[Geophysical Research Letters]

Supporting Information for

[Forcing of the MJO-related Indian Ocean heating on the Intraseasonal Lagged NAO]

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Introduction

This supporting information provides the method for calculating the horizontal components of the wave activity flux (Text S1), and description of the model experiments (Table S1). Figures S1–S9 are provided to support the analysis presented in the main text.

Text S1.

We calculate the horizontal components of the phase-independent wave activity flux derived by the Takaya and Nakamura (2001), and assume that the group velocity is zero. Using their equation (38), a two-dimensional (horizontal) wave activity flux is expressed as follows:

$$W = \frac{p\cos\phi}{2|U|}\left(W_\lambda, W_\phi\right) + C_U M \quad (1)$$

with

$$W_\lambda = \frac{U}{a^2\cos^2\phi}\left[\left(\frac{\partial\psi'}{\partial\lambda}\right)^2 - \psi'\frac{\partial^2\psi'}{\partial\lambda^2}\right] + \frac{V}{a^2\cos\phi}\left[\frac{\partial\psi'}{\partial\lambda}\frac{\partial\psi'}{\partial\phi} - \psi'\frac{\partial^2\psi'}{\partial\lambda\partial\phi}\right] \quad (2)$$

$$W_\phi = \frac{U}{a^2\cos\phi}\left[\frac{\partial\psi'}{\partial\lambda}\frac{\partial\psi'}{\partial\phi} - \psi'\frac{\partial^2\psi'}{\partial\lambda\partial\phi}\right] + \frac{V}{a^2}\left[\left(\frac{\partial\psi'}{\partial\lambda}\right)^2 - \psi'\frac{\partial^2\psi'}{\partial\phi^2}\right] \quad (3)$$

where ψ' is the perturbation streamfunction, (*U*, *V*) are the basic state zonal and meridional winds, (φ, λ) are latitude and longitude, *a* is the earth's radius, and *p* is pressure.

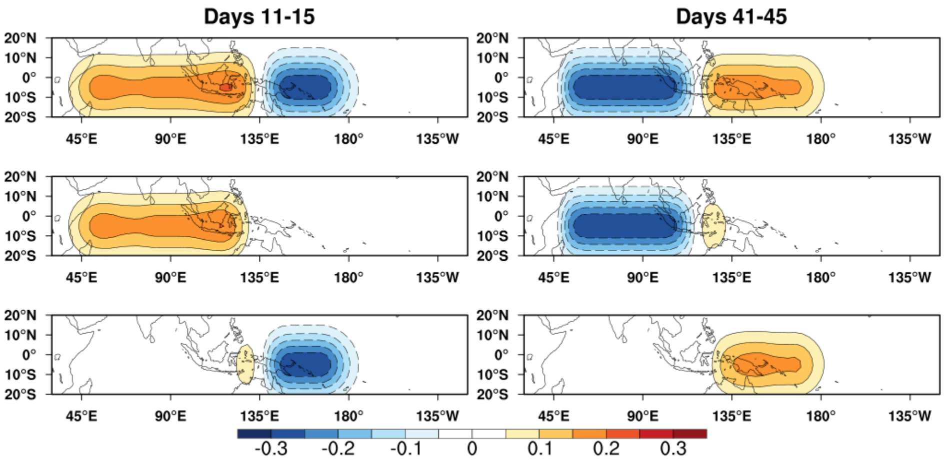


Figure S1. The vertically averaged (over 1000–50 hPa) added heating anomalies (unit: K day^{-1}) in the MJO_IP (top), MJO_IO (middle), and MJO_WP runs (bottom).

