

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



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Climate Prediction Center / NCEP  
8 May 2017

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

- Both RMM-based and CPC velocity potential-based MJO indices indicate an amplifying signal with some eastward propagation.
- Dynamical model RMM index forecasts generally indicated eastward propagation. The GEFS has a slower, and less amplified signal, while the ECMWF output is quite a bit faster. Both have a signal moving into the Indian Ocean by Week-2. Statistical tools such as the constructed analog generally favor more canonical evolution of the MJO index.
- The continued propagation of the MJO to the Indian Ocean is favored in this week's outlook, with the MJO playing a role in the overall pattern of tropical convection. Other modes of variability are also likely to influence the pattern over the West Pacific.
- During Week-1, the MJO may play a role in unusual early May tropical cyclone formation over the East Pacific, as well as enhanced convection across parts of the tropical Atlantic and Africa. During Week-2, the convective signal from the MJO is likely to be centered over the Indian Ocean.

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>

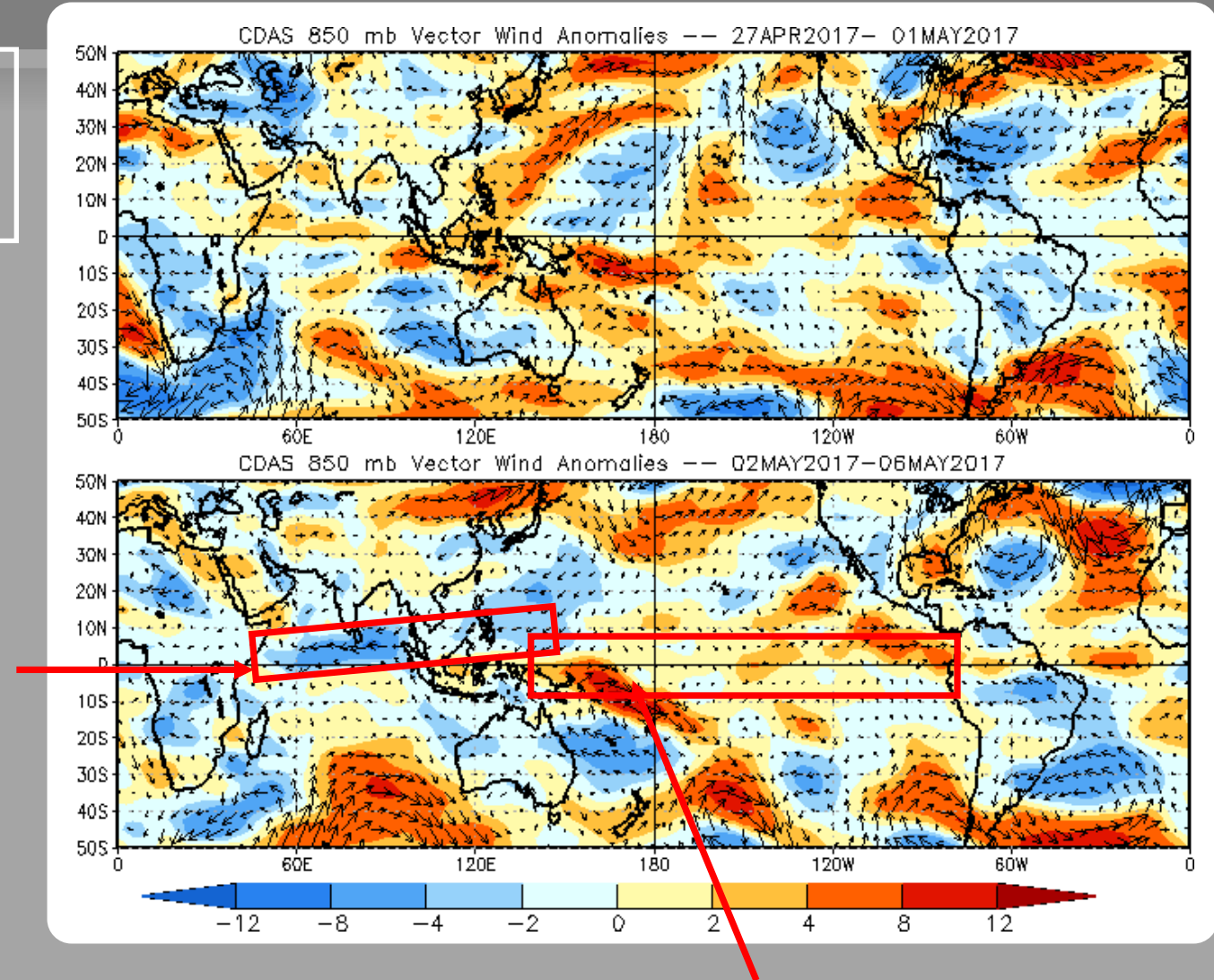
# 850-hPa Vector Wind Anomalies ( $\text{m s}^{-1}$ )

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Easterly anomalies build in over the Indian Ocean and portions of the West Pacific.



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

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

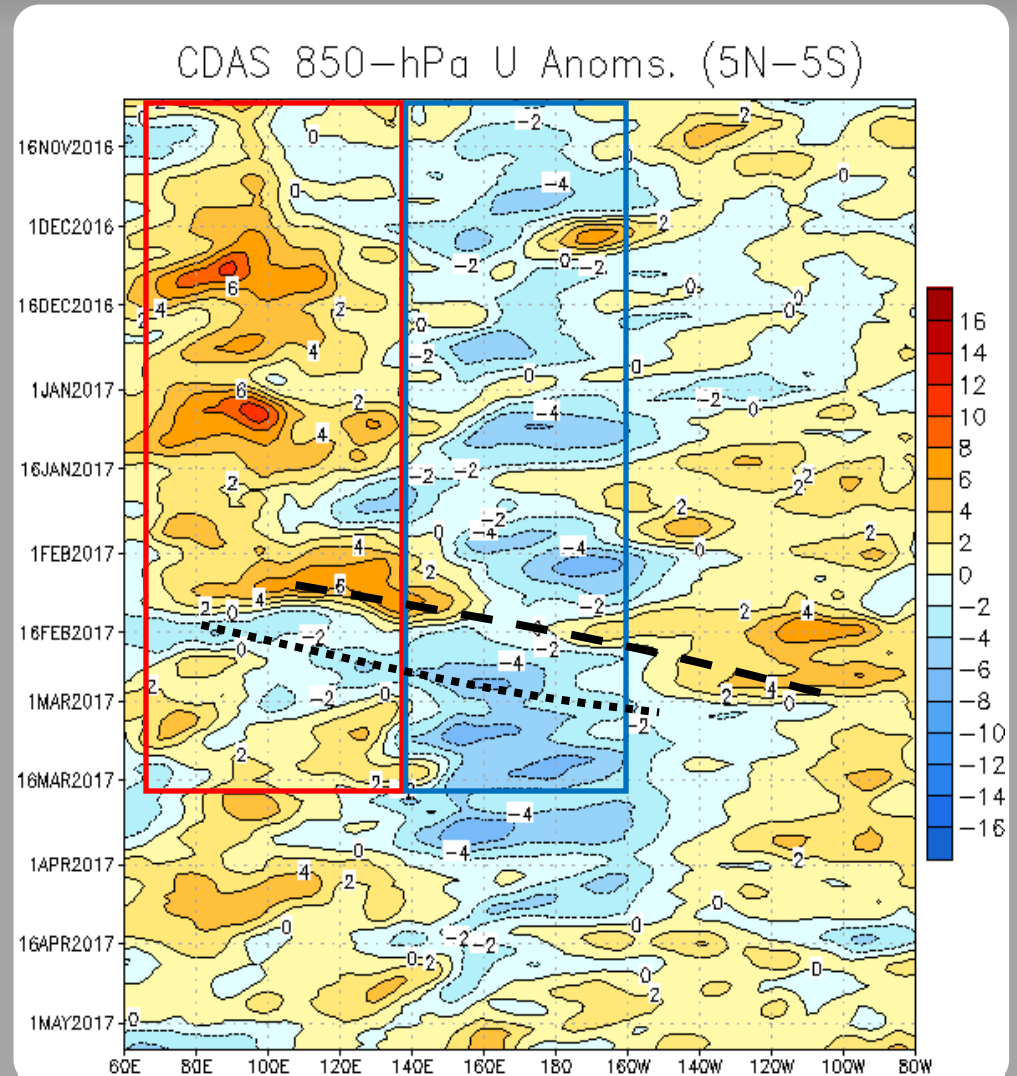
Easterly anomalies (blue shading) represent anomalous east-to-west flow

Persistent westerly (easterly) anomalies, shown by the red (blue) box at right, were associated with the negative phase of the Indian Ocean Dipole (IOD), and later, La Niña.

