

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



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# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

- The MJO remained weak over the Indian Ocean during the past 7-days, with western retrogression of the signal apparently due to an Equatorial Rossby Wave (ERW) and/or other westward-moving modes of tropical variability.
- Dynamical model forecasts generally agree on the continuation of a weak MJO signal, with the exception of the CFS which develops a significant MJO signal over the Pacific during the Week-2 period. However, there is significant disagreement among models regarding the predicted phase of the MJO, with a wide range of solutions indicated.
- Areas of enhanced convection over the eastern Indian Ocean, Gulf of Carpentaria, and western North Pacific are related, in part, to tropical cyclone activity either ongoing or anticipated during Week-1.

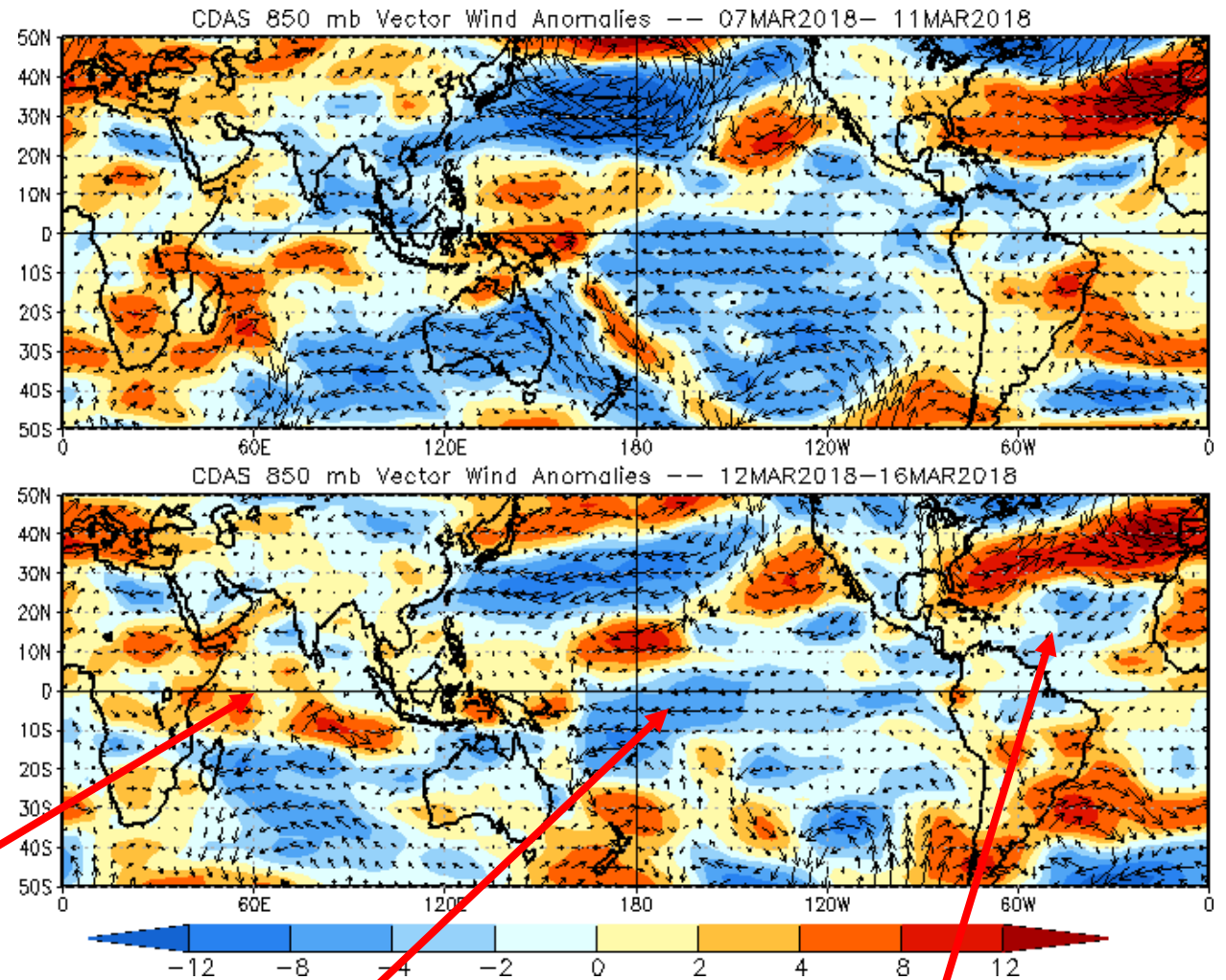
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:  
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php>

# 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



Weak anomalies throughout the near-equatorial Indian Ocean are consistent with the weak MJO enhanced phase.

Anomalous easterlies are present along the equator, consistent with La Niña.

Mid-latitude waves dominate the Atlantic flow.

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

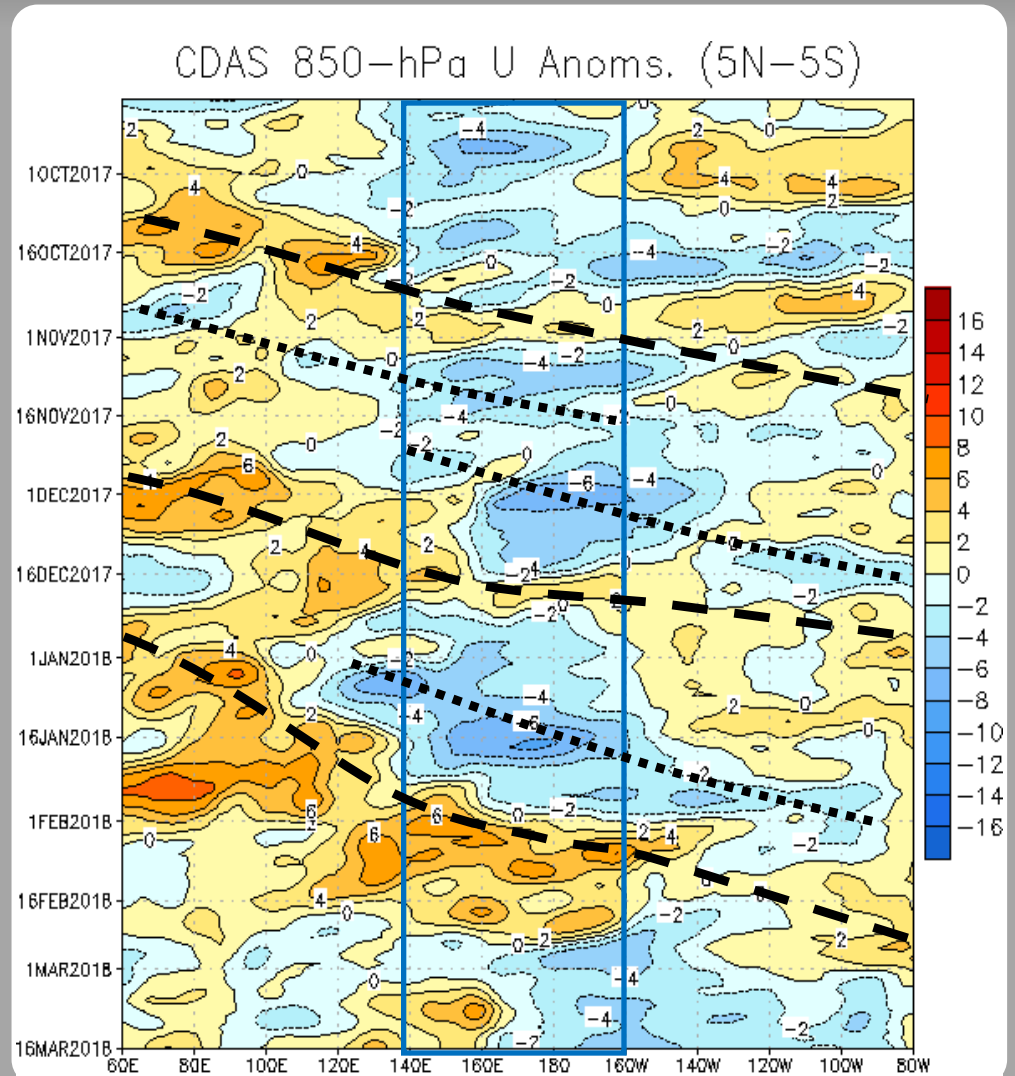
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

Low frequency anomalous easterlies that have been present since September reversed sign during February.

During October and early November, a robust MJO event developed, with eastward propagation of westerly and easterly anomalies. This event weakened in early to mid-November.

