# Madden-Julian Oscillation: Recent Evolution, Current Status and Predictions

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# Outline

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Recent Evolution and Current Conditions

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# Overview

The emerging MJO signal across the Indian Ocean strengthened during the past week, with eastward propagation apparent.

Most dynamical models suggest that the MJO signal will continue during week-1, with some suggesting decay over the Maritime Continent late in week-2.

Enhanced tropical rainfall is likely across the Eastern Indian Ocean and Maritime Continent during the next two weeks. Tropical activity is favored across the Eastern Indian Ocean and Bay of Bengal, with an invest area currently near the Palk Strait bearing particular monitoring.

Extratropical impacts of the MJO on the U.S. are anticipated to be negligible, given the typically weak teleconnections during this time of year.

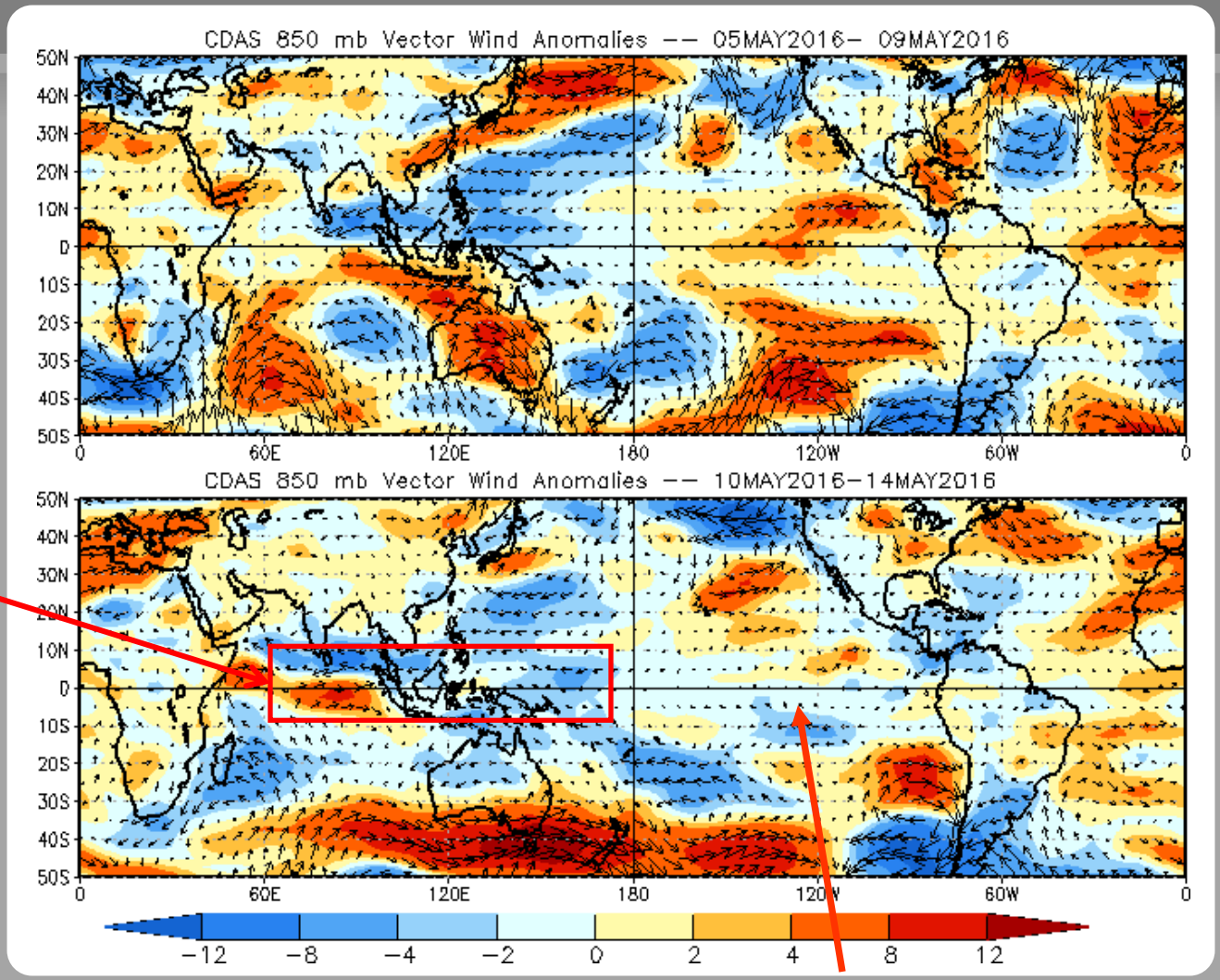
**Additional potential impacts across the global tropics and a discussion for the U.S. are available at:**
**http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php**

# 850-hPa Vector Wind Anomalies (m s-1)

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies




Westerly (easterly) anomalies have developed across the Indian Ocean (Western Pacific) associated with a growing MJO signal.

Weak anomalies are evident from near 160 W to the South American coast.

# 850-hPa Zonal Wind Anomalies (m s-1)

**Westerly anomalies (orange/red shading) represent anomalous west-to-east flow**

**Easterly anomalies (blue shading) represent anomalous east-to-west flow**

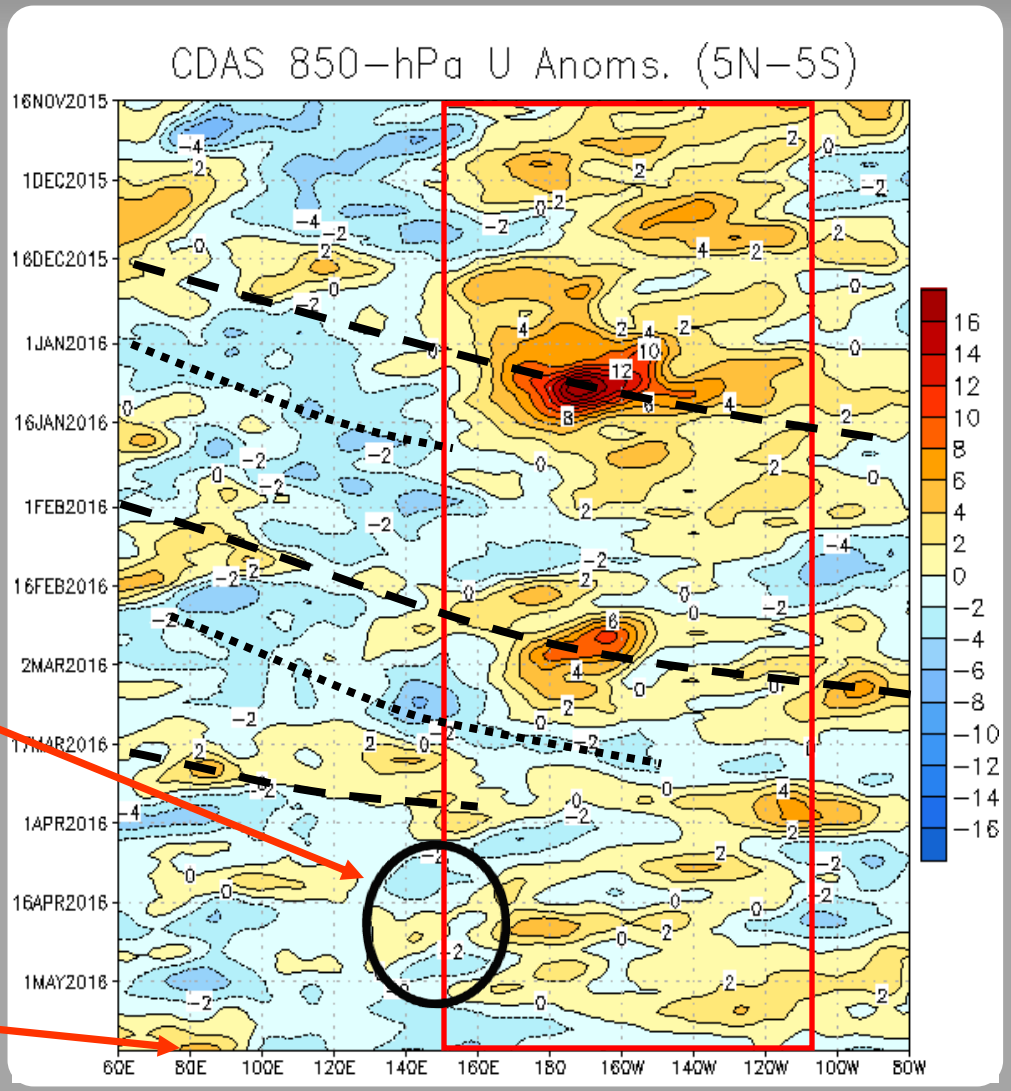
The red box highlights the persistent low-frequency westerly wind anomalies associated with ENSO.

The MJO was most coherent and robust during December 2015 and this past February.

During March, a fast eastward propagating intraseasonal signal crossed the Pacific.

During April, the pattern included more high frequency variability including an equatorial Rossby Wave activity (ERW) that shifted westward from near the Date Line to 130 E. During the last 2-3 weeks, easterlies prevailed over the Maritime Continent.

Low-level westerlies have emerged across much of the Indian Ocean during the past week.