During late January, Rossby wave activity was evident, with destructive interference on the base state evident through 100E.

During February, MJO activity also destructively interfered with the base state. During mid-March and April, the low frequency state seemed to reemerge, with some intraseasonal variability evident in late March.

Recently, the anomaly pattern is rather stationary, but opposite in phase from what was observed earlier this year.



# OLR Anomalies - Past 30 days

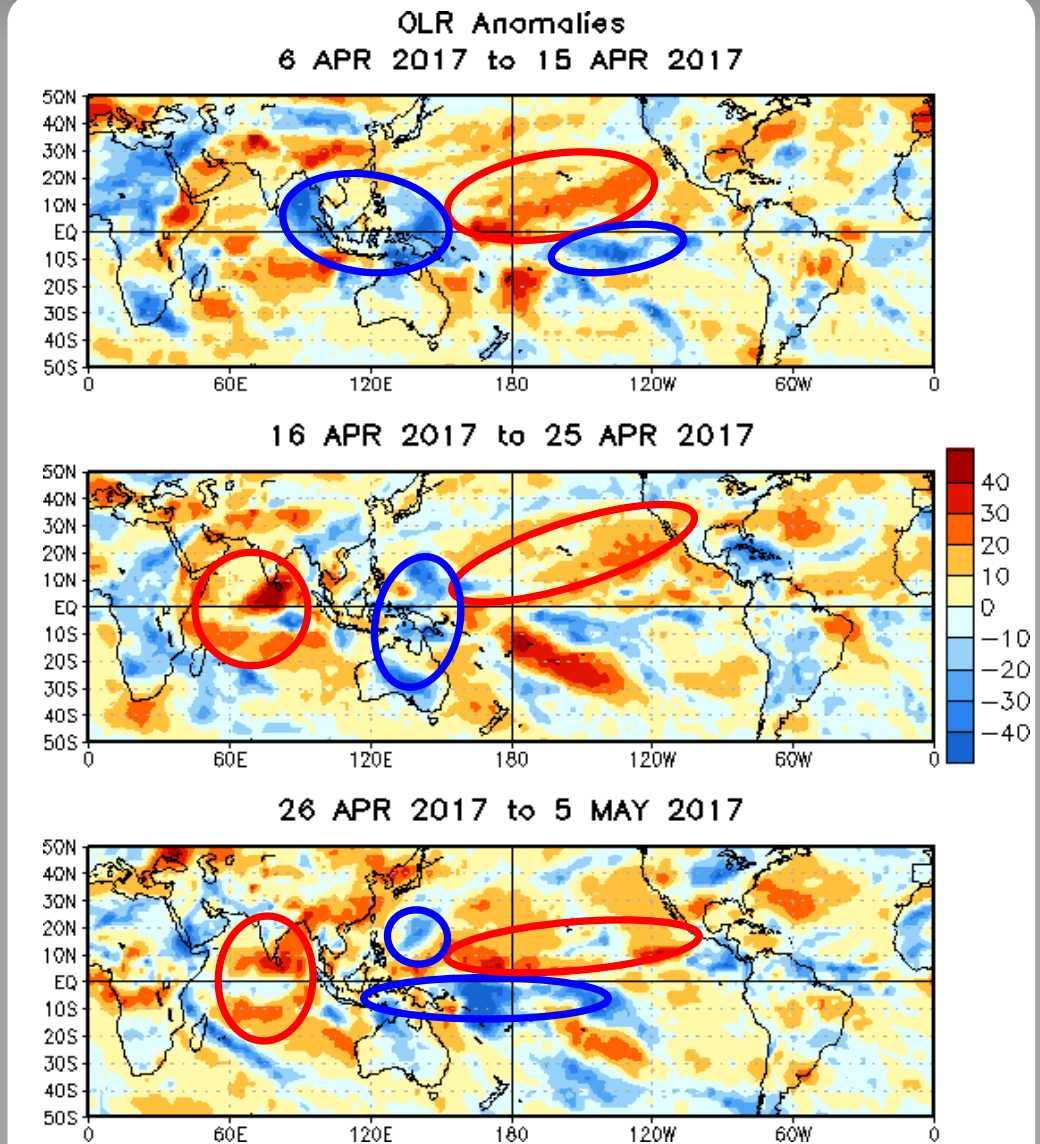
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During mid-April, suppressed convection persisted over much of the Pacific and Indian Oceans. Discrete features (e.g., tropical cyclones) evident over the Bay of Bengal and the northwestern Pacific influenced the pattern of enhanced convection.

The low frequency state continued to influence the pattern in mid- to late April. Smaller scale areas of enhanced convection related to tropical cyclone activity persisted over parts of the Maritime Continent and northwest Pacific.

Anomalies over the Pacific became more east-west oriented, while subsidence was apparent over the off-equatorial Indian Ocean. Higher frequency anomalies appear in the OLR field over the northwest Pacific Ocean.



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

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

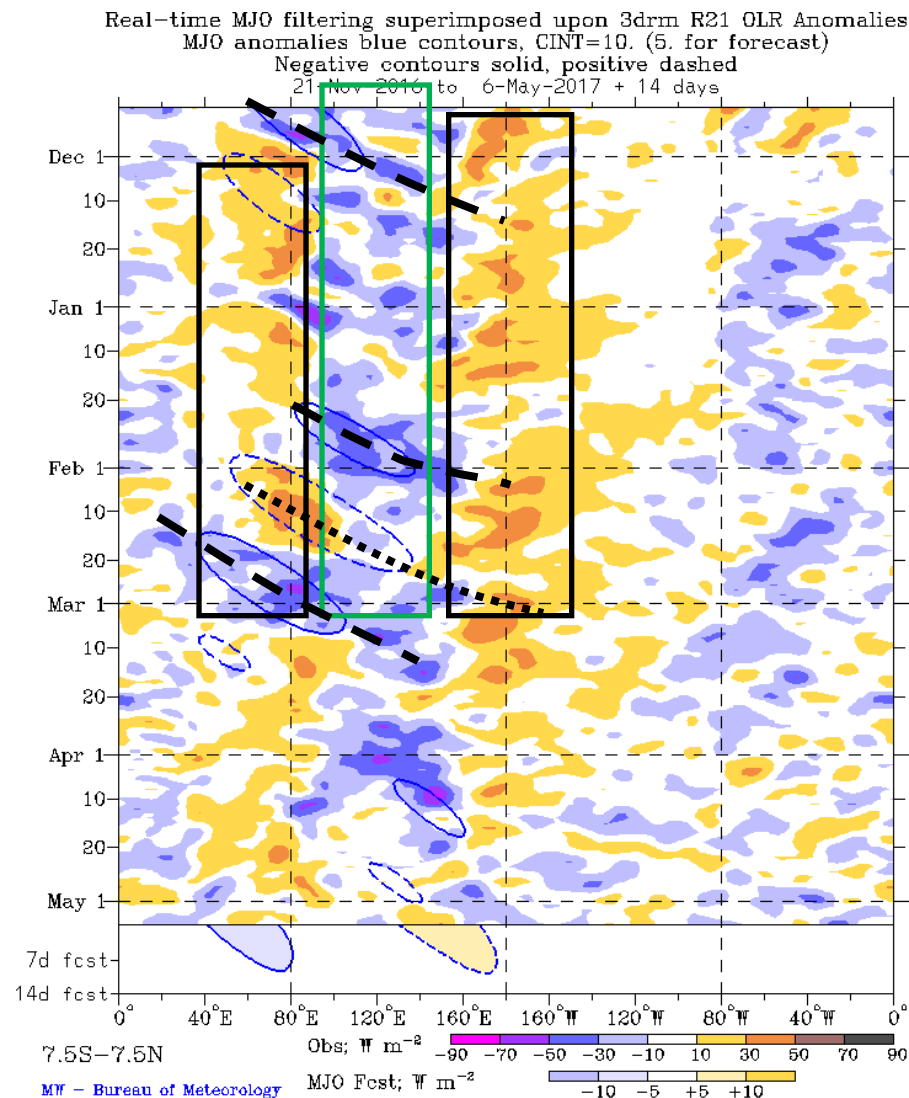
**Wetter-than-normal conditions, negative OLR anomalies (blue shading)**

A low frequency state favoring enhanced convection over the eastern Indian Ocean and the Maritime Continent has been evident from July through mid-February (green box), with suppressed convection over the Indian Ocean and near the Date Line (black boxes).

Intraseasonal events in January through mid-March have served to alter the low frequency states. Particularly, with the suppressed phase reversing the low frequency enhanced convective signal over the Maritime Continent in late February.