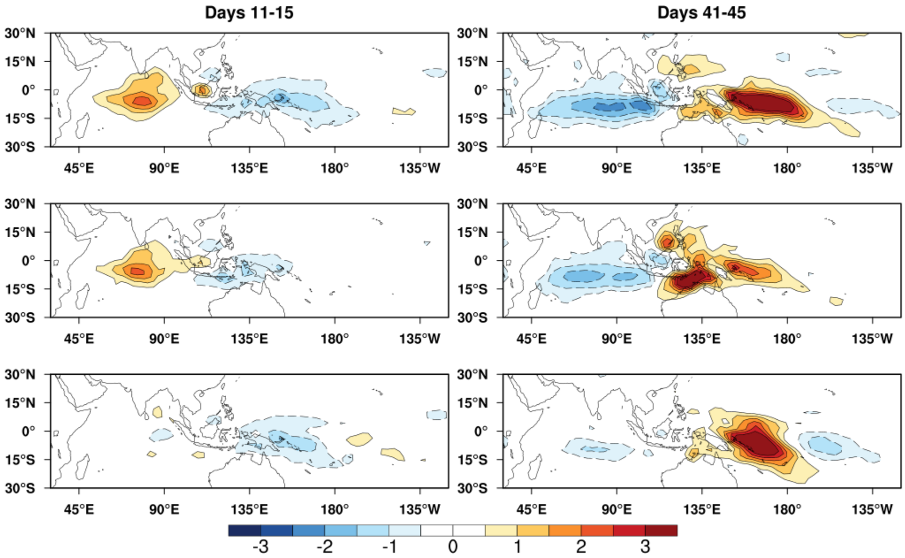


Figure S2. The vertically averaged (over 1000–50 hPa) diabatic heating anomalies (unit: K day^{-1}) in the MJO_IP (top), MJO_IO (middle), and MJO_WP runs (bottom).

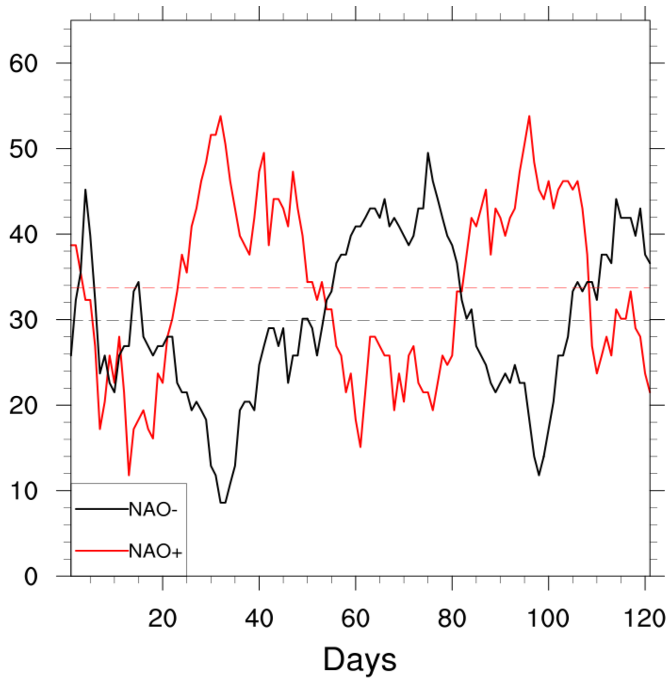


Figure S3. Occurrence probabilities (%) of the positive (red curve) and negative (black curve) NAO from day 1 to day 121 in the MJO_IP runs. The red (black) reference line represents the climatological mean of the positive (negtive) NAO with value 33.7 (29.9).