A new MJO event became organized in December, propagating from the Indian Ocean to the Pacific. The signal crossed the Western Hemisphere in late December, re-emerging over the Indian Ocean in early January. The signal continued to propagate eastward, moving into the central and eastern Pacific and began weakening over the past couple of weeks. Most recently, stationary easterly anomalies are noted between 140W and the Date Line.



# OLR Anomalies - Past 30 days

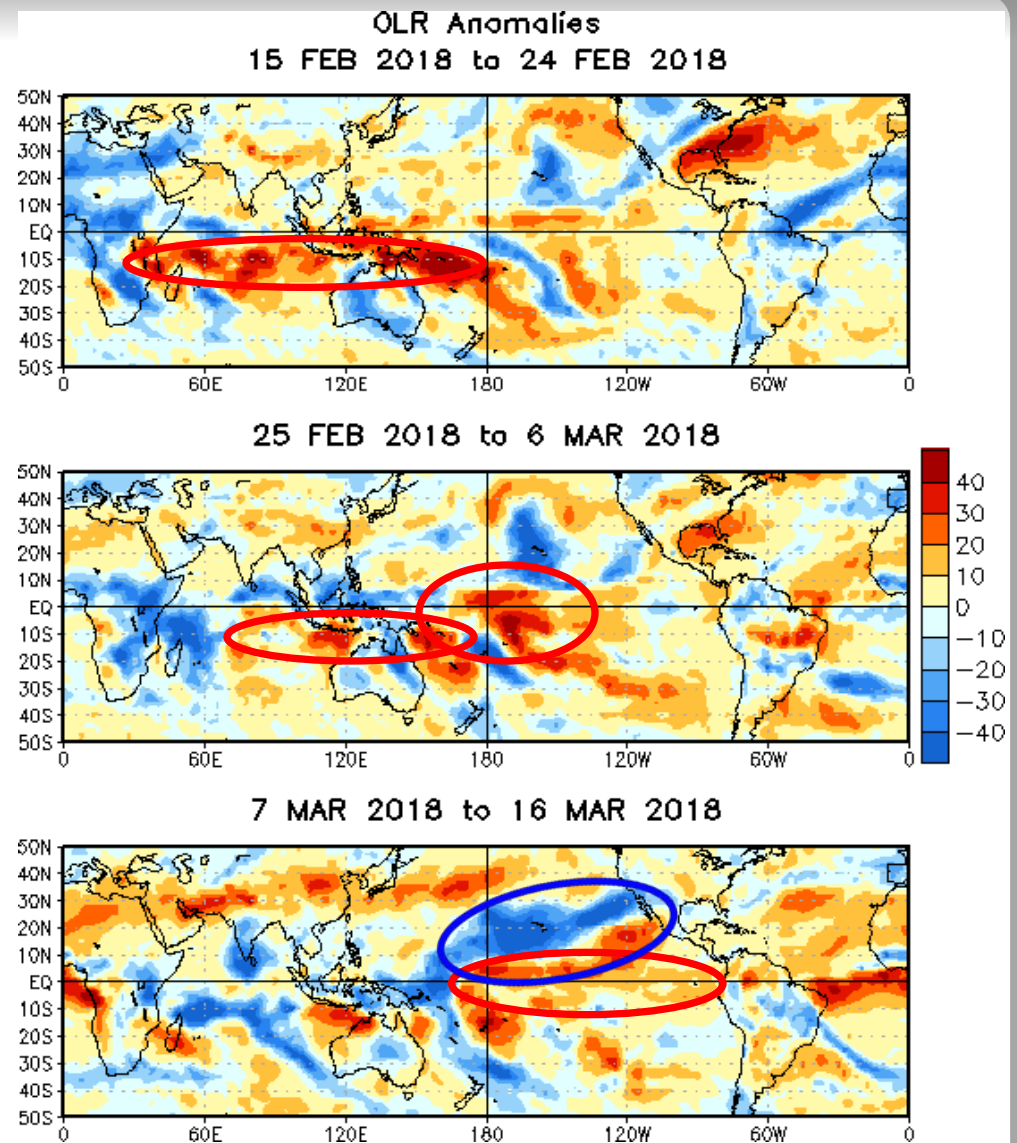
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During mid-late February, a zonally oriented band of positive OLR anomalies straddling 10S stretched from Tanzania across the Indian Ocean, Indonesia, and the Solomon Islands.

Positive OLR anomalies over the southern Indian Ocean and Maritime Continent weakened substantially from late February into early March. During the same period, positive OLR anomalies strengthened over the central Pacific associated with anomalously low cloud cover and convection.

The bottom panel depicts a bifurcation of negative OLR anomalies around an area of positive OLR anomalies that is noted from the Date Line to the South American coast. The northern branch of the negative OLR anomalies is consistent with a subtropical moisture feed across Hawaii toward California during this period.





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

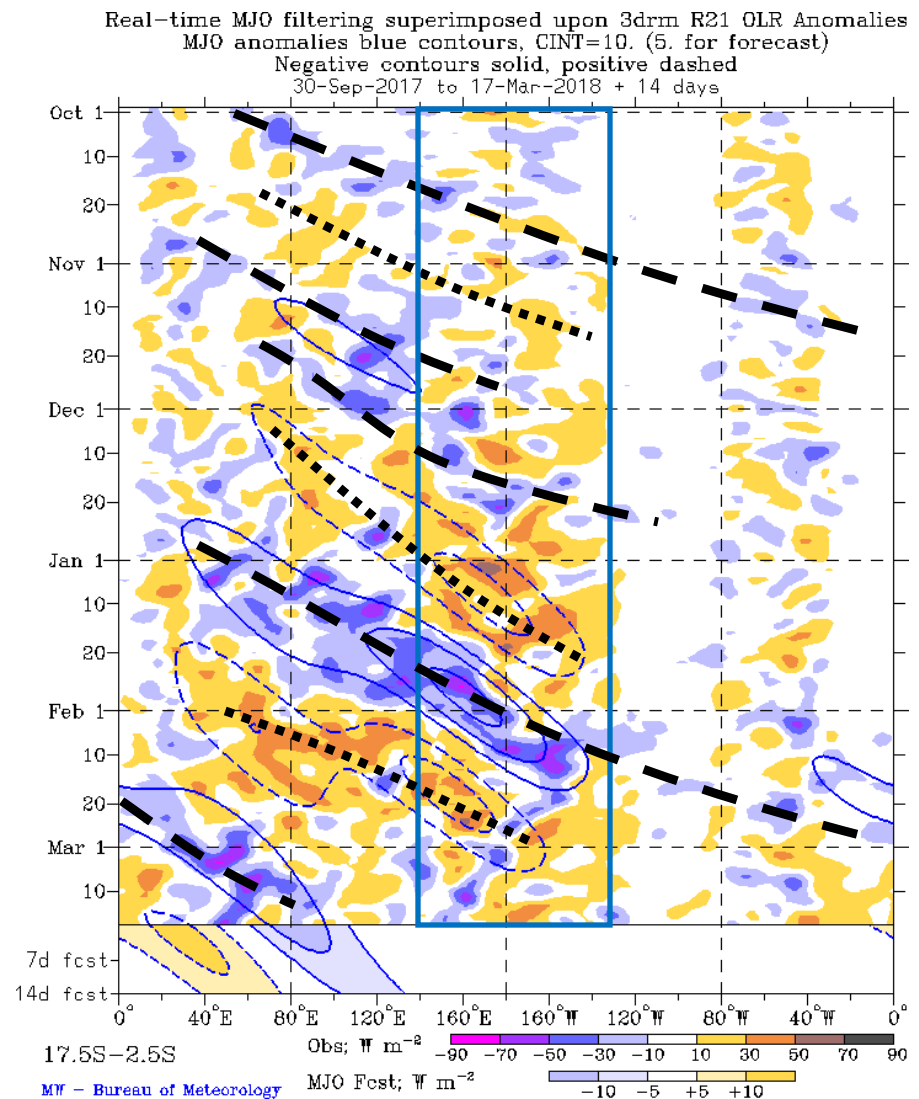
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

An active MJO formed in early October and circumnavigated the globe by early November.

Another MJO event developed in late November over the eastern Indian Ocean and Maritime Continent that was able to briefly disrupt the La Niña convective suppression near the Date Line in mid-December.

The MJO re-emerged in the Indian Ocean at the end of December and strengthened as it shifted east toward the Date Line. This led to a reversal of the canonical La Niña convective suppression signal in early February. This MJO signal circumnavigated the global tropics during February, reaching the Indian Ocean and weakening substantially by mid-March.