The MJO signal weakened by mid-March. Kelvin wave activity was evident from the Pacific through the Western Hemisphere.

More recently, the OLR field has some hints of eastward propagation near the Date Line. East of Date Line, there is a tendency for enhanced convection.





# 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

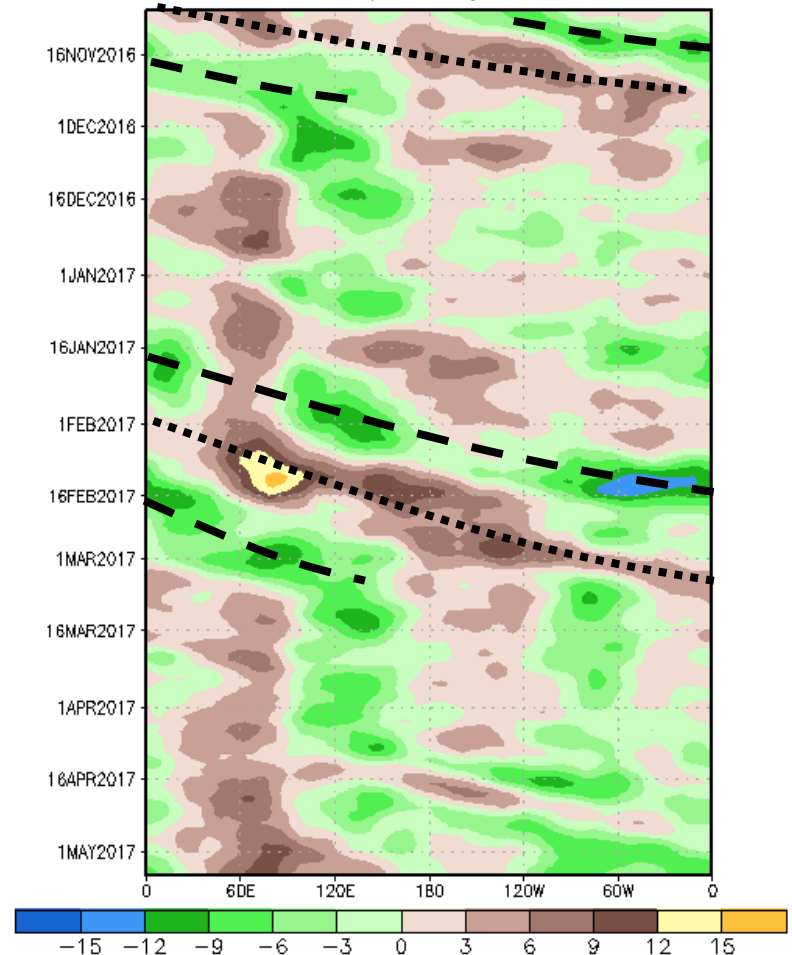
During November, eastward propagation was observed consistent with MJO activity on the fast end of the intraseasonal spectrum.

After a break in apparent MJO activity during December and early January, a signal emerged over the Maritime Continent and continued propagating through early March, creating alternating periods of constructive and destructive interference with the base state.

During March, a low frequency signal favoring enhanced (suppressed) convection over the Maritime Continent (Indian Ocean) once again became the primary component of the anomaly field.

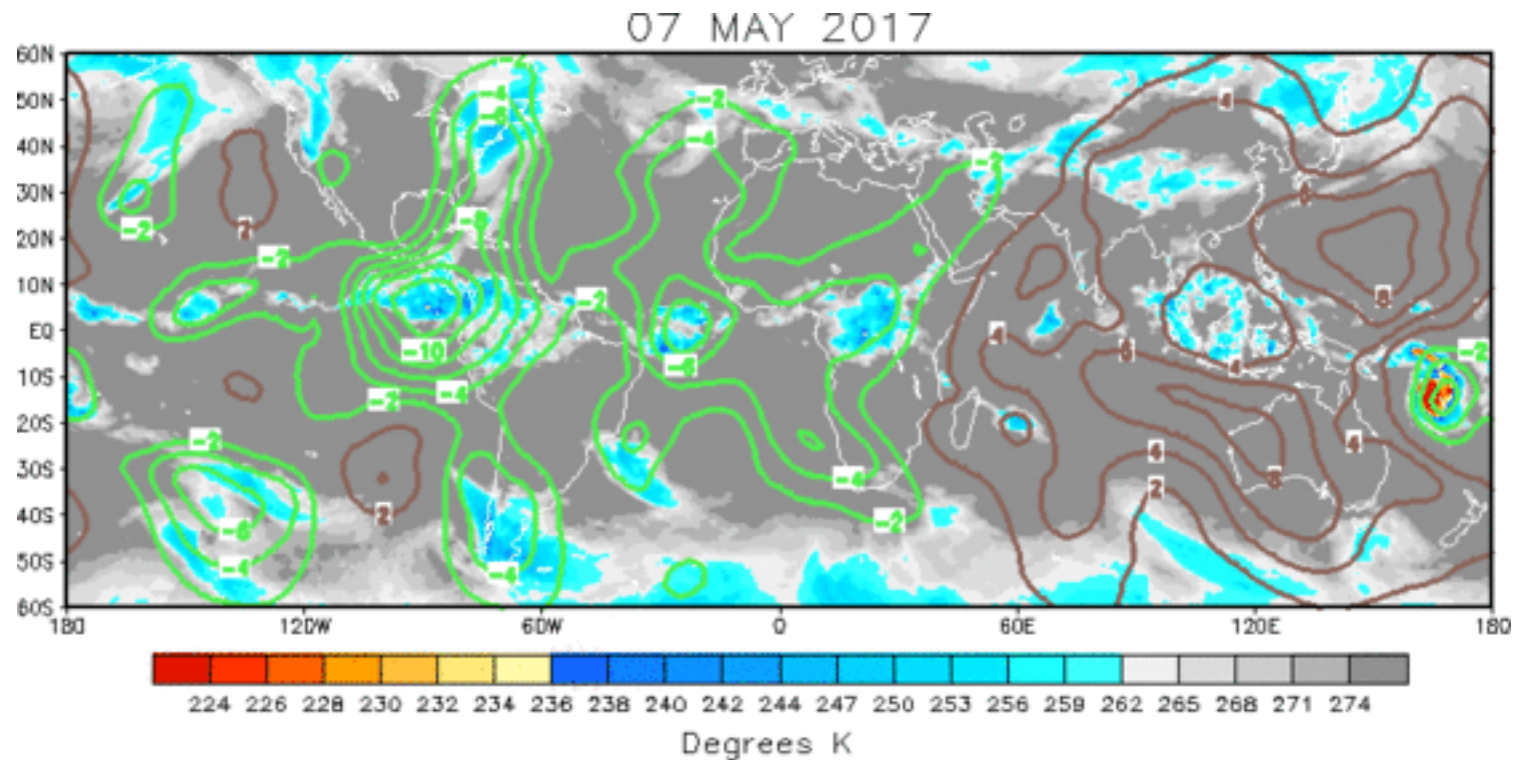
Kelvin wave activity has been apparent during April, primarily east of the Date Line. Some stagnation of the pattern is evident during May, though some eastward propagation is noted.

200-hPa Velocity Potential Anomaly: 5N-5S  
5-day Running Mean





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



The spatial distribution of the upper-level VP anomaly field depicts a fairly coherent pattern favoring large scale anomalous ascent (descent) over the Western Hemisphere (Indian Ocean). A second area of strong upper-level divergence is present over the southwest Pacific.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

Negative anomalies (green contours) indicate favorable conditions for precipitation