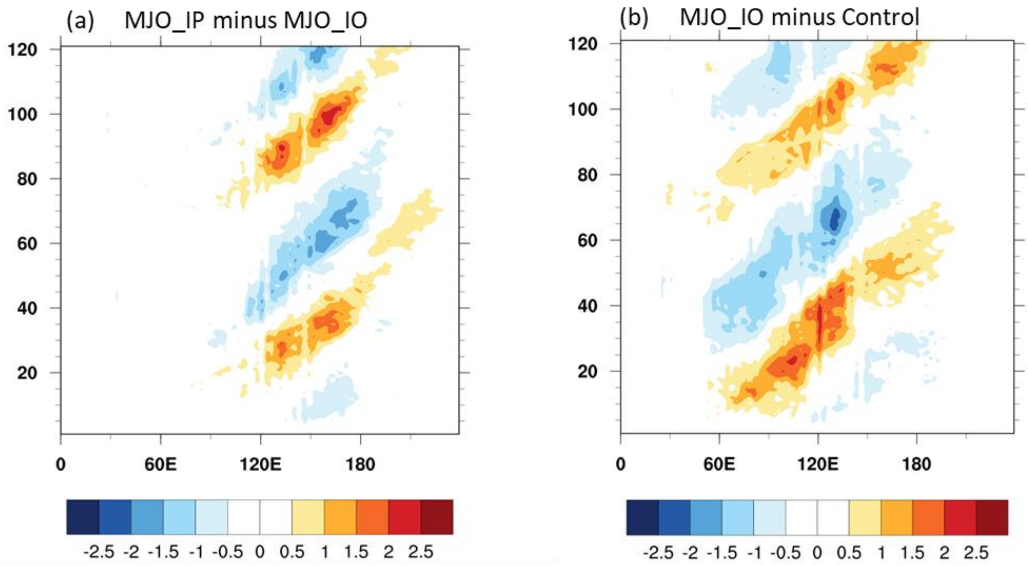


Figure S4. The differences of the vertically averaged (over 1000–50 hPa) diabatic heating (unit: K day^{-1}) averaged over latitudes 15°S–15°N between the MJO_IP and MJO_IO runs (a), and between the MJO_IO and Control runs (b).