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

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

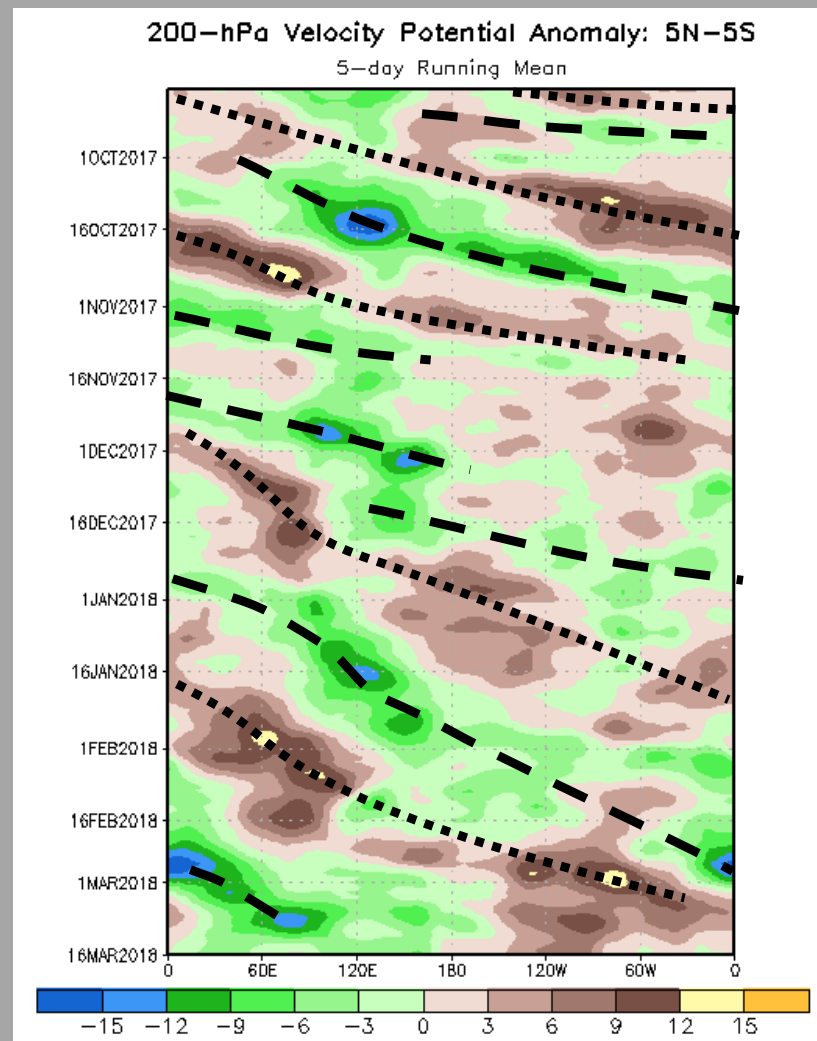
Negative anomalies (green shading) indicate favorable conditions for precipitation

An MJO event developed near the Maritime Continent during early October with strong anomalous upper-level winds near 120E. The signal circumnavigated the global tropics and weakened about 30 days later.

MJO activity renewed in November. The intraseasonal signal associated with this MJO event was weaker than the previous episode due to destructive interference from an equatorial Rossby wave.

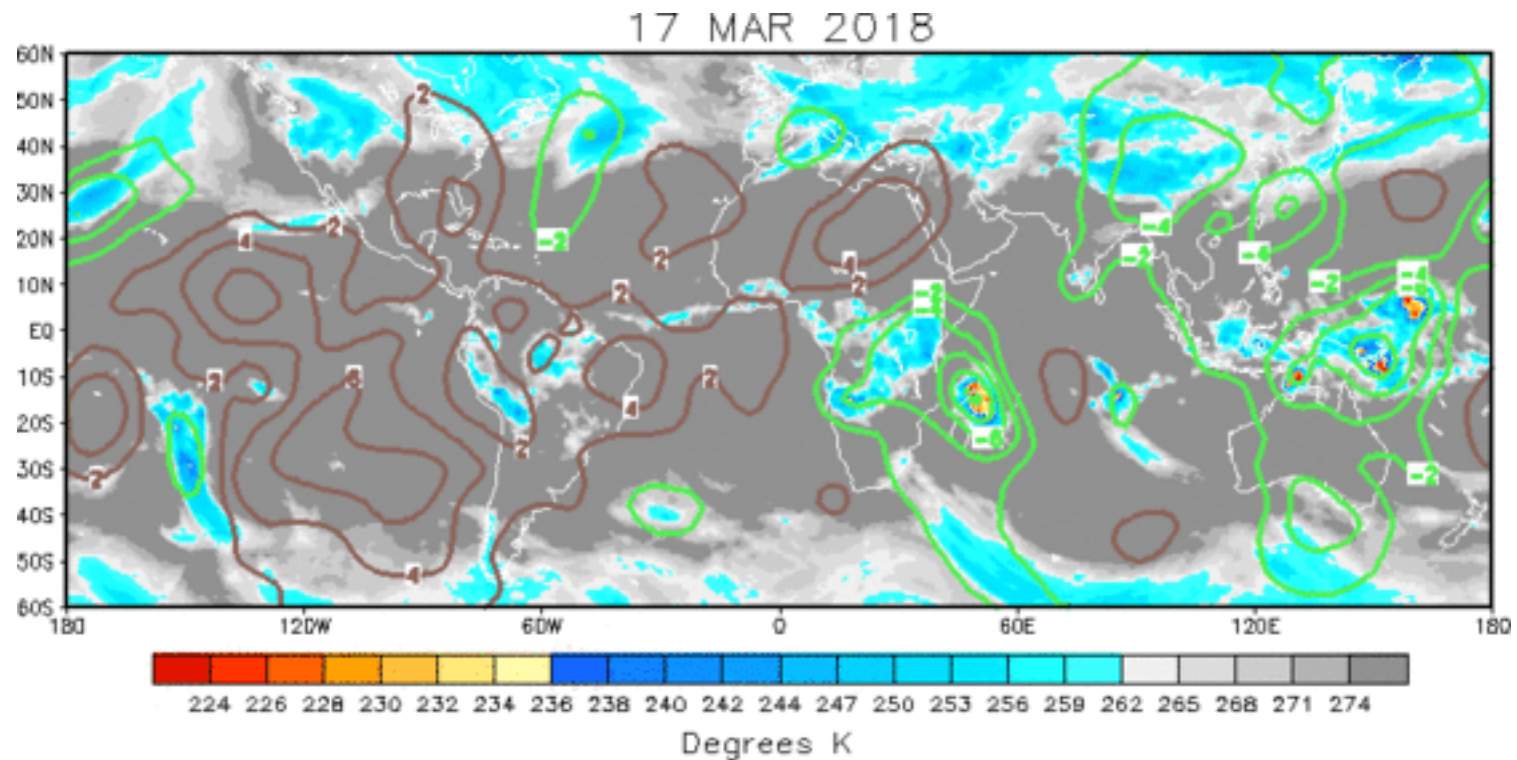
The signal destructively interfered with the base state through the end of December, crossing the Western Hemisphere into the Indian Ocean for the beginning of January.

This MJO event further intensified during January and early February, leading to another period of destructive interference with the ENSO state, prior to weakening during March.





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



A fairly noisy wave-1 pattern is present with enhanced (suppressed) convection generally over the Eastern (Western) Hemisphere. The areas of enhanced convection over the Indian Ocean and Maritime Continent are related to tropical cyclone activity now in progress, or expected to develop in the next week.

