

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



Update prepared by: Kyle MacRitchie  
Climate Prediction Center / NCEP  
20 August 2018

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

- The MJO signal remains fairly disorganized, as other modes of tropical variability, including Pacific tropical cyclone activity and the developing low-frequency state, continue to influence the pattern.
- Dynamical model MJO index forecasts suggest that an active MJO may emerge over the Maritime Continent during Week-1 or the early part of Week-2, but considerable disagreement among the ensemble members indicates that this is a low confidence forecast.
- A coherent MJO signal would likely help the transition to El Nino.

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>

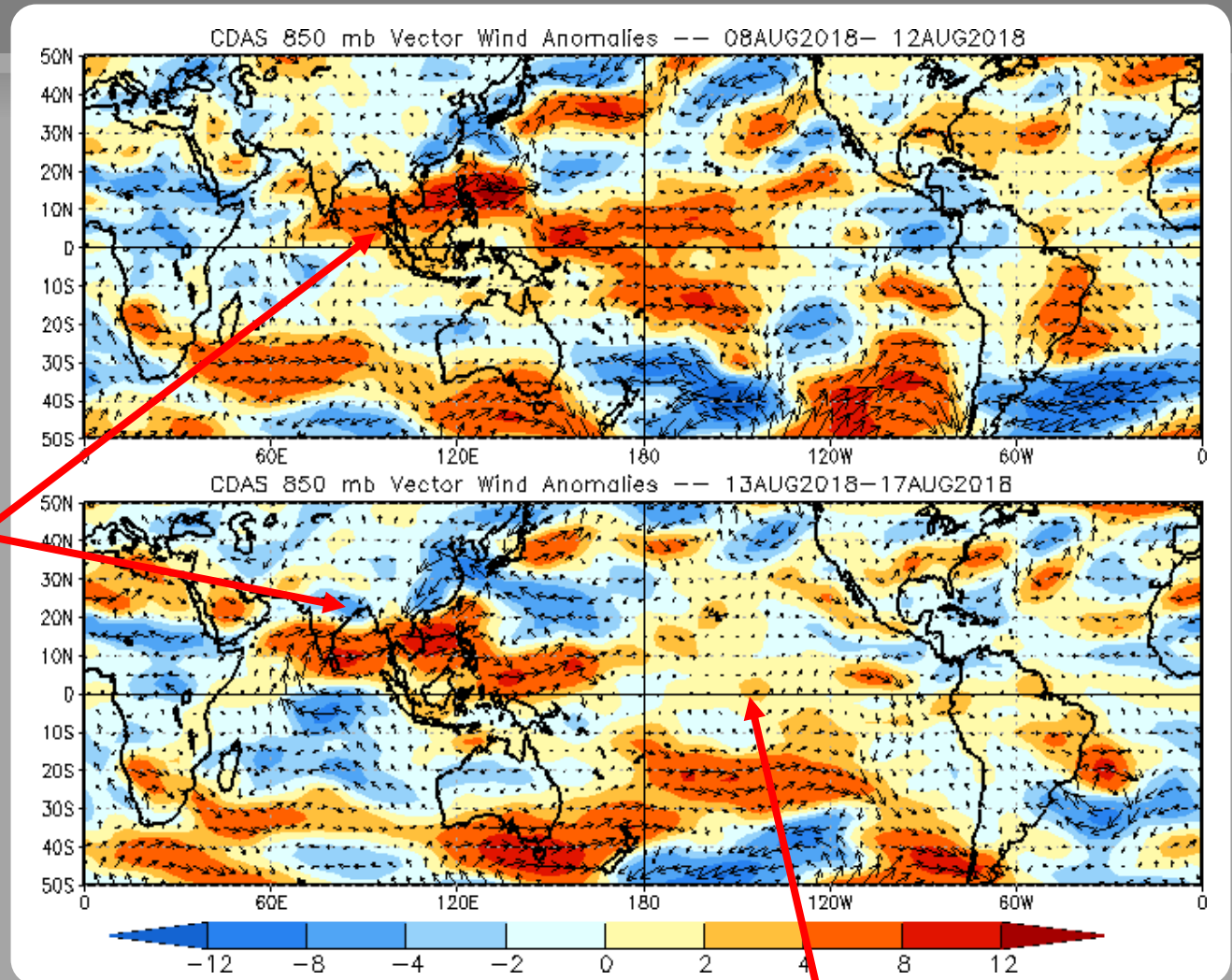
# 850-hPa Vector Wind Anomalies ( $\text{m s}^{-1}$ )

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Strong westerlies, partly associated with tropical cyclone (TC) activity, remained entrenched over the tropical Northwest Pacific.



Westerlies have diminished over the central Pacific in the most recent pentad.

# 850-hPa Zonal Wind Anomalies (m s<sup>-1</sup>)

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

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

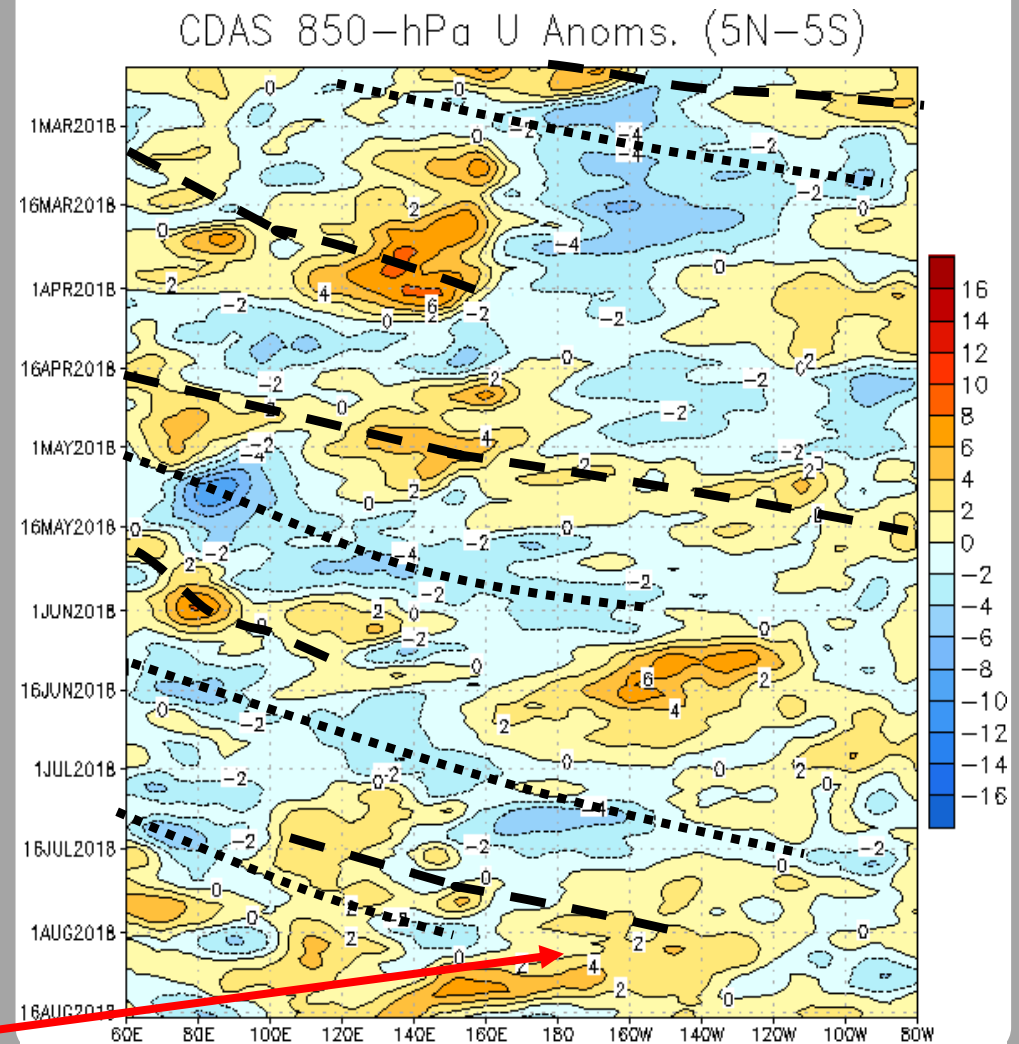
MJO activity was observed during March, but the signal rapidly broke down by early April.

The MJO was active again during late April and May. Westward moving variability, including TC activity over the Pacific and equatorial Rossby waves, weakened the signal during June.

A weak intraseasonal signal re-emerged during mid to late July.

More recently in August, widespread westerly anomalies developed over the Pacific basin, due in part to TC activity. These westerlies have weakened substantially over the past week.

An equatorial Rossby wave propagated over the central Pacific during the first half of August.



