Pacific Northwest
NATIONAL LABORATORY

A relationship between zonal migration of monsoon moisture flux convergence and variability in the strength of Madden-Julian Oscillation events

Samson Hagos, Chidong Zhang, Ruby Leung, Karthik Balaguru, Casey Burleyson

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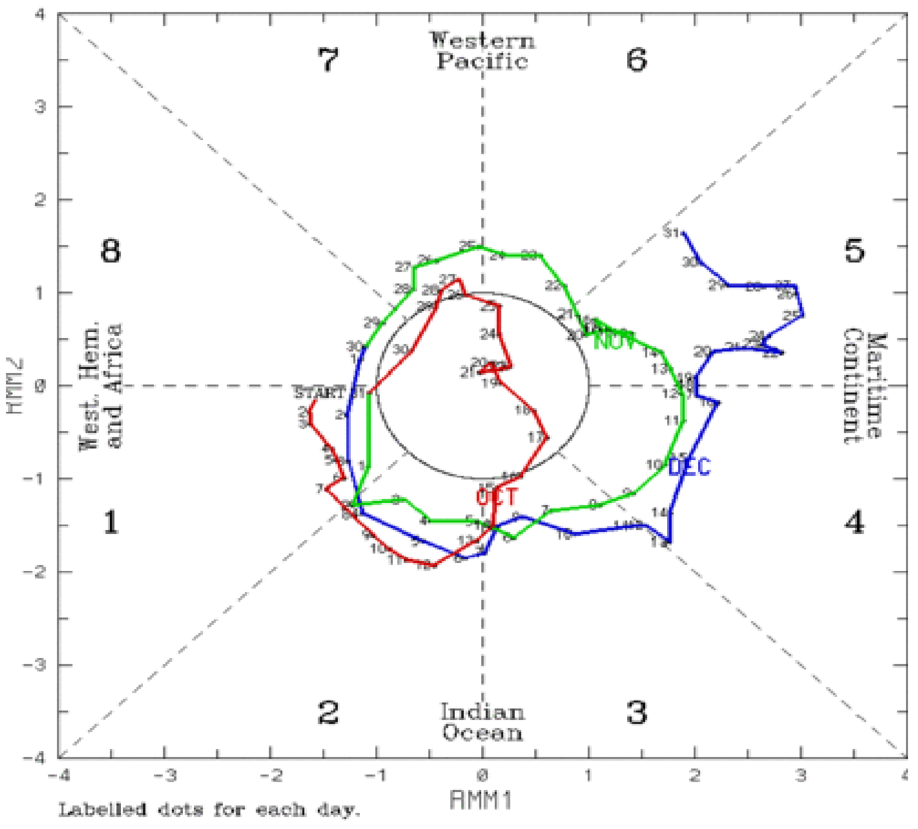
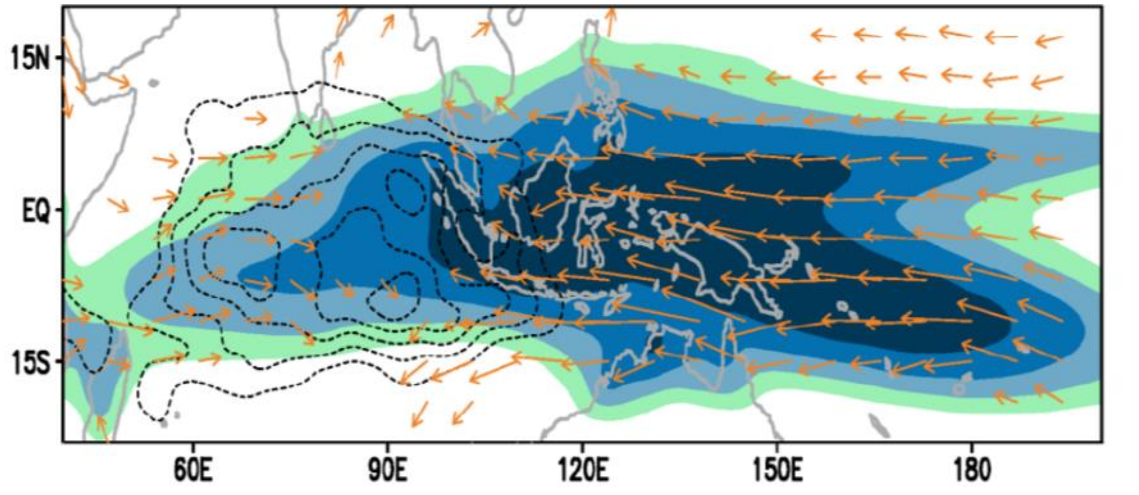
Background

October-November-December 2018
MJO events in RMM phase space



▶ An example of variability in the strength of successive MJO events.