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

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

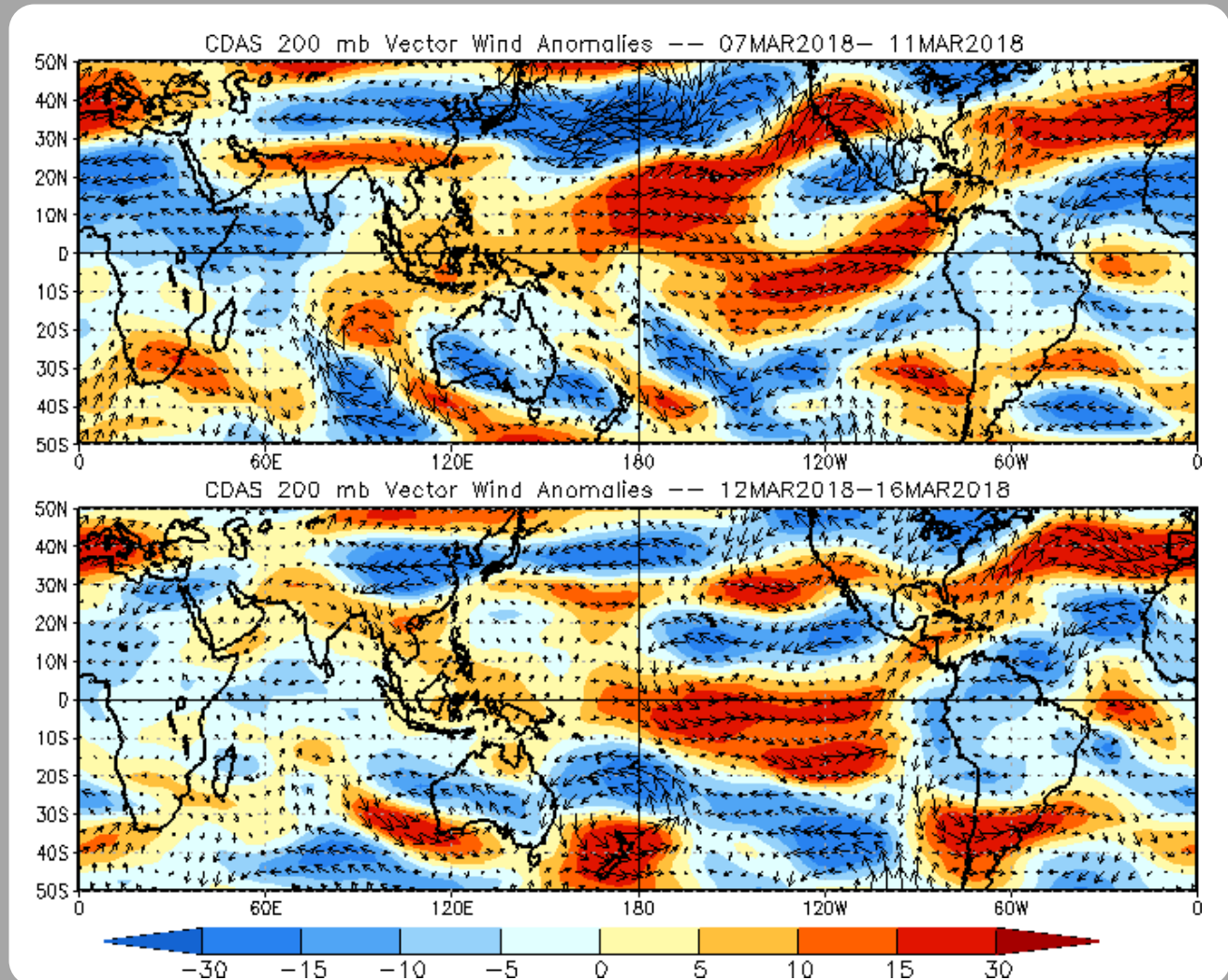
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

A bifurcating jet stream is depicted over the central Pacific, with cross-equatorial flow indicated downstream over the eastern Pacific.

The most recent analysis shows weak upper-level wind anomalies across the Eastern Hemisphere, but a much more robust anomaly pattern across the tropical and mid-latitude regions of the Western Hemisphere.



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

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

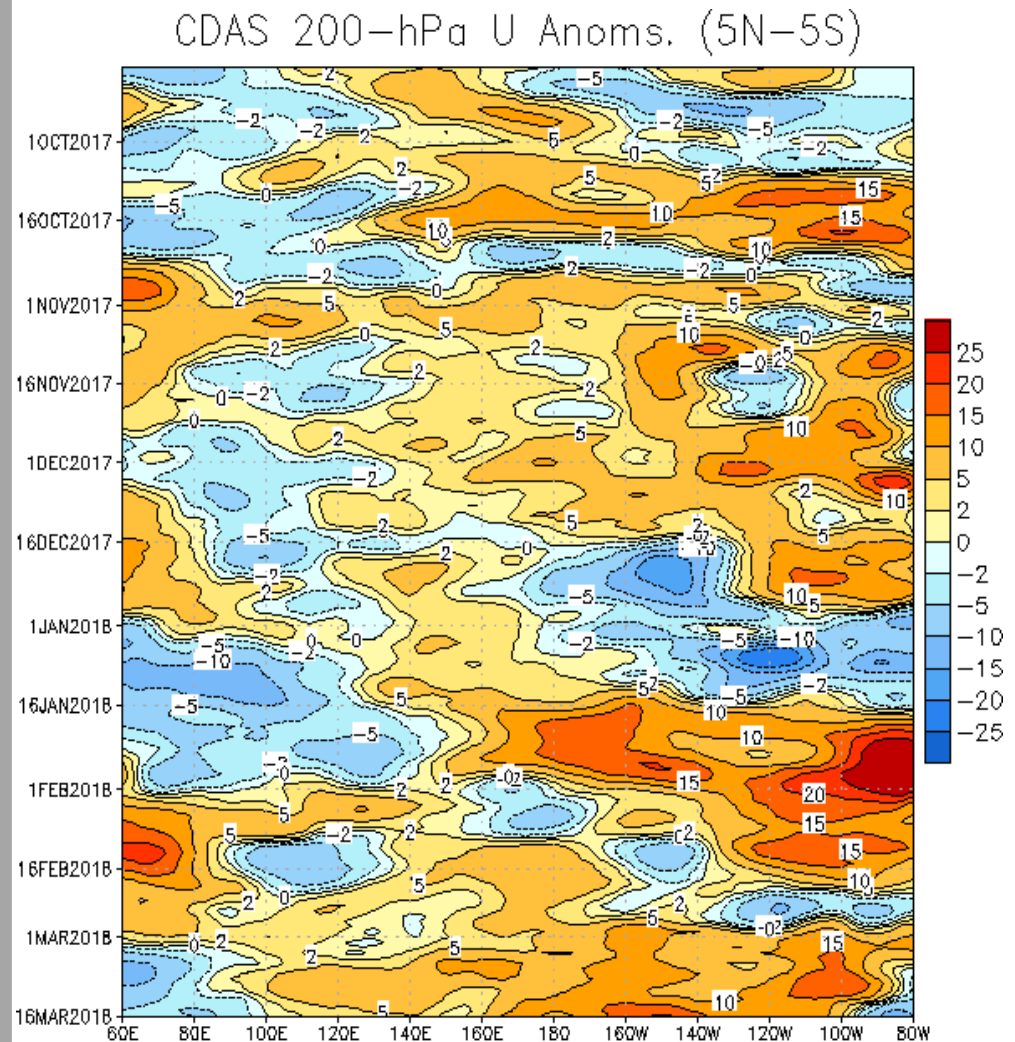
Easterly anomalies (blue shading) represent anomalous east-to-west flow

Low-frequency westerly anomalies remained in place east of 140°E starting in October, with the exception of a brief period of easterlies in late October. There is also some recent evidence of easterlies over the far Eastern Hemisphere over the last week or so that appear to have extratropical sourcing.

In mid-December anomalous easterlies developed east of the Date Line, replacing the westerly anomalies that had been generally present since October.

Strong anomalous westerlies that formed in early January just west of the Date Line propagated eastward, consistent with a strong MJO event during this period.

More recently, relatively stationary anomalous westerlies have dominated from 100°E across the Date Line to 100°W.



