Impact of the Indian part of the summer MJO on West Africa using nudged climate simulations

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1.Abstract

Observational evidence suggests a link between the summer Madden Julian Oscillation (MJO; Madden and Julian 1994) and anomalous convection over West Africa. This link is further studied with the help of the LMDZ atmospheric general circulation model. The approach is based on nudging the model towards the reanalysis in the Asian monsoon region.

The simulation successfully captures the convection associated with the summer MJO in the nudging region. Outside this region the model is free to evolve. Over West Africa it simulates convection anomalies that are similar in magnitude, structure, and timing to the observed ones. In accordance with the observations, the simulation shows that 15 to 20 days after the maximum increase (decrease) of convection in the Indian Ocean there is a significant reduction (increase) in West African convection. The simulation strongly suggests that in addition to the eastward-moving MJO signal, the westward propagation of a convectively coupled equatorial Rossby wave is needed to explain the overall impact of the MJO on convection over West Africa.

These results highlight the use of MJO events to potentially predict regional-scale anomalous convection and rainfall spells over West Africa with a time lag of approximately 15 to 20 days.

2.Data

OBSERVATIONS:
- Daily interpolated OLR from NOAA (Liebmann and Smith 1996) for 1979-2008
- ERA-40 (Uppala et al. 2005) for 1979-2000
- ERA-Interim (Dee and Uppala 2009) for 2001-08

SIMULATIONS:
Nudged experiment: 10 ensemble member integrations for each summer in the period 1971-2008 **relaxed to reanalysis (u,v,T)** (ERA-40 1971-2000 and ERA-Interim 2001-08) in the South Asia and northern Indian Ocean domain **(47ºE-130ºE 15ºS-29ºN)**. SST climatology as boundary condition.

3. Analysis

Similar approach as Wheeler and Hendon (2004):
- **EEOF** of summer **u at 850hPa and 200hPa and OLR** averaged in latitude between 15ºS and 15ºN and previously filtered in 20-90 day band.

The two first EEOFs describe the evolution of the summer MJO

- Represent each day of data as a point in **2D phse space** using **PC1 and PC2** (Fig. 1a). Composites are created by using the dates of all points in a given phase (above threshold 1.0 standard deviation) (Fig. 1b). We use the same "observed" dates to build the composite with the simulation. Average time between phases is 5 days, **whole cycle of 40 days**

