What determines the propagation speed of the Madden-Julian Oscillation?

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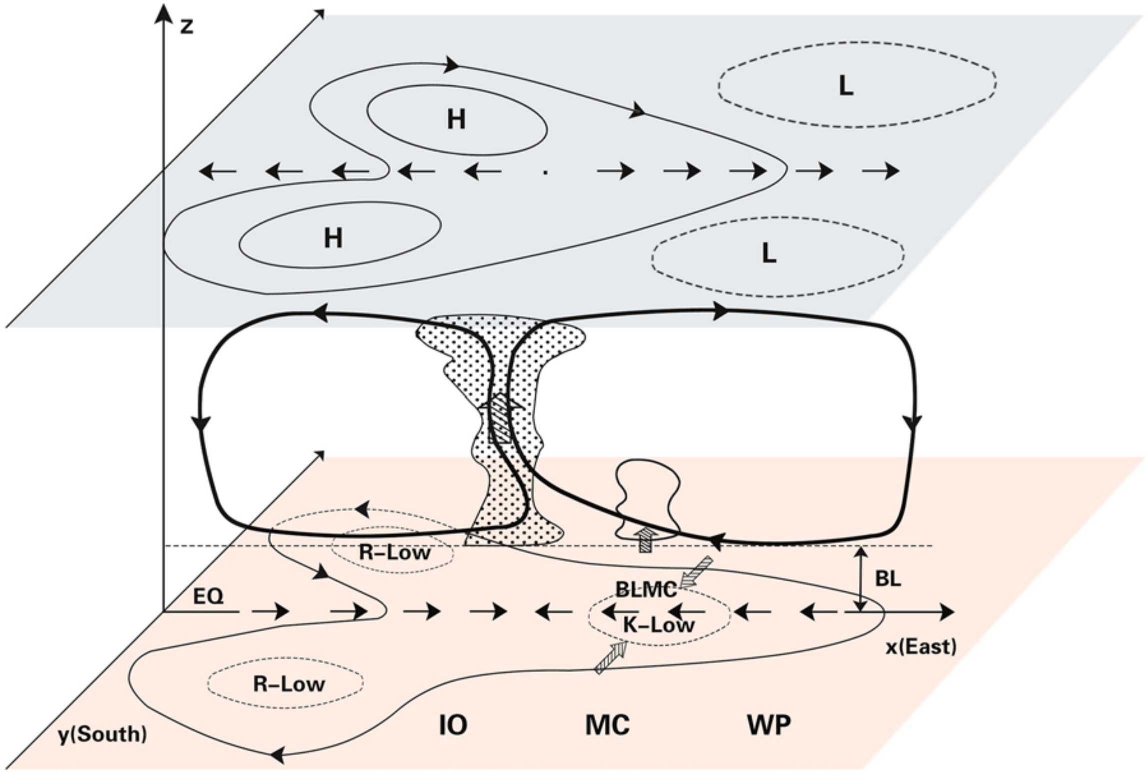
Outline

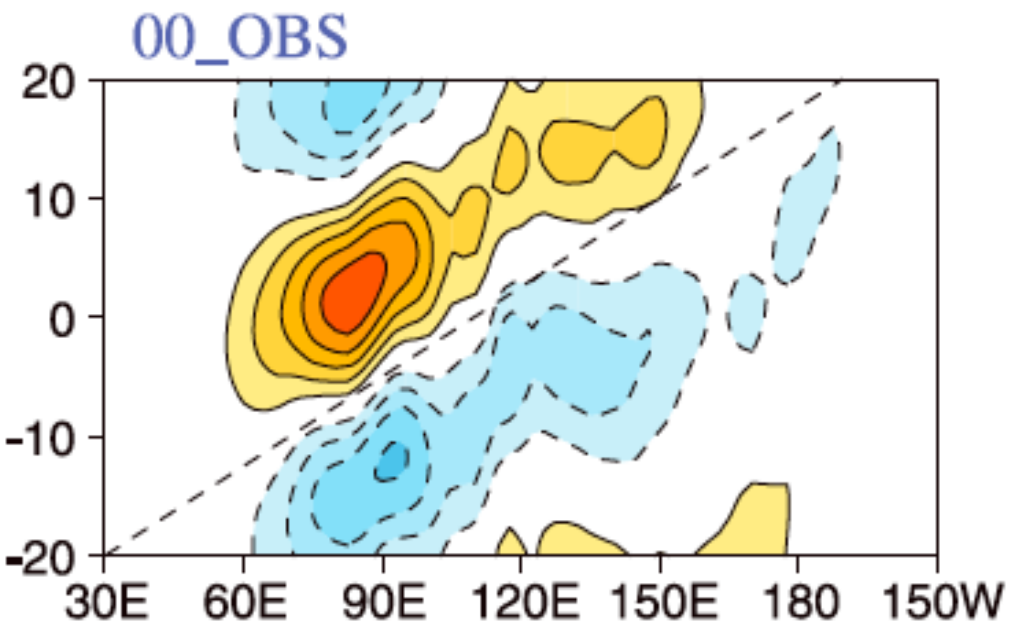
- 1. Background
- 2. Data and methods
- 3. Observational results
- 4. Numerical results
- 5. Conclusions