Reanalyses



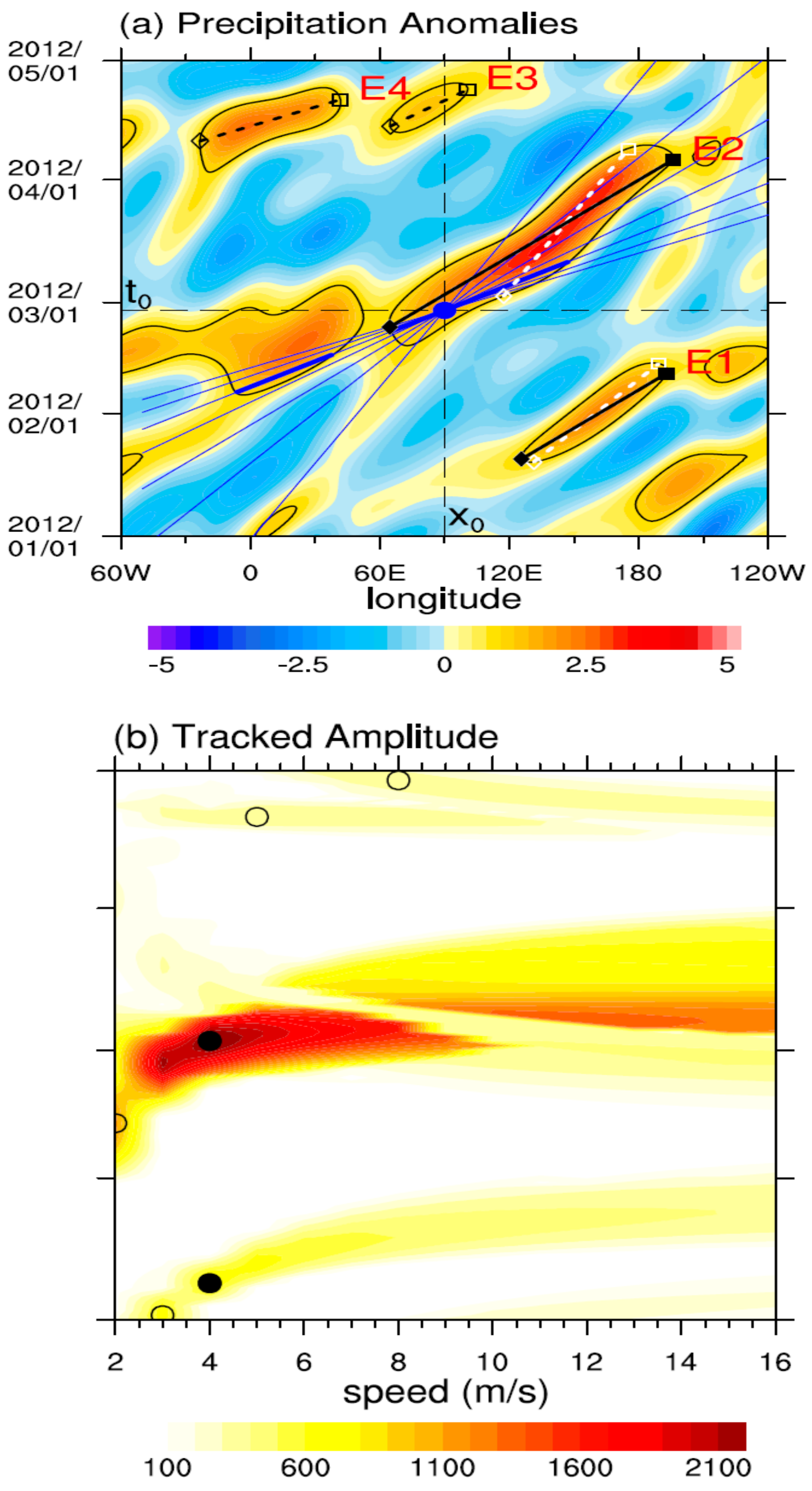
From H. Kim et al. (2016)

▶ Moisture budget analyses indicate MJO is sustained by zonal advection of mean moisture by MJO zonal wind.

Question: So why does the strength of MJO events vary with longitude from event to event?

H. Kim et al. (2016), Maloney (2009), Andersen and Kuang (2012), Kim et al. (2014), Jiang (2017)

Zhang and Ling (2017) MJO tracking

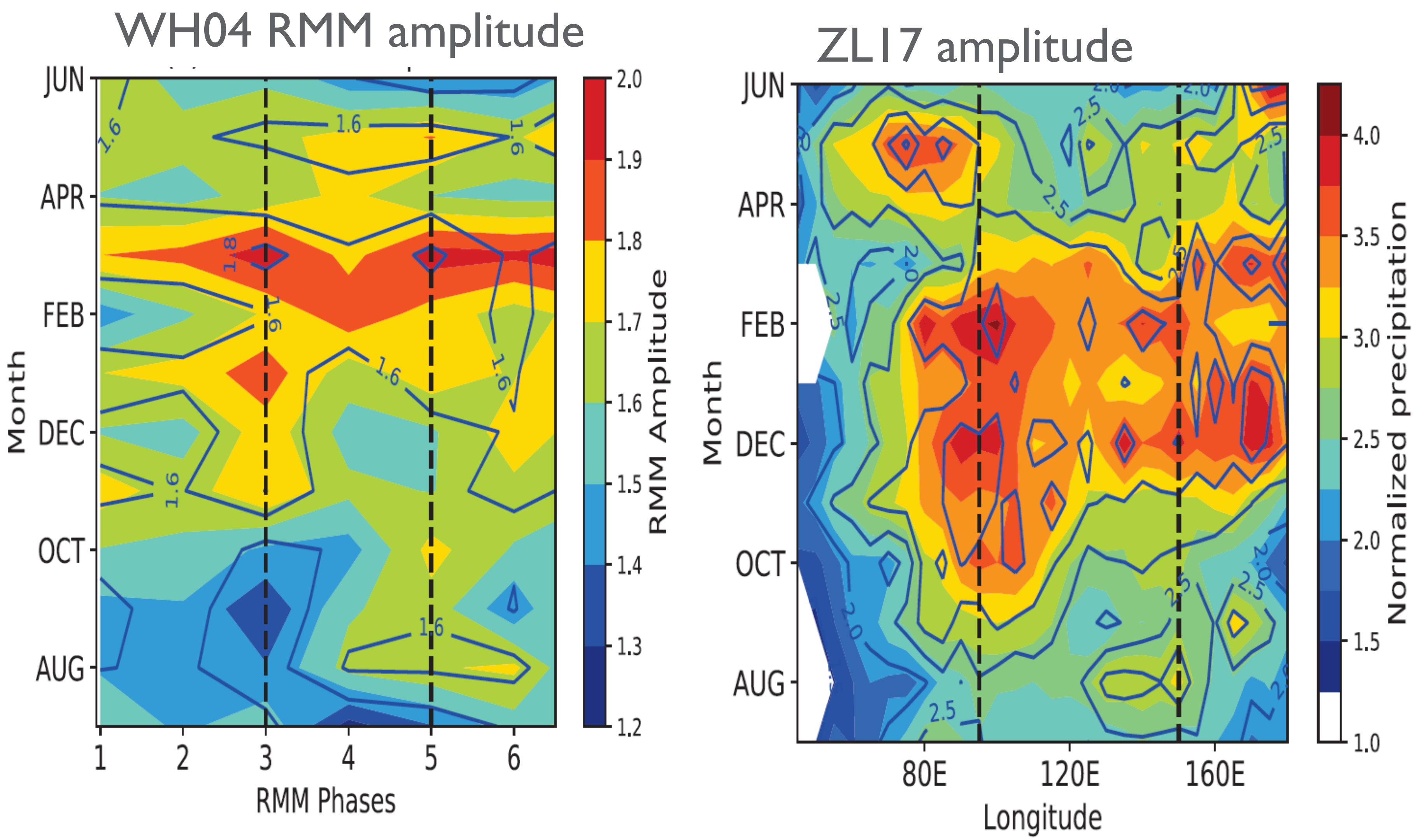


Procedure

- Select a reference longitude x_0 and a tracking domain
- Run a set of straight lines passing the reference longitude at a given day t_0,
- Identify a longest segment along each trial line that satisfied $P > P_0$
- Calculate the amplitude of each selected segment as integrated P_0 along the segment
- Repeat steps (ii)–(iv) for each day.
- Identify eastward-propagating precipitation events. Local maxima in A

From Zhang and Ling (2017)

Seasonality in MJO strength



LEFT: The seasonal cycle of mean (shaded) and median (contours) Wheeler and Hendon (2004) RMM amplitude > 1.0
RIGHT: Same for ZL17 MJO tracking index as function of longitude.