# OLR Anomalies - Past 30 days

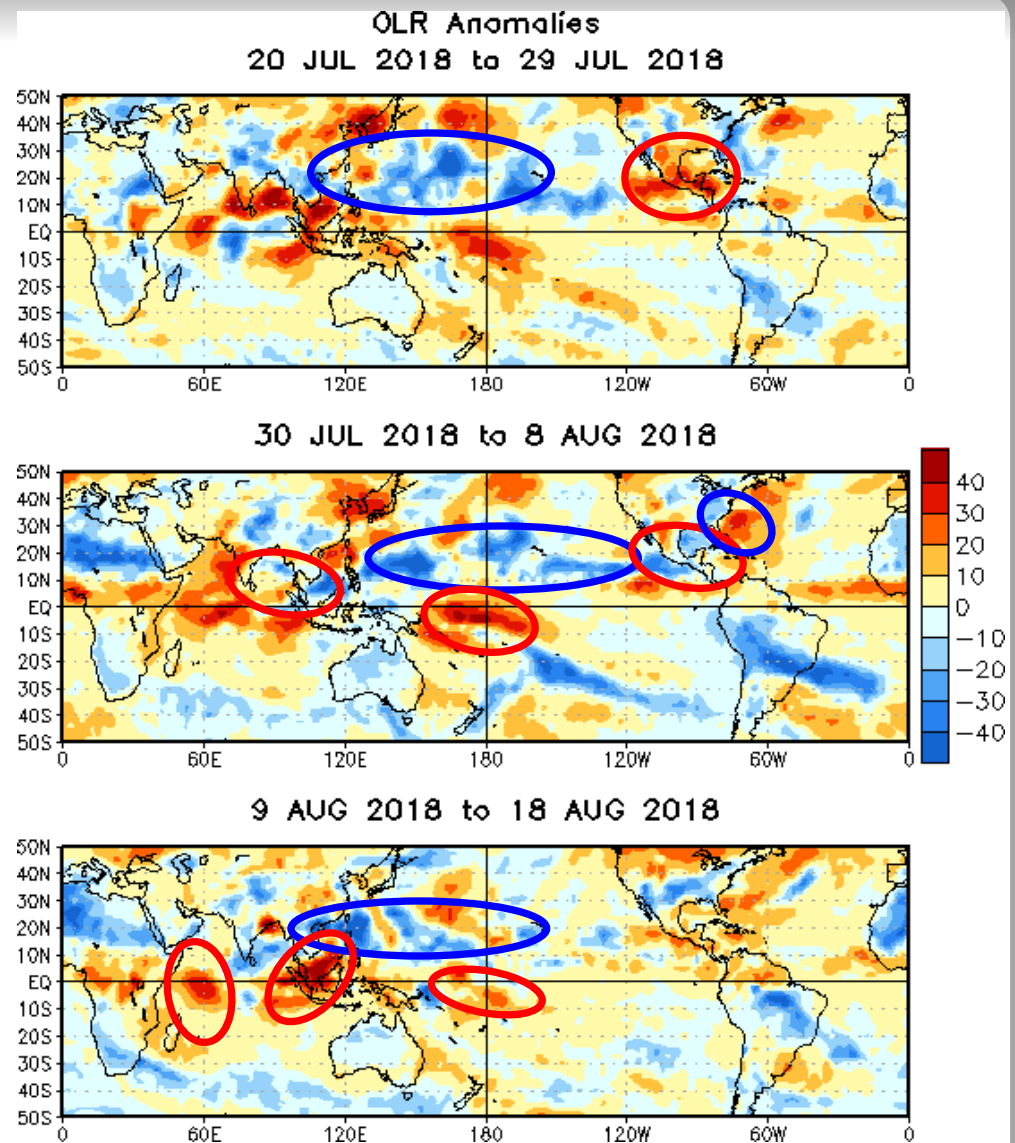
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

Enhanced convection shifted northward over Southeast Asia and the West Pacific during mid-July, while suppressed convection persisted over the far East Pacific and Central America. Enhanced convection spread eastward across the North Pacific.

During late July, suppressed convection overspread the Bay of Bengal and the western Maritime Continent while enhanced (suppressed) convection, including tropical cyclone activity, persisted over the North Pacific (near and south of the equator). An influx of tropical moisture is notable over the eastern U.S.

By early August OLR anomalies became somewhat less coherent, though enhanced convection due to TC activity is still evident over the North Pacific, with suppressed convection observed over the Indian Ocean and Maritime Continent.



# Outgoing Longwave Radiation (OLR) Anomalies (2.5°N - 17.5°N)

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

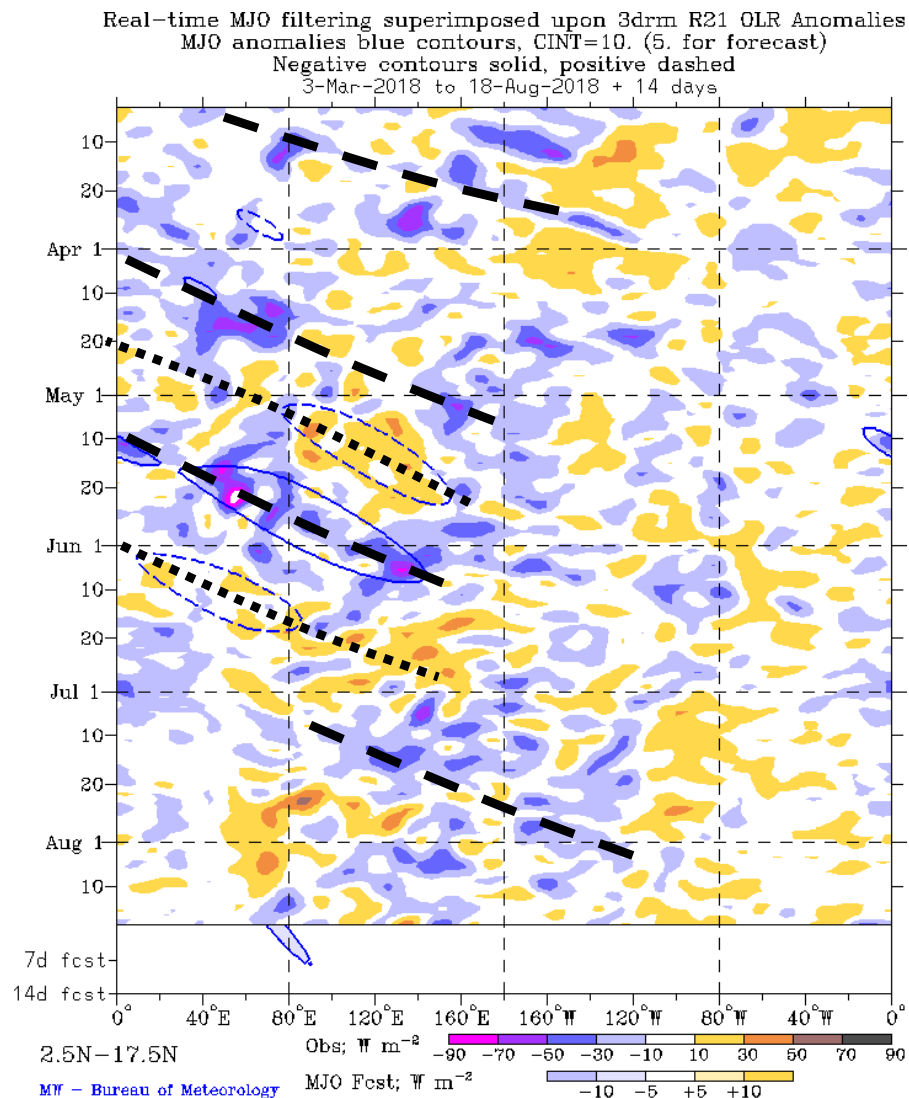
**Wetter-than-normal conditions, negative OLR anomalies (blue shading)**

MJO activity during April weakened in early May as the suppressed phase destructively interfered with the low frequency La Niña base state. Stronger MJO activity emerged in late May, and weakened again during June coincident with pronounced Rossby wave activity.

The MJO remained weak during most of June.

During July, the intraseasonal signal re-emerged, with some eastward propagation evident in the OLR field.

An atmospheric Kelvin wave propagated across the western and central Pacific during early August and activity since then has been weak.