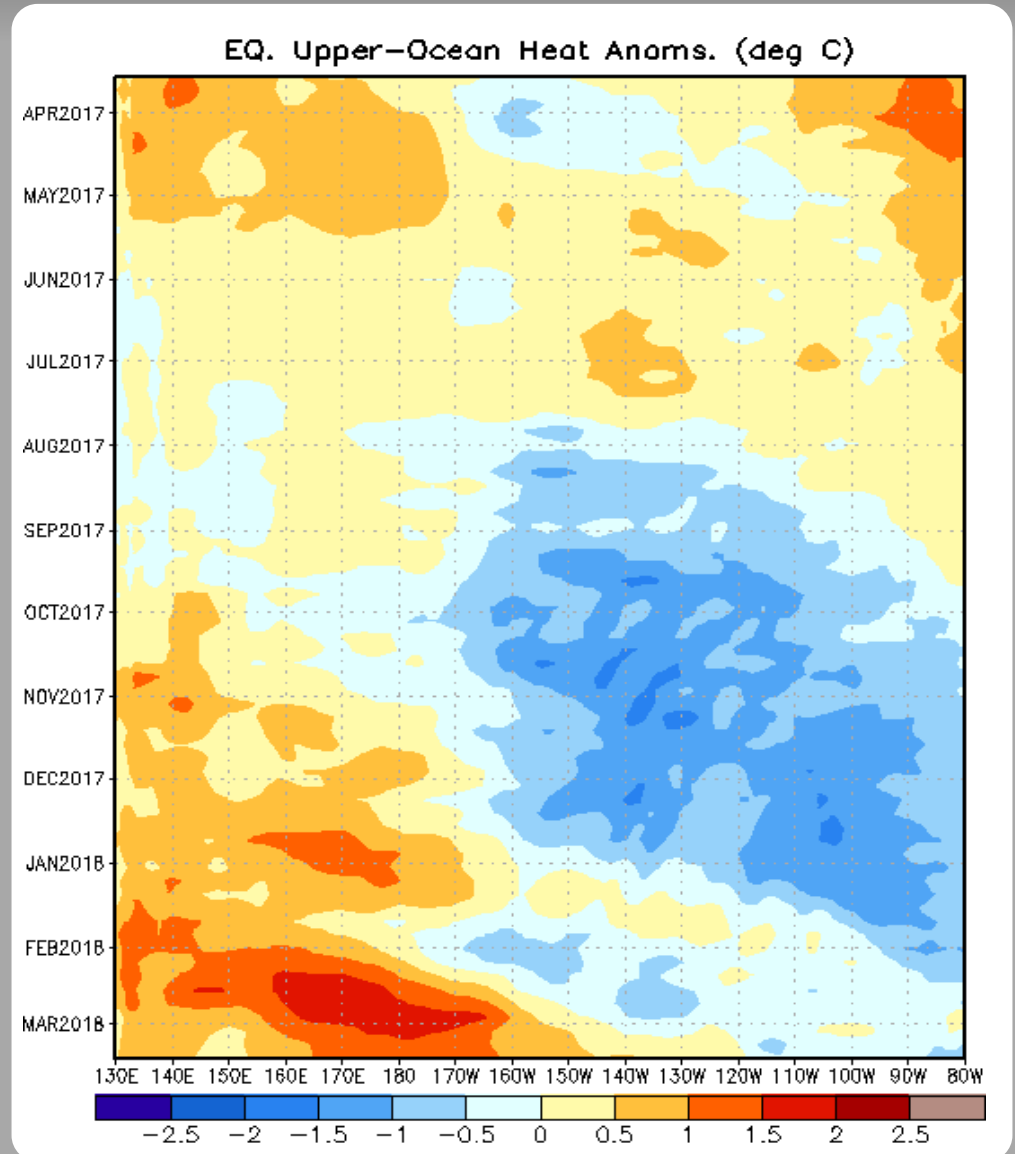
# Weekly Heat Content Evolution in the Equatorial Pacific

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.

Another downwelling Kelvin wave is leading to highly positive, eastward-propagating anomalies near and east of the Date Line.



# 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

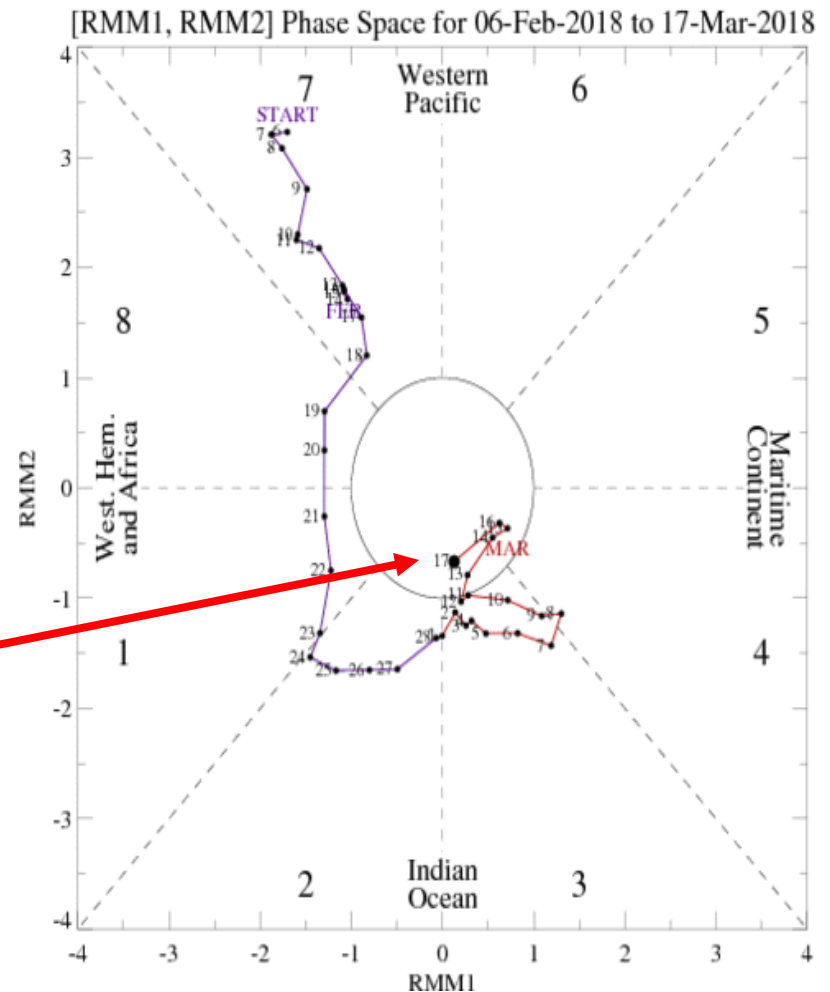
The triangular areas indicate the location of the enhanced phase of the MJO

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 MJO signal weakened significantly during March, and is now within the unit circle of RMM space over the Indian Ocean. It appears an Equatorial Rossby Wave (ERW) is at least partly responsible for the westward shift in the convective signal between March 8-11.