- MJO events tend to be strongest over the western and eastern boundaries of the MC region (phases 3 and 5 in RMM index).
- Seasonally the peak over the eastern boundary of the MC region occurs later than that over the western boundary.

Analysis of moisture sources and sinks

- Given moisture convergence field, one can identify sources and sinks moisture and moisture flux vectors.

$$-\nabla \cdot \frac{1}{g}\int_{ps}^{pt} (q\mathbf{v})dp \simeq P - E$$

$$-\nabla^2\Phi \simeq P - E \quad \text{and} \quad \mathbf{v}_q = \nabla \cdot \Phi$$

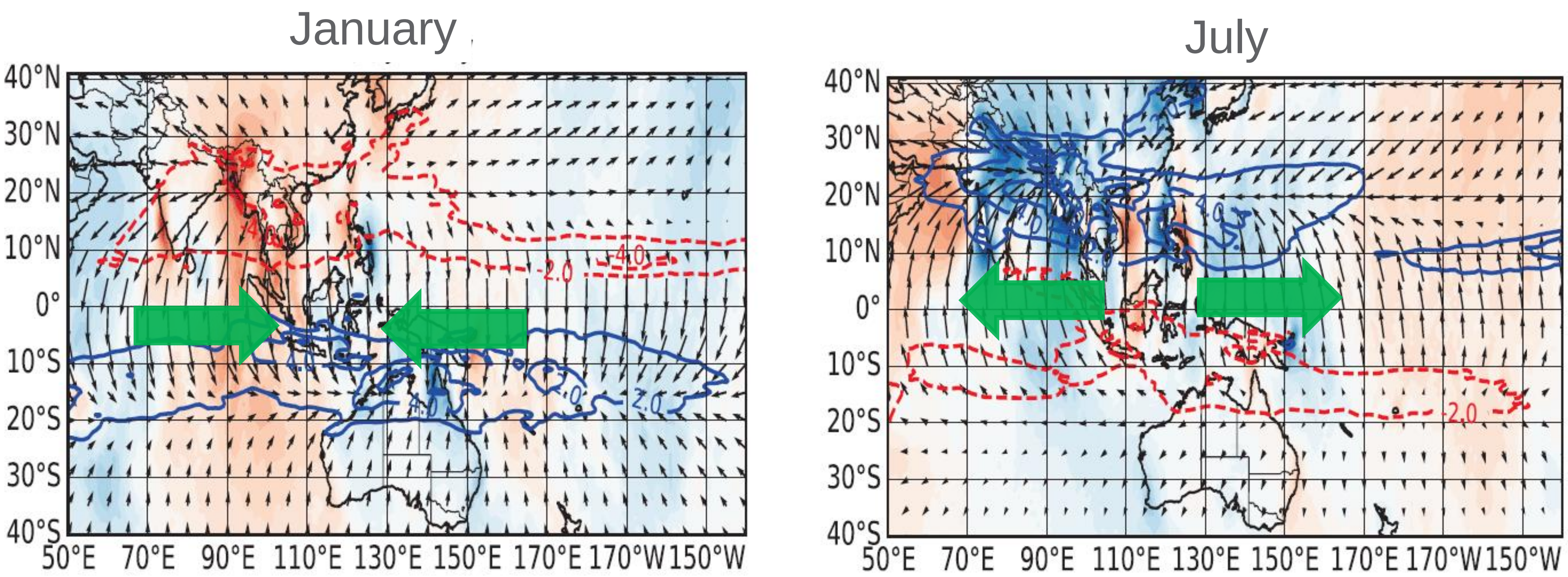
$$-\nabla^2\Phi_p \simeq P$$

- Contributions from zonal and meridional components of moisture flux convergence are calculated.

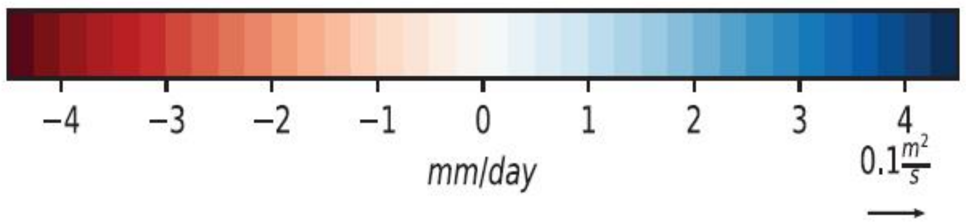
$$P_x = -\frac{\partial^2\Phi}{\partial x^2} \quad \text{and} \quad P_y = -\frac{\partial^2\Phi}{\partial y^2}$$

- We use 30 years of daily precipitation from Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN Ashouri et al 2018) dataset.