1. Background

Wang et al 2016

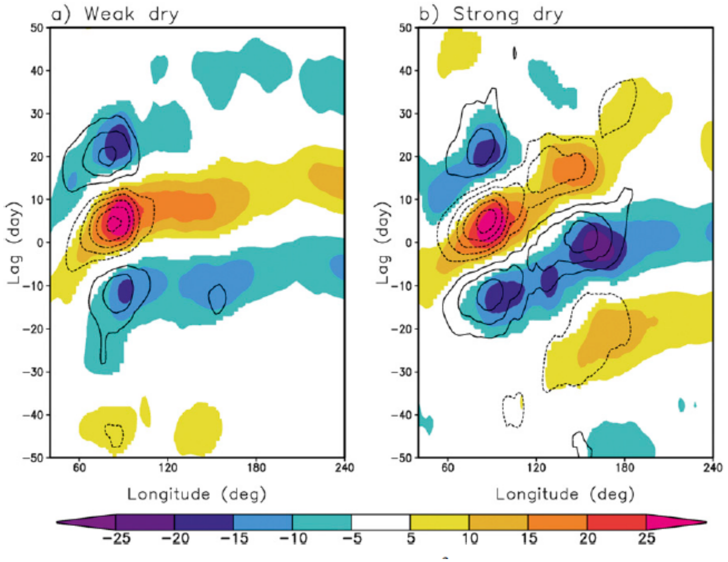


Jiang et al 2015

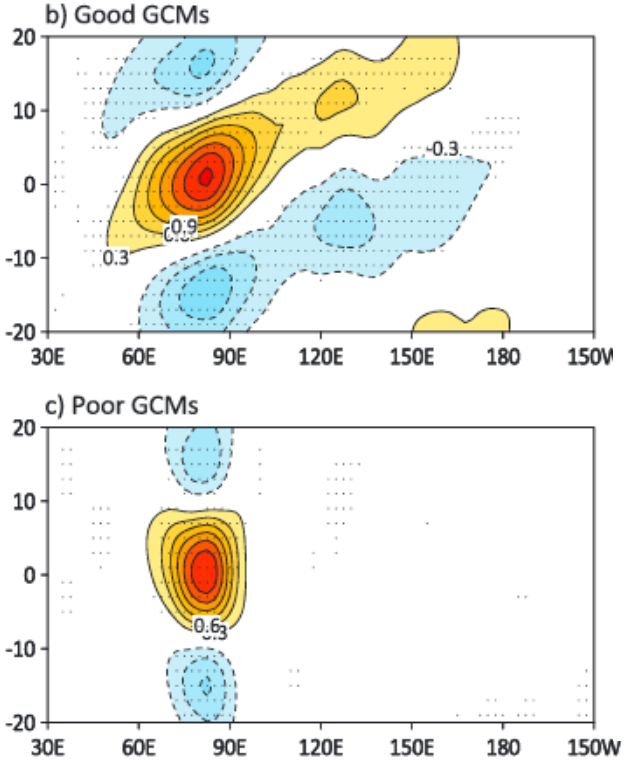


Canonical structural and propagation features of the MJO

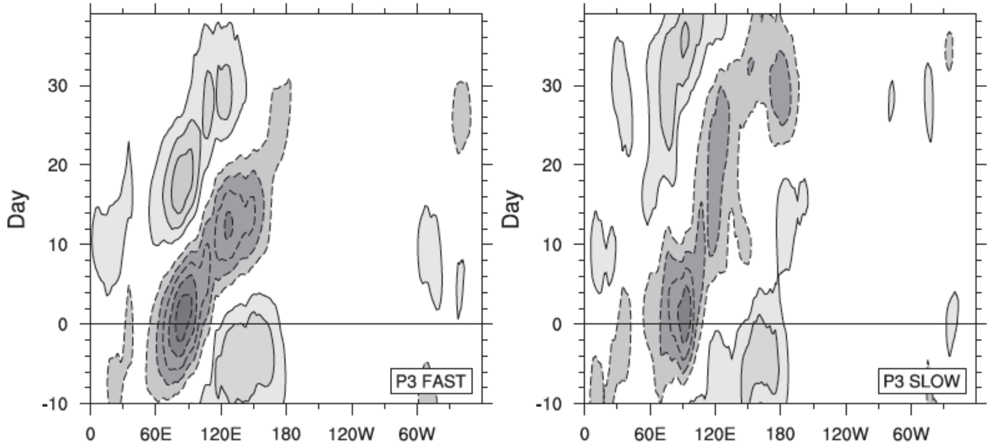
Kim et al 2014



Jiang et al 2015



Yadav and Straus 2017



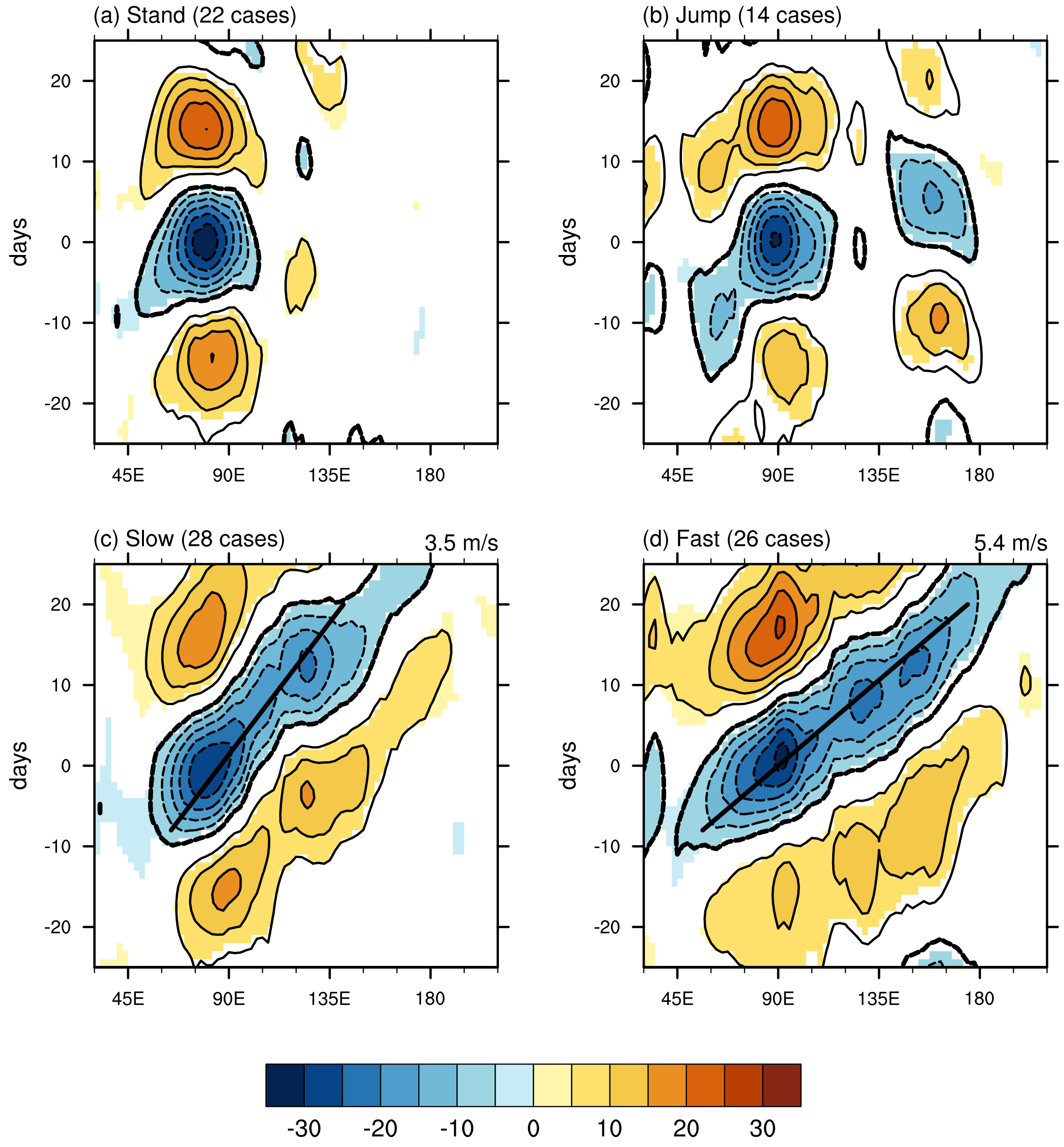
The dynamic and thermodynamic structural differences distinguish the propagating and non-propagating MJO (Wang et al 2018)

It remains unclear what controls the propagation speed of the MJO

Observed and modeling diversities in MJO propagation