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

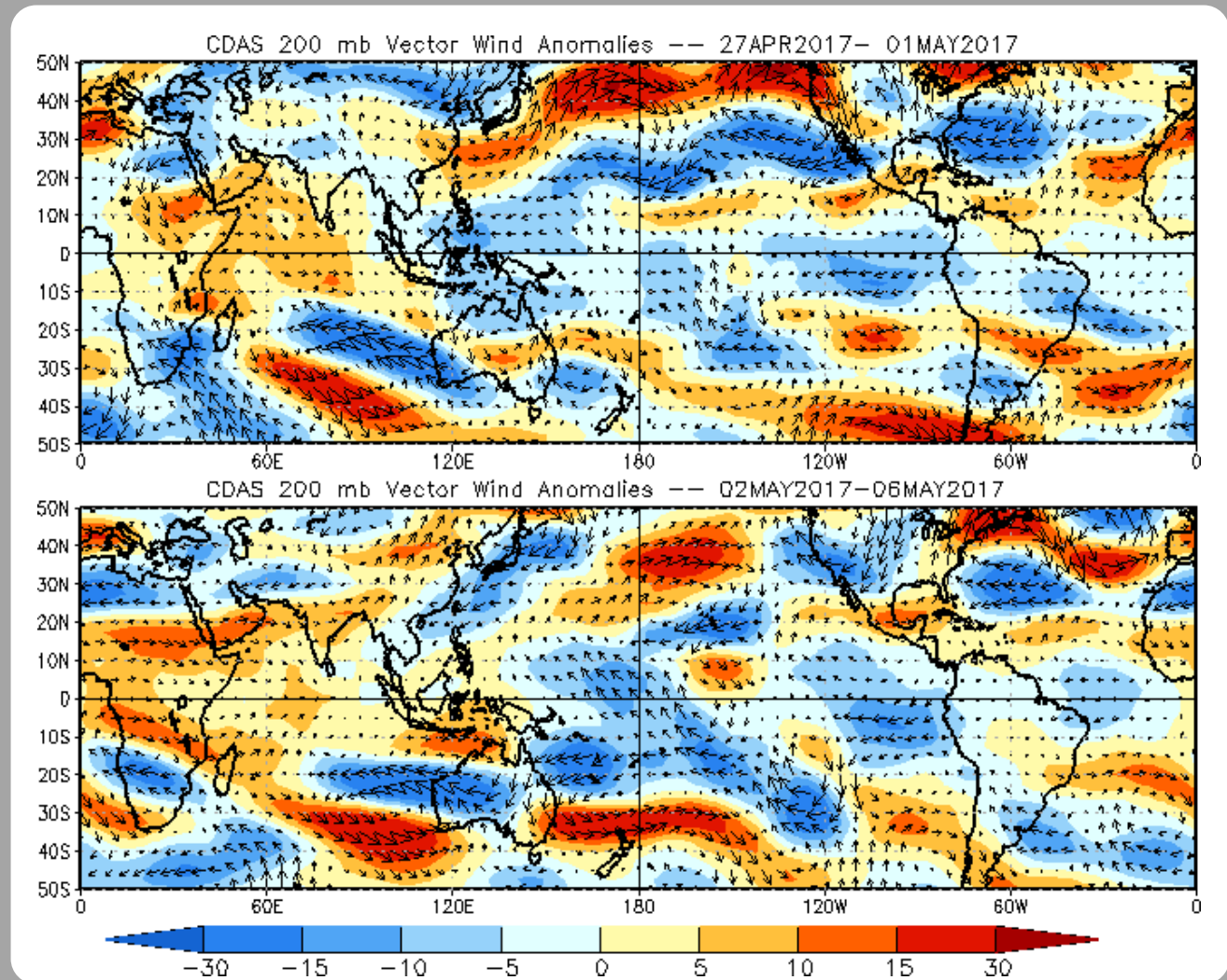
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

An anticyclonic gyre persisted over the northwest Pacific during late April.

During early May, the anticyclone gyre shifted eastward. The variability is much higher frequency east of the Date Line than from Africa to the West Pacific.



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

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

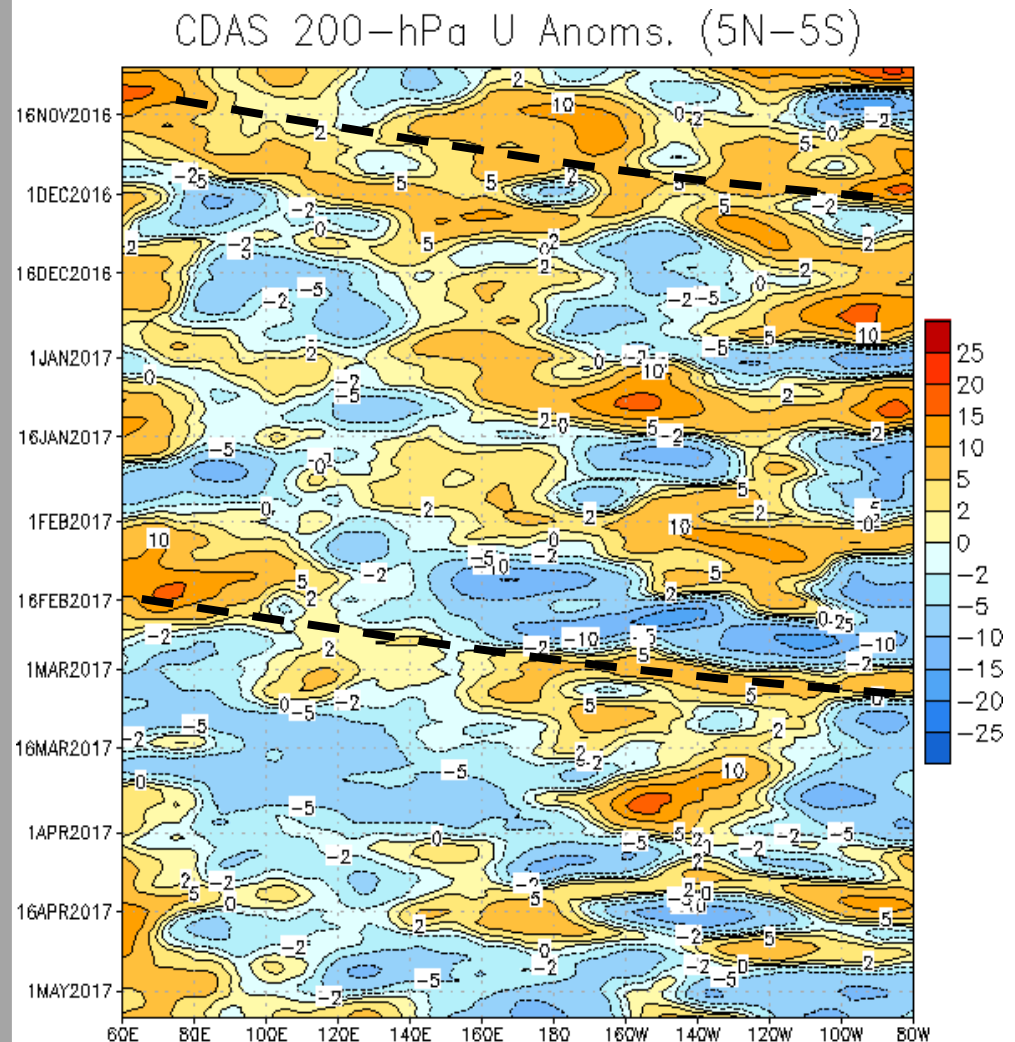
Easterly anomalies (blue shading) represent anomalous east-to-west flow

In November, anomalous westerlies persisted near the Date Line, though intraseasonal variability associated with the MJO is evident.

In late November, easterly anomalies re-emerged across the Indian Ocean and Maritime Continent, consistent with the passage of sub-seasonal activity and the re-alignment of the low frequency base state.

Near the end of 2016 a period of westerlies disrupted the low frequency state between 80-130E and continued propagating eastward through the Western Hemisphere.

Easterly anomalies returned to the East Pacific during late April. During early May, easterly (westerly) anomalies also developed over the Central Pacific (Maritime Continent)