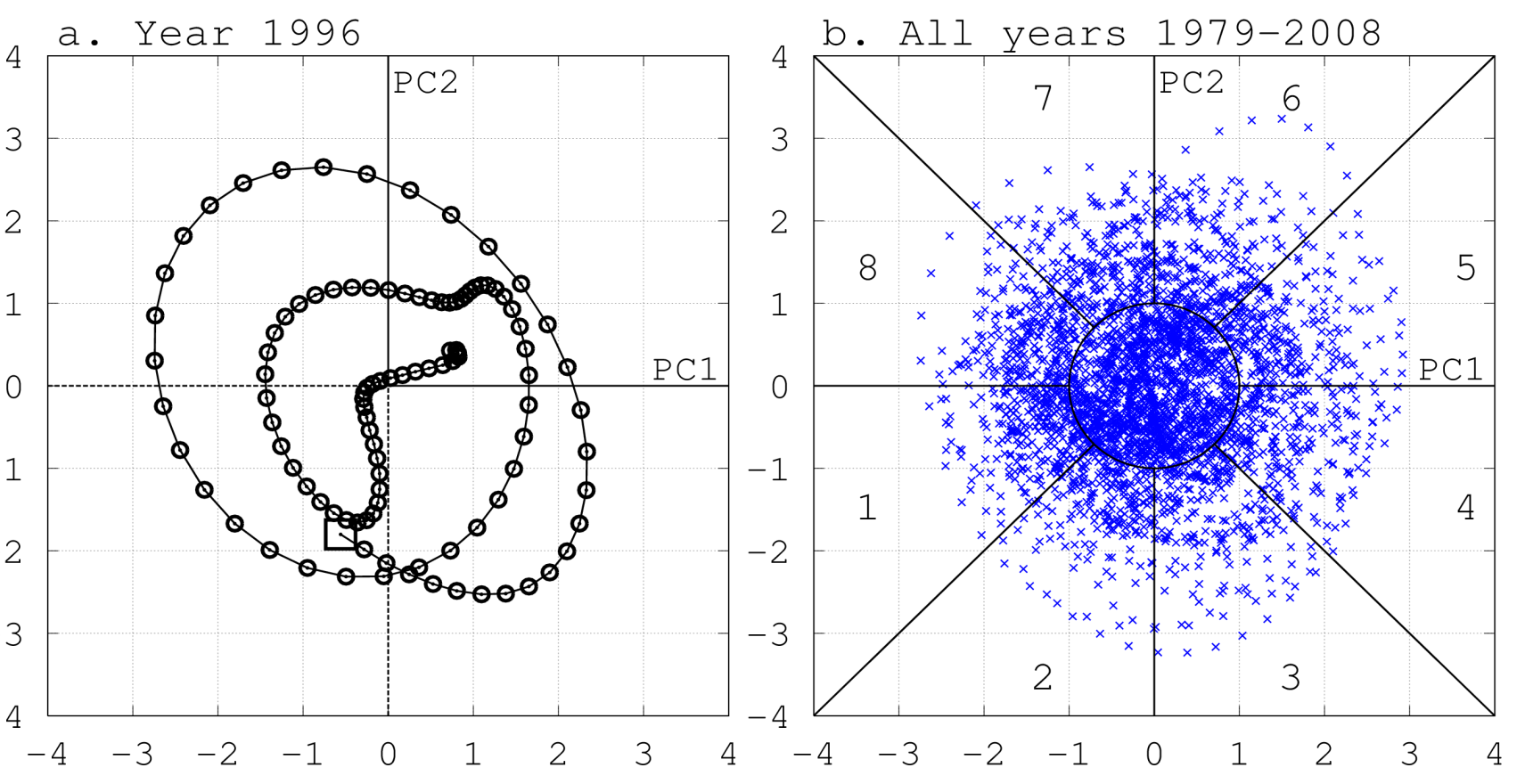


Fig. 1 Representation of summer (June 1 to September 15) days as points in the phase space defined by the standardized PC1 (abscissa) and PC2 (ordinate) obtained from the EEOF on the observed OLR and zonal wind at 850 hPa and 200 hPa: (a) for year 1996. The sequence starts the first of June with the square. It shows an anticlockwise rotation around the origin, which means that PC1 leads PC2. This is the general behaviour for all the years. (b) for all years in the 1979-2008 period. The 8 phases defined for the composite analysis are also displayed in (b)