MJO propagation diversity

- Different types of MJO are distinguished by different dynamic and thermodynamic structures, which are controlled by the background mean states.
- However, this study focused on the causes of the diversified MJO propagation patterns and did not fully address what controls the MJO propagation speed.



Wang, B., **G. Chen***, and F. Liu, 2019: Diversity of the Madden-Julian Oscillation. *Science Advances*, **5,** eaax0220.

Tasks

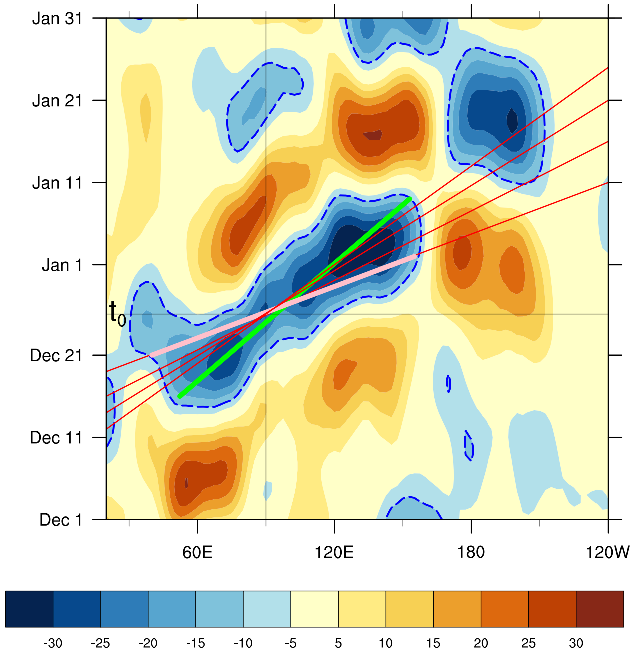
- **Aim:**
  - Identifying factors controlling the MJO propagation speed in observations.