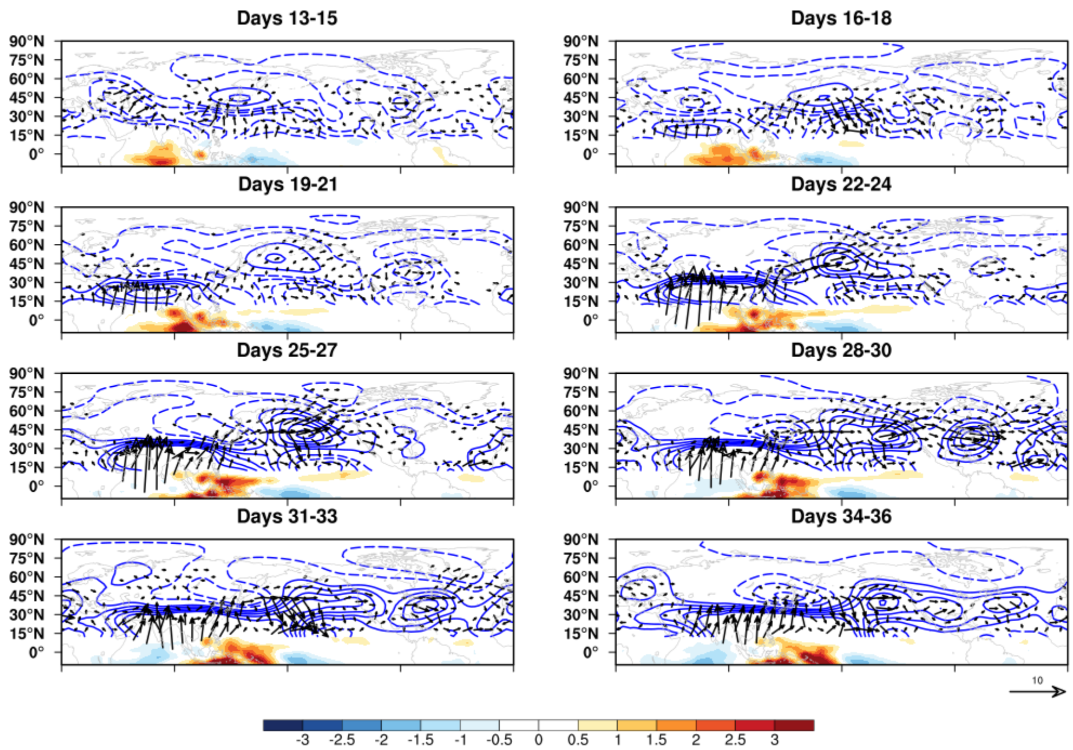


Figure S5. Composites of the 200-hPa streamfunction (contours), horizontal components of phase-independent wave activity flux (arrows) and diabatic heating anomalies (shaded) in the raw MJO_IP runs. Contour interval is 1.0×10^{-6} m^2 