4. OLR Composites

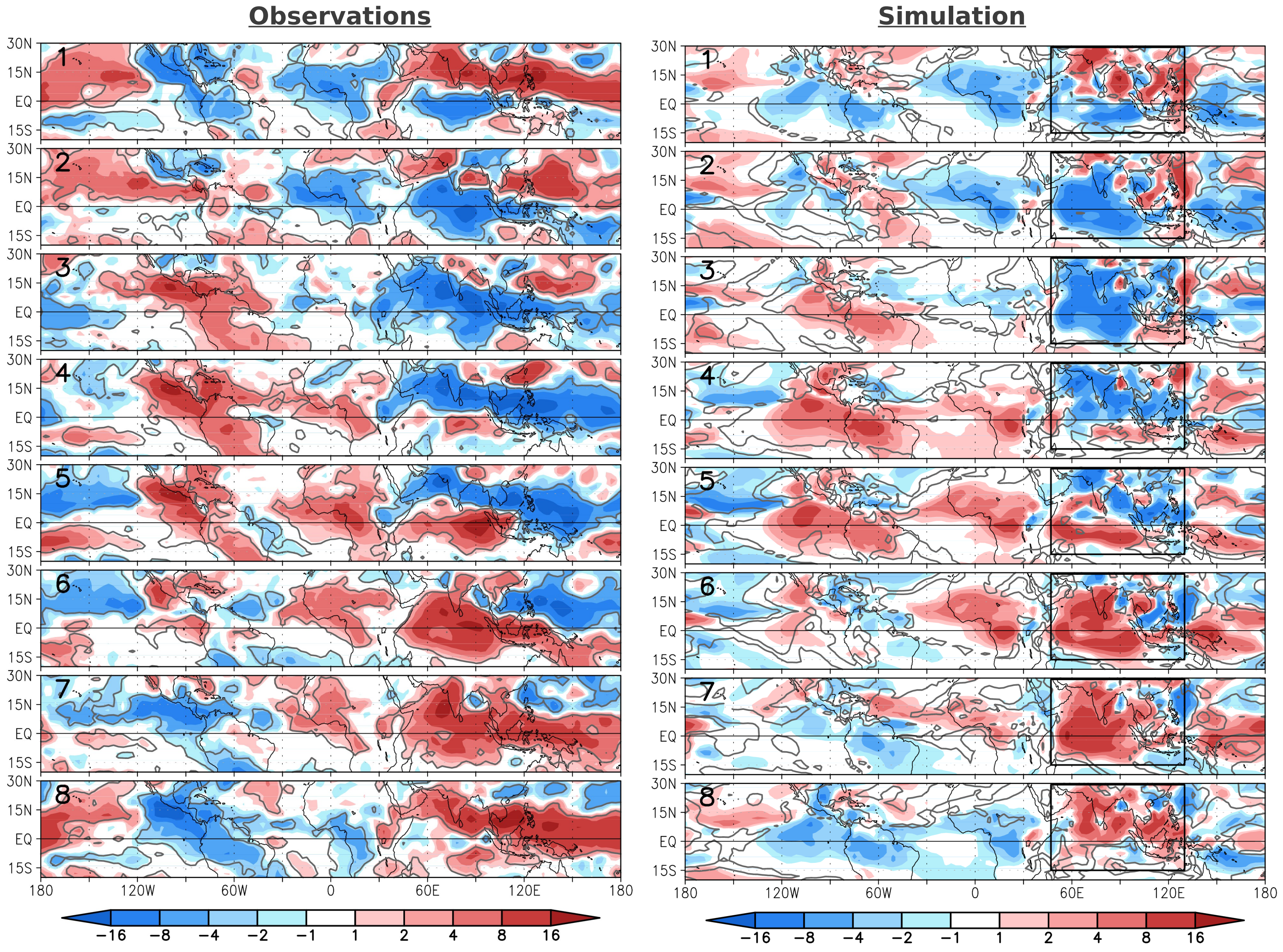