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

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

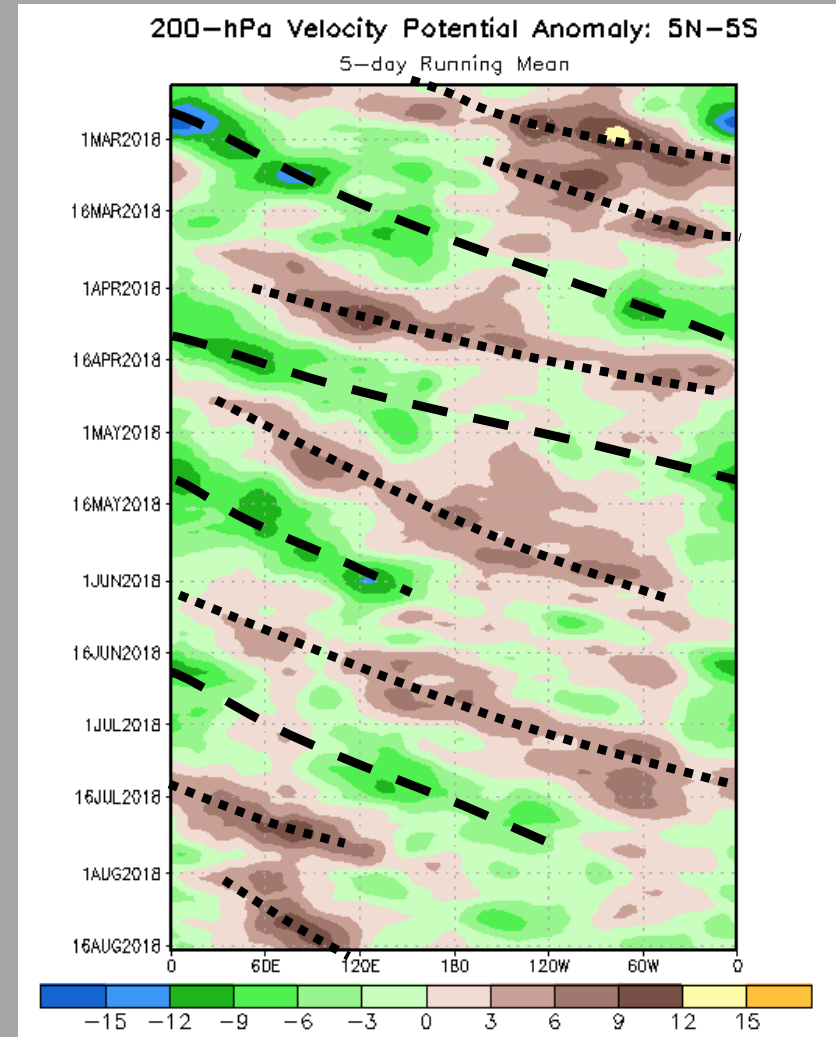
Negative anomalies (green shading) indicate favorable conditions for precipitation

Robust MJO activity was observed throughout the cold season despite the background La Niña state. Stationary upper-level divergence over the Maritime Continent associated with the base state began to wane by April.

The enhanced phase of the MJO weakened east of the Date Line during June. Eastward propagation of broad suppressed convection continued into early July.

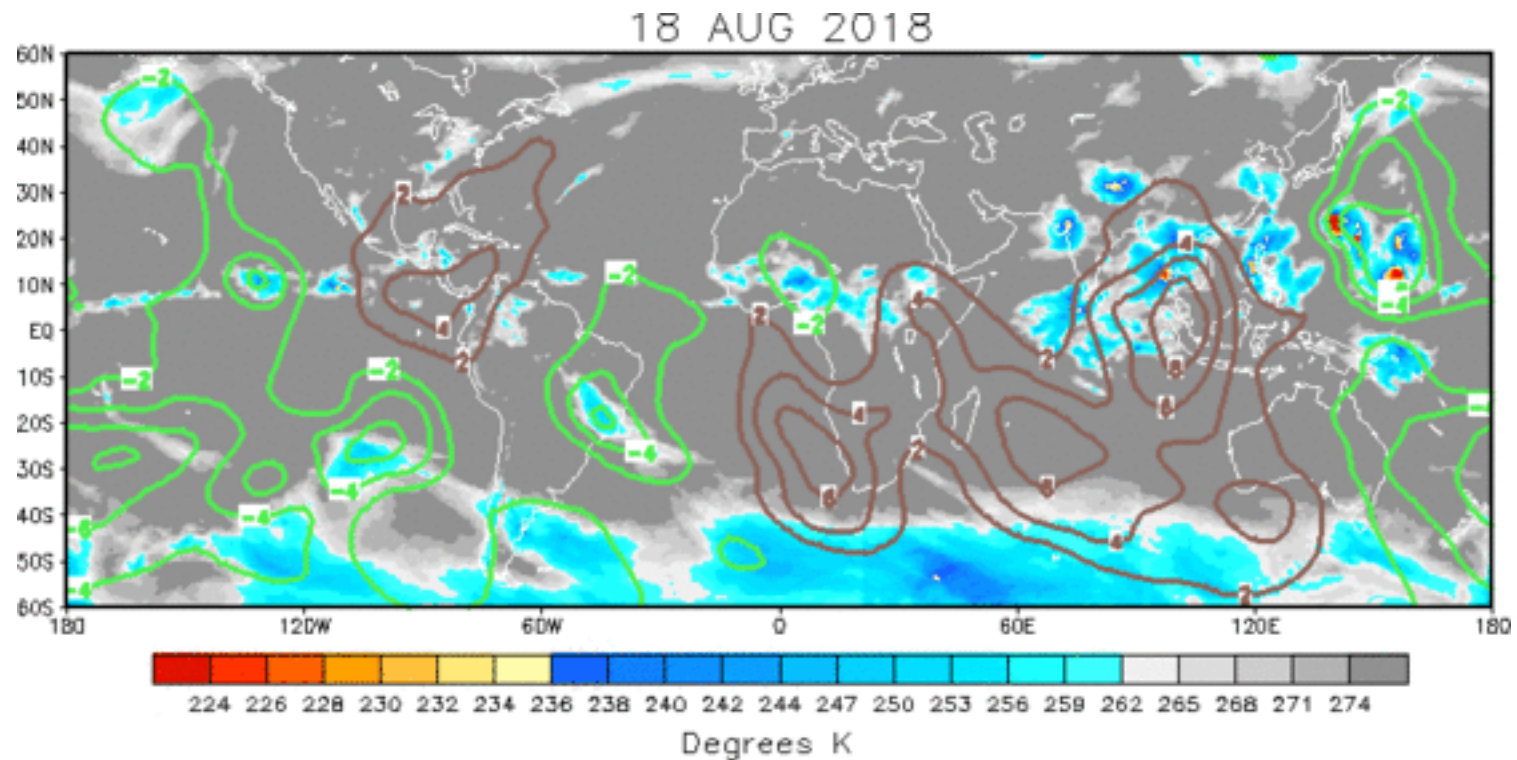
The upper-level footprint of the MJO re-emerged during mid-July, with a broad divergent signal propagating from the Maritime Continent to the central Pacific.

More recently, a somewhat stationary pattern of enhanced (suppressed) convection over the east-central Pacific (Indian Ocean) has emerged. Influence from Rossby wave activity, including strong tropical cyclones, may be contributing to this slowdown, as is the gradual transition to El Niño.





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



The upper-level velocity potential pattern remains disorganized, but broad-scale enhanced divergence (convergence) is apparent over the Pacific (Americas and southern Indian Ocean). Robust Southeast Asia monsoon activity and tropical cyclone activity over the Northwest Pacific continue to dominate the pattern southeast of Asia.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

