

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



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29 February 2016

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

The MJO was active during the past week with the enhanced phase now centered over the eastern Pacific basin. The suppressed phase is centered over the Indian Ocean and Maritime Continent.

Some of the dynamical model MJO index forecasts support continued eastward propagation of a coherent, though generally weakening, MJO signal, across the Western Hemisphere over the period.

Constructive interference between the intraseasonal signal and the ENSO background state is likely during some of the period.

The MJO favors enhanced convection continuing for areas of the south central Pacific Ocean during Weeks 1 and 2, and in southeast Africa during Week 2. Suppressed convection is favored for parts of the Indian Ocean and the western Maritime continent (Weeks 1 and 2), and southeast Africa (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>

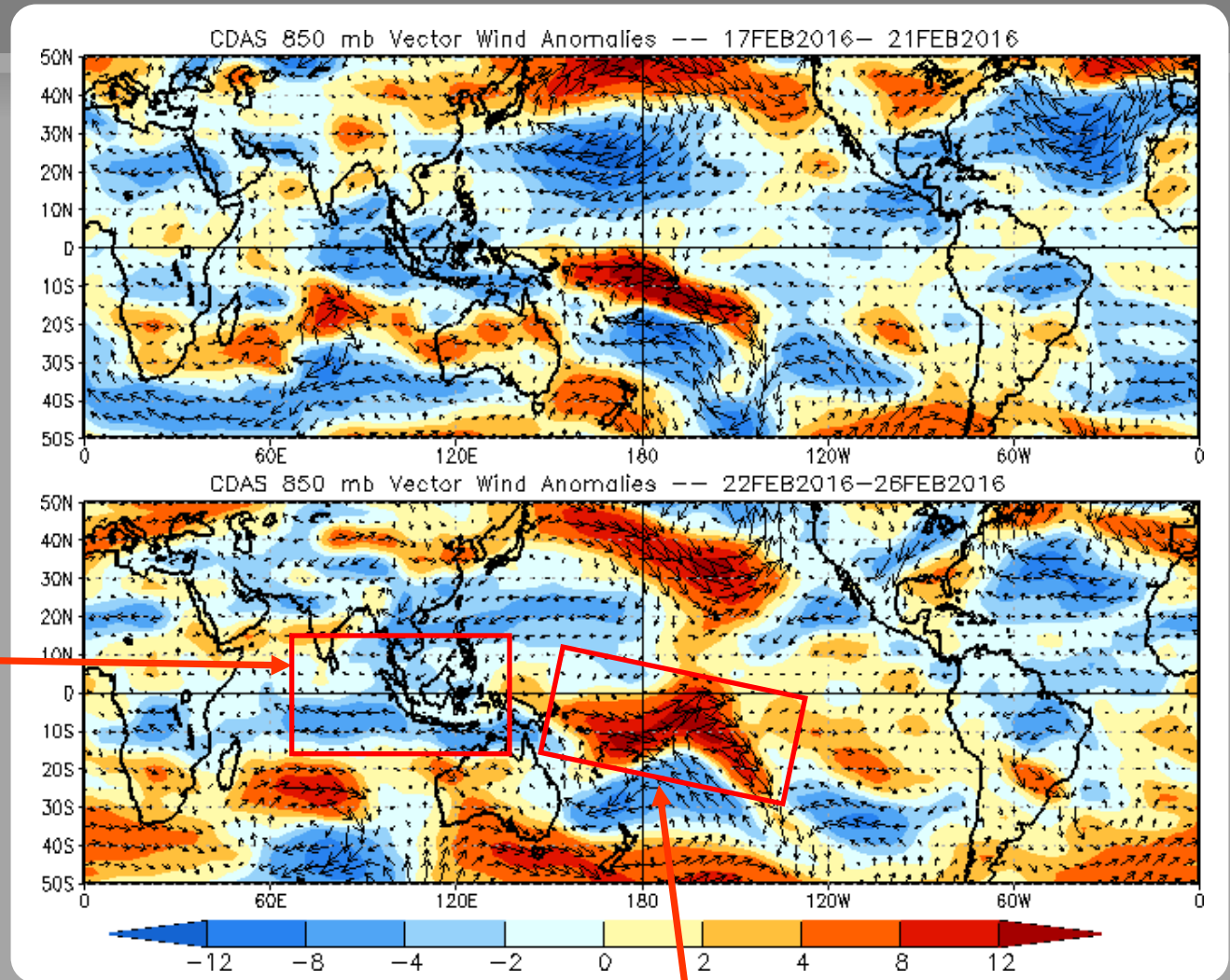
# 850-hPa Vector Wind Anomalies ( $\text{m s}^{-1}$ )

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Easterly anomalies weakened over the northern Indian Ocean, but persisted over the southern Indian Ocean and western Maritime Continent during the most recent five days.



Strong westerly anomalies expanded over the southwest Pacific during the most recent five days.

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

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

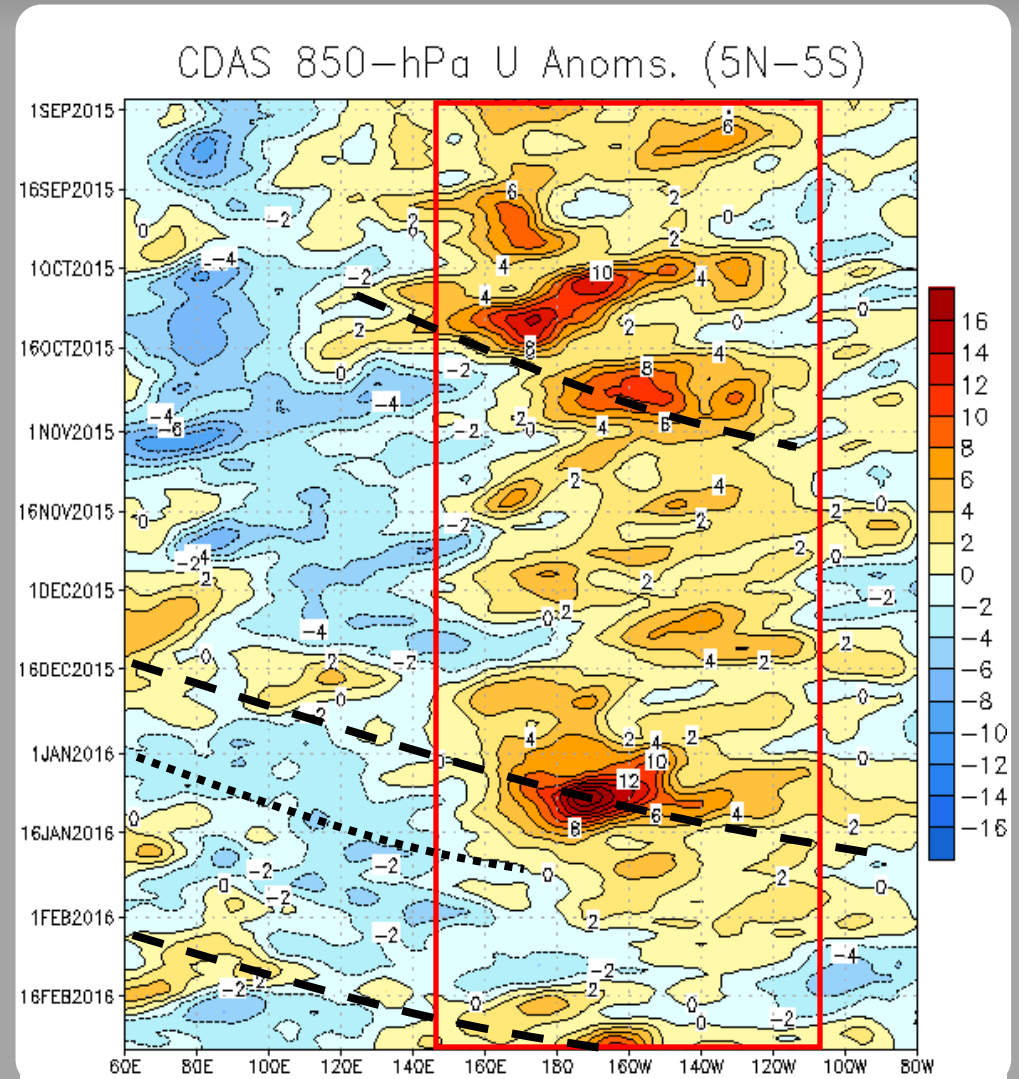
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

An eastward shift in the pattern was observed in late October, related to subseasonal activity.

Renewed MJO activity during December produced an eastward propagation of westerly anomalies from the Indian Ocean. During early January, a strong westerly wind burst near the Date Line was related to constructive interference with the ongoing El Niño.