# OLR Anomalies – Past 30 days

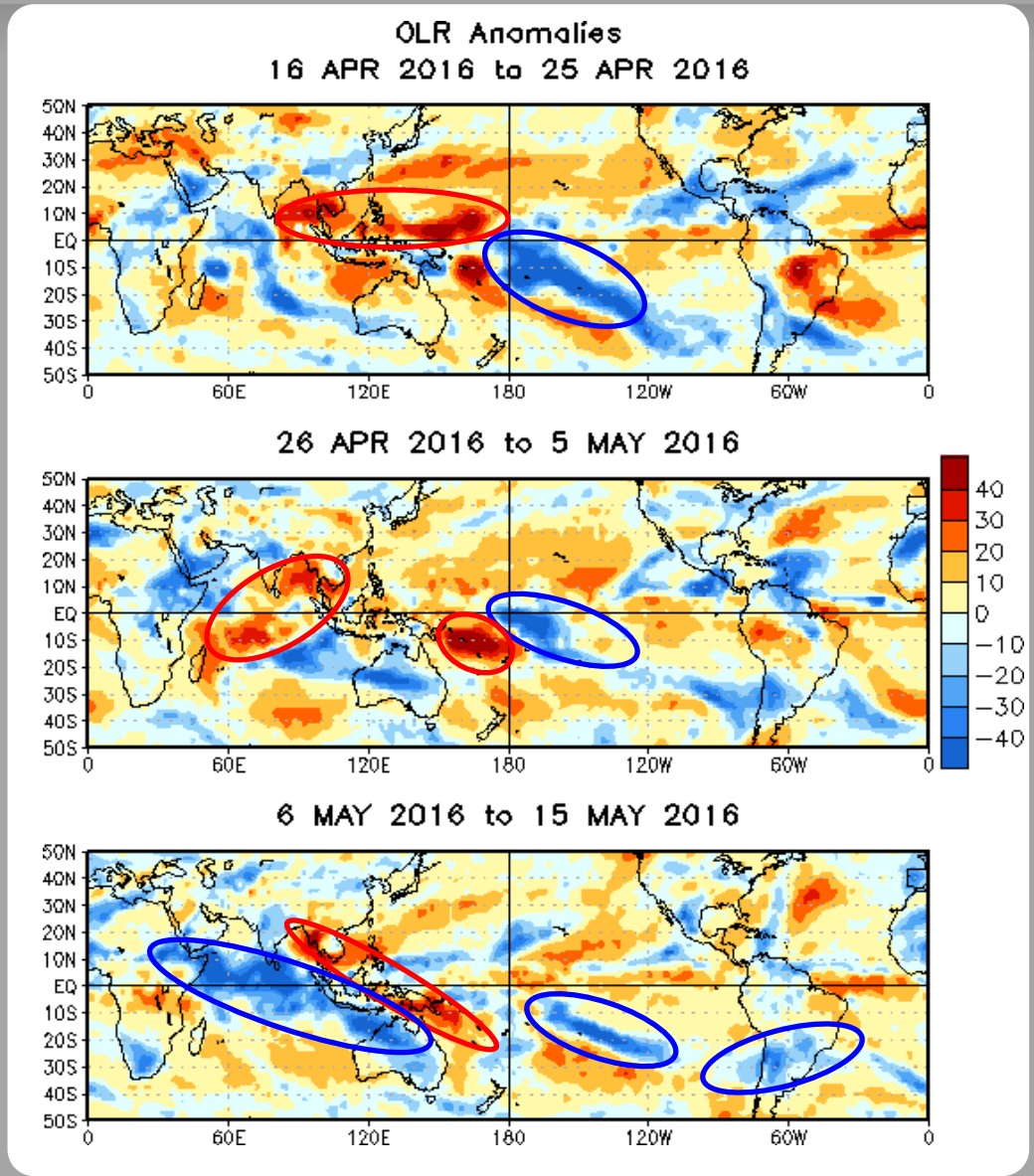
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

Wetter-than-normal conditions, negative OLR anomalies (blue shading)

During mid-April, suppressed convection spread from the eastern Indian Ocean to the Western Pacific, while enhanced convection remained over the SPCZ.

During late April to early May, suppressed convection remained over the eastern Indian Ocean, while the signal became more mixed over the Maritime Continent. SPCZ convection waned.

During early to mid-May, enhanced convection filled in over the Indian Ocean, while generally suppressed convection developed over the eastern Pacific. Some convection remained over the South Pacific.



# Outgoing Longwave Radiation (OLR) Anomalies (7.5°S - 7.5°N)

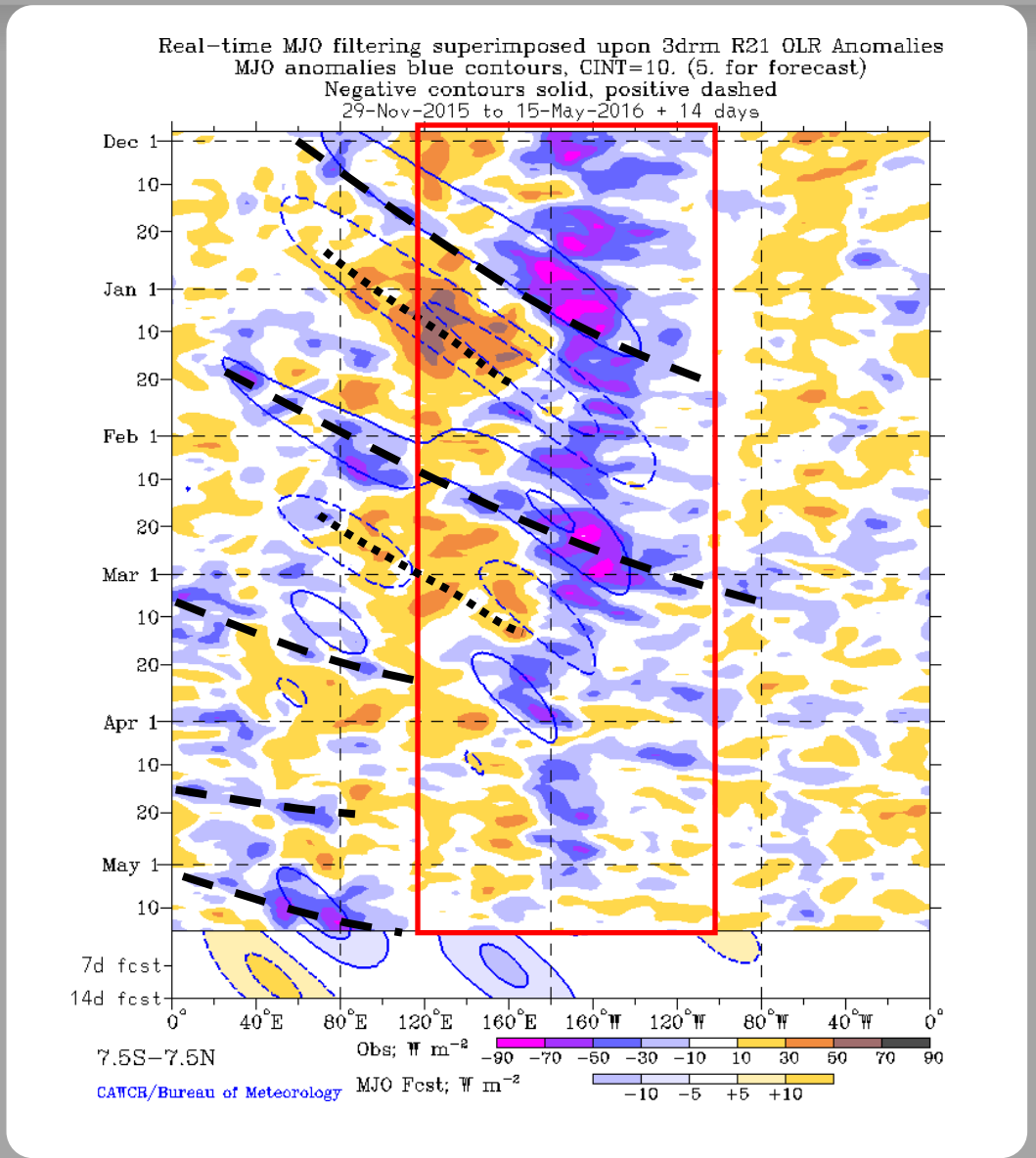
**Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)**

**Wetter-than-normal conditions, negative OLR anomalies (blue shading)**

The ongoing El Niño is observed (red box) as a dipole of anomalous convection extending from the Maritime Continent to the East Pacific.

Alternating periods of constructive/destructive interference with ENSO is evident. A fast eastward propagating signal raced across the Pacific during mid-March.

Since early May an eastward-propagating convective envelope associated with the nascent MJO has developed east of the Prime Meridian. Substantial negative OLR anomalies occurred across the Indian Ocean over the previous week.



