The MJO, (very) briefly

Weston Anderson

November 9, 2018

Contents

1 Introduction

In this section we'll briefly discuss the Madden-Julian Oscillation (MJO), which is the primary mode of subseasonal climate variability in the tropics, although it is not a normal mode of the tropical atmosphere. The MJO is a coupled ocean-atmosphere phenomena that has an average period of ∼40-60 days. It describes an eastward propagating center of enhanced/suppressed convection, which is often strongest in the Indian and west Pacific Oceans. It is important for climate in both the tropics because of the centers of enhanced or suppressed convection and extratropics because the tropical heating acts as a source of Rossby wave propagation into in the extratropics.

2 Structure

The MJO can be thought of as a wave-like disturbance that modulates wind, pressure and precipitation anomalies and propagates eastward at a rate of ~ 5 m/s, although its eastward propagation speeds up to ~ 10 m/s when it moves into the east Pacific. The driving mechanism of the MJO is still an active area of research, but involves a combination of air/sea interactions and equatorially trapped Kelvin and Rossby waves. The horizontal structure of the MJO resembles a Gill-type wave response to equatorial heating anomalies: equatorial easterlies along the equator to the east of the heating and a pair of cyclonic gyres that flank (meridionally) a region of westerlies to the west of the convection. In contrast to a typical Gill response, however, the lower-level easterlies are diminished in zonal extent and strength compared to the westerlies (Chen et al., 2017). The vertical structure has a westward tilt with height.

See Figure 1 for a 3-D representation of this structure. This is, however, an idealized structure of composite MJO events. In any particular event not all aspects – the convection, zonal wind, moisture convergence and SST anomalies – are always visible.

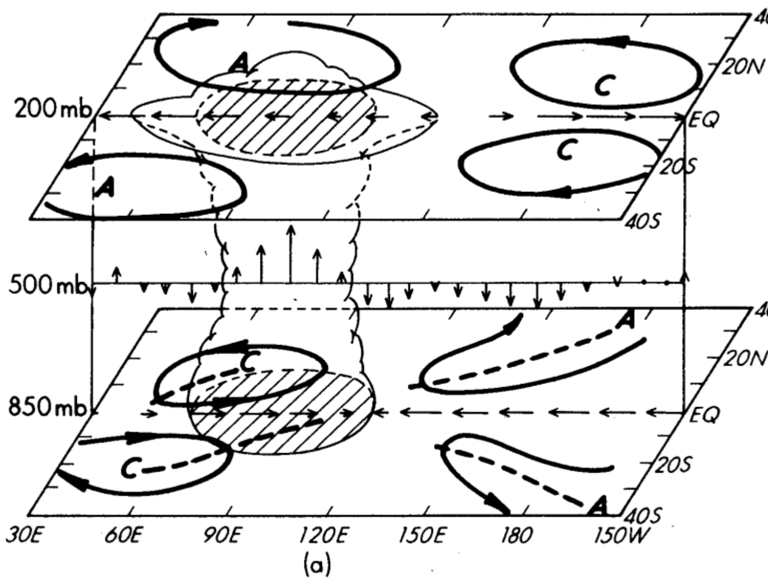

Figure 1: 3-D dynamics of the MJO. Figure credit: (Rui and Wang, 1990).

3 Evolution

Figure 2 shows a cartoon of the evolution of the MJO, depicting in each panel the height of the tropopause, the zonal circulation, zonal sea level pressure, and convective activity. The phenomena develops in the Indian ocean off the coast of east Africa and propagates eastward, affecting the circulation, precipitation and sea level pressure as it goes. Figure 3 shows satellite observations of rainfall rate anomalies during each phase of an MJO. The MJO travels at a faster speed in the western as opposed to eastern hemisphere (as is clear in the satellite images) because it is a different mix of Kelvin and Rossby waves in each. While all of these figures depict the MJO as an oscillation that initiates in Phase 1 and propagates through to Phase 8, in reality an individual MJO event can initiate