s^{-1} for streamfunction, plotted north of 15°N. Units of wave activity flux are m^2 s^{-2}, and only vectors larger than 0.5 are shown. Units of heating anomalies are K day^{-1}.

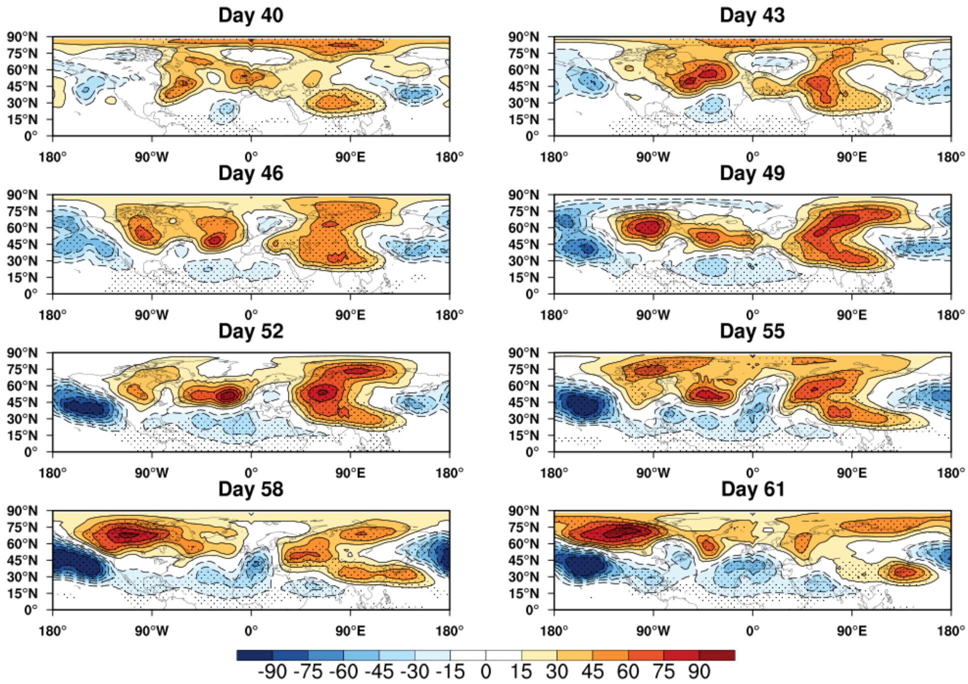
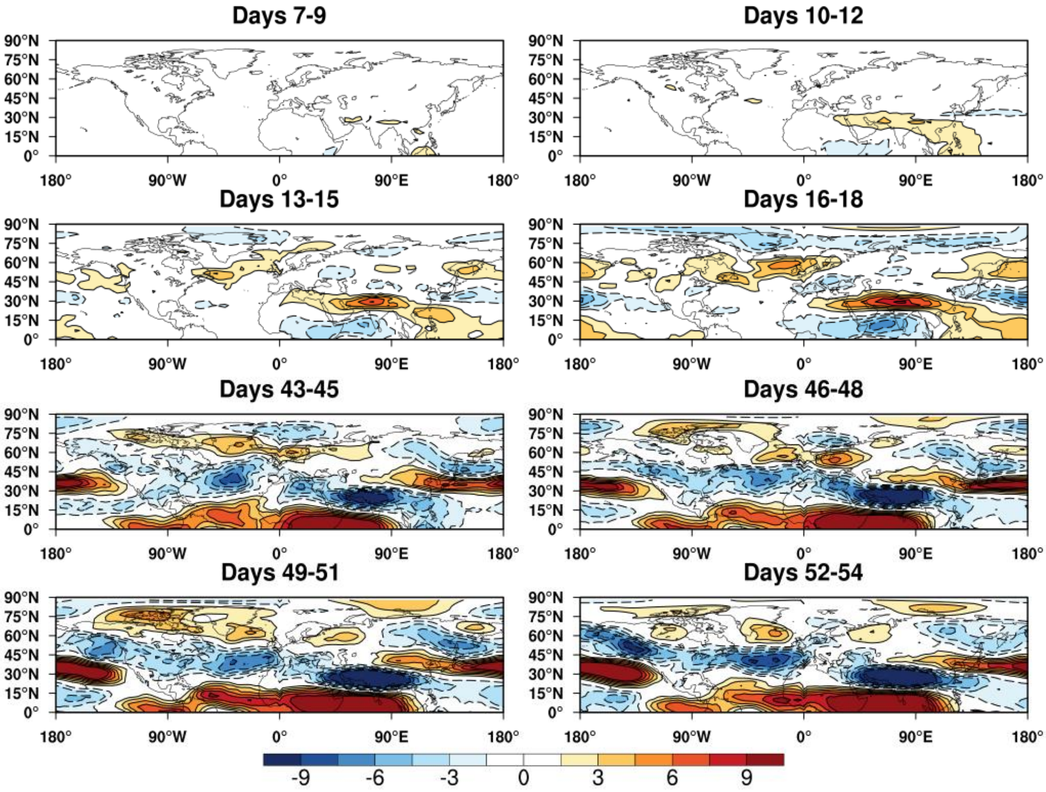