# 200-hPa Velocity Potential Anomalies (5°S - 5°N)

**Positive anomalies (brown shading) indicate unfavorable conditions for precipitation**

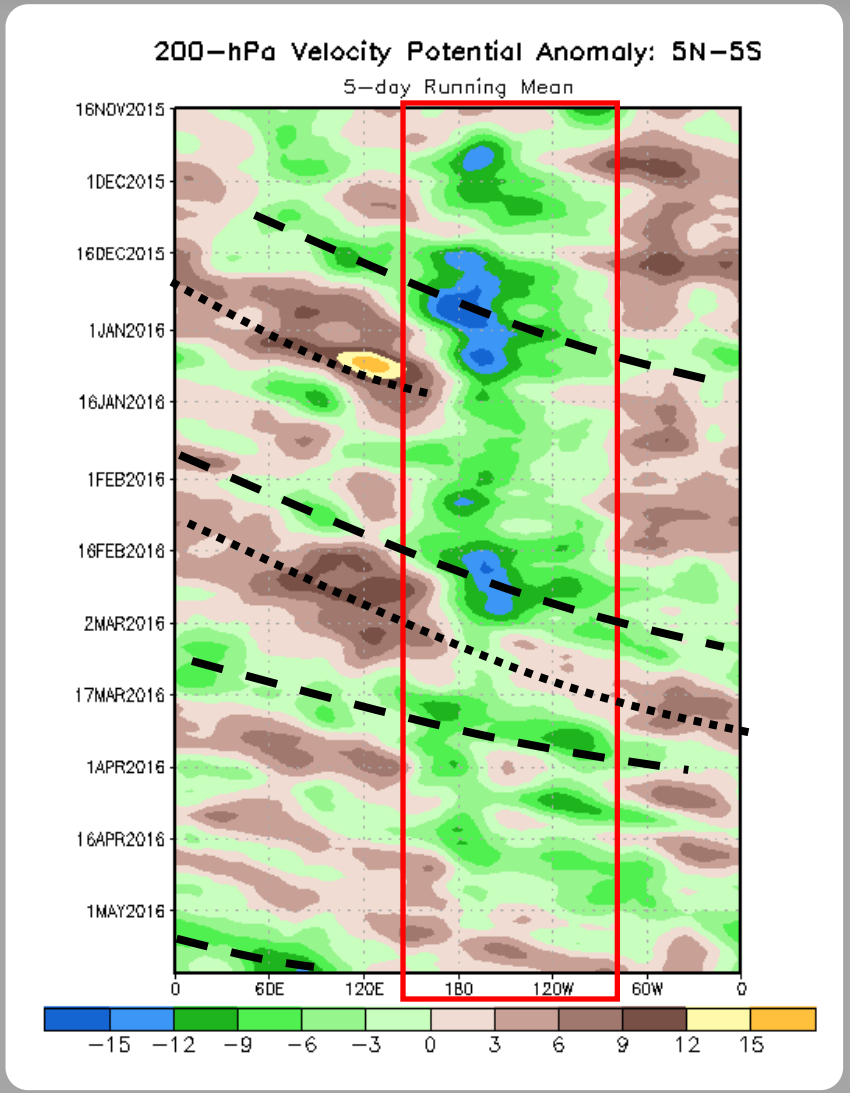
**Negative anomalies (green shading) indicate favorable conditions for precipitation**

The ongoing ENSO state is highlighted by the red box, showing anomalous divergence over the central and eastern Pacific.

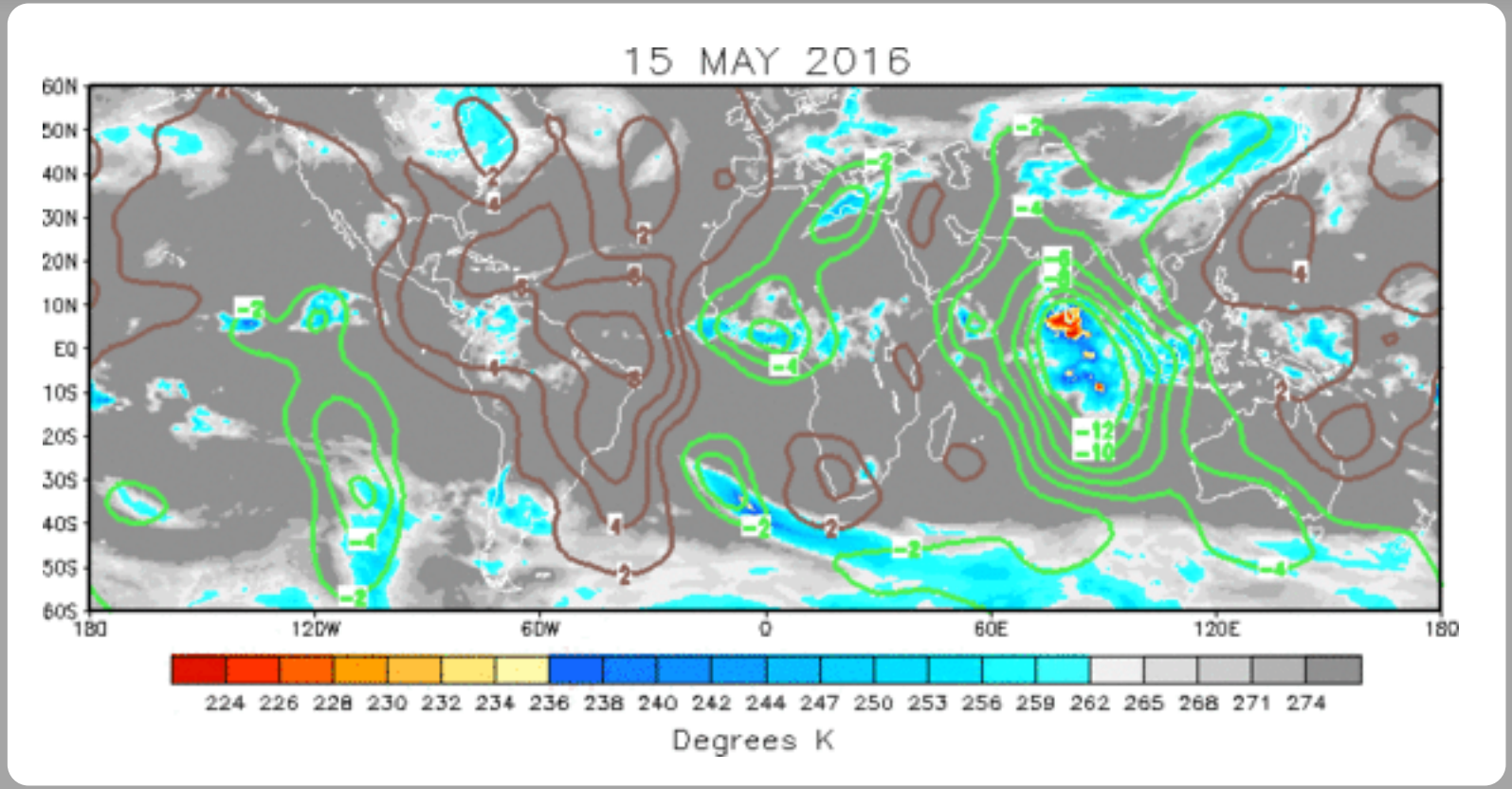
During late February, intraseasonal variability constructively interfered with the ongoing El Nino. During mid-March, the intraseasonal variability destructively interfered with the ENSO signal.

In April, the pattern in upper-level velocity potential anomalies is incoherent with respect to MJO activity, and more reflective of other modes of tropical variability.

During the past 1-2 weeks, an area of upper-level divergence has moved into the region between the Prime Meridian and 160E associated with the MJO. Upper-level convergence is noted between 160E and 90W.



# IR Temperatures (K) / 200-hPa Velocity Potential Anomalies




With the exception of the Americas, the large scale upper-level velocity potential anomaly pattern indicates a wave-2 structure, with upper-level divergence (convergence) eastward from about 30W to 100E (120E to 30W). The upper-level divergence in the East-central Pacific is tied to a passing Kelvin Wave.

| |
|---|
| Positive anomalies (brown contours) indicate unfavorable conditions for precipitation |
| Negative anomalies (green contours) indicate favorable conditions for precipitation |

