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

Update prepared by:
Climate Prediction Center / NCEP
1 May 2017

Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

Overview

- Both RMM-based and CPC velocity potential-based MJO indices portray an increase in amplitude of the intraseasonal signal, with the enhanced convective phase currently over the East Pacific.

- Dynamical model RMM index forecasts are mixed, with the GEFS depicting little to no eastward propagation and a weakening signal, while the ECMWF shows a more robust eastward propagation of the MJO to the Indian Ocean by the end of Week-2.

- Statistical tools such as the constructed analog generally favor continued evolution of the MJO index.

- Due to the conflicting dynamical model guidance, the continued propagation of the MJO to the Indian Ocean is uncertain.

- During Week-1, the MJO may play a role in unusual early May tropical cyclone formation over the East Pacific, as well as enhanced convection across parts of South America and the tropical Atlantic.

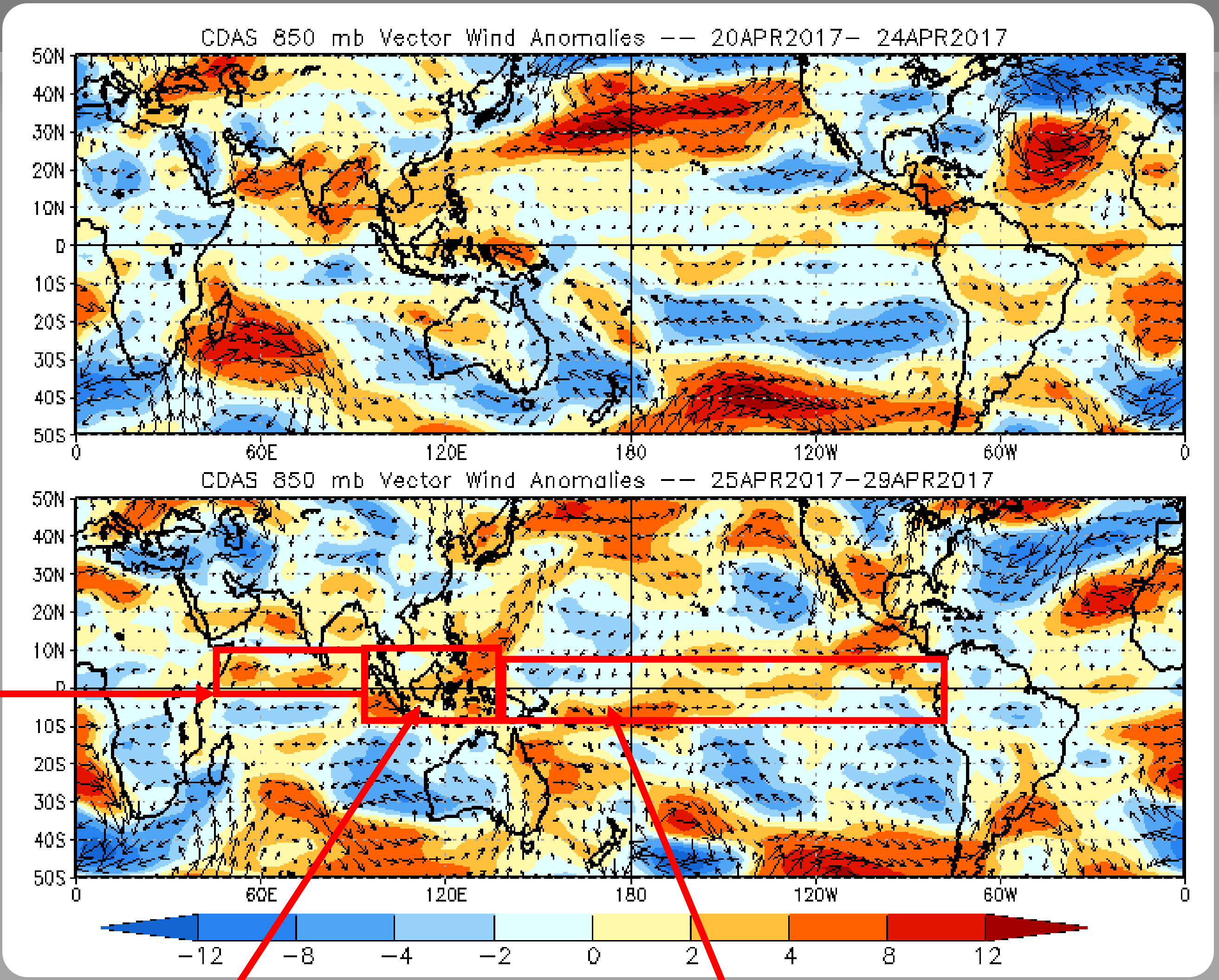
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php

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

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies



Weak westerlies north of the equator returned to the Indian Ocean.

Westerly anomalies shifted westward over the Maritime Continent.

Robust N-S cross-equatorial flow was observed over the western Pacific, while weak westerlies persisted over the East 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

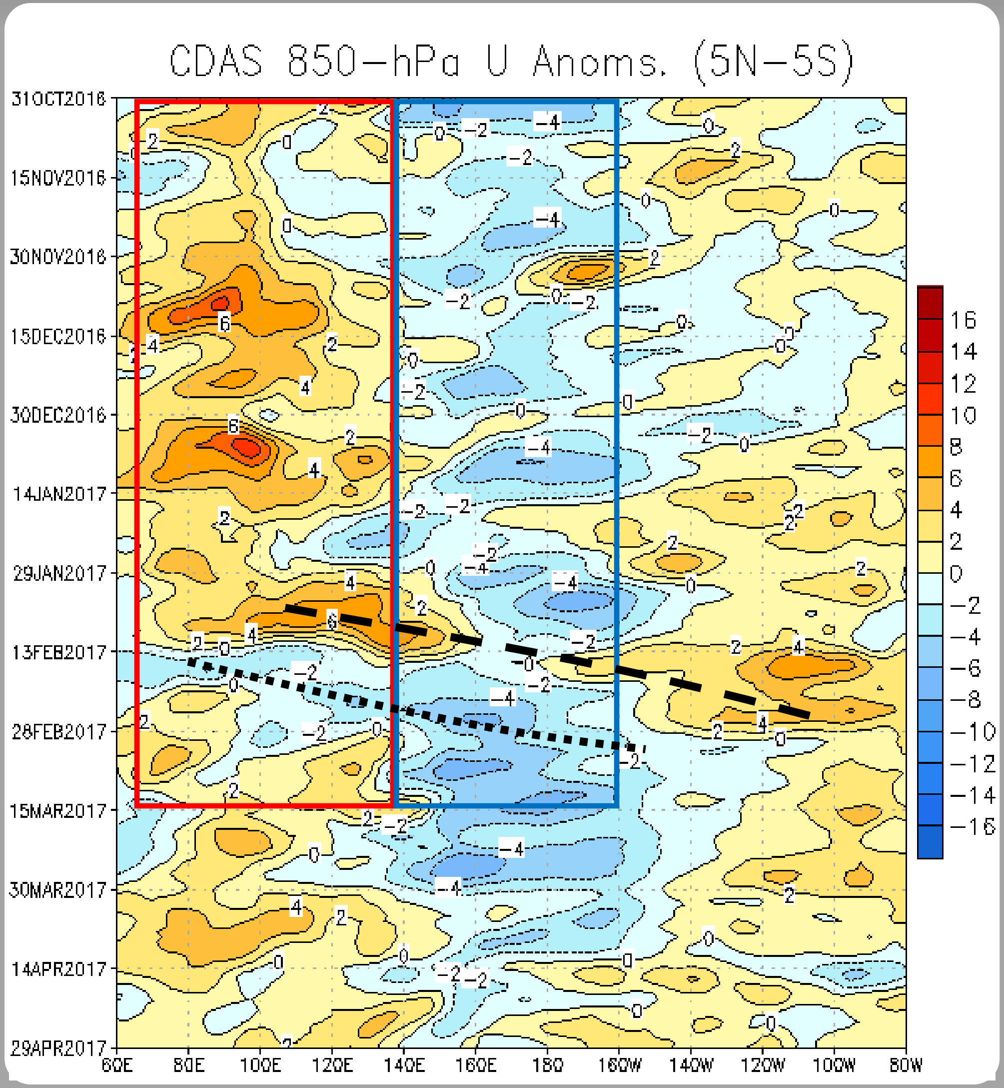
Persistent westerly (easterly) anomalies, shown by the red (blue) box at right, were associated with the negative phase of the Indian Ocean Dipole (IOD), and later, La Niña.

