Journal Club

Diversity of the Madden-Julian Oscillation

machine learning in climate science

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RESEARCH ARTICLE | ATMOSPHERIC SCIENCE

Diversity of the Madden-Julian Oscillation

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Outline

Key Questions, Results and Impact

Key Questions & Results

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- How to distinguish and group different Madden-Julian Oscillation (MJO) events?
- What mechanisms are responsible for MJO diversity and how can MJO propagation be better foreseen?

Key results:

- Cluster analysis of propagation patterns of MJO events reveal four archetypes of propagation.
- The Pacific sea surface temperature anomalies can affect MJO diversity.

Impact:

- Climate modeling and prediction of MJO can be enhanced due to better understanding of the MJO diversity.

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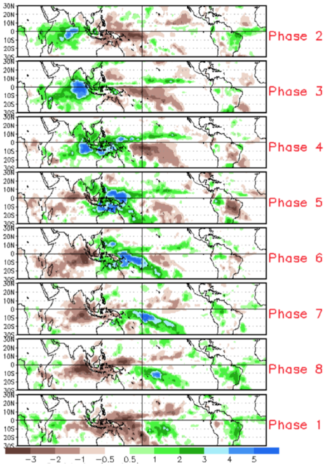
Data and Methods

- **Outgoing longwave radiation (OLR):** National Centers for Environmental Prediction /National Oceanic and Atmospheric Administration–interpolated OLR dataset
- **Sea Surface Temperature (SST)**: monthly averaged, period 1948-2003, provided by National Oceanic and Atmospheric Administration (NOAA) extended reconstructed SST (ERSST)
- **Horizontal and vertical winds, temperature, specific humidity**: daily averaged European Centre for Medium-Range Weather Forecasts Interim (ERA-Interim) reanalysis data, from 1000 to 100 hPa.
- For the whole analysis the period between 1980-2010 on a 2.5°x2.5° grid is used.

What are the Madden Julian Oscillations (MJO)?

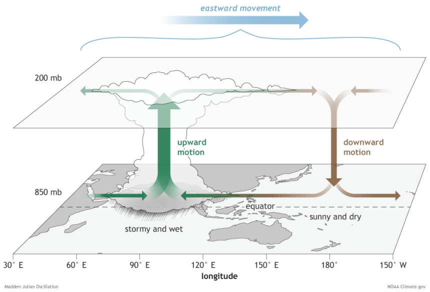
- MJO is an eastward moving disturbance of clouds and heavy rainfalls that traverses the planet in the tropics and returns to its initial starting point in 30 to 60 days ($\rightarrow$ *intraseasonal* tropical climate variability).
- The MJO consists of two parts: i) enhanced rainfall (or convective) phase ii) the suppressed rainfall phase.
- This entire dipole propagates eastward.



taken from https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care

What are the Madden Julian Oscillations (MJO)?

- In the enhanced convective phase, winds at the surface converge, and air is pushed up throughout the atmosphere ($\rightarrow$ rainfalls and clouds).
- In the suppressed convective phase, winds converge at the top of the atmosphere, forcing air to sink and, later, to diverge at the surface ($\rightarrow$ warm and dry air).

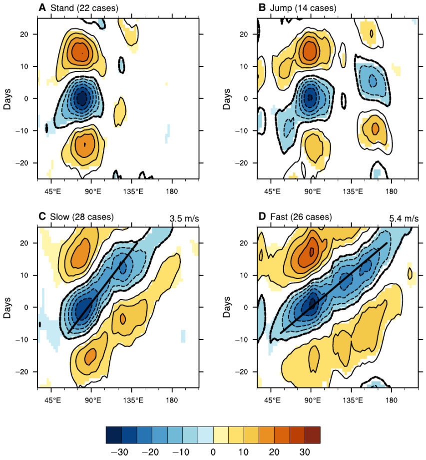


Scheme of MJO, taken from `https://www.climate.gov/news-features/blogs/enso/what-mjo-and-why-do-we-care`

MJO propagation

Cluster analysis

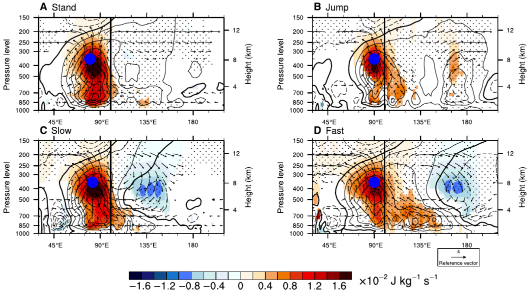
- 1. cluster: standing oscillation over the Equatorial Indian Ocean (EIO)
- 2. cluster: Wet phase "jumps" from the EIO across the maritime continent (MC) to the equatorial western Pacific (EWP).
- 3. + 4. cluster: systematic east-ward propagation from the EIO across the MC to EWP with different speed (3.5 m/s and 5.4 m/s).