Moisture transport during Asian and Australian monsoons



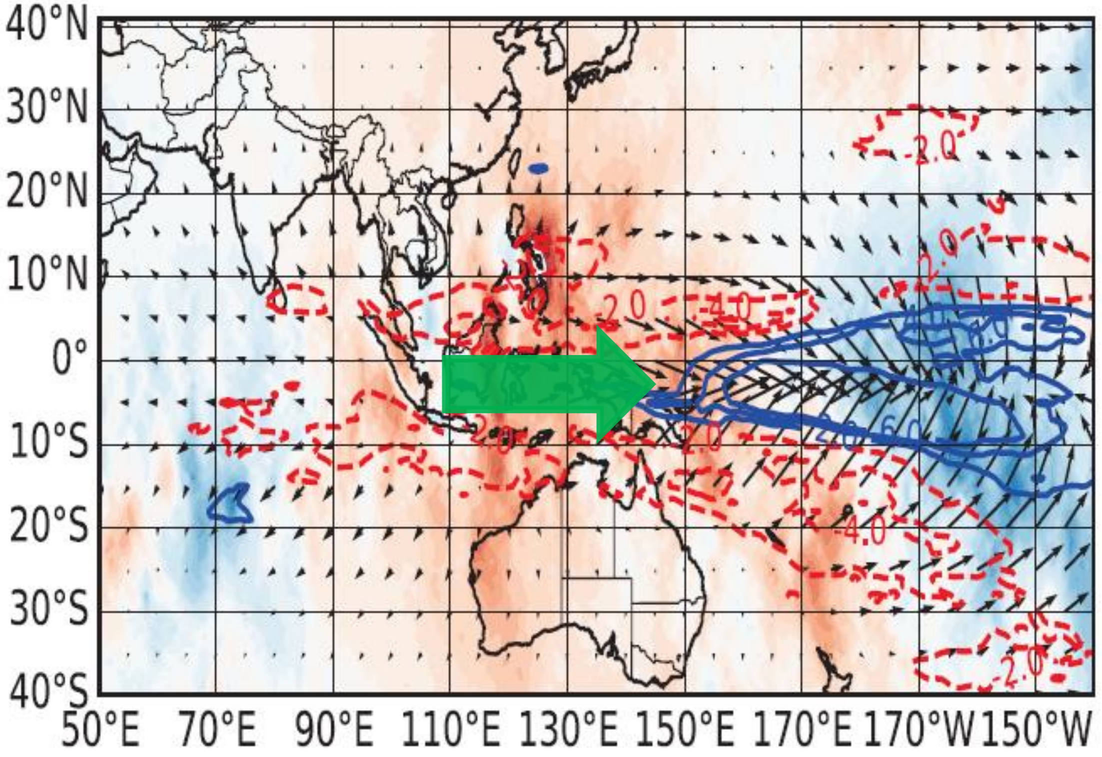
Climatological zonal (shadings) and meridional (contours) moisture flux convergence and moisture flux (arrows).



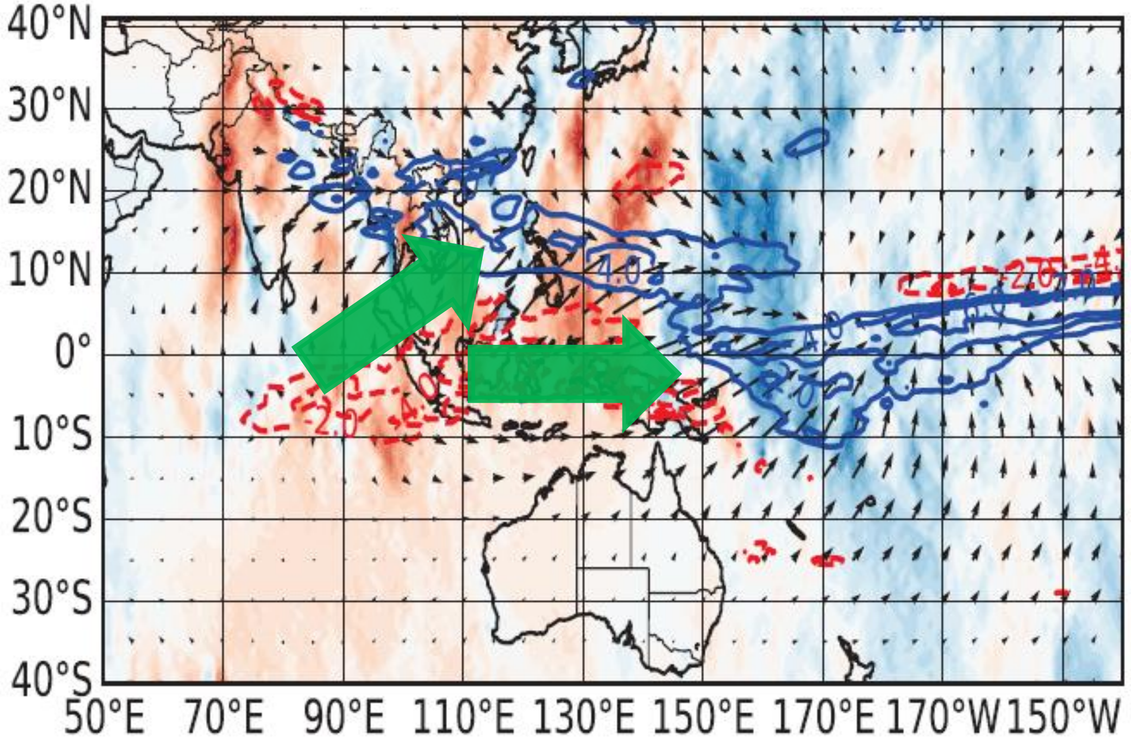
- In **Boreal winter**, zonal convergence is over the **MC region**.
- In **Boreal summer** zonal convergence is over **eastern Indian Ocean and Western Pacific**.

Effect of ENSO on moisture flux convergence

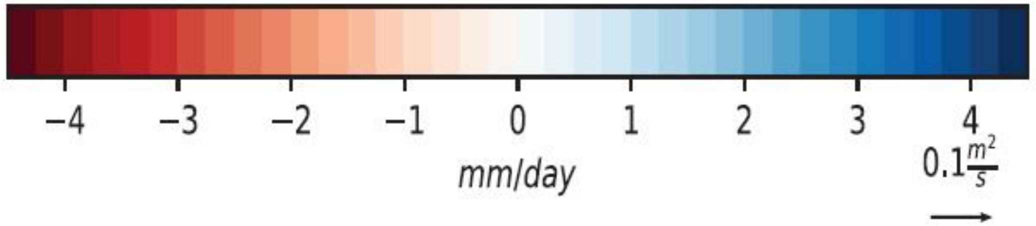
El-Nino minus La-Nina (January)



El-Nino minus La-Nina (July)