Figure S6. Composite differences of the 500-hPa geopotential height (unit: gpm) between the MJO_IO and Control runs from day 40 to day 61. The composite results at the 95% confidence level according to a Student's t test are dotted.



61 **Figure S7.** Composite differences of the 300-hPa zonal wind (unit: m s^{-1}) between the MJO_IO and Control runs averaged every 3 days.

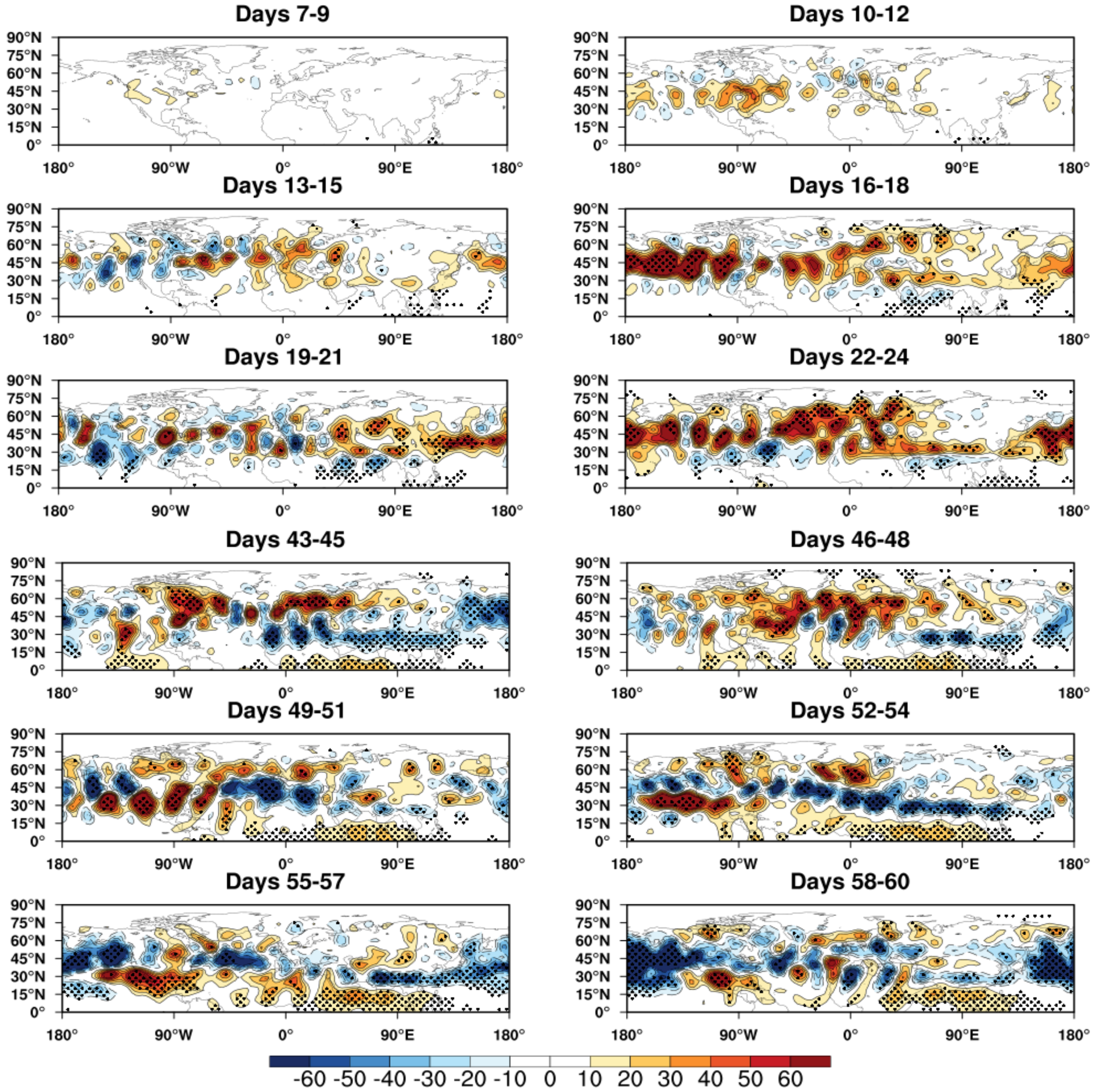


Figure S8. Composite differences of the 300-hPa synoptic *v'v'* (unit: $m^2\ s^{-2}$) between the MJO_IO and Control runs averaged every 3 days. The composite results at the 90% confidence level according to a Student's t test are dotted.

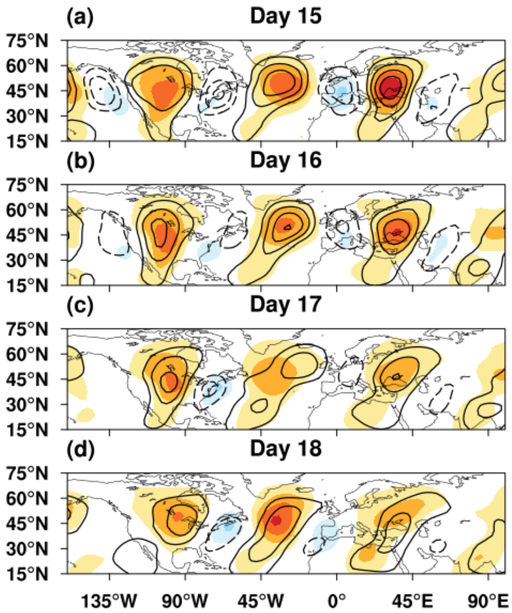


Figure S9. One-point lagged regression coefficients of the 300-hPa anomalous synoptic-scale streamfuction for the base point at 45°N, 30°E on day 15 in Control runs (shading) and MJO_IO runs (contours) respectively, from day 15 to day 18. The interval of the contours is 0.2.

Table S1. Description of Model Experiments

Experiments	Added heating region	Ensemble size	Duration	Simulations
Control	none	3	December to March in 1980–2010	93
MJO_IP	45°–180°E, 20°S–10°N	3	December to March in 1980–2010	93
MJO_IO	45°–130°E, 20°S–10°N	3	December to March in 1980–2010	93
MJO_WP	115°–180°E, 20°S–10°N	3	December to March in 1980–2010	93