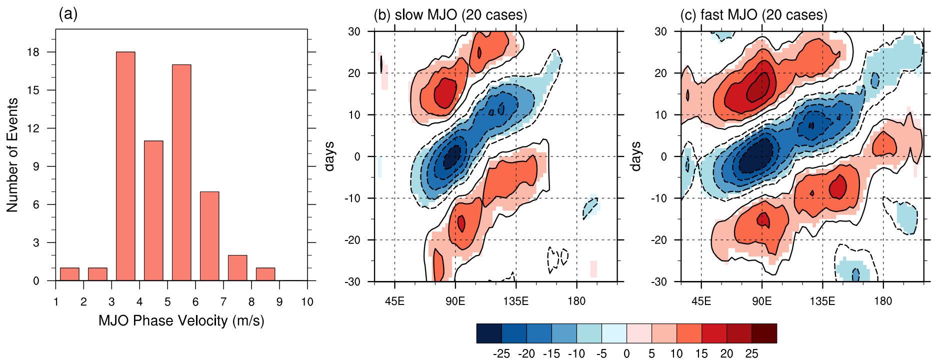
- **Questions:**
  - What are the structural characteristics that determine the MJO propagation speed in observation?
  - How does the background mean state modify the MJO structures?

2. Data and methods

- **Datasets:**
- NOAA interpolated OLR
- ERA-Interim
- NOAA ERSST
- Period : 1979-2013
- Boreal winter (NDJFMA) is considered

- **Methods:**
- Time filter: 20-70-day Lanczos band-pass filter
- Hough function decomposition (Kasahara 1976; Kasahara and Puri 1981)