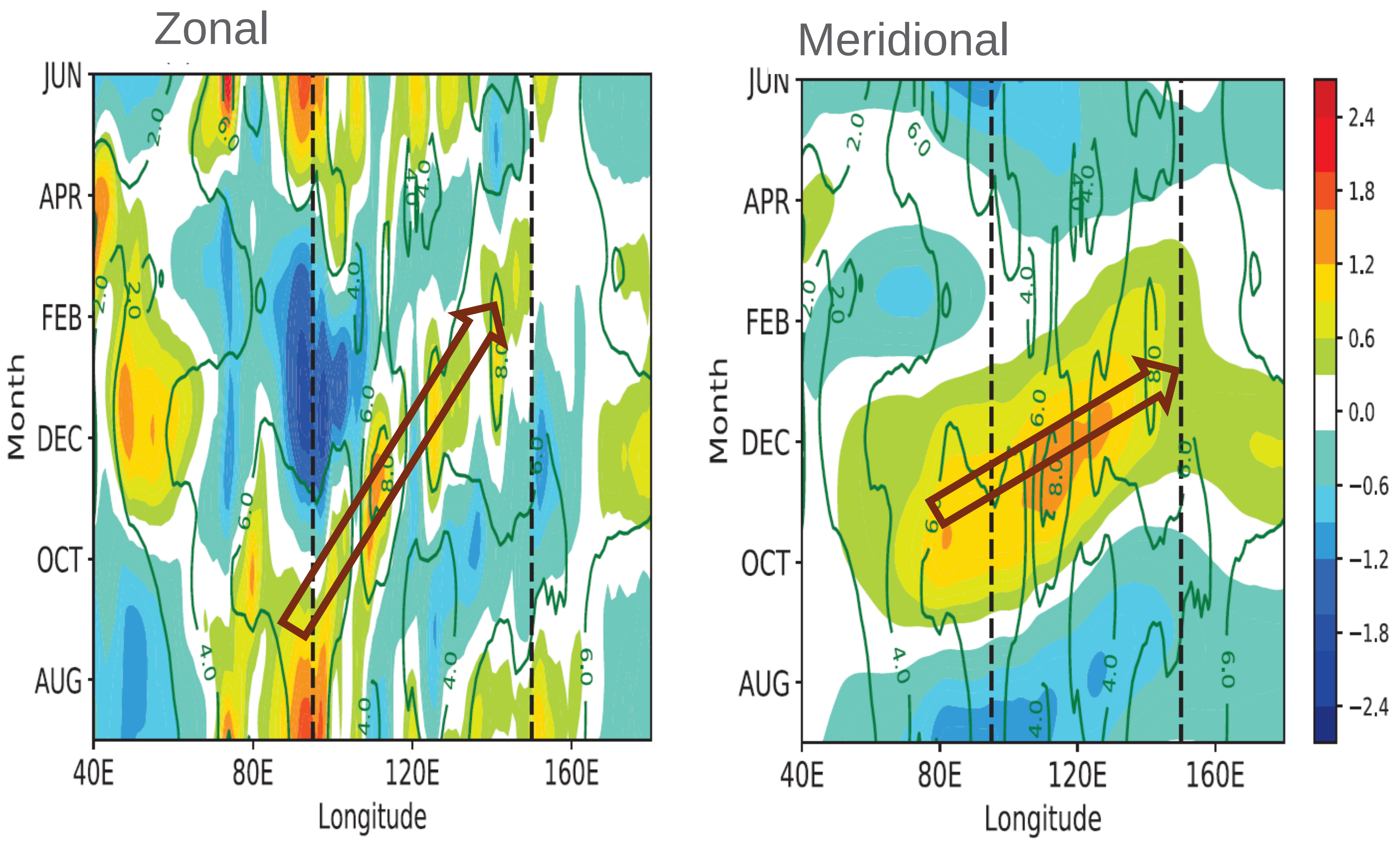


Moisture flux potential (shadings) and moisture flux vectors (arrows) calculated directly from 30 years of PERSIAN precipitation data



- El-Nino introduces divergence over the MC and convergence over the Western Pacific in winter.
- This effect is tilted poleward in summer.

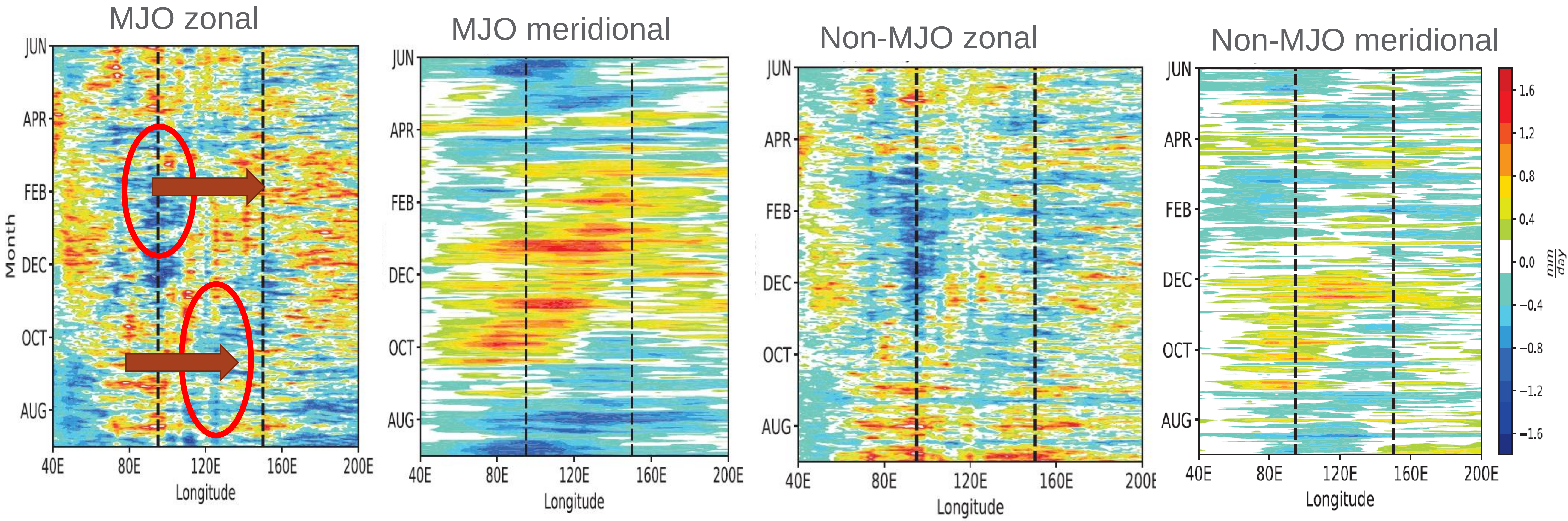
Seasonal cycle of moisture convergence



The seasonal cycles of the total zonal and meridonal components of moisture flux convergence (shadings) overlaid on precipitation (contours). All are averaged between 15S and 15N. The dashed lines mark the approximate boundary of the maritime continent region.

- Eastward migration of convergence is apparent in both the zonal and meridional components of moisture flux convergence.
- There is a sharp meridional gradient in the zonal component.