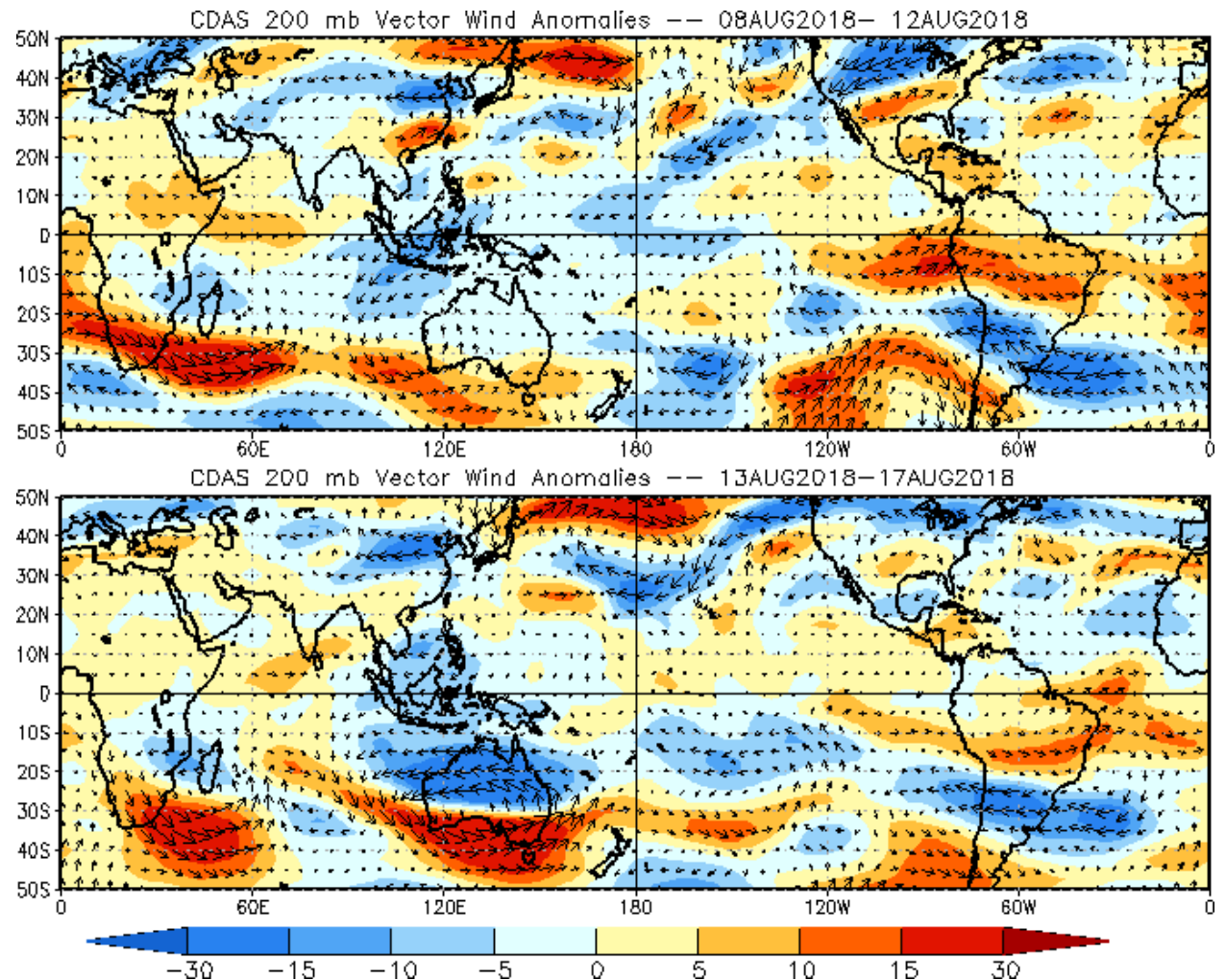
Negative anomalies (green contours) indicate favorable conditions for precipitation

# 200-hPa Vector Wind Anomalies ( $\text{m s}^{-1}$ )

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies



The upper-level pattern over the North Pacific remains amplified with a strong anomalous gyre over the Dateline.

# 200-hPa Zonal Wind Anomalies (m s<sup>-1</sup>)

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

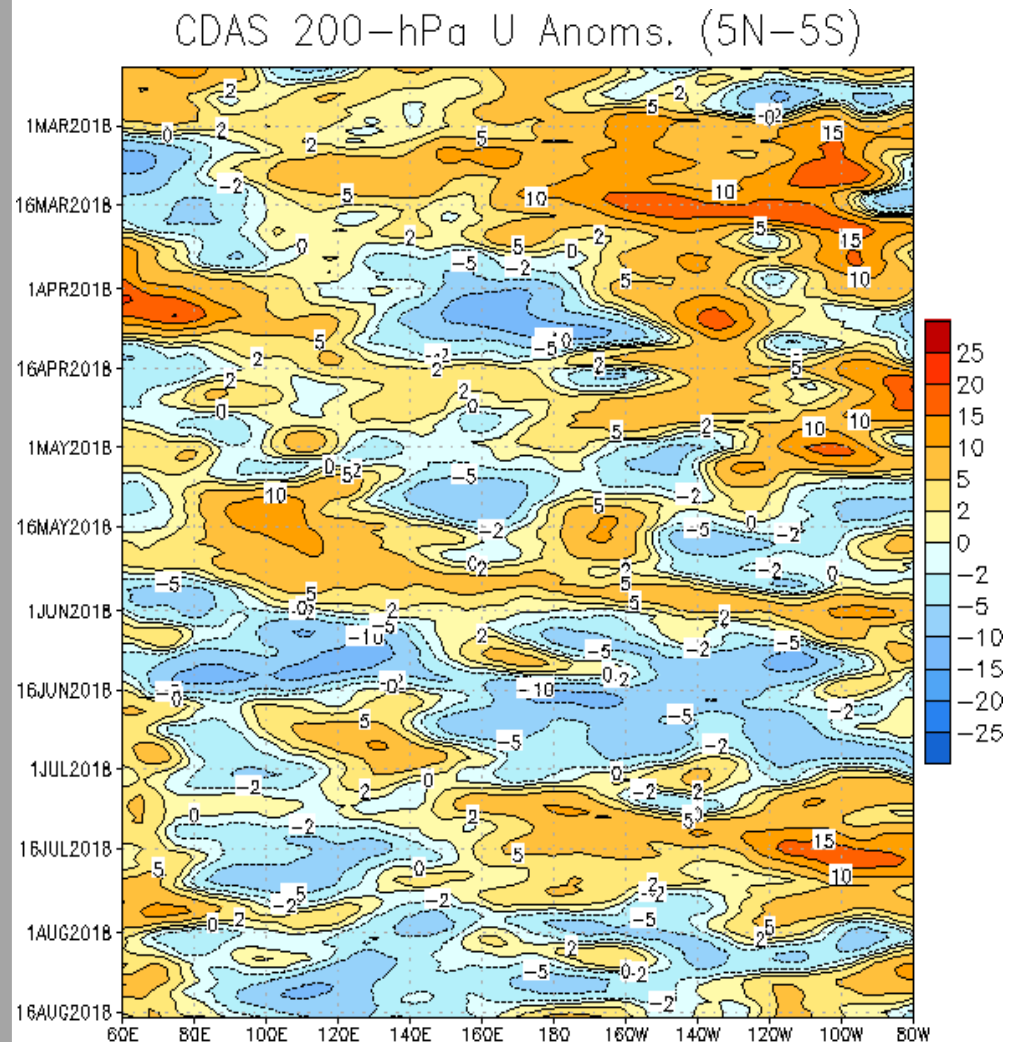
Easterly anomalies (blue shading) represent anomalous east-to-west flow

Low-frequency anomalous westerlies remained in place east of 140°E through late April 2018, with a few periods of brief interruptions.

Since the beginning of May, weak westerly anomalies have continued to propagate eastward from the Indian Ocean to the Americas; this pattern broke down in early June.

Anomalous westerlies amplified over the Maritime Continent in mid-June and have propagated eastward at MJO-like phase speeds since then.

During early August the intraseasonal pattern weakened and predominantly easterly anomalies emerged, but have begun to weaken over the past few days.



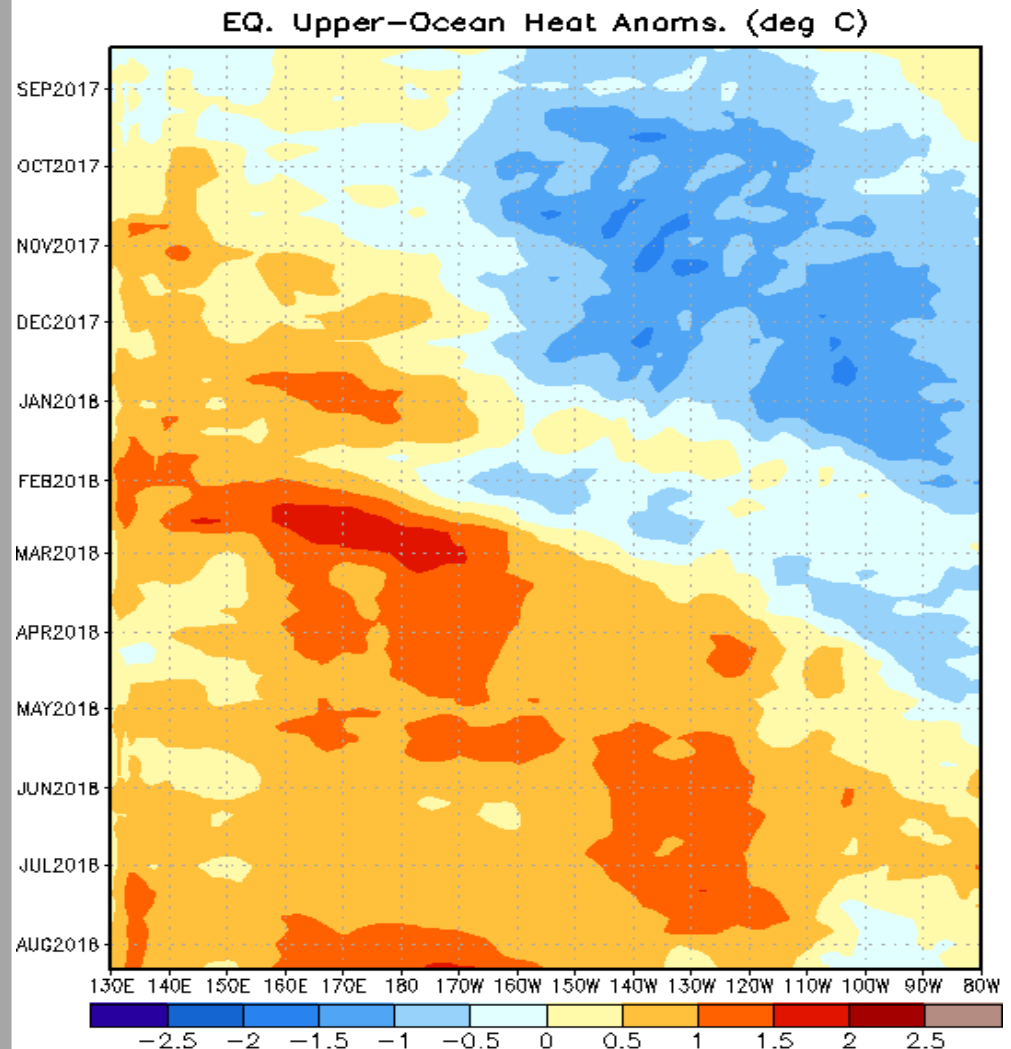
# Weekly Heat Content Evolution in the Equatorial Pacific