During late January, Rossby wave activity was evident, with destructive interference on the base state evident through 100E.

During February, MJO activity also destructively interfered with the base state.

During mid-March, the low frequency state of anomalies returned similar to this past winter.

More recently, robust Rossby wave activity was evident over the West Pacific and Maritime Continent, with several Kelvin waves over the East Pacific potentially suggesting a slower evolving envelope.



OLR Anomalies – Past 30 days

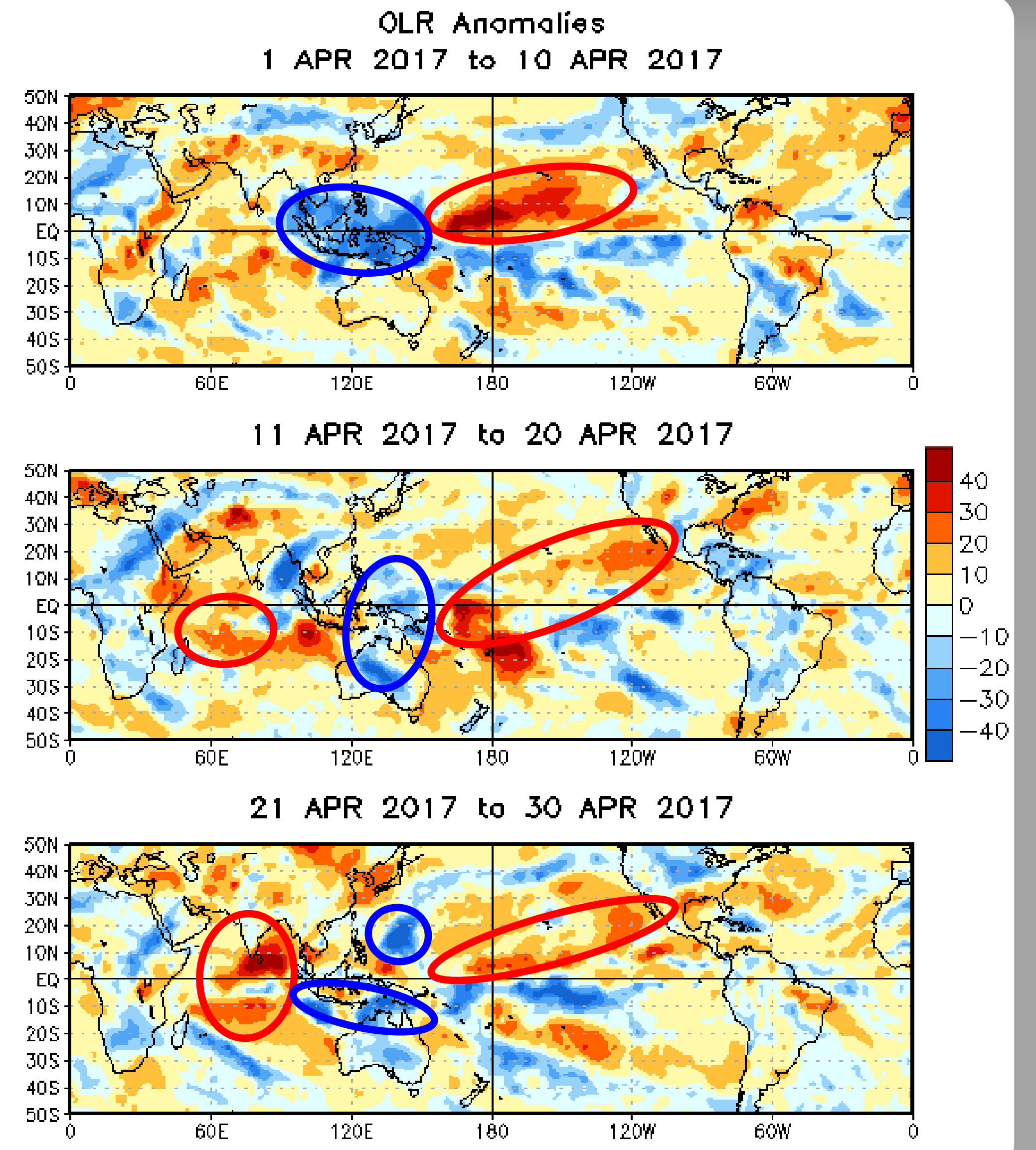
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

Robust envelopes of enhanced (suppressed) convection were observed over the Maritime Continent (central Pacific) during early April, consistent with the low frequency pattern.

During mid-April, suppressed convection persisted over much of the Pacific and Indian Oceans. The larger envelope of enhanced convection over the Maritime Continent weakened, with discrete features (e.g., tropical cyclones) evident over the Bay of Bengal and the northwestern Pacific.

The low frequency state continued to influence the pattern in late April. Smaller scale areas of enhanced convection related to tropical cyclone activity persisted over parts of the Maritime Continent and northwest Pacific.



