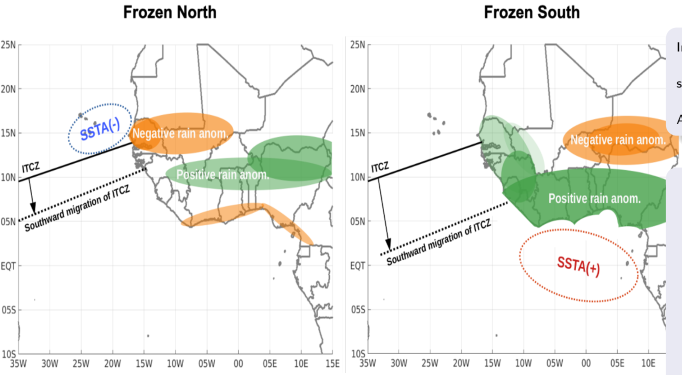


Figure 7: *Conceptual figures*

Investigate the atmospheric response to seasonal variations of the Eastern Tropical Atlantic SST during from July-August

- +/- SST anomalies has a strong impact on the local ocean-atmosphere interaction and the large scale atmospheric circulation over WA, particularly over Sahel
- Influence of the SST anomalies in Senegal offshore is more important to the Western Sahel (west of 10°W).
- Positive anomaly (composite warm) is associated with significant enhanced rainfall anomalies occuring first in the Sahelian coastal regions and its amplitude slow down towards the east
- Cooling of the SST in this region induces a decrease in the Sahelian rainfall which is more marked in the western Sahel region, particularly over Senegal

Three set of experiments on the regional atmospheric model (WRF-ARW)

- Atmospheric response associated with SST sensitivity experiments is characterized by the appearance of a dipole zonal of rain anomalies on the Sahel
- SST anomalies to the large of Senegal effect is most pronounced in the western Sahel, particularly over Senegal., with a strong reduction in rainfall in this region.
- Up to 50% of the precipitation variability in the east (west) of the Sahel is associated with SST anomalies in the south (north) eastern Atlantic

Acknowledgement

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THANKS FOR LISTENING