

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



Update prepared by:
Climate Prediction Center / NCEP
28 March 2016

Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

Overview

The MJO remained active, with the enhanced phase currently over the central Pacific. The intraseasonal signal is transitioning from destructively interfering with the ENSO background state to constructively interfering.

Several dynamical model MJO index forecasts depict continued eastward propagation of a weak MJO signal during the next week, before strengthening the signal in Week-2. Statistical tools favor additional eastward propagation of the MJO, although slightly slower than the dynamical models.

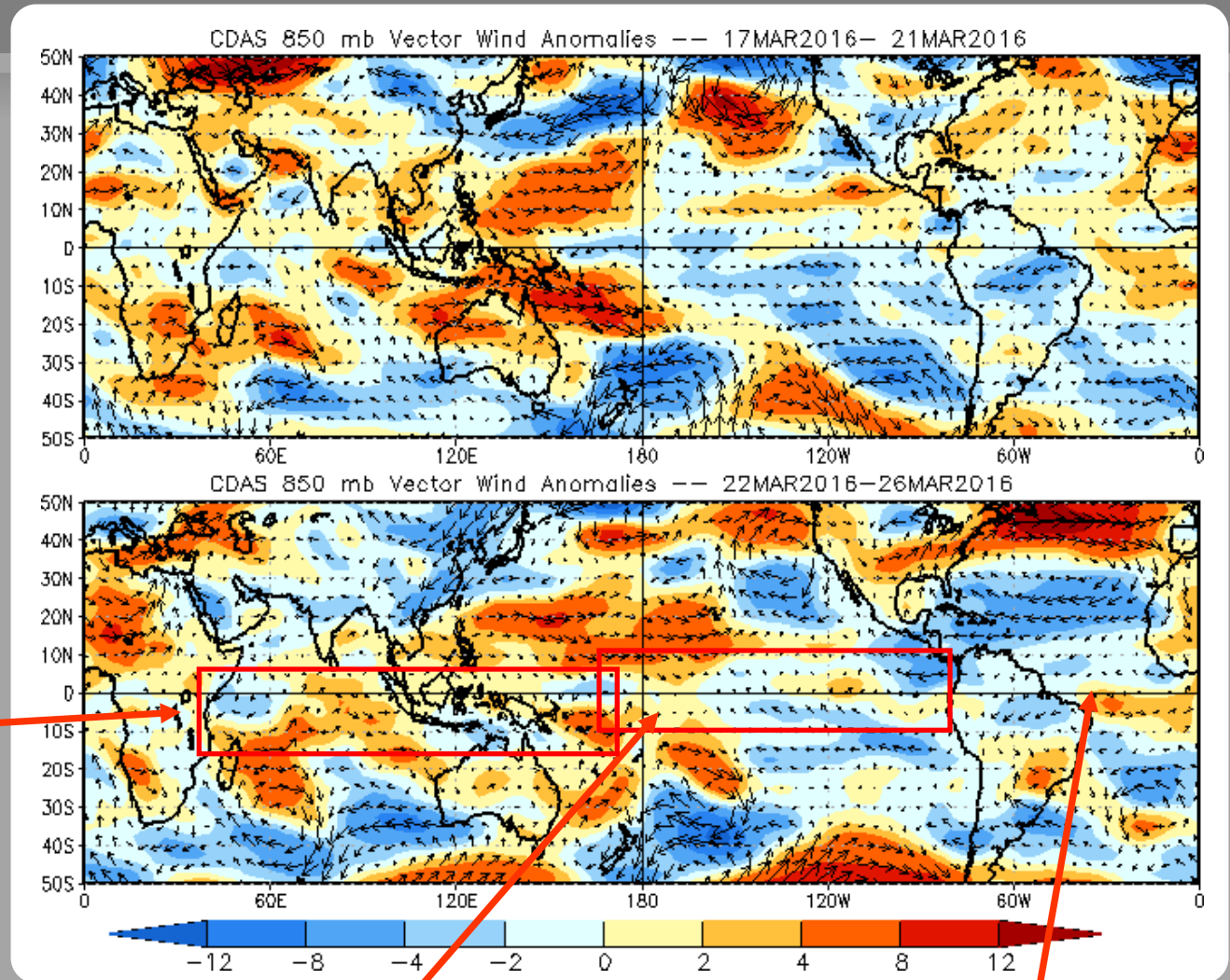
Interference of the MJO with the background ENSO signal is likely to result in a noisy and low confidence forecast during Week-1, while constructive interference during Week-2 should result in a more robust signal.

The MJO may contribute to enhanced (suppressed) convection across the equatorial central Pacific (Maritime Continent) during the period.

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



A dipole in the anomaly pattern remained over the Indian Ocean.

Westerly anomalies filled in over the Maritime Continent.

Easterly anomalies over the eastern Pacific relaxed, while some westerly anomalies built in over the central Pacific.

Easterly anomalies developed over the tropical Atlantic.

850-hPa Zonal Wind Anomalies (m s⁻¹)

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

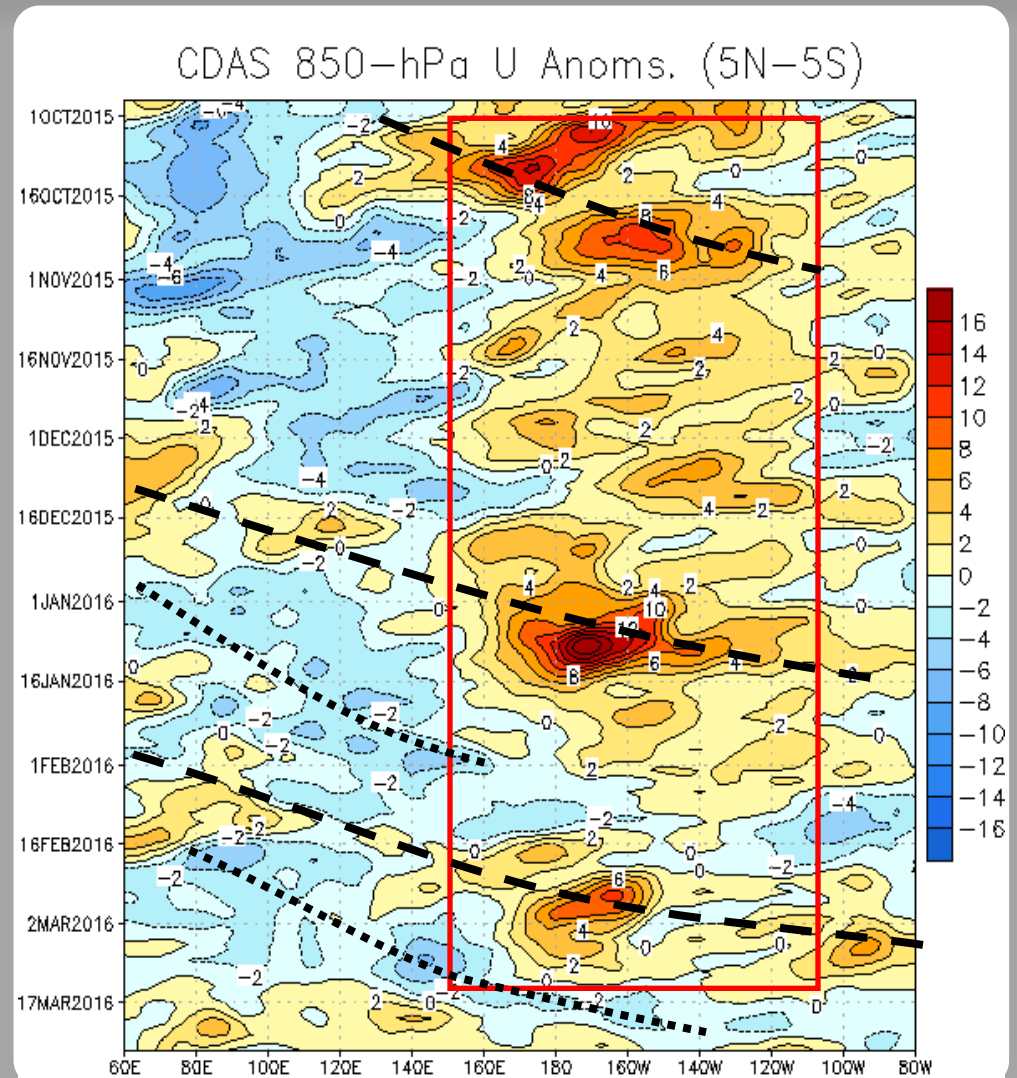
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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.

MJO activity during December produced an eastward propagation of westerly anomalies from the Indian Ocean, which constructively interfered with El Niño during January, and lead to a westerly wind burst near the Date Line. Another period of constructive interference occurred in late February, followed by destructive interference in early March.

More recently, intraseasonal signals have begun to align with seasonal forcings.



OLR Anomalies - Past 30 days

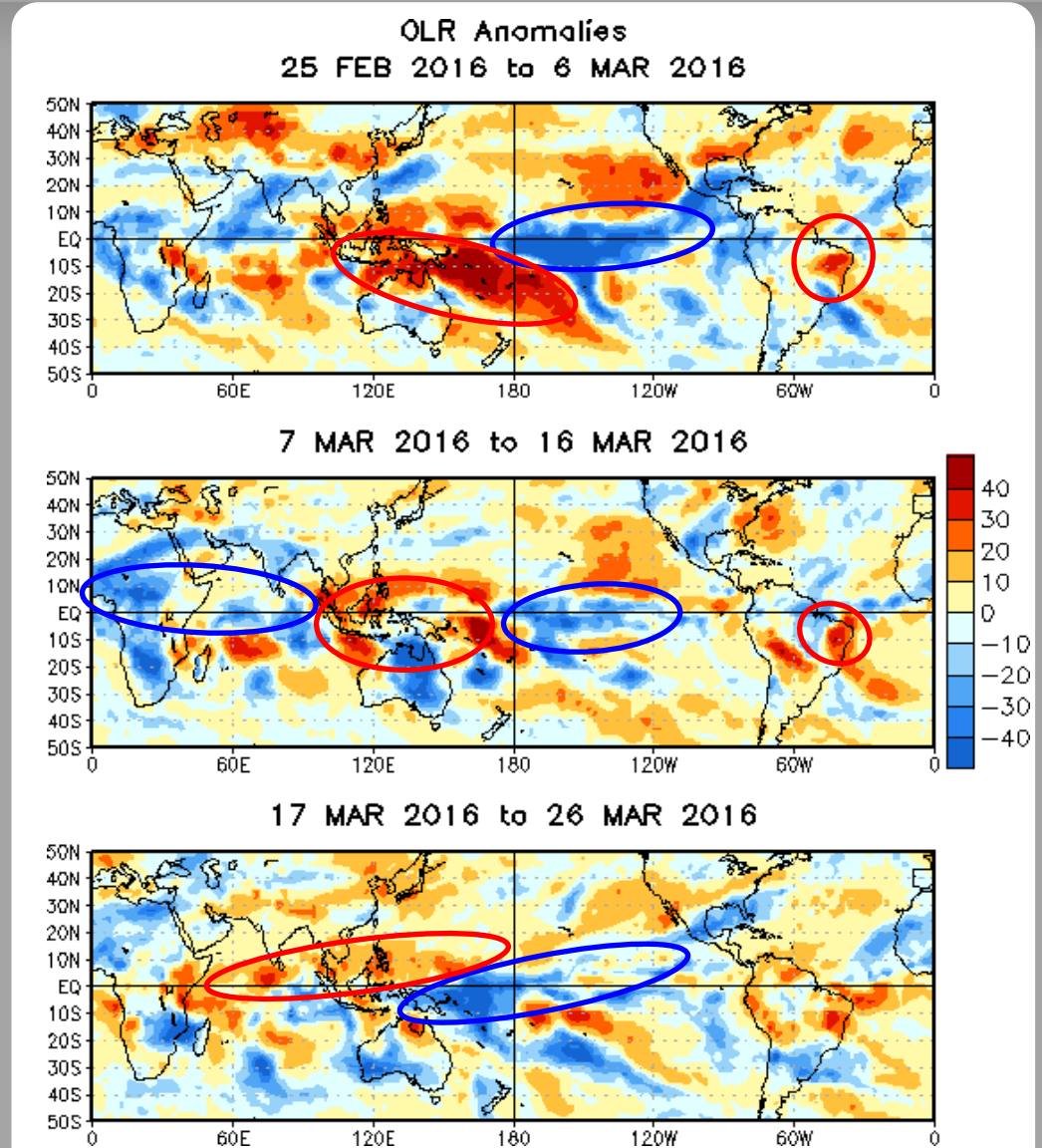
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late February and early March, constructive interference between the MJO and ENSO signals was evident, with an eastward shift in the enhanced (suppressed) convective anomalies to the Western Hemisphere (west/south Pacific).

As the intraseasonal signal propagated to the Indian Ocean, convective anomalies began to weaken due to destructive interference with the El Niño background state.

As the intraseasonal signal moved to the western Pacific, some of the destructive nature of the interference weakened. Convection strengthened just west of the Date Line, while eastern Pacific convection had no clear signal.



Outgoing Longwave Radiation (OLR) Anomalies (17.5°S-2.5S)

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

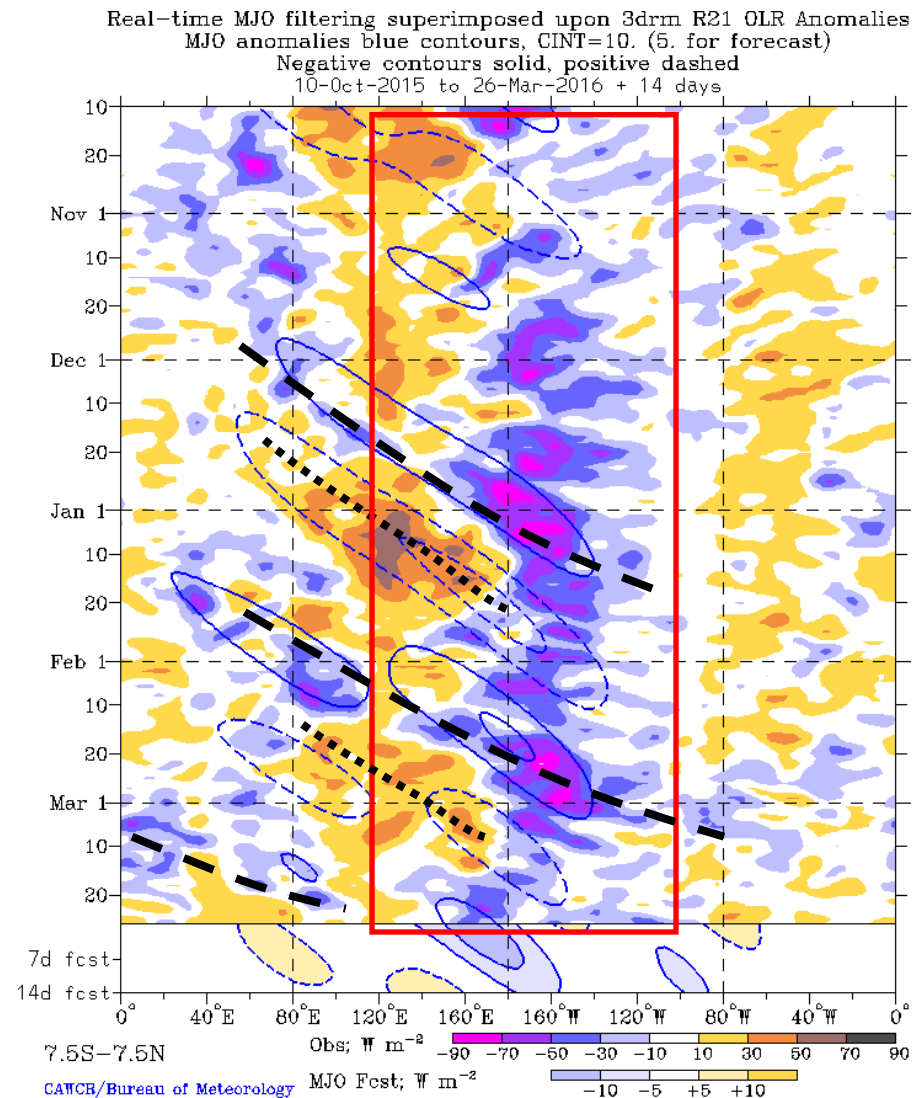
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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

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

Renewed MJO activity was evident, beginning in late January and lasting through the current week. Alternating periods of constructive/destructive interference with ENSO is evident.

Recently, MJO is becoming more aligned with ENSO, leading to constructive interference over the central Pacific.



200-hPa Velocity Potential Anomalies (5°S - 5°N)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

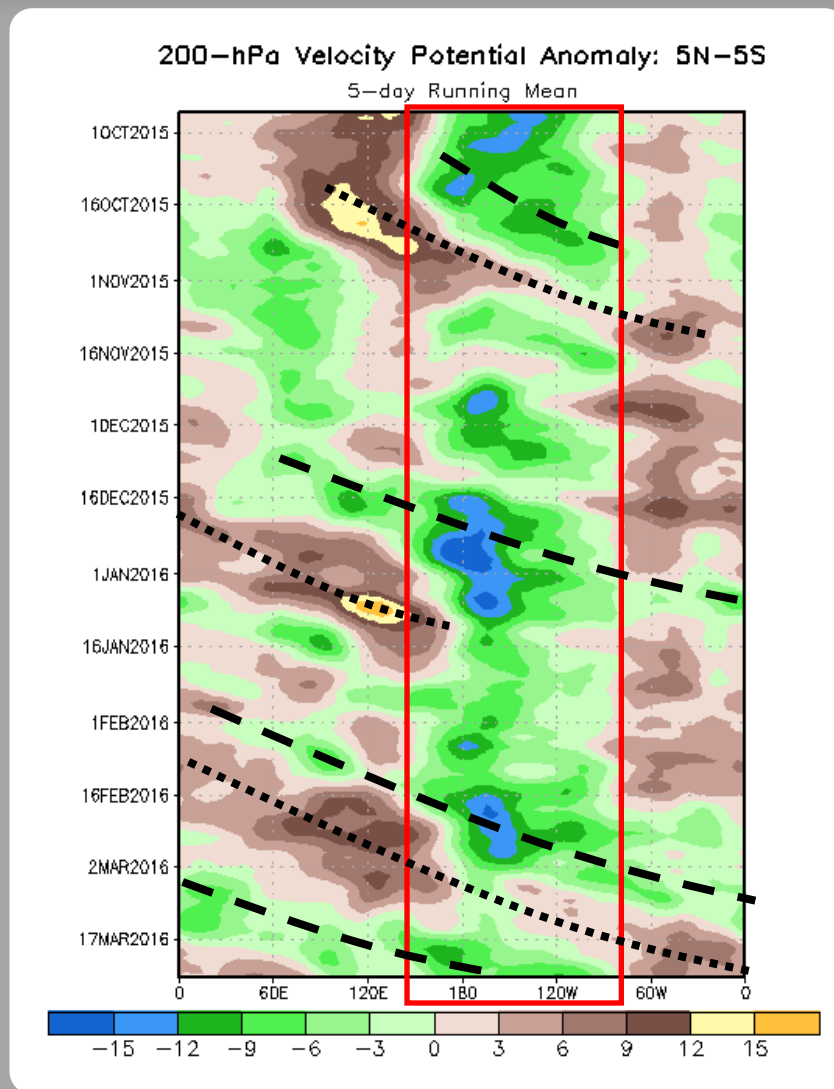
Negative anomalies (green shading) indicate favorable conditions for precipitation

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

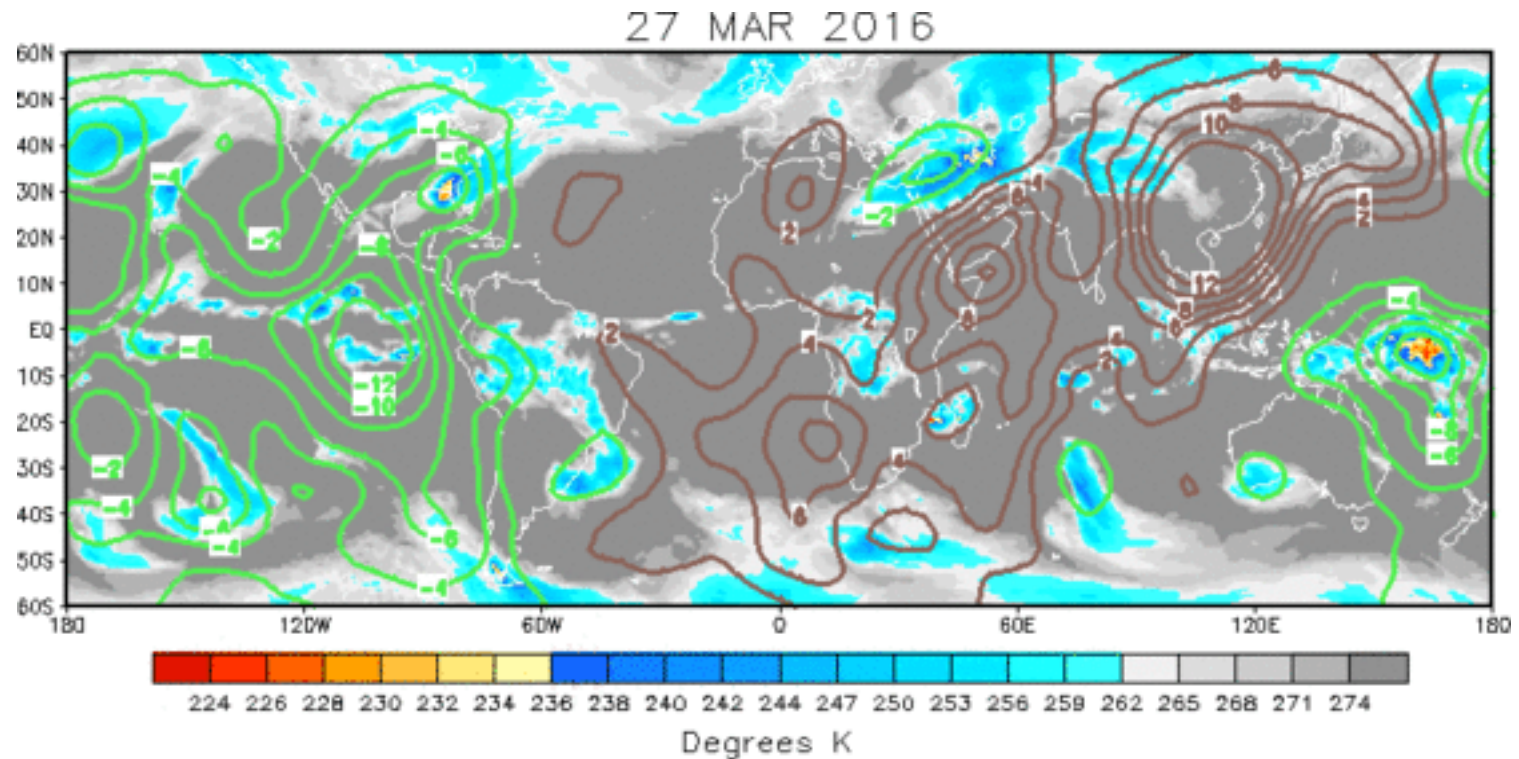
During late October, there was an eastward shift in the pattern. Renewed MJO activity was also observed during December and early January, yielding a robust signal in the upper levels. This signal weakened during mid-January.

During late February, intraseasonal variability constructively interfered with the ongoing El Niño. During mid-March, the intraseasonal variability destructively interfered with the ENSO signal.

Most recently, the MJO signal in the velocity potential is constructively interfering with the ENSO, with enhanced divergence over the central Pacific.



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



The large scale upper-level velocity potential anomaly pattern exhibits a coherent Wave-1 structure, with large scale anomalous ascent across the Pacific, and anomalous descent from the Atlantic to the 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⁻¹)

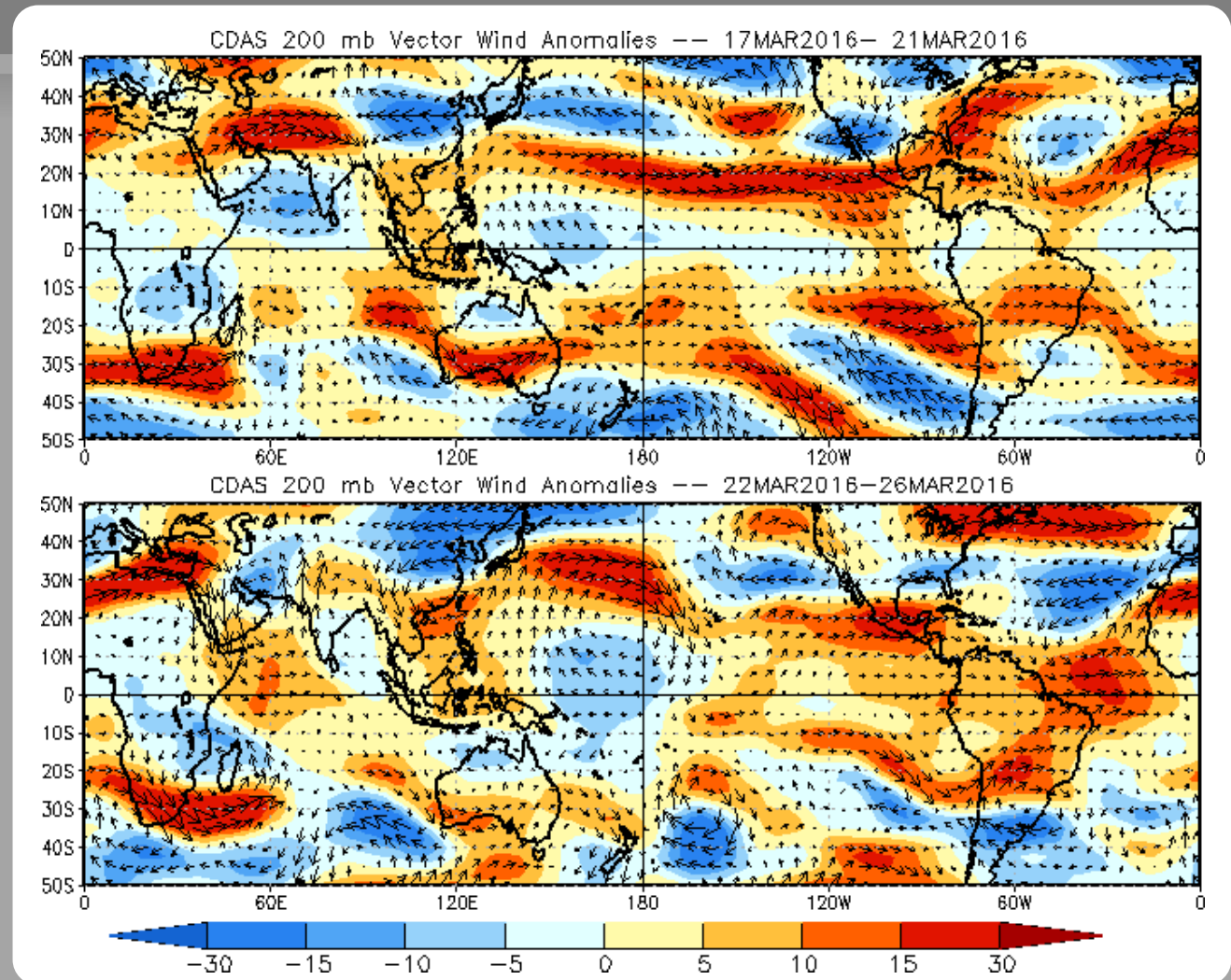
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Easterly anomalies reversed to become westerly over the eastern Pacific, while easterly anomalies remained over the West Pacific.

The upper-level pattern looks to be aligned with ongoing MJO activity and is disturbed from what would be expected from an ongoing El Niño.



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

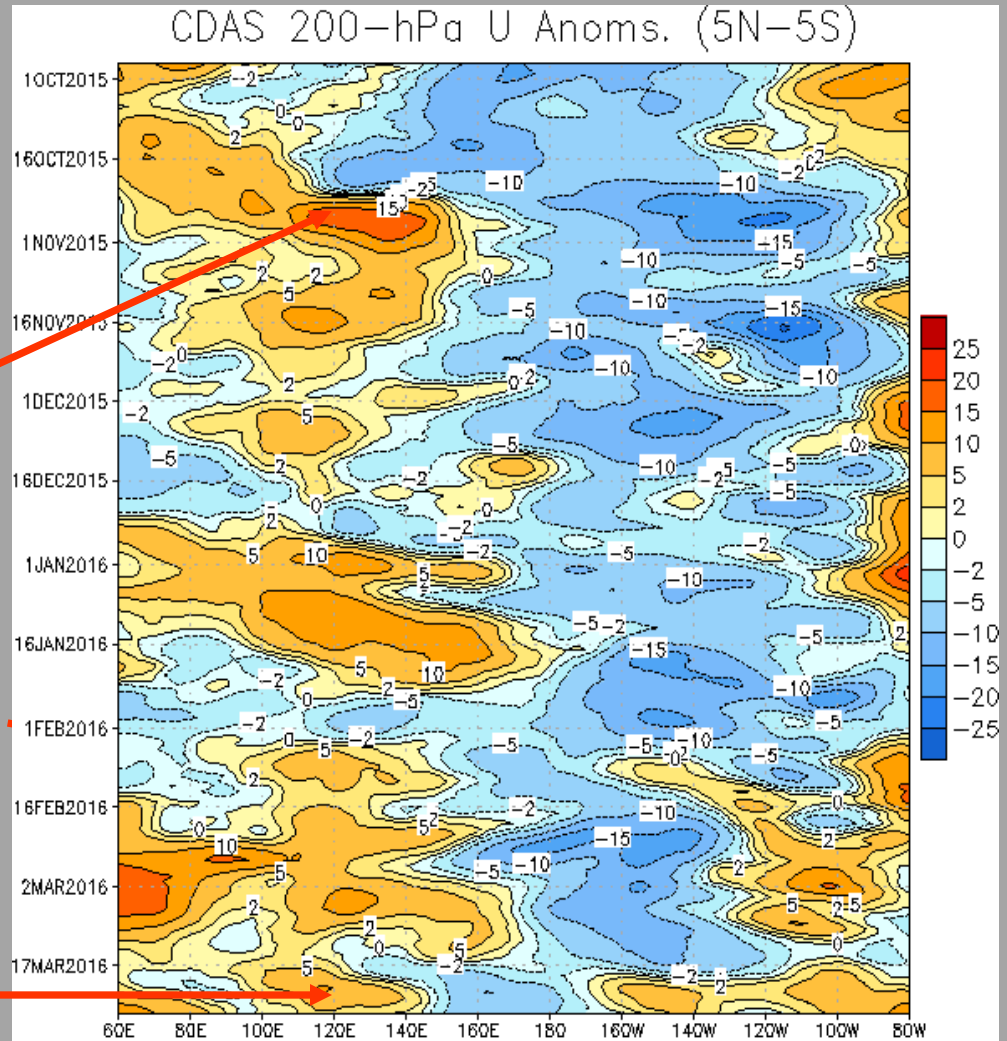
Easterly anomalies have persisted over the central and eastern Pacific since June associated with El Niño (red box).

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.

During early March, westerly anomalies returned to the Indian Ocean and Maritime Continent, with easterly anomalies between about 170E - 120W.

Recently, westerly anomalies are evident over much of the eastern Pacific.



Weekly Heat Content Evolution in the Equatorial Pacific

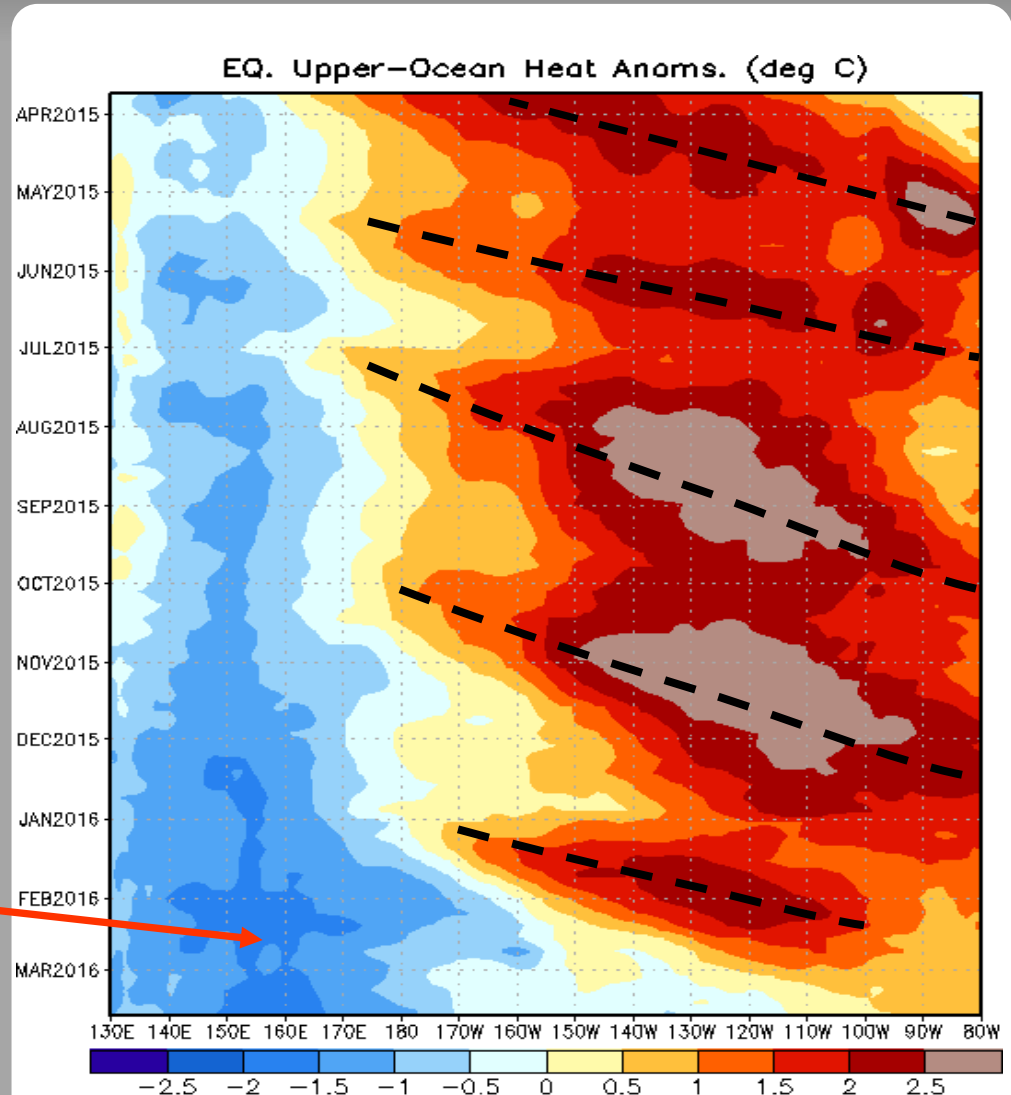
Oceanic Kelvin waves have alternating warm and cold phases. The warm phase is indicated by dashed lines. Downwelling and warming occur in the leading portion of a Kelvin wave, and upwelling and cooling occur in the trailing portion.

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 expanded to near 120W during March.



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

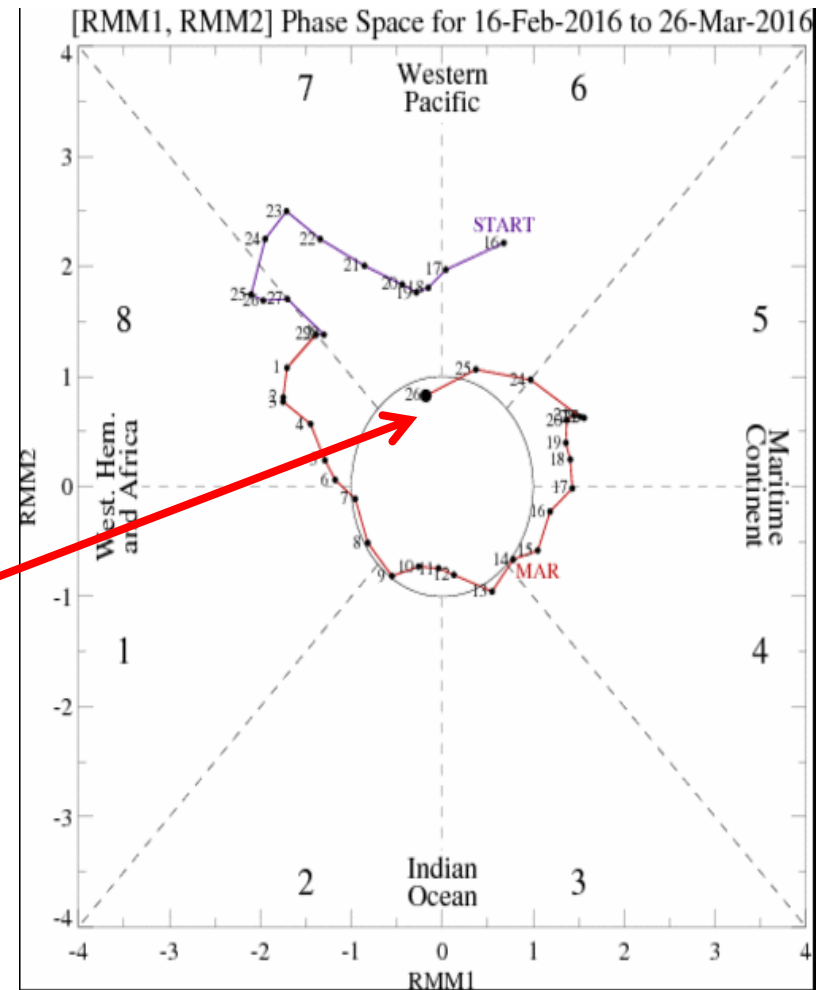
The triangular areas indicate the location of the enhanced phase of the MJO

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

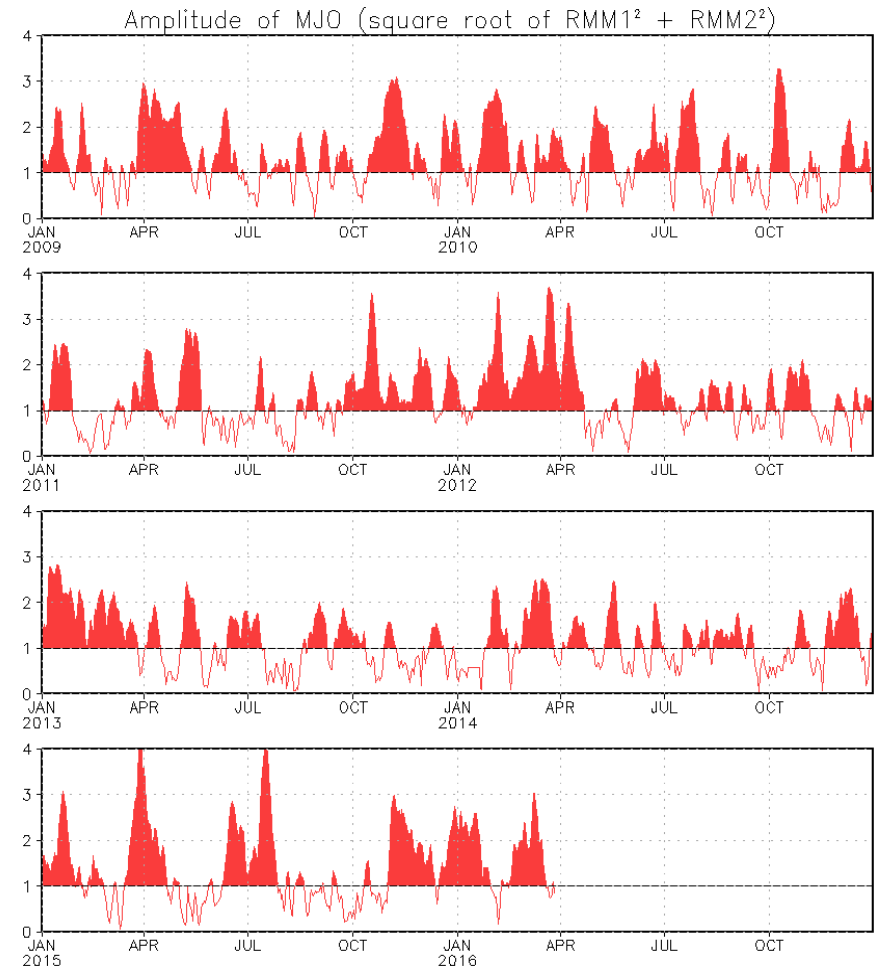
The MJO index depicts continued propagation over the western Pacific, with a slight decrease in amplitude.



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

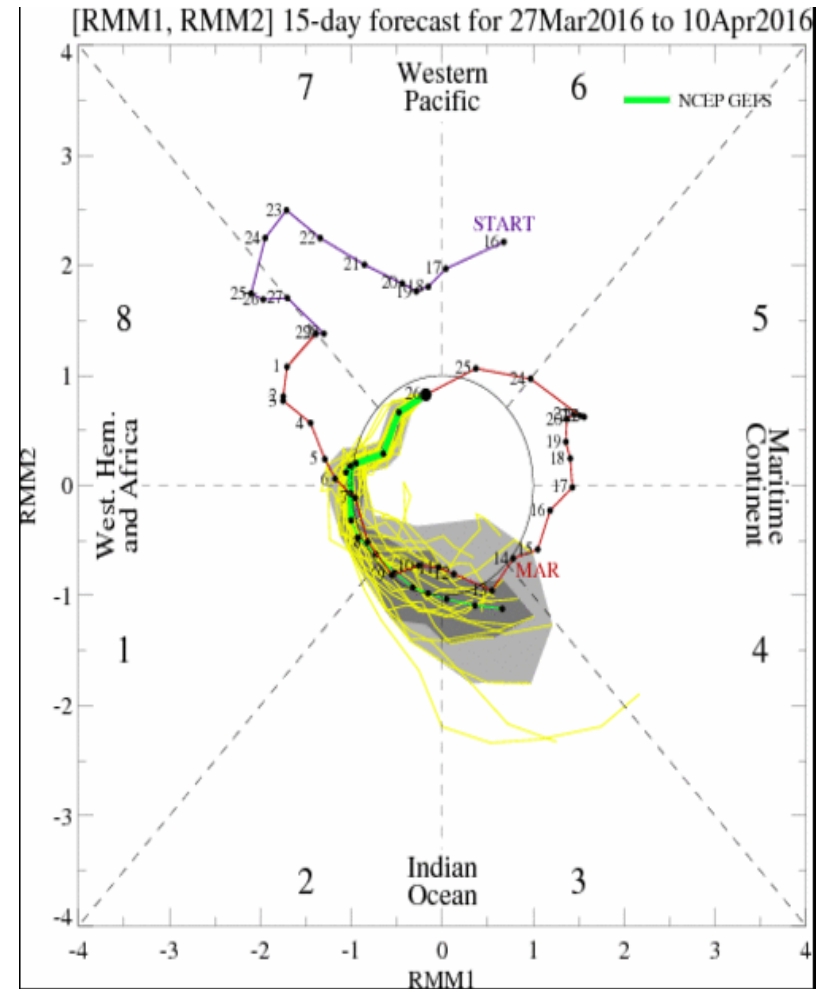
RMM1 and RMM2 values for the most recent 40 days and forecasts from the ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

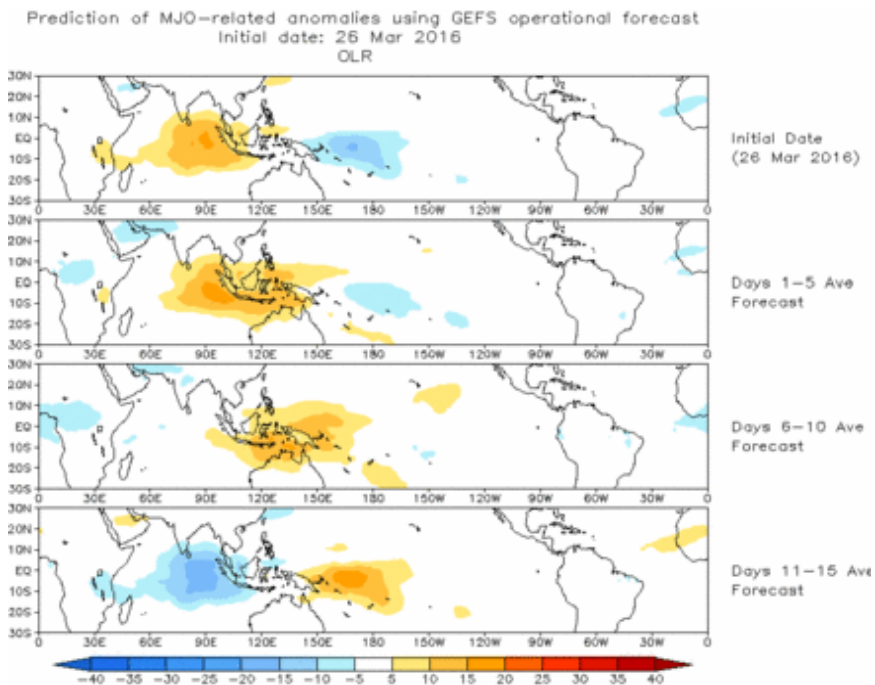
The GFS ensemble MJO index forecast depicts continued propagation of an MJO related signal.

Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean



Ensemble GFS (GEFS) MJO Forecast

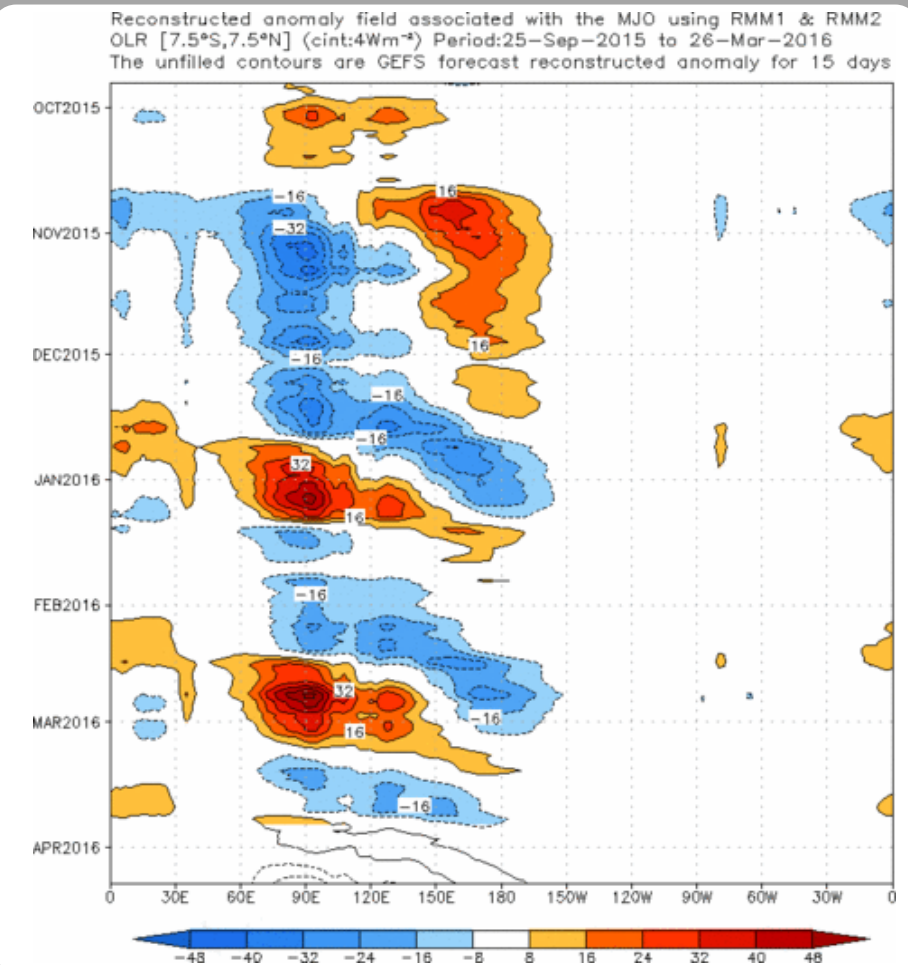
Spatial map of OLR anomalies for the next 15 days



The GEFS OLR forecast depicts continued eastward propagation of weak to moderate signal through the next 2 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.)

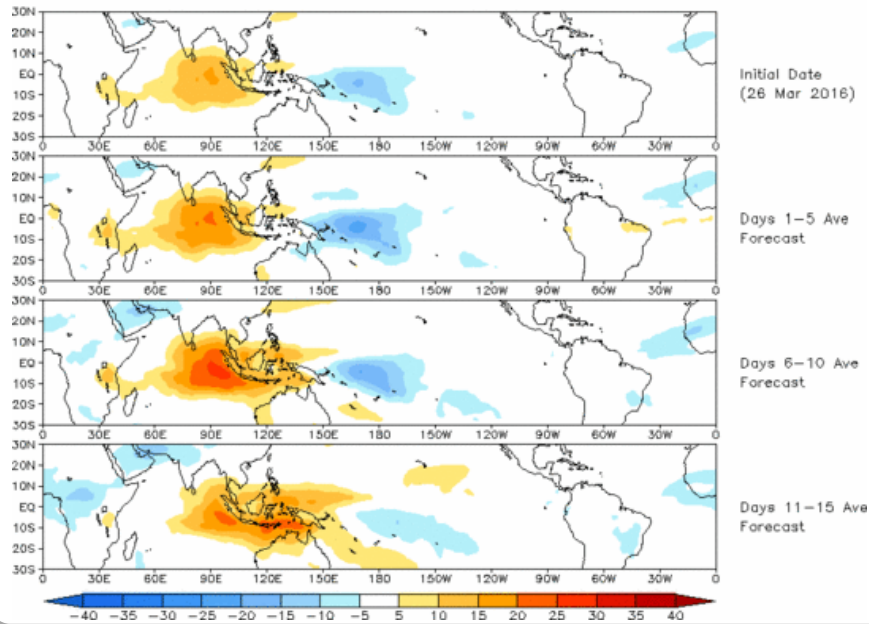
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



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 (26 Mar 2016)

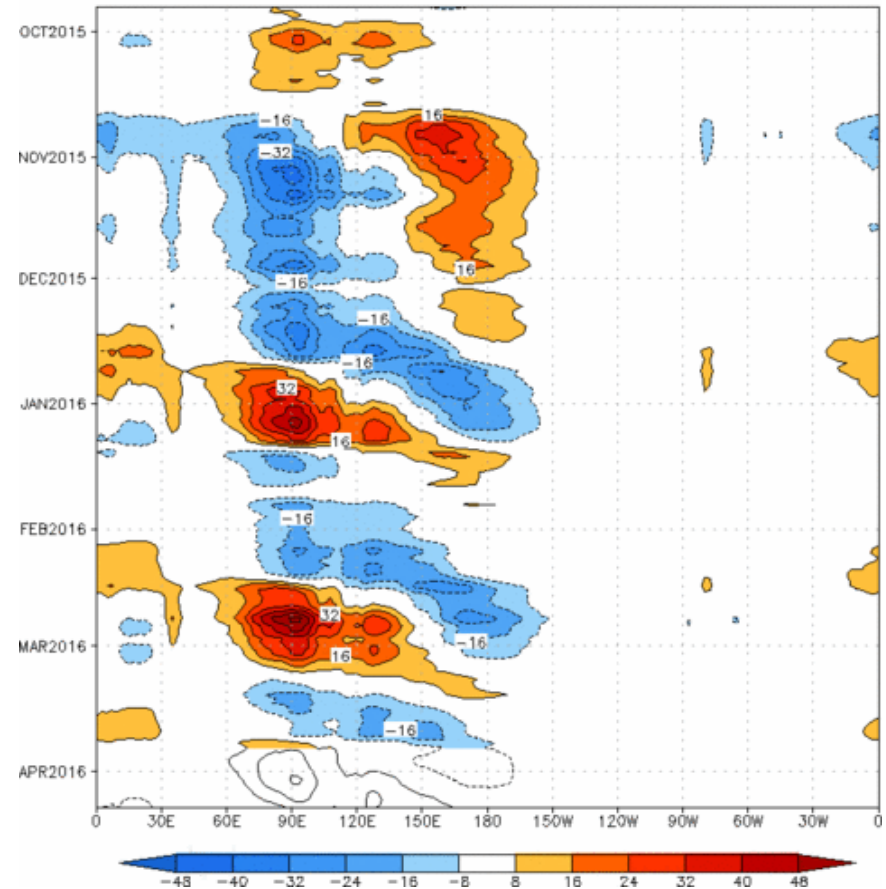


The constructed analog model depicts continued eastward propagation of the MJO signal, slightly slower than the GEFS model representation.

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.)

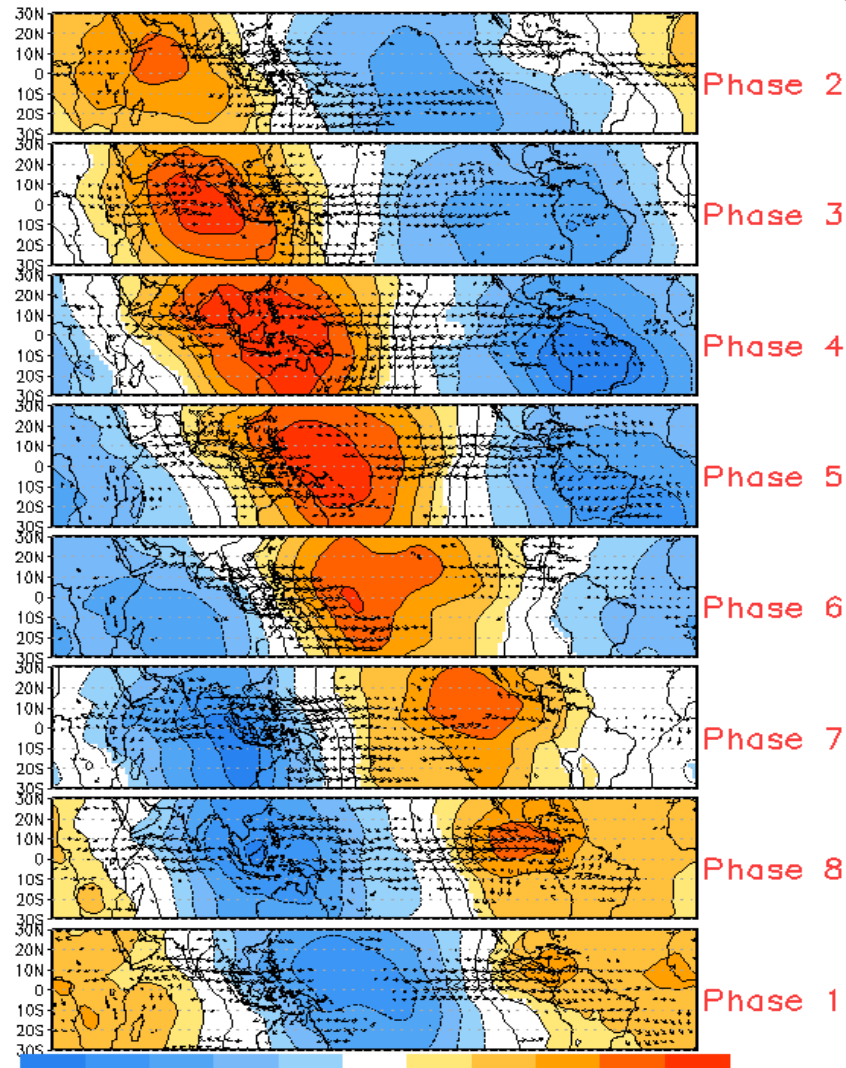
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2 OLR [7.5°S,7.5°N] (cont:4Wm⁻²) Period:25-Sep-2015 to 26-Mar-2016
The unfilled contours are CA forecast reconstructed anomaly for 15 days

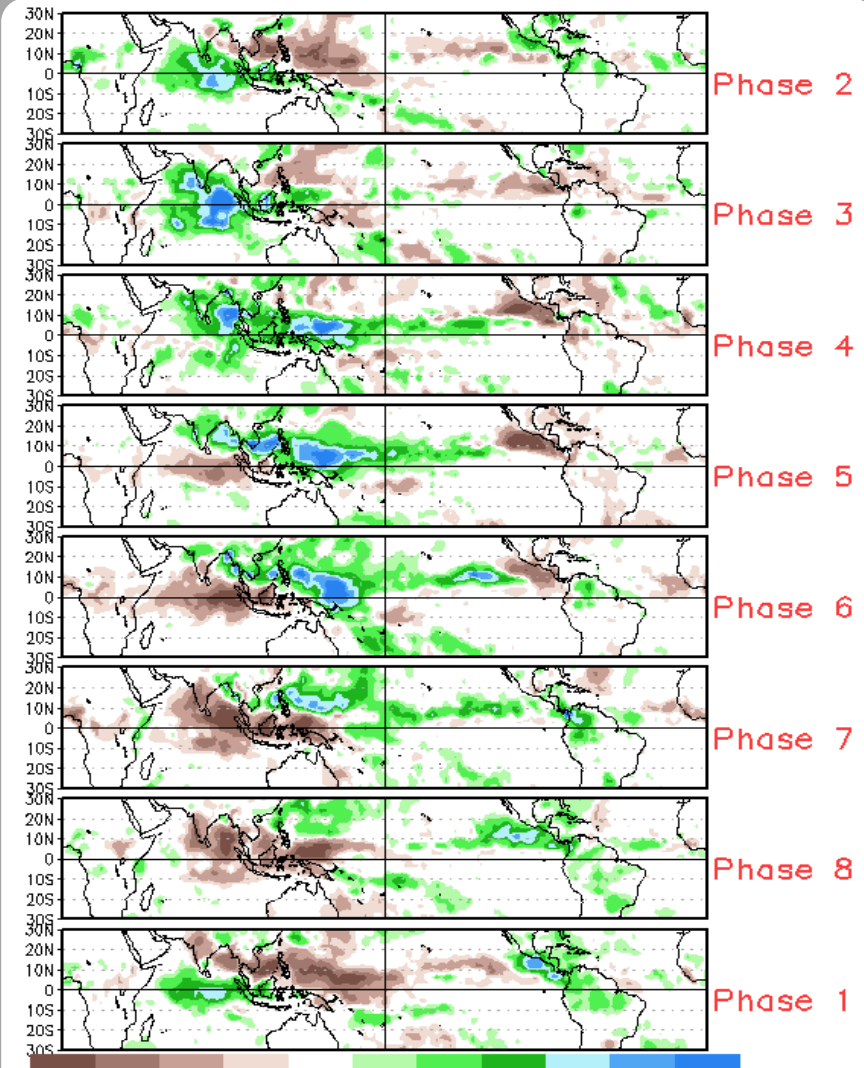


MJO Composites - Global Tropics

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



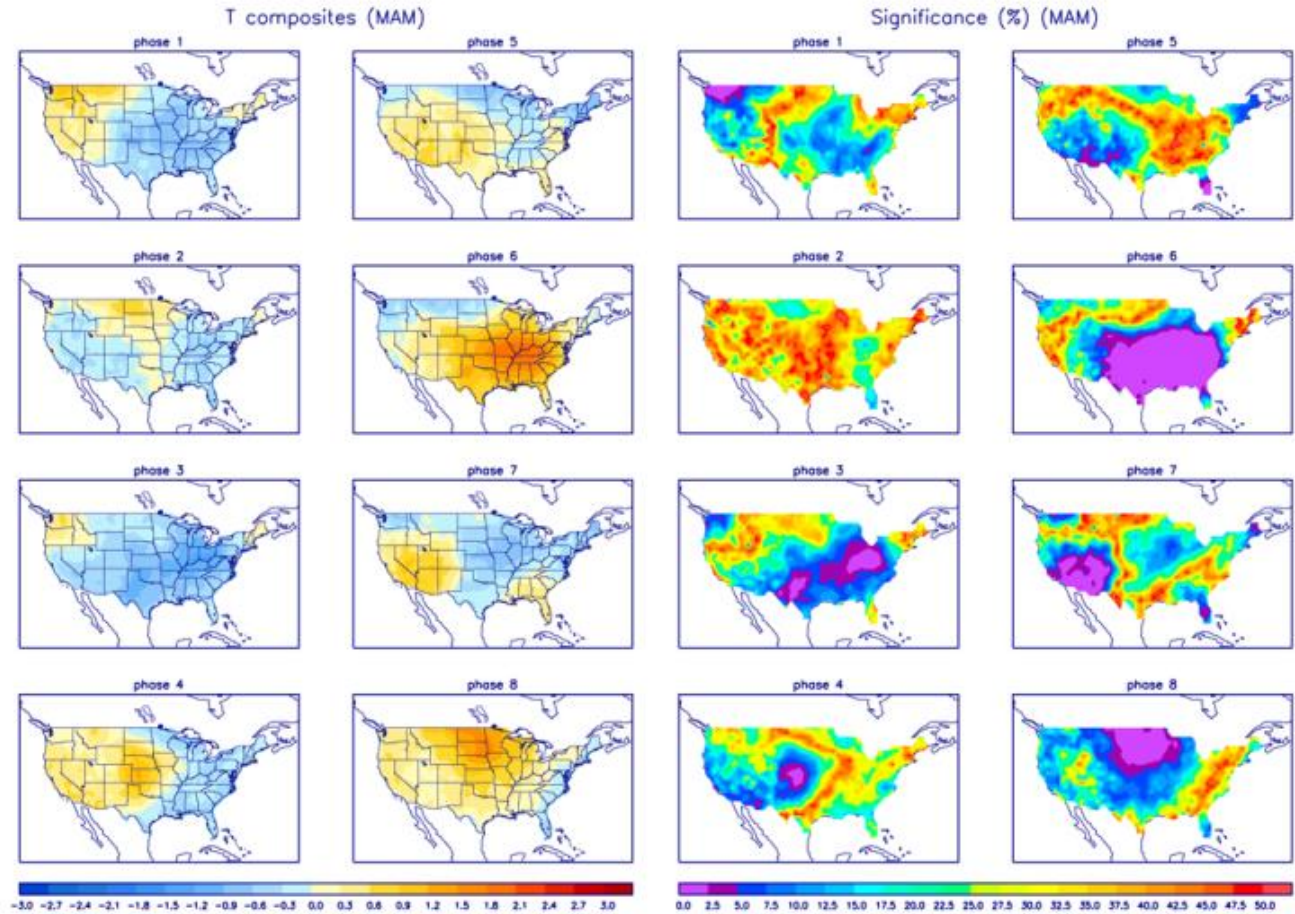
Precipitation Anomalies (Nov-Mar)



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.



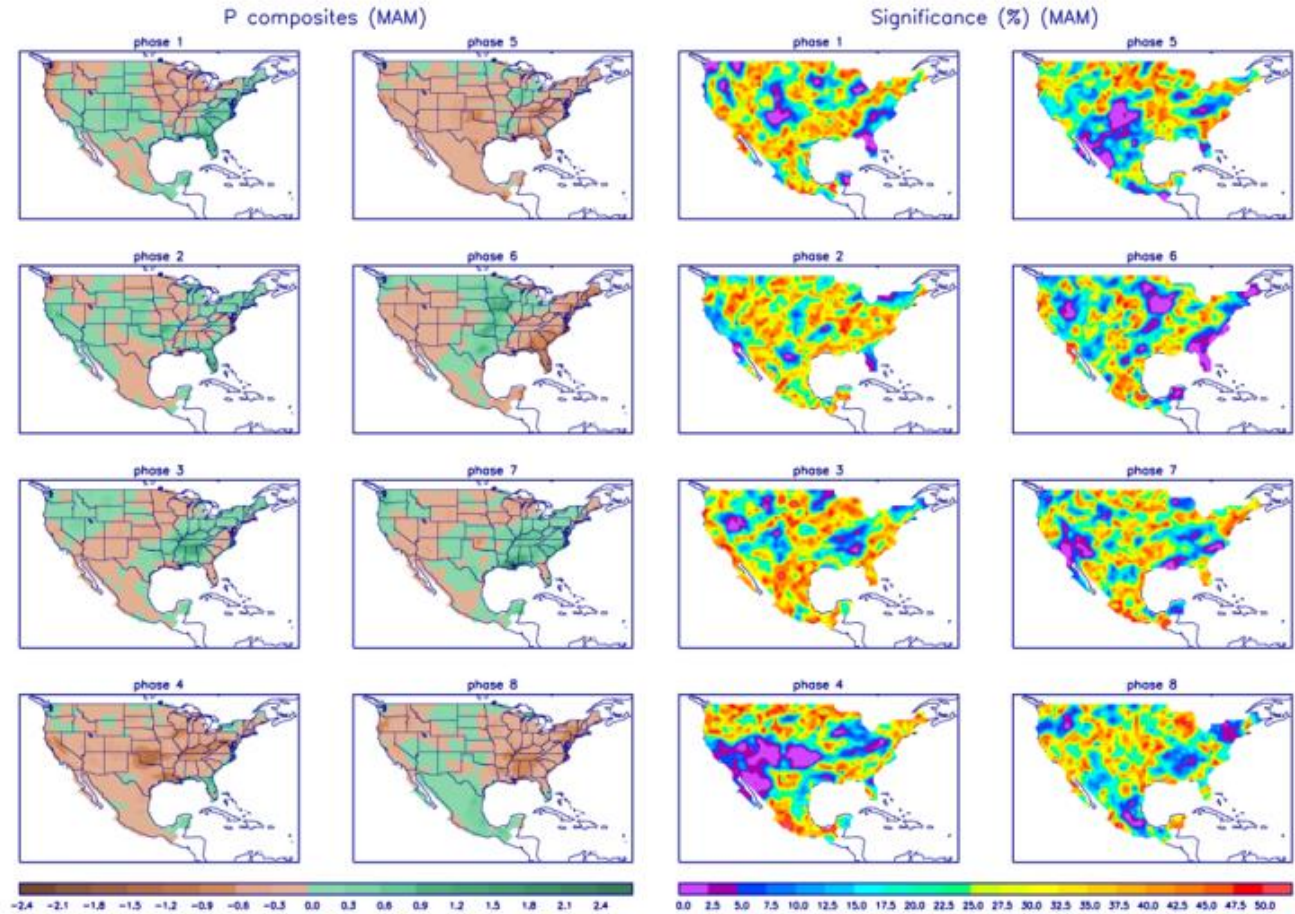
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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>