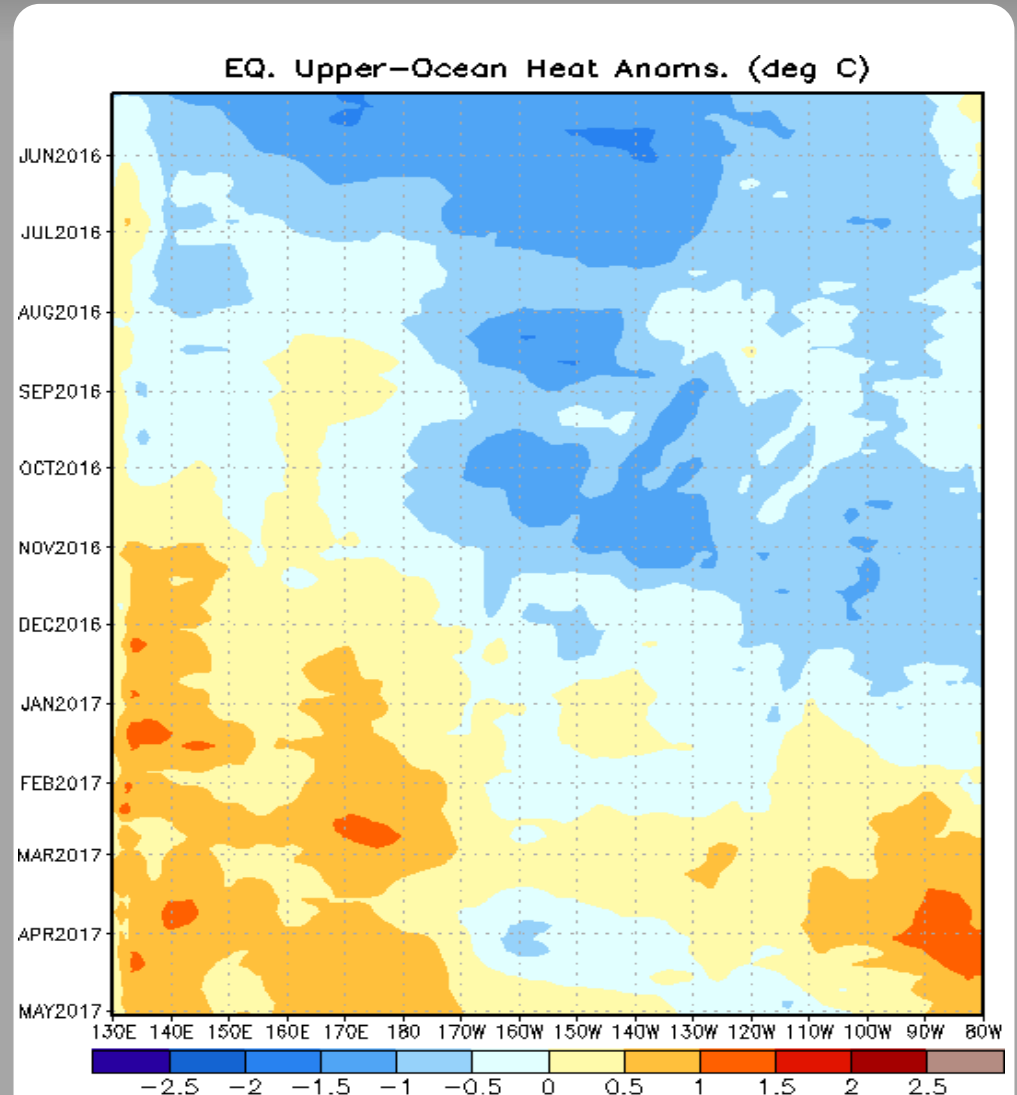


# Weekly Heat Content Evolution in the Equatorial Pacific

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.

An eastward expansion of below average heat content over the western Pacific is evident through June, with widespread negative anomalies building across the Pacific over the course of boreal spring and summer.

The anomaly field has weakened across the central and eastern Pacific, with positive anomalies persisting over much of the Pacific, except for a small portion of the eastern 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

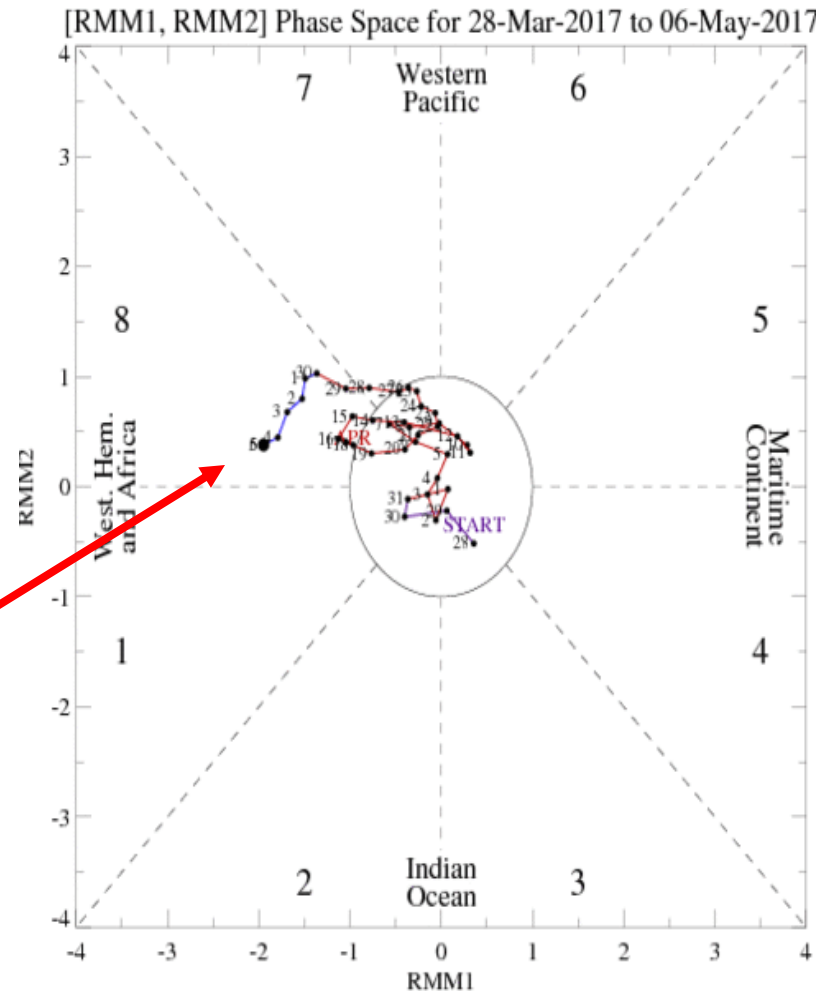
The triangular areas indicate the location of the enhanced phase of the MJO

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

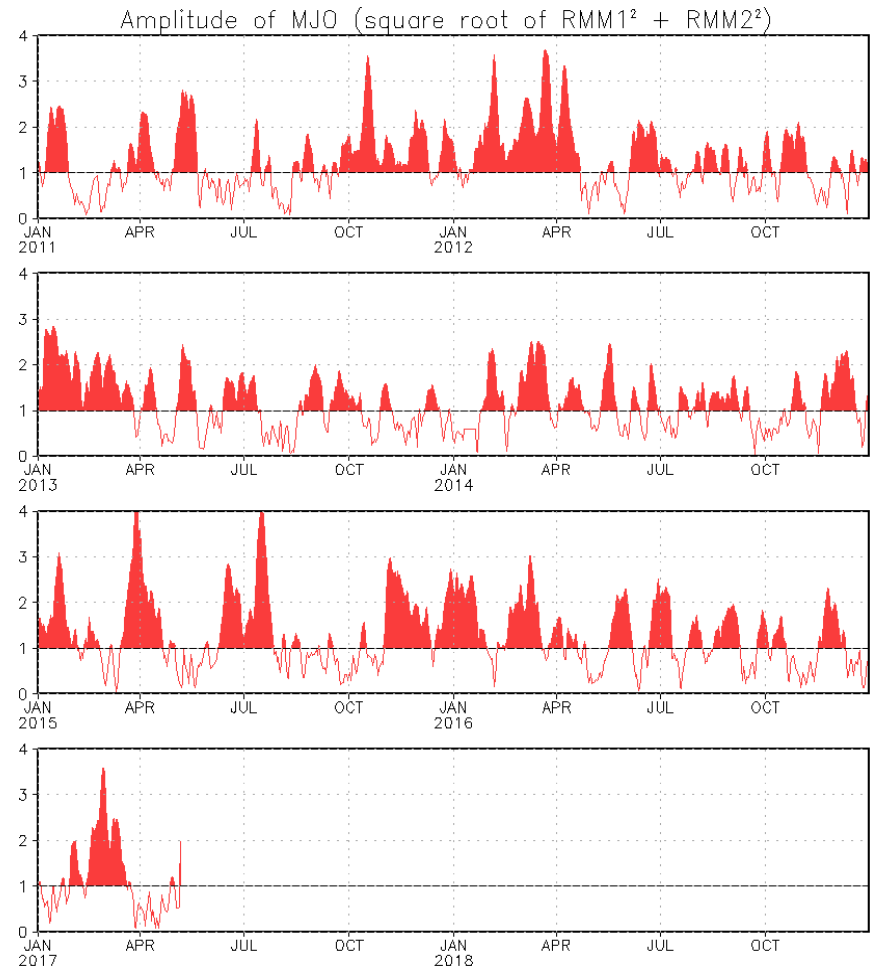
During the past several days, the amplitude of the RMM-based MJO index has increased, suggesting an emerging enhanced phase over the East Pacific.



