Impact of MJO on Extreme Precipitation over West Africa

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1. Introduction

Rainfall variability as well as extreme rainfall events are associated with the Madden-Julian Oscillation (MJO; Madden and Julian, 1971; Niang et al, 2016, 2023) over the tropical regions. The MJO is the most prominent mode of tropical intraseasonal variability in the climate system (Madden and Julian, 1994; Jones and Carvalho, 2012) and has a wide range of impacts, affecting precipitation and atmospheric circulation around the tropics (Donald et al., 2006). However, it remains unclear how MJO could induce extreme precipitation events over West Africa (WA). So, understanding the dynamics of MJO-related extreme precipitation is of prime importance for predicting those variabilities and evaluating the vulnerability of population in response to future warming and climate mitigation attempts over WA.

2. Objective

Assess how large-scale MJO could affect extreme precipitation over WA in order to improve our understanding of the processes that contribute to the seasonal predictability of those weather patterns.

3. Data and Methodology

Datasets	Resolution	Period
Daily precipitation from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)	0.25° x 0.25°	1981-2022
Daily GPCP global rainfall data	1° x1°	1997-2022
Interpolated Outgoing Longwave Radiation (OLR) from NOAA	1° x1°	1981-2022
ERA5 data from ECMWF (zonal and meridional winds, geopotential and vertical integral of northward/eastward water vapour flux)	0.25° x 0.25°	1981-2022

- Heavy precipitation = 95th percentile (JJAS season)
- Wheeler and Hendon (2004) approach: 30-60-day band-pass of variables then CEOF analysis performed on zonal winds at 850 and 200hPa and OLR.
- Two leading CEOFs modes used to describe MJO activity and build composite maps (growing/decaying stages of seasonal-intraseasonal events along equator).

4. Climatological mean and extreme precipitation

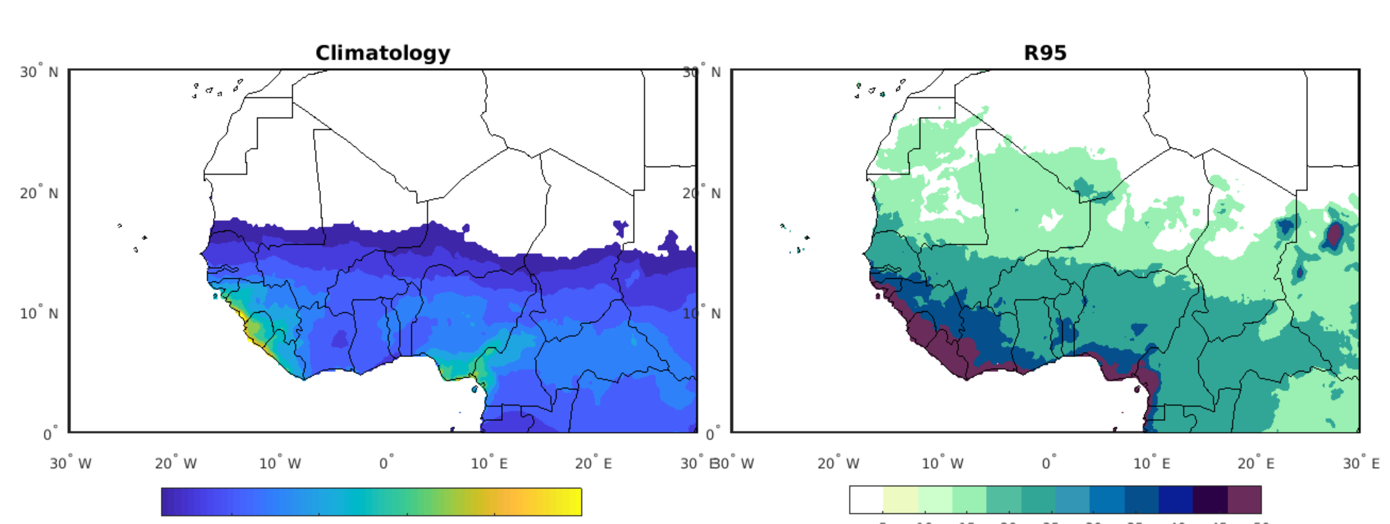

Figure 1: JJAS mean precipitation (left) and 95th percentile of JJAS daily mean precipitation over WA

-Decreasing trend: north ⇒ south .