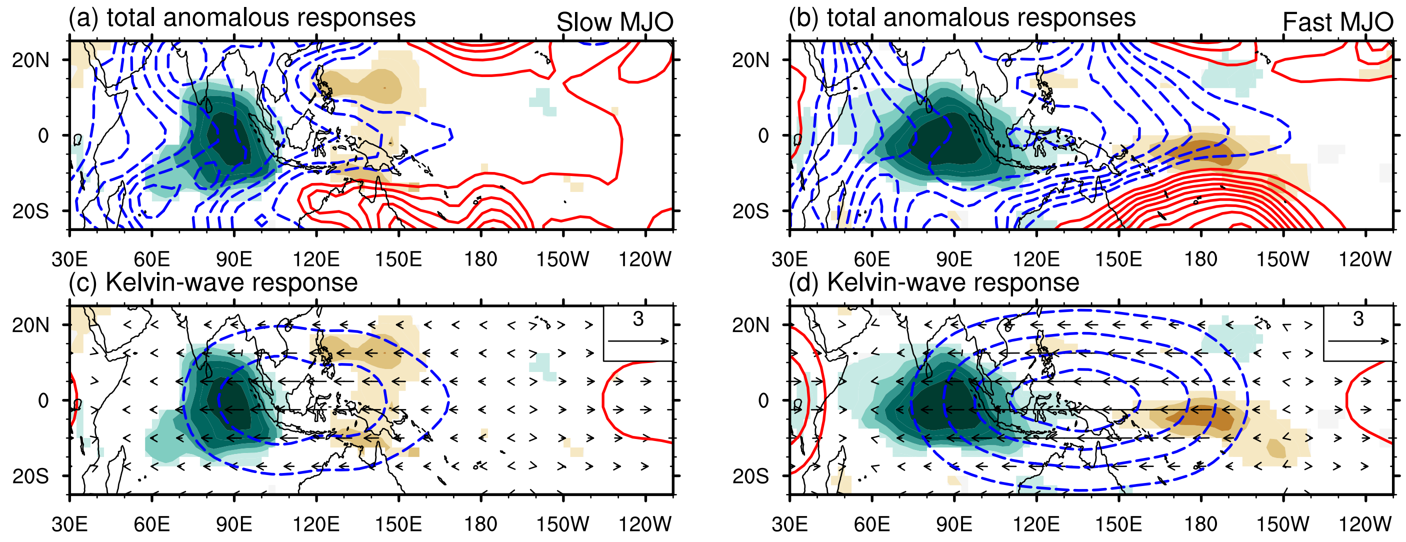


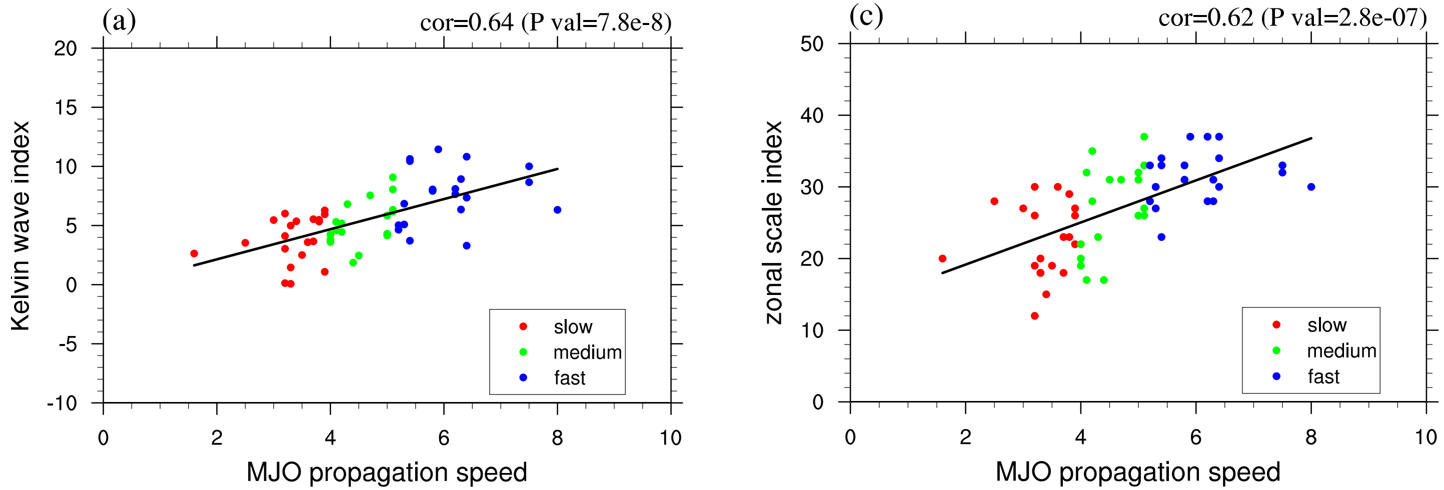
Selecting MJO events and tracking MJO propagation speed

- 1. Select MJO events that develops in Indian Ocean, there are 127 MJO events
- 2. Find the propagation track of each MJO event (Zhang and Ling 2017)
- 3. Select propagating MJO events: starting longitude < 82.5E and ending longitude > 120E. There are 58 propagating MJO episodes.
- 4. Fast MJO (C > 5.1 m/s), slow MJO (C < 4 m/s)

3. Observational Results

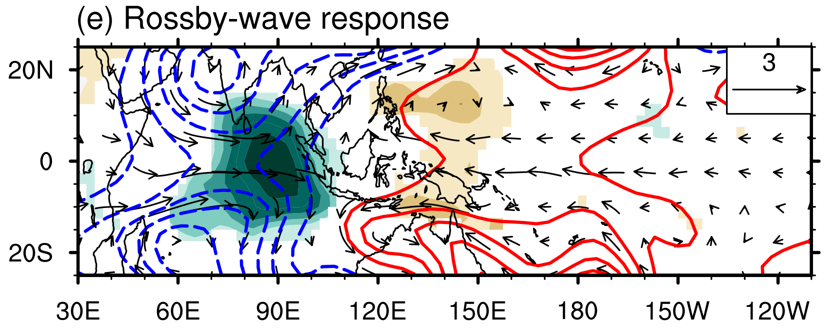
a. Circulation factors affecting the MJO propagation speed