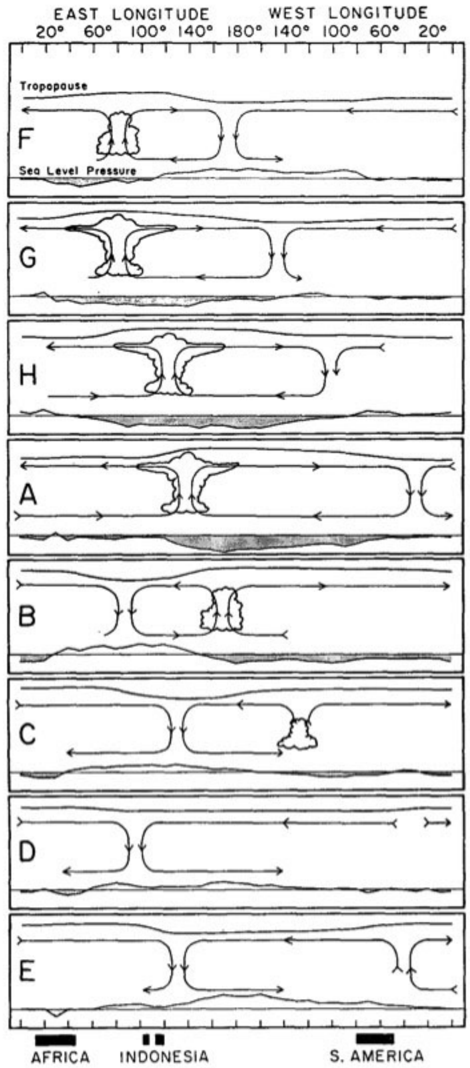

Figure 2: Eastward propagation of the oscillation. Figure credit: (Madden and Julian, 1972).

in any phase at various amplitudes, and it may or may not propagate through to the end of its "life cycle". Individual events also differ in their phase speed, although the average time the MJO spends in a given phase is ∼6 days.

While each event can be variable, it's still worthwhile to discuss properties of the MJO at different stages in its life cycle. MJO events tend to be strong and slowly propagating in the Indian Ocean and western Pacific. When convection reaches the Maritime continent, convection is disrupted. In general the convection over land is 1 phase ahead of the convection over the ocean. In the cooler eastern Pacific the convective anomalies weaken, but the circulation anomalies – particularly at higher atmospheric levels – persist and continue to propagate eastward. Once out of the Indian Ocean and into the western hemisphere the phase speed of eastern propagation speeds up from ∼5 m/s to ∼10 m/s.