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

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

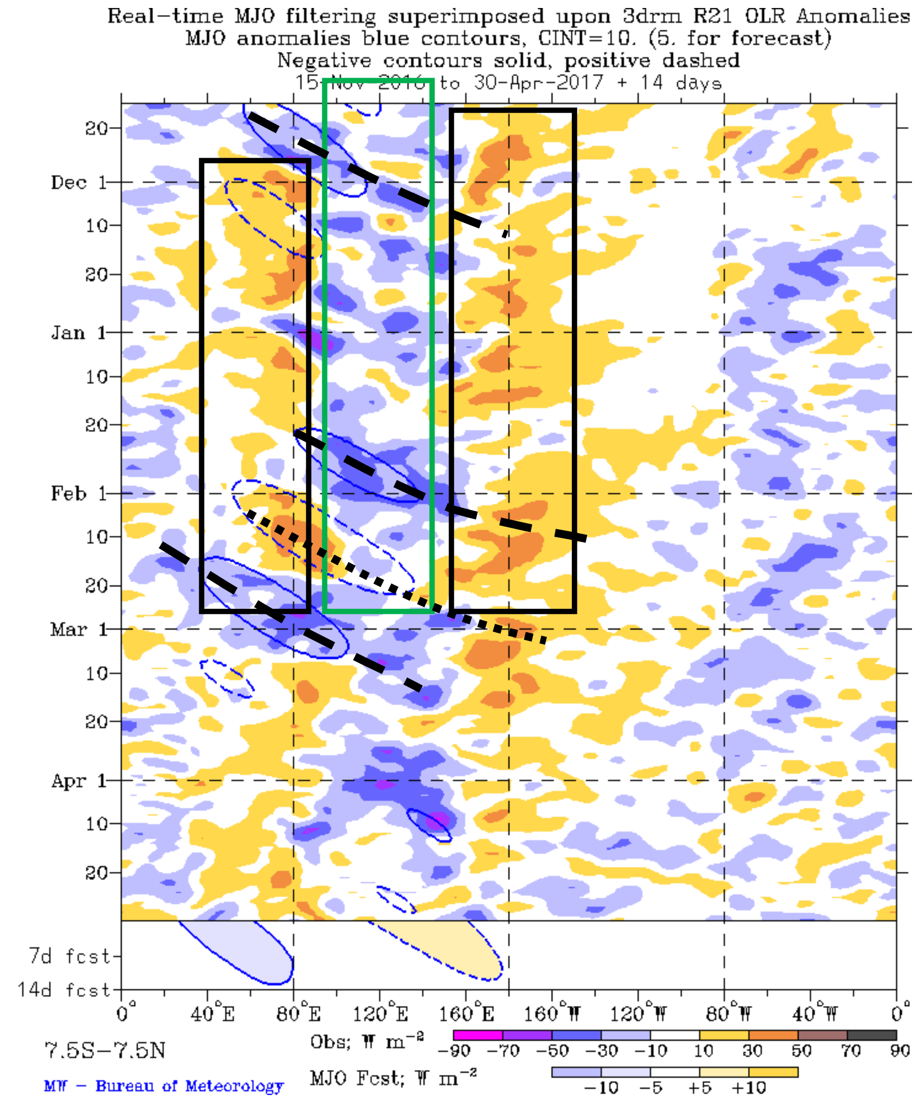
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

A low frequency state favoring enhanced convection over the eastern Indian Ocean and the Maritime Continent has been evident from July through mid-February (green box), with suppressed convection over the Indian Ocean and near the Date Line (black boxes).

Intraseasonal events in January through mid-March have served to alter the low frequency states. Particularly, with the suppressed phase reversing the low frequency enhanced convective signal over the Maritime Continent in late February.

The MJO signal weakened by mid-March with a return of the low frequency state. Kelvin wave activity was evident from the Pacific through the Western Hemisphere.

More recently, the OLR field was generally weak, with some hints of eastward propagation.



200-hPa Velocity Potential Anomalies (5ºS - 5ºN)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

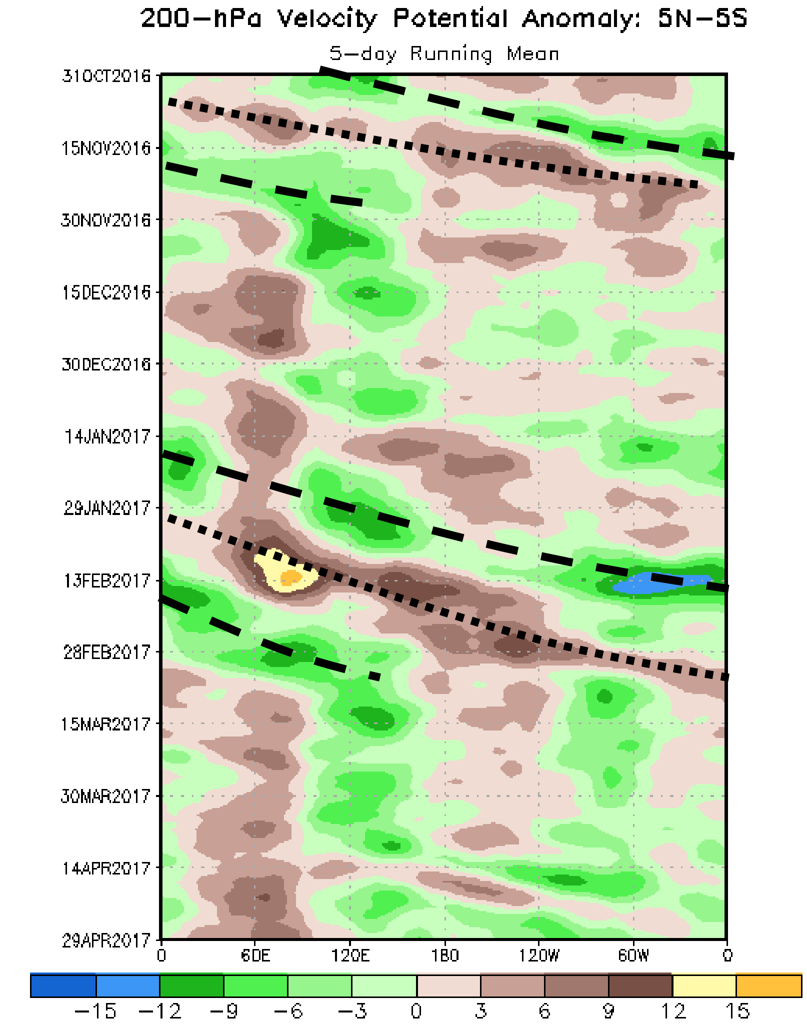
Negative anomalies (green shading) indicate favorable conditions for precipitation

During November, eastward propagation was observed consistent with MJO activity on the fast end of the intraseasonal spectrum.