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.

Negative upper-ocean heat content anomalies persisted in the central and eastern Pacific from August-December.

A downwelling Kelvin wave associated with the intraseasonal signal weakened the negative anomalies across the east-central Pacific during late January and early February.

Several downwelling oceanic Kelvin waves (associated with a relaxation of the trade winds) have contributed to the eastward expansion of relatively warm subsurface water (as much as 1.5-2.0°C above normal between 160E and 170W during February). Positive anomalies have now observed over most of the basin since April-May.



# 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

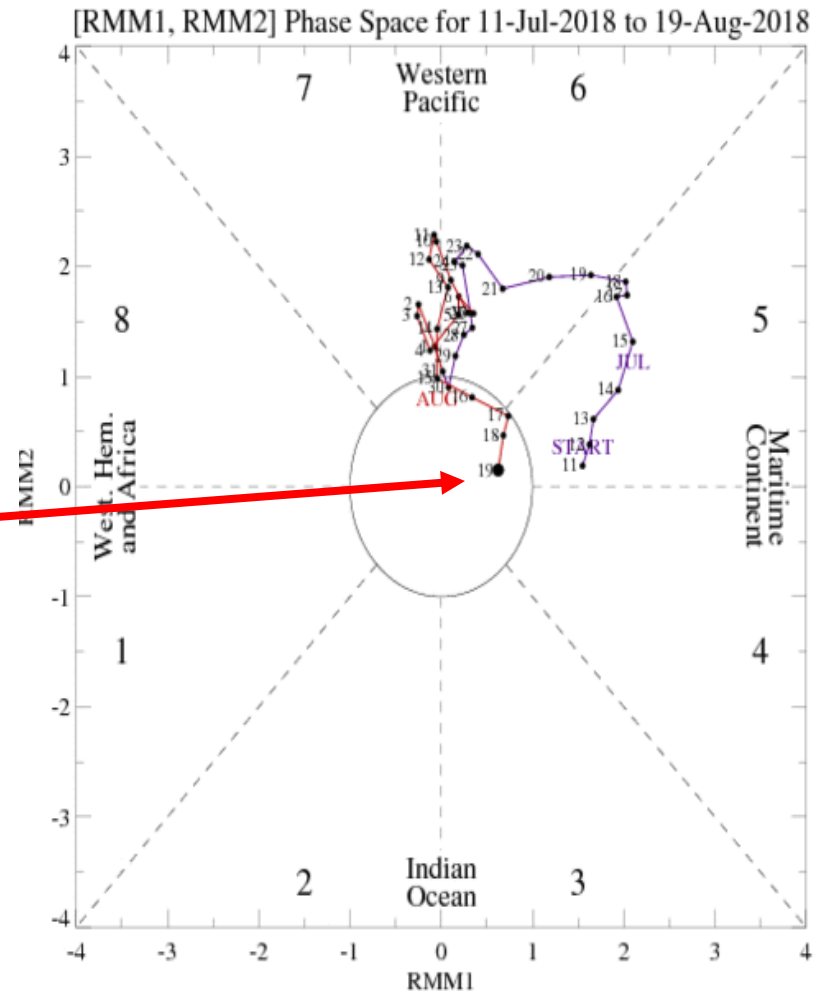
The triangular areas indicate the location of the enhanced phase of the MJO

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

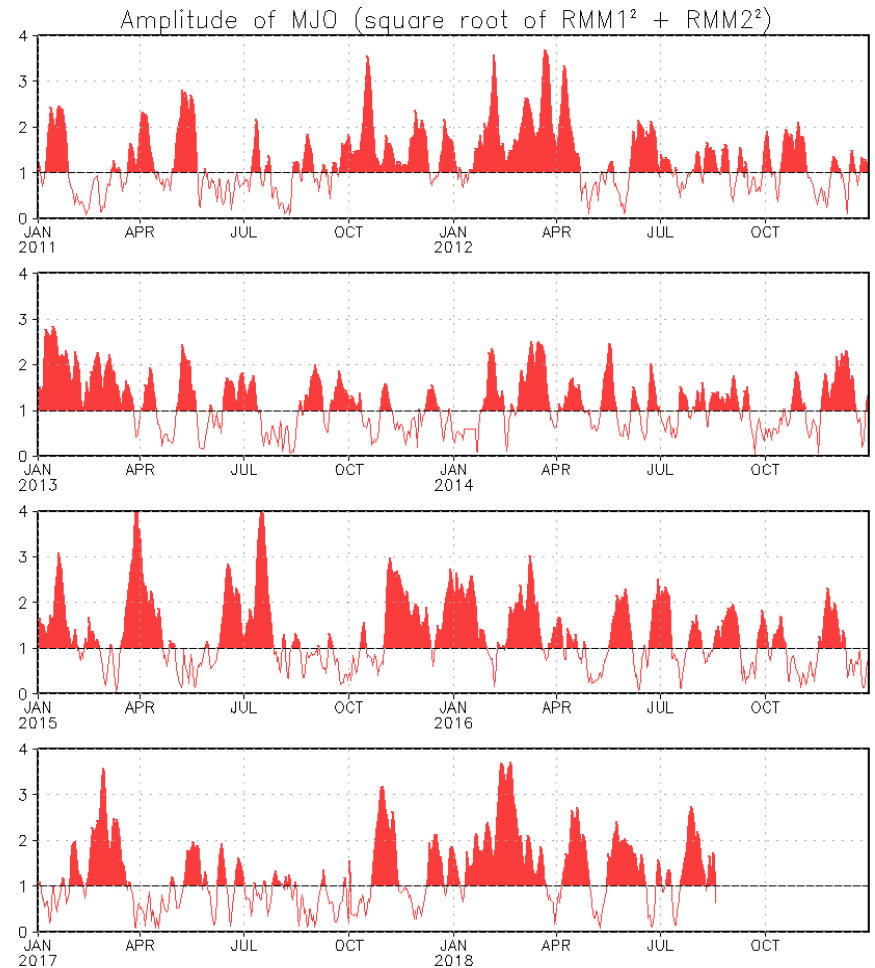
The RMM index continues to show a weak MJO, which is now within the unit circle and considered inactive.