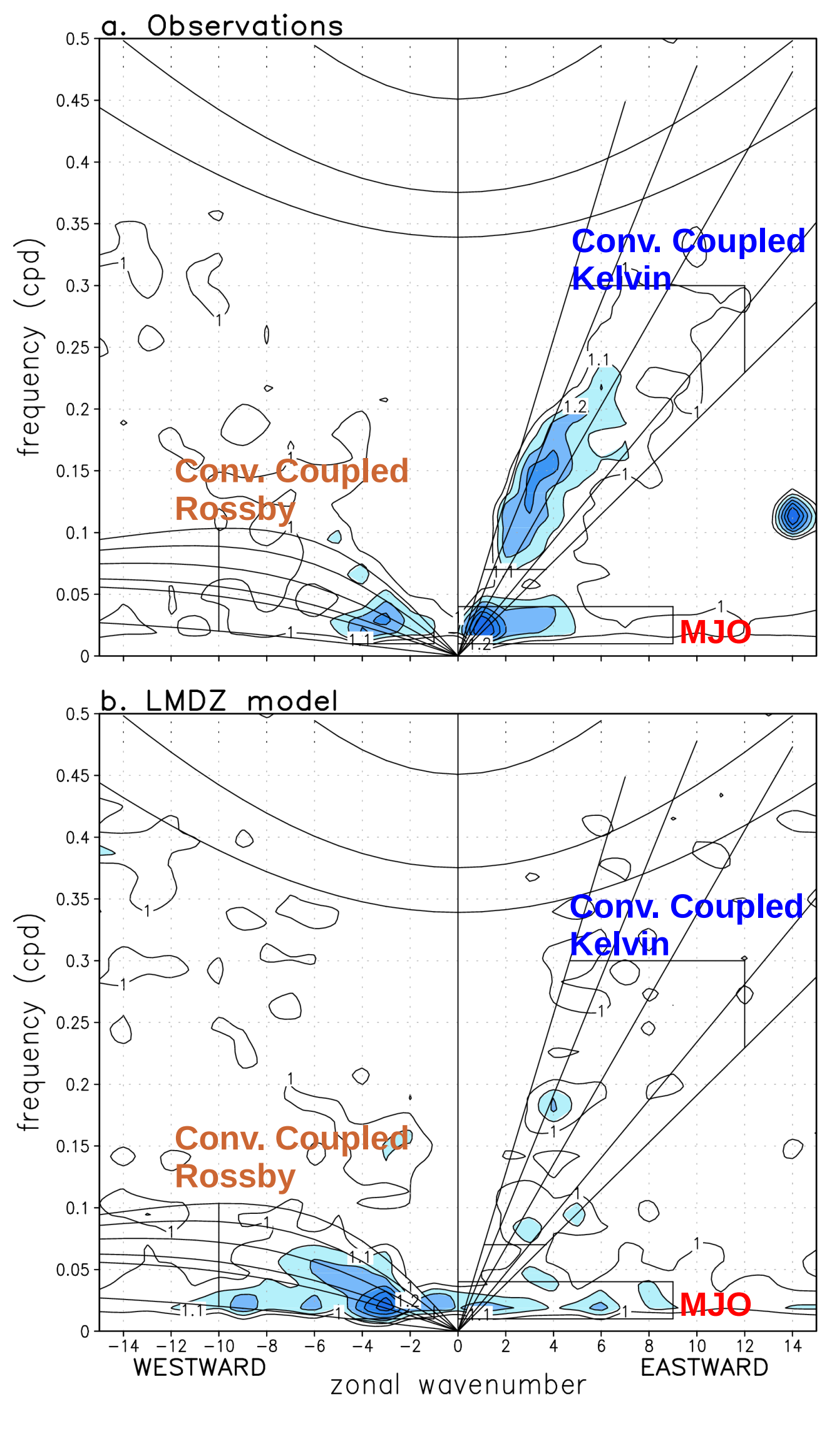