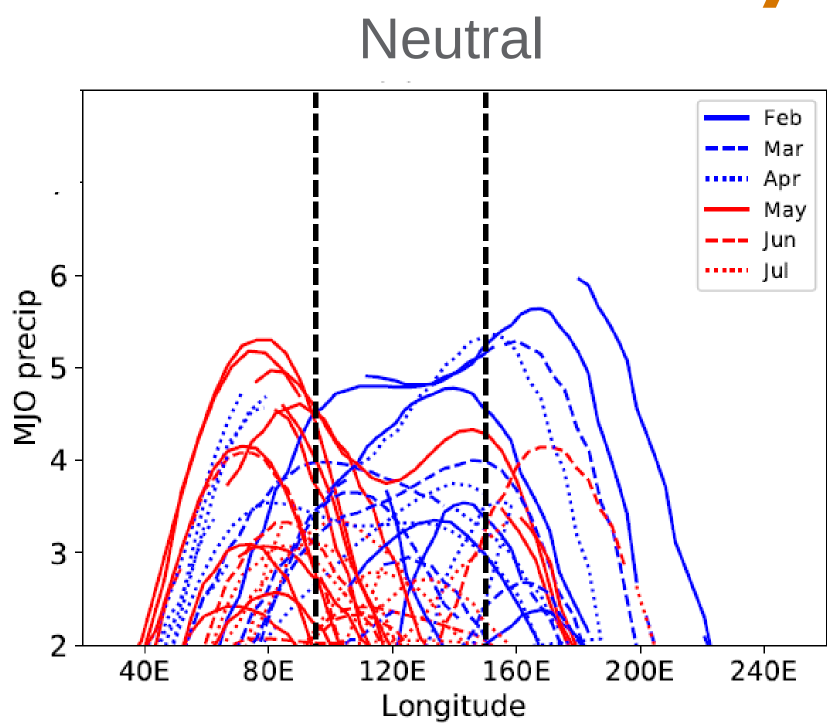
Moisture convergence for MJO and Non-MJO precipitation

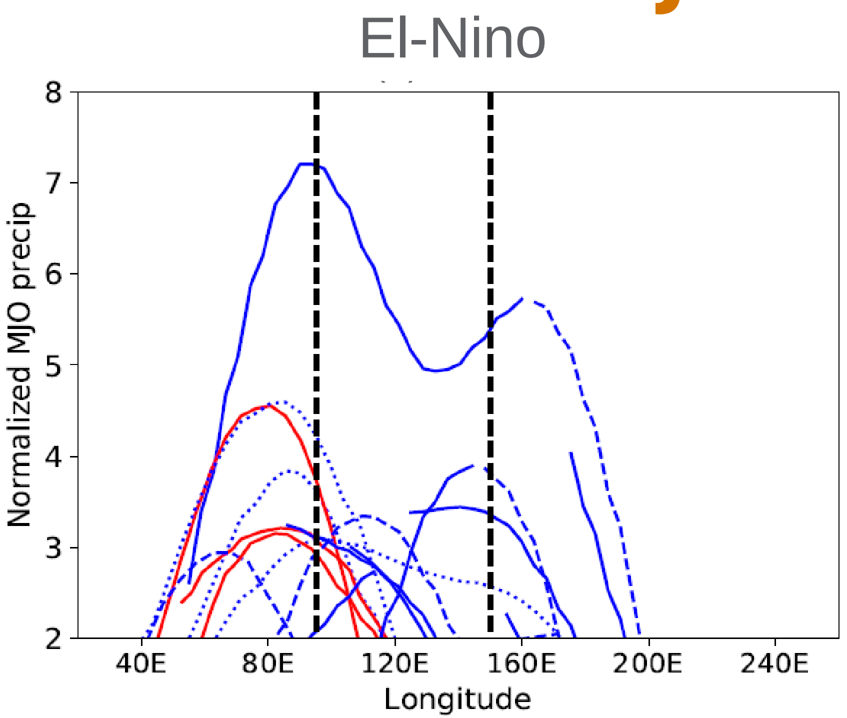


The seasonal cycles of the total zonal and meridonal components of moisture flux convergence only for when RMM amplitude is greater and less than 1.0

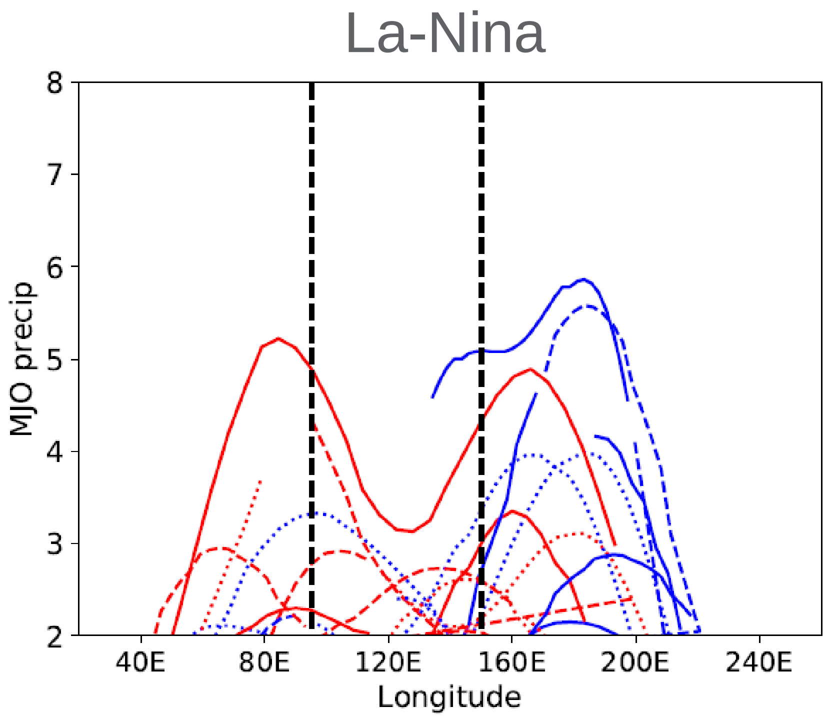
- MJO constitutes a large fraction of the seasonal cycle of moisture flux convergence.
- Much of the zonal contrast in MJO moisture convergence is in the zonal convergence.
- The seasonality is associated with meridional moisture convergence.