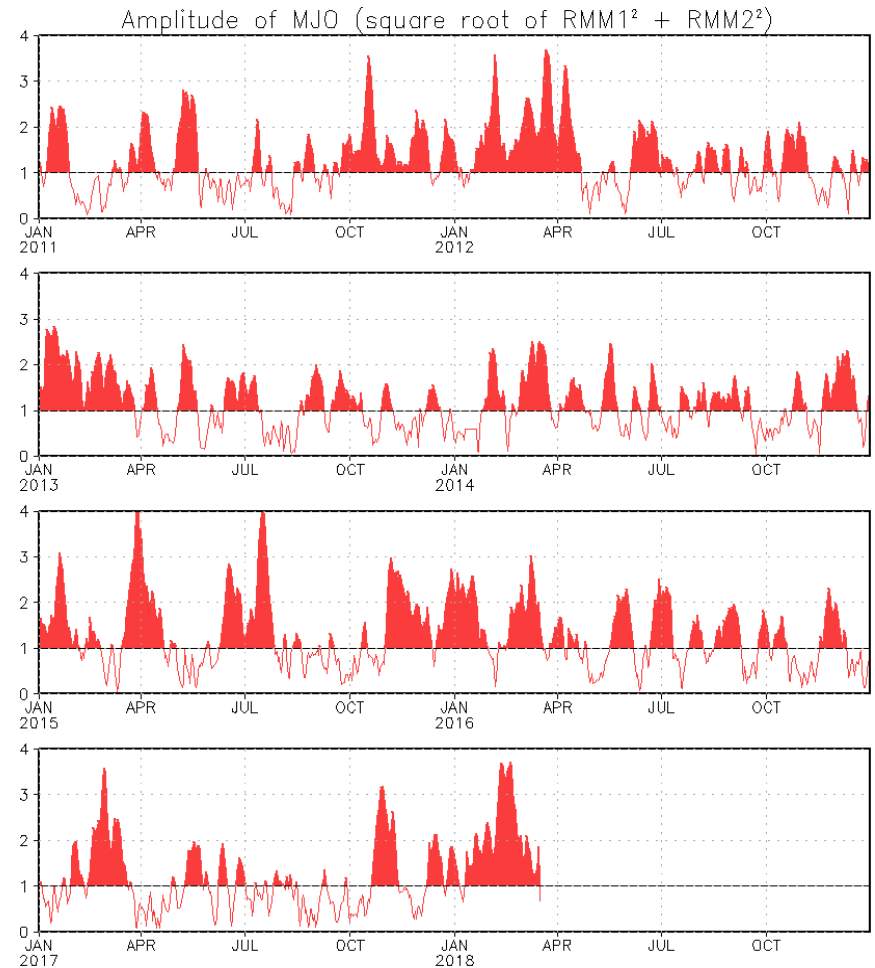




# MJO Index - Historical Daily Time Series

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

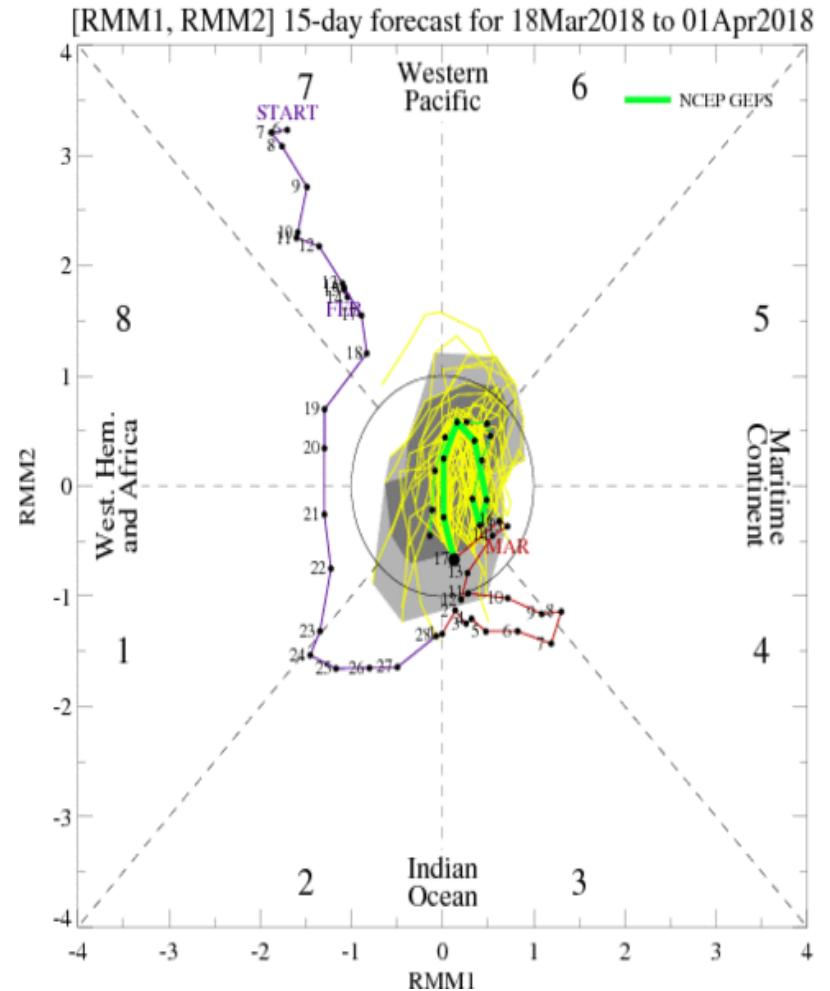
RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS forecasts the continuation of a weak MJO signal during the next two weeks between the eastern Indian Ocean and the Western Pacific. Westward-moving modes of tropical variability are likely responsible for the predicted westward motion of the MJO signal during Week-2.

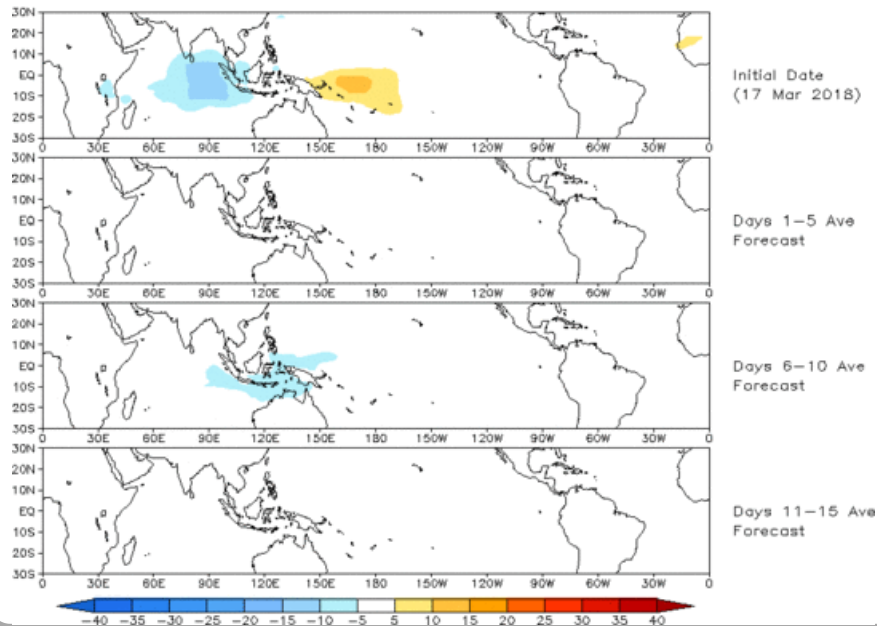
Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean



# 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: 17 Mar 2018  
OLR

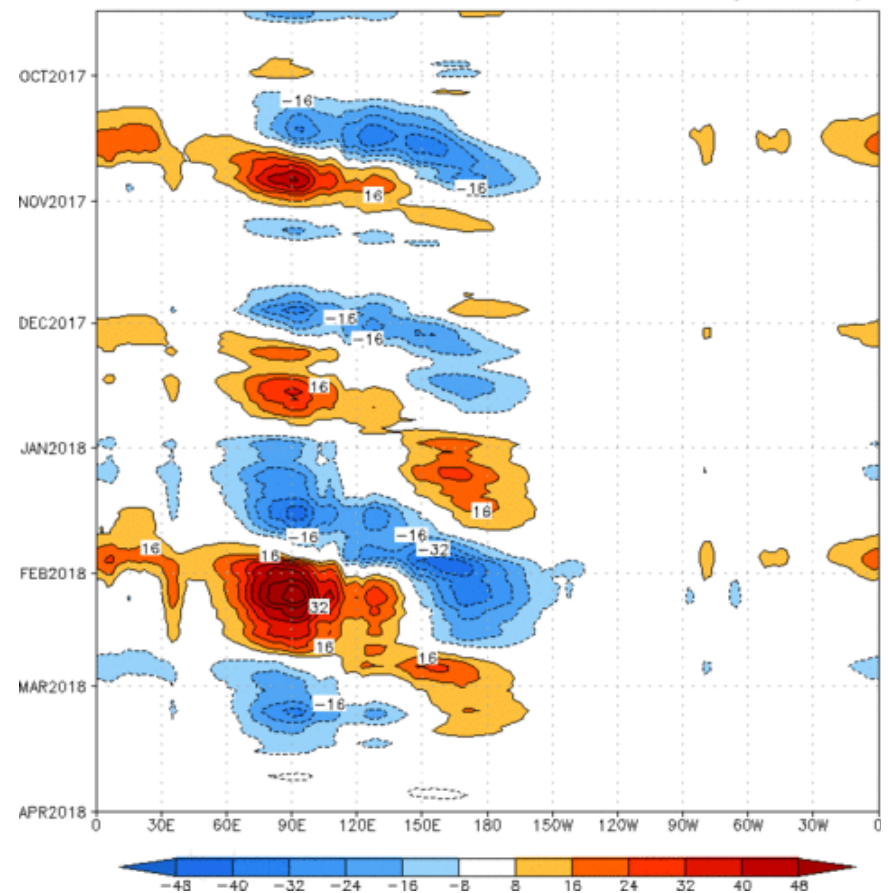


OLR anomalies associated with the MJO based on the GEFS show a weakened MJO signal, with the enhanced convective phase forecast to move from the eastern Indian Ocean across the Maritime Continent.

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° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days

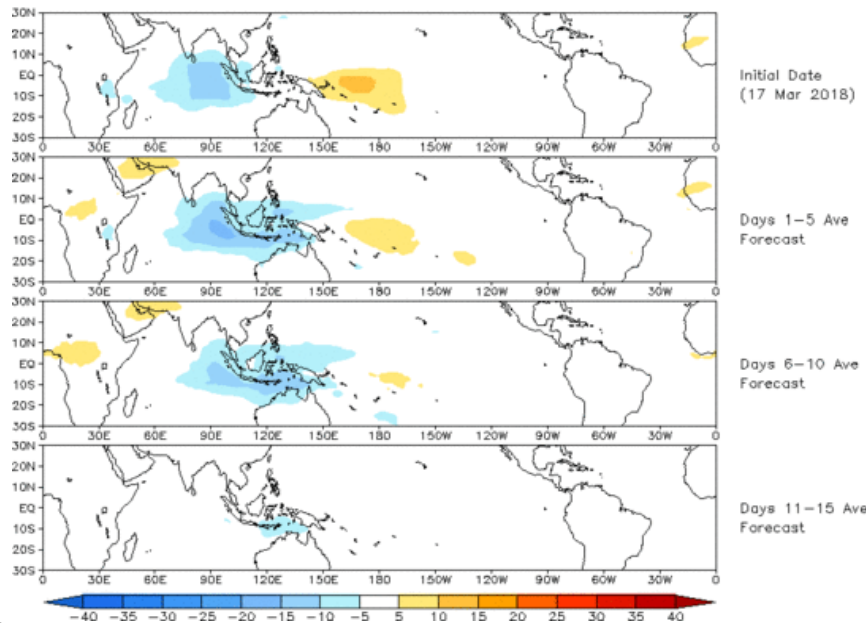
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [7.5°S,7.5°N] (cint:4Wm<sup>2</sup>) Period:15-Sep-2017 to 17-Mar-2018  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# 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 (17 Mar 2018)

