Initiation Processes of the Tropical Intraseasonal Variability Simulated in an Aqua-Planet Experiment: Implication for MJO onset

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1. Introduction

The Madden-Julian Oscillation (MJO) is a dominant intraseasonal variability in the tropics, which is characterized as the eastward propagation of large-scale convective envelopes coupled with an overturning zonal circulation. Since the active cumulus convection associated with the MJO has a great impact on the global weather and climate systems, the physical mechanism or the predictability of MJO onset is one of the interesting issues in tropical meteorology.

Previous studies have proposed many kinds of theories about the MJO initiation such as the influences of the equatorially circumnavigating Kelvin waves (e.g., Hendon & Salby, 1994; Kikuchi & Takayabu, 2004), the discharge-recharge mechanism (e.g., Bladé & Hartmann, 1993; Benedict & Randall, 2007), moistening via horizontal advection (e.g., Zhao et al. 2013; Maloney & Wolding, 2015), and the tropical-extratropical interaction as a trigger for tropical convection (e.g., Hsu et al., 1990; Ray & Zhang, 2010). However, a consensus on its essential mechanisms has yet to be reached partly because of the diversity of MJO behavior affected by the seasonality or land-sea distributions.

To help overcome this situation and get an intrinsic insight into the MJO onset, we examined a set of initiation processes of the MJO-like disturbances in 10 year aqua-planet experiments under an idealized SST distribution mimicking the real warm pool distribution (Takasuka et al., 2018).

2. Experimental Design and Analysis Method

We used the Nonhydrostatic Icosahedral Atmospheric Model (NICAM) with an approximately 56 km horizontal mesh. In this study, we adopted an aqua-planet configuration with perpetual March 20 solar insolation with diurnal cycles. The use of the zonal non-uniform SST distributions in the tropics and an explicit cloud scheme (NSW6; Tomita, 2008) led to reproducing the MJO-like disturbances over the western warm pool region. Although the 56 km mesh is clearly too coarse to treat the cloud physics explicitly, an explicit cloud scheme appears to be valid in realizing MJO-like disturbances even in low-resolution simulations (e.g., Holloway et al., 2013; Takasuka et al., 2015). Thus, we performed a 10 year simulation under the above setting as the control experiment.

We detected the simulated MJO-like disturbances using outgoing longwave radiation in the tropics, and conducted a lagged-composite analysis with reference to the onset date of each case.

3. Main Results

In the control experiment, there were the 34 MJO-like disturbances that propagate eastward at about 4 m s^{-1}. We particularly focused on the following three points: (1) moistening processes, (2) convective triggering mechanism, and (3) convective organization feedback processes.

We first recognized the mid-tropospheric moistening in the initiation region 5–9 days before the onset, which made a favorable condition for deep convective outbreaks. This moistening was mainly caused by horizontal moisture advection due to cross-equatorial shallow circulations associated with mixed Rossby-gravity waves, as well as anomalous flows of a negative Rossby response to suppressed convection as documented previously (Figure 1). After that, the intrusion of low sea level pressure anomalies of circumnavigating Kelvin waves triggered active convection through the low-level convergence. Finally, the large-scale convective organization in the initial and later stages was efficiently driven by surface latent heat flux (LHF) and cloud-radiation feedbacks, respectively.

Based on the above results in the control experiment, we conducted two sensitivity experiments that assess the two processes related to the convective onset: the roles of circumnavigating Kelvin waves and the LHF feedback. The comparison of the results between control and sensitivity experiments showed that the Kelvin waves effectively regulate the periods of the MJO-like disturbance, and that the LHF feedback contributes to the rapid convective organization. Meanwhile, it was also suggested that neither is essential for the existence of the MJO.

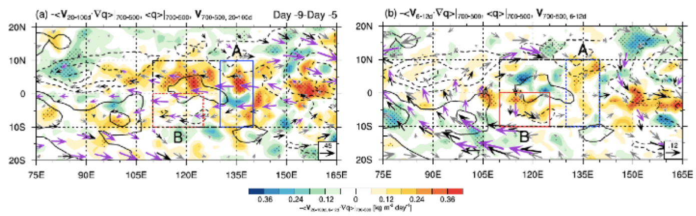

Figure 1. 700-500 hPa moisture (contours) and its horizontal advection anomalies (shading) by a) 20-100-day and b) 6-12-day component flows (vectors). A black square shows the initiation region.

4. Concluding Remarks

This study investigated the intrinsic mechanism of MJO onset with 10-year NICAM aqua-planet simulations. In spite of adopting a relatively coarse resolution, we successfully reproduced the disturbances with similar characteristics to the real MJO. The results have informative implications for interpreting the observed MJO onset processes, including the scale interaction between the MJO and mixed Rossby-gravity waves or the role of equatorial circumnavigation of Kelvin waves. In future, we will examine the resolution dependence of the structure or physical processes of the MJO-like disturbances simulated at multiple resolutions.

References:

Takasuka, D., M. Satoh, T. Miyakawa, and H. Miura (2018), Initiation processes of the Tropical Intraseasonal Variability Simulated in an Aqua-Planet Experiment: What is the Intrinsic Mechanism for MJO Onset? *Journal of Advances in Modeling Earth Systems*, **10**, 1047−1073. doi:10.1002/2017MS001243