# 200-hPa Vector Wind Anomalies (m s-1)

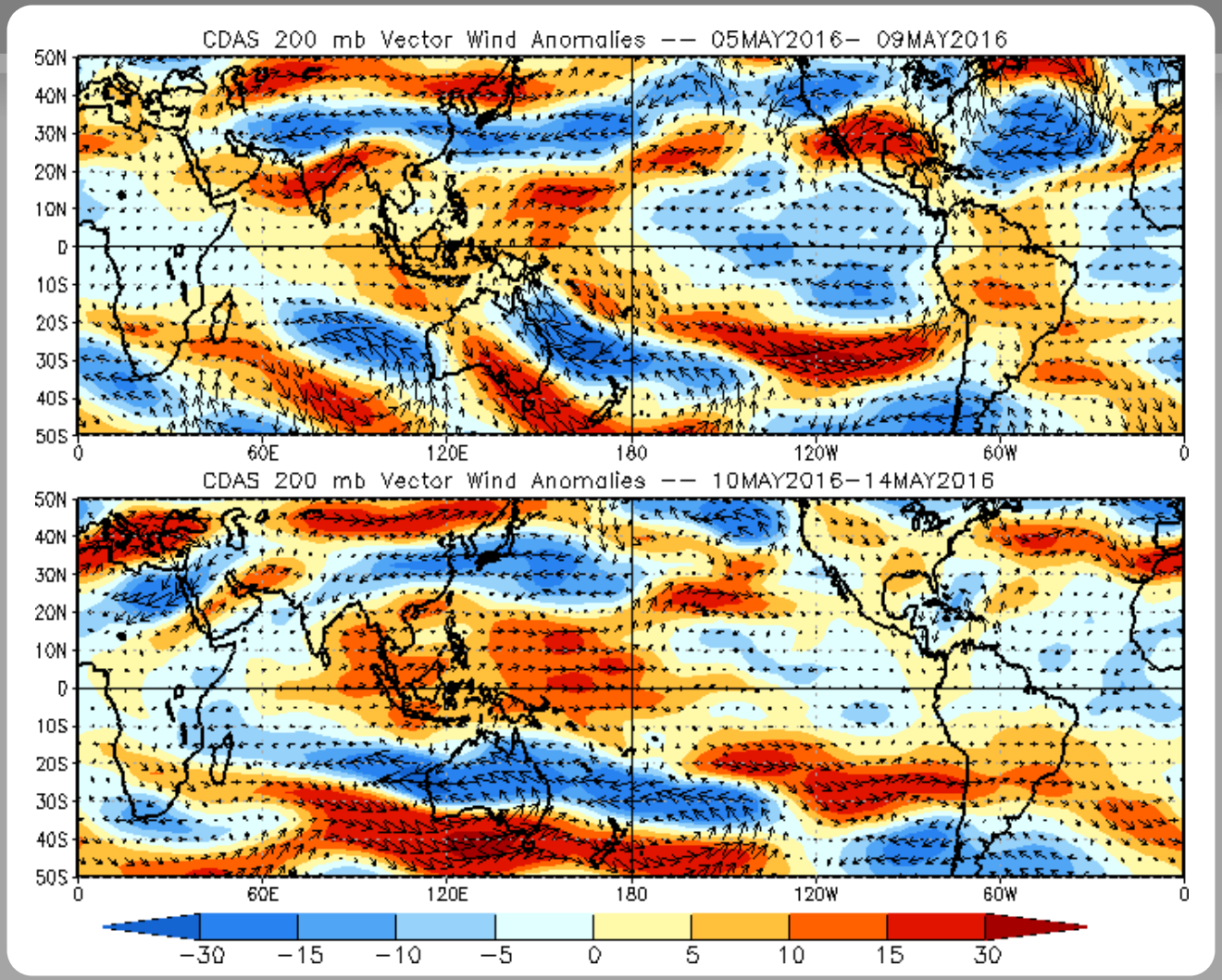
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Anomalous anticyclones remain apparent in the Pacific associated with the decaying El Nino event, but have weakened and become less aligned over the past week.

Westerly anomalies now extend across the entirety of the equatorial Indian Ocean through the Central Pacific.



# 200-hPa Zonal Wind Anomalies (m s-1)

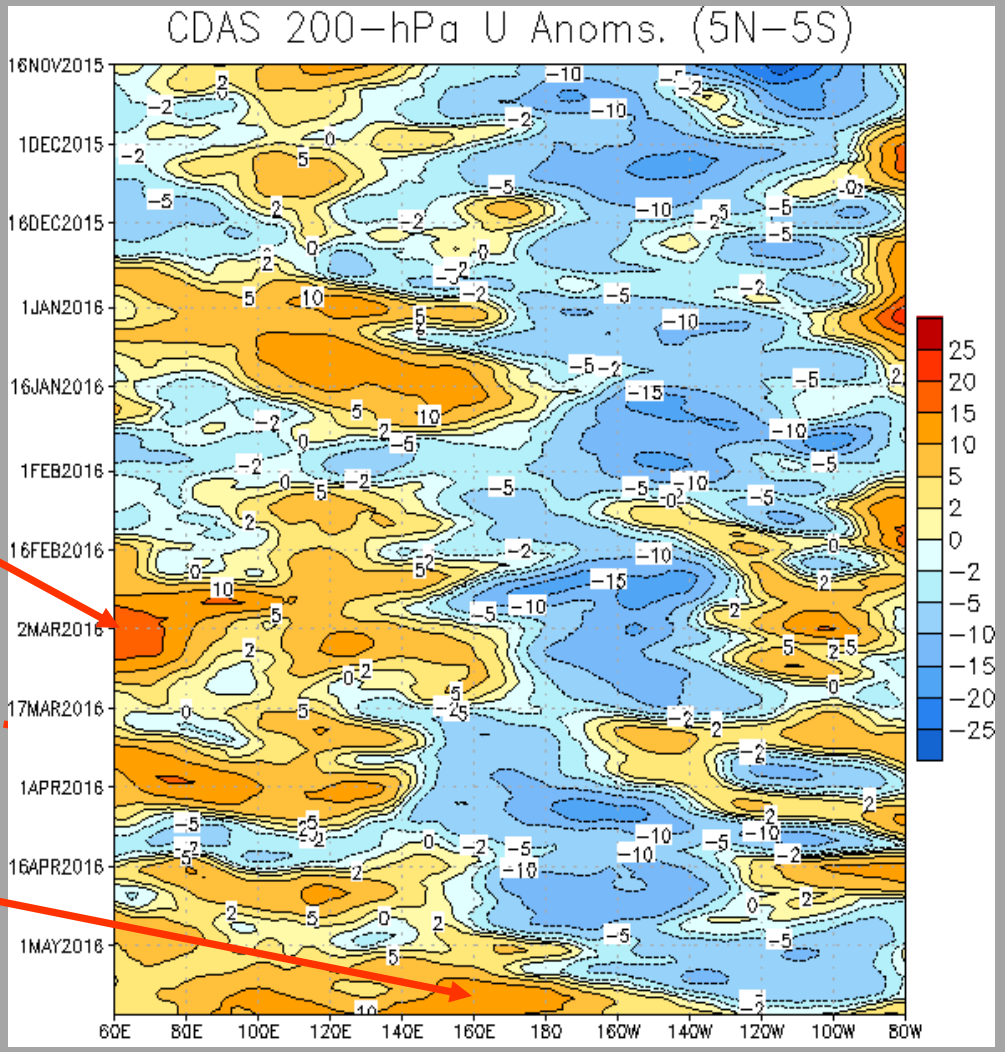
**Westerly anomalies (orange/red shading) represent anomalous west-to-east flow**

**Easterly anomalies (blue shading) represent anomalous east-to-west flow**

Easterly anomalies have persisted over the central and eastern Pacific since June 2015 associated with El Niño (red box).

During early March, westerly anomalies returned to the Indian Ocean and Maritime Continent, with easterly anomalies between about 170E - 120W.

Since mid April, westerly anomalies weakened and then re-strengthened over the Indian Ocean & Maritime Continent. These westerlies now extend through the Central Pacific. Easterly anomalies remain only east of 130W.



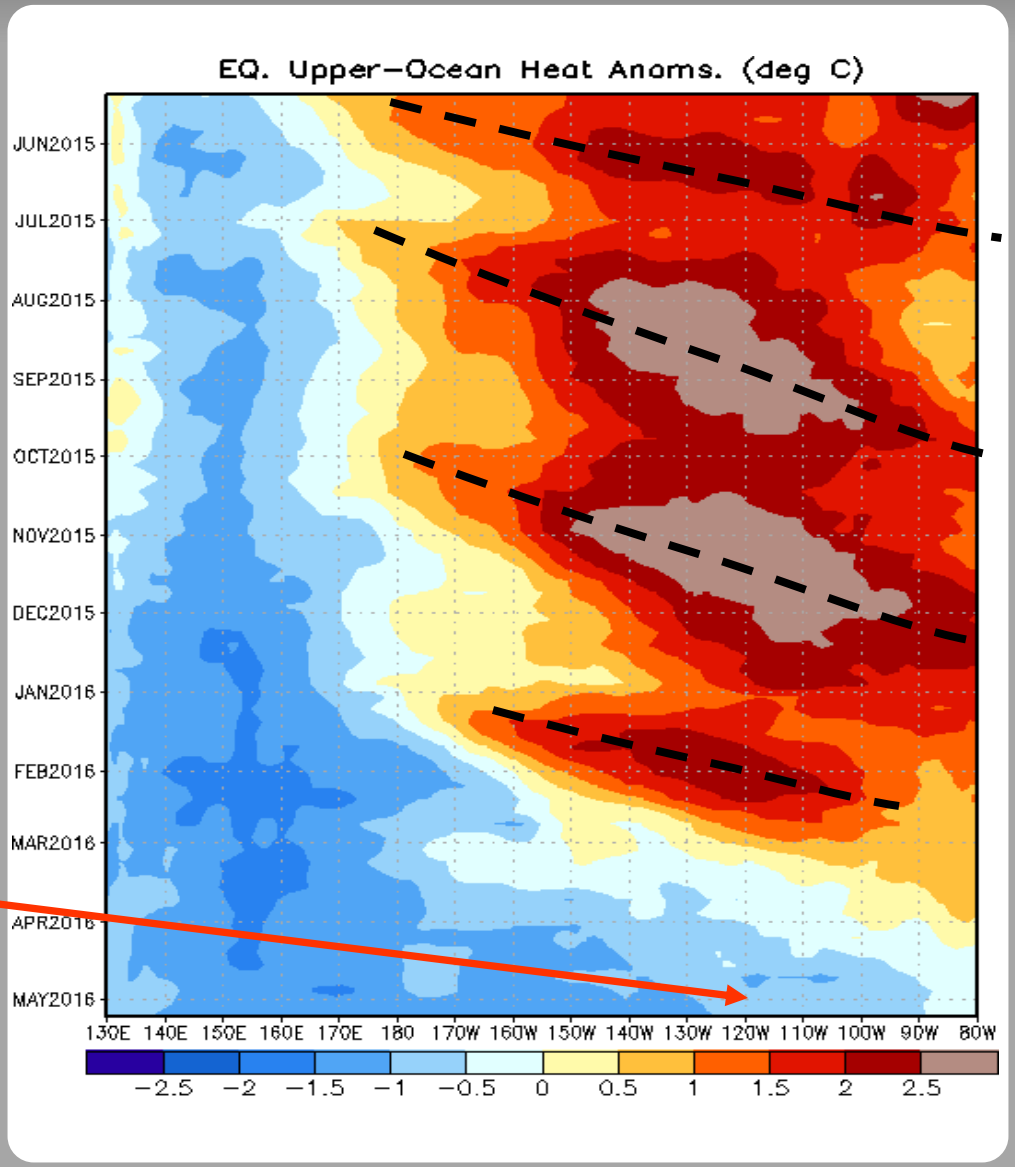
# Weekly Heat Content Evolution in the Equatorial Pacific

