

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



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4 January 2016

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

The MJO remained active during the past week, with the enhanced phase now over the central Pacific.

Dynamical model forecasts of the MJO index generally support a continued eastward propagation of the MJO signal, although there is considerable spread among the guidance.

The MJO continues to constructively interfere with the background El Niño state, resulting in widespread intense convection across the equatorial central Pacific.

The MJO is likely to continue playing a role in the pattern of anomalous convection along with the ongoing El Niño.

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>

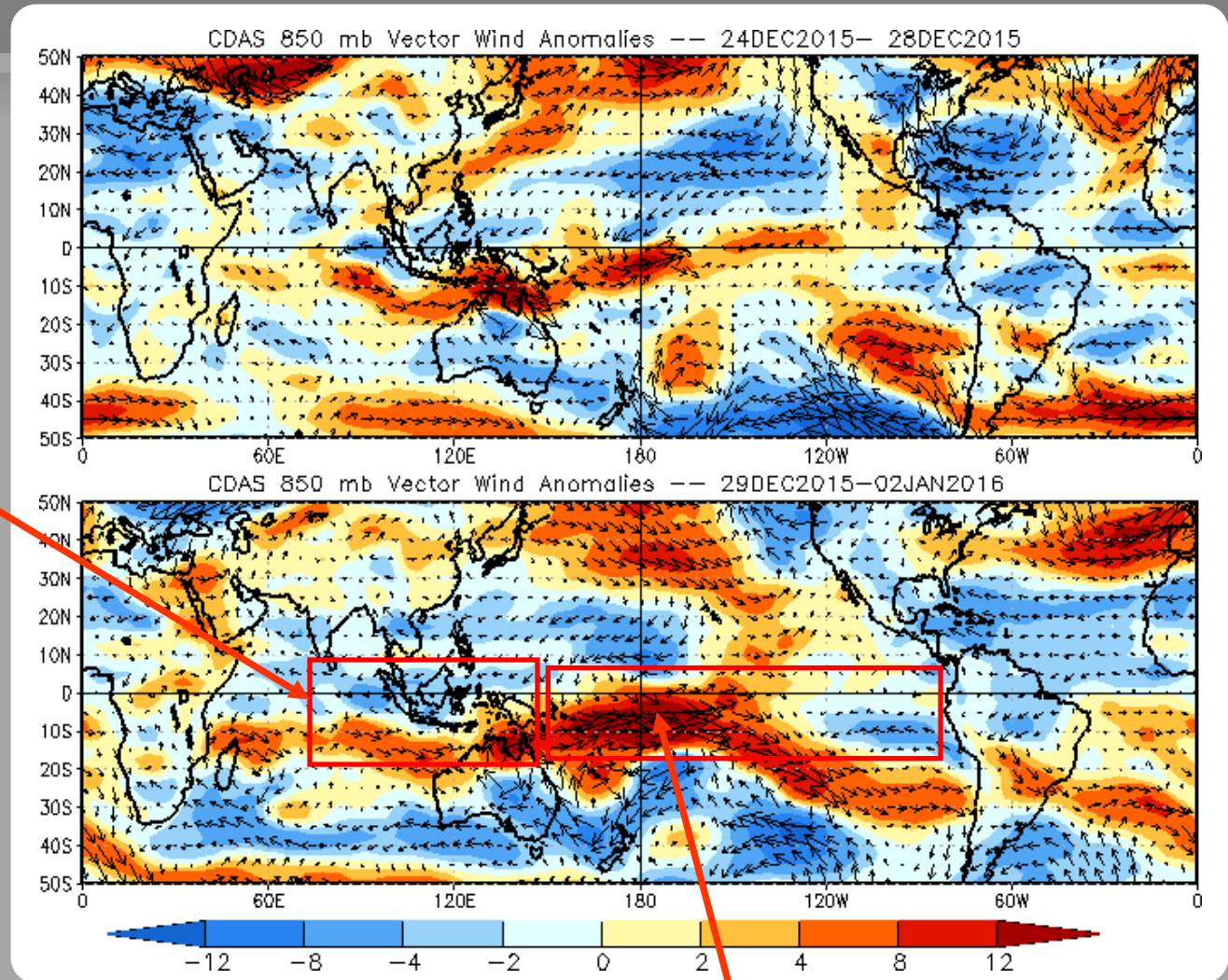
# 850-hPa Vector Wind Anomalies (m s<sup>-1</sup>)

Note that shading denotes the zonal wind anomaly

**Blue shades:** Easterly anomalies

**Red shades:** Westerly anomalies

Westerly anomalies persisted over the southeastern Indian Ocean and northern Australia, while easterlies expanded across the equatorial Maritime Continent.



A strong westerly wind burst was observed along and south of the equator over the central Pacific. Westerly wind anomalies diminished over the eastern Pacific.

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

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

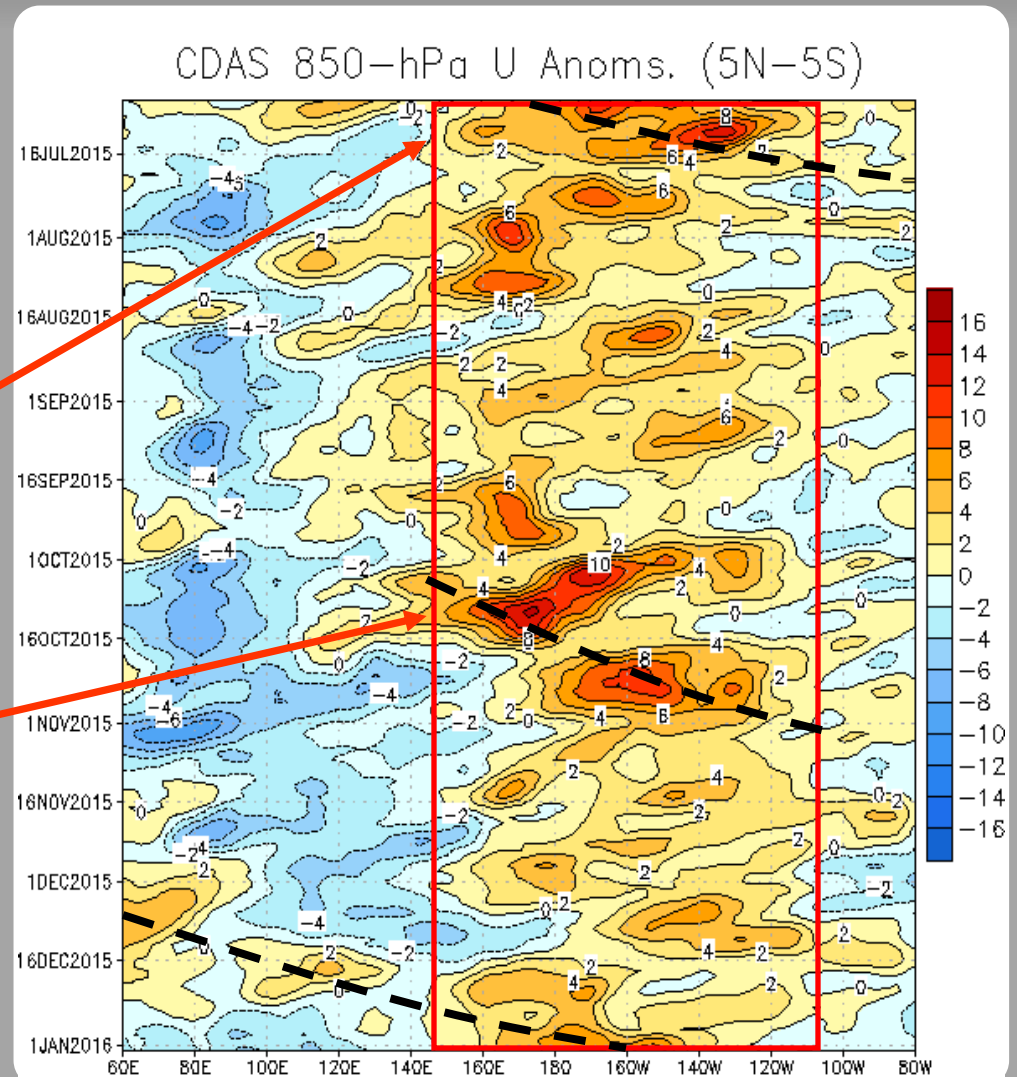
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

A robust MJO event was observed in late June through mid-July. Otherwise, tropical cyclone activity across much of the Pacific provided the primary transient influence on the overall ENSO pattern for much of the NH summer.

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

More recently, renewed MJO activity produced an eastward propagation of westerly anomalies from the Indian Ocean to the central Pacific during December and early January.



# OLR Anomalies - Past 30 days

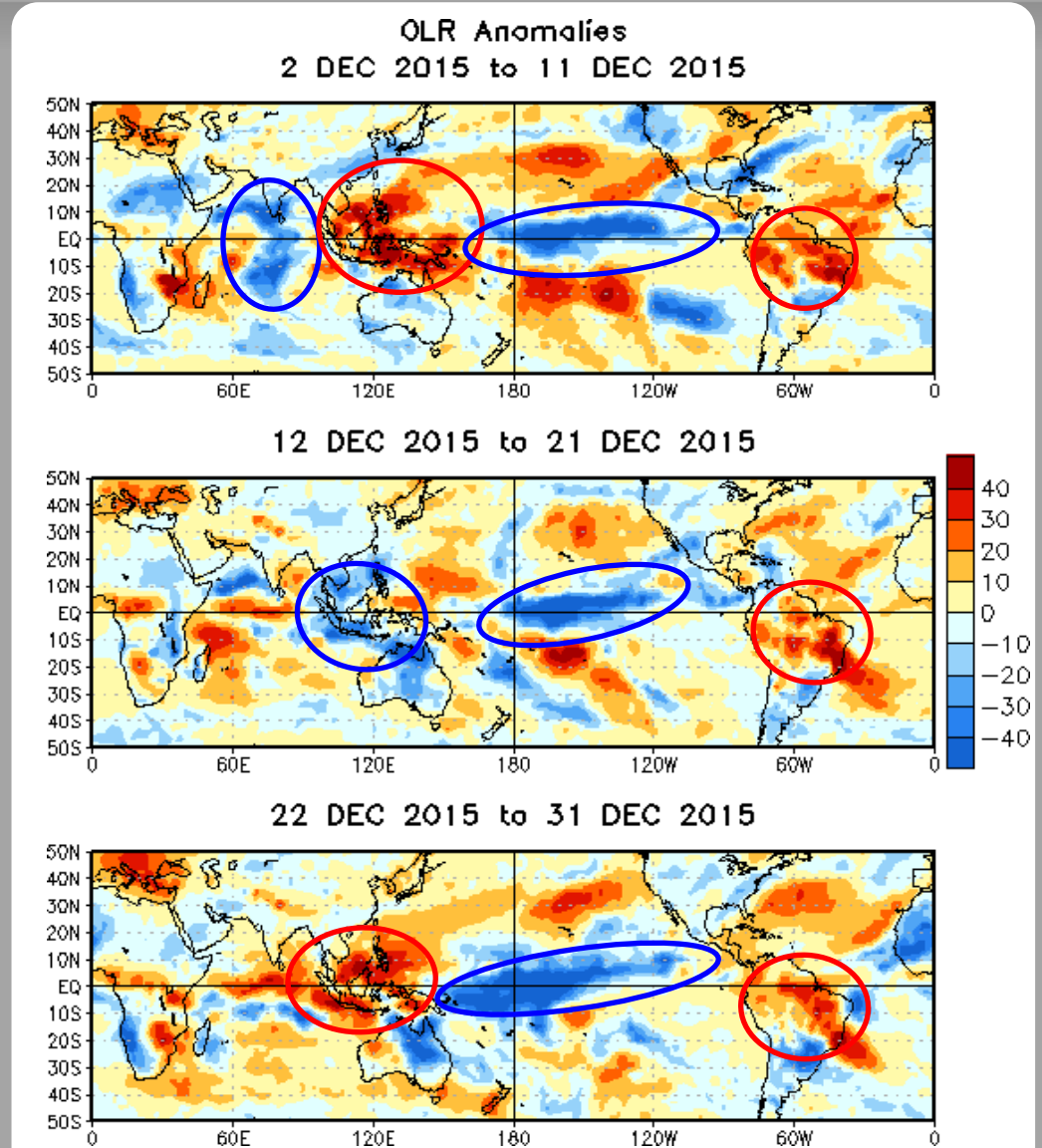
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During early December, the developing MJO signal produced enhanced convection over the central Indian Ocean. Enhanced (suppressed) convection over the Pacific (Maritime Continent and northern Brazil) were consistent with El Niño.

During mid-December, the MJO signal overcame the lower frequency ENSO base state over the Maritime Continent, resulting in enhanced convection.

During late December, suppressed convection quickly returned to the Maritime Continent as the MJO propagated eastward to the West Pacific. Constructive interference between the MJO and ENSO signals resulted in widespread intense convection and TC development over the west-central Pacific.



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

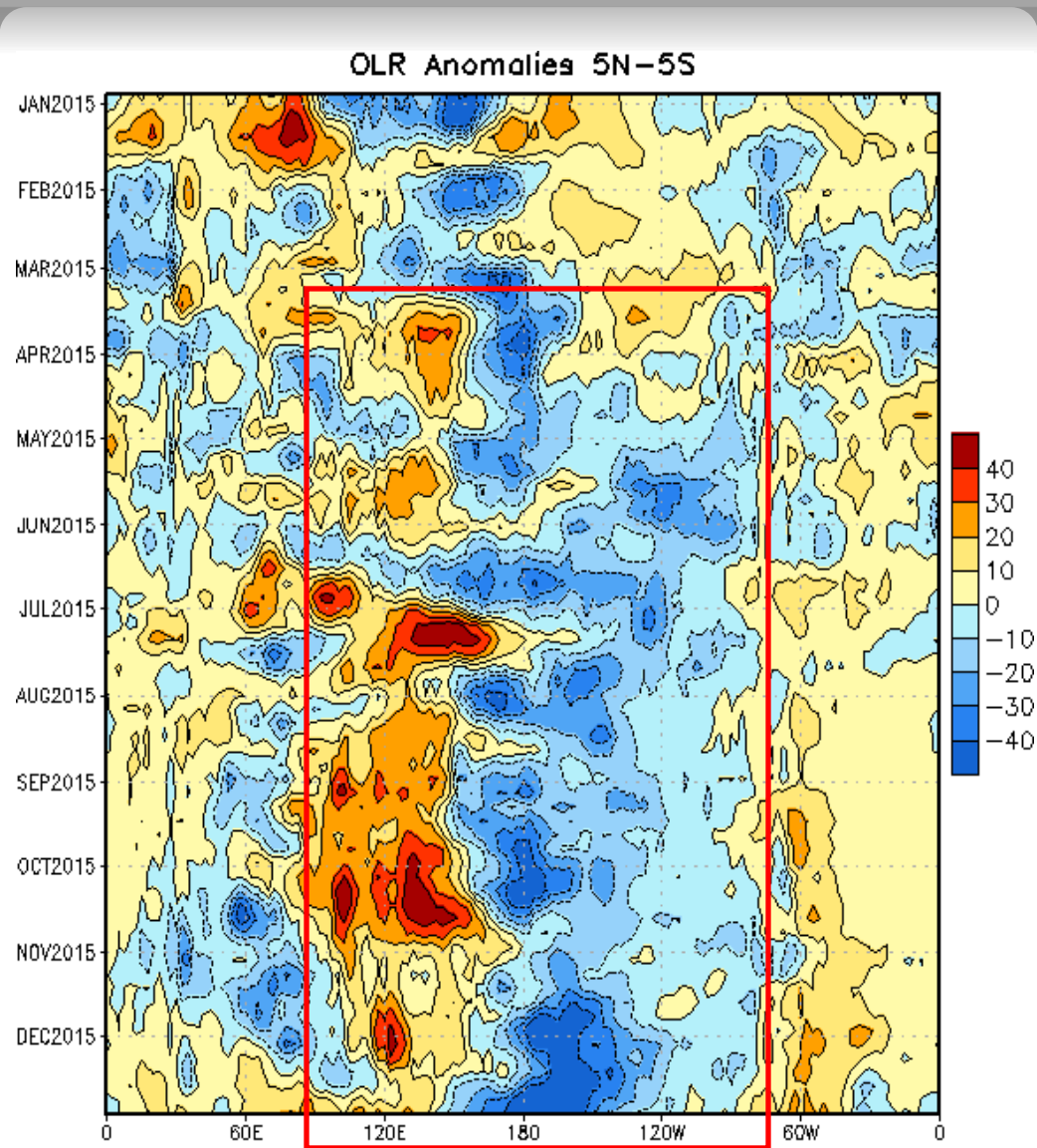
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

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

During June and early July, the MJO became active, interfering with the ENSO signal at times. From August through October, the MJO remained weak, with strong El Niño conditions and tropical cyclone activity dominating the pattern.

During December, the MJO became active again, with the enhanced phase propagating from the Indian Ocean to the west-central Pacific during the month. Constructive interference between the MJO and ENSO signals resulted in widespread convection across the central Pacific.



# 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

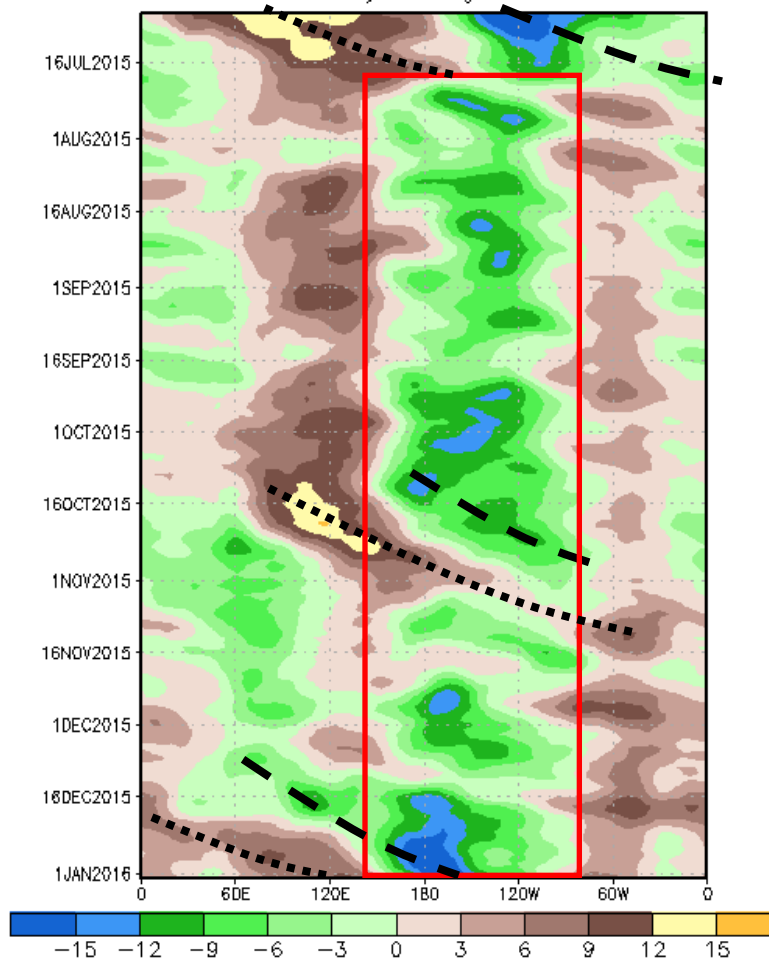
The ongoing ENSO state is highlighted by the red box, showing anomalous divergence over the central and eastern Pacific. This pattern has only been temporarily interrupted by strong Kelvin wave/MJO activity at times.

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 associated with subseasonal activity followed by evidence of equatorial Rossby and Kelvin wave activity impacting the central Pacific.

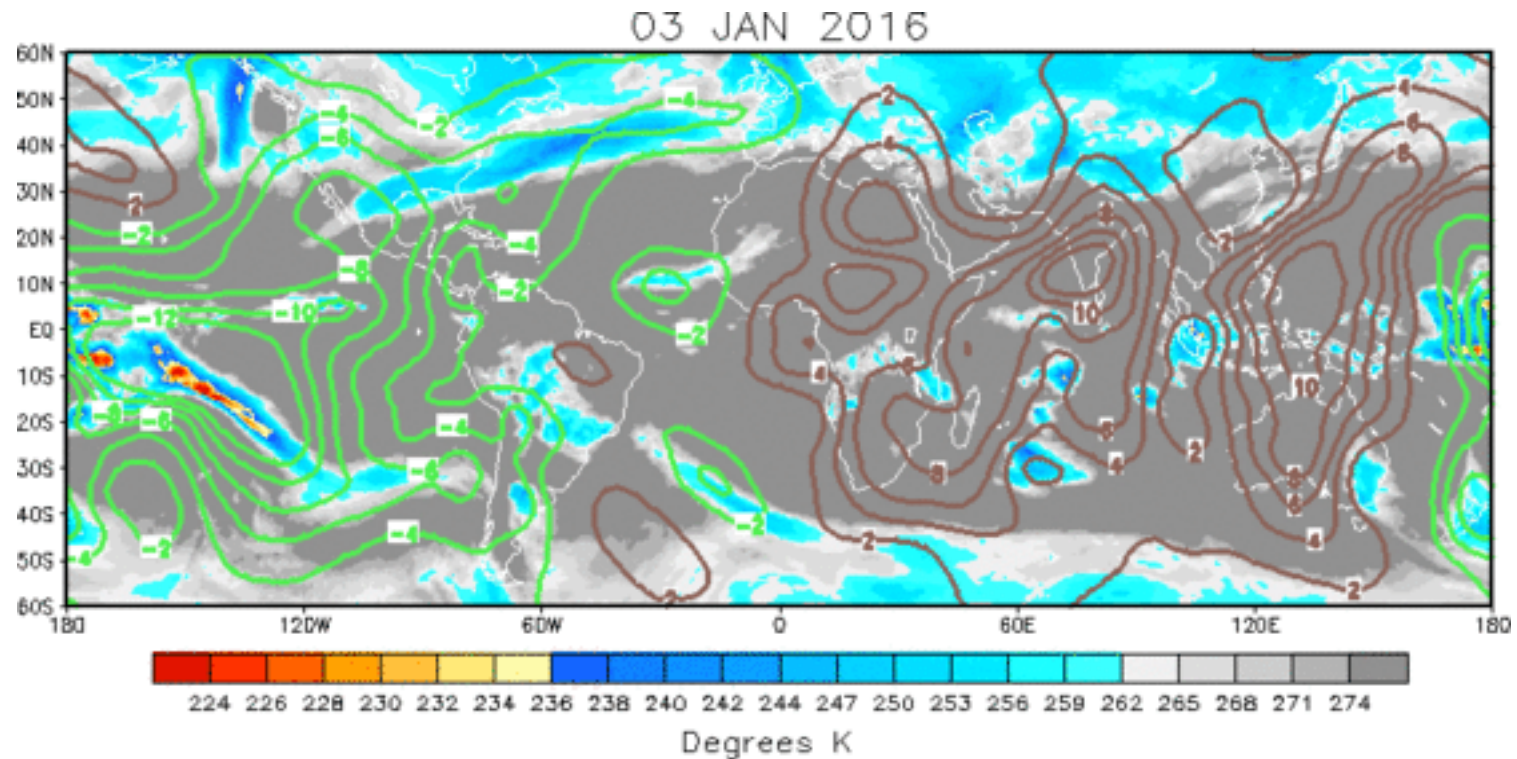
Renewed MJO activity was observed during December and early January, yielding a robust signal in the upper levels.

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





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



The upper-level velocity potential anomaly pattern is very coherent as the robust MJO constructively interferes with the El Niño. A Wave-1 pattern is evident, with enhanced upper-level divergence (convergence) over the Pacific (Africa, Indian Ocean, and Maritime Continent).

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<sup>-1</sup>)

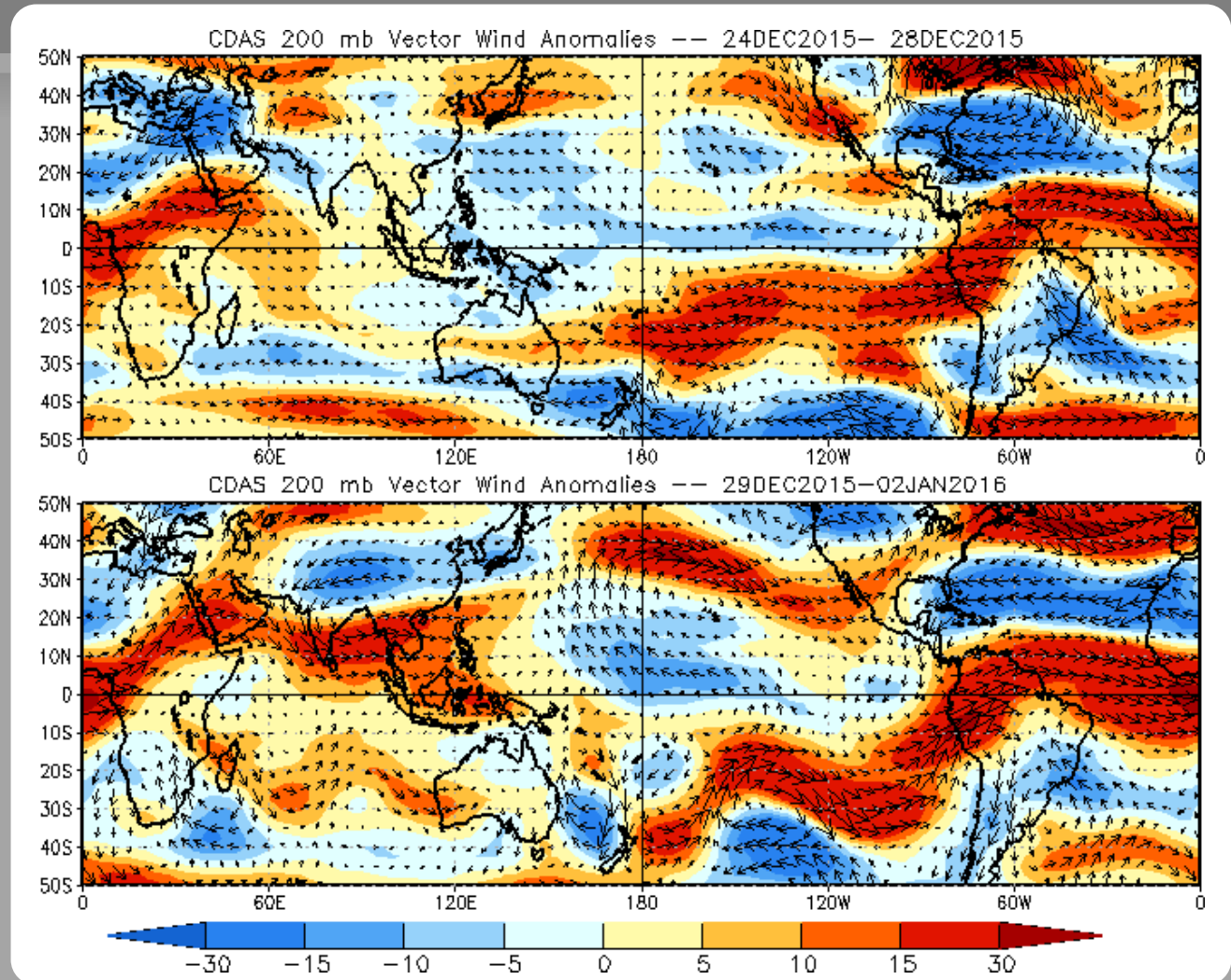
Note that shading denotes the zonal wind anomaly

**Blue shades:** Easterly anomalies

**Red shades:** Westerly anomalies

Upper-level westerly anomalies overspread the Maritime Continent during late December and early January.

Strong upper-level meridional divergence is apparent near the Date Line.



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

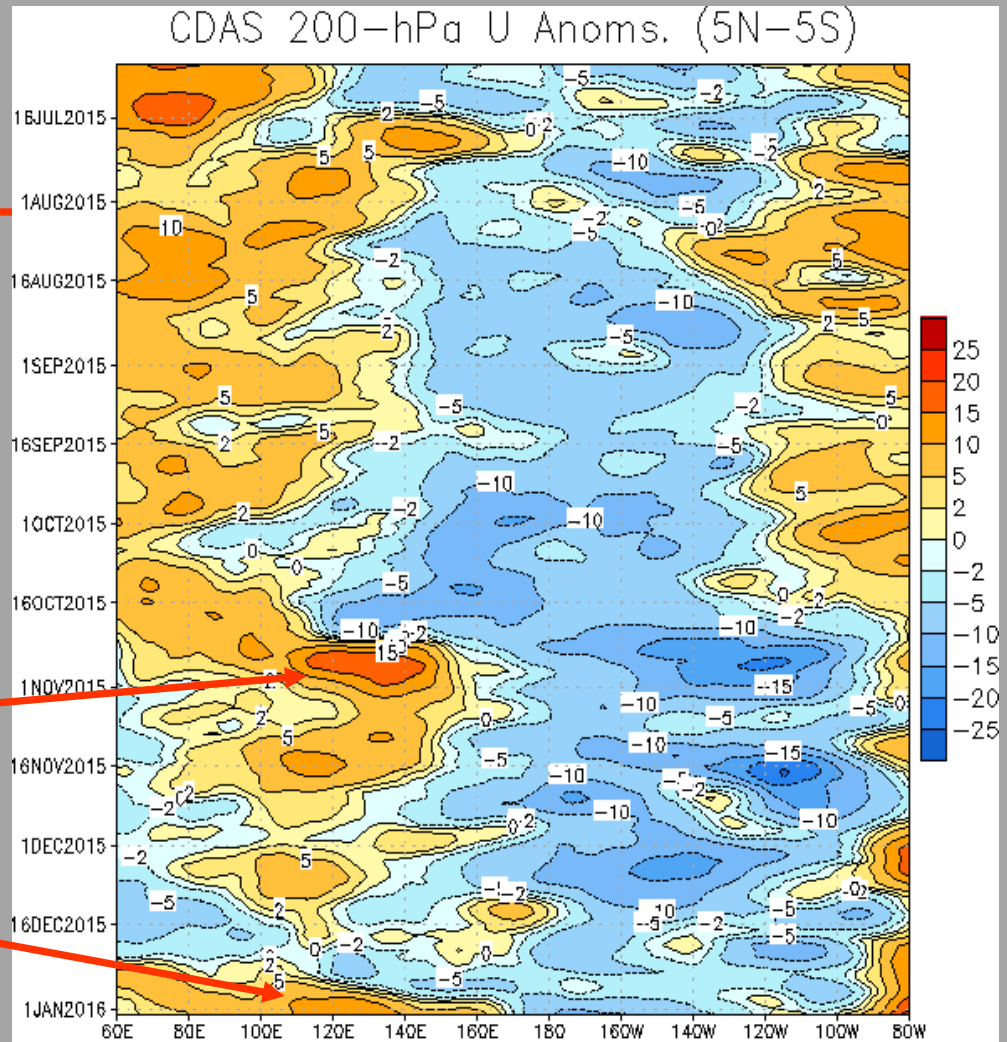
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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 June and July, these easterly anomalies were briefly interrupted by robust atmospheric Kelvin wave/MJO activity.

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.



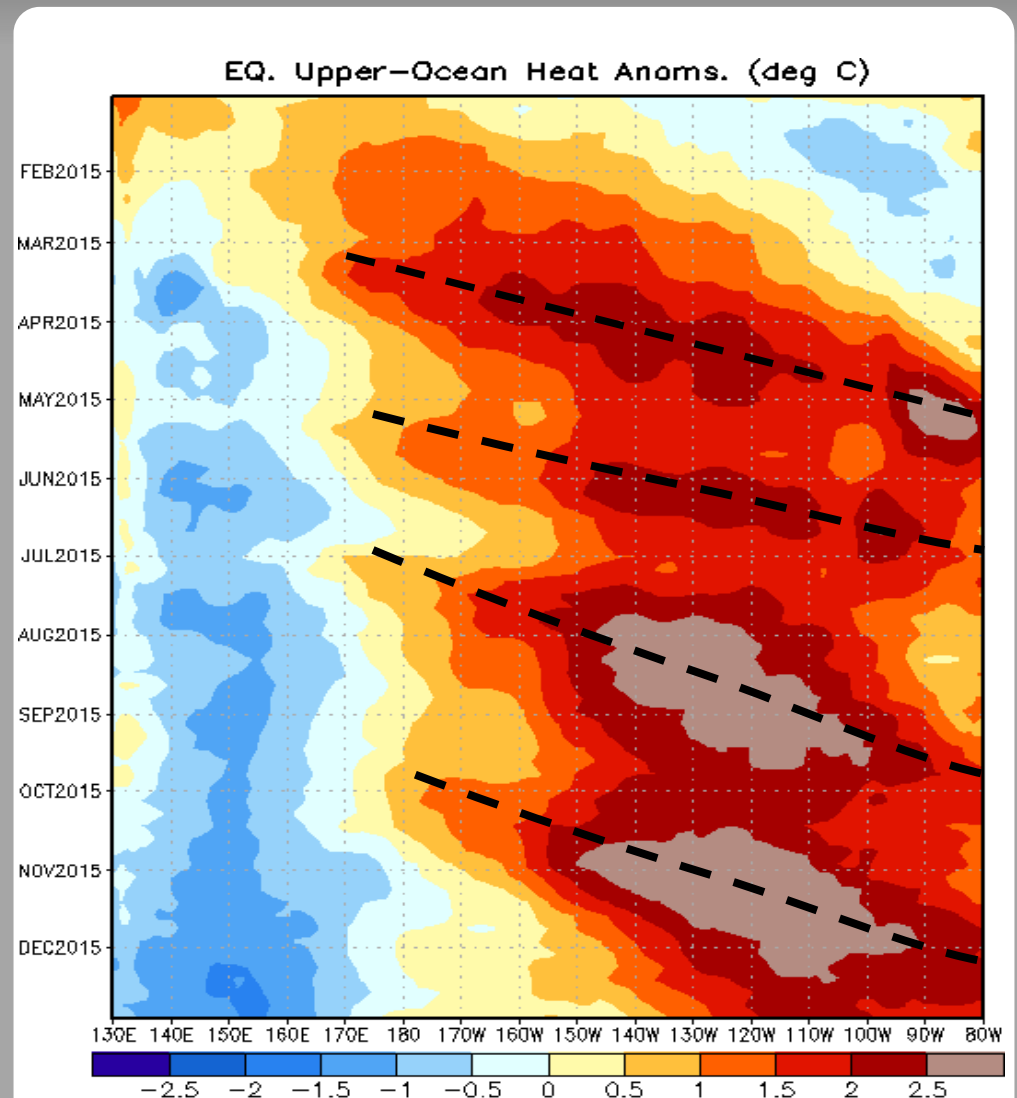
# Weekly Heat Content Evolution in the Equatorial Pacific

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 expansion of below average heat content over the western Pacific is evident since spring and this area has increased during November and December 2015.



# 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

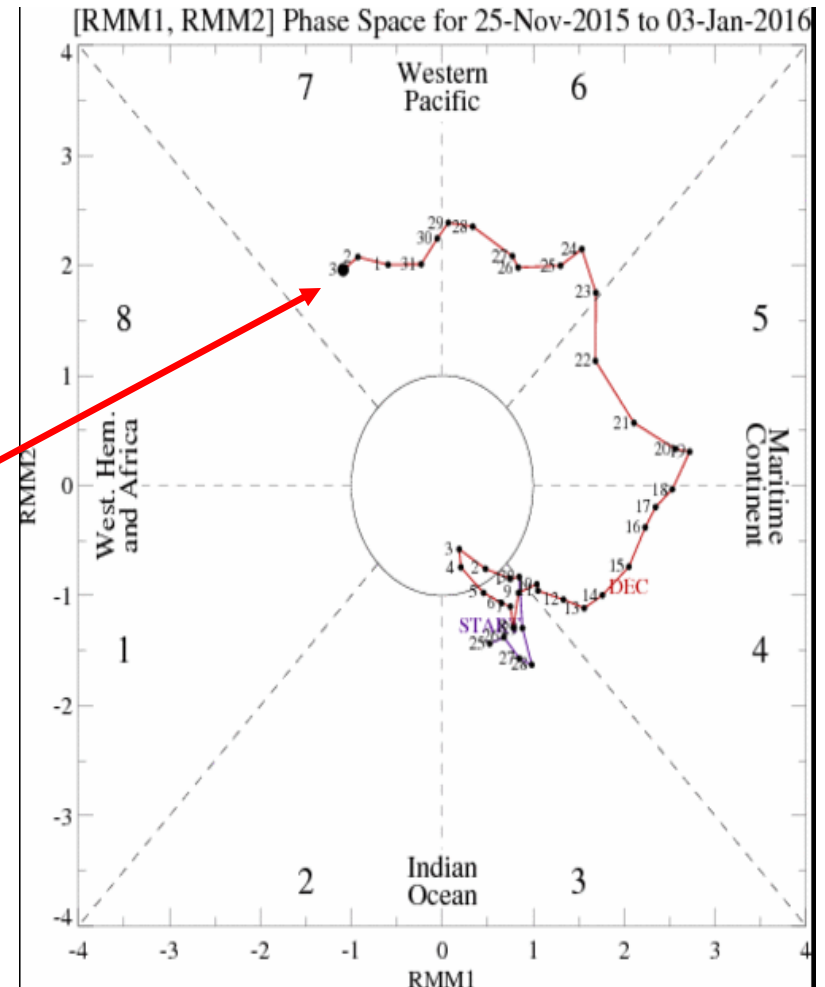
The triangular areas indicate the location of the enhanced phase of the MJO

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

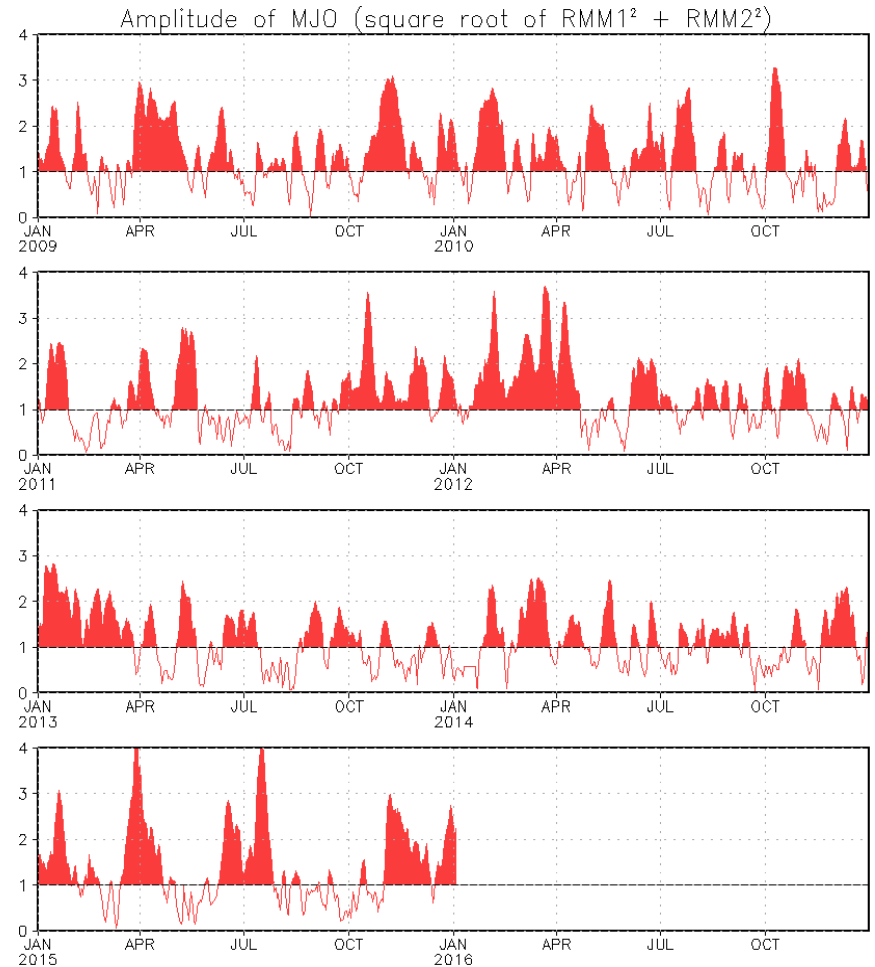
The MJO index remained highly amplified, with continued eastward propagation across the Pacific during the past week.



# 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

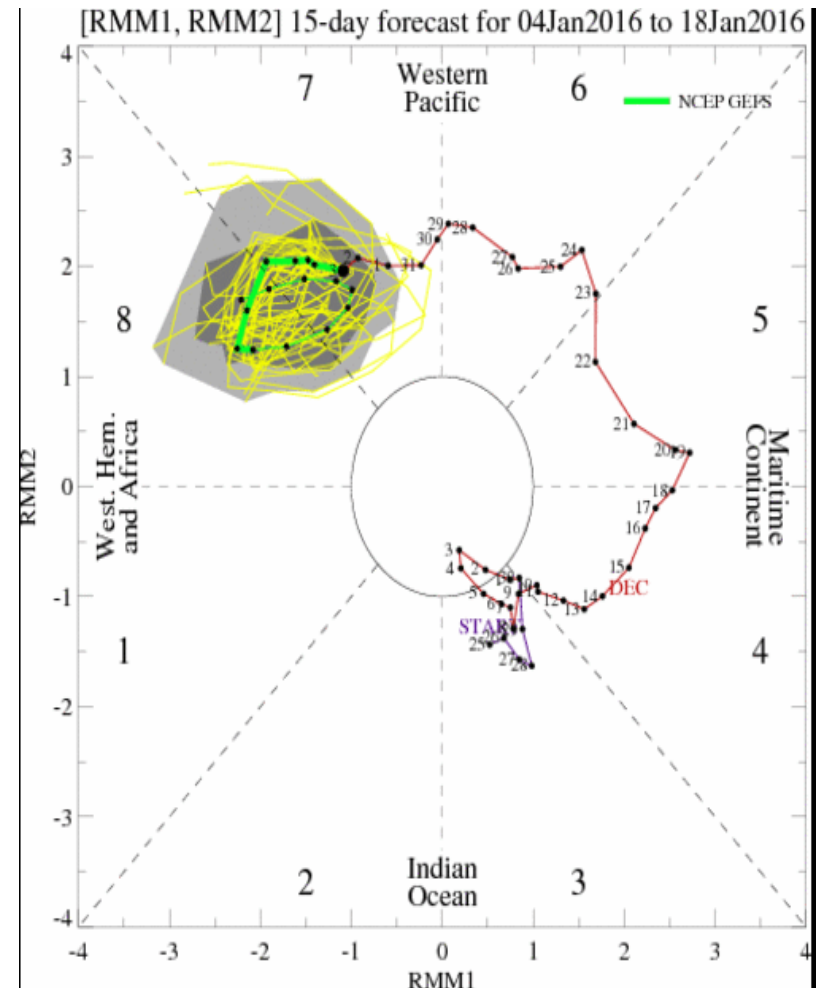
RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GFS ensemble MJO index forecast depicts a highly amplified signal over the next two weeks, with reduced eastward propagation as other modes potentially interfere with the pattern.

Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean

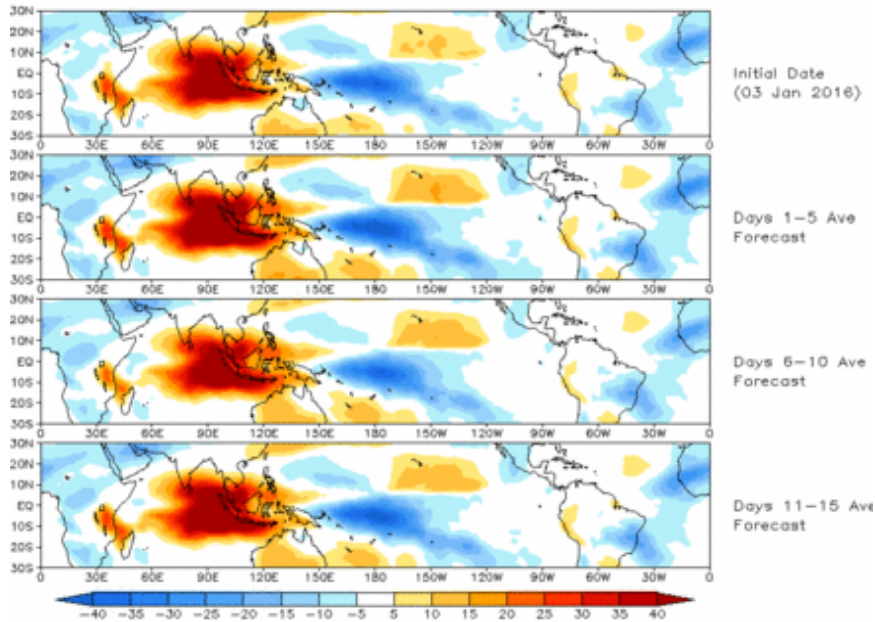




# Ensemble GFS (GEFS) MJO Forecast

Spatial map of OLR anomalies for the next 15 days

Prediction of MJO-related anomalies using GEFS operational forecast  
Initial date: 03 Jan 2016  
OLR

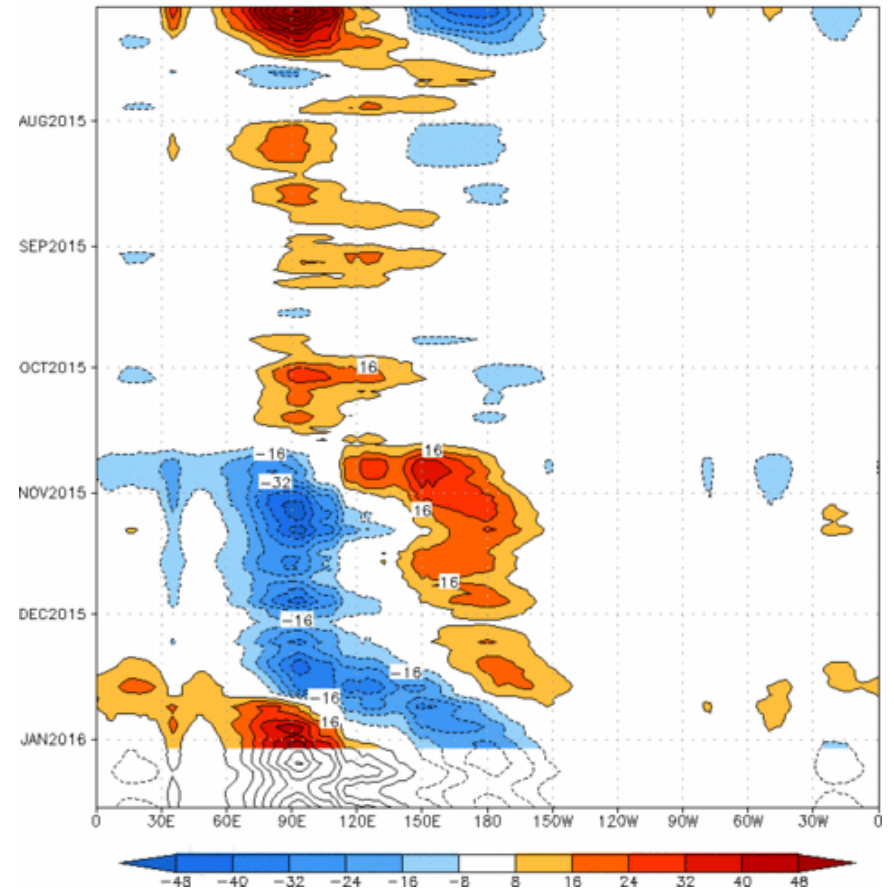


The GEFS MJO index-based OLR forecast depicts a high amplitude anomaly pattern with little eastward propagation during the next two weeks.

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

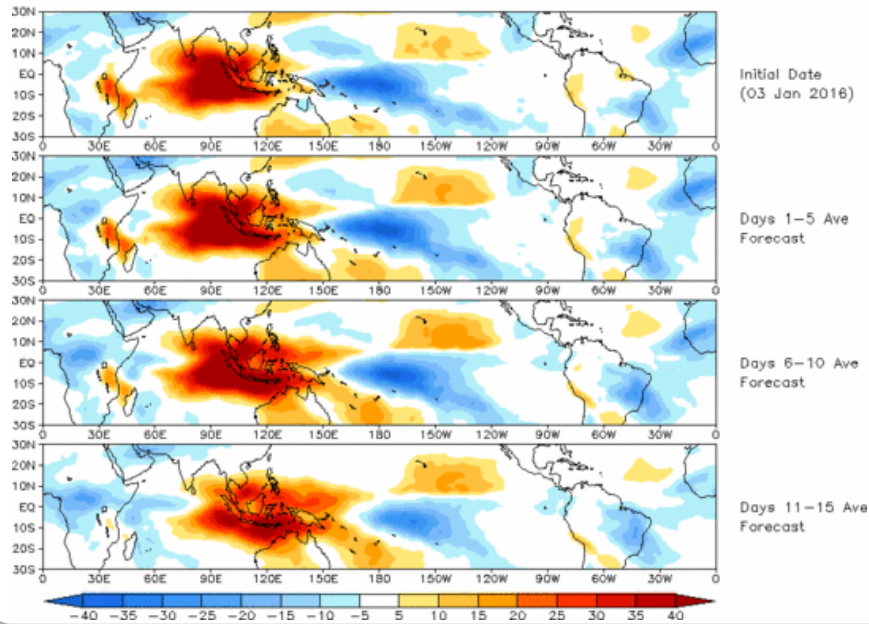
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [7.5°S,7.5°N] (cont:4Wm<sup>-2</sup>) Period:04-Jul-2015 to 03-Jan-2016  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# 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 (03 Jan 2016)

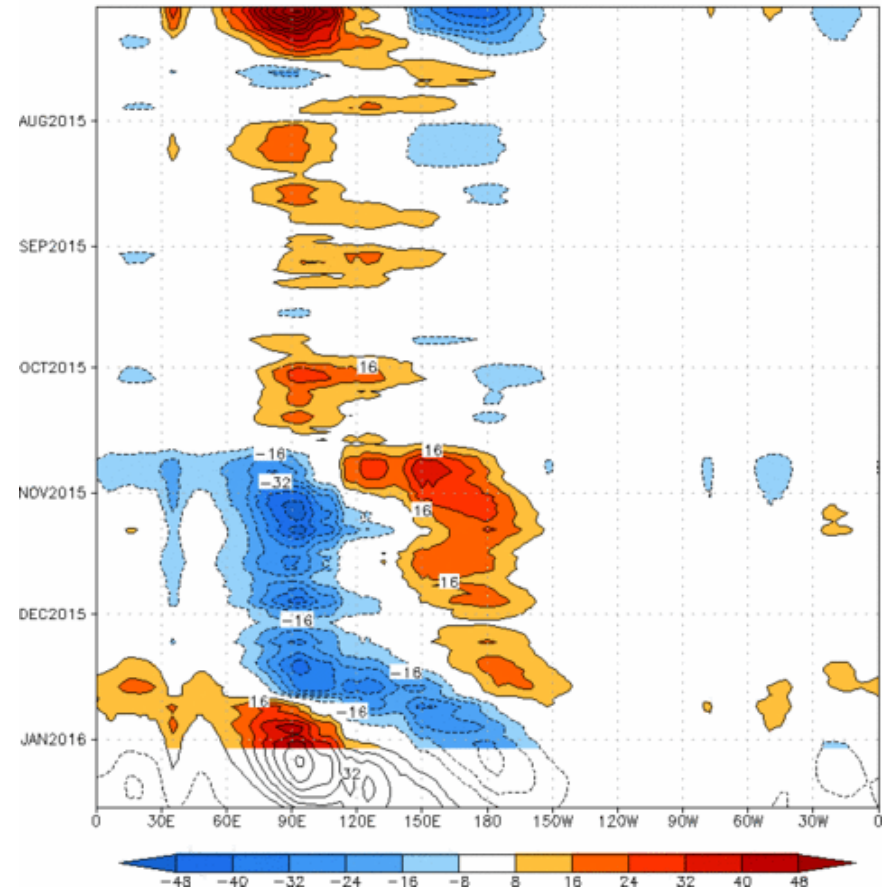


The constructed analog model depicts a more robust eastward propagation of the strong OLR anomaly field.

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.)

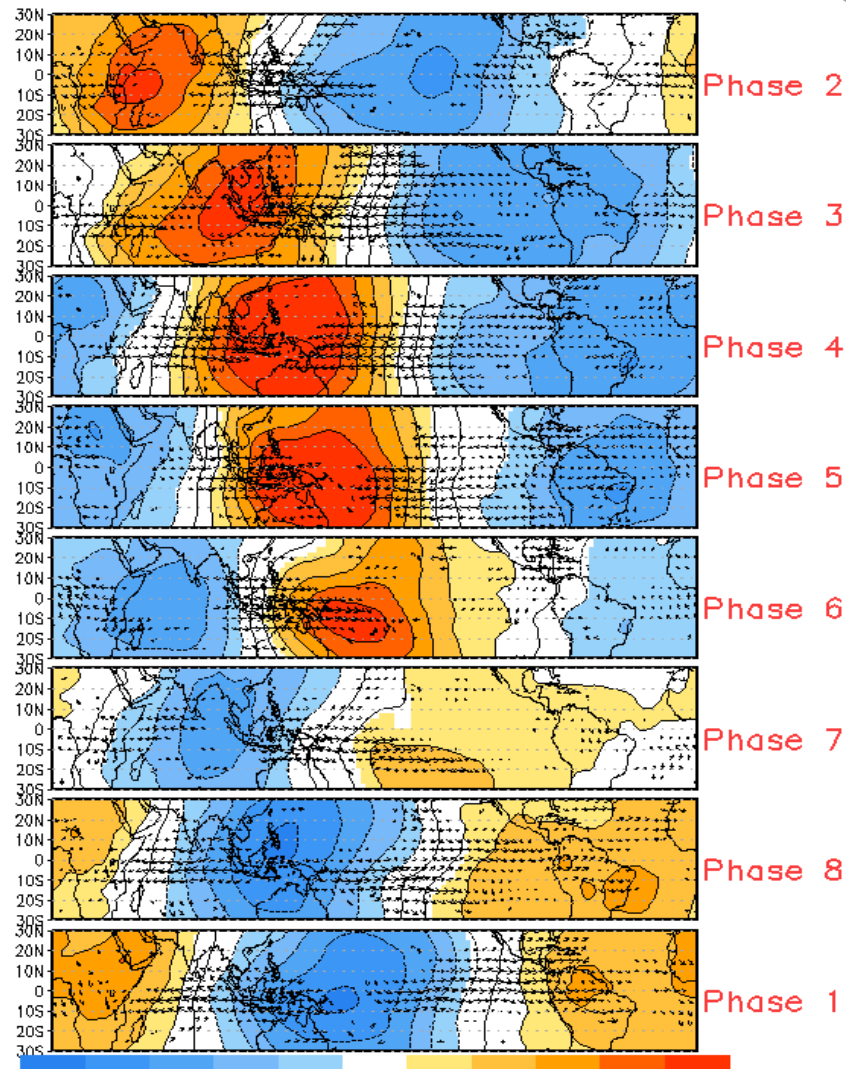
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [7.5°S,7.5°N] (cont:4Wm<sup>-2</sup>) Period:04-Jul-2015 to 03-Jan-2016  
The unfilled contours are CA forecast reconstructed anomaly for 15 days

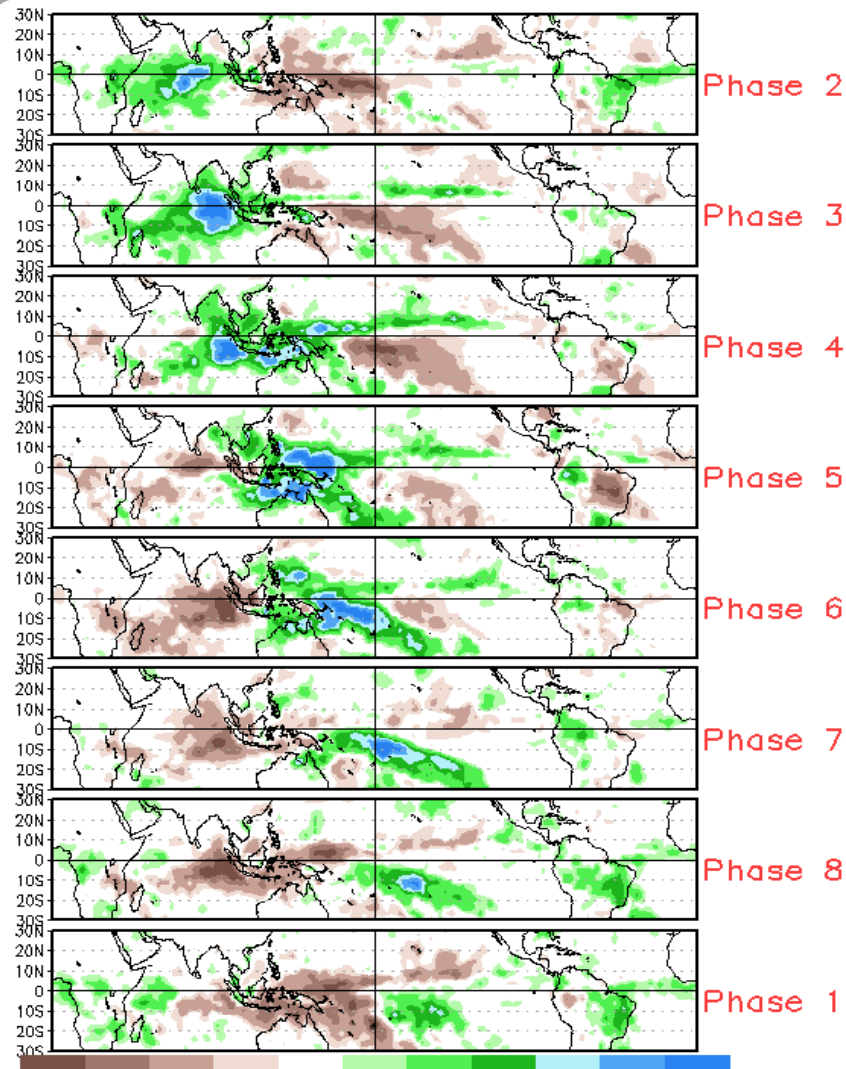


# MJO Composites - Global Tropics

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



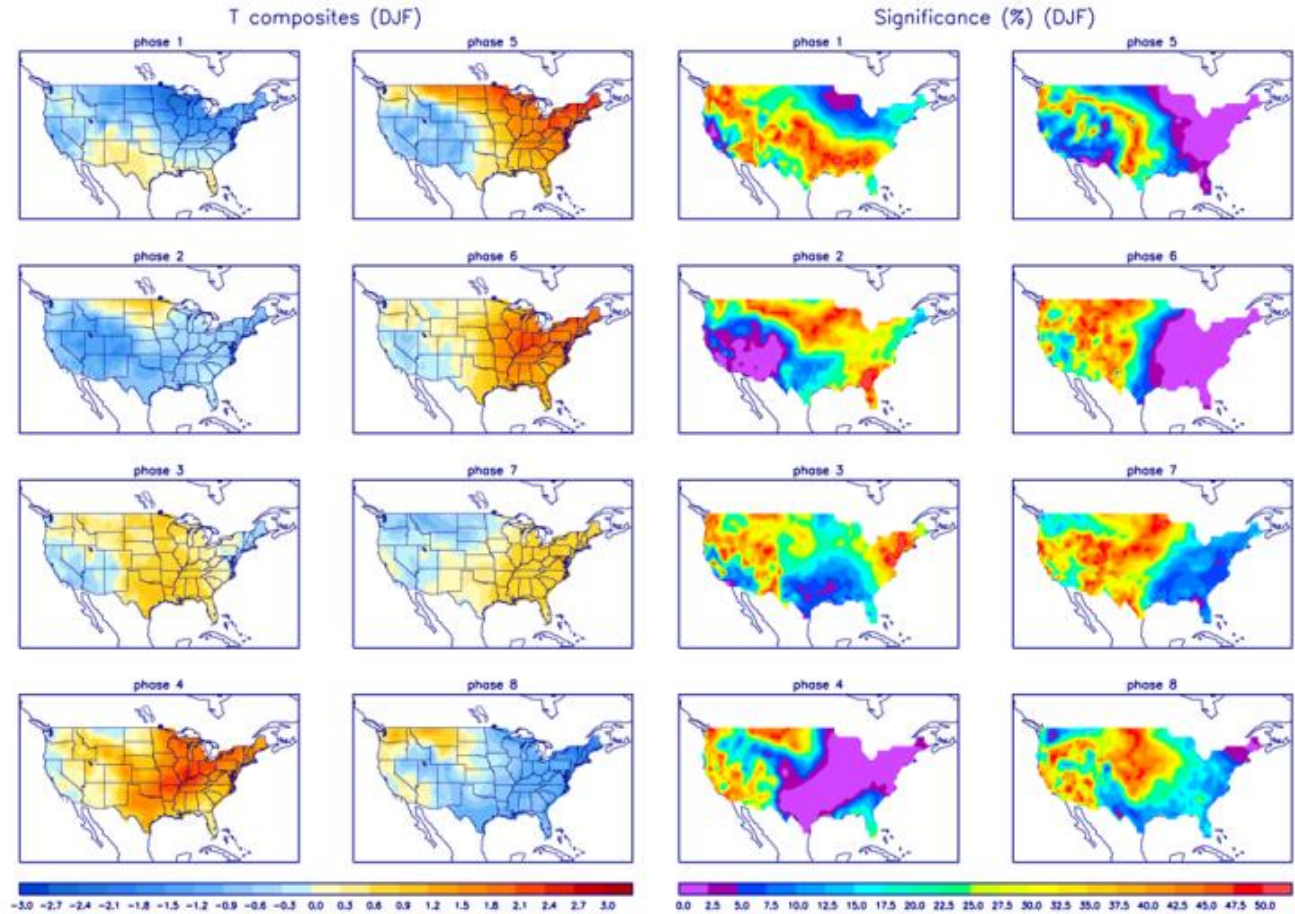
Precipitation Anomalies (Nov-Mar)



# 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.



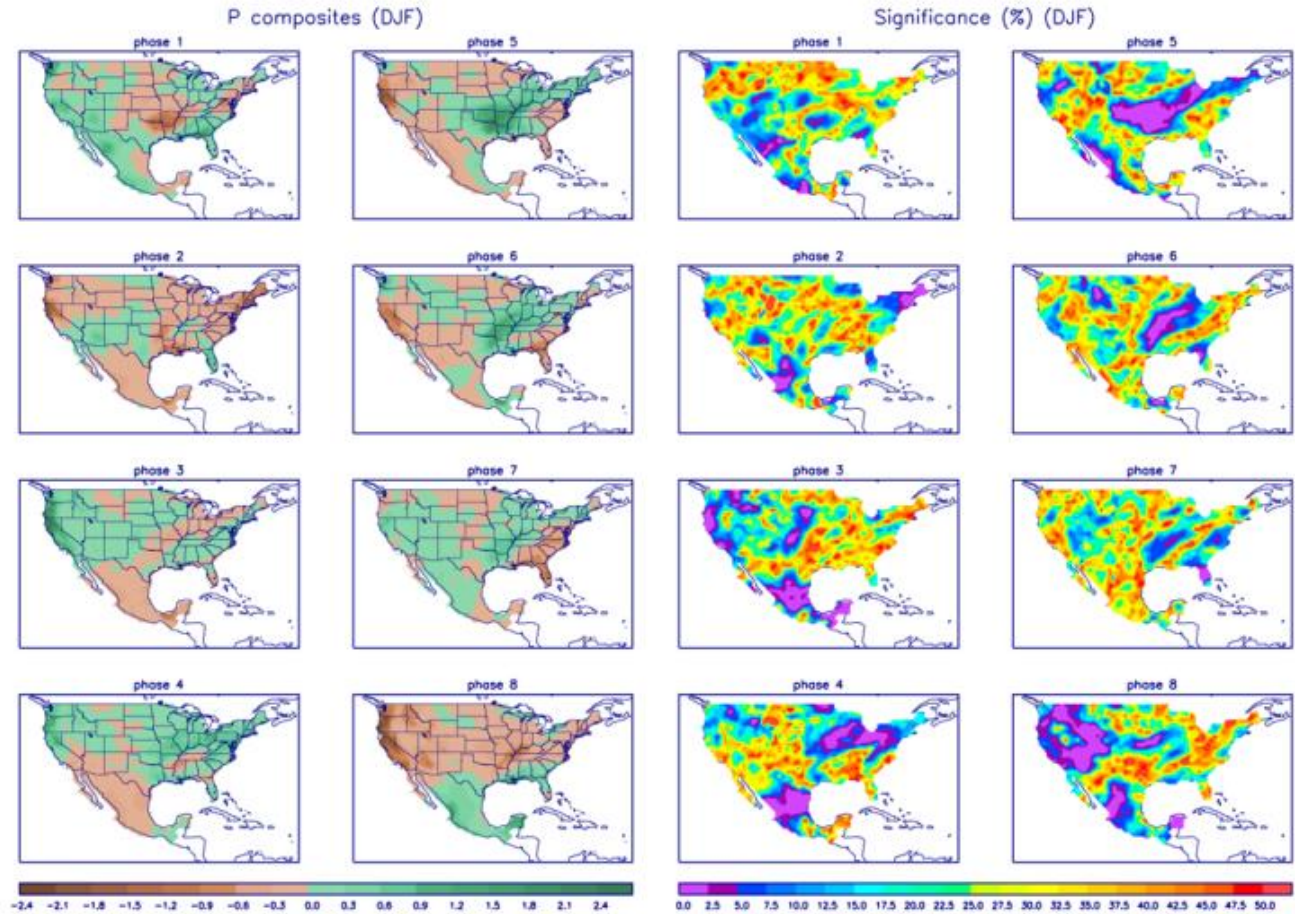
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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

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