Recently, stronger westerly anomalies have appeared just east of the Date Line in response to renewed MJO activity. Easterly anomalies prevailed from about 120°E westward across the northern Indian Ocean.



# OLR Anomalies - Past 30 days

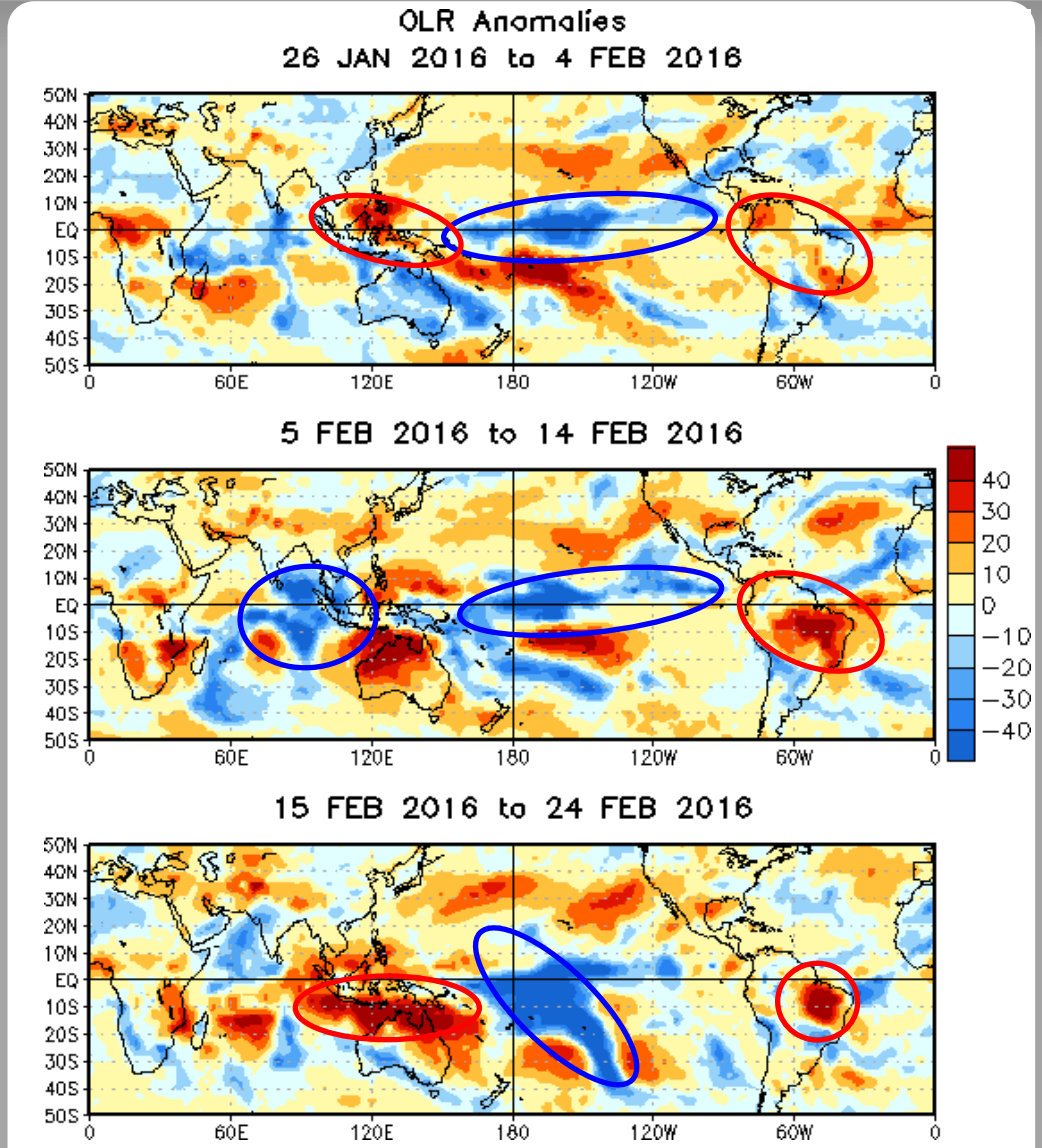
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late January, the pattern of anomalous tropical convection was largely consistent with ongoing El Nino conditions.

By early February, an emerging MJO signal resulted in enhanced convection across the eastern Indian Ocean and a disruption of the suppressed convective signal across the Maritime continent near the equator. Enhanced convection continued over the equatorial Pacific.

During mid to late February, MJO activity resulted in widespread enhanced convection over the western and central Pacific. Suppressed convection was evident over northern Australia, much of Indonesia, and Brazil.





# Outgoing Longwave Radiation (OLR) Anomalies (5°N-5°S)

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

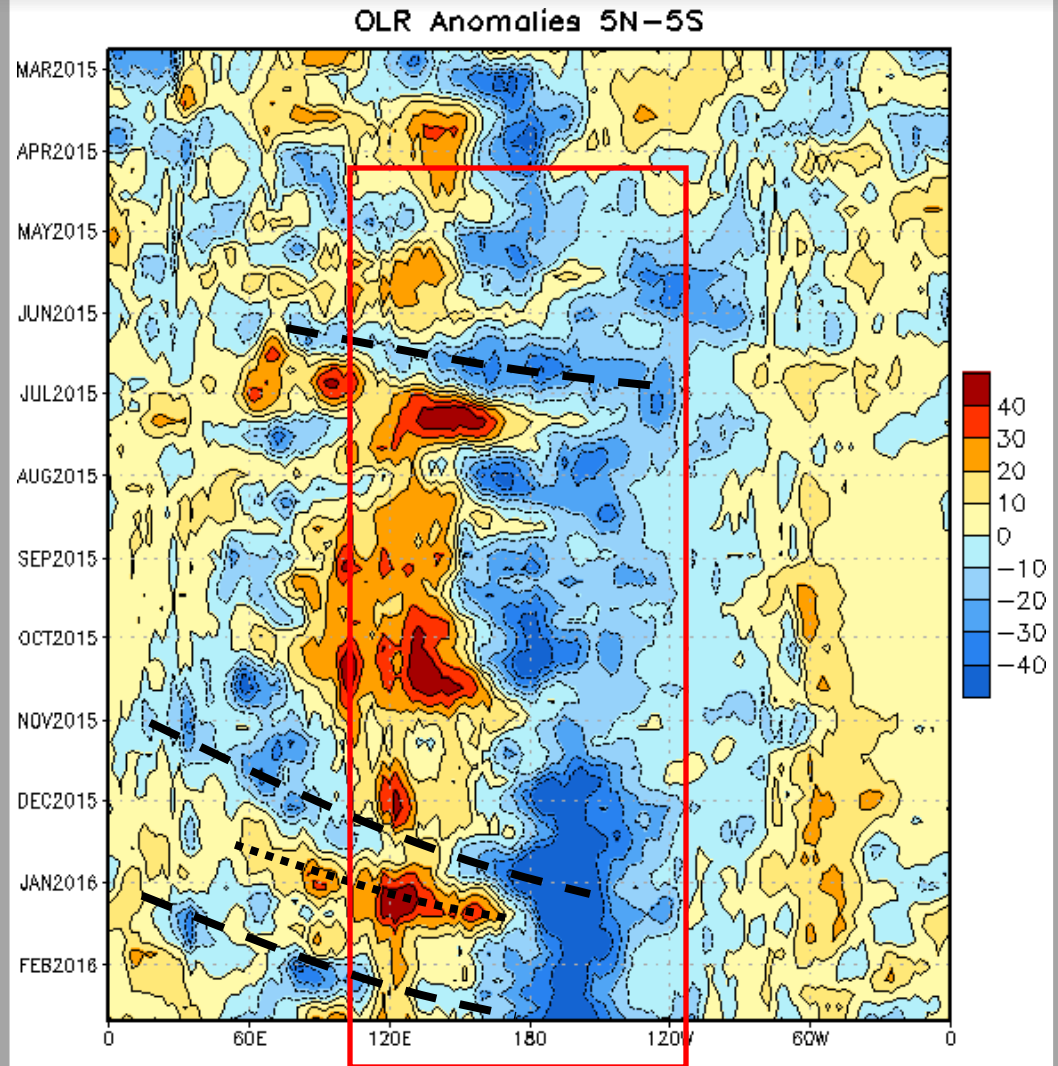
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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

During June and early July, the MJO became active, interfering with the ENSO signal at times. From August through October, other modes of subseasonal activity did impact tropical convection.

During December, the MJO became active again, with the enhanced phase propagating from the Indian Ocean to the west-central Pacific during the month.