- Sharp meridional gradient from north of the Sahel southward toward Gulf of Guinea coastal regions

- High threshold values along Guinean coast and over southern Sahel centered along 14°N

5. MJO composite cycle

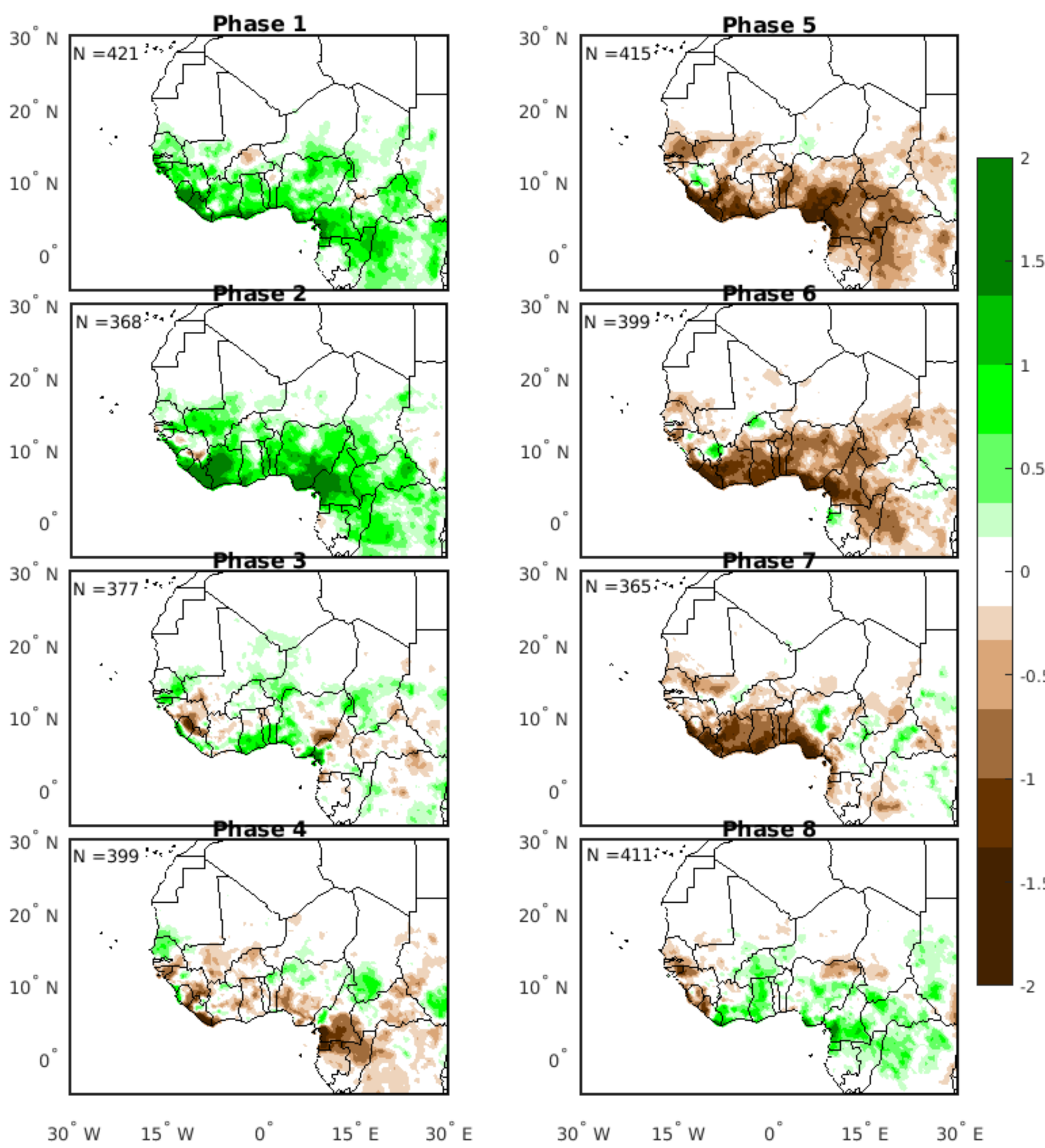

Figure 2: Composites of JJAS deseasonalized precipitation anomalies with the MJO eight phases.