Fig. 4 Summer composites of observed (left) and simulated (right) deseasonalized anomalies of OLR (Wm^{-2}) according to the eight phases defined in Fig 1b. Grey contours mark 95% significant regions (according to a one-sample t-test). The box in the right column marks the nudged area

Nudged in the Asian Monsoon region, the simulation is able to reproduce the timing, structure and magnitude of the convection anomalies over West Africa related to the summer MJO

5.2 Wavenumber-frequency spectra



The model simulates weaker than observed dry (Fig. 3) and convective coupled Kelvin waves (Fig. 4)

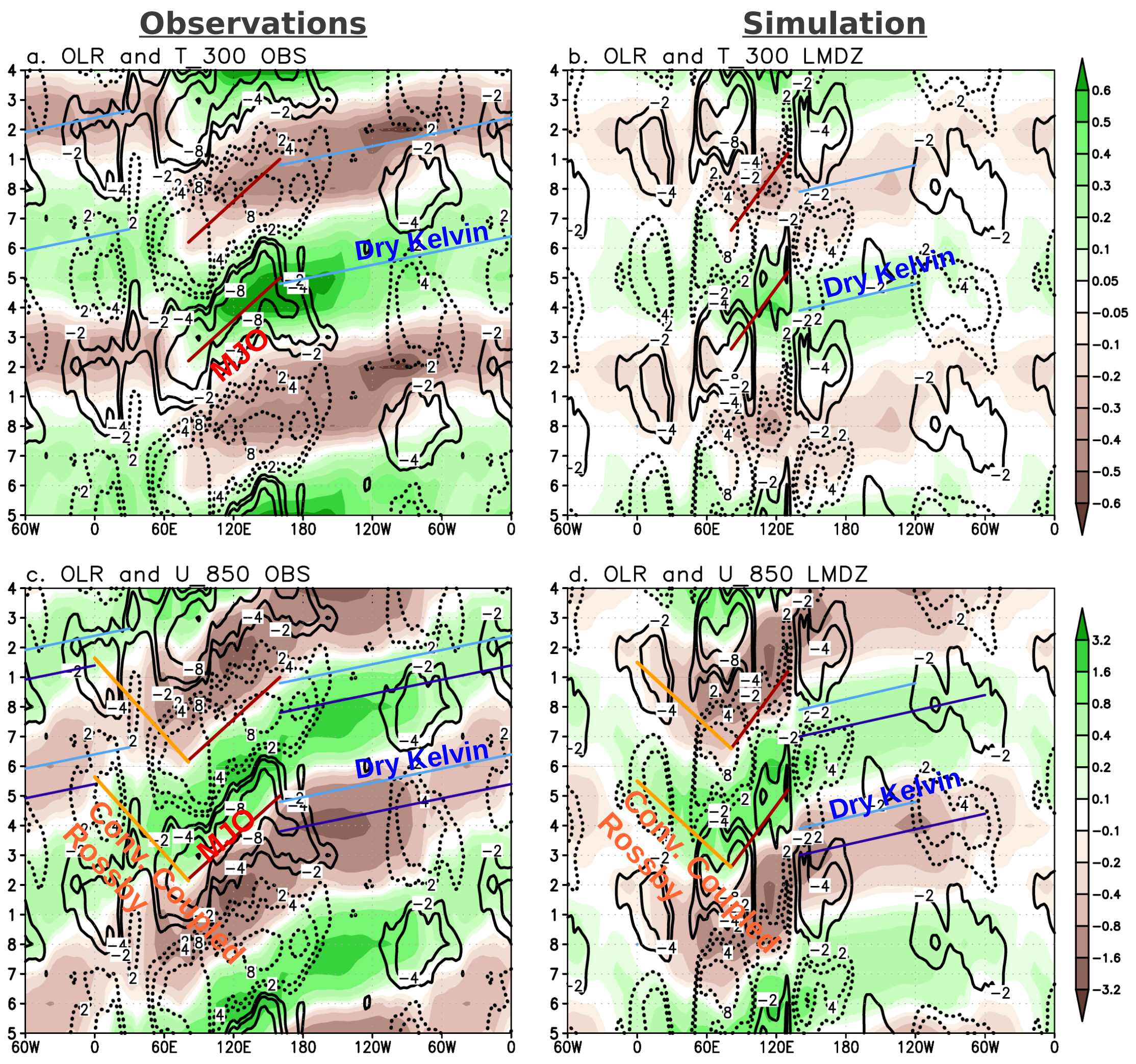
Fig. 4 Wavenumber-frequency spectral analysis of the OLR component symmetric about the equator summed from 15ºS to 15ºN for 1 June – 15 September 1979-2008 for: (a) the observations and (b) the nudged simulation. The spectra is calculated as the ratio of the raw power and the background spectrum (see Wheeler and Kiladis 1999 for details on the computation techniques). Contours intervals start at a ratio of 1.0 and are drawn at an interval of 0.1. The shading above the ratio of 1.1 indicates statistically significant signals. The dispersion curves for various equatorial waves are drawn for the equivalent depths of h = 8, 12, 25, 50 and 90 m. An additional dispersion curve for h = 1 m is added for the Equatorial Rossby wave. The boxes show the wavenumber-frequency regions used for filtering the MJO, Kelvin and Rossby convective coupled equatorial waves.

6.Conclusions

- The summer **MJO has a clear impact on convection over West Africa.**
- Approximately **15 to 20 days** after the main positive (negative) convection anomalies over the equatorial Indian Ocean there is reduced (increased) convection over West Africa.
- The simulation strongly suggests that in addition to the eastward moving MJO signal, the westward **propagation of a convectively coupled equatorial Rossby wave** is needed to explain the overall impact on West Africa
- The simulation suggests that the **Indian part** of the summer MJO is the **key area** for the observed link with West Africa
- The observation of an MJO event over the Indian Ocean could be potentially used to predict regional-scale decreased anomalous convection and rainfall spells over West Africa with a time lag of approximately 15 to 20 days.

5. Equatorial waves

5.1 Hovmöller composites



- MJO propagating eastward at ~ 7 ms^{-1} from the Indian Ocean into the warm pool
- Signature of dry Kelvin wave propagating eastward at ~ 30 ms^{-1}
- Signature of convectively coupled equatorial Rossby wave propagating westward at ~ 6-7 ms^{-1}

The simulated dry Kelvin wave does not propagate further east than 60ºW

Fig. 3 Composite Hovmöller (longitude versus phase) diagram of observed (left) and simulated (right) deseasonalized anomalies averaged in latitude between 10ºS and 10ºN of: (a) tropospheric temperature (in K) at 300hPa; (b) zonal wind (in ms^{-1}) at 850hPa. The solid (dashed) contours mark OLR (in Wm^{-2}) negative (positive) anomalies. The red line indicates the **MJO** propagation. Eastward (westward) dry (convectively coupled) equatorial **Kelvin** (**Rossby**) wave propagation is indicated by the blue dashed (orange dot dashed) lines