# 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.





# GFS Ensemble (GEFS) MJO Forecast

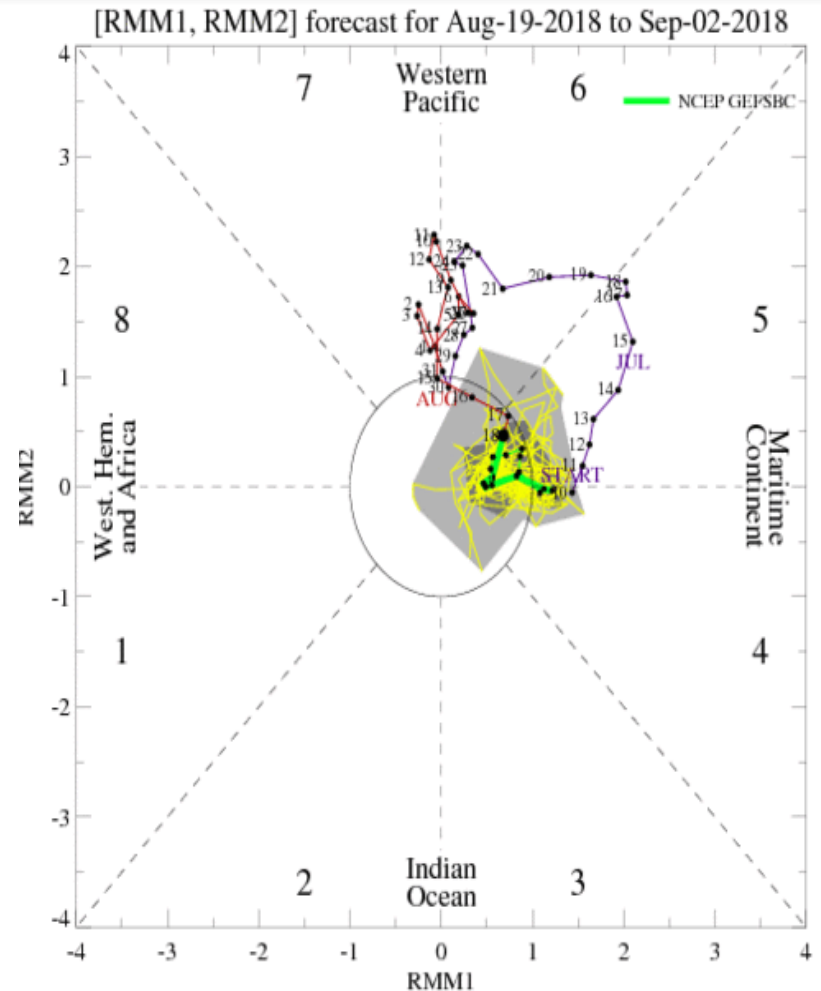
RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS RMM index forecast suggests that the MJO may emerge over the Maritime Continent during the next week, but there is considerable variability among the ensemble members.

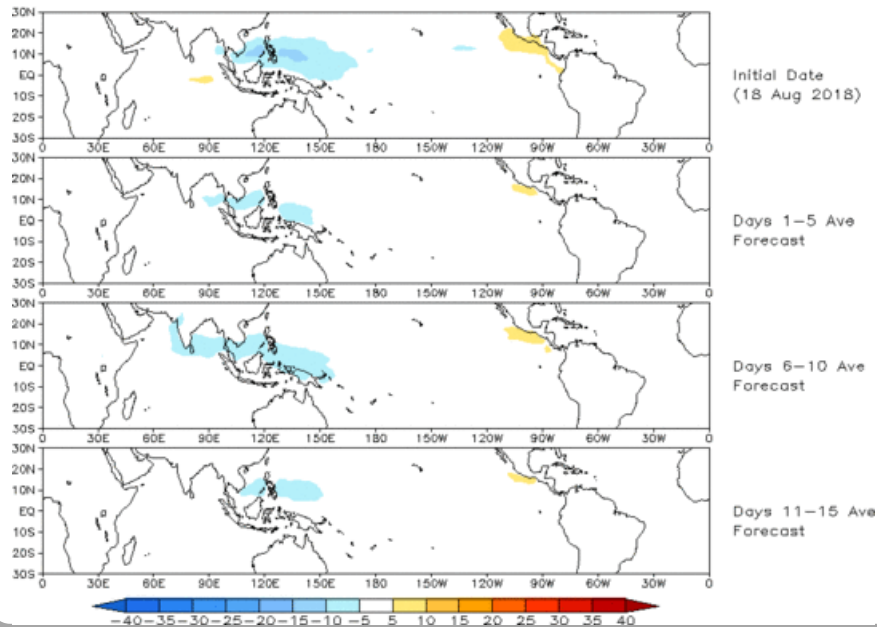
Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean



# Ensemble GFS (GEFS) MJO Forecast

Spatial map of OLR anomalies for the next 15 days

Prediction of MJO-related anomalies using GEFS operational forecast  
Initial date: 18 Aug 2018  
OLR

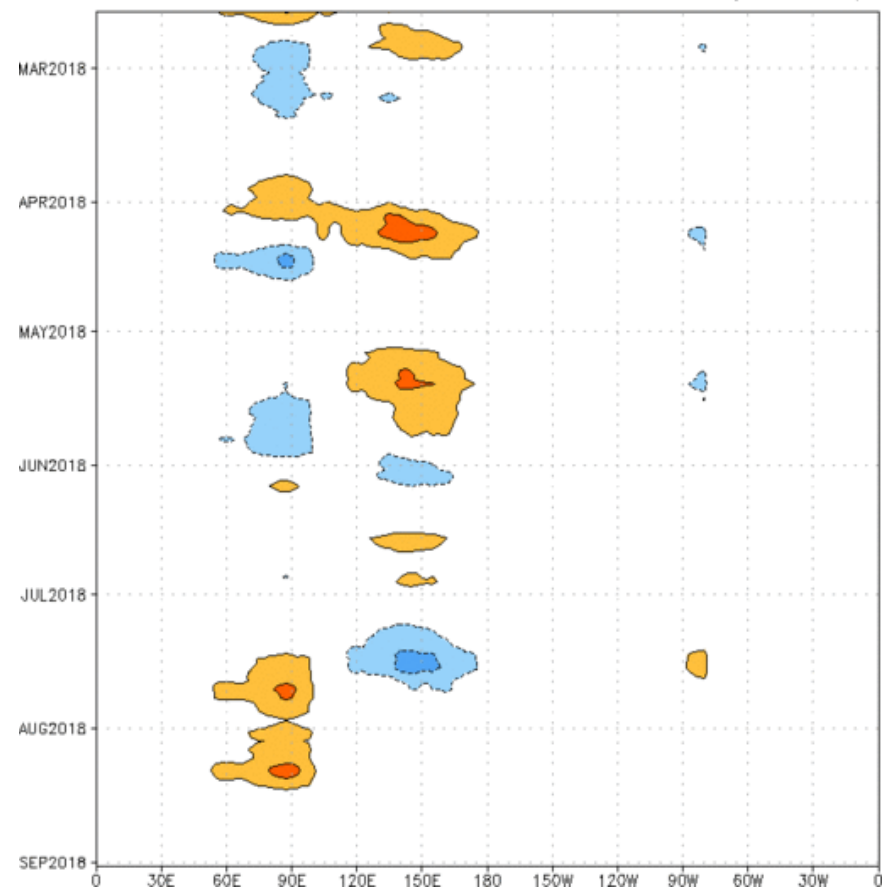


OLR anomalies based on the GEFS RMM-index forecast show a weakening and mostly stationary MJO signal.

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.)

Time-longitude section of ( $7.5^{\circ}$  S– $7.5^{\circ}$  N) OLR anomalies - last 180 days and for the next 15 days

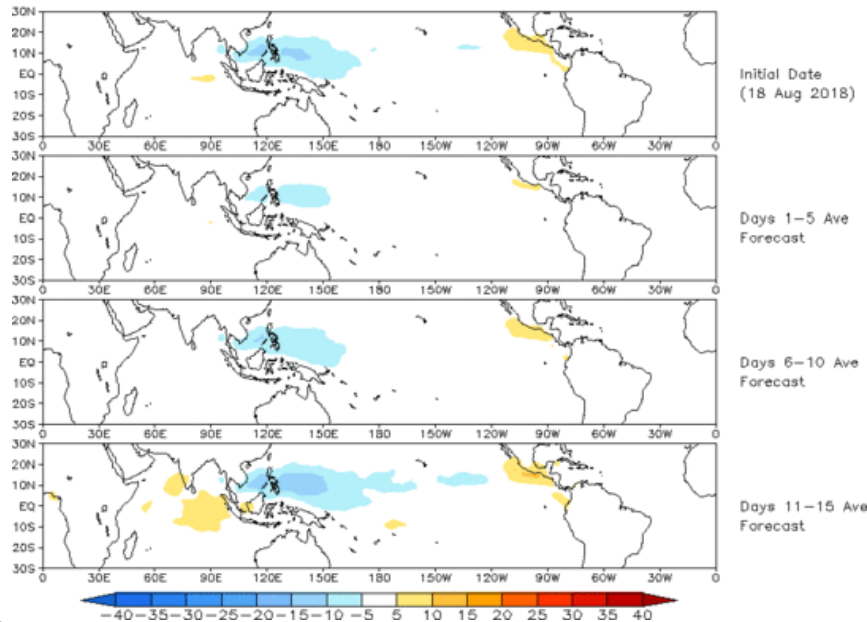
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S,  $7.5^{\circ}$ N] (cont:  $4\text{Wm}^{-2}$ ) Period: 16-Feb-2018 to 18-Aug-2018  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# Constructed Analog (CA) MJO Forecast