**Oceanic Kelvin waves have alternating warm and cold phases. The warm phase is indicated by dashed lines. Downwelling and warming occur in the leading portion of a Kelvin wave, and upwelling and cooling occur in the trailing portion.**

Reinforcing downwelling events were observed during the second half of 2015, resulting in persistently above-normal heat content from the Date Line to 80W throughout the period.

An eastward expansion of below average heat content over the western Pacific is evident since January, with negative anomalies beginning to spread east of the Date Line during this month.

In the last two months, there has been a rapid eastward expansion of below-average oceanic heat content across the central and eastern Pacific. Negative anomalies now extend across the entire equatorial Pacific.



# MJO Index -- Information

The MJO index illustrated on the next several slides is the CPC version of the Wheeler and Hendon index (2004, hereafter WH2004).

Wheeler M. and H. Hendon, 2004: An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction, *Monthly Weather Review*, 132, 1917-1932.

The methodology is very similar to that described in WH2004 but does not include the linear removal of ENSO variability associated with a sea surface temperature index. The methodology is consistent with that outlined by the U.S. CLIVAR MJO Working Group.

Gottschalck et al. 2010: A Framework for Assessing Operational Madden-Julian Oscillation Forecasts: A CLIVAR MJO Working Group Project, *Bull. Amer. Met. Soc.*, 91, 1247-1258.

The index is based on a combined Empirical Orthogonal Function (EOF) analysis using fields of near-equatorially-averaged 850-hPa and 200-hPa zonal wind and outgoing longwave radiation (OLR).

# MJO Index – Recent Evolution

**The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes**

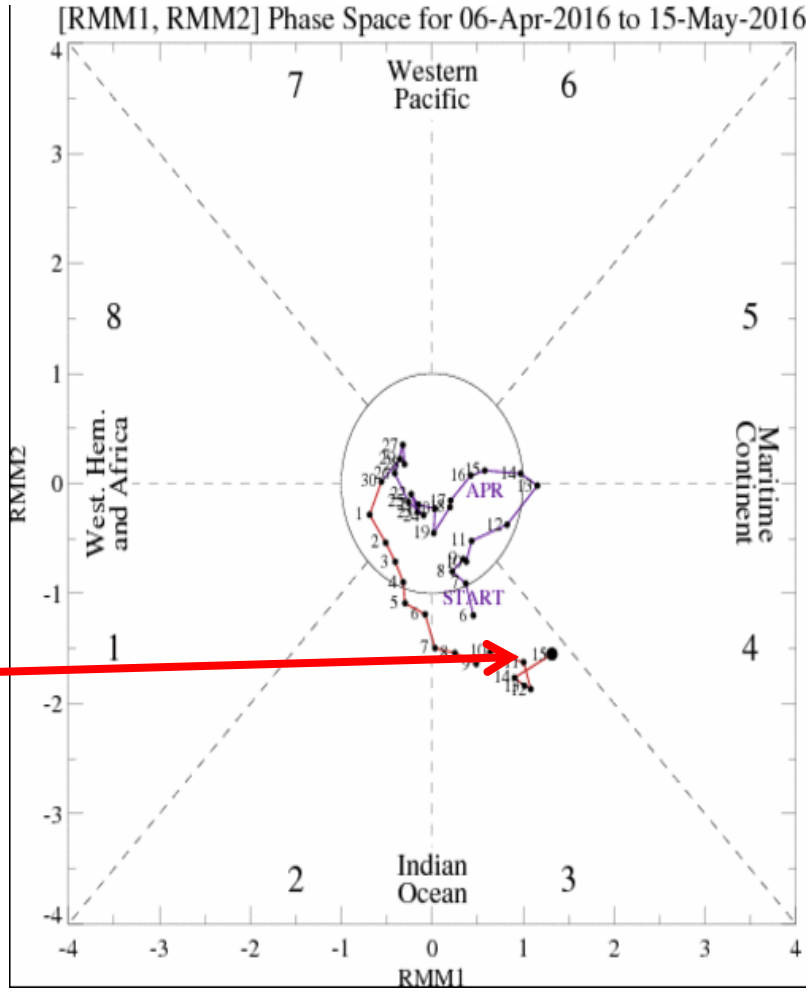
**The triangular areas indicate the location of the enhanced phase of the MJO**

**Counter-clockwise motion is indicative of eastward propagation. Large dot most recent observation.**

**Distance from the origin is proportional to MJO strength**

**Line colors distinguish different months**

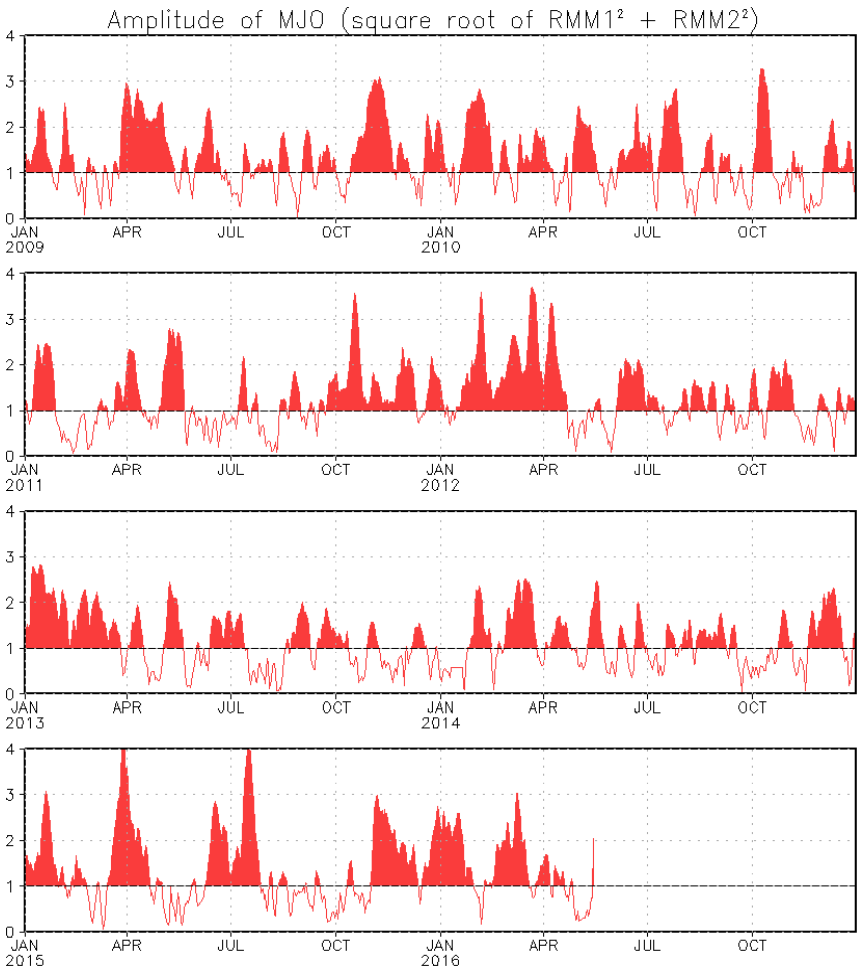
A strong MJO signal continues to persist across the eastern Indian Ocean. Eastward propagation was apparent over the past week, however during the latter half of the week the signal became stagnant, related to interference from other modes of variability and a somewhat noisy pattern.