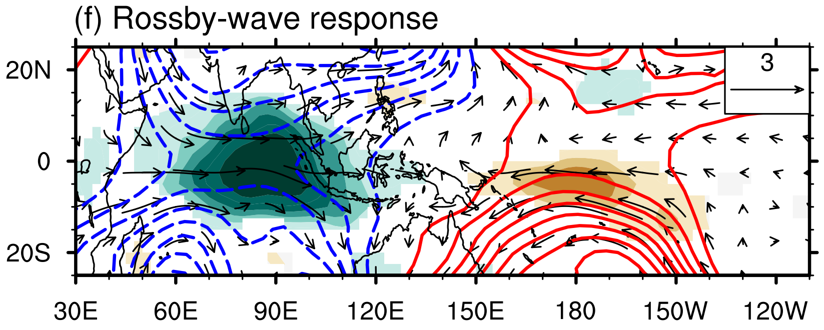


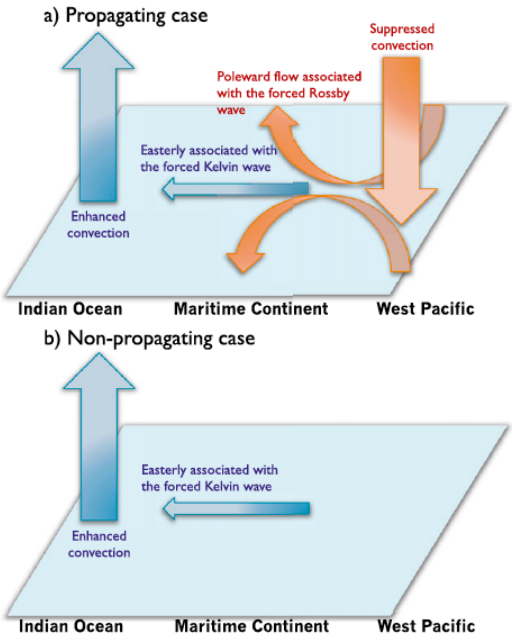


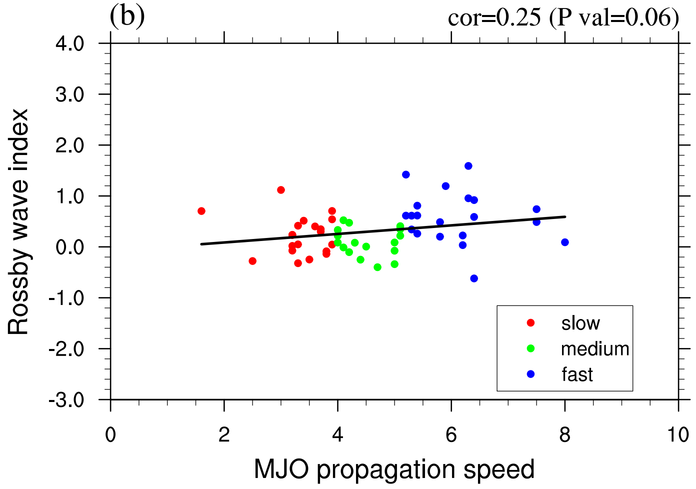
The MJO propagation speed is highly correlated to its Kelvin-wave response and its zonal scale.