Renewed MJO activity was evident during late January and February, with enhanced convection propagating over the Indian Ocean and a reduction of suppressed convection over the Maritime Continent.



Data updated through 22 FEB 2016

# 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

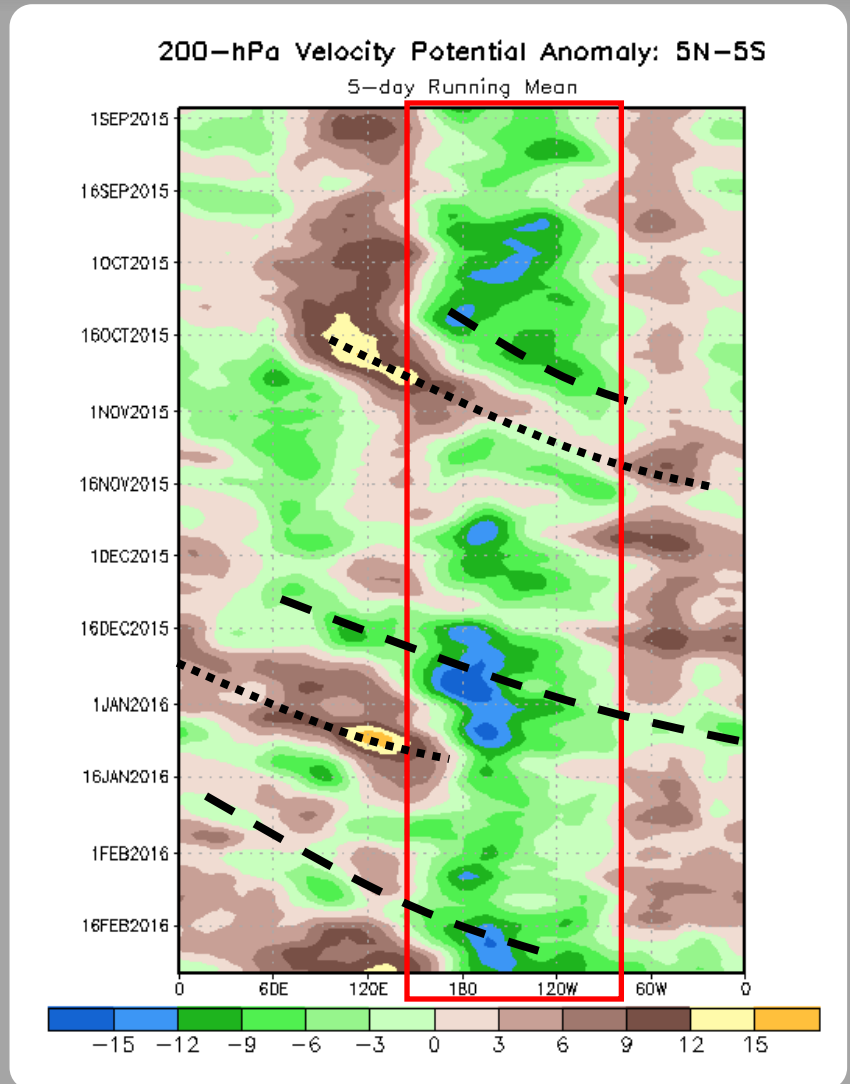
The ongoing ENSO state is highlighted by the red box, showing anomalous divergence over the central and eastern Pacific.

During June and early July, a high-amplitude MJO event was observed, constructively interfering with the El Niño signal in early July.

From July through early October, a generally stationary pattern, reflective of El Niño conditions, was observed. During late October, there was an eastward shift in the pattern.

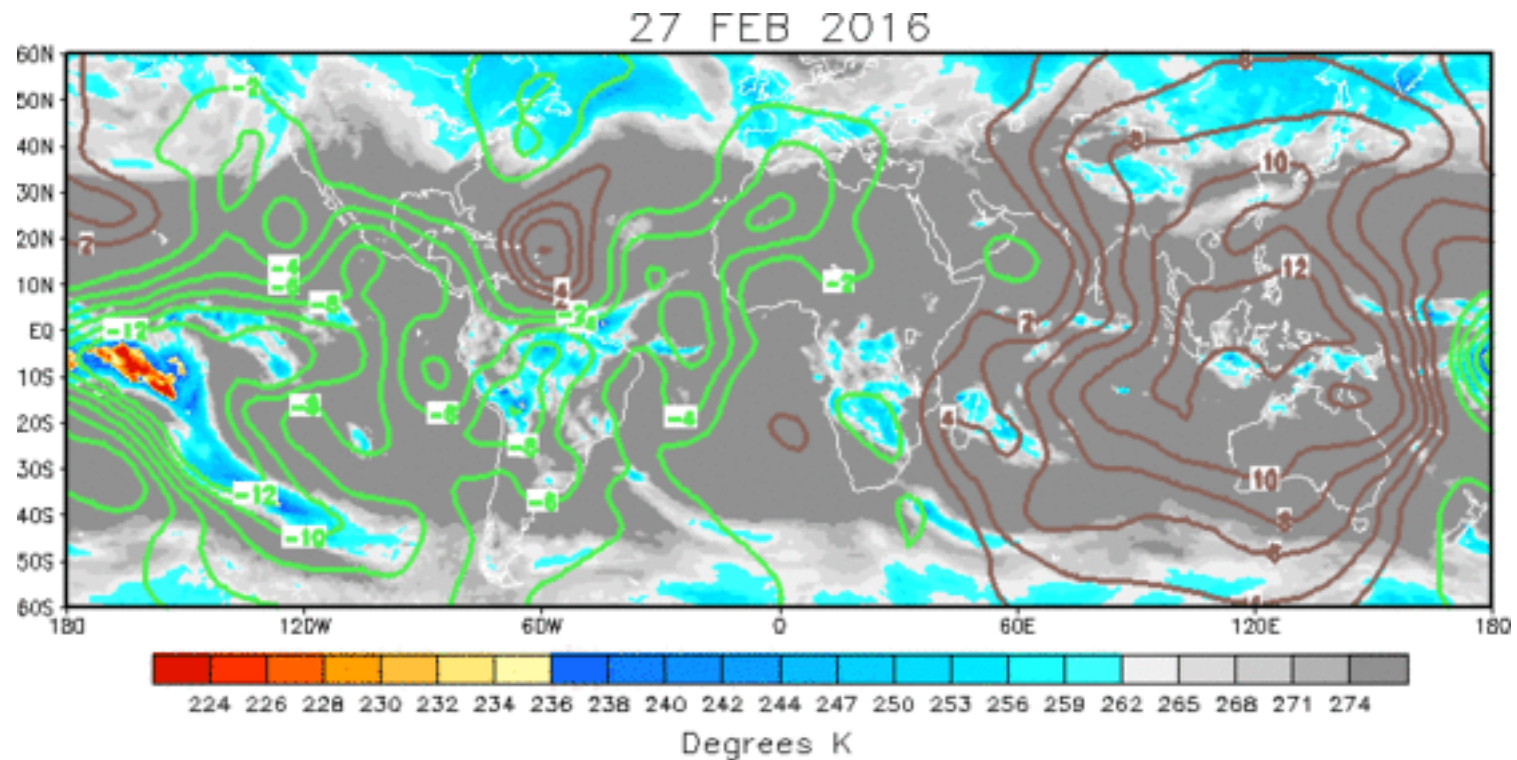
Renewed MJO activity was observed during December and early January, yielding a robust signal in the upper levels. This signal weakened during mid-January.

More recently, constructive interference between an intraseasonal signal and the ENSO background state is evident.





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



The upper-level velocity potential anomalies depict a Wave-1 pattern, consistent with coherent MJO activity. The enhanced phase is centered over the 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

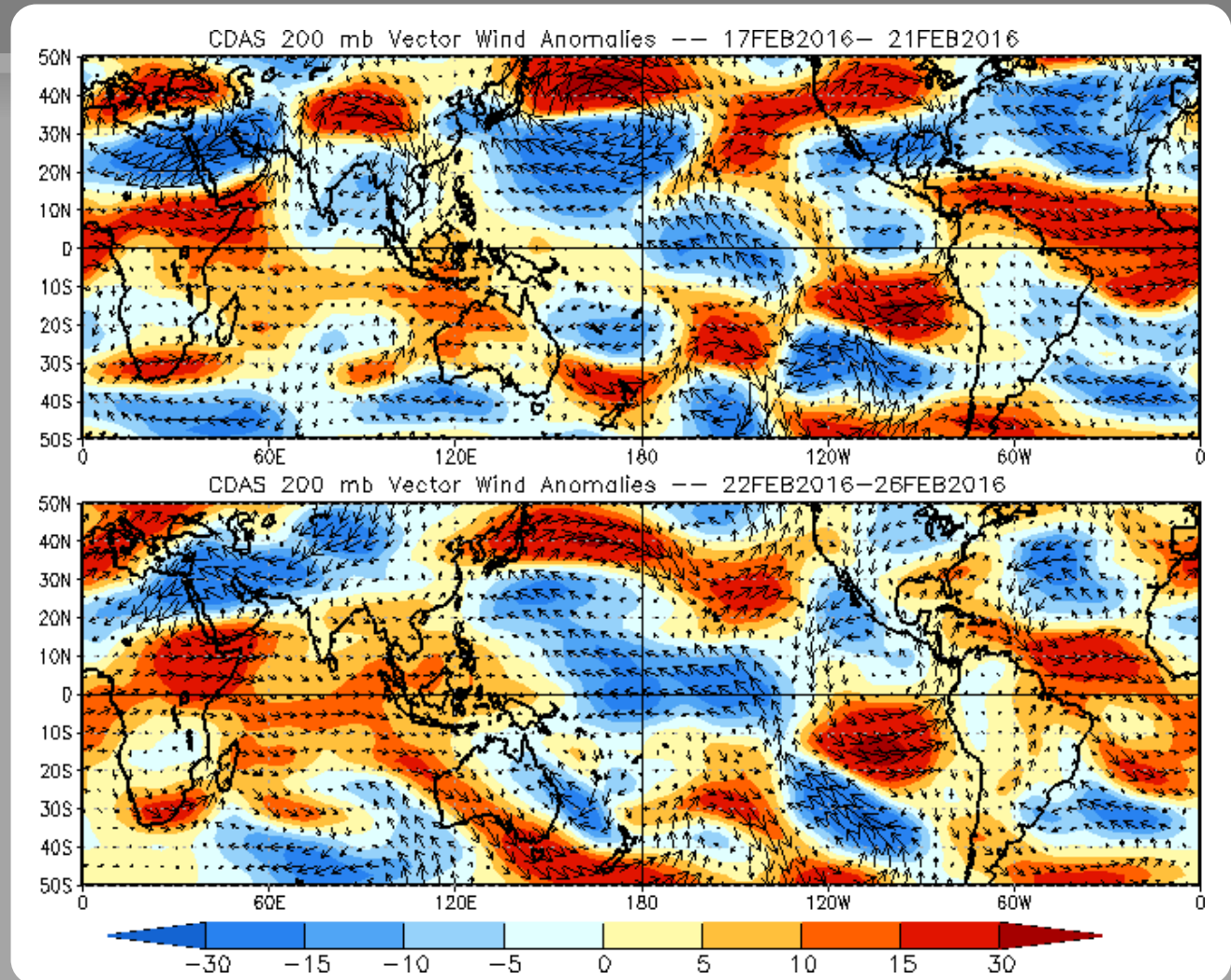
Blue shades: Easterly anomalies

Red shades: Westerly anomalies

An amplified wave pattern is evident during the recent period over the Pacific and North America domains.

Easterly anomalies over the central tropical Pacific have now expanded west of the Date Line, while westerly anomalies continue over the tropical Indian Ocean and Maritime Continent.

A large subtropical High (common during El Niño events) has redeveloped over the eastern Pacific.



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

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

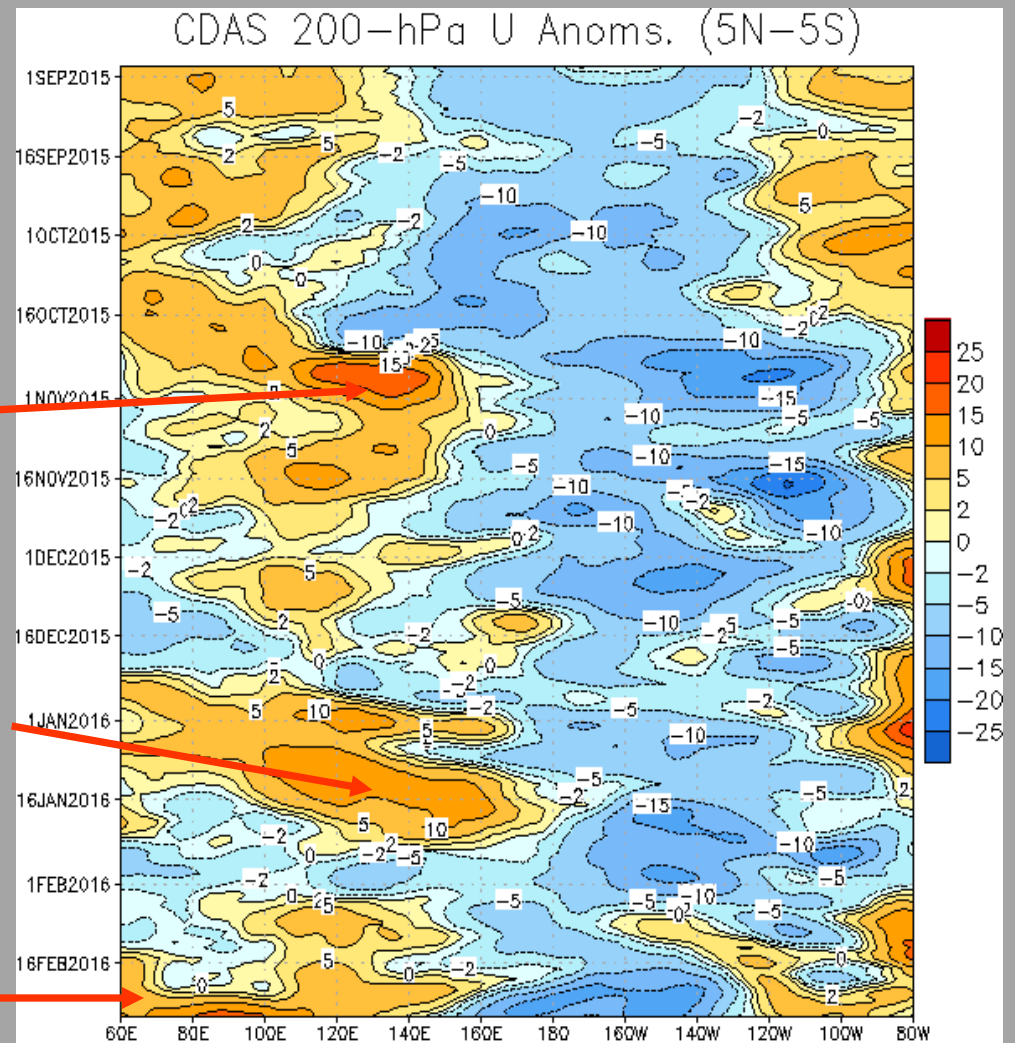
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

During late October, a temporary eastward shift in the westerly anomalies was evident across the Pacific.

Eastward propagation of upper-level zonal wind anomalies was apparent over the Maritime Continent and West Pacific during late December and early January, consistent with MJO activity.

More recently, westerly anomalies returned to the Indian Ocean and Maritime Continent, while easterly anomalies persisted between about 150E - 130W.



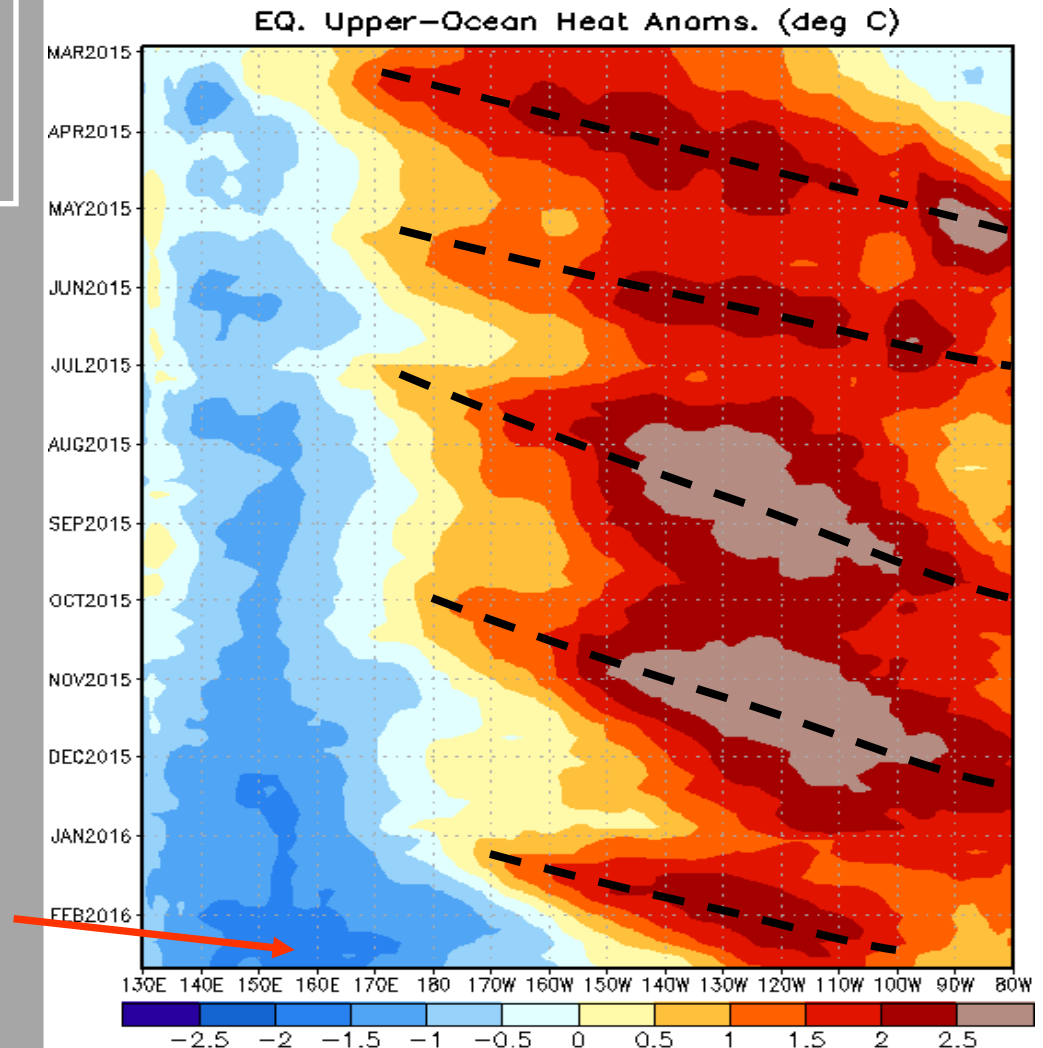
# Weekly Heat Content Evolution in the Equatorial Pacific

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.

Following a strong westerly wind burst in March, a strong downwelling phase of a Kelvin wave propagated eastward, reaching the South American coast during May.

Reinforcing downwelling events have followed, 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, and negative anomalies spread east of the Date Line during February 2016. The below average heat content has also increased in magnitude.





# 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

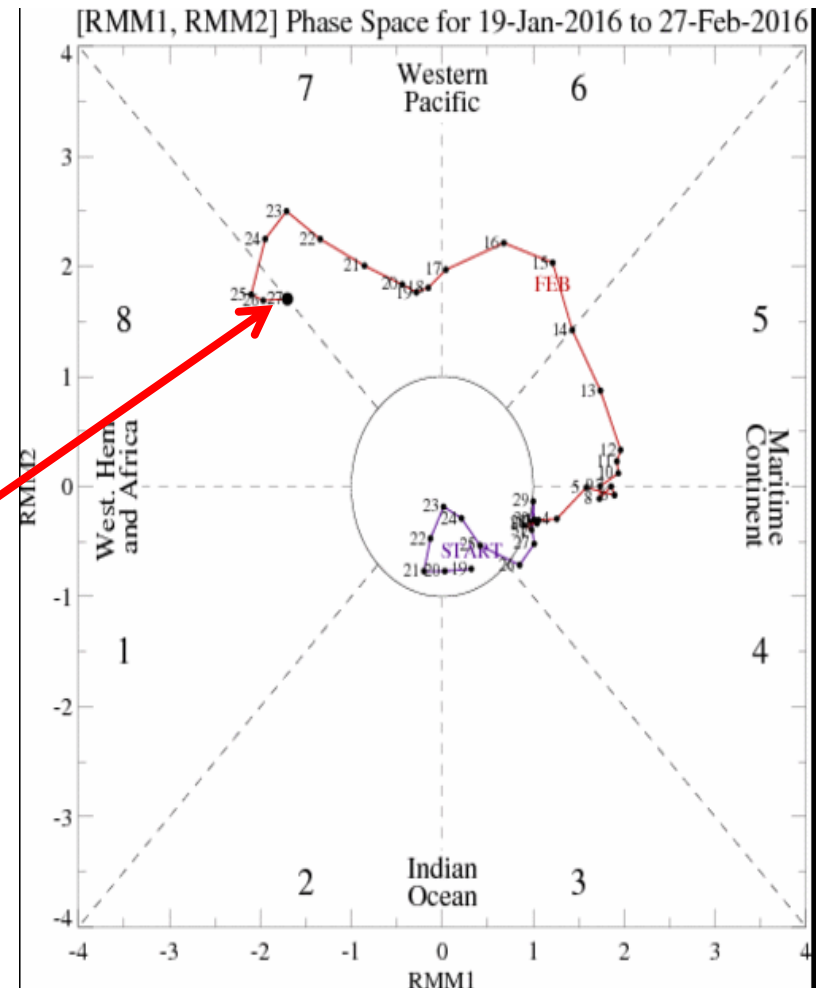
The triangular areas indicate the location of the enhanced phase of the MJO

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 index indicates coherent MJO activity with the enhanced phase shifting eastward across the eastern Pacific during the past week, while slowing down.

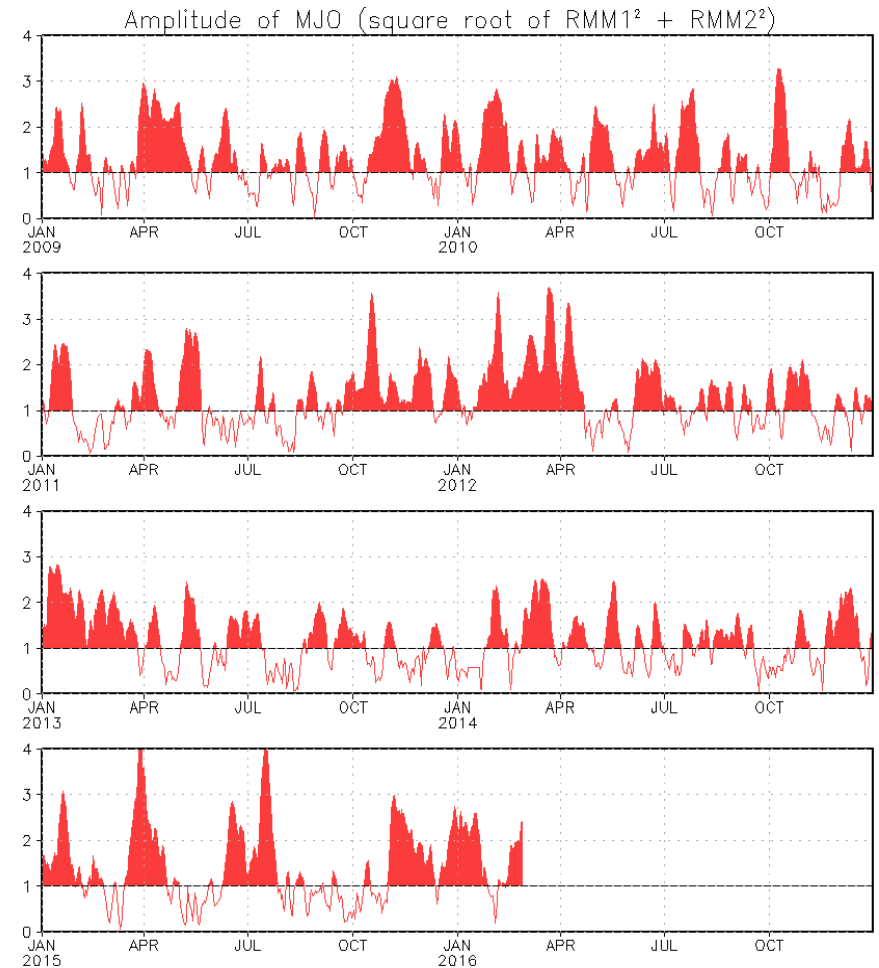




# MJO Index - Historical Daily Time Series

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

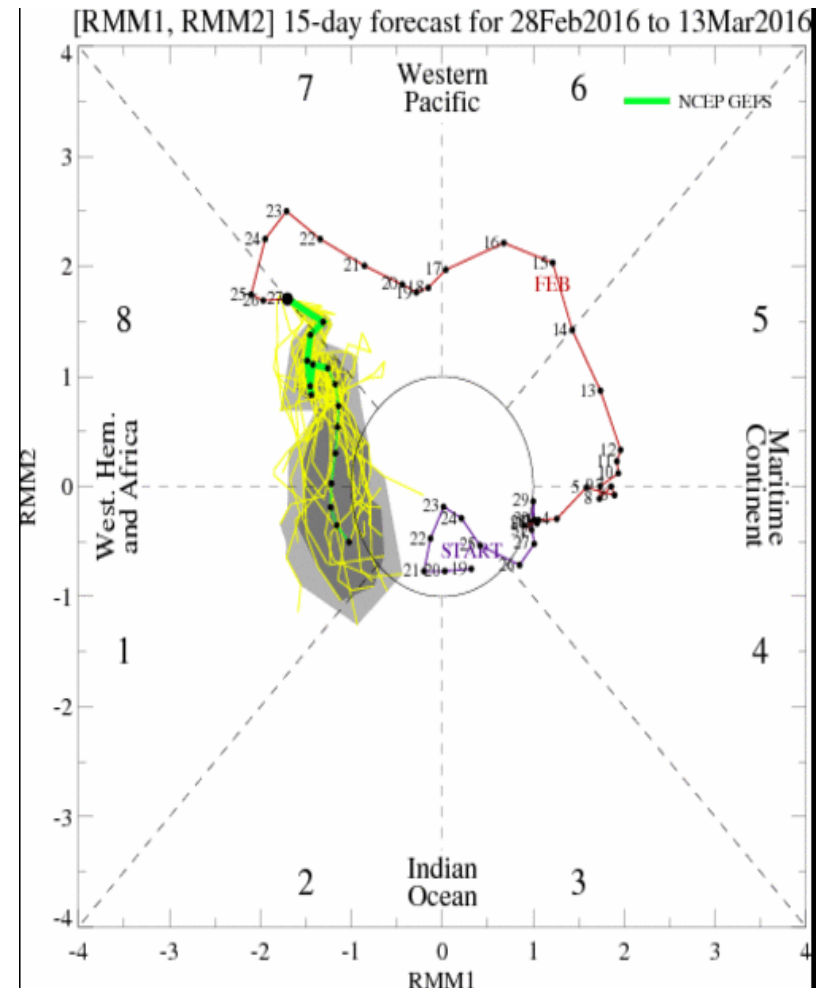
RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GFS ensemble MJO index forecast depicts a continuation of MJO activity during the period with eastward propagation through Phases 8 and 1, but with a predicted decrease in amplitude.

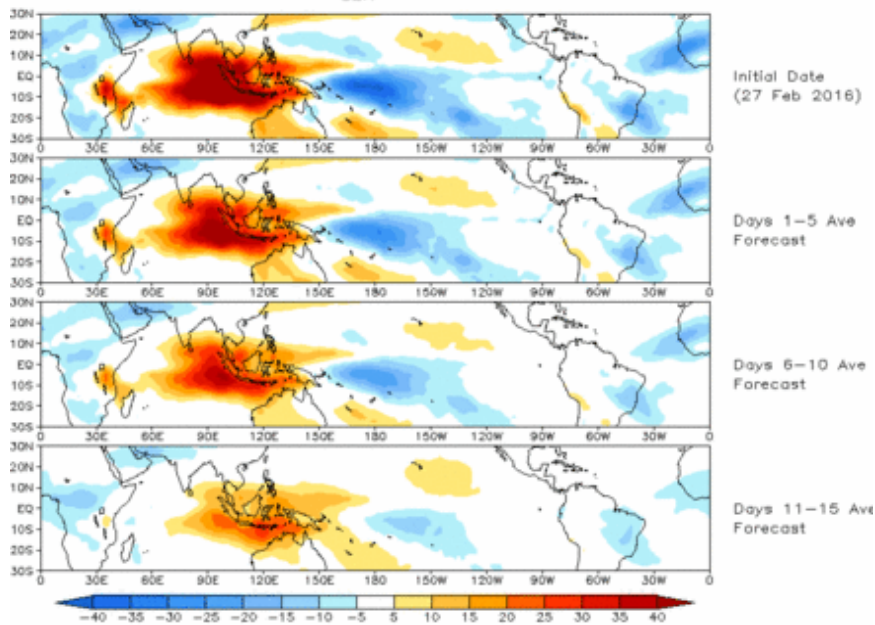
Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean



# 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: 27 Feb 2016  
OLR

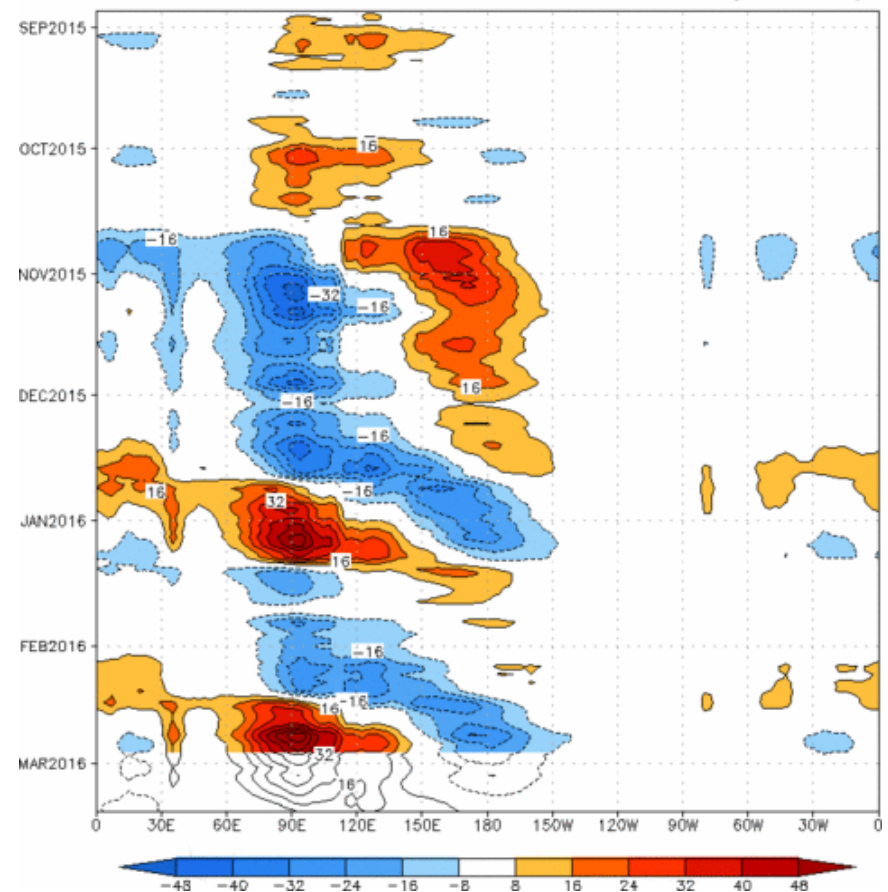


The GEFS OLR forecast depicts slowly eastward shifting negative (positive) OLR anomalies over the western and central Pacific (Indian Ocean and Maritime Continent). Constructive interference with the ENSO signal is likely.

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

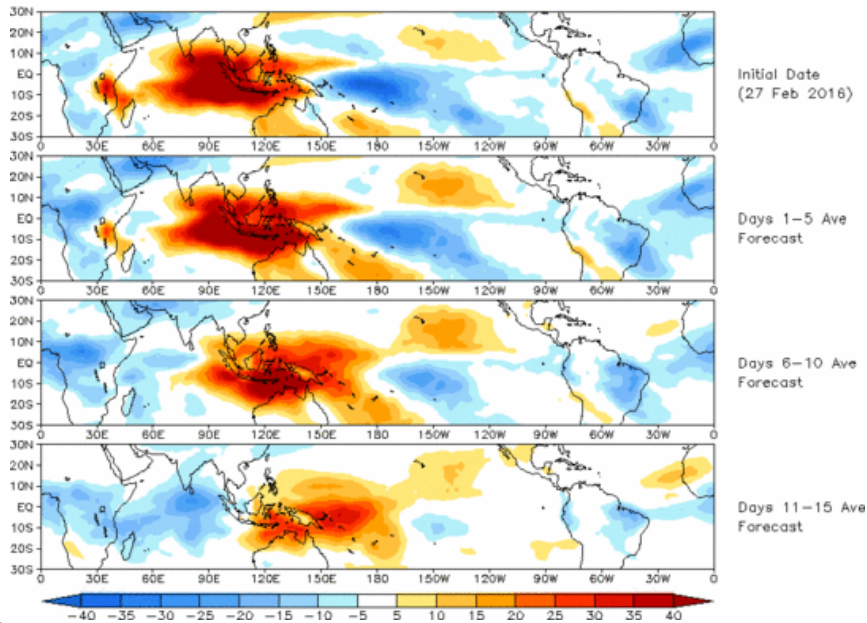
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [7.5°S,7.5°N] (cint:4Wm<sup>-2</sup>) Period:28-Aug-2015 to 27-Feb-2016  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# 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 (27 Feb 2016)

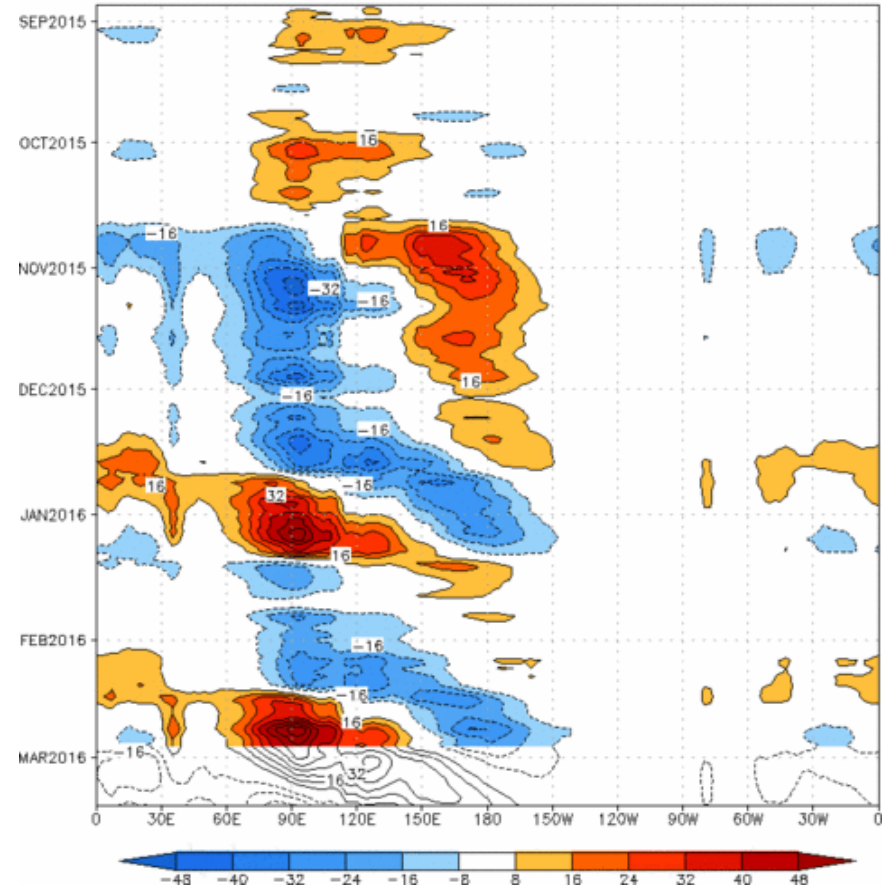


The constructed analog model depicts faster eastward propagation of the MJO-associated OLR anomalies with gradually diminishing amplitude.

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

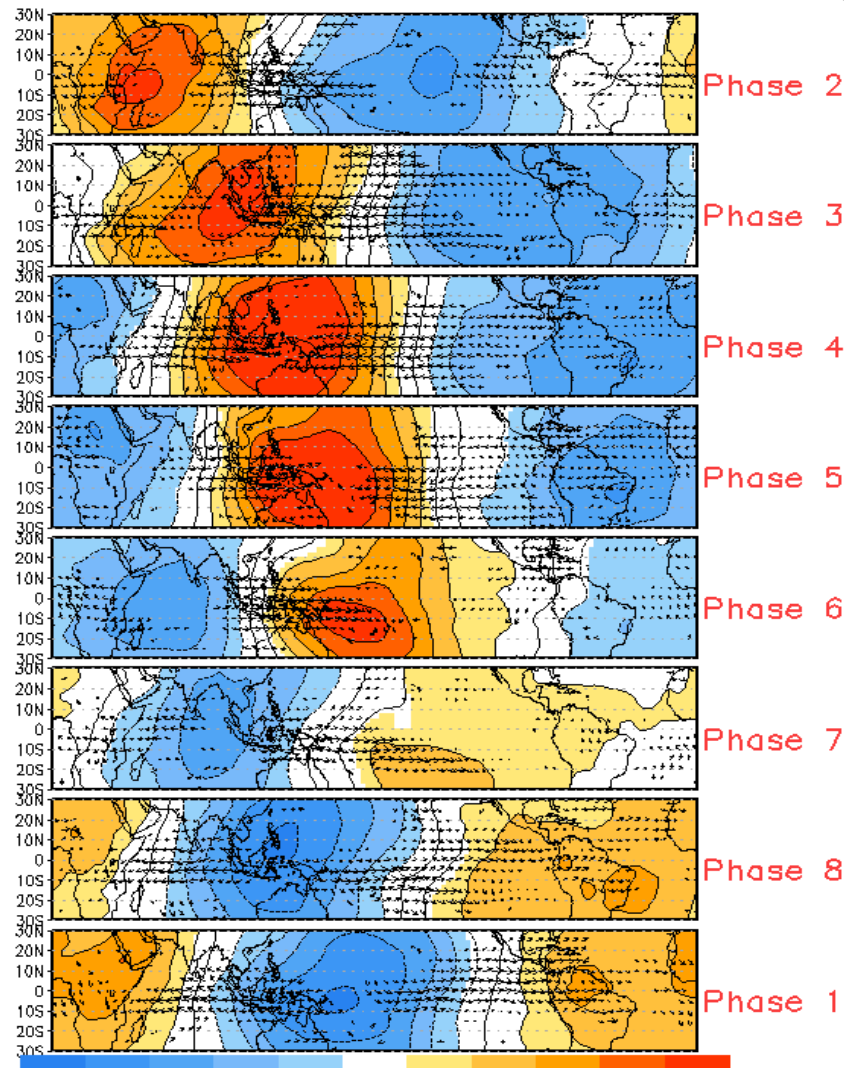
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [ $7.5^{\circ}$ S,  $7.5^{\circ}$ N] ( $\text{cint: } 4 \text{ Wm}^{-2}$ ) Period: 28–Aug–2015 to 27–Feb–2016  
The unfilled contours are CA forecast reconstructed anomaly for 15 days



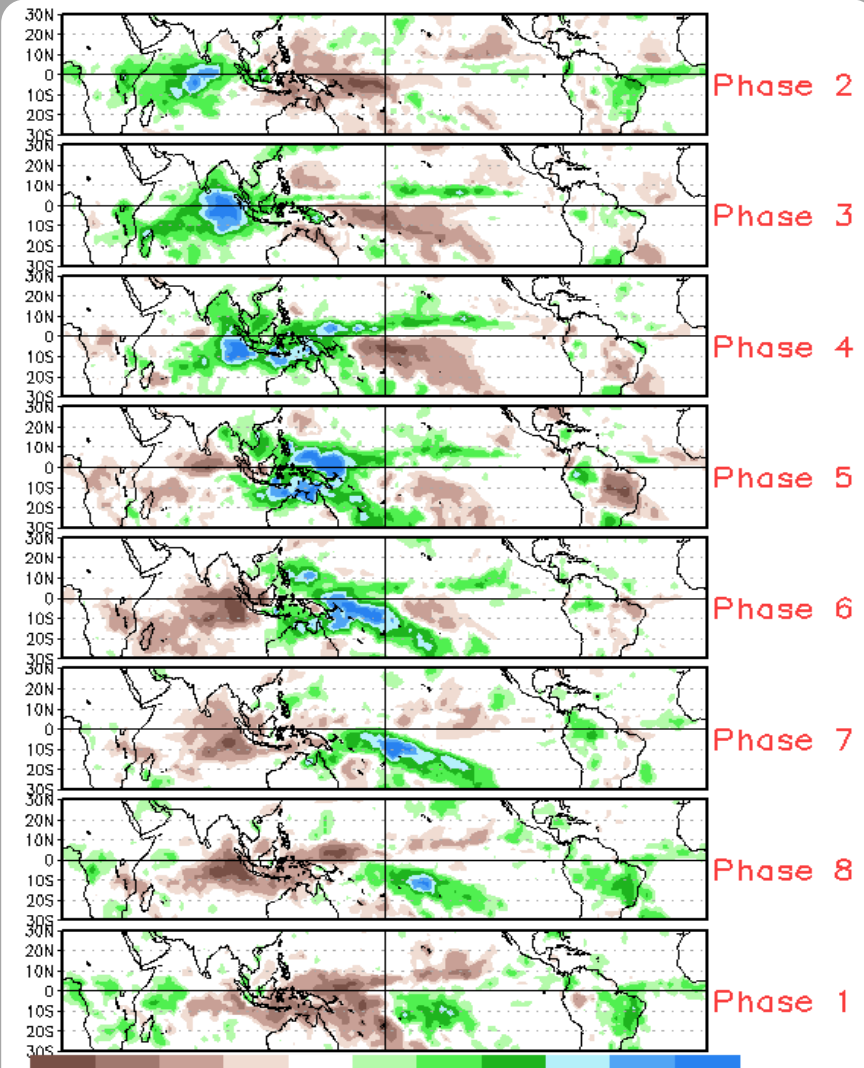


# MJO Composites - Global Tropics

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



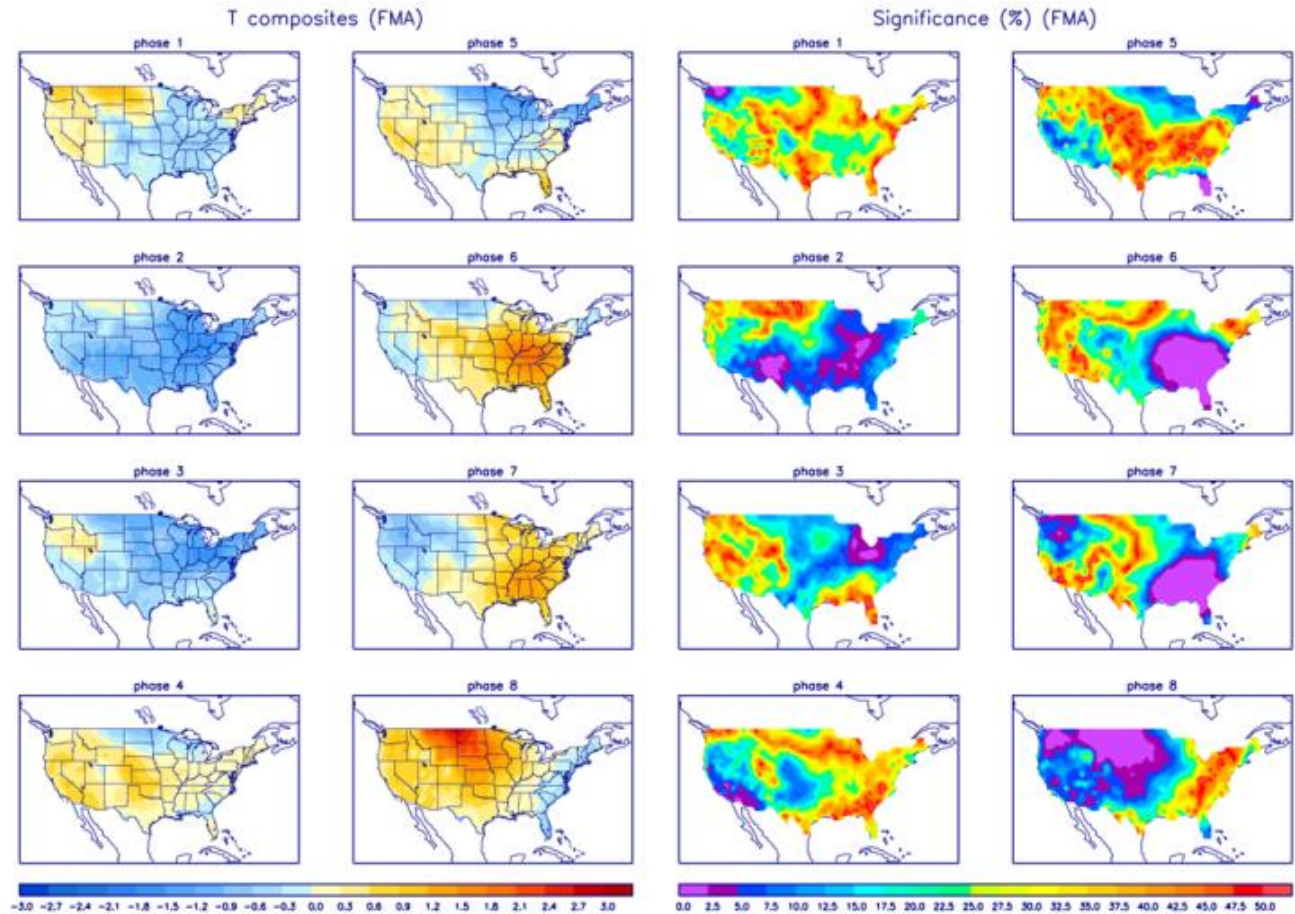
Precipitation Anomalies (Nov-Mar)



# 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

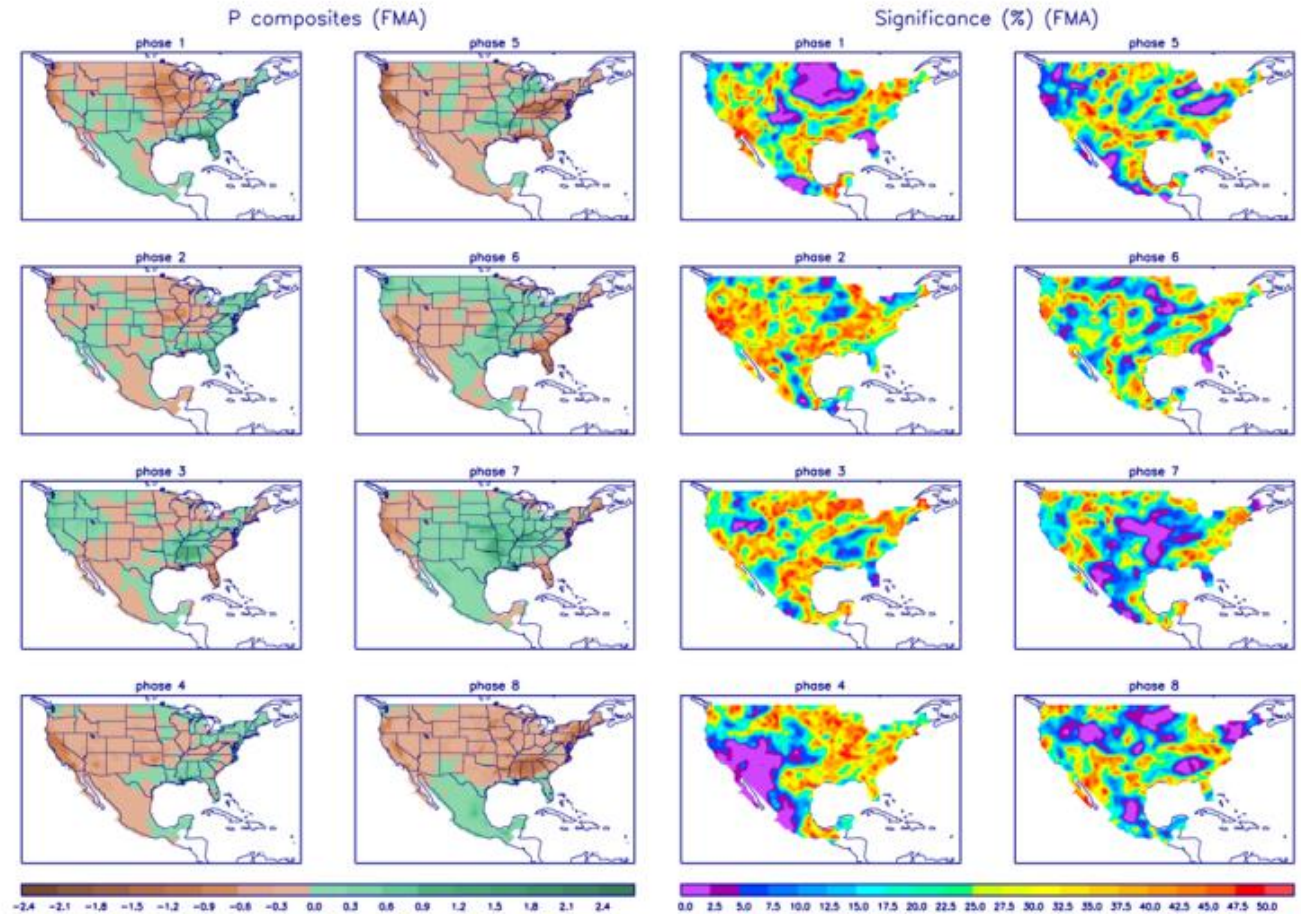
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml>



# 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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