Spatial map of OLR anomalies for the next 15 days

OLR prediction of MJO-related anomalies using CA model  
reconstruction by RMM1 & RMM2 (18 Aug 2018)

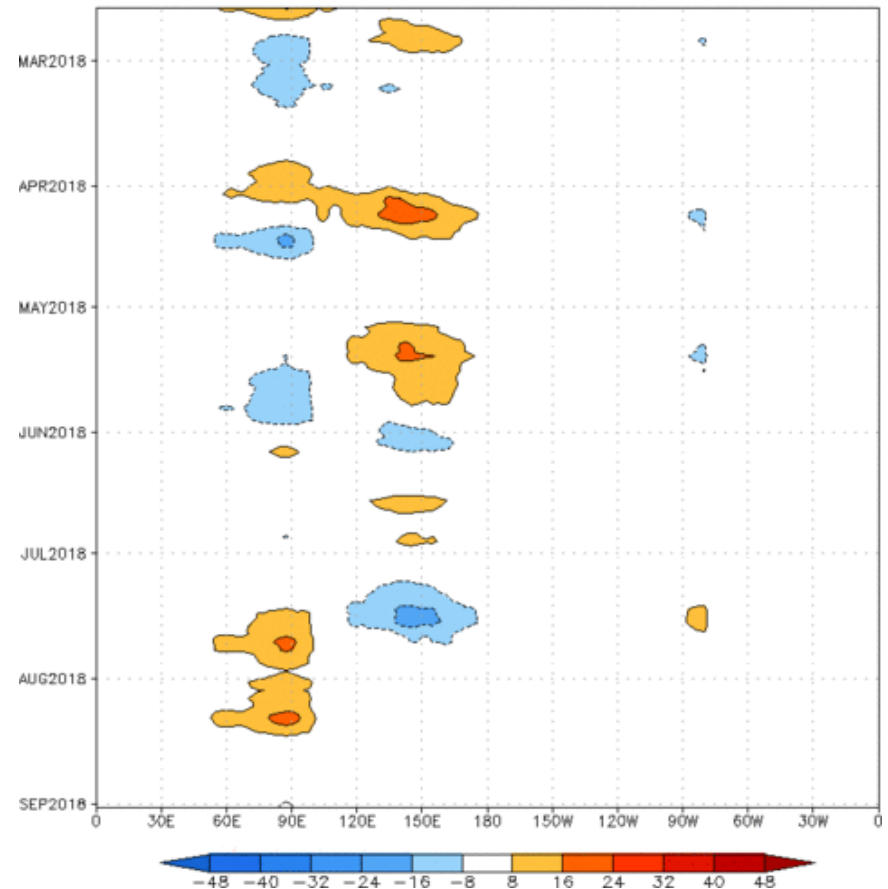


The constructed analog RMM-based OLR anomaly forecast also shows a stationary signal, but suggests that amplification is possible during Week-2.

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.)

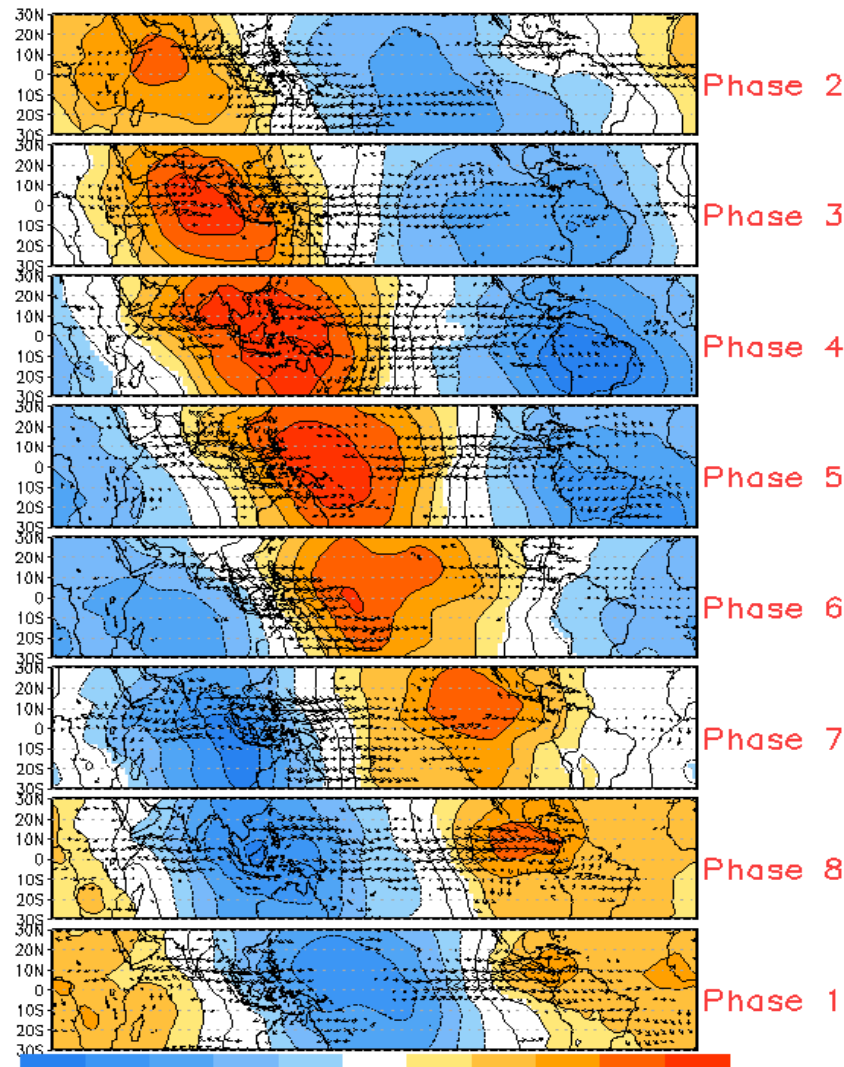
Time-longitude section of ( $7.5^{\circ}$  S- $7.5^{\circ}$  N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S, $7.5^{\circ}$ N] (cint: $4\text{Wm}^{-2}$ ) Period:16-Feb-2018 to 18-Aug-2018  
The unfilled contours are CA forecast reconstructed anomaly for 15 days

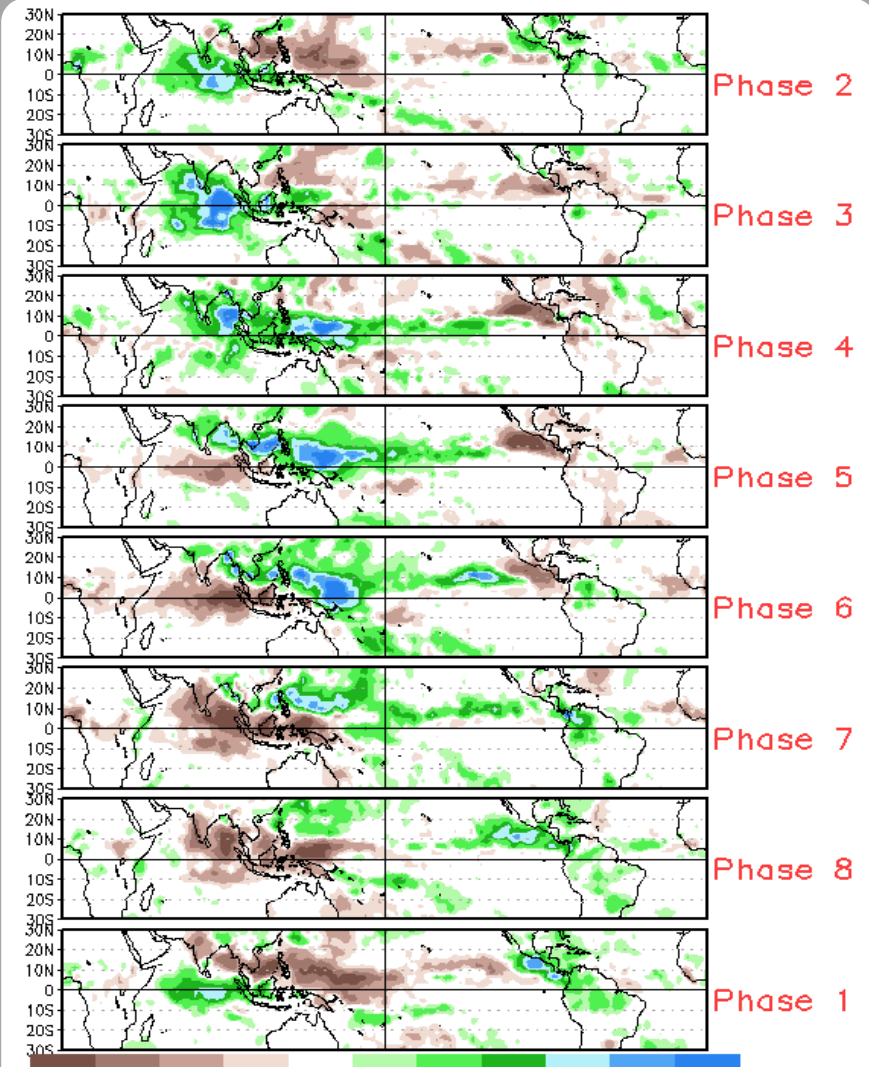


# MJO Composites - Global Tropics

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



Precipitation Anomalies (May - Sep)