# MJO Index - Historical Daily Time Series

**Time series of daily MJO index amplitude for the last few years.**

**Plot puts current MJO activity in recent historical context.**



# Ensemble GFS (GEFS) MJO Forecast

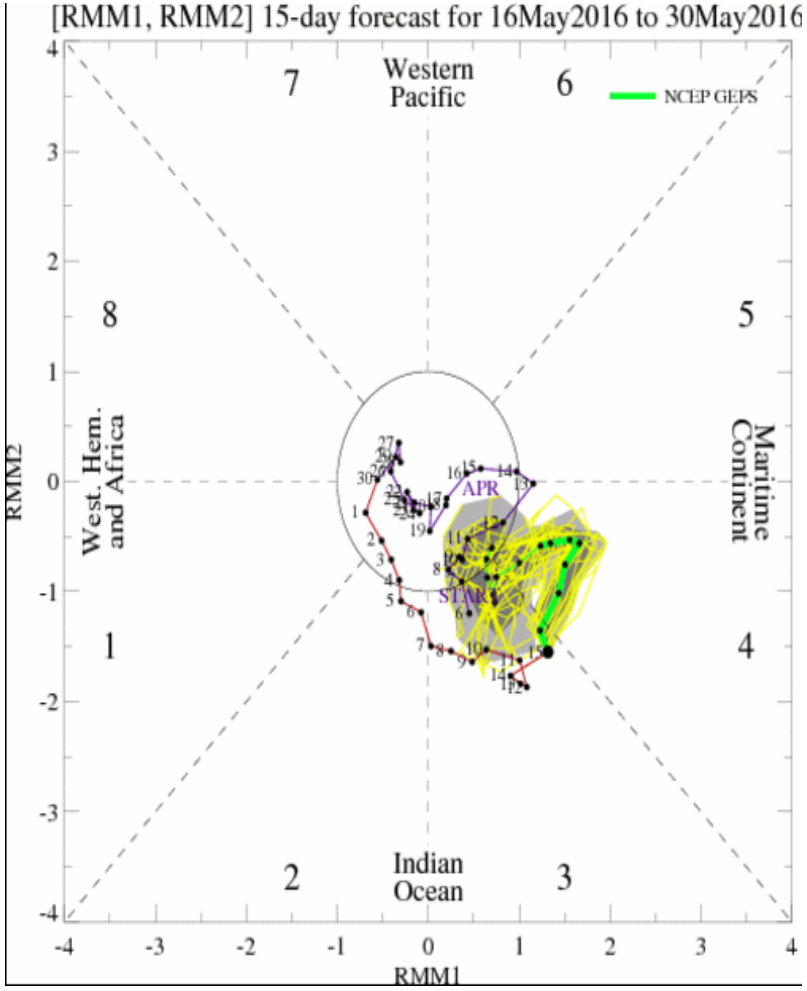
**Yellow Lines** - 20 Individual Members
**Green Line** - Ensemble Mean

**RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days**

**light gray shading: 90% of forecasts**

**dark gray shading: 50% of forecasts**

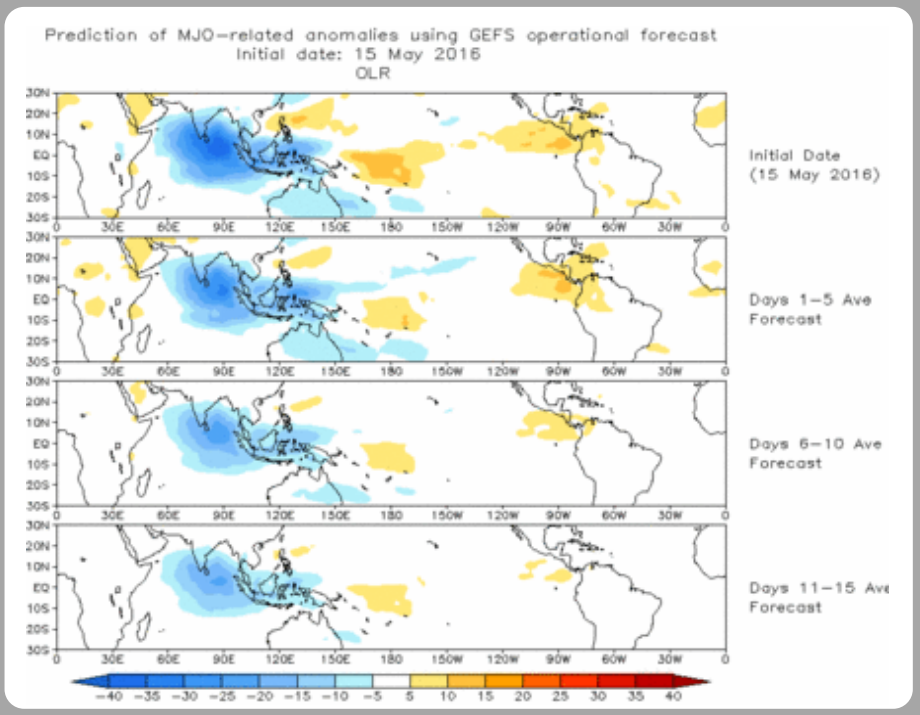
During the next two weeks, the GFS ensemble MJO index forecast depicts the continued eastward propagation of a robust MJO signal towards the Maritime Continent.



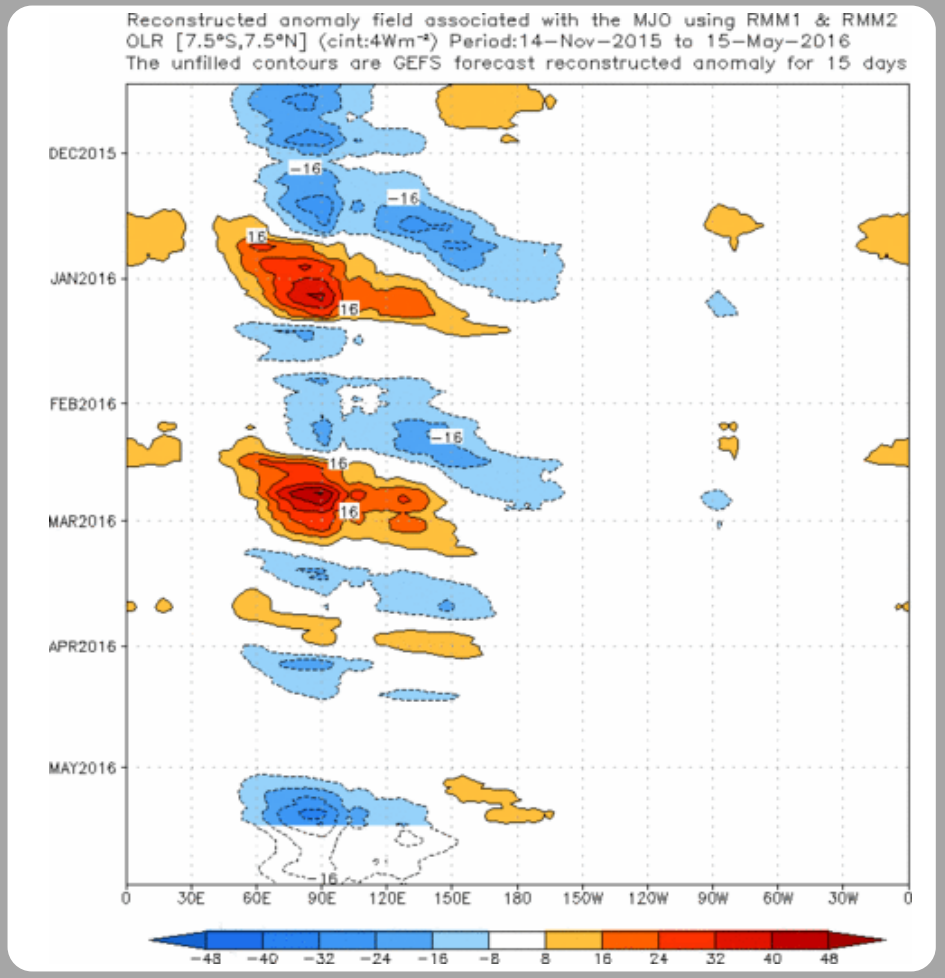
# Ensemble GFS (GEFS) MJO Forecast

**Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)**

Spatial map of OLR anomalies for the next 15 days




Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days

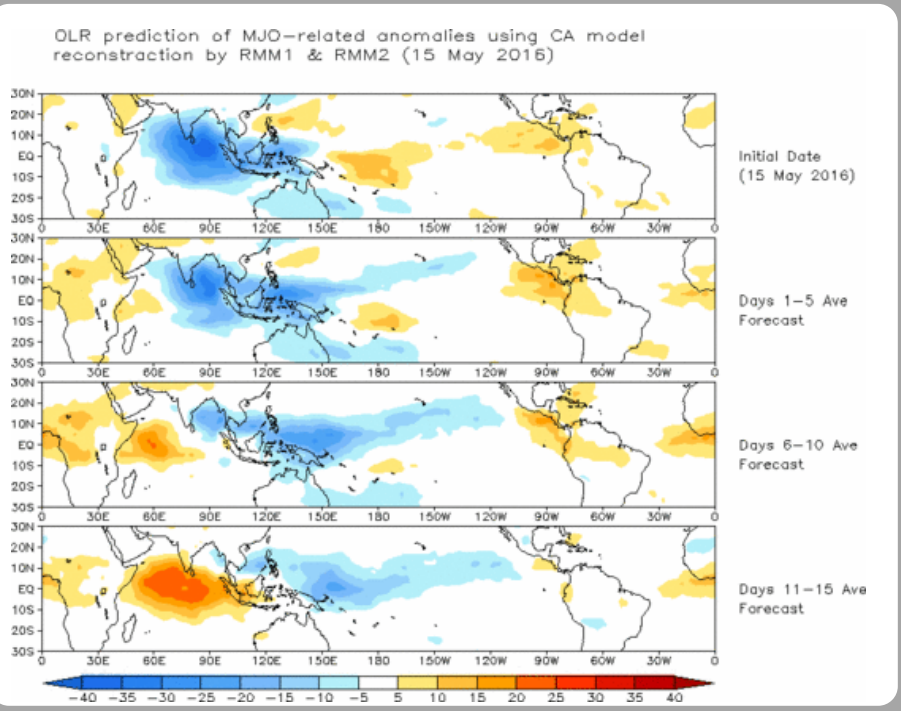



The GEFS OLR forecast based on the RMM Index depicts a slow eastward propagation over the next two weeks with the enhanced (suppressed) phase over the Indian Ocean and Maritime Continent (Date Line vicinity and the Americas).