Structural factors related to the MJO propagation speed





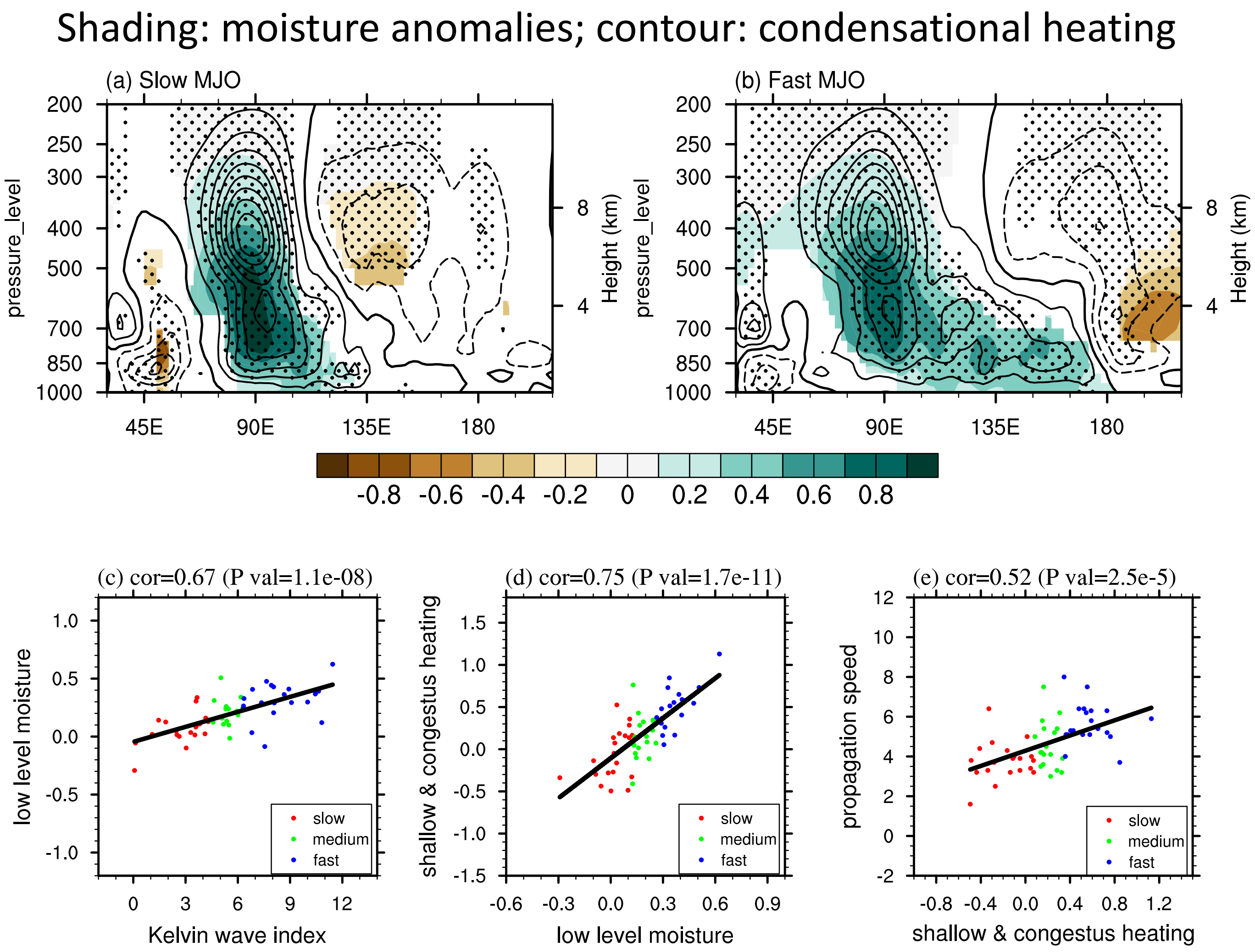




Kim et al 2014

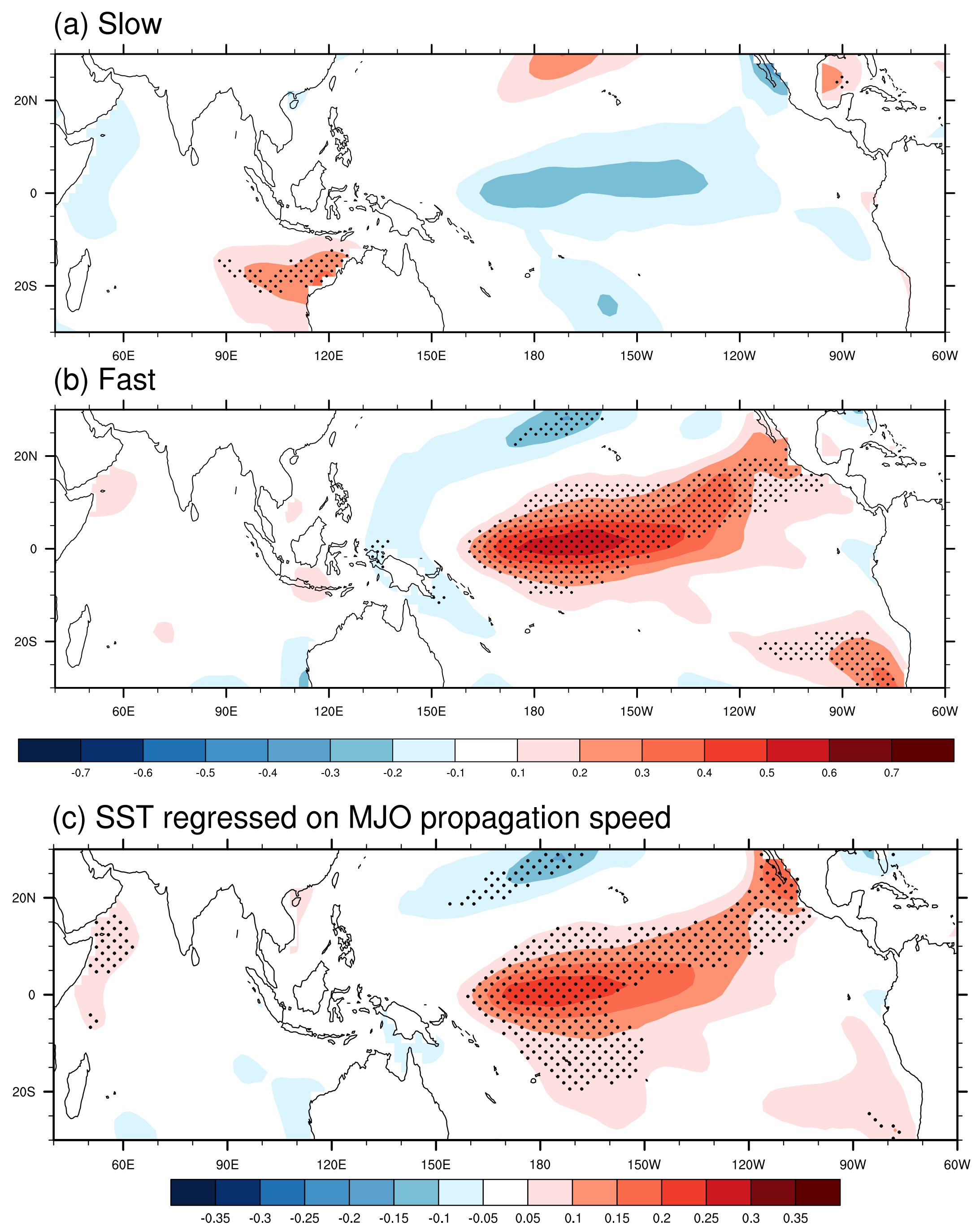
The the Rossby-wave anticyclones to the east of the MJO are not the main cause of MJO speed variability, although they are important for whether the MJO can propagation across the Maritime continent.

b. How does the Kelvin wave response affect MJO propagation speed



Strong Kelvin wave response → Enhanced Low-level moistening (Boundary layer convergence) → Enhanced congestus convection → Faster eastward development of MJO convection

c. The factors controlling the intensity of the Kelvin wave response



How does the central Pacific SST variation affect the Kelvin-wave response and the MJO propagation speed?

Central Pacific warming

Expanded Indo-Pacific warm pool

Eastward expansion of MJO activity

Increase in MJO zonal scale

Stronger Kelvin wave response

+ MJO is active over warm ocean — Zhang 2005

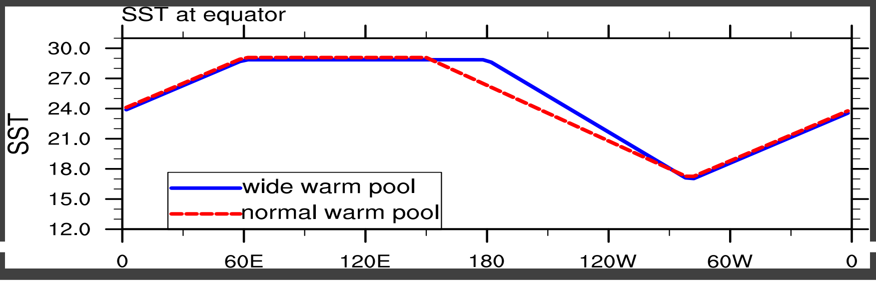
+ MJO tends to amplify on larger zonal scale — (Adames and Kim 2016; Fuchs and Raymond 2017; Chen and Wang 2019)