The seasonal cycle of strength of individual MJO events



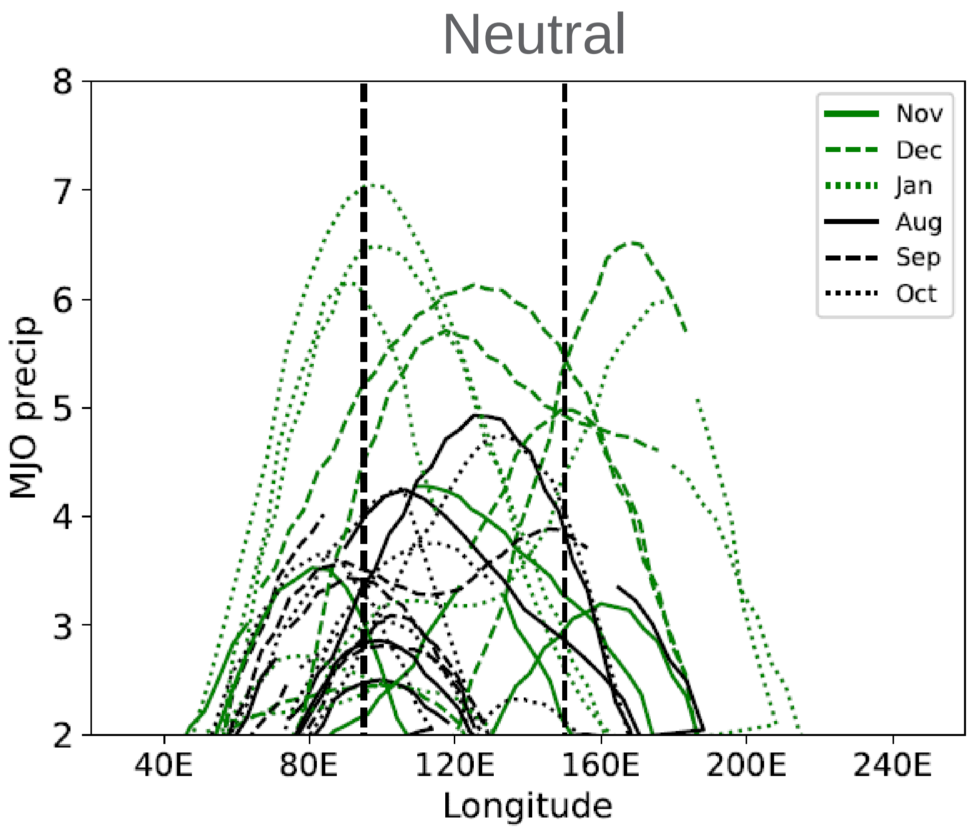


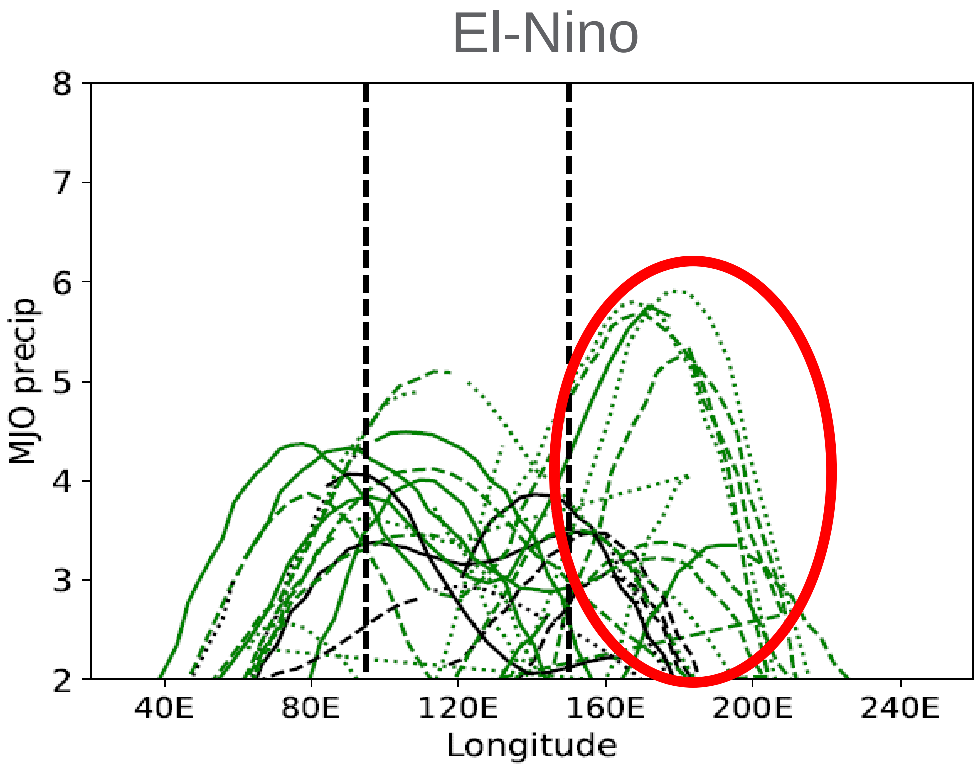
Evolution of ZL17 normalized precipitation index for individual MJO events during neutral, El-Nino and La-Nina years.

