

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



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5 December 2016

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

- The RMM-based and CPC velocity potential-based MJO indices showed considerable weakening of the MJO during the past week. Kelvin wave activity and westward-moving variability are interfering with the MJO signal.
- Dynamical model forecast solutions generally predict a continued weak MJO signal during the next week. During Week-2, many ensemble members from the GEFS and ECMWF show a more coherent signal redeveloping over the Maritime Continent or West Pacific.
- Due to the complex pattern in the global tropics, the future evolution of the intraseasonal signal is uncertain.
- Midlatitude MJO impacts over North America would depend heavily on the evolution of the tropical convective pattern. Anomalous convection (suppression) over the West Pacific (Indian Ocean) would favor a colder North American solution.

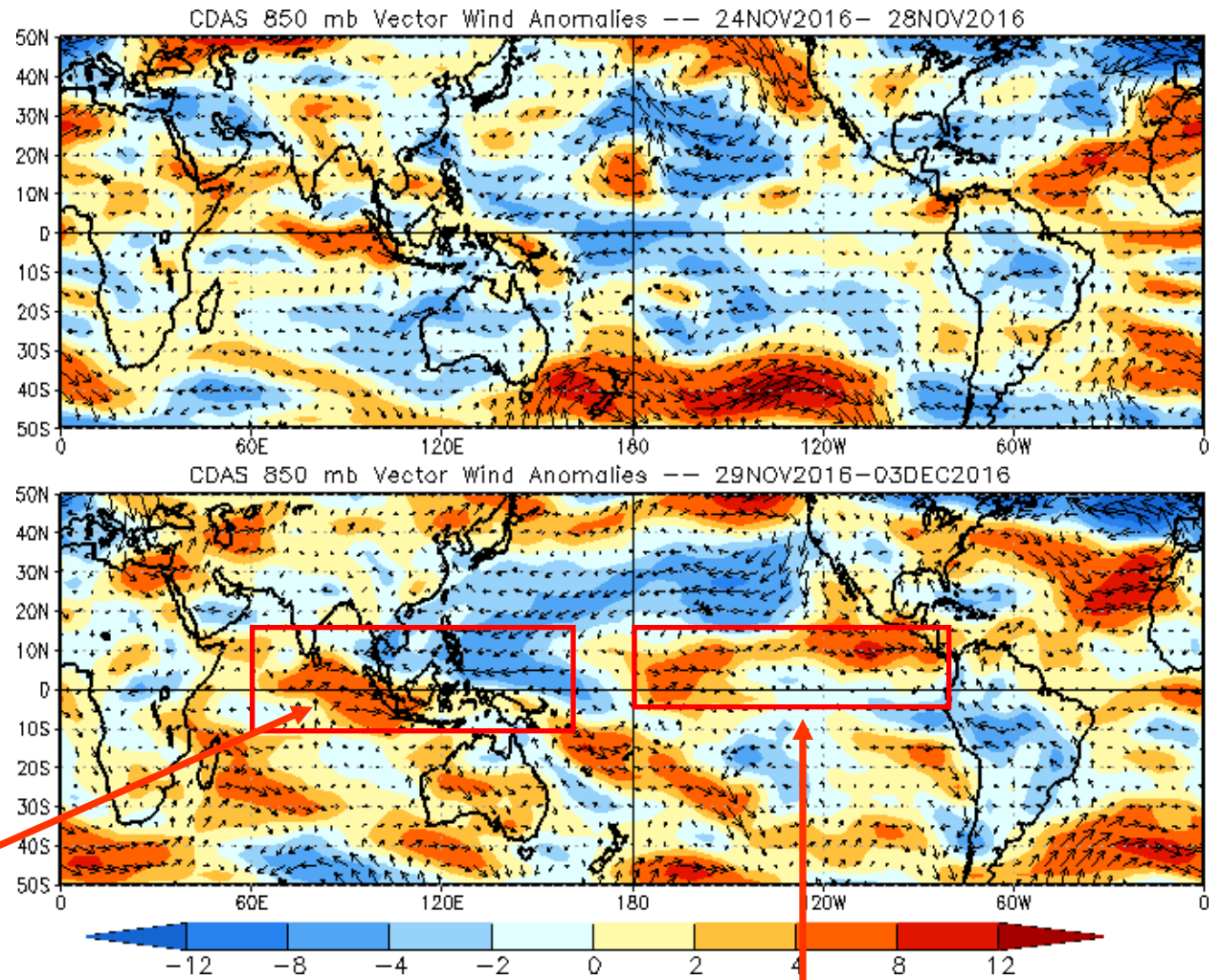
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:  
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php>

# 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



A dipole consisting of anomalous westerlies (easterlies) over the eastern Indian Ocean (West Pacific) is consistent with the low-frequency pattern.

Westerly anomalies re-intensified over parts of the central and eastern Pacific.

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

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

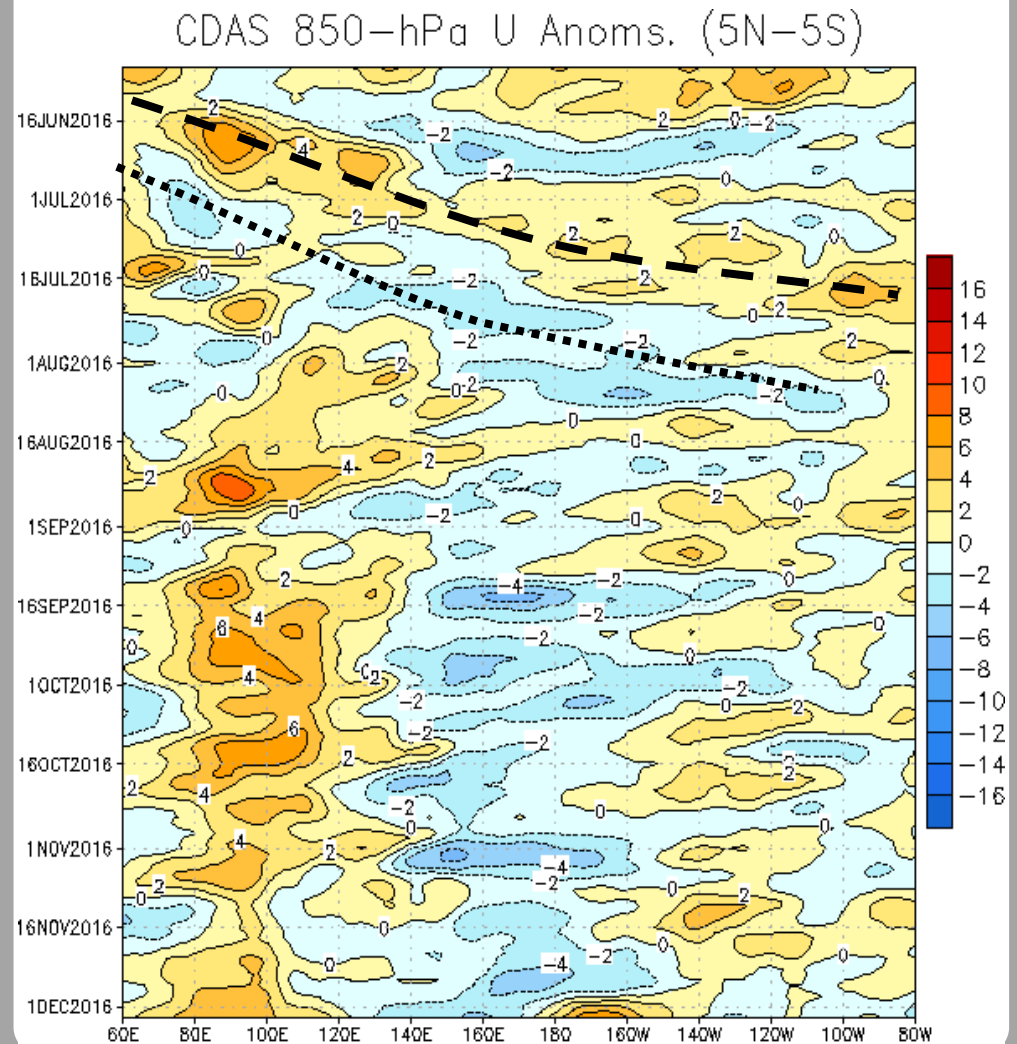
Easterly anomalies (blue shading) represent anomalous east-to-west flow

During June, westerly anomalies were persistent over the Indian Ocean (IO), with higher frequency modes periodically propagating across the Pacific.

During late August, westerly anomalies were evident across the IO and western Pacific.

During September and October, persistent westerly (easterly) anomalies were evident over the eastern Indian Ocean and western Maritime Continent (central Pacific). These anomalies are low frequency in nature, and reflect a developing La Niña base state as well as a negative phase of the Indian Ocean Dipole (IOD).

During November, intraseasonal variability briefly interrupted the La Niña related pattern. Anomalous westerlies have emerged recently east of the Date Line.



# OLR Anomalies - Past 30 days

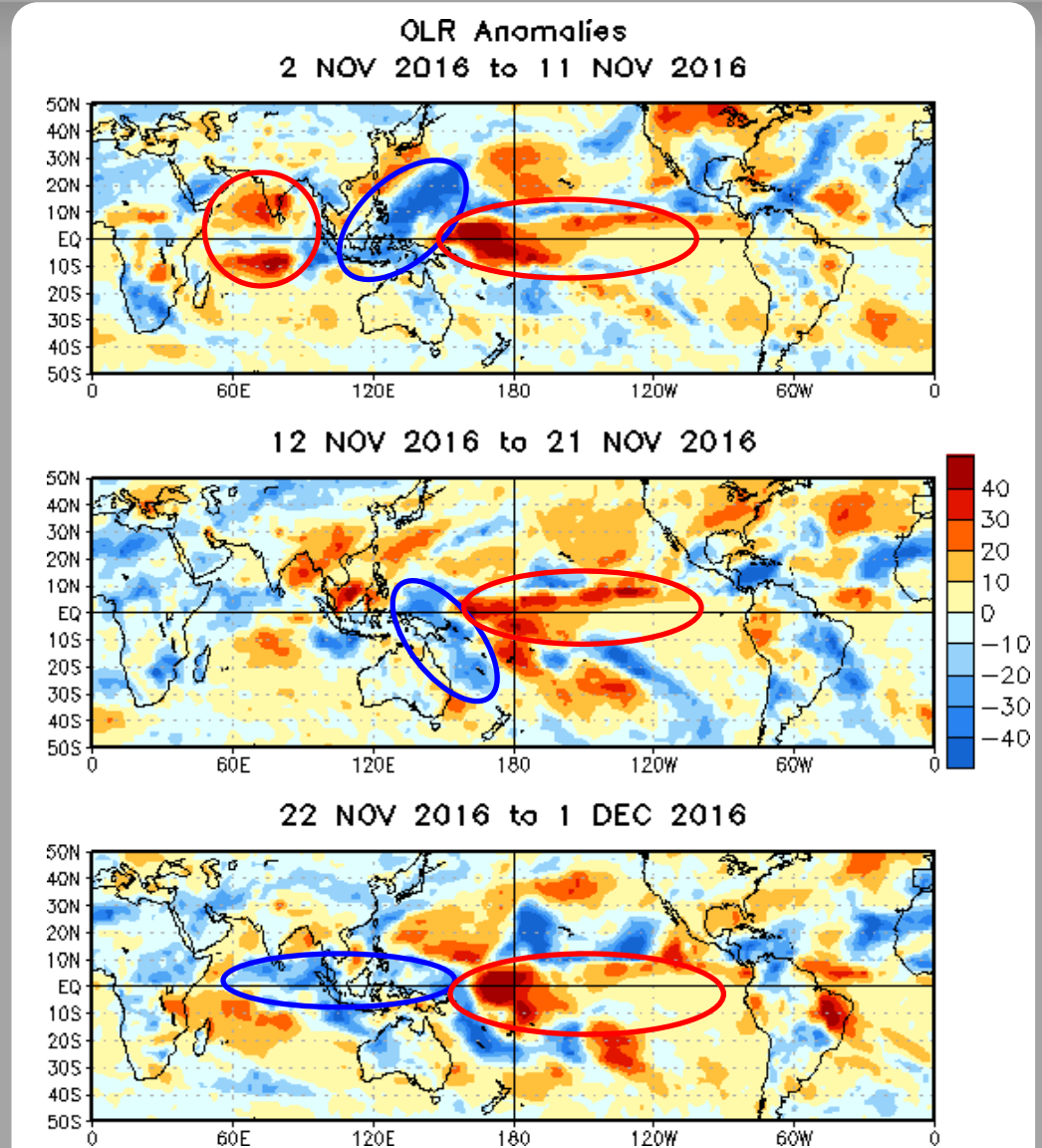
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During early November, enhanced (suppressed) convection was observed over the Maritime Continent (central Indian Ocean and equatorial Pacific basin). This activity was primarily associated with the base state.

The low-frequency pattern continued to influence the pattern mid-month, but subseasonal variability shifted the pattern eastward, reducing anomalous convection over the Maritime Continent.

By late November, enhanced convection developed over the central Indian Ocean and extended eastward across the Maritime Continent, consistent with La Niña and ongoing MJO variability.



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

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

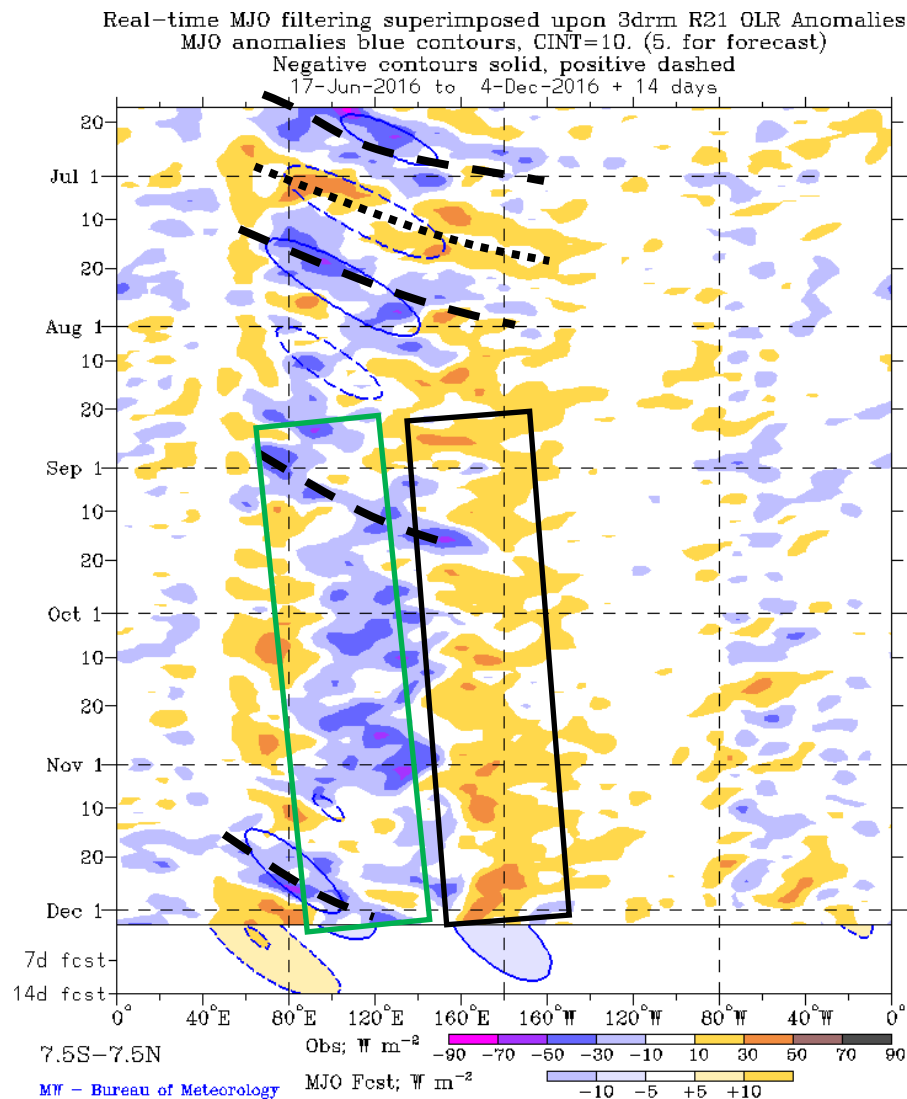
**Wetter-than-normal conditions, negative OLR anomalies (blue shading)**

Several intraseasonal events were observed through July, with other modes such as tropical cyclone activity also influencing the pattern.

A low frequency state favoring enhanced convection shifted slowly east from the eastern Indian Ocean to the Maritime Continent has been evident since July (green box). Low-frequency suppressed convection, tied to building La Niña conditions, has been apparent near the Date Line since late July (black box).

A fast eastward propagating convective envelope was evident during early September.

More recently, faster moving modes (Kelvin waves, possibly MJO) were evident in the OLR field.





# 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

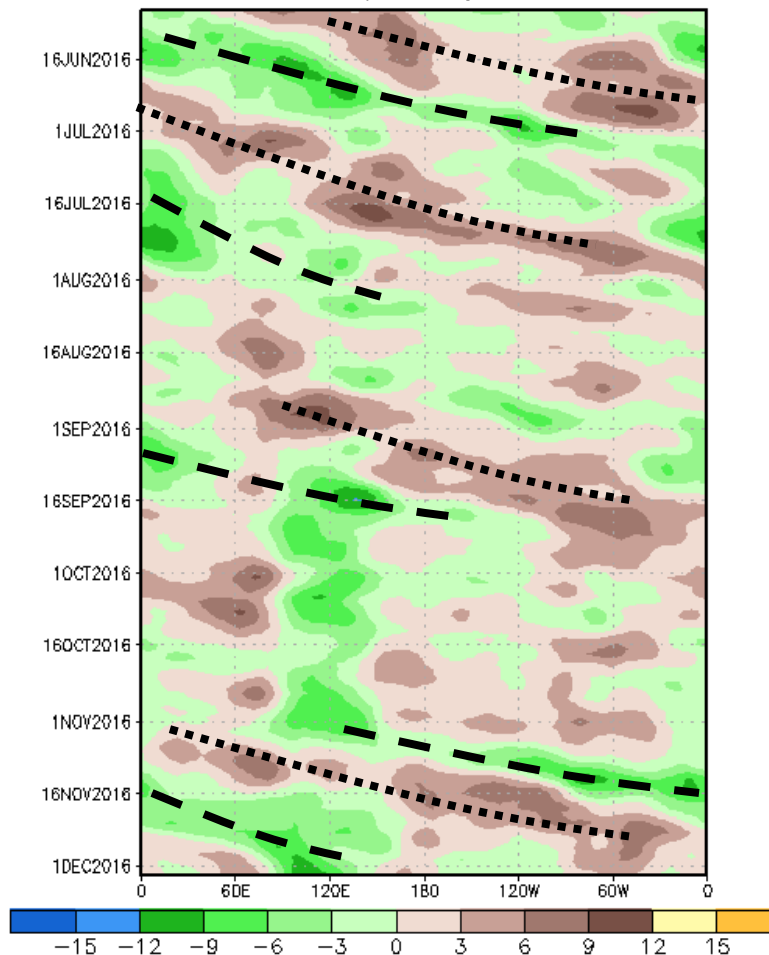
From June through early August, an eastward propagating signal was evident, with multiple periods of variability apparent.

During August, the intraseasonal signal became less coherent, with a weaker and somewhat more stationary anomaly field in place. By late August and early September, there was renewed propagation of the intraseasonal signal.

From mid-September to late October, the low frequency signal dominated the pattern. An absence of intraseasonal variability during that period resulted in the standing negative velocity potential anomalies near 120E associated with the negative IOD event.

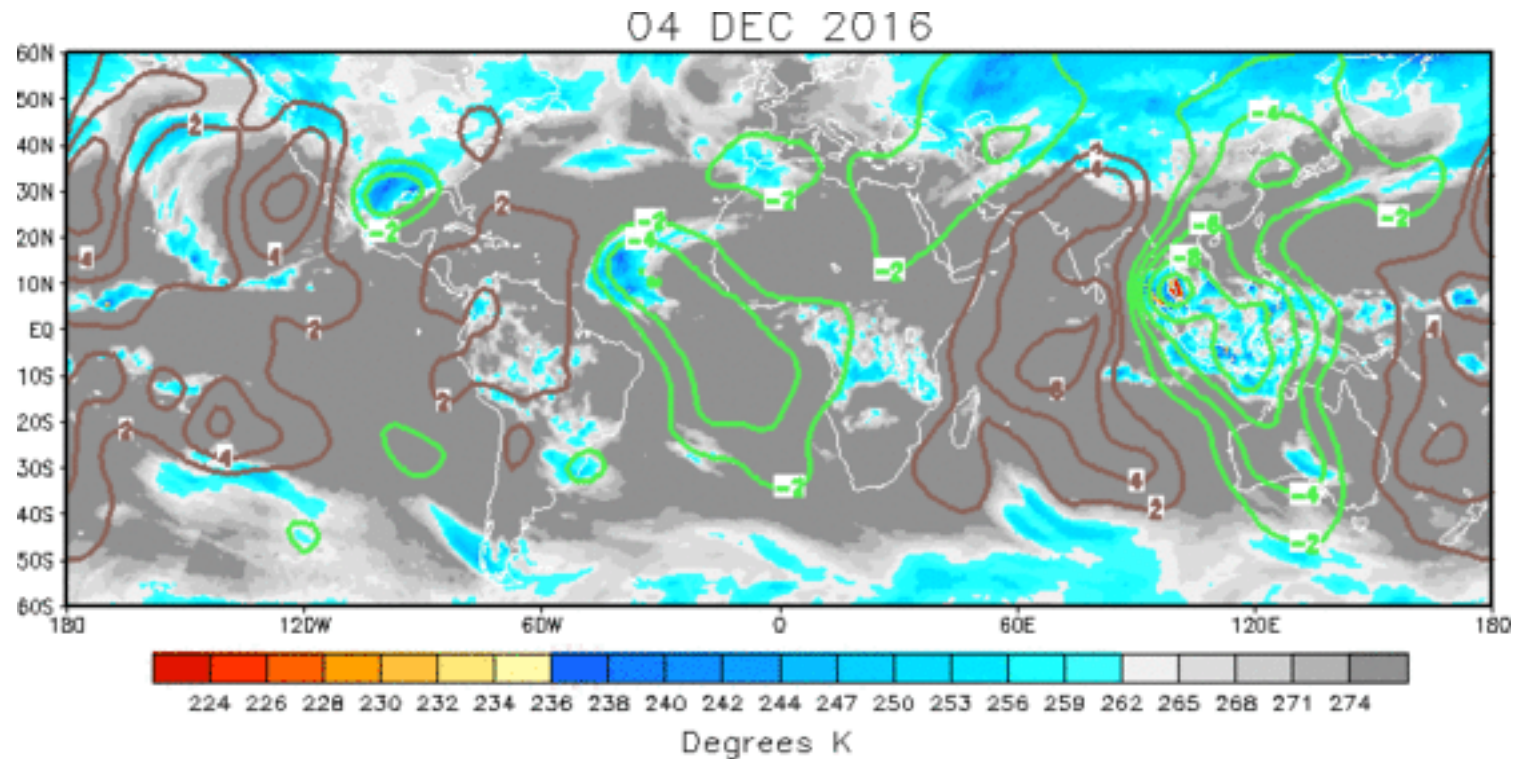
During November, rapid eastward propagation has been observed consistent with MJO activity on the fast end of the intraseasonal spectrum, with negative VP anomalies most recently returning to the Maritime Continent.

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





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



The spatial pattern of upper-level velocity potential anomalies has become less organized over the past several days. Anomalous divergence is centered over the Maritime Continent, but velocity potential anomalies elsewhere are fairly low amplitude.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

Negative anomalies (green contours) indicate favorable conditions for precipitation

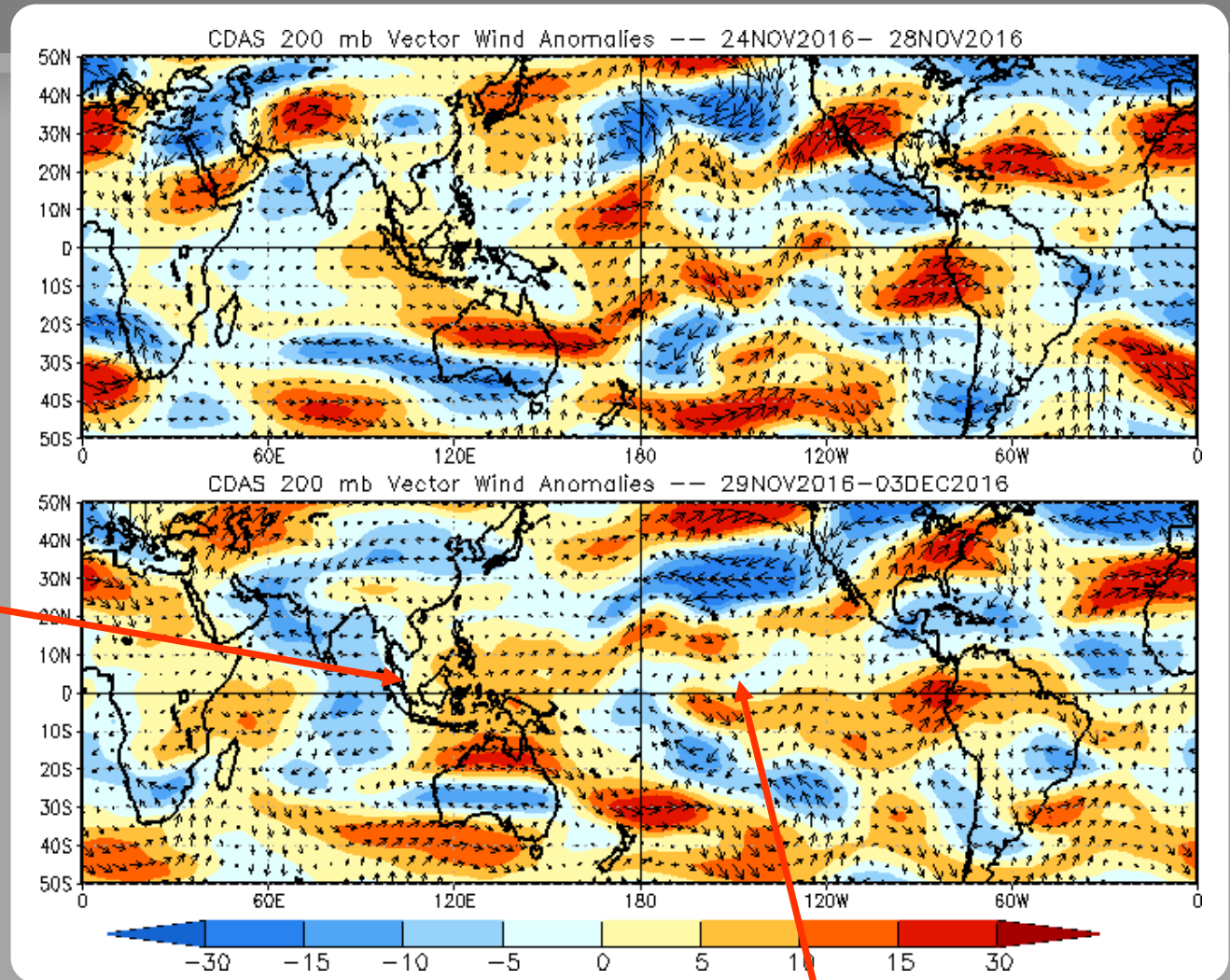
# 200-hPa Vector Wind Anomalies (m s<sup>-1</sup>)

Note that shading denotes the zonal wind anomaly

**Blue shades:** Easterly anomalies

**Red shades:** Westerly anomalies

Anomalous divergence of the zonal component of the upper-level wind field is evident over the Maritime Continent recently.



Westerly anomalies persisted over much of the equatorial Pacific.

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

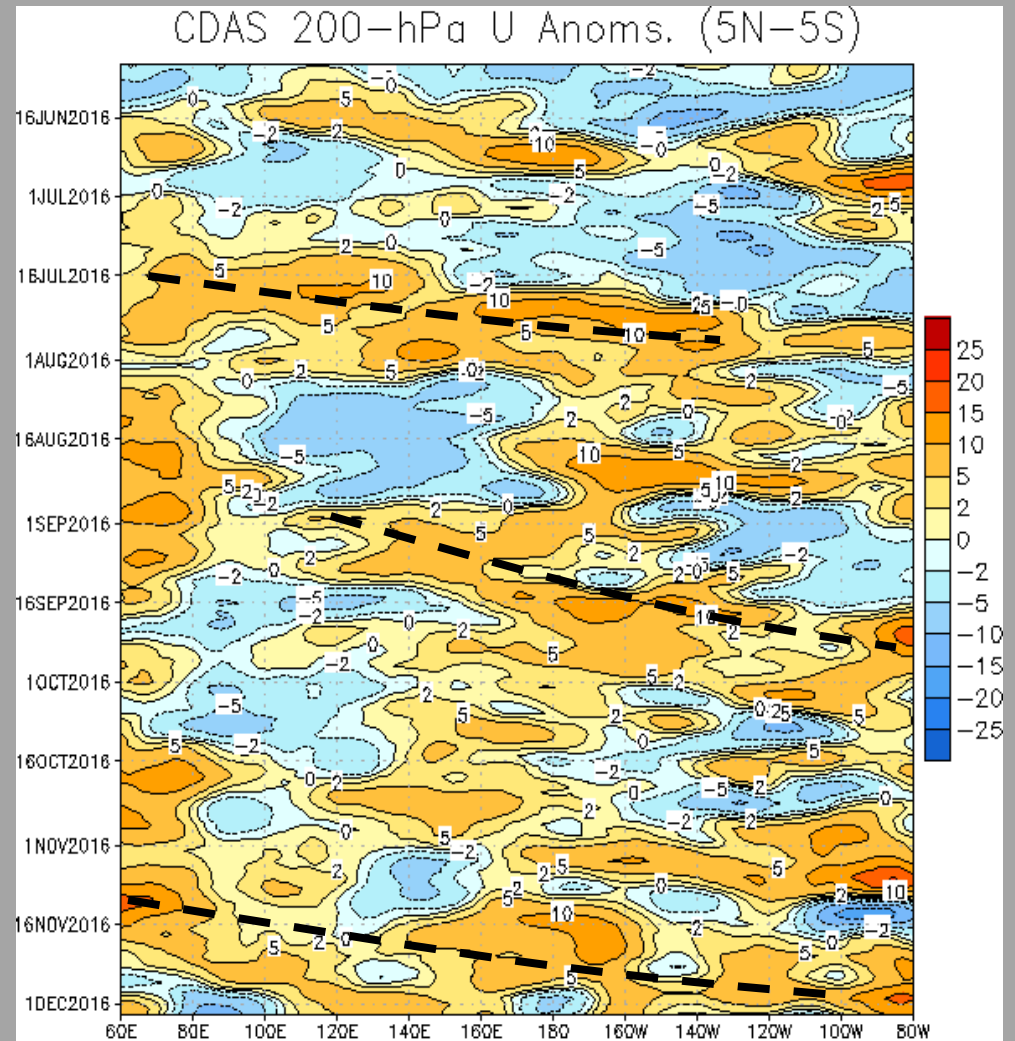
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

During July, some eastward propagation in large scale anomalies was evident, although the spatial consistency implies higher frequency variability than expected with MJO activity.

During September, eastward propagation of westerly anomalies was broadly consistent with organized MJO activity.

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



# Weekly Heat Content Evolution in the Equatorial Pacific

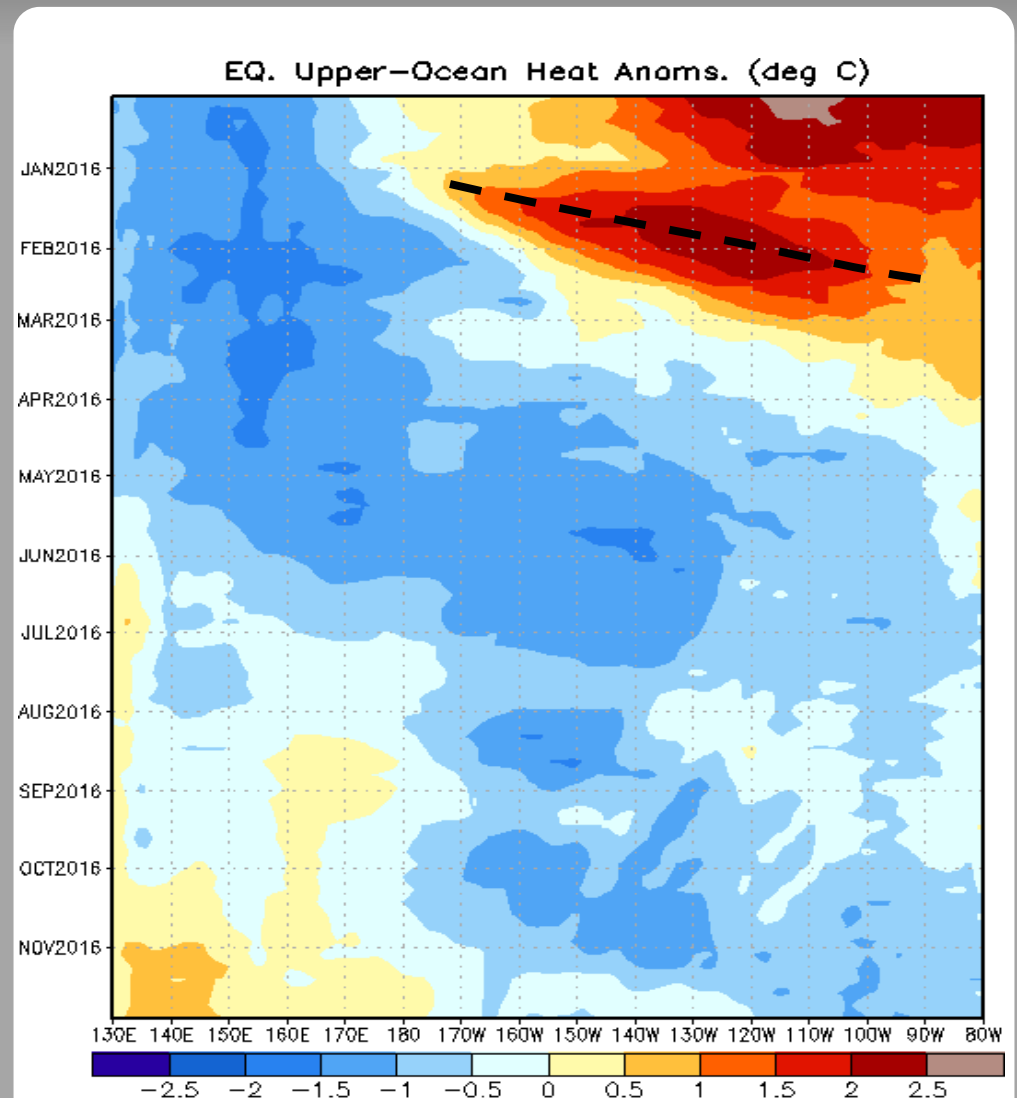
Oceanic Kelvin waves have alternating warm and cold phases. The warm phase is indicated by dashed lines. Downwelling and warming occur in the leading portion of a Kelvin wave, and upwelling and cooling occur in the trailing portion.

Downwelling events were observed through early February, resulting in persistently above-normal heat content from the Date Line to 80W over that period.

An eastward expansion of below average heat content over the western Pacific is evident since January, with widespread negative anomalies building across the Pacific.

The strongest negative anomalies now persist in the East Pacific.

More recently, the negative oceanic heat content anomalies have weakened across the central Pacific although some hints of reinvigorated cooling may be apparent.



# 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

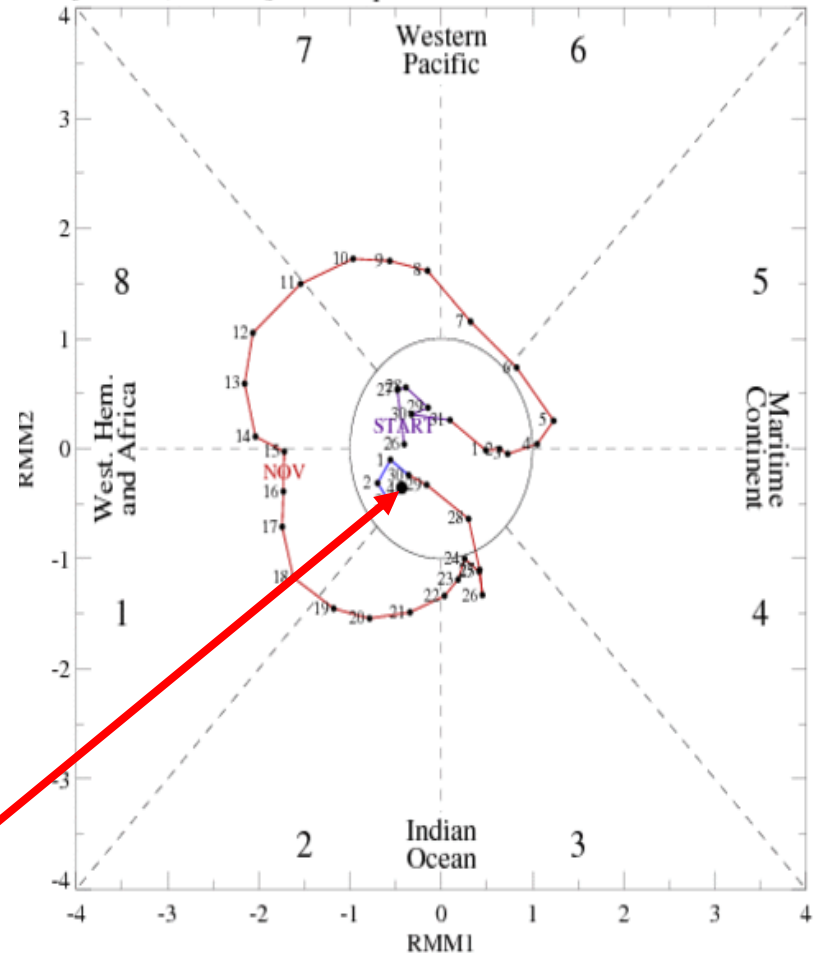
The triangular areas indicate the location of the enhanced phase of the MJO

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

[RMM1, RMM2] Phase Space for 26-Oct-2016 to 04-Dec-2016

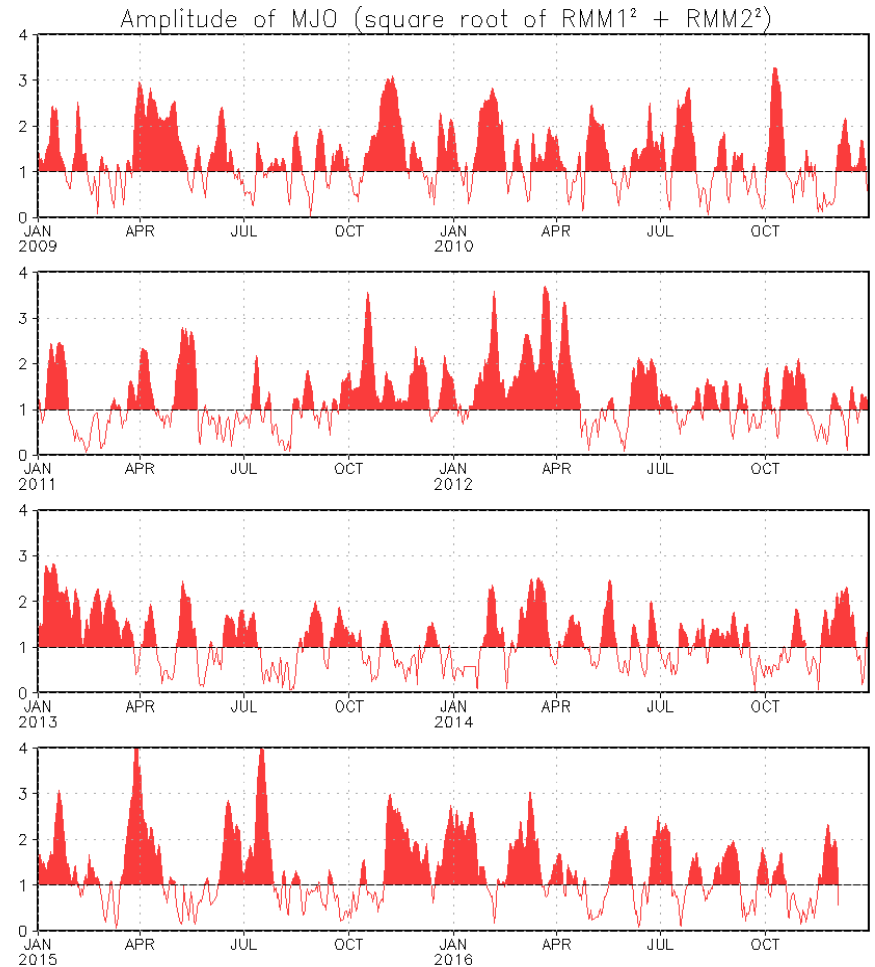


The RMM index has weakened over the past several days. The westward propagation is due to interference from an equatorial Rossby wave.

# 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

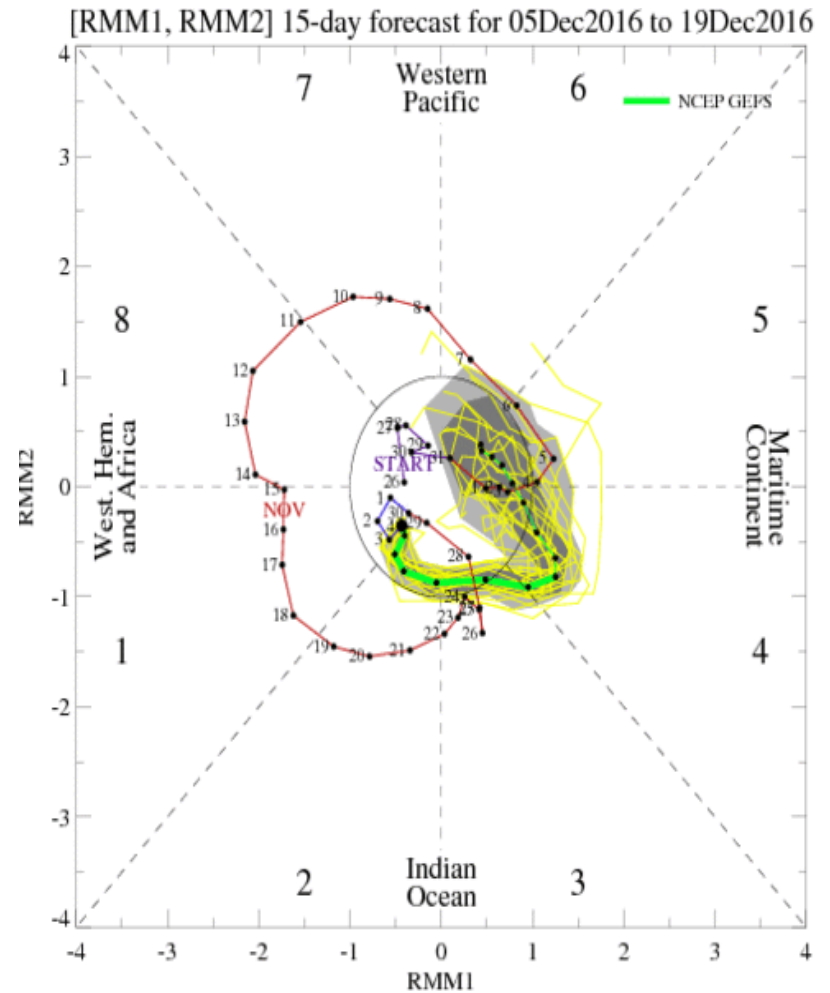
RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

For the next two weeks, the GFS ensemble forecast depicts eastward propagation of a weak signal over the Maritime Continent.

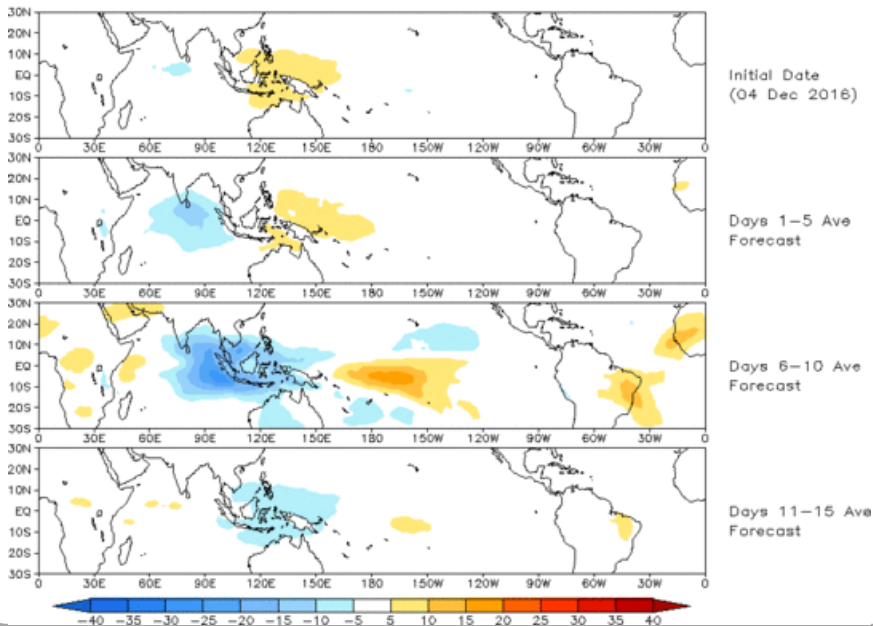
Yellow Lines - 20 Individual Members  
Green Line - Ensemble Mean



# 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: 04 Dec 2016  
OLR

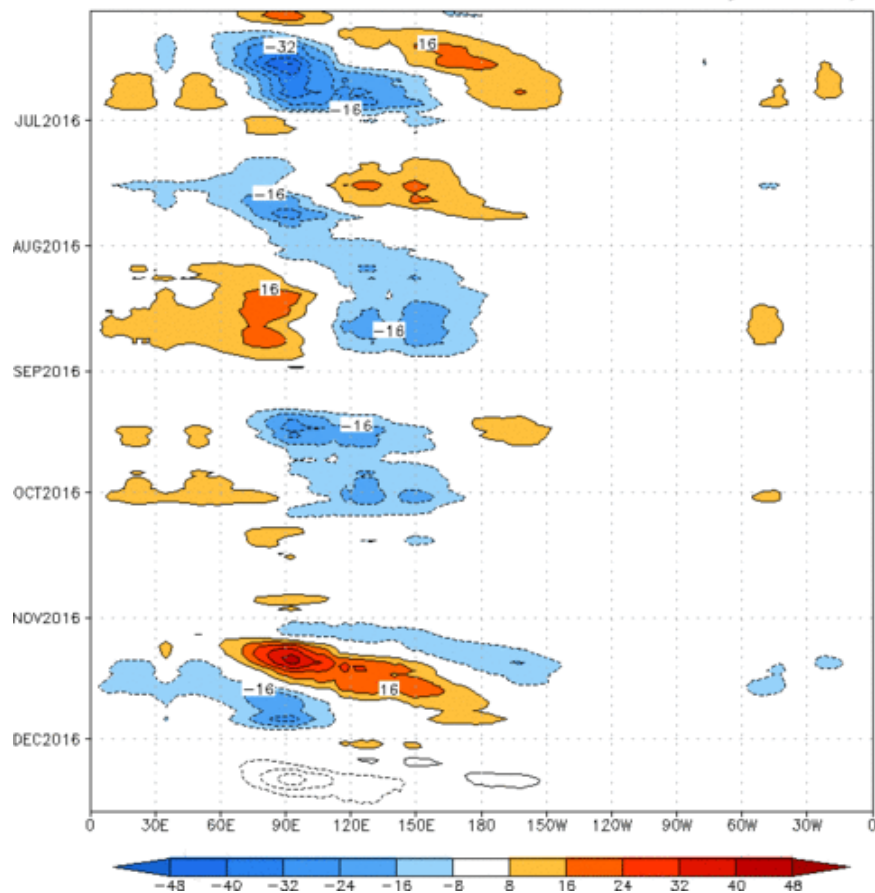


The GEFS RMM Index forecast of OLR anomalies shows an eastward shifting pattern at varying amplitude.

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

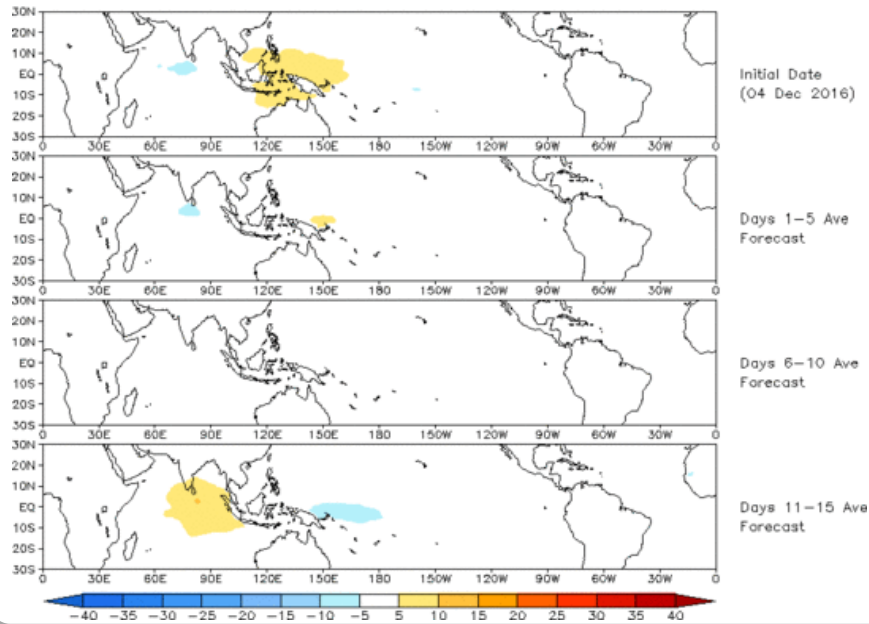
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2  
OLR [7.5°S,7.5°N] (cont:4Wm<sup>-2</sup>) Period:04-Jun-2016 to 04-Dec-2016  
The unfilled contours are GEFS forecast reconstructed anomaly for 15 days



# 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 (04 Dec 2016)

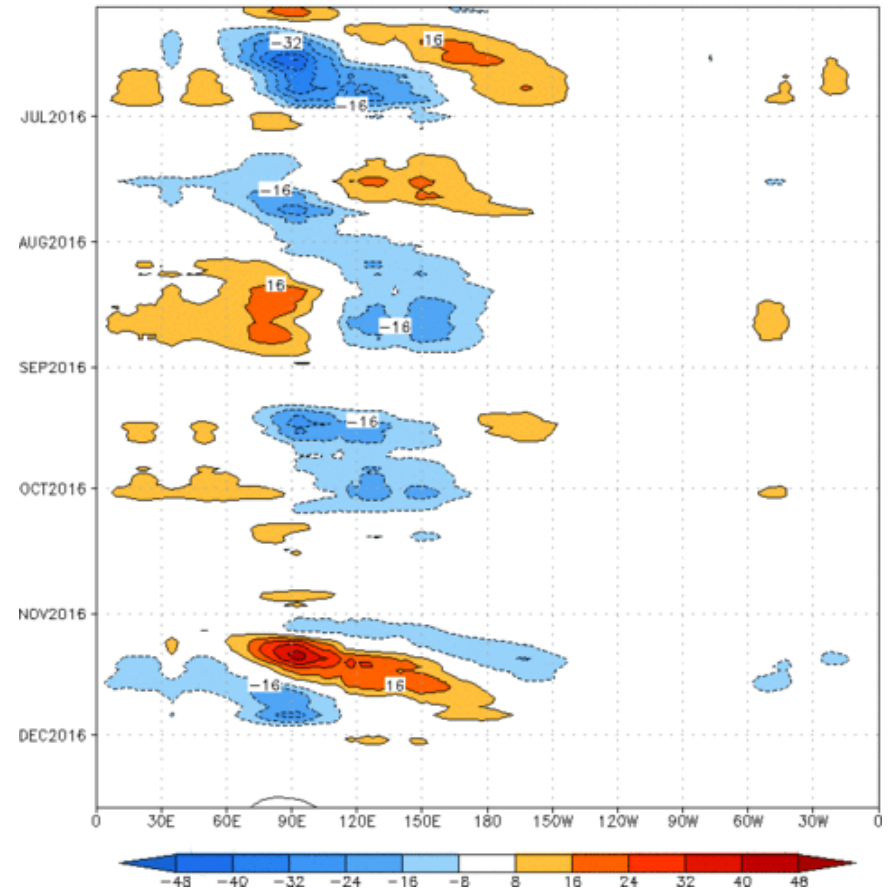


The Constructed Analog model depicts more rapid propagation of a very weak subseasonal signal.

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.)

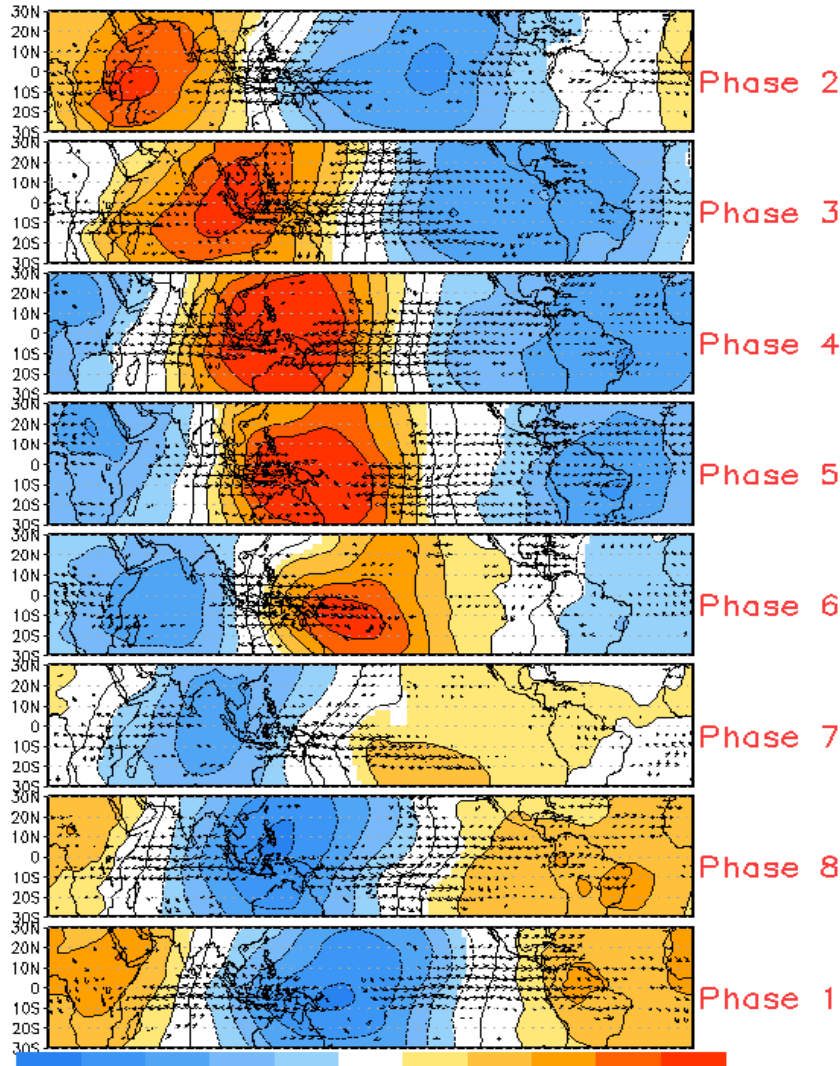
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days

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

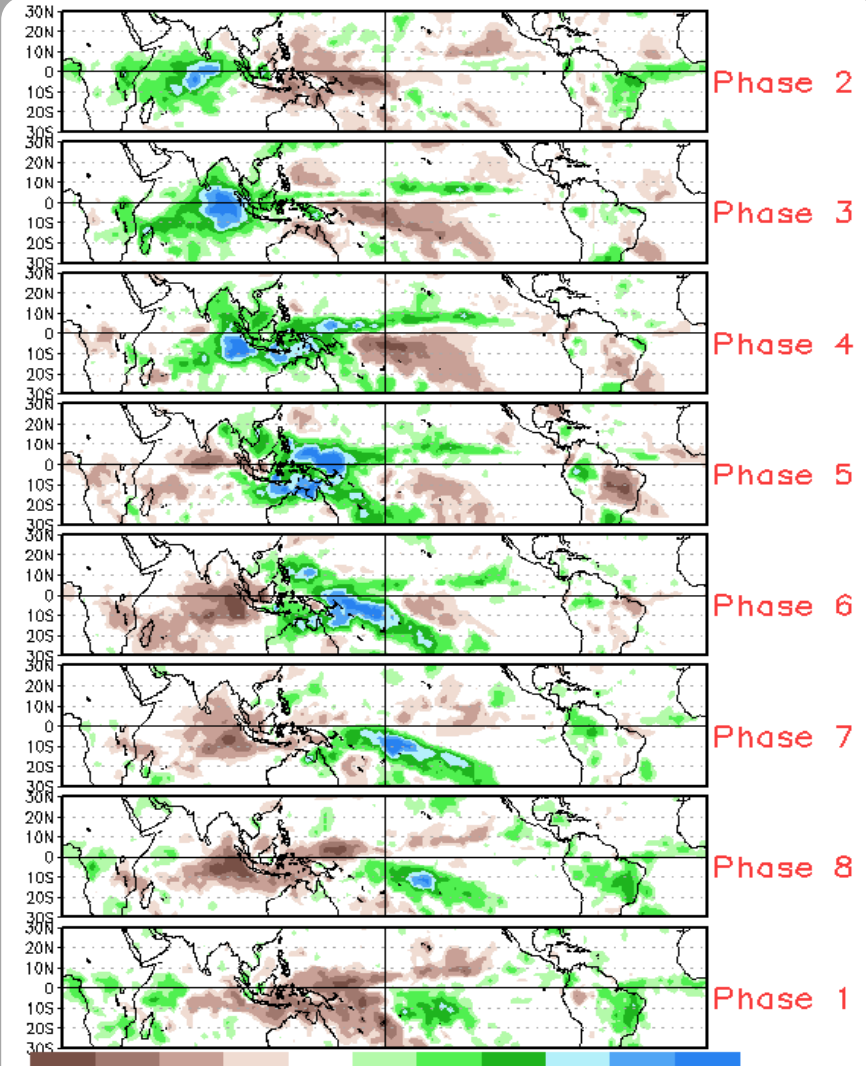


# MJO Composites - Global Tropics

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



Precipitation Anomalies (Nov - Mar)

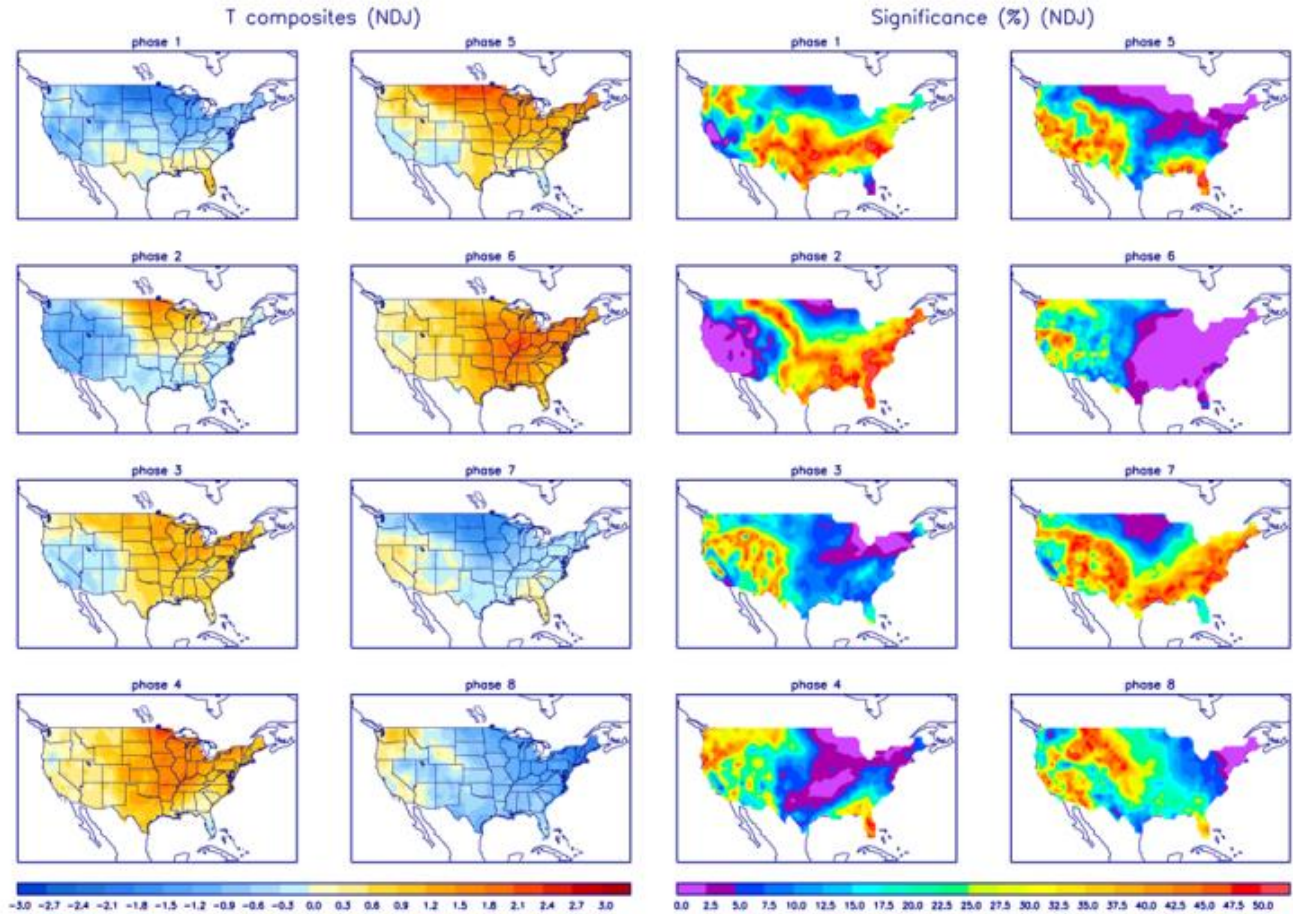




# U.S. MJO Composites - Temperature

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.



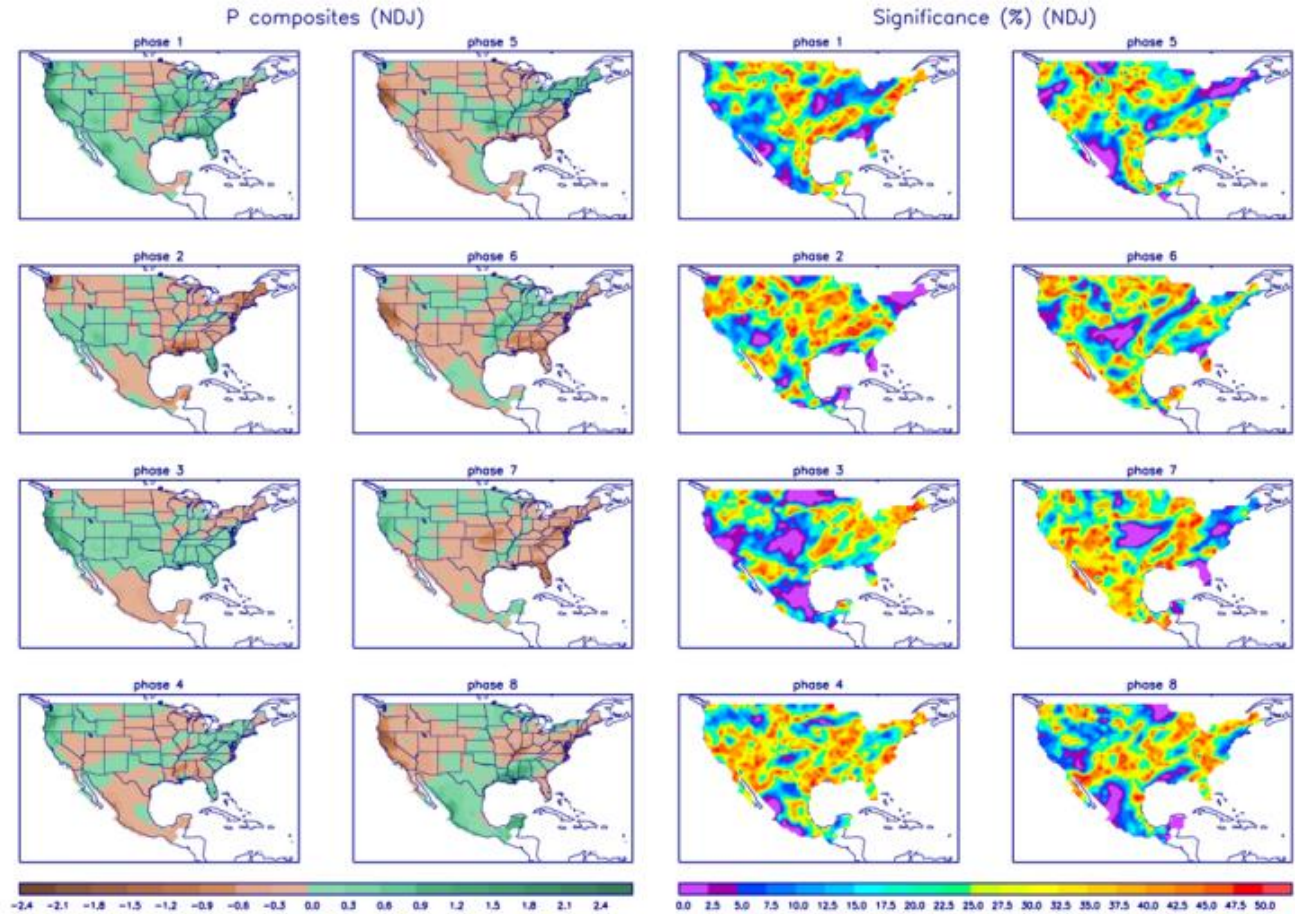
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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>