Hovmöller diagramms of OLR anomalies between 10°S and 10°N during boreal winter (Nov-April) for (A) standing, (B) jumping, (C) slow propagation, and (D) fast propagation clusters.

Structural Differences between MJO events

- Maximum equivalent potential temperature (EPT) anomalies are coupled with a deep updraft, which is a feature common to all clusters.
- Difference propagating nonpropagating: the propagating events feature a deep layer of lower-tropospheric easterlies, whereas in the nonpropagating clusters, the easterlies are absent or very weak and shallow.
- Difference slow-propagating fast-propagating clusters: Different zonal spans of the leading low-level easterly anomalies

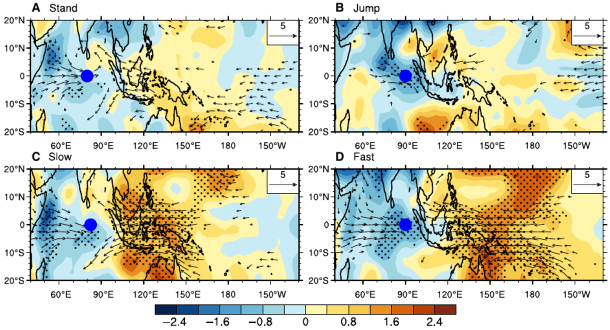


Common features and differences between four types of MJO propagation. Composited equatorial (averaged between 10°S and 10°N) vertical structure of circulation (vectors), equivalent potential temperature (EPT, contours), and precipitation heating (colormap).

Explanation for different types

Differences in circulation patterns

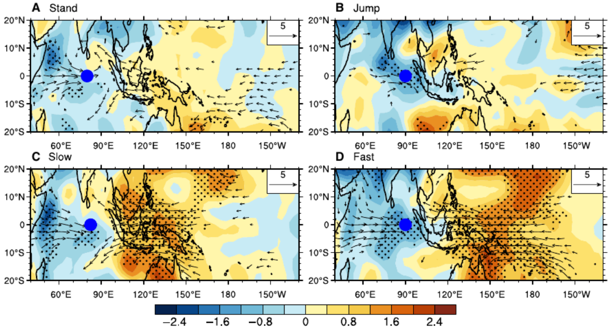
- Standing cluster: Strong Rossby wave response (cyclonic gyres) $\rightarrow$ strong Rossby wave component and negligible Kelvin wave component.
- Propagating clusters, the anomalous Kelvin wave easterlies to the east of the major convection are much stronger than those in the non-propagating events $\rightarrow$ a stronger Kelvin wave response produces faster east-ward propagation of MJO.



Wind vectors: composited 700-hPa wind anomalies (vector, m/s), the shading indicates the EPT difference between 850 and 400 hPa. Blue circle: the MJO convective center on the equator.

Differences in thermodynamical structure

- EPT represents the moist static energy (MSE) and the convective instability is closely linked to the deep layer of MSE.
- The propagating clusters are characterized by strong lower tropospheric convective instability.
- The standing cluster show no significant regions of convectively unstable layer.



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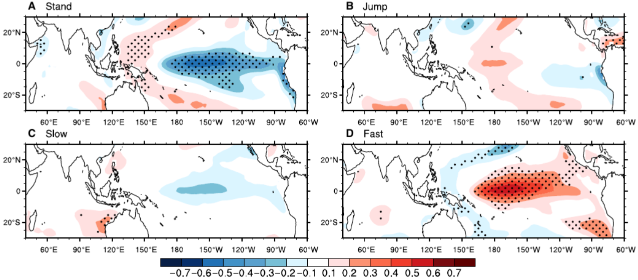
Discussion: Mechanism of the diversified MJO propagation

What mechanism is responsible?

- Key feature distinguishing propagating and nonpropagating events are strong easterly Kelvin waves and their tight coupling to the major convection $\rightarrow$ could explain the MJO eastward propagation
- The propagating cluster develop in the east of East Indian Ocean (EIO) due to strong convective instability which promotes the development of congestus convection and lower tropospheric heating and further promotes development of deep convection which consequently leads to the eastward propagation of the MJO.

What are the causes for different Kelvin wave responses?

- The standing cluster is associated with a significant sea surface cooling over the central and eastern Pacific → **La Niña state**
- The fast cluster is associated with a significant warming over the central and eastern Pacific → **El Niño state**.
- The slow cluster is associated with a weak central Pacific cooling.
- The jumping cluster is associated with a weak central Pacific warming.
- These teleconnections are in accordance with current literature.



The background SST anomalies are obtained by compositing the 3-month average of monthly SST anomalies over the Pacific ocean.

Summary

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- MJO propagation patterns can be classified into four archetypes of clusters: standing, jumping, slow eastward propagation, and fast eastward propagation.
- One good indicator that distinguishes propagating from nonpropagating events is the strength of the Kelvin wave response and its coupling to the east of the MJO main convection.
- the SST conditions over the Pacific affect the Kelvin wave response and are therefore responsible for MJO propagation.

Wang, Chen, and Liu 2019

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