Source: `http://physicstoday.scitation.org/do/10.1063/PT.5.4014/full/`

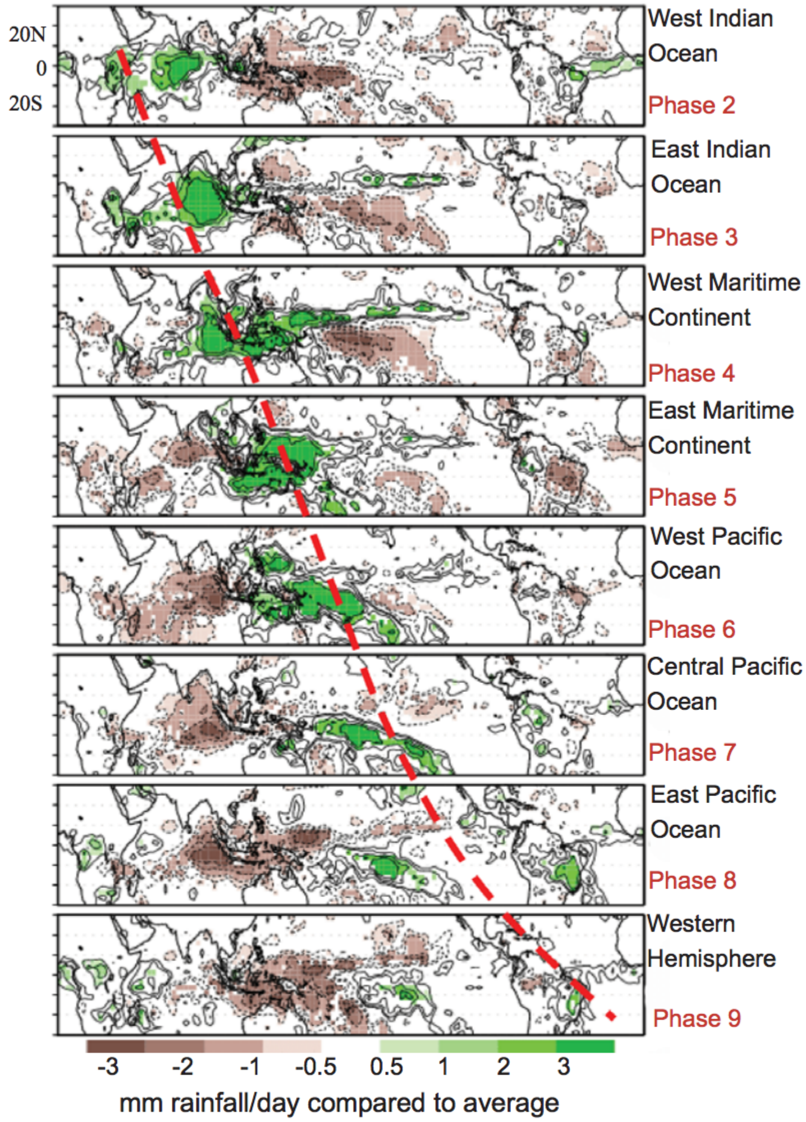

Figure 16b: Global tropics precipitation anomaly composite: precipitation anomaly composite (mm/day) by MJO phase moving from the western Indian Ocean (top row) to Africa (bottom row) based on MJO events in the historical record from 1979-2007 (note that the MJO typically starts with phase 2). The green (brown) areas indicate above (below) average rainfall and the red dashed line shows the eastward propagation.

Figure 3:

Source: `http://wwa.colorado.edu/climate/iwcs/archive/IWCS_2008_May_focus.pdf`

4 Theories of propagation and maintenance

Propagation theories relate to both the large-scale latent heat release from convection and to the anomalous surface fluxes. One theory is that propagation is related to the dynamical convergence through a prescribed humidity field that is dictated by factors like SSTs, but doesn't evolve with the eastward propagation. Other theories, however, have focused on how precipitation intensity is modulated by moisture in the air column. Air-sea interactions may increase short-wave insolation, and easterly wind anomalies in a westerly background flow reduce wind speed and shoal the thermocline to the east of the convection, which drives warmer SSTs east of the convective center and cooler SSTs to the west of convection.

5 Tropical-extratropical teleconnections

Diagnosing subseasonal teleconnections poses a problem compared to seasonal-scale teleconnections. While seasonal teleconnections from phenomena such as ENSO may be considered stationary, subseasonal teleconnections that happen on timescales of days or a week may be lagged compared to the forcing that generated them. As with seasonal teleconnections, however, it is the tropical heating that leads to divergence aloft, convergence in subtropical jet regions, which act as a Rossby wave source and propagate teleconnections into the extratropics. Tropical-extratropical teleconnections are strongly influenced by the mean state and are also affected by synoptic-scale transients. The response pattern has preferred action centers, although the magnitude is affected by the location and intensity of heating. The strongest extropical response is produced when convective heating is located in the Indian Ocean or western Pacific, and the weakest response occurs when the thermal forcing is over the Maritime continent.

References

Roland A Madden and Paul R Julian. Description of global-scale circulation cells in the tropics with a 40–50 day period. *Journal of the atmospheric sciences*, 29(6):1109–1123, 1972.

Hualan Rui and Bin Wang. Development characteristics and dynamic structure of tropical intraseasonal convection anomalies. *Journal of the Atmospheric Sciences*, 47(3):357–379, 1990.