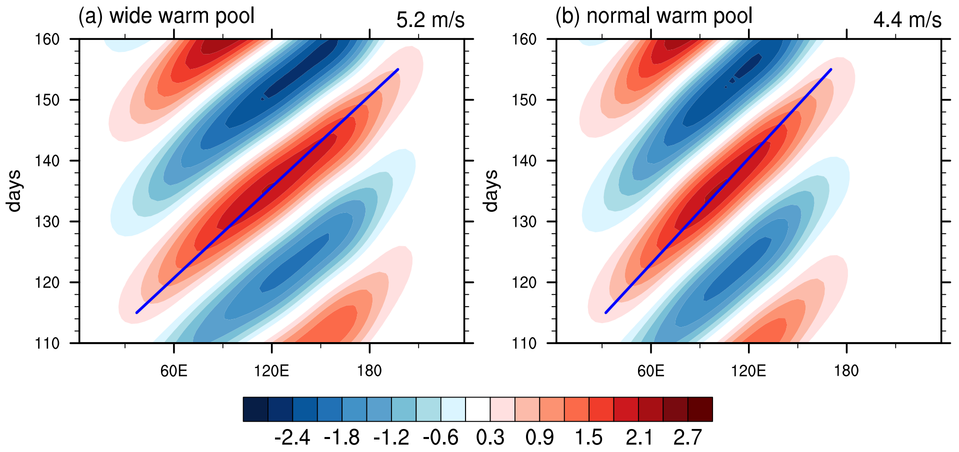
+ Boundary layer convergence feedback tends to amplify the Kelvin wave response on larger zonal scale

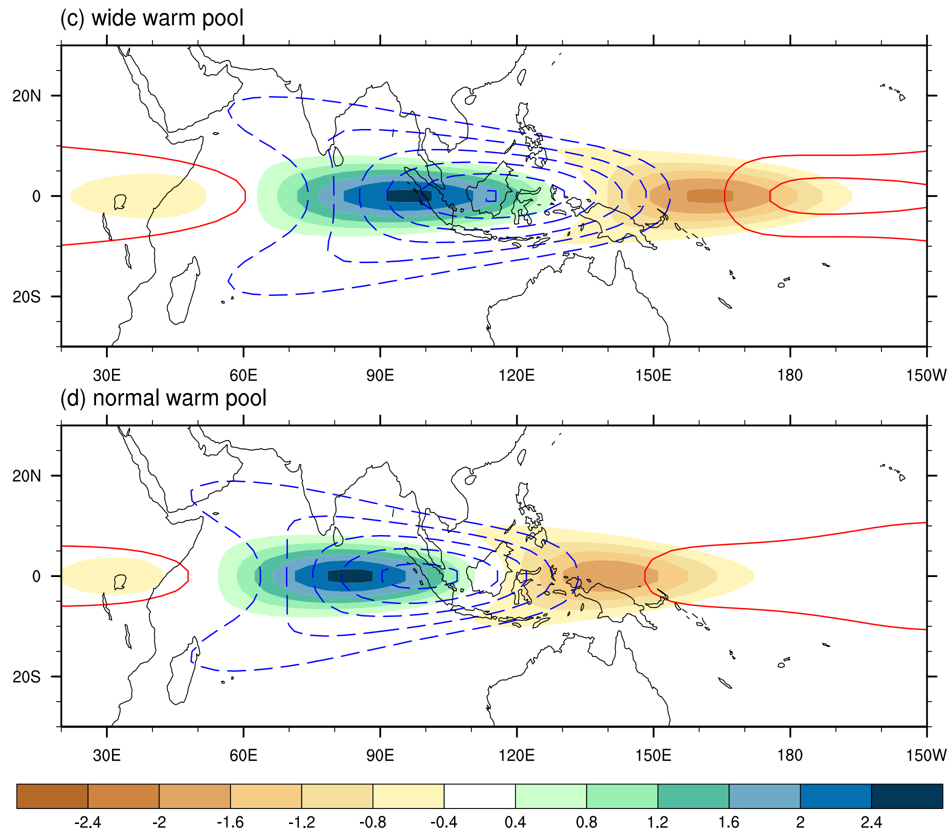
Chen, G*., and B. Wang, 2019. *Clim. Dyn.*, 52, 5127.

4. Numerical results

- **Theoretical Model: Wang and Chen, (2017)**
- **Modification: linear heating (precipitation)**
- **Warm pool SST configuration (Gaussian distribution in meridional direction)**







The numerical work verifies that the zonally expanded warm pool favors faster propagation of MJO through enlarging the MJO zonal scale and enhancing the Kelvin-wave response

5. Conclusions

The strength of the Kelvin wave response is a major circulation factor affecting the MJO propagation speed

Stronger Kelvin wave response accelerates the MJO propagation through enhancing the pre-moistening and pre-conditioning processes.

The strength of the Kelvin wave response is affected by the background SST variation in central Pacific.

This effect of the background SST has been verified by theoretical model

Chen, G.*, and B. Wang, 2020: Circulation factors determining the propagation speed of the Madden-Julian Oscillation. J. Climate: revised.

Thank You

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