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

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Climate Prediction Center / NCEP
28 November 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 continue to indicate an intraseasonal signal with the enhanced phase over the eastern Indian Ocean. A pair of Kelvin waves over the eastern Indian Ocean and western Pacific are apparent in the OLR field, and these features may be contributing to the amplitude of the indices.

- Dynamical model forecast solutions generally predict a weakening of the MJO index, although many GFS and ECMWF ensemble members depict renewed eastward propagation of the enhanced phase to the Maritime Continent by the end of Week-2.

- 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. Persistent West Pacific convection would favor a colder North American solution, while a slower evolution over the Indian Ocean and western Maritime Continent would favor ridging.

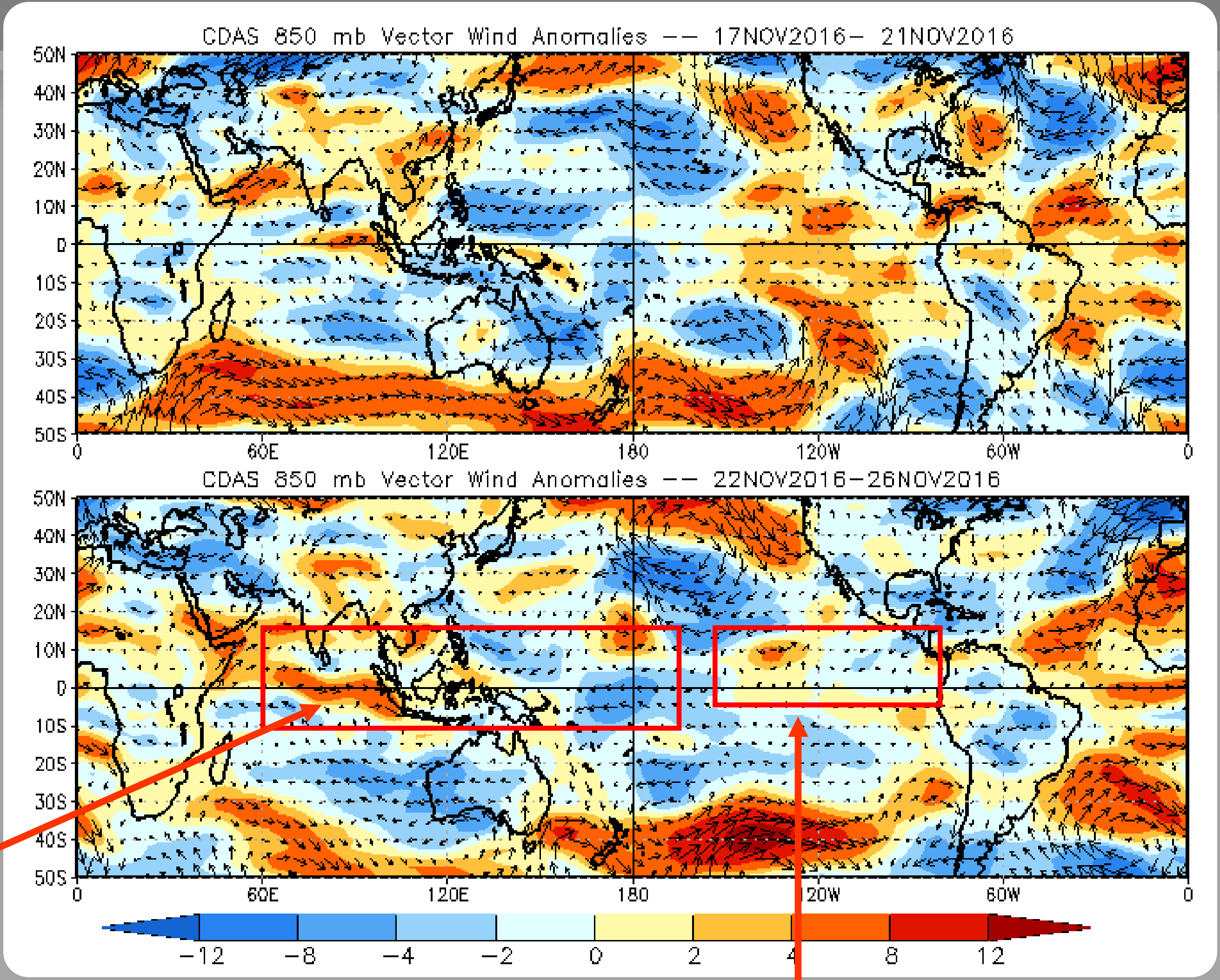
**Additional potential impacts across the global tropics and a discussion for the U.S. are available at:**
**http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php**

# 850-hPa Vector Wind Anomalies (m s-1)

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies




Westerly anomalies expanded across the central and eastern Indian Ocean, while easterly anomalies persisted over the northwestern Pacific and along the equator near the Date Line.

Westerly anomalies weakened over the eastern Pacific.

# 850-hPa Zonal Wind Anomalies (m s-1)

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

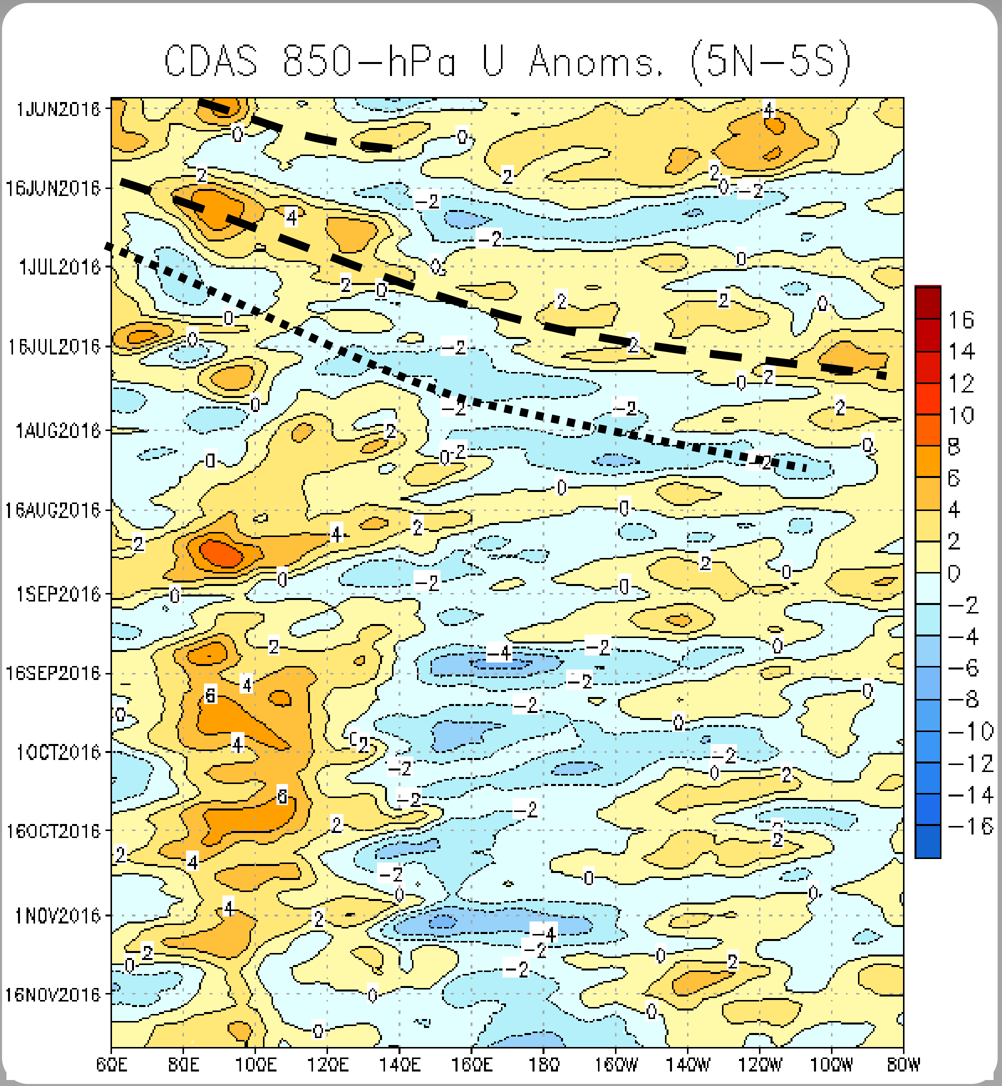
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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. More recently, the base state has re-emerged.



# OLR Anomalies – Past 30 days

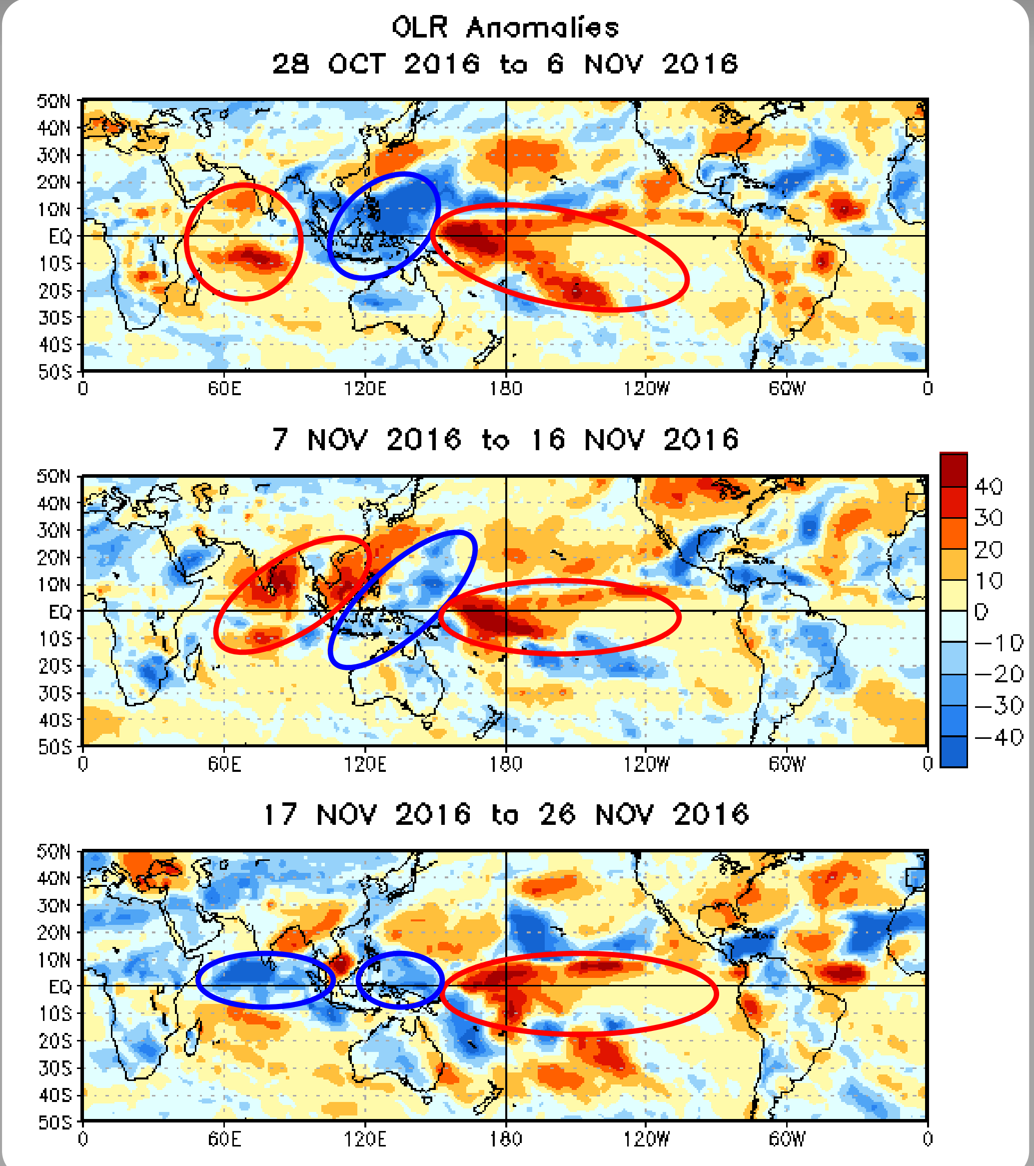
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late October and 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 freqency pattern continued to influence the pattern through mid-November, but subseasonal variability shifted the pattern eastward, reducing anomalous convection over the Maritime Continent.

During mid to late November, enhanced convection developed over the central Indian Ocean, possibly related to a developing intraseasonal signal. A second area of enhanced convection persisted over the western Pacific, associated with the base state.



# Outgoing Longwave Radiation (OLR) Anomalies (7.5ºS - 7.5ºN)

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

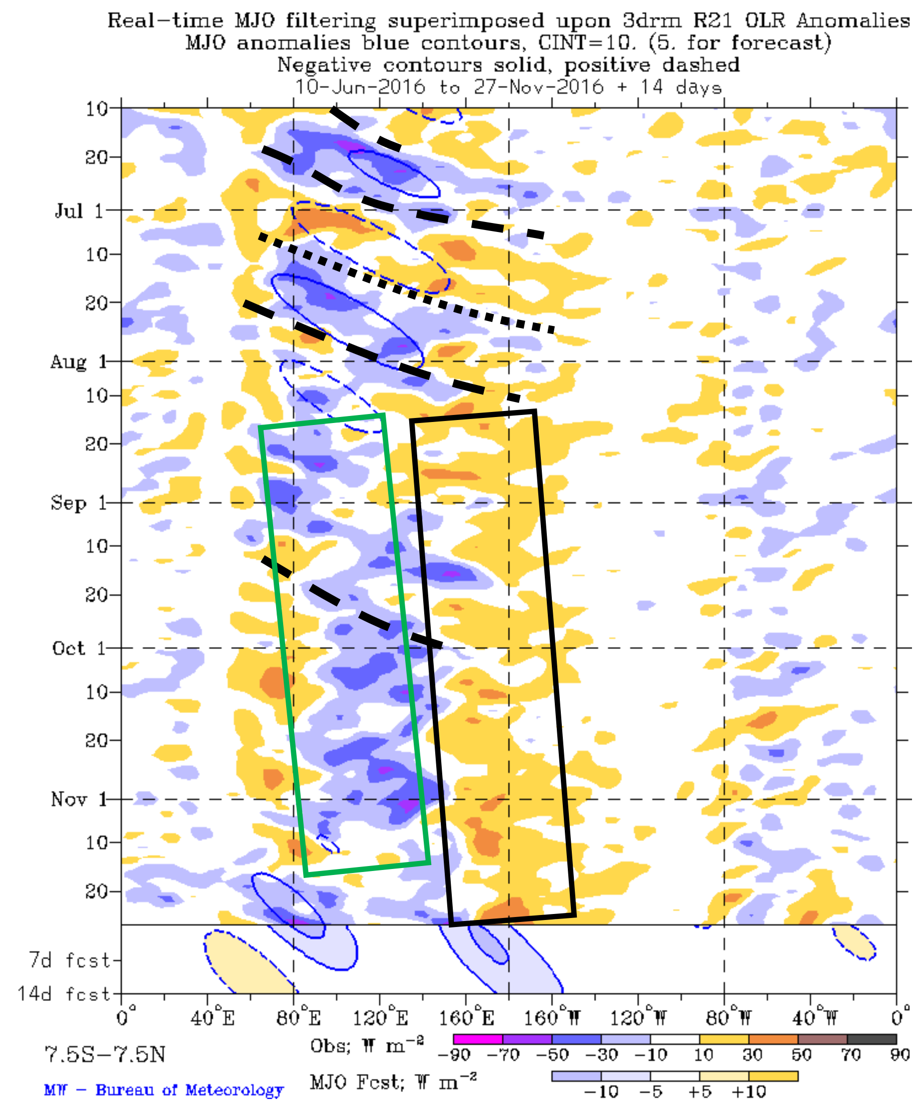
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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 (5ºS - 5ºN)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

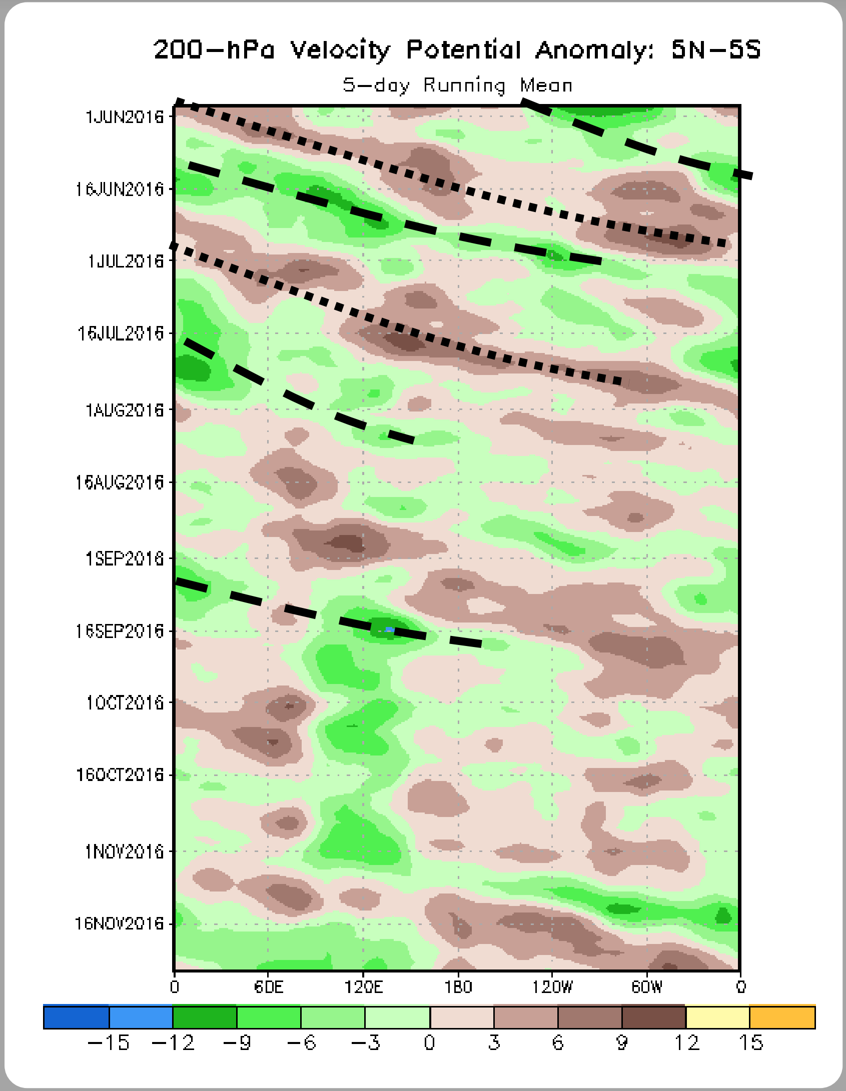
Negative anomalies (green shading) indicate favorable conditions for precipitation

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

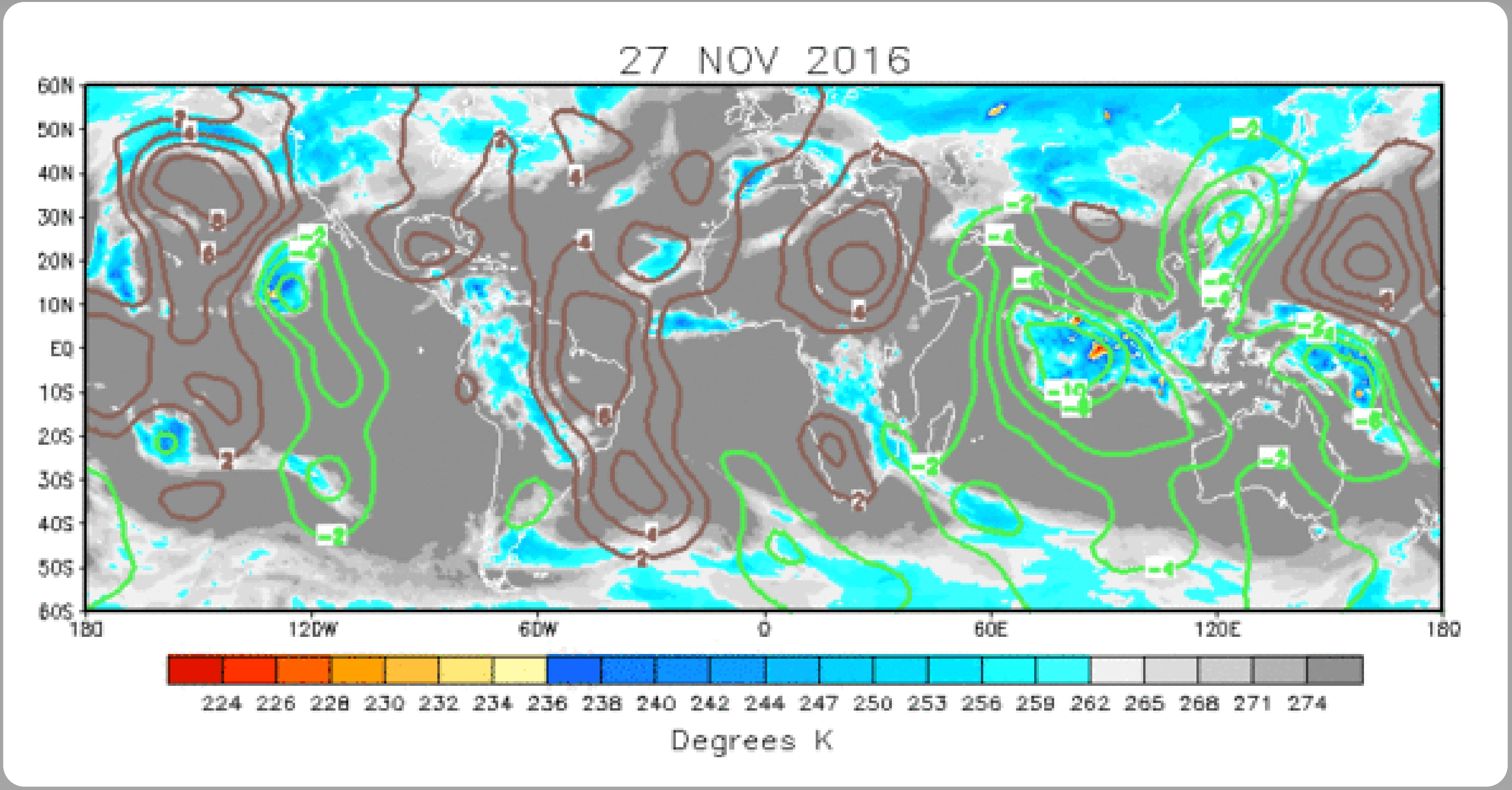
During August, the intraseasonal signal became less coherent, with a weaker and somewhat more stationary anomaly field in place. By late August and early September, there was renewed propagation of the intraseasonal signal.

Since mid-September, a 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, fast eastward propagation has been observed, with negative VP anomalies most recently returning to the Maritime Continent.



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




The spatial pattern of upper-level velocity potential anomalies is somewhat organized, with an elongated region of enhanced anomalous upper-level divergence extending from the central Indian Ocean to the Maritime Continent. The pattern is less coherent over the central Pacific and Western Hemisphere.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

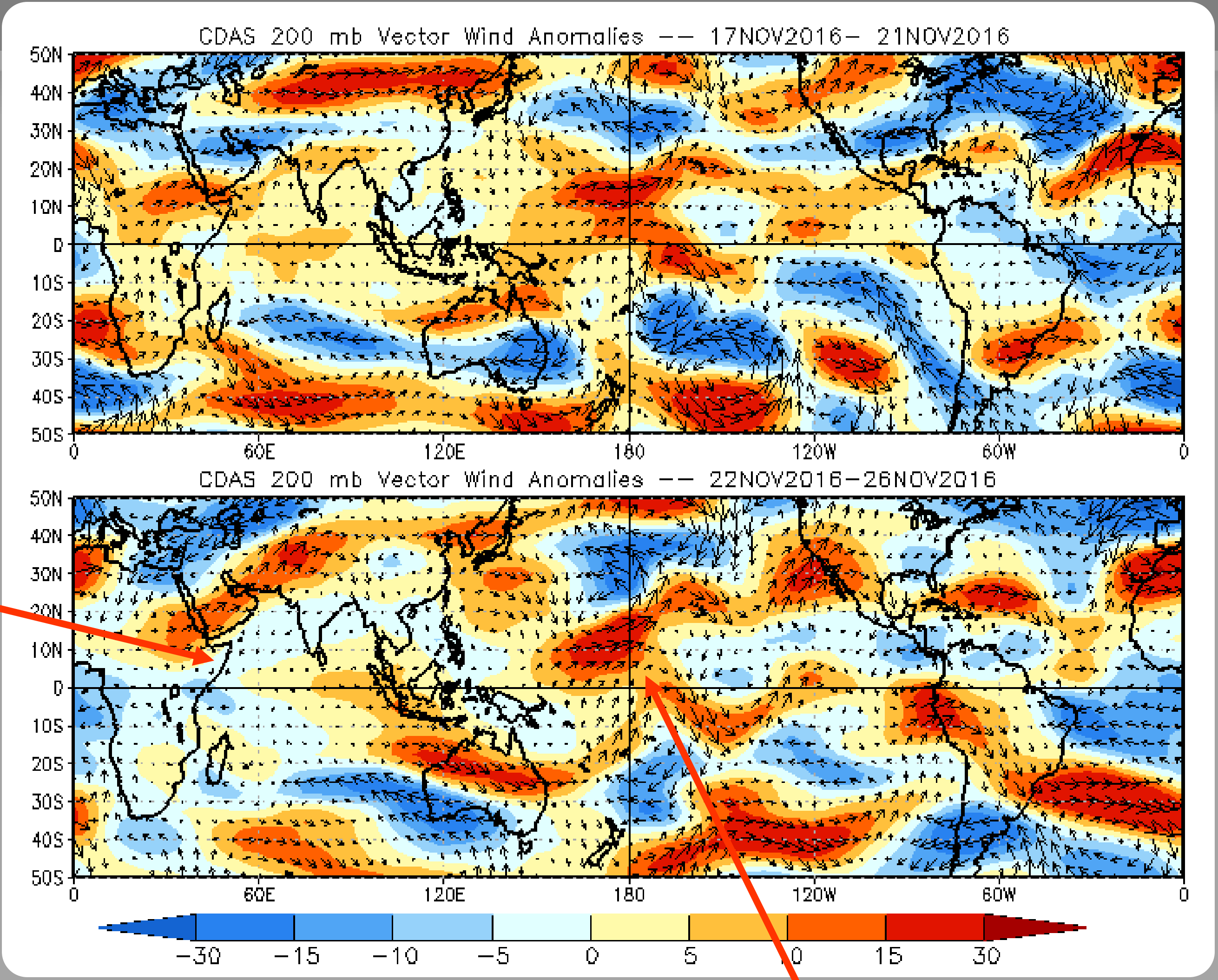
Negative anomalies (green contours) indicate favorable conditions for precipitation

# 200-hPa Vector Wind Anomalies (m s-1)

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies




The upper-level zonal wind anomaly field was weak over the Indian Ocean, which permitted sufficient ventilation for central Indian Ocean convection.

Westerly anomalies persisted near the Date Line during late November.

# 200-hPa Zonal Wind Anomalies (m s-1)

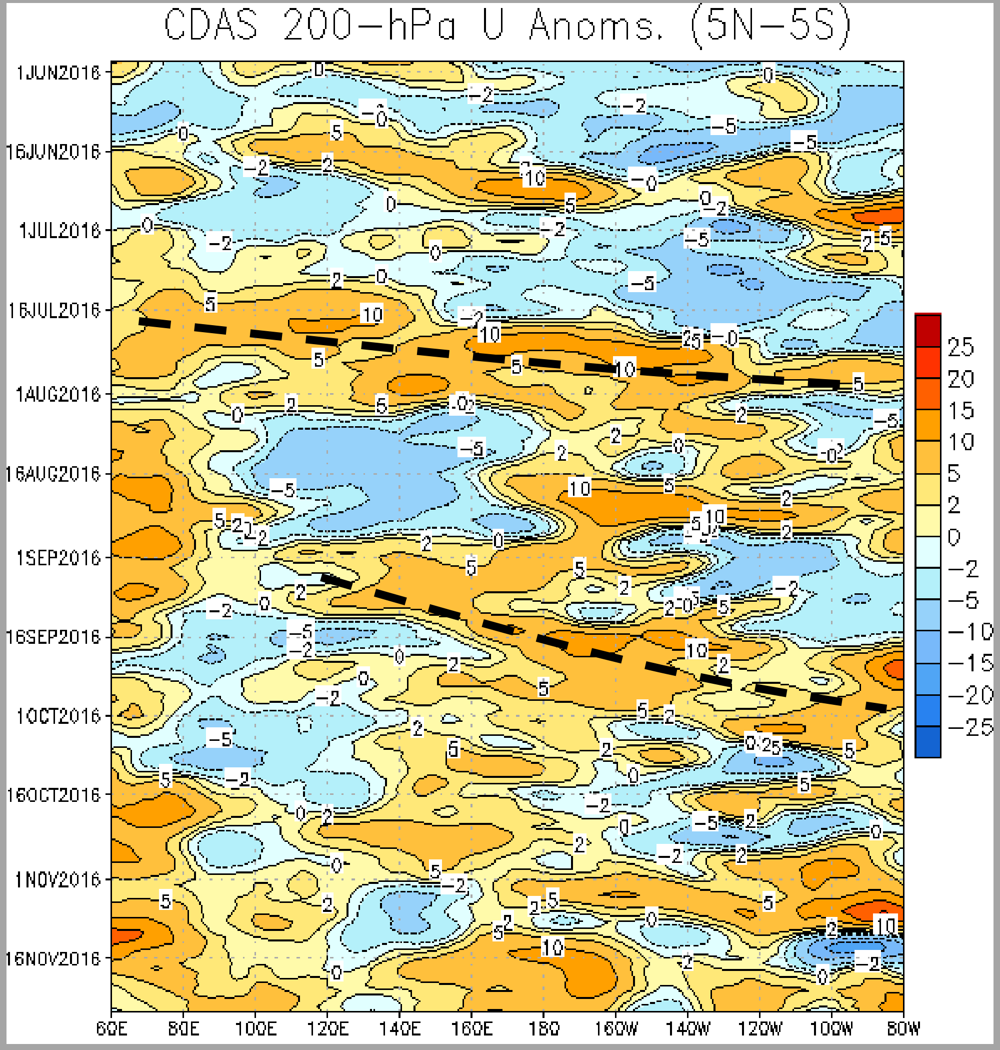
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

During July, some eastward propagation in large scale anomalies are 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. There is also evidence of an intraseasonal signal, which has most recently propagated across the Indian Ocean.



# Weekly Heat Content Evolution in the Equatorial Pacific

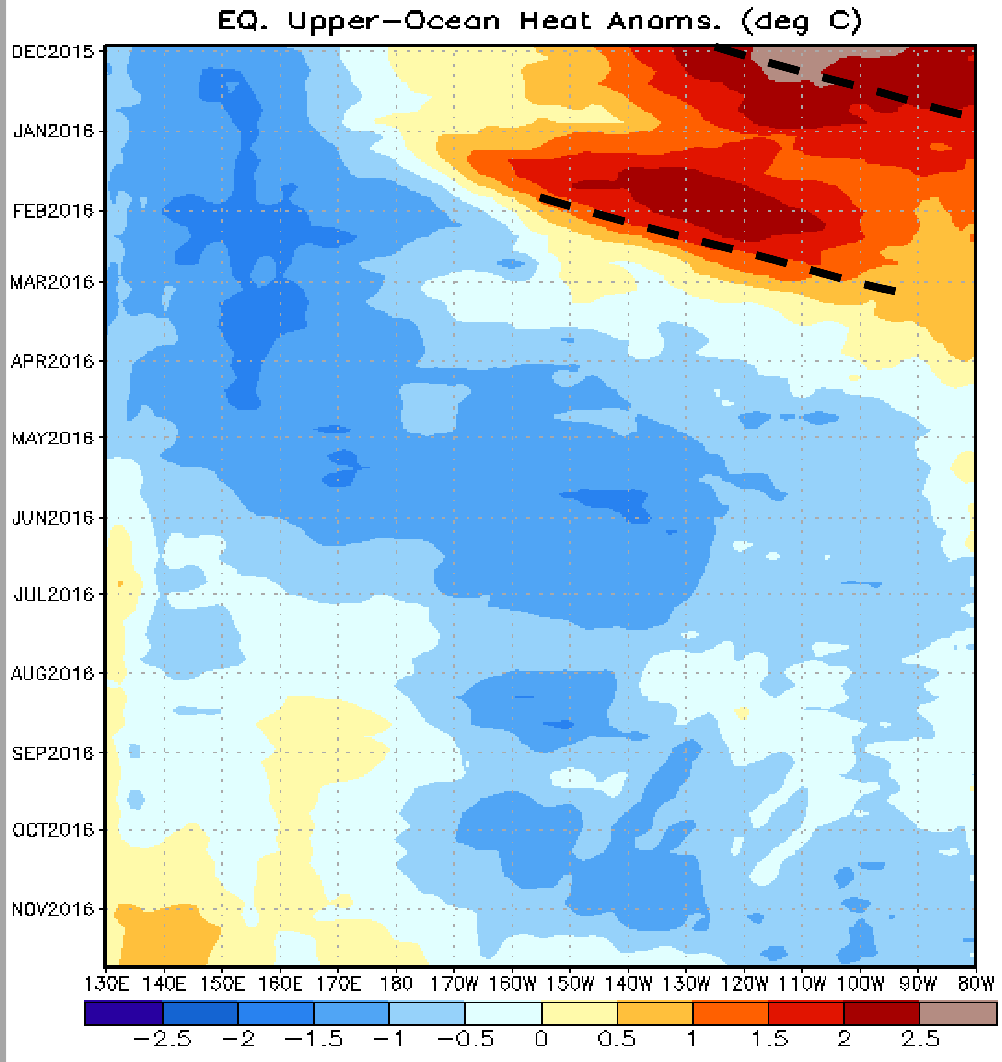
Oceanic Kelvin waves have alternating warm and cold phases. The warm phase is indicated by dashed lines. Downwelling and warming occur in the leading portion of a Kelvin wave, and upwelling and cooling occur in the trailing portion.

Downwelling events were observed during late 2015, 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 east of the Date Line.

More recently, the negative oceanic heat content anomalies have weakened across the central 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

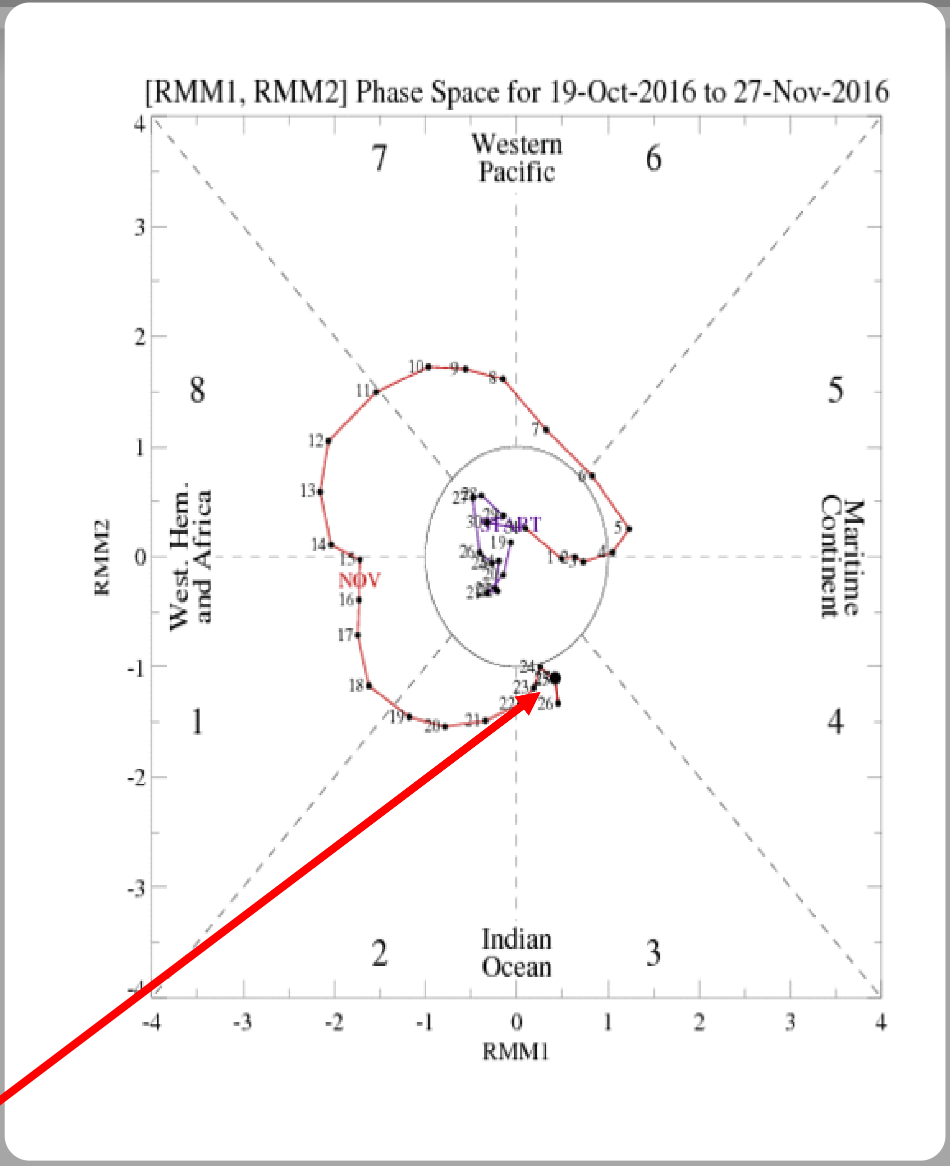
**The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes**

**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**

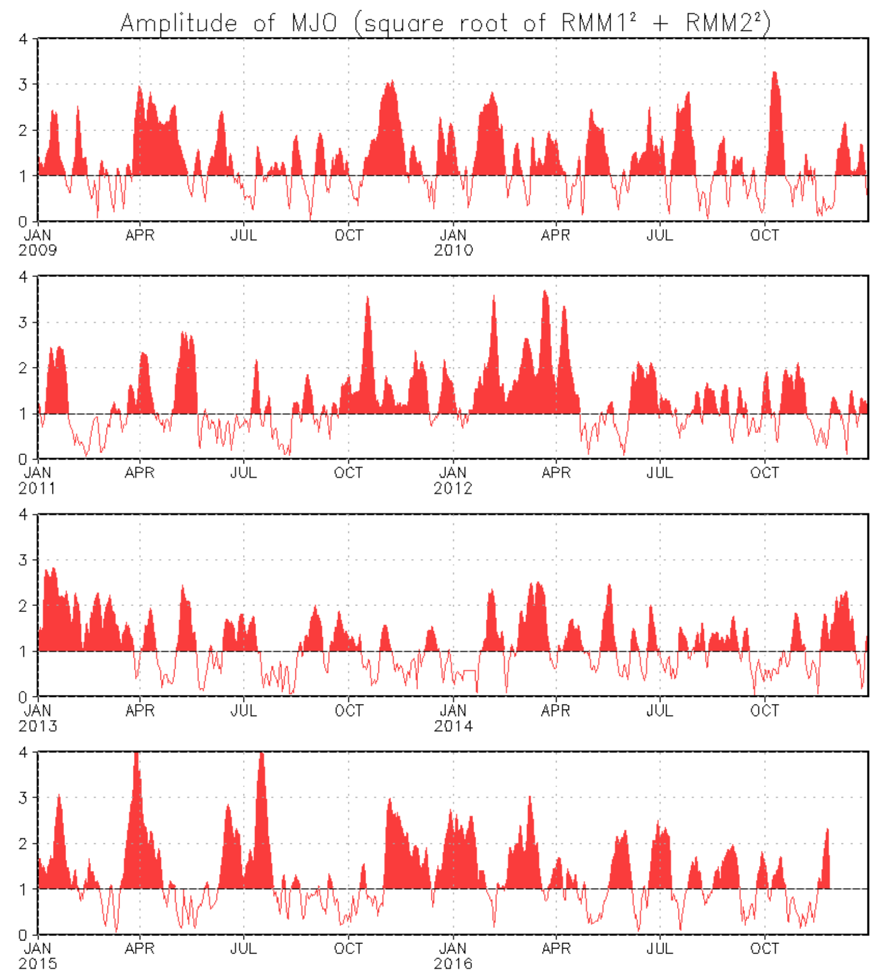



The RMM index continues to suggest an enhanced convective envelope over the eastern Indian Ocean, with a marked slowdown in eastward propagation during the past week.

# 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.



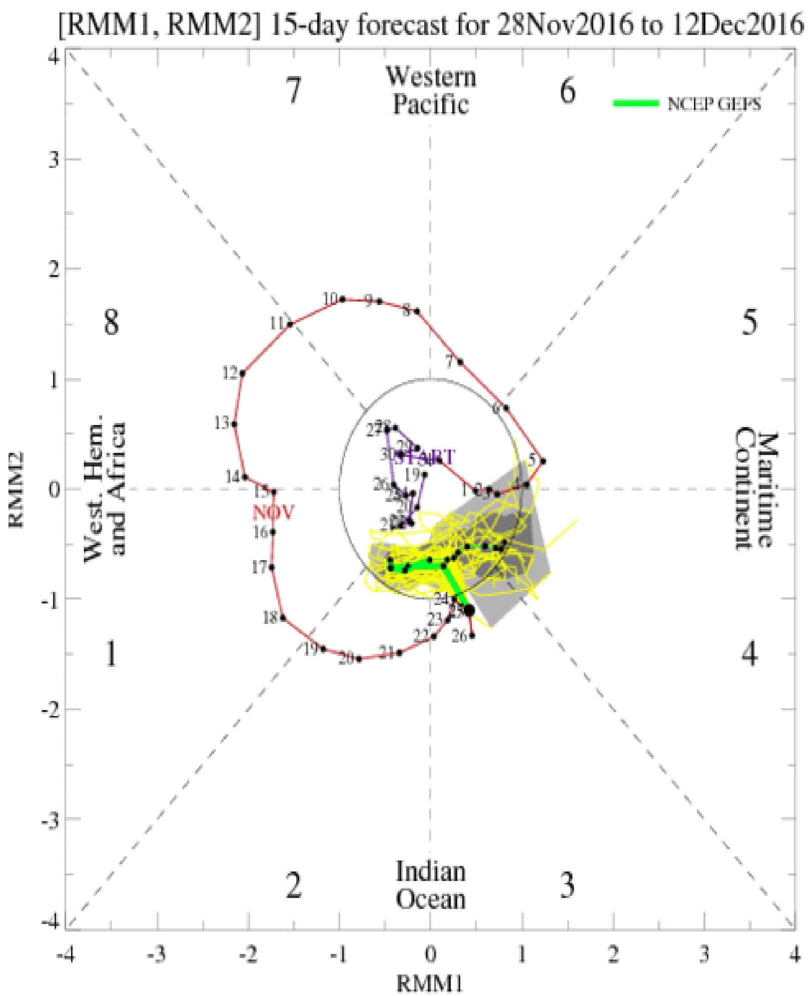
# Ensemble GFS (GEFS) MJO Forecast

**Yellow Lines** - 20 Individual Members
**Green Line** - Ensemble Mean

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



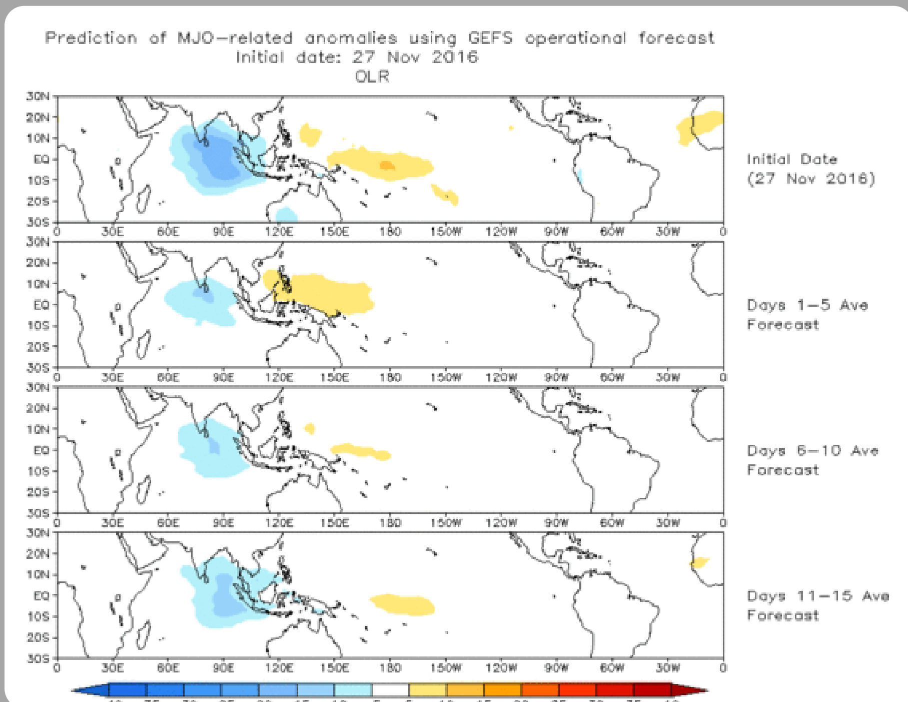

For the next two weeks, the GFS ensemble forecast depicts a weakening signal due to competing convective signals over the Indian Ocean and western Pacific. Still, some eastward propagation of the enhanced phase to the Maritime Continent is suggested by the ensembles.

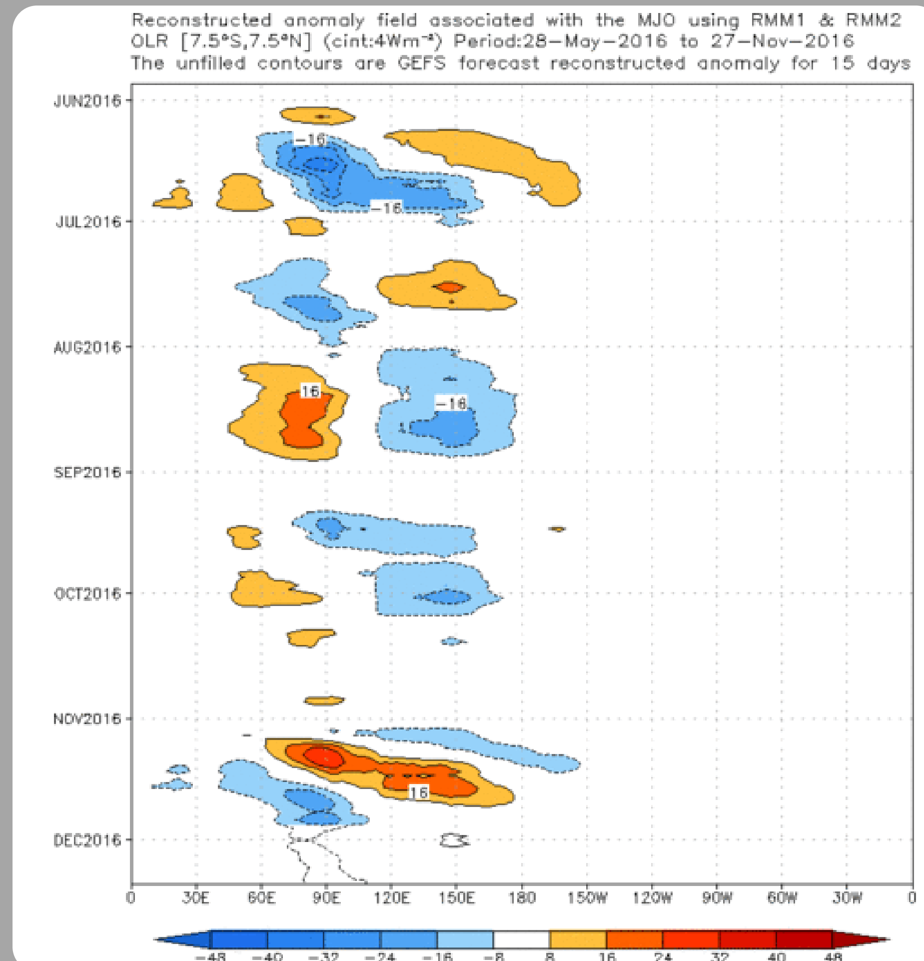
# Ensemble GFS (GEFS) MJO Forecast

**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.)**

Spatial map of OLR anomalies for the next 15 days

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



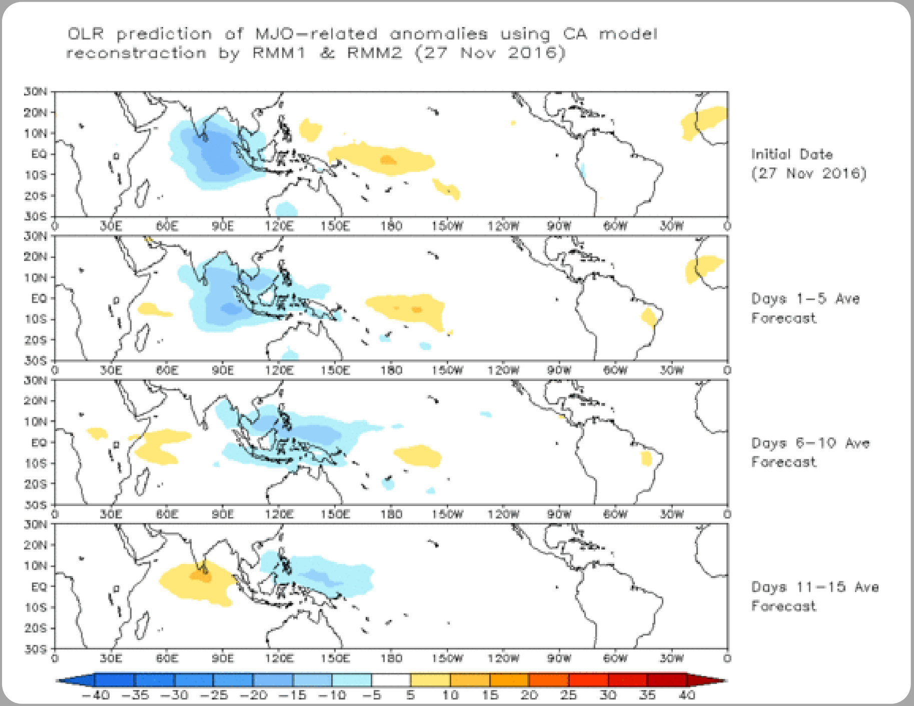




The GEFS RMM Index forecast of OLR anomalies show a slowly evolving pattern over the next two weeks.

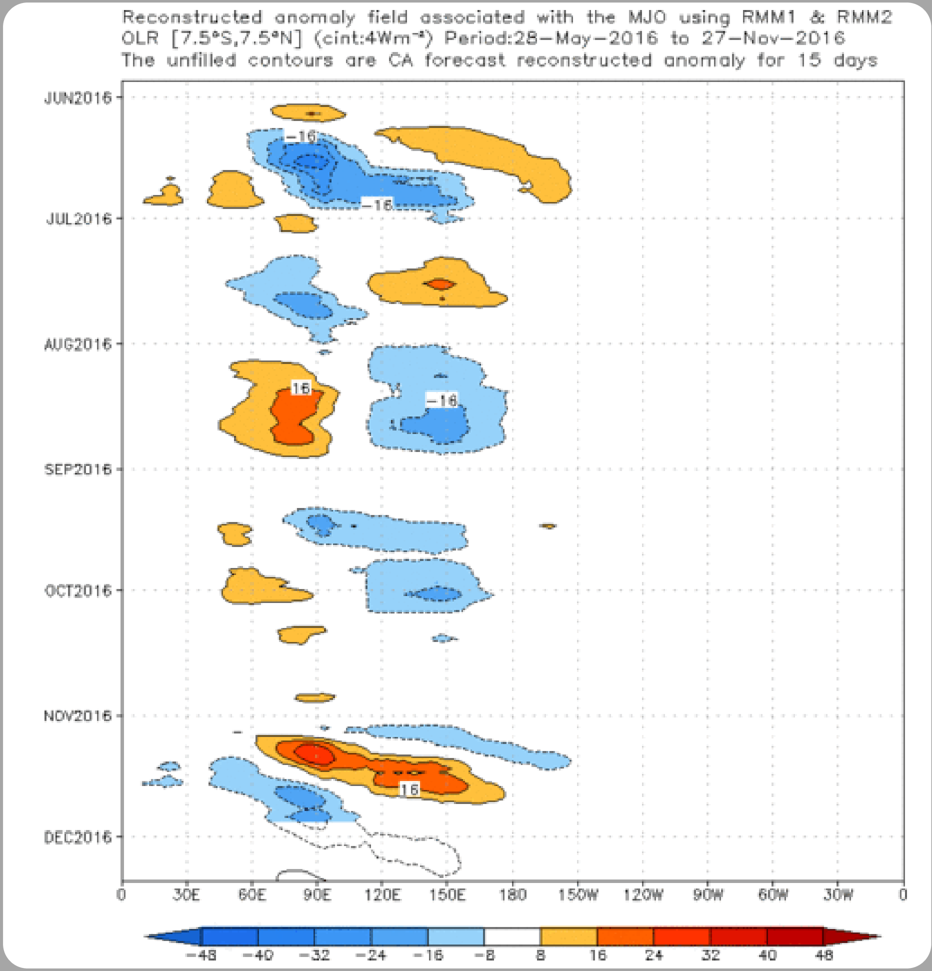
# Constructed Analog (CA) MJO Forecast

**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.)**

Spatial map of OLR anomalies for the next 15 days



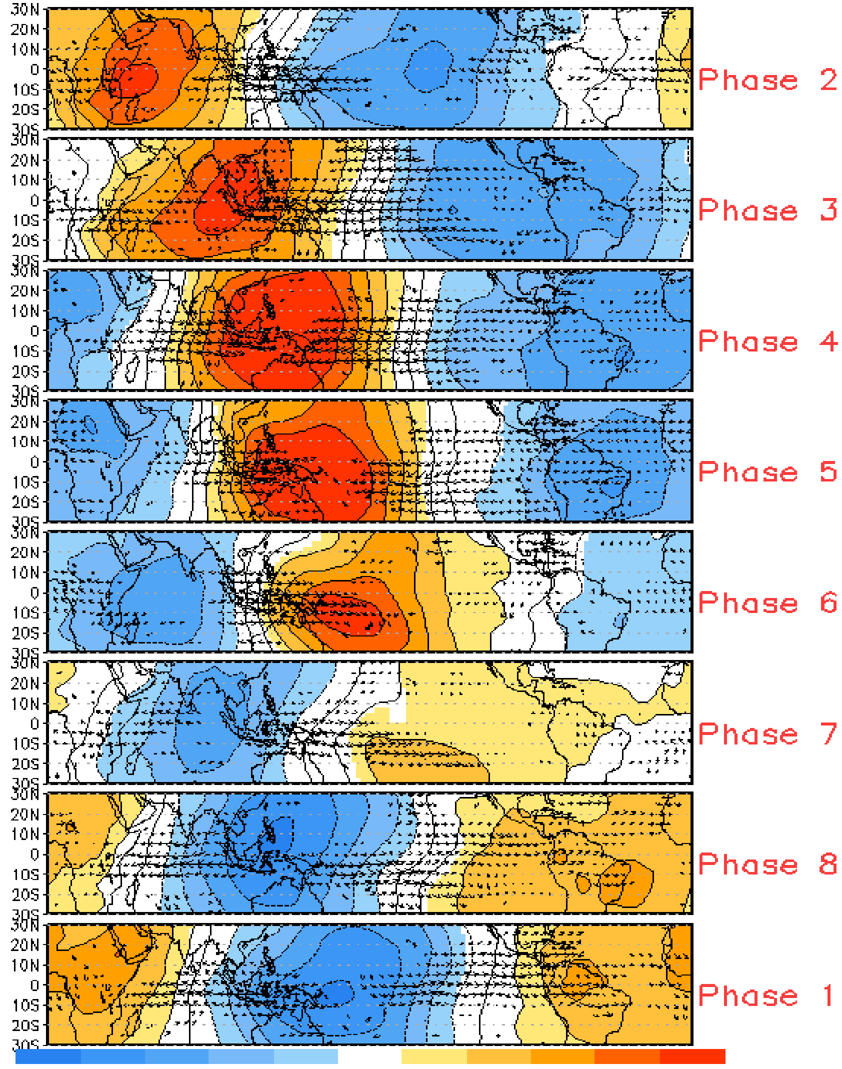

Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



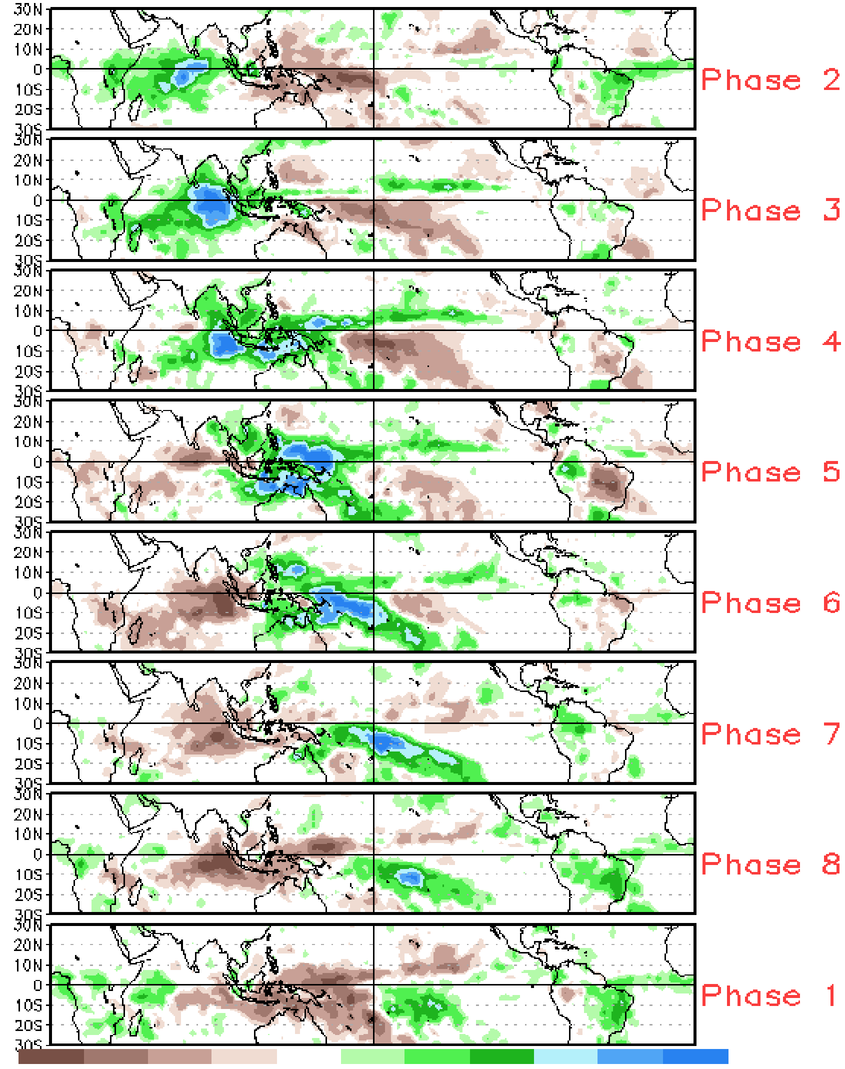

The Constructed Analog model depicts substantial eastward propagation of the MJO during the next two weeks.

# MJO Composites - Global Tropics

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



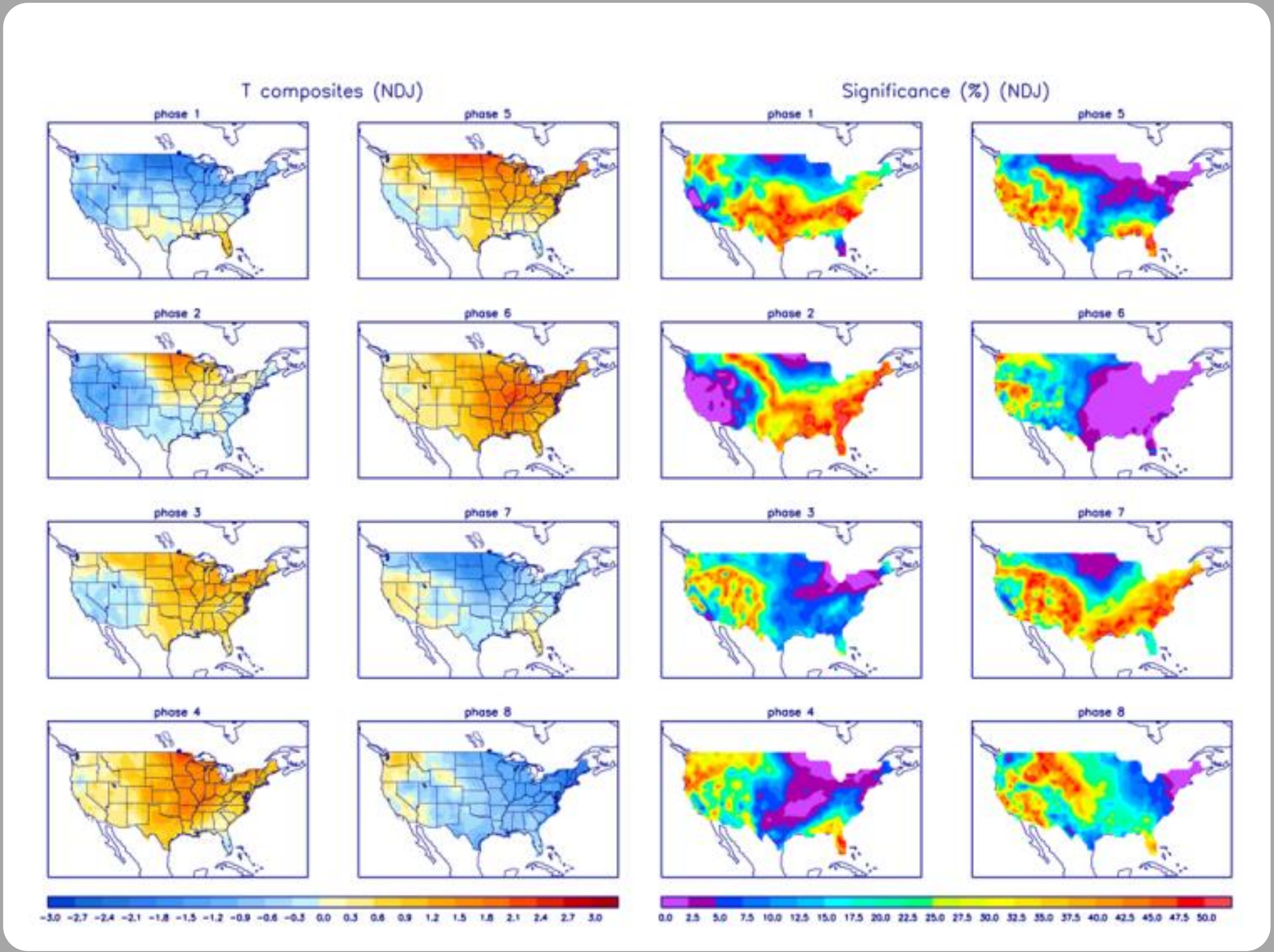

Precipitation Anomalies (Nov - Mar)



# 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.

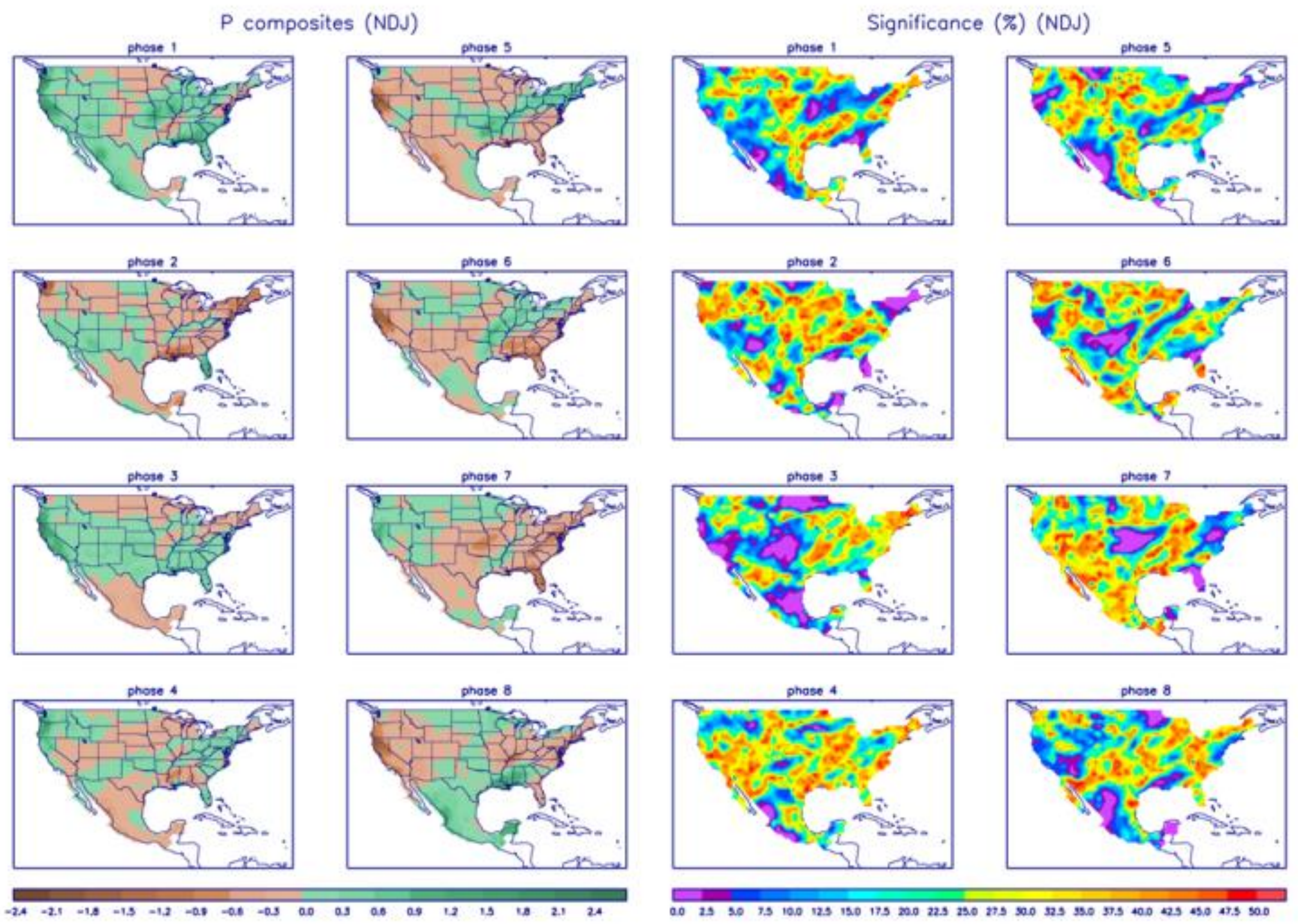
Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.




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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