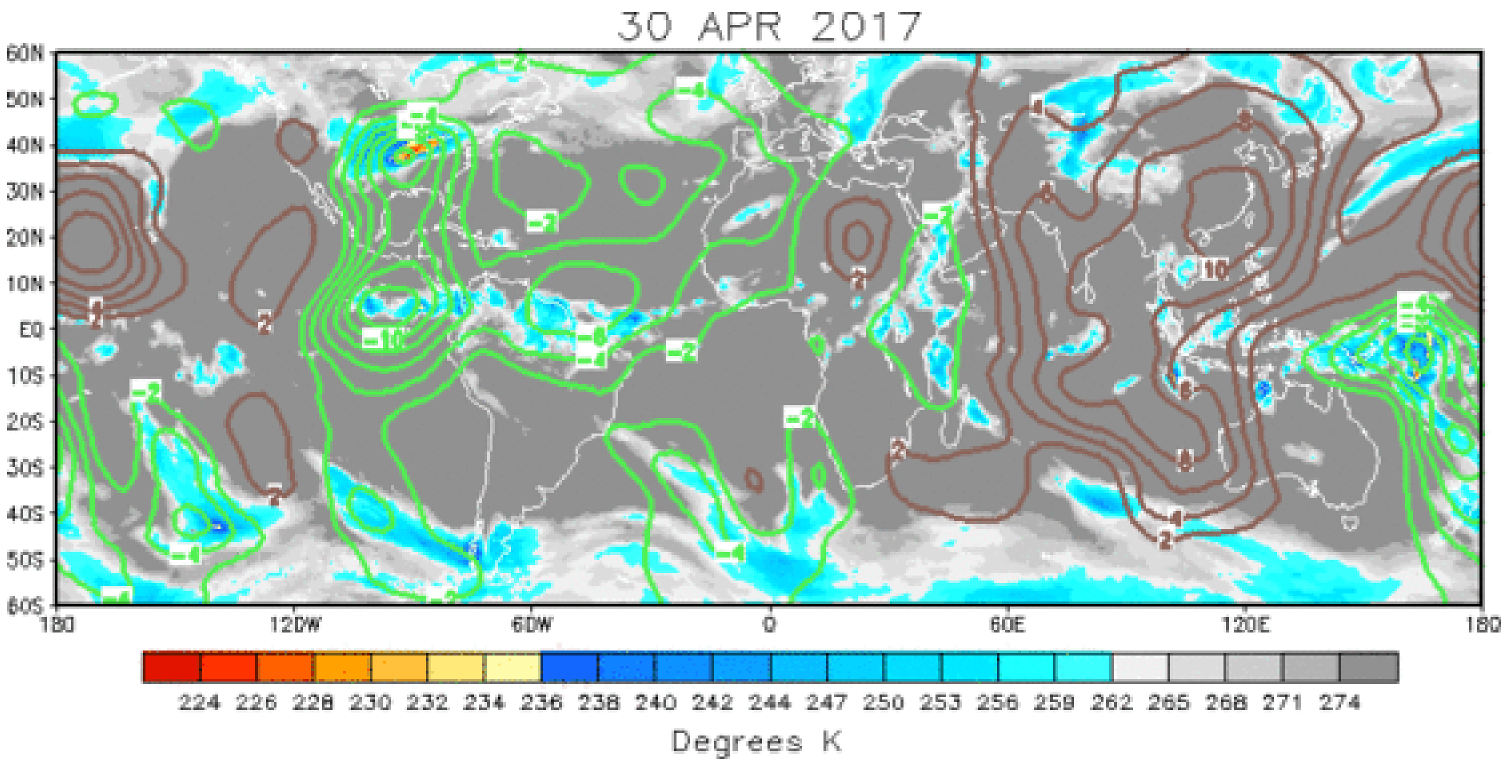
After a break in apparent MJO activity during December and early January, a signal emerged over the Maritime Continent and continued propagating through early March, creating alternating periods of constructive and destructive interference with the base state.

During March, a low frequency signal favoring enhanced (suppressed) convection over the Maritime Continent (Indian Ocean) once again became the primary component of the anomaly field.

Kelvin wave activity has been apparent during April, primarily east of the Date Line.



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



The spatial upper-level VP anomaly field depicts a fairly coherent pattern favoring large scale anomalous ascent (descent) over the Western Hemisphere (Indian Ocean). A second area of strong upper-level divergence is present over the western Pacific.

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)

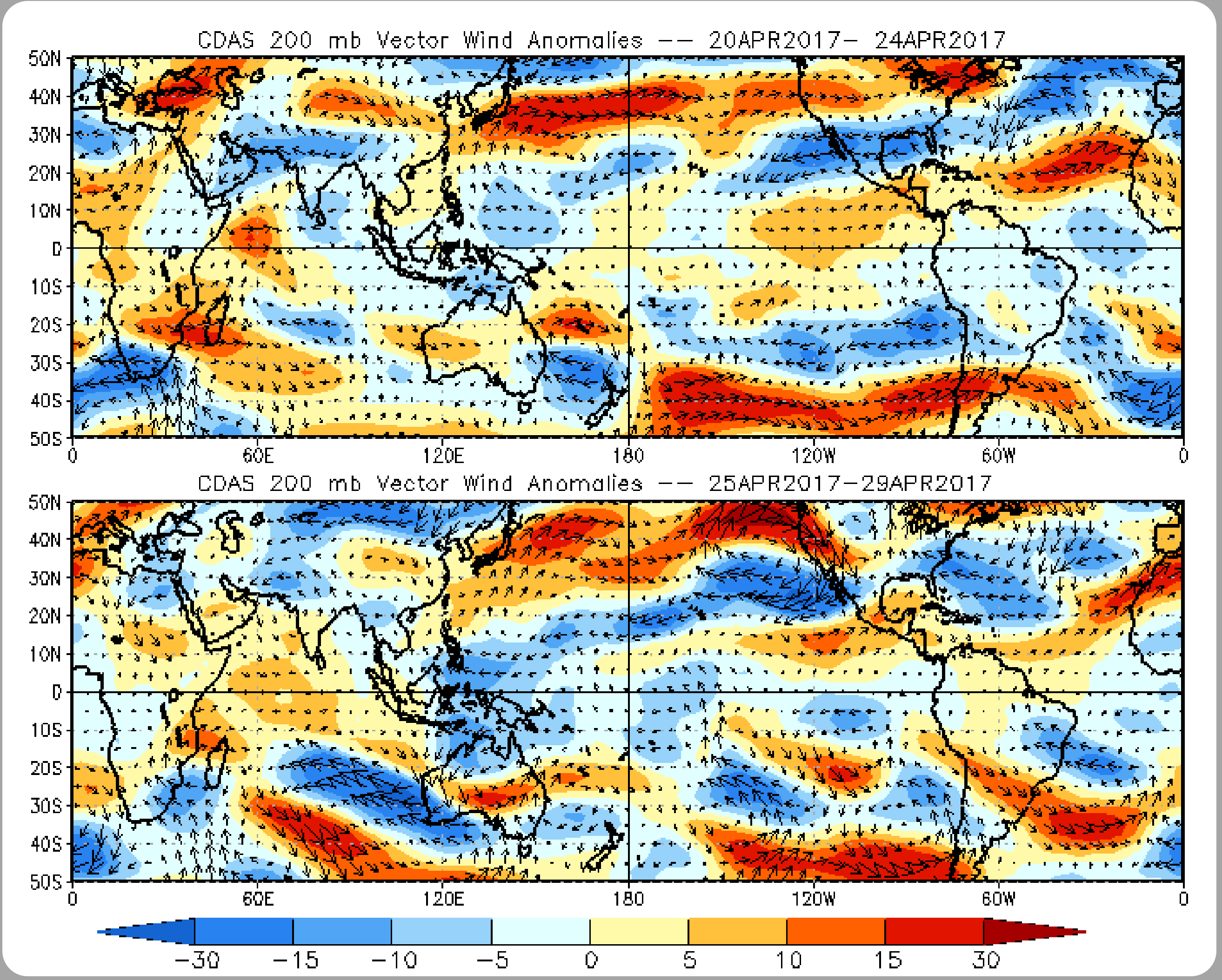
Note that shading denotes the zonal wind anomaly

<u>Blue shades</u>: Easterly anomalies

<u>Red shades</u>: Westerly anomalies

An anticyclonic gyre has persisted over the northwest Pacific during late April.