# Constructed Analog (CA) MJO Forecast

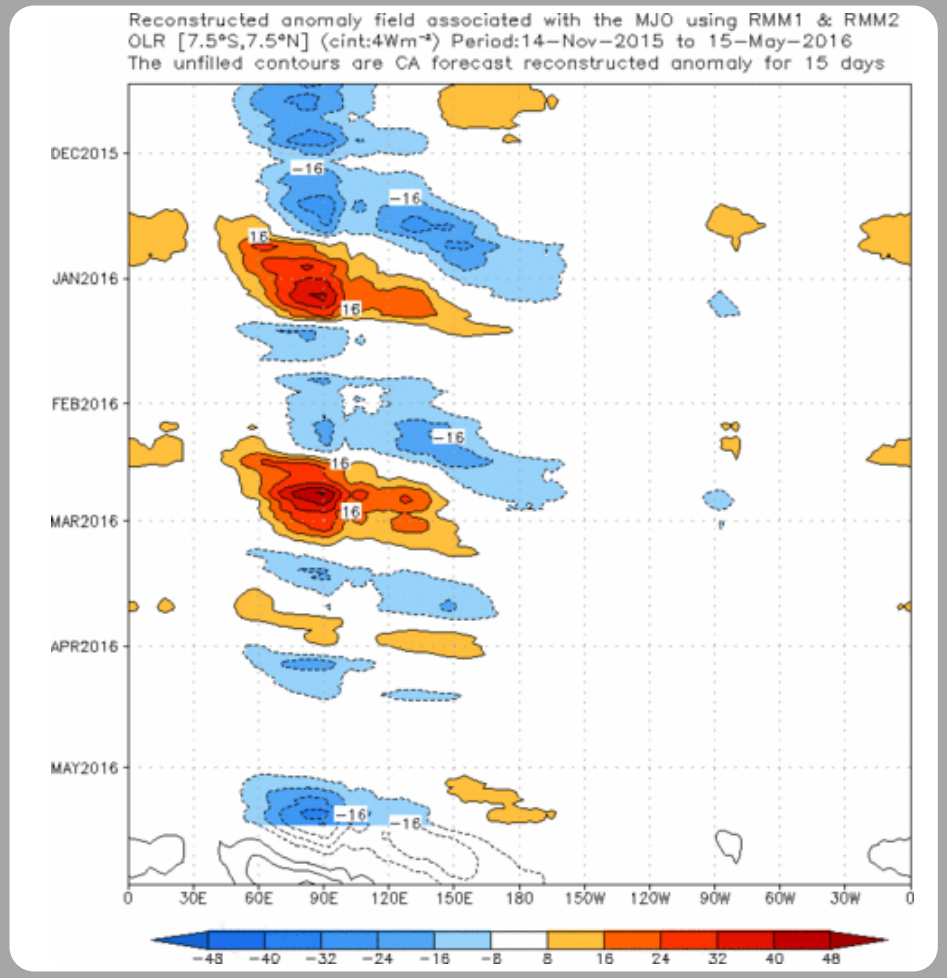
**Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)**

**Spatial map of OLR anomalies for the next 15 days**



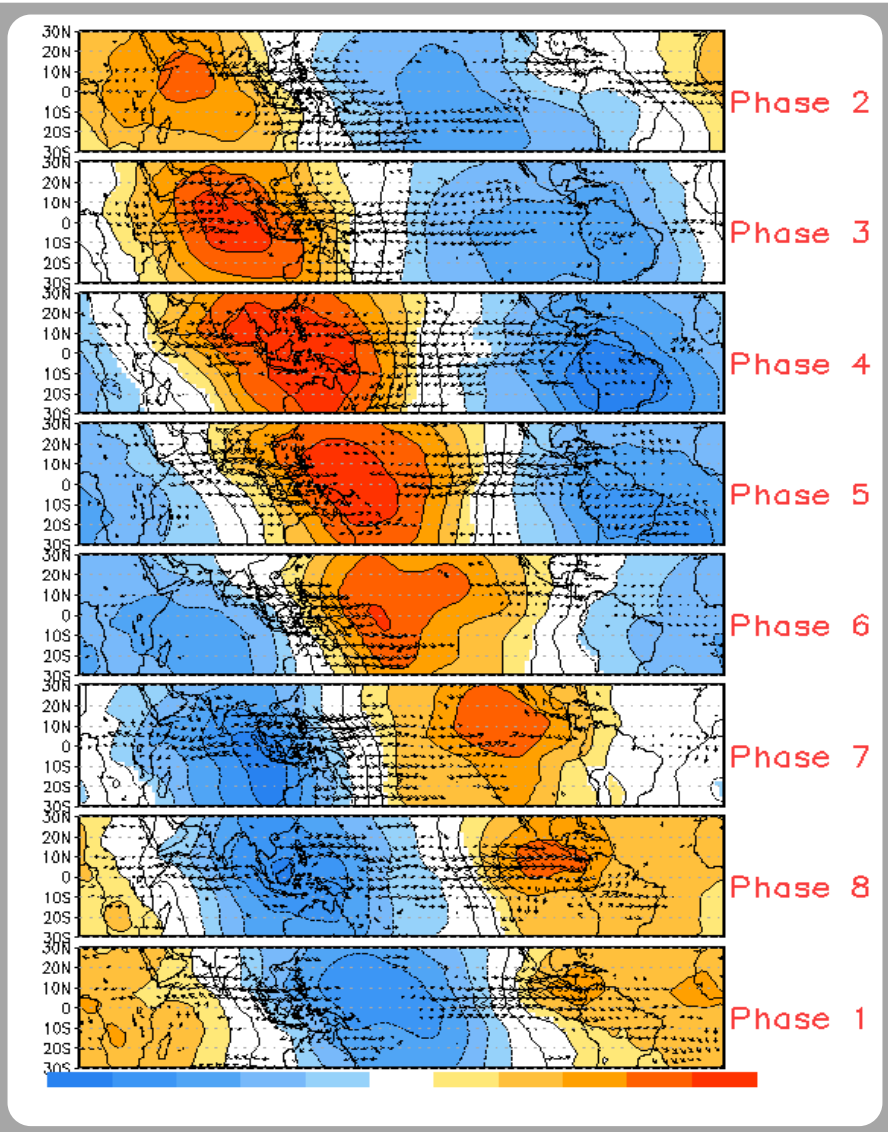

The Constructed Analog (CA) model predicts a weakening and eastward propagating intraseasonal signal during the next two weeks with suppressed convection developing across the Indian Ocean.

**Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days**

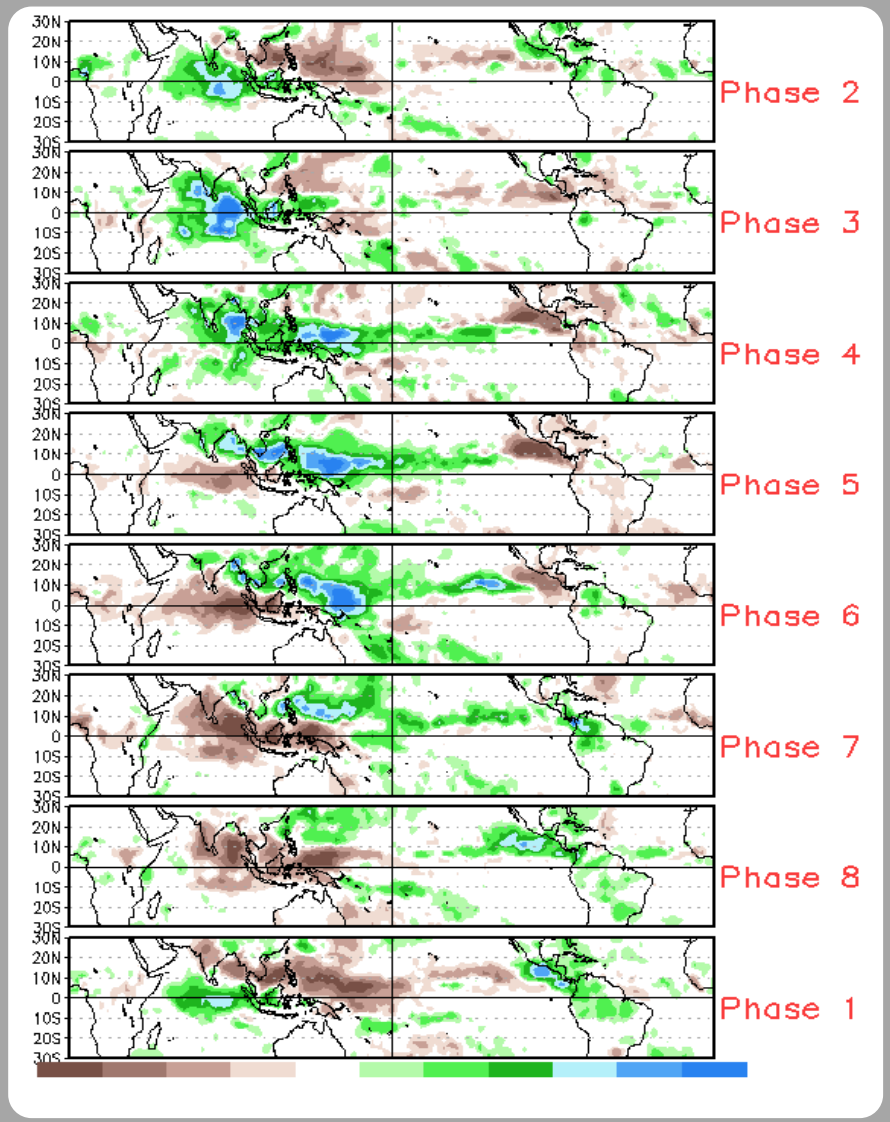


# MJO Composites - Global Tropics

**850-hPa Velocity Potential and Wind Anomalies (May - Sep)**



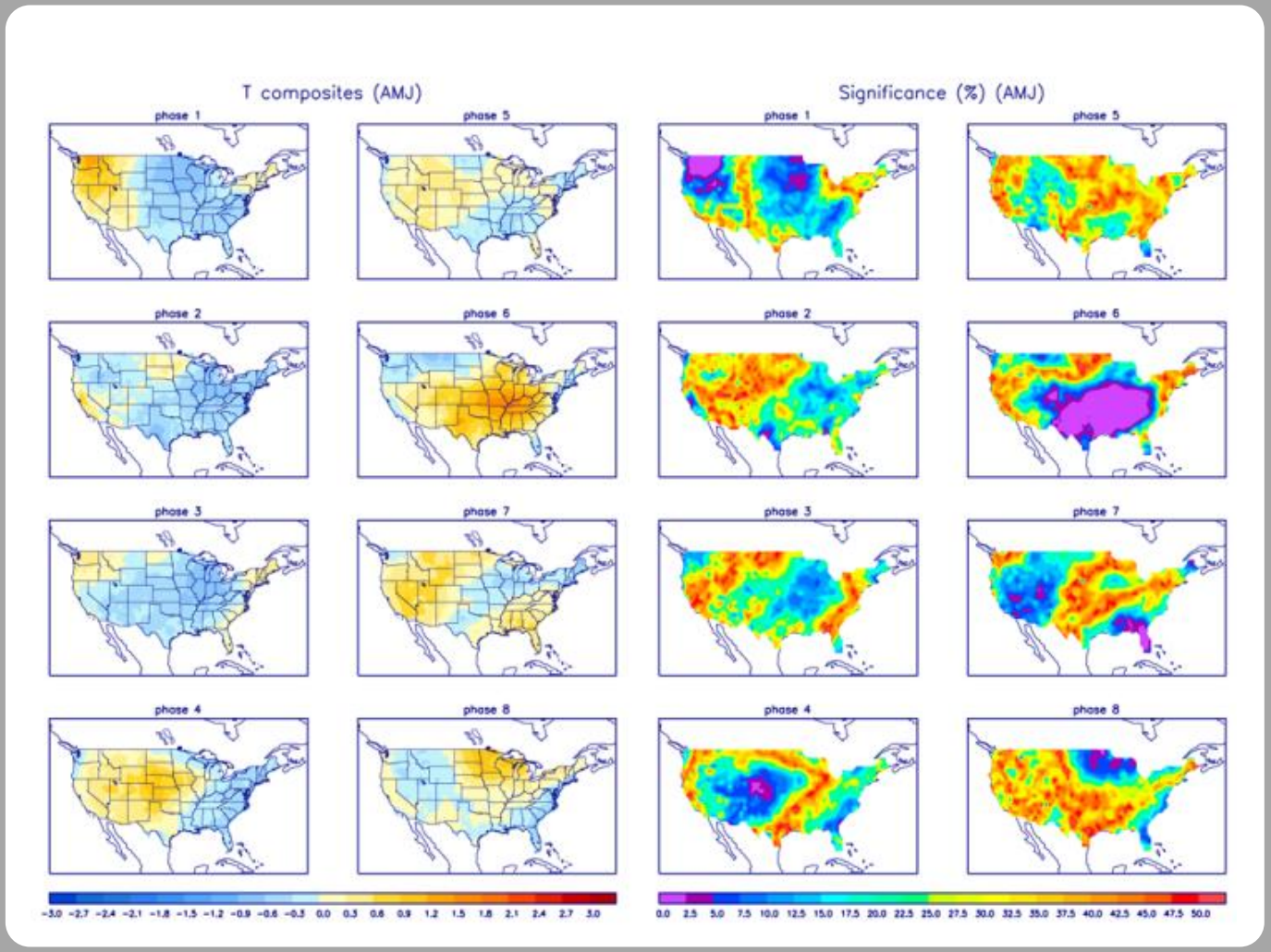

**Precipitation Anomalies (May - Sep)**



# U.S. MJO Composites – Temperature

**Left hand side plots show temperature anomalies by MJO phase for MJO events that have occurred over the three month period in the historical record. Blue (orange) shades show negative (positive) anomalies respectively.**

**Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.**



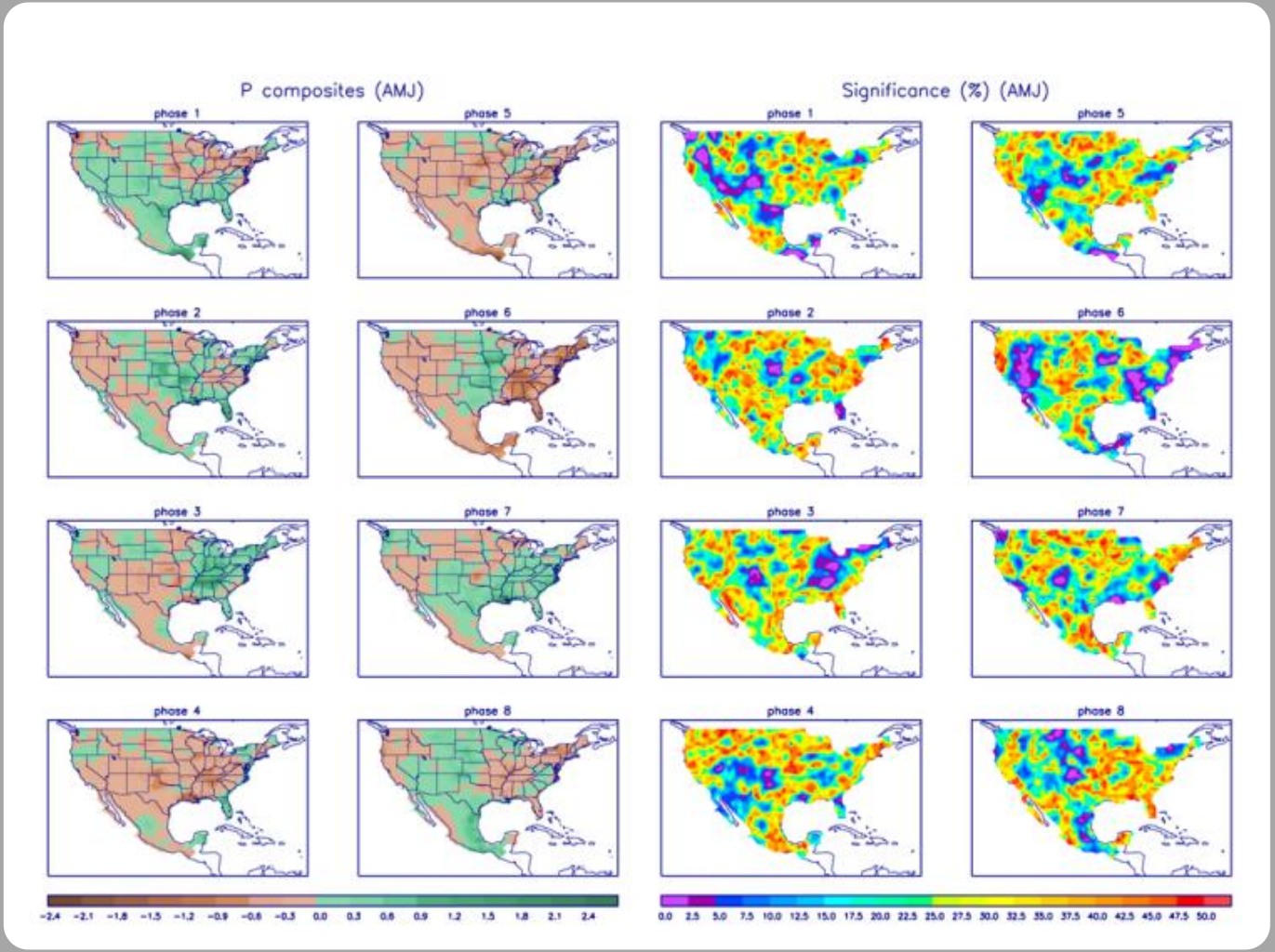

Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml

# U.S. MJO Composites – Precipitation

**Left hand side plots show precipitation anomalies by MJO phase for MJO events that have occurred over the three month period in the historical record. Brown (green) shades show negative (positive) anomalies respectively.**

**Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.**

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