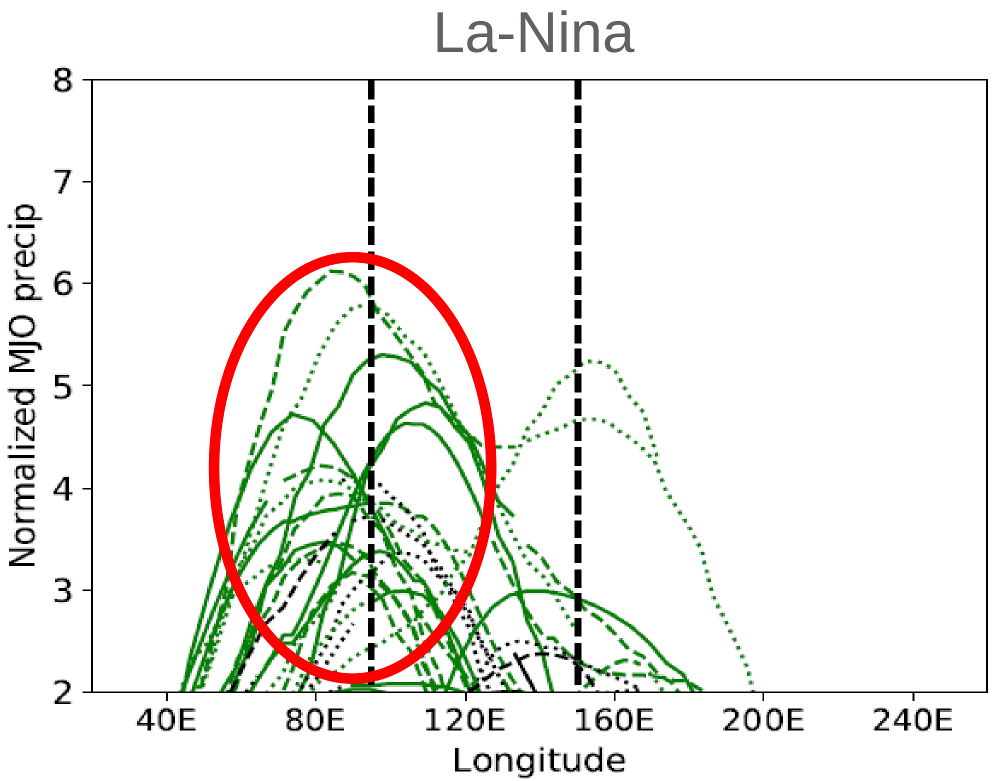


- February, March and April MJO events tend to start weak over eastern Indian Ocean and strengthen later as they propagate into the moisture convergence over western Pacific.
- During May, June and July, the moisture convergence patterns are reversed and MJO events weaken.

The seasonal cycle of strength of individual MJO events



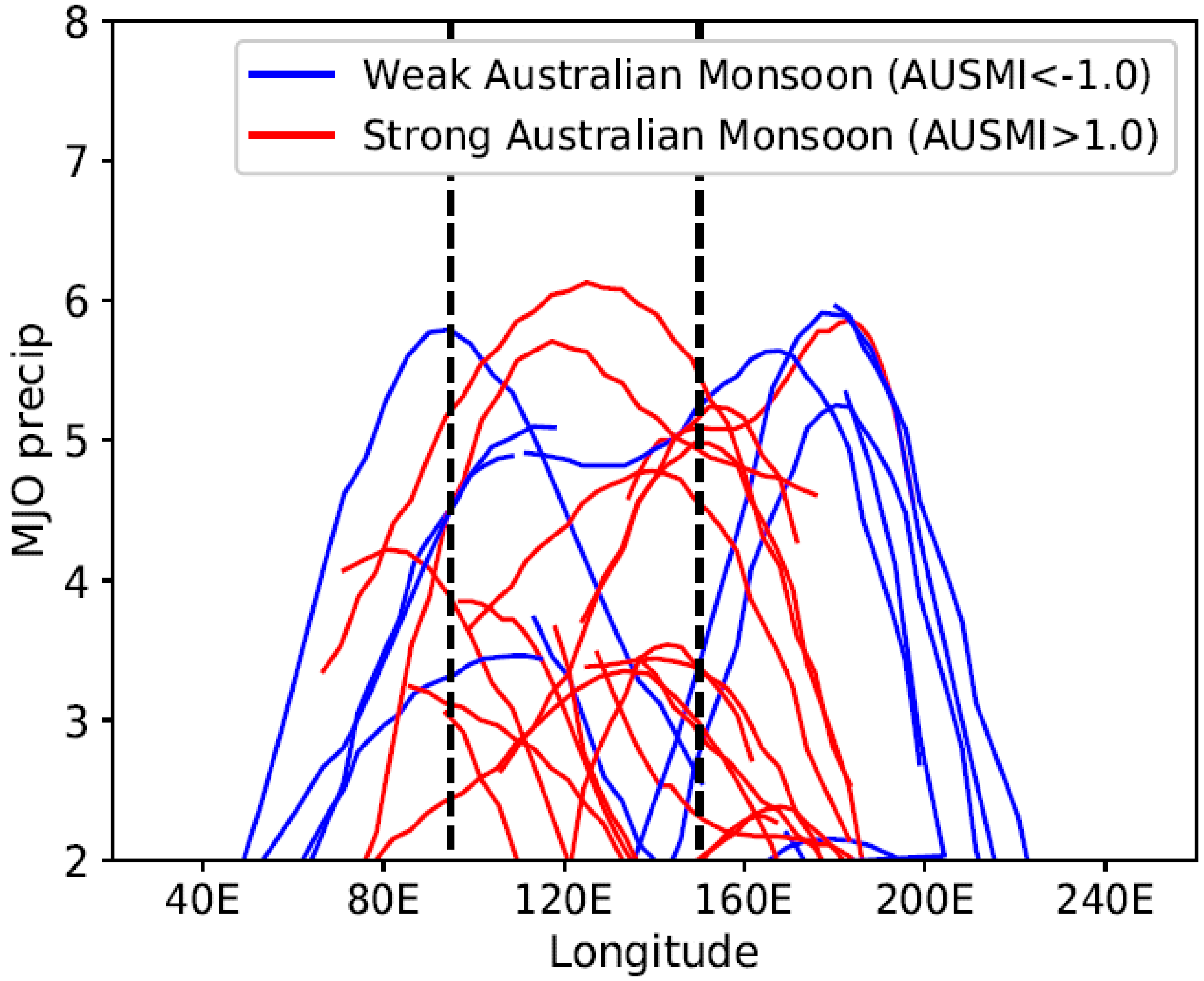




Evolution of ZL17 normalized precipitation index for individual MJO events during neutral, El-Nino and La-Nina years.

- Between August and January much of the variability is related to seasonal strengthening.
- El-Nino favors the strengthening of MJO events.

Relationship to Australian Monsoon Index



The strength of December, January and February MJO events during weak and strong Australian monsoon months represented by Austrialian Monsoon index of Kijikawa et al. (2010)

- During weak monsoon MJO precipitation peaks over on either end of the the MC region, while during active phase of the monsoon MJO events could be strongest over the MC region.

Summary

- A method of estimating the moisture fluxes associated with sustenance of the MJO strength directly from precipitation observation is introduced.
- February, March and April MJO events tend to start weak over eastern Indian Ocean and strengthen later as they propagate into the moisture convergence over western Pacific. During May, June and July, the moisture convergence patterns are reversed and MJO events weaken.
- Winter MJO events are most likely to be strongest over the middle of the MC region particularly when the Australian monsoon is strong.
- The zonal structure of moisture convergence along with the MJO propagation speed could modulate MJO predictability.