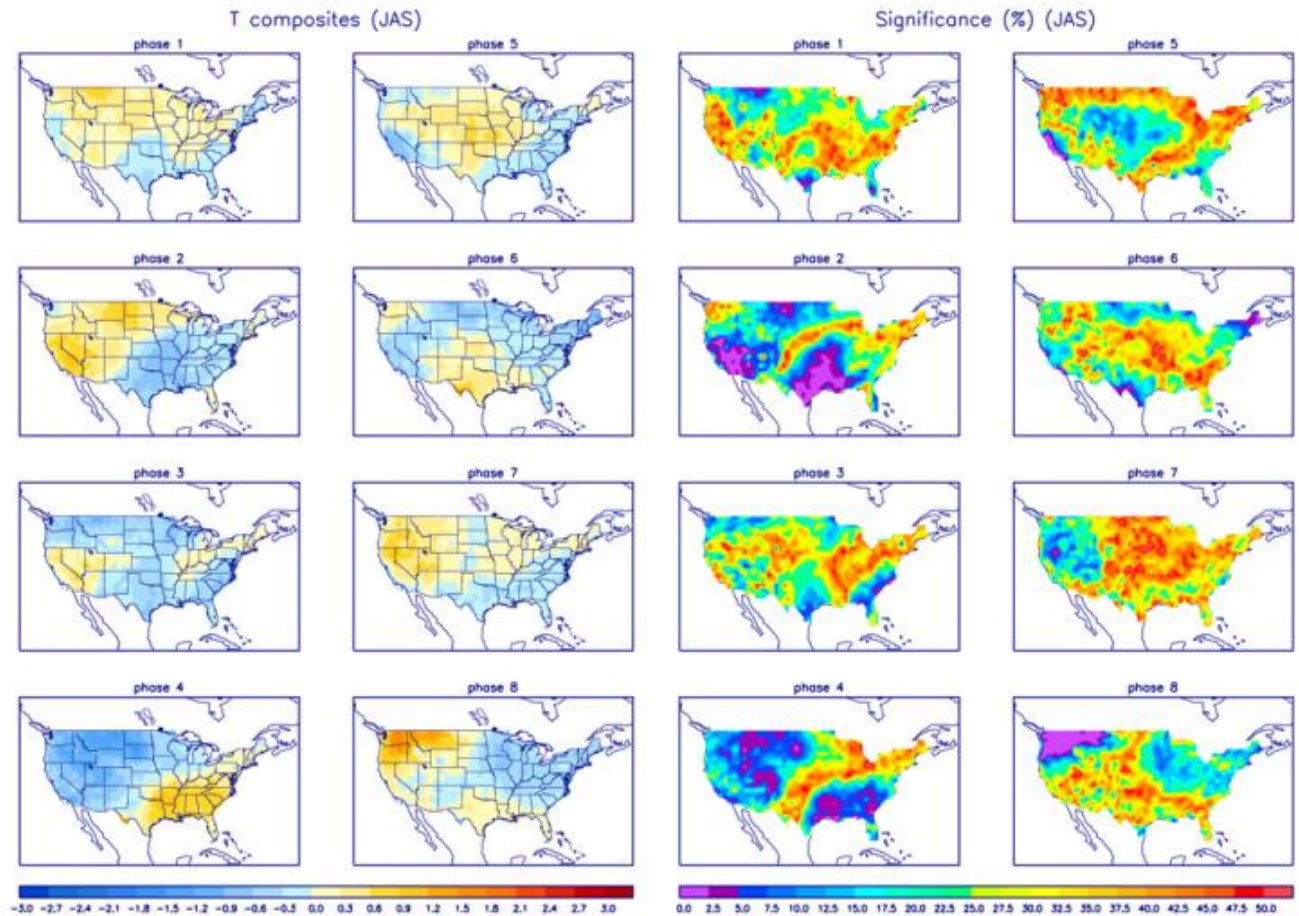




# U.S. MJO Composites - Temperature

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.



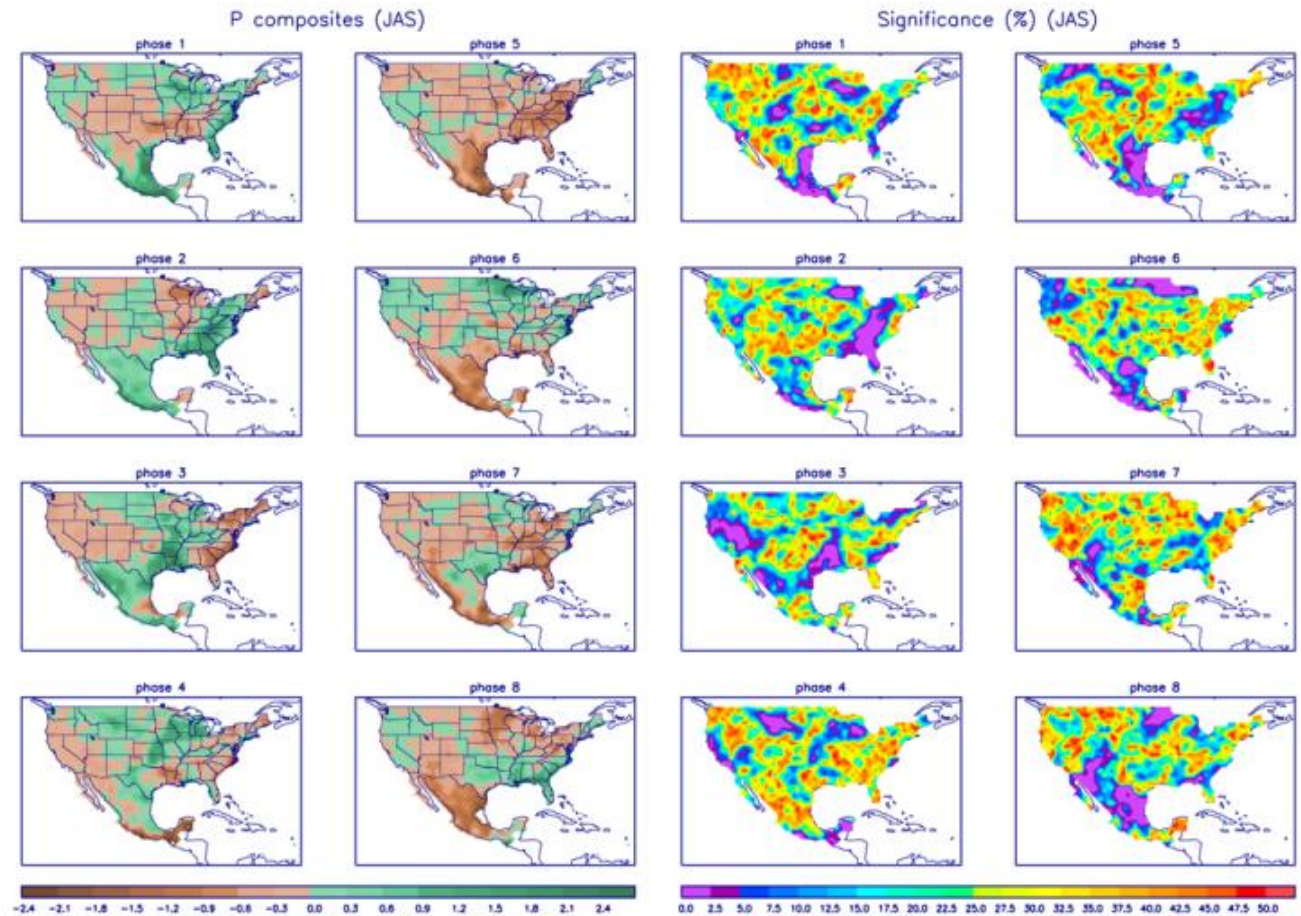
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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.



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>