5.3 Composites of filtered OLR

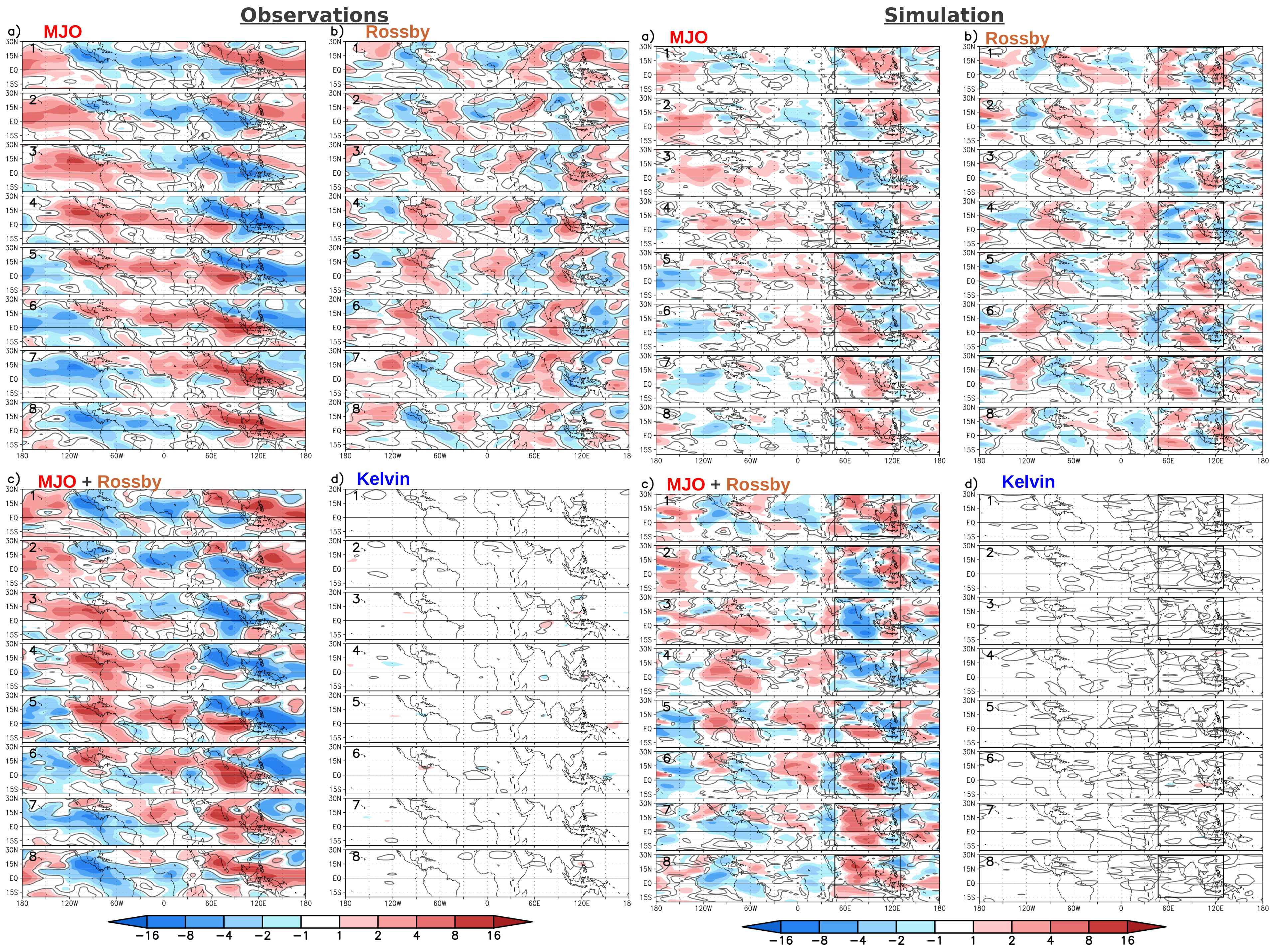


Fig. 5 Summer composites (according to the phases defined in Fig. 1b) of **observed** (left) and **simulated** (right) **OLR filtered using the boxes depicted in Fig. 4** for the: (a) **MJO**; (b) **Rossby**; (c) **Rossby plus MJO**; and (d) **Kelvin** wavenumber-frequency regions.

The effect over West Africa is explained by the addition of the eastward-moving MJO signal and the westward propagation of convectively coupled equatorial Rossby waves. The effect of the convectively coupled equatorial Kelvin waves is negligible.

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