During late April, easterly (westerly) anomalies increased over the Maritime Continent (Indian Ocean). Zonal anomalies were generally weak across the Western Hemisphere.



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

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

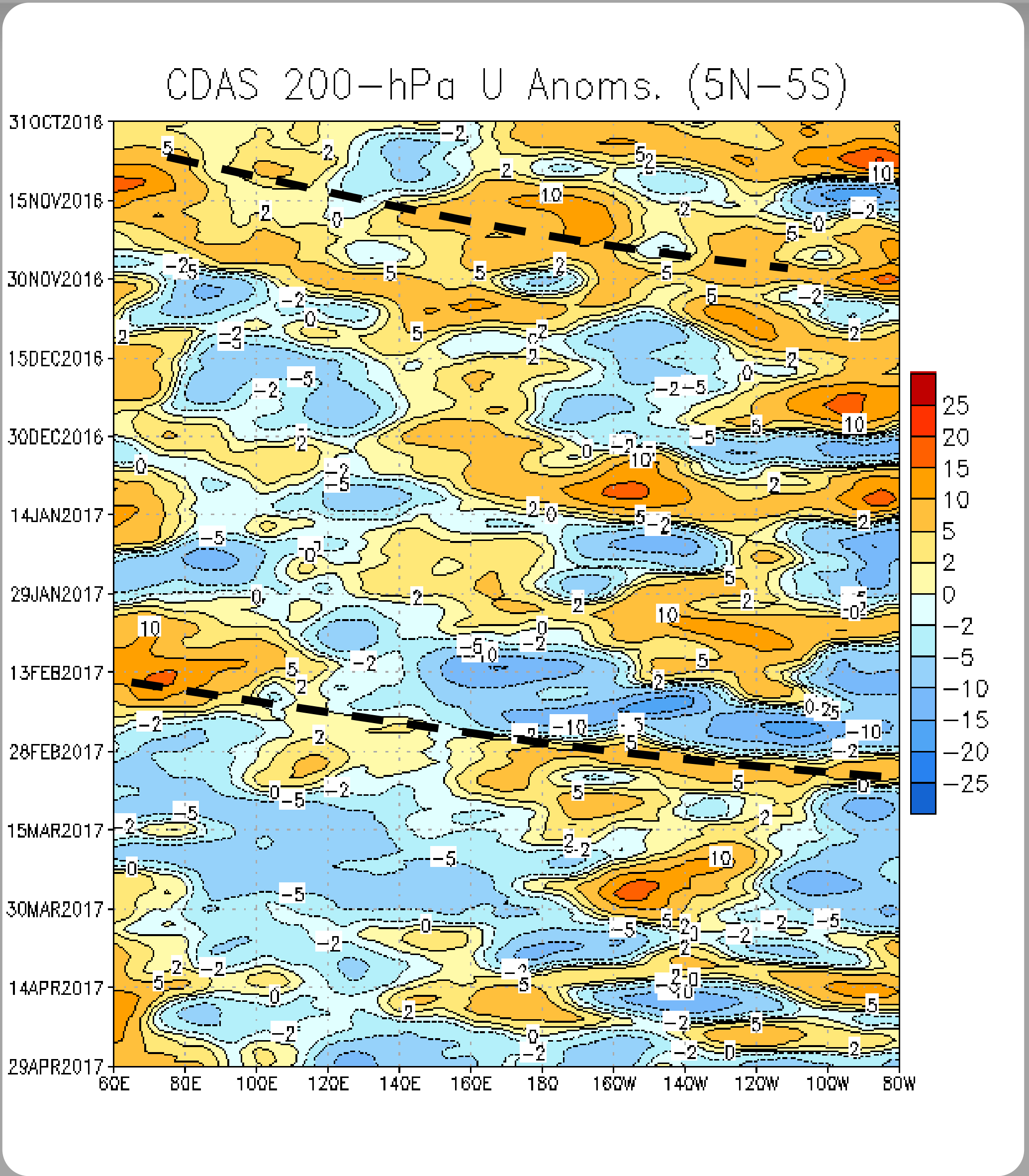
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

In late November, easterly anomalies re-emerged across the Indian Ocean and Maritime Continent, consistent with the passage of sub-seasonal activity and the re-alignment of the low frequency base state.

Near the end of 2016 a period of westerlies disrupted the low frequency state between 80-130E and continued propagating eastward through the Western Hemisphere.

Easterlies have recently returned to the East Pacific during late April.