# 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

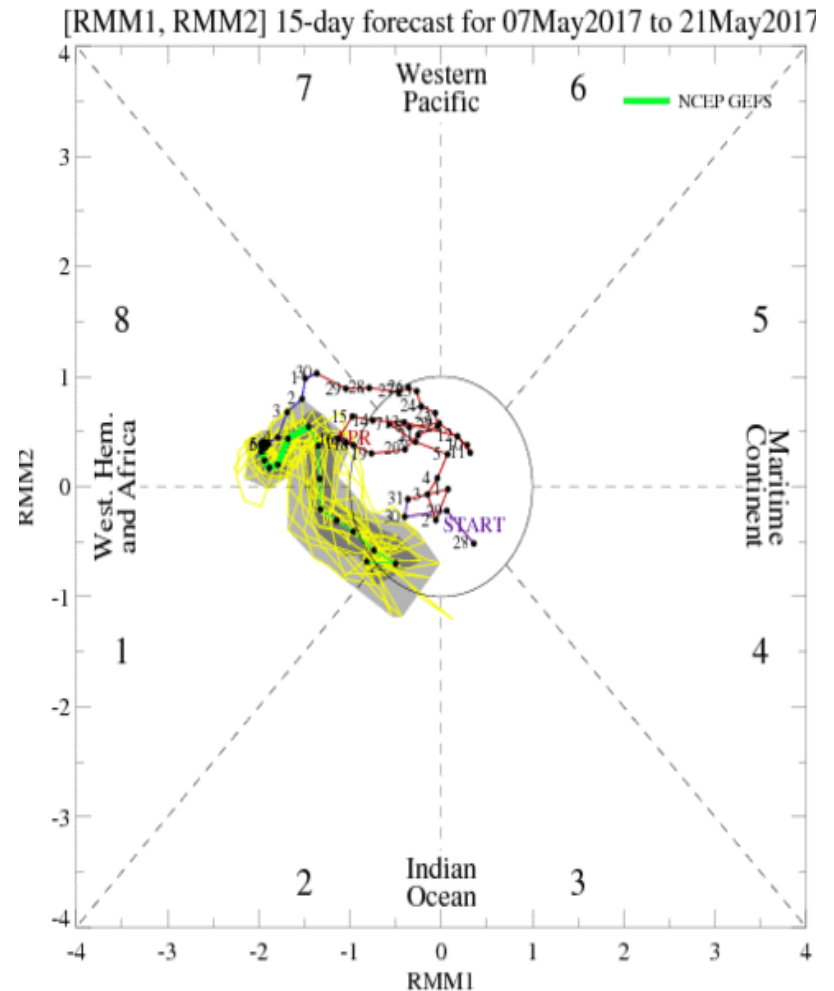
light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS depicts a gradual decrease in the amplitude of the MJO index over the next two weeks, with some eastward propagation.

There are indications of influence from other modes of variability (the “S” shape in the forecast plot).

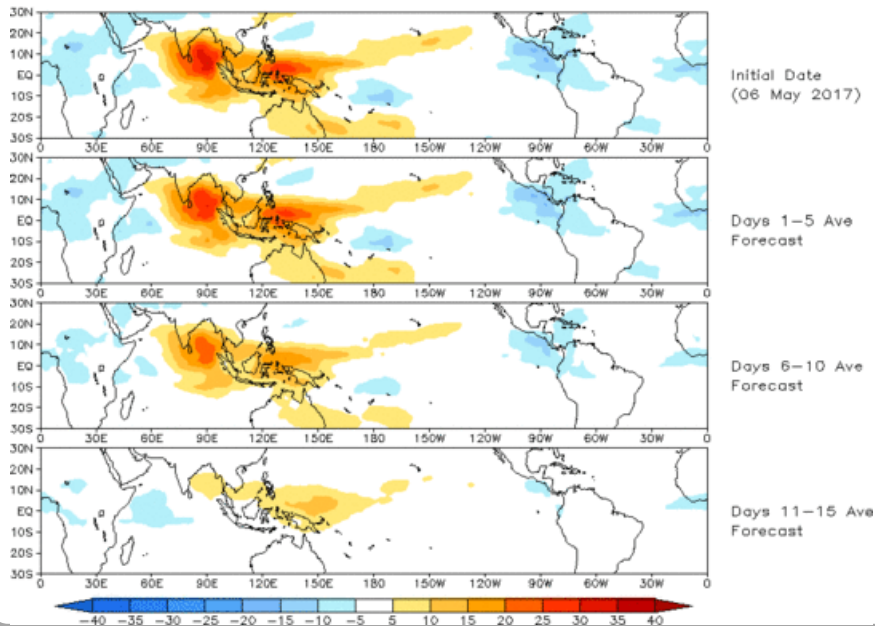
Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean



# 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: 06 May 2017  
OLR

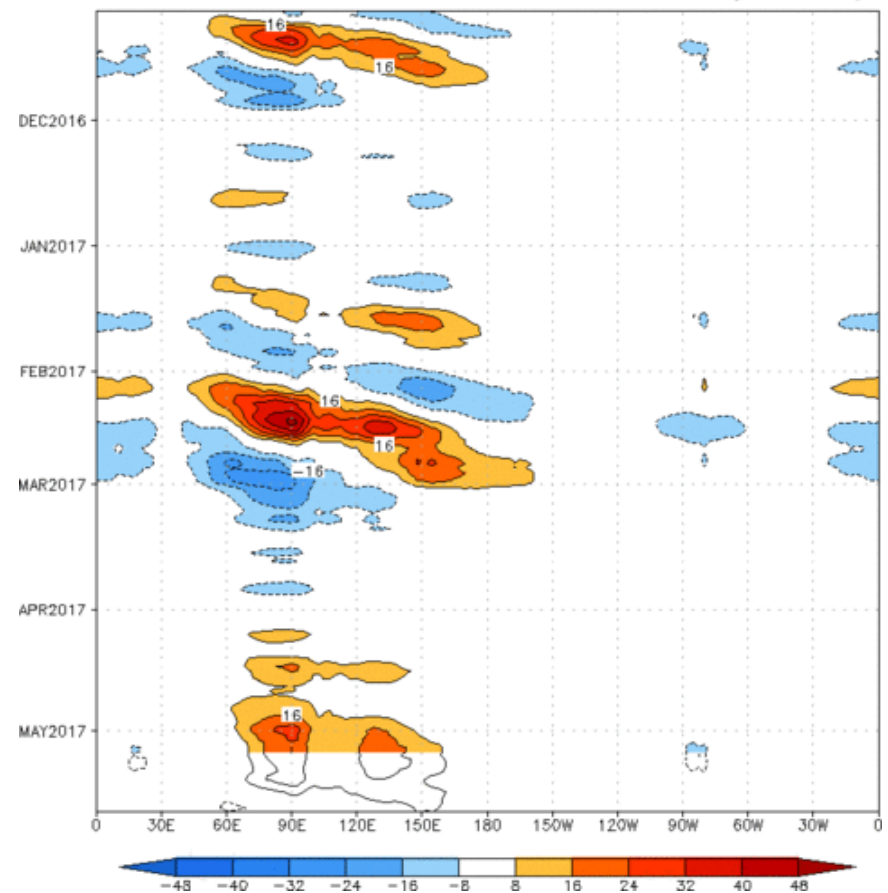


The GEFS RMM-based OLR anomaly forecast depicts a gradual weakening of a fairly stationary anomaly field over the next two weeks. There is slight eastward propagation.

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

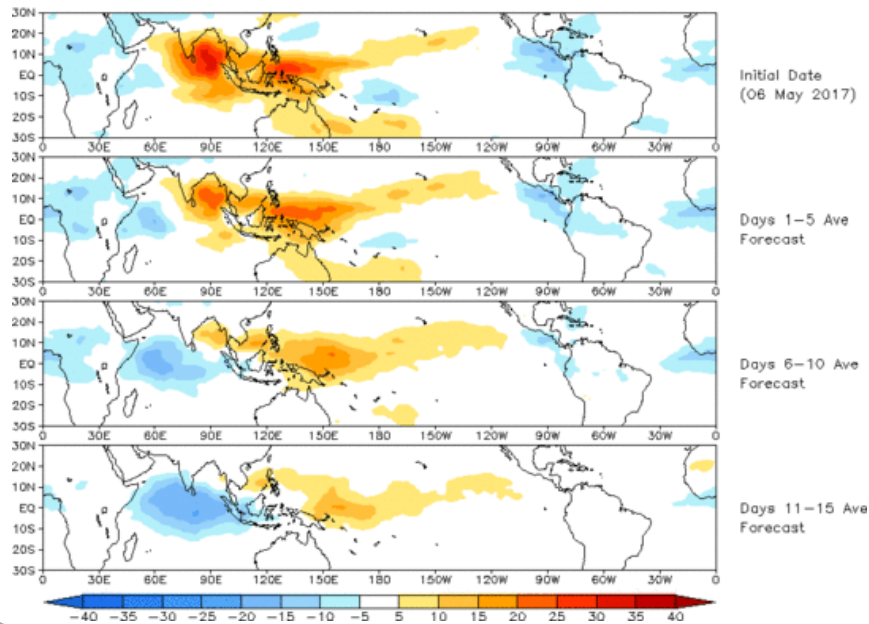
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S,  $7.5^{\circ}$ N] (cint:  $4Wm^{-2}$ ) Period: 04-Nov-2016 to 06-May-2017  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# 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 (06 May 2017)