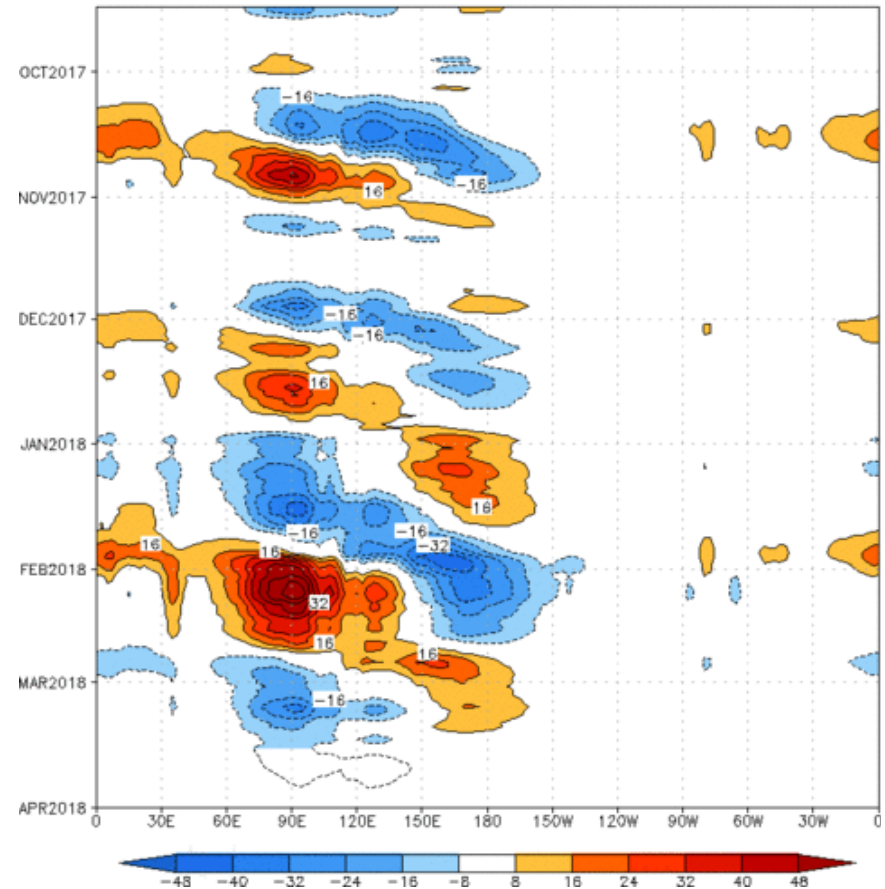


The constructed analog predicts a slowly propagating signal, with rapid weakening of the signal expected during Week-2.

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.)

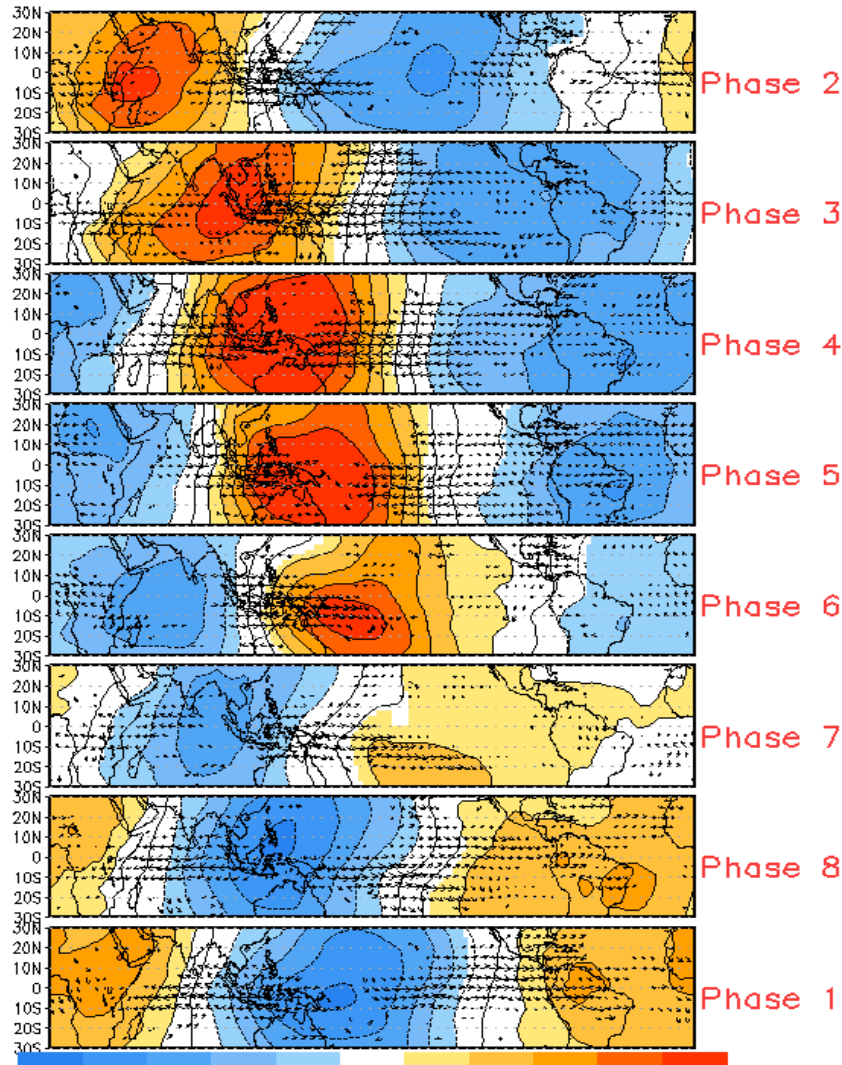
Time-longitude section of ( $7.5^{\circ}$  S- $7.5^{\circ}$  N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S, $7.5^{\circ}$ N] (cont:  $4\text{Wm}^{-2}$ ) Period: 15-Sep-2017 to 17-Mar-2018  
The unfilled contours are CA forecast reconstructed anomaly for 15 days

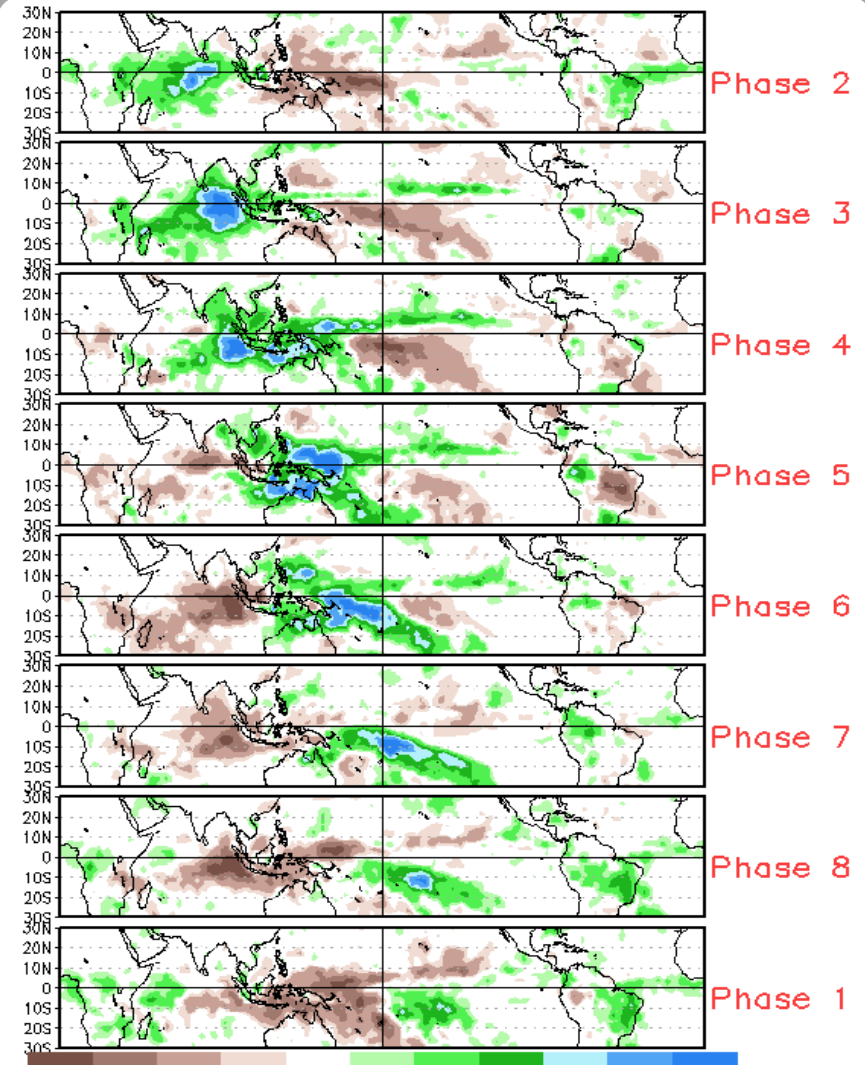


# MJO Composites - Global Tropics

850-hPa Velocity Potential and  
Wind Anomalies (Nov - Mar)



Precipitation Anomalies (Nov - Mar)

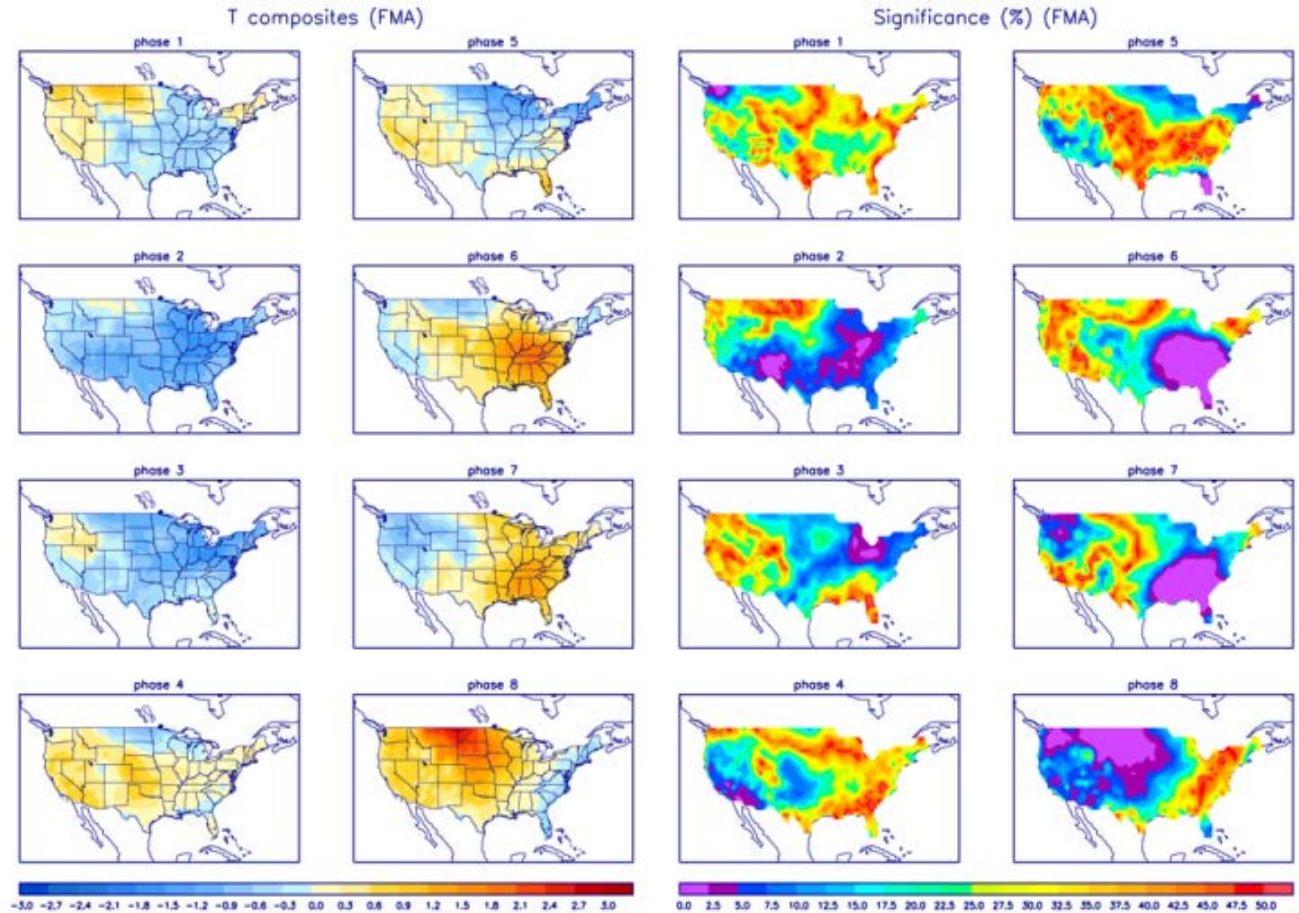




# U.S. MJO Composites - Temperature

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

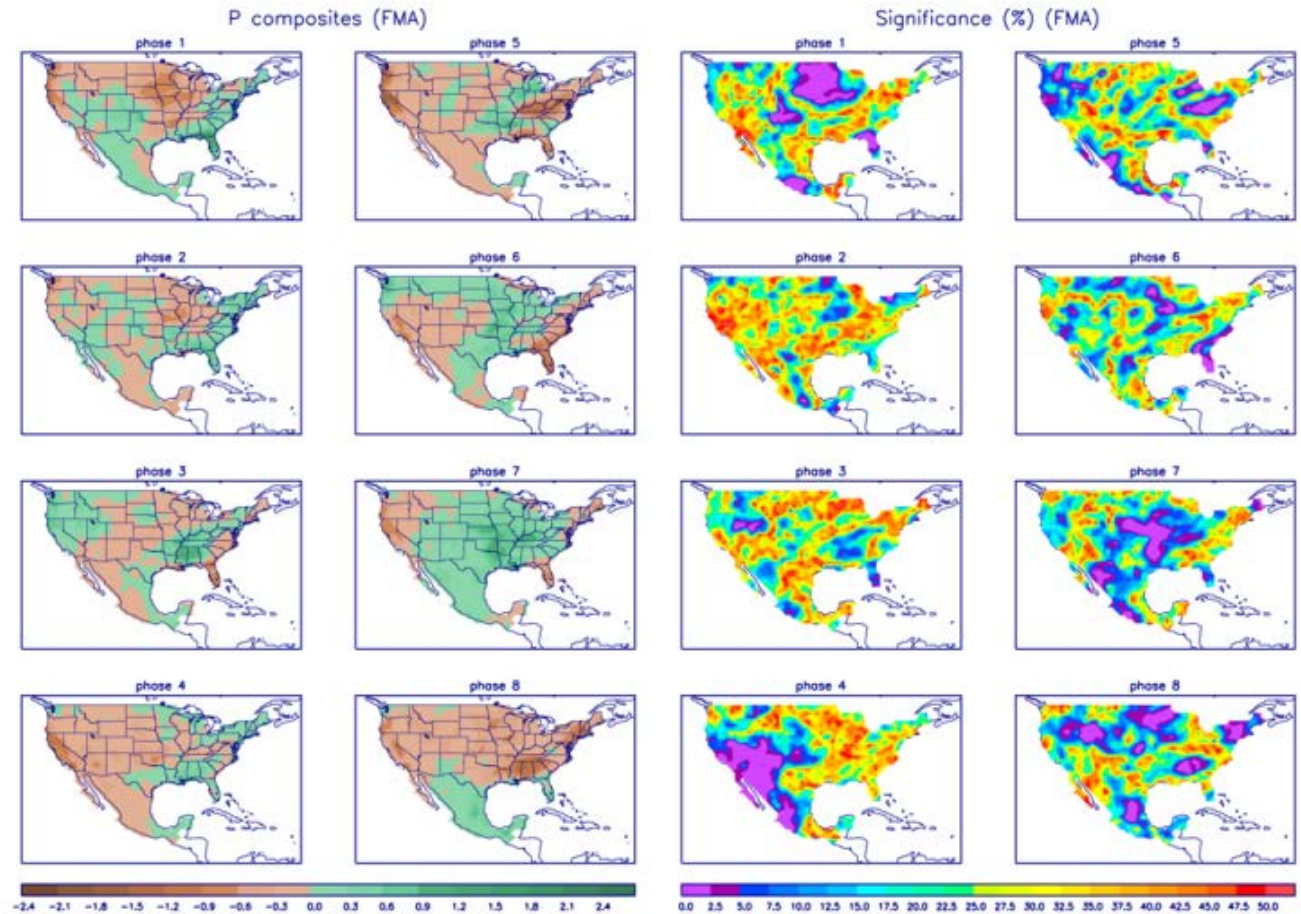
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml>



# 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

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