- Enhanced convection phases 8-2 and suppressed ones from phases 5-7
- Maximum neg and pos values at phases 1 and 5 respectively.
-Phases 8-2: Eastward MJO propagation evident indicating broad region of enhanced convection

- Phases 5, 6, and 7: reversed configuration ⇒ Influence of MJO on convection robust especially during phases 1-2 (phases 5-6) for the neg (pos) anomalies

8. Conclusions

- Strong MJO phases (8-1) associated with more frequent extreme events relative to climatology while Weak phases (5-7) with less extreme events
- MJO impact more pronounced over Gulf of Guinea and WA dominated with strong trough during strong MJO phases and the increase moisture supply over the region lead to an increase precipitation intensity and frequency
- However, the presence of ridge during weak phases tend to a decrease of extreme events with relatively dry conditions

9. References

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6. Extreme precipitation frequency pattern within the MJO phases

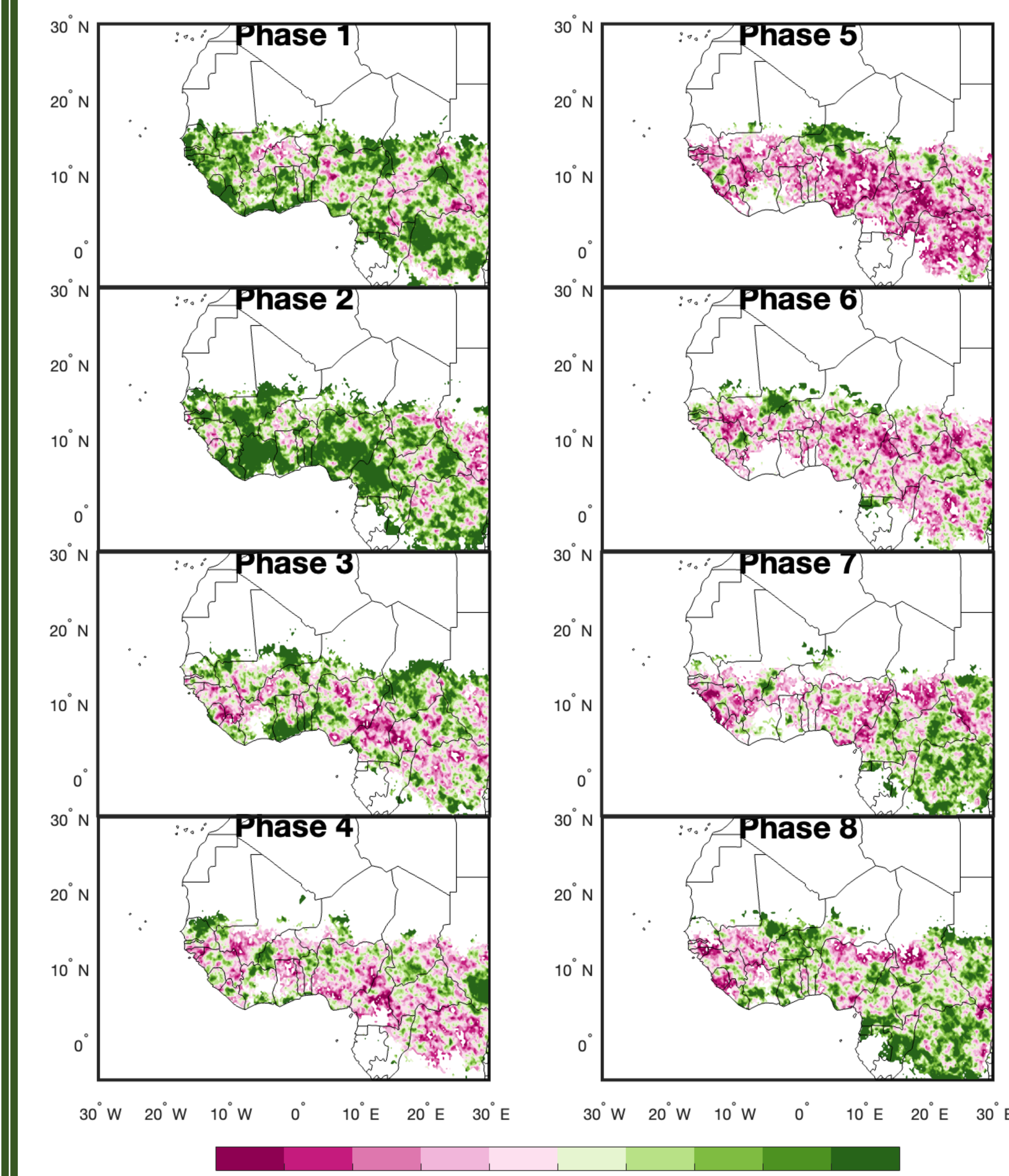

Figure 3: Ratio of relative frequency of observed extreme precipitation (95th percentile) within each individual MJO phase during JJAS period.

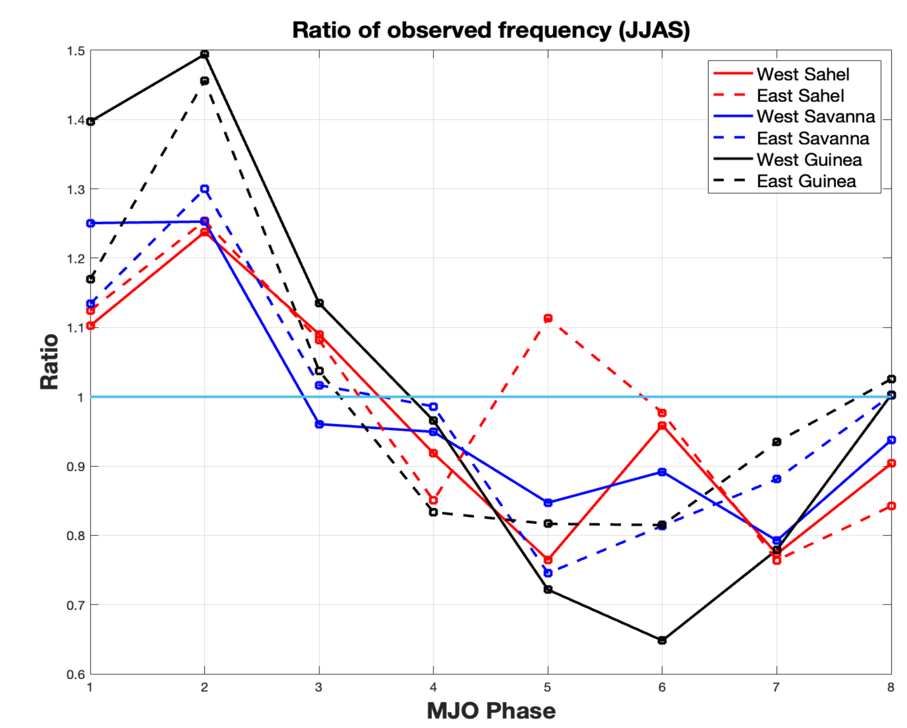

Figure 4: Averaged Ratio of frequency of observed extreme precipitation over different WA zones within MJO phases

- Clear MJO cycles in extreme rainf over the six regions ⇒ large impact on occurrence of extreme
- Extreme increased in phases 1-2 over all regions and reduced in phases 3-6 in Guinean regions, phase 3-5 in Savanna and WS.
- Phases 6-7: changes of extreme slightly increase over all regions except in Sahel (up to 0.65 ie 35% decrease)

- Extremes frequencies pattern ⇔ mean annual precip anomalies
- Phases 1-2: probability of observing extreme in convect enhanced zones (5ºN-15ºN) increase to R>1.5 over West Sahel (WS) and significant value of R>2 over Guinean regions (Fig.3)

- Phase 5-6: Probability reduced to below R=0.8 (20%) in WS (up to R=0.2 ie 80%) and to R<0.2 over East/Central Africa associated with significant decrease (Fig.3)

7. Impact mechanisms of MJO on the intensity of extremes precipitations events

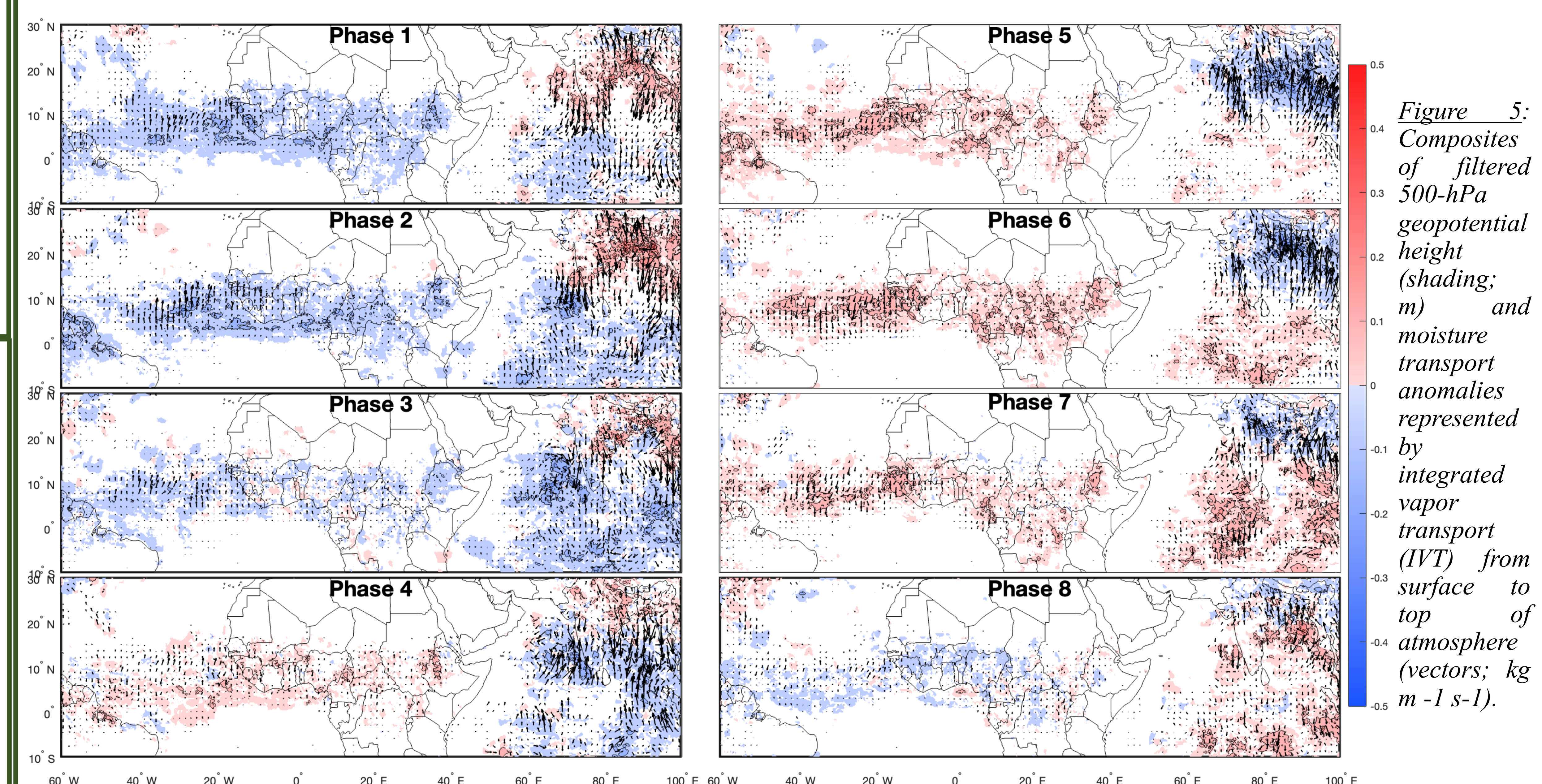

Figure 5: Composites of filtered 500-hPa geopotential height (shading; m) and moisture transport anomalies represented by integrated vapor transport (IVT) from surface to top of atmosphere (vectors; kg m -1 s-1).

- Phases 8-3: Trough strengthen associated with strong IVTa with more moisture from Western Atlantic Ocean to WA ⇒moisturized environment that favors increased extreme frequency

- Strong troughs noticed over IO ⇒ significant southward IVTa (more moisture from maritime regions to IO)

- Phases 5-7: anomalous ridges with zonal IVTa from WA to Western Atlantic Ocean ⇒ significant decrease in extreme

⇒Weak IVTa around the weak IO ridge and significant zonal IVTa over maritime continent with strong through

- Strong phases: dominant trough⇒ moisture transport tend to bring moisture from Western AO to WA ⇒ increase of extreme

-Ridge during phases 5-7 are associated with dry conditions leading to a decrease of extremes