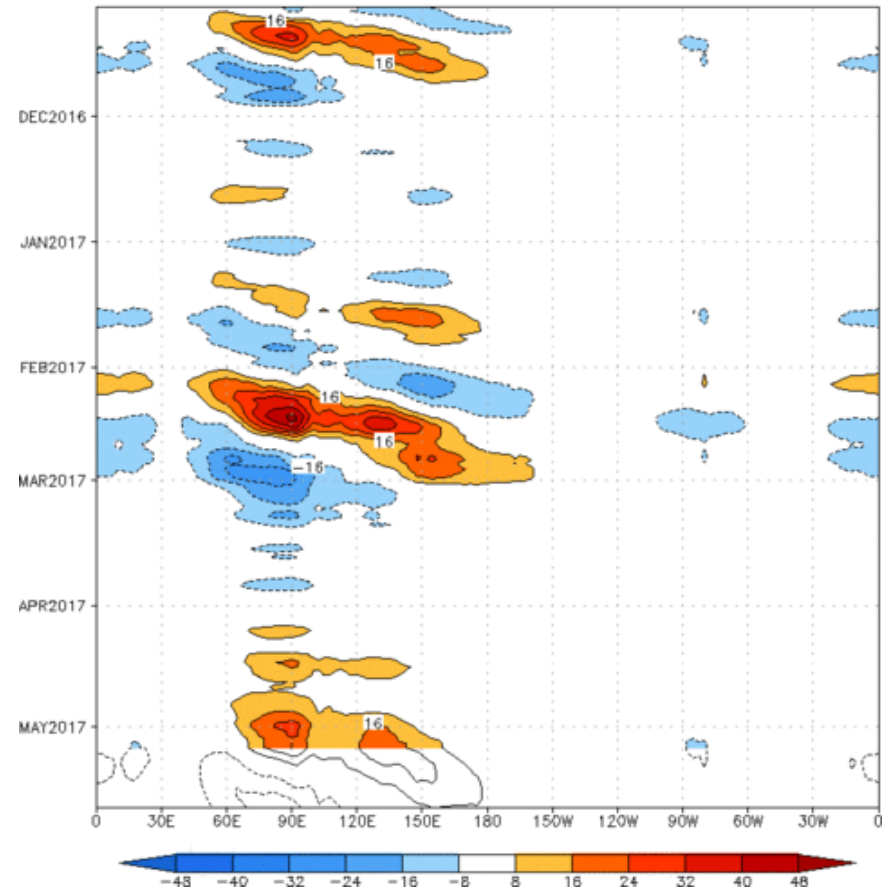


The statistical (Constructed Analog) RMM-based OLR anomaly prediction indicates more robust eastward propagation of the anomaly pattern, with the enhanced phase of the MJO emerging over the Indian Ocean by the middle of Week-2.

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.)

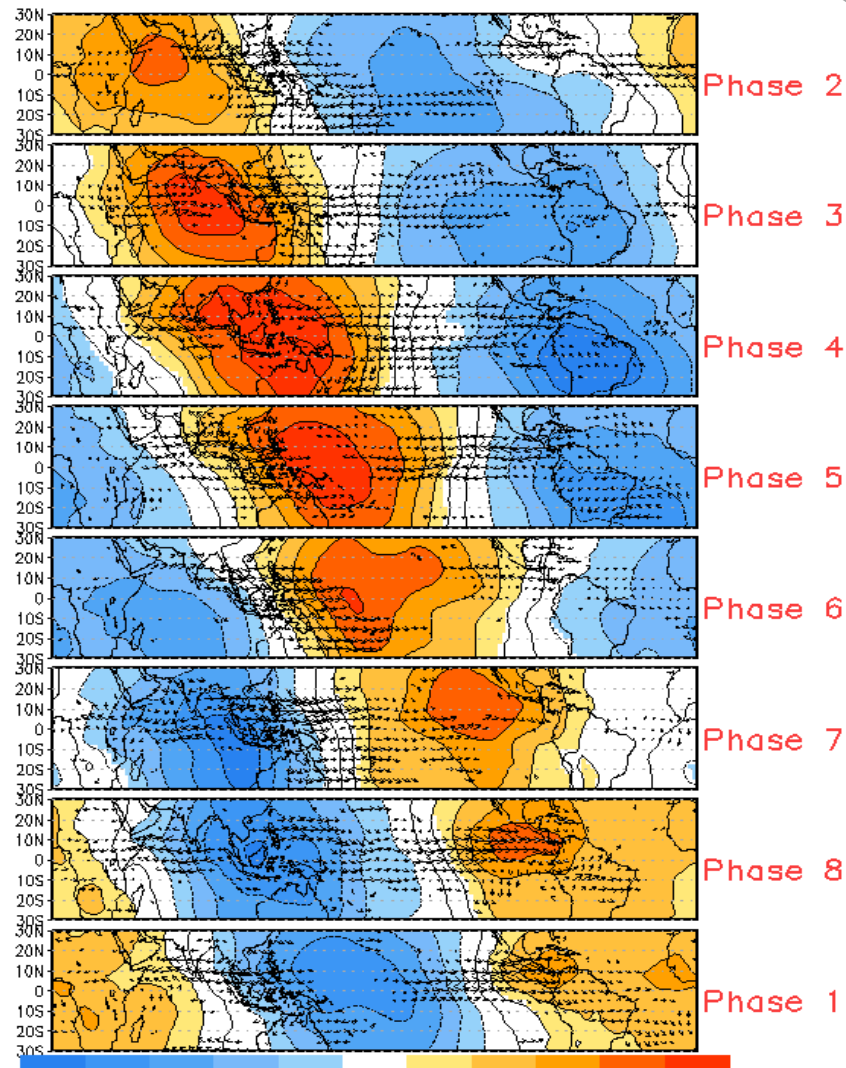
Time-longitude section of ( $7.5^{\circ}$  S– $7.5^{\circ}$  N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S,  $7.5^{\circ}$ N] ( $\text{cint: } 4\text{Wm}^{-2}$ ) Period: 04–Nov–2016 to 06–May–2017  
The unfilled contours are CA forecast reconstructed anomaly for 15 days

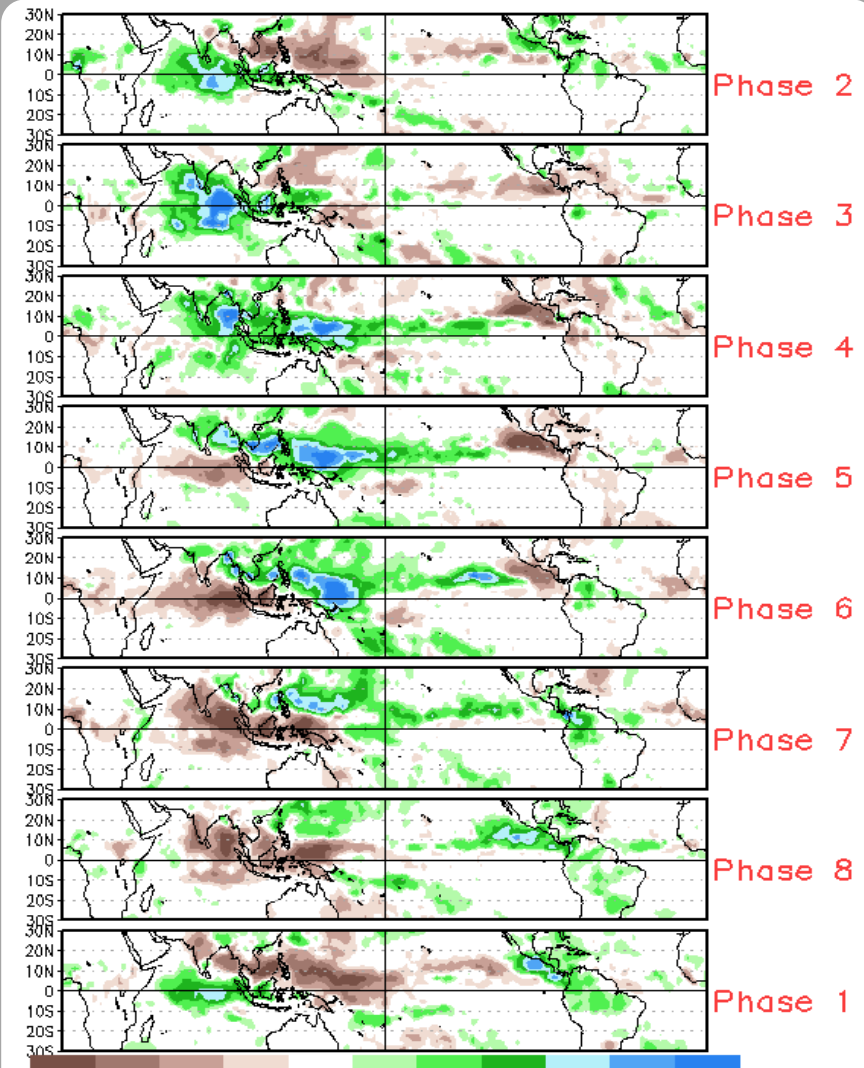


# MJO Composites - Global Tropics

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



Precipitation Anomalies (Nov - Mar)

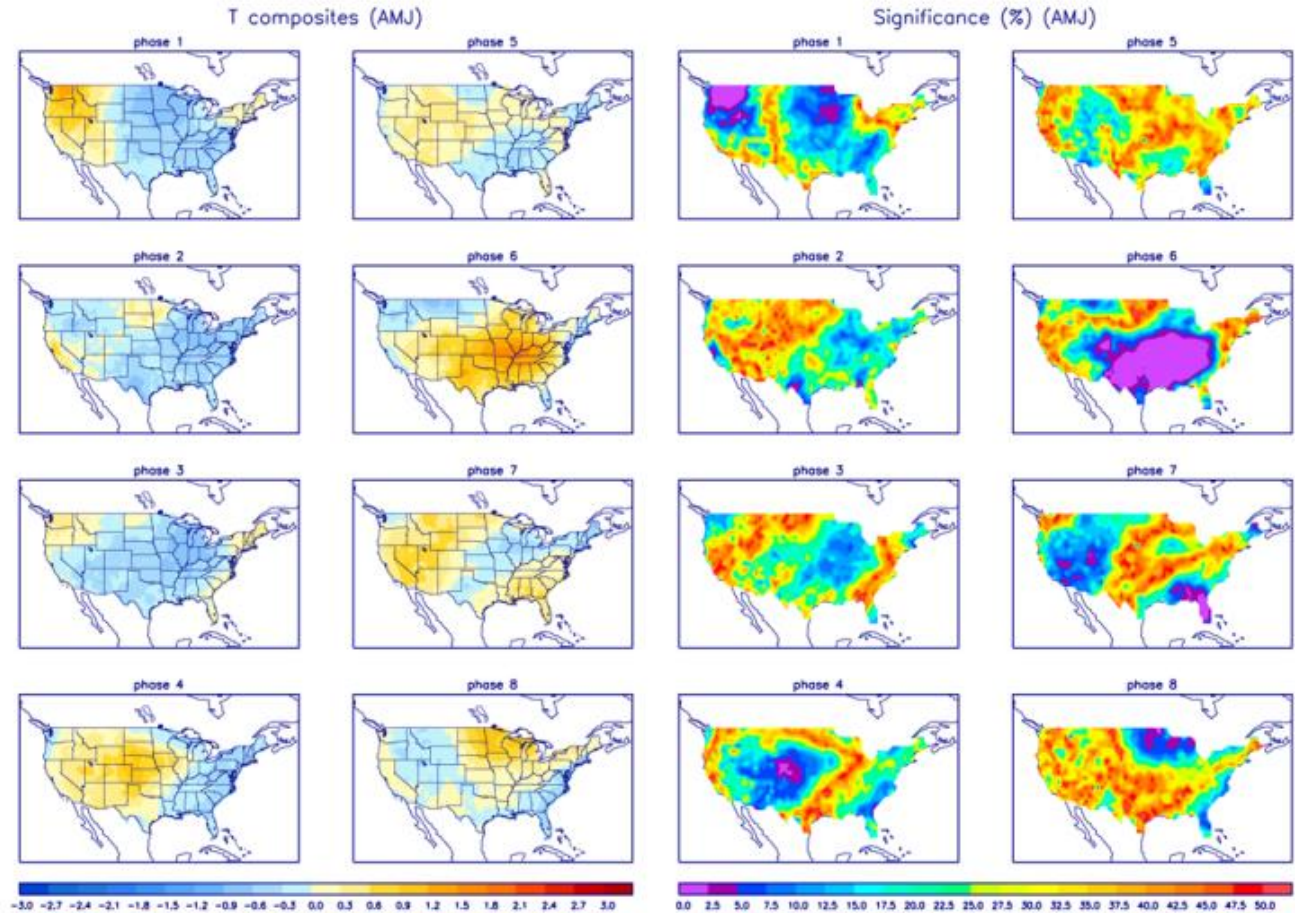




# U.S. MJO Composites - Temperature

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.



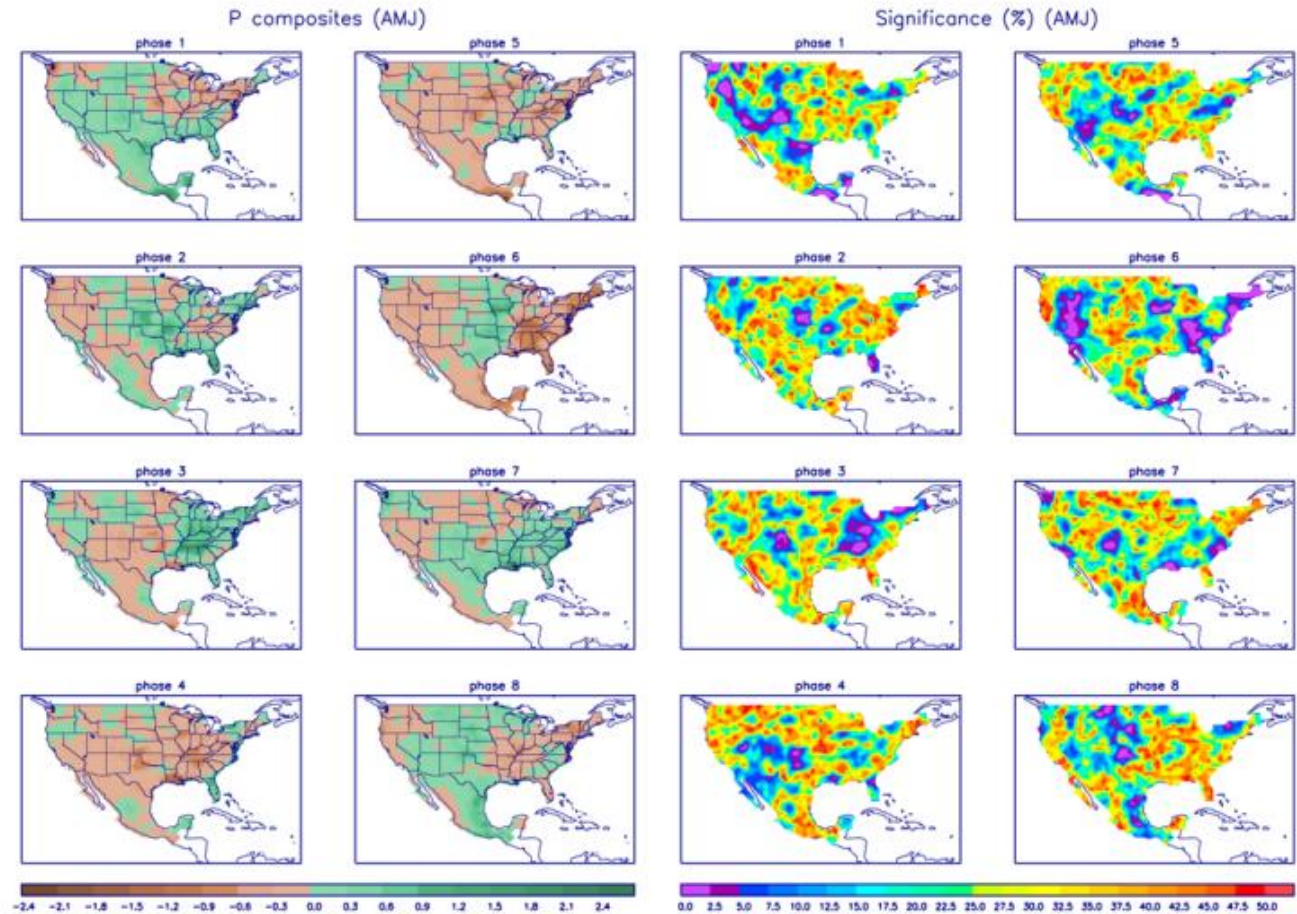
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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

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