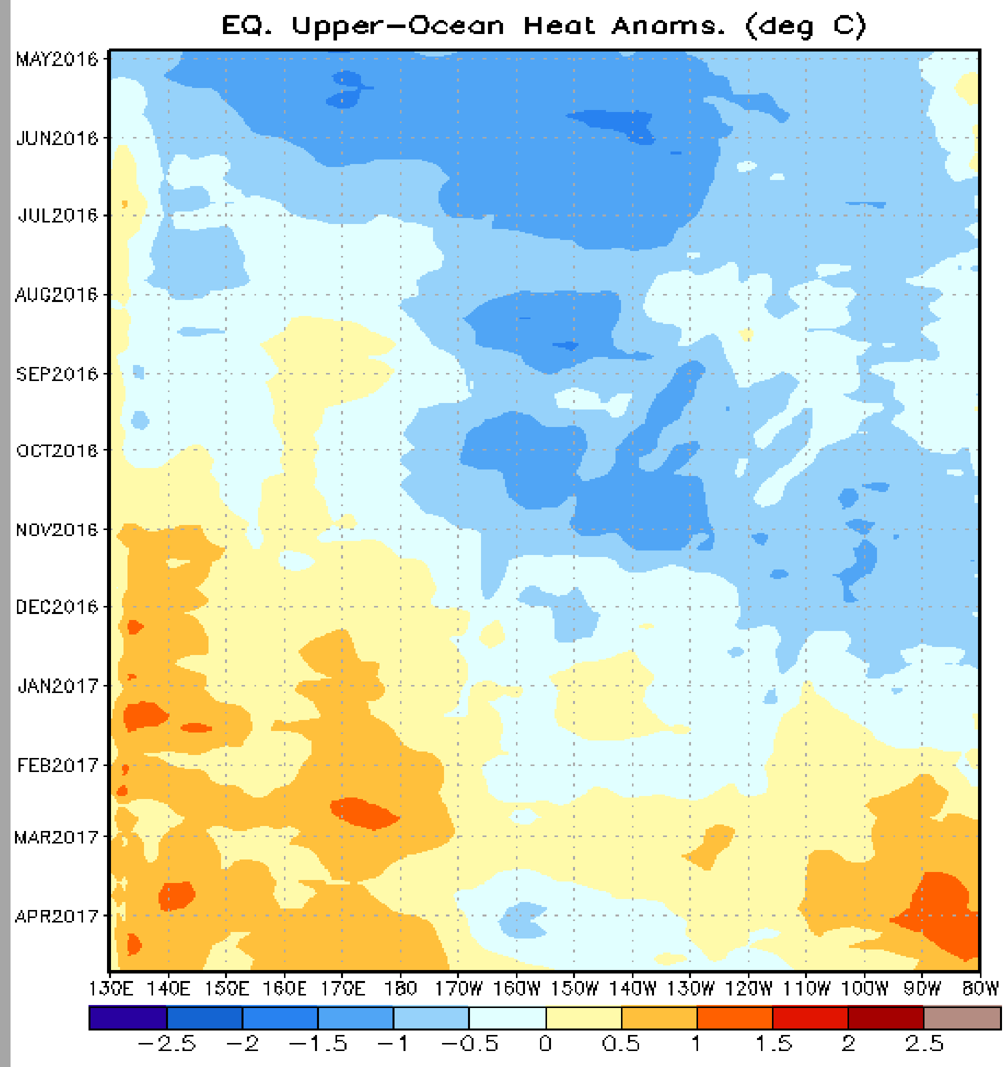


Weekly Heat Content Evolution in the Equatorial Pacific

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.

An eastward expansion of below average heat content over the western Pacific is evident through June, with widespread negative anomalies building across the Pacific over the course of boreal spring and summer.

The anomaly field has weakened across the central and eastern Pacific, with positive anomalies persisting over the far eastern Pacific and near and west of the Date Line.



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

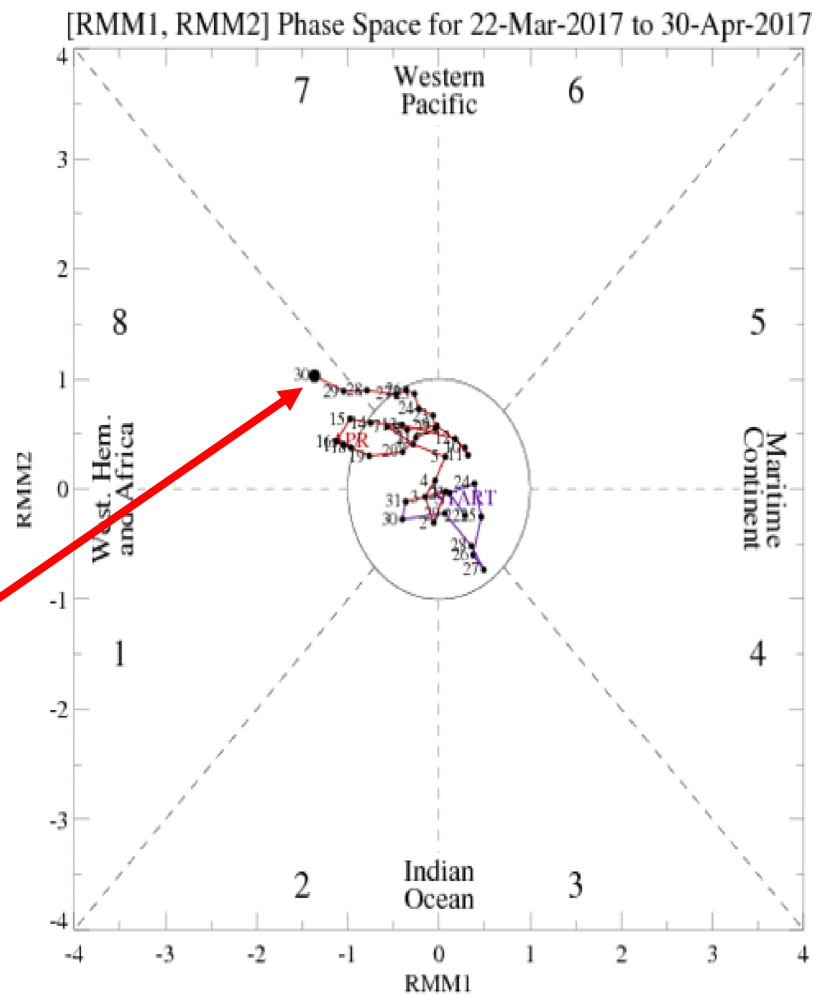
The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes

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

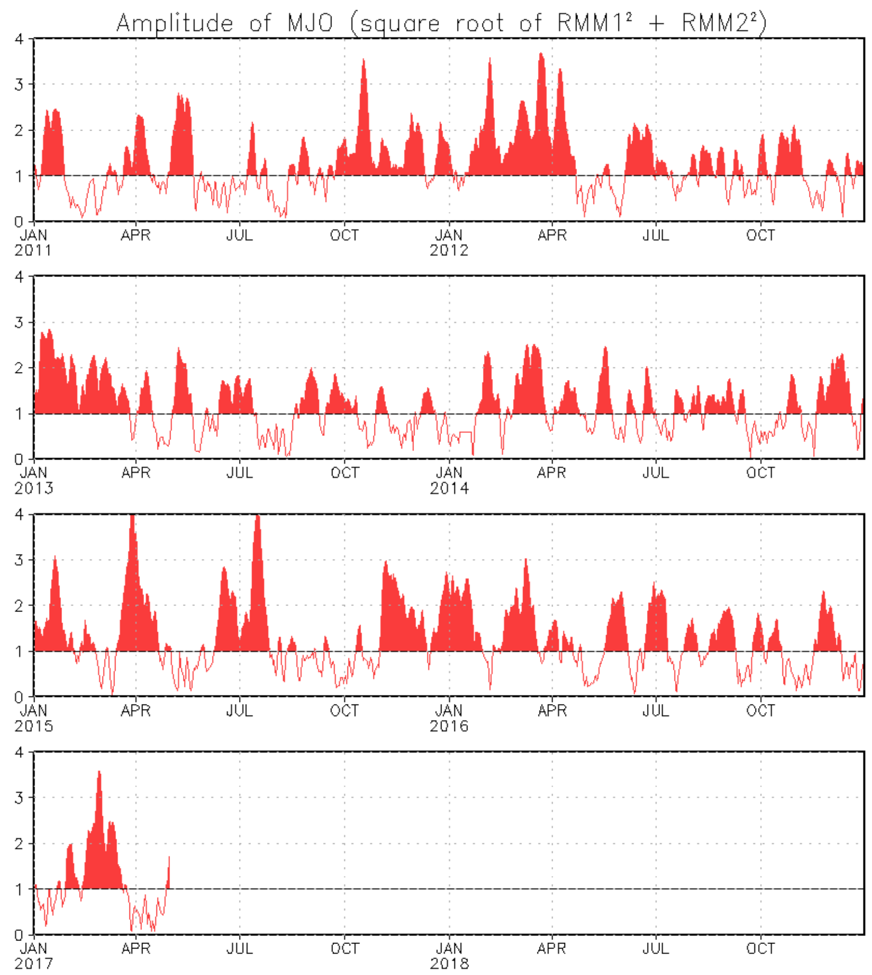


During the past several days, the amplitude of the RMM-based MJO index has increased, suggesting an emerging enhanced phase over the East Pacific.

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.



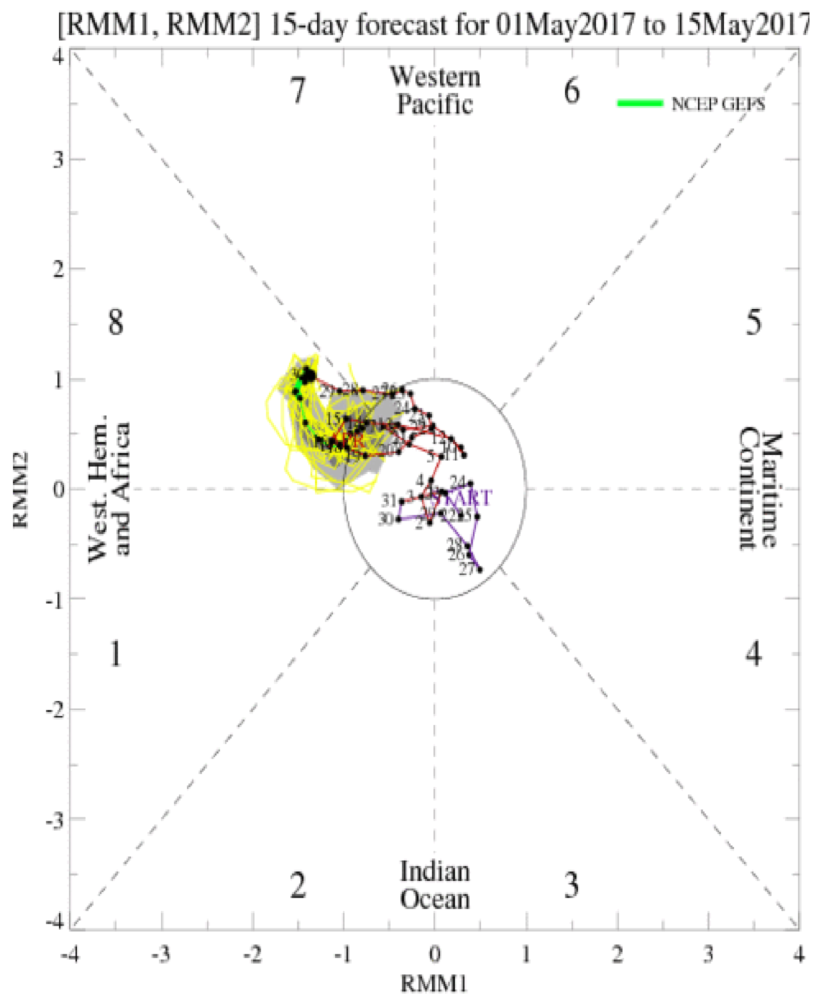
GFS Ensemble (GEFS) MJO Forecast

Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean

RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts



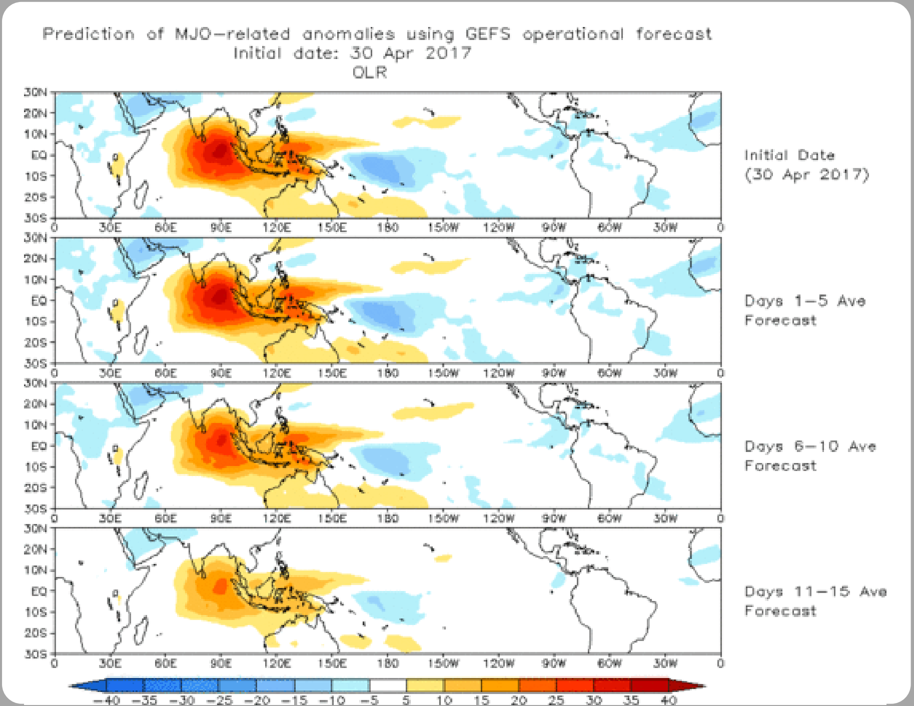
The GEFS depicts a gradual decrease in the amplitude of the MJO index over the next two weeks, with little eastward propagation.

Other models, most notably the ECMWF, depict a more robust MJO event propagating to the Indian Ocean by Week-2.

Ensemble GFS (GEFS) MJO Forecast

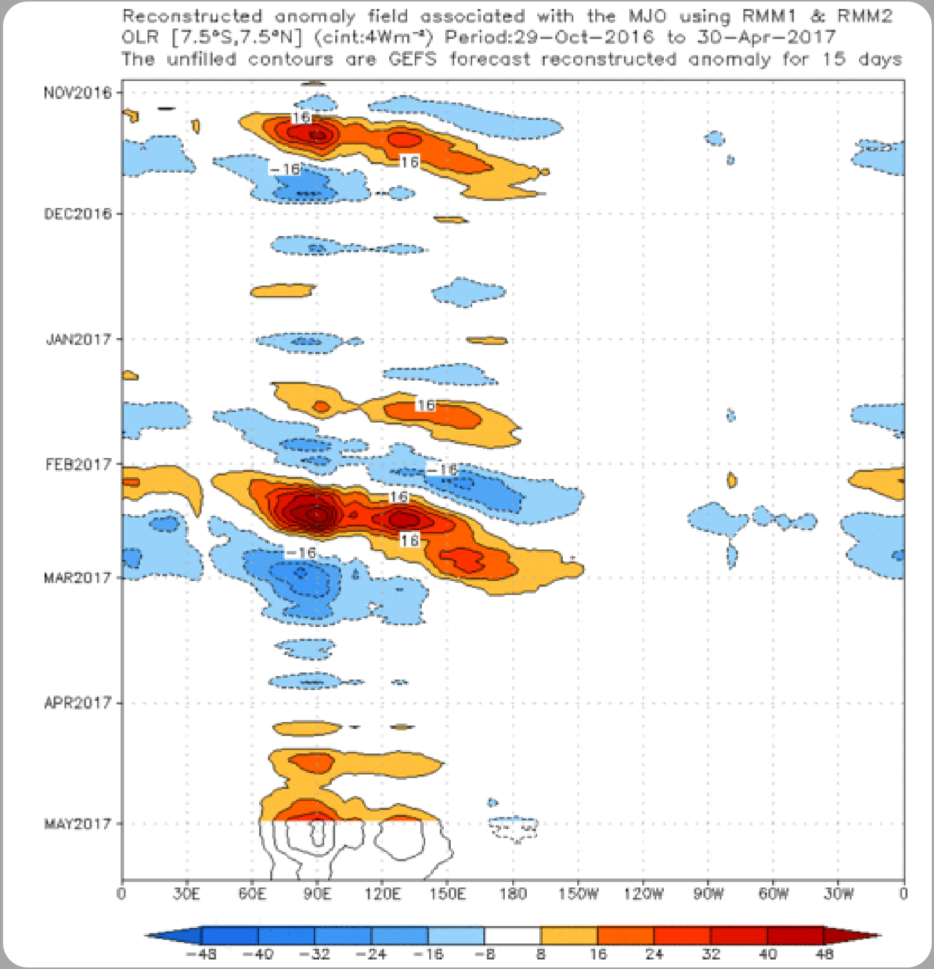
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



The GEFS RMM-based OLR anomaly forecast depicts a gradual weakening of a fairly stationary anomaly field over the next two weeks.

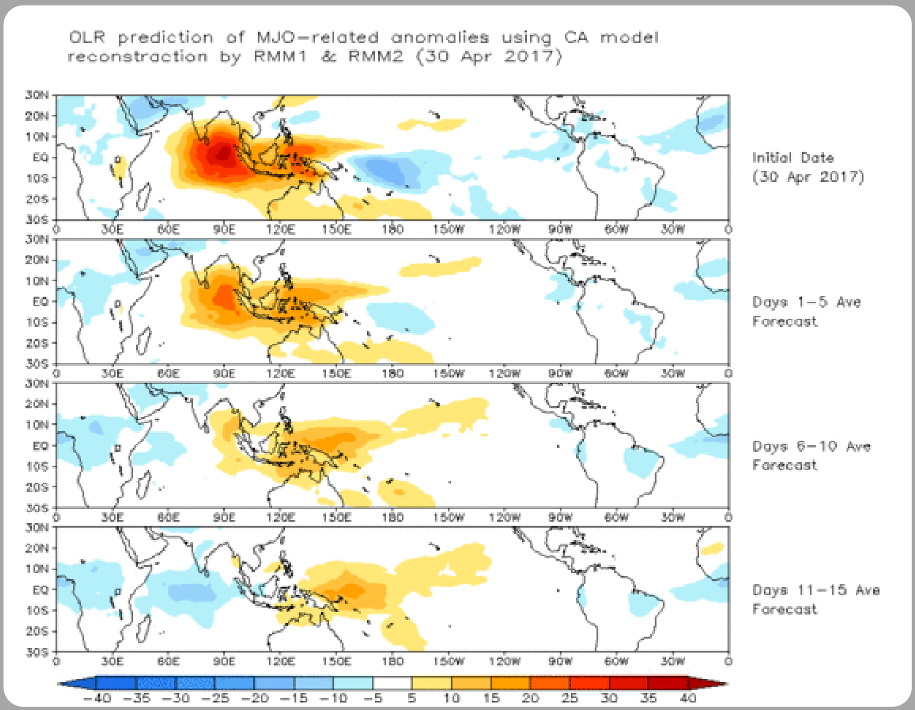
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



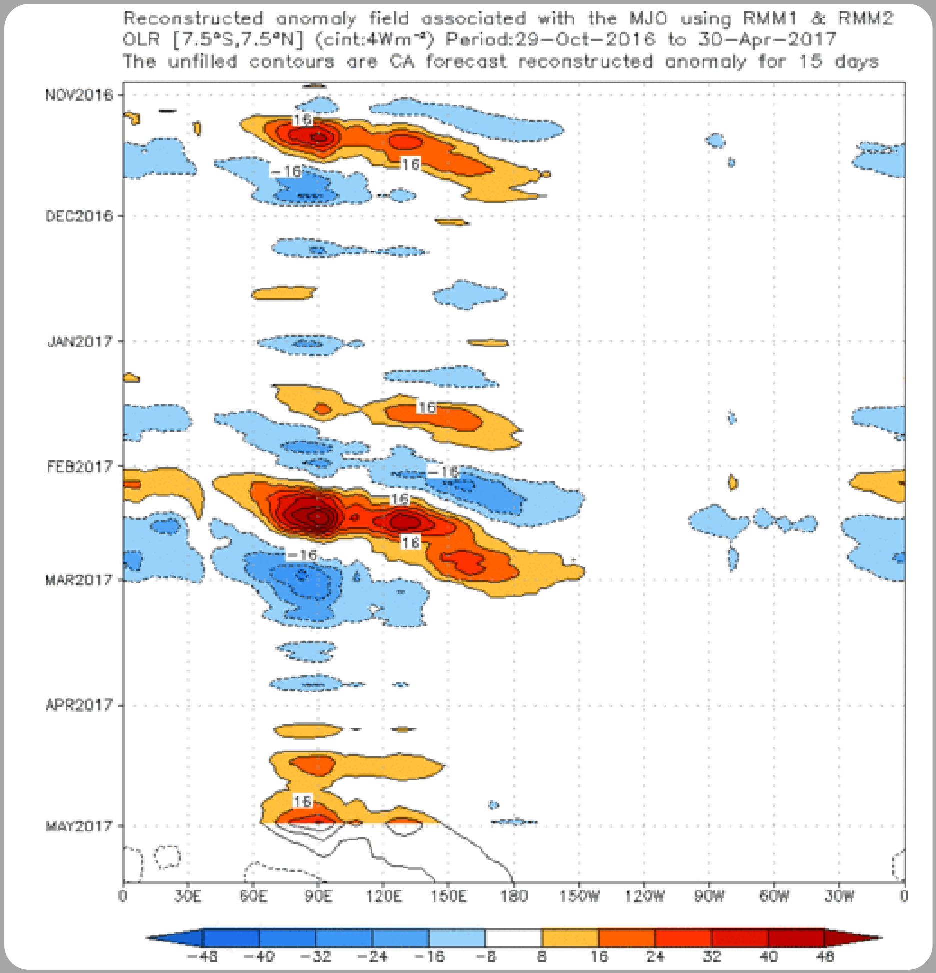
Constructed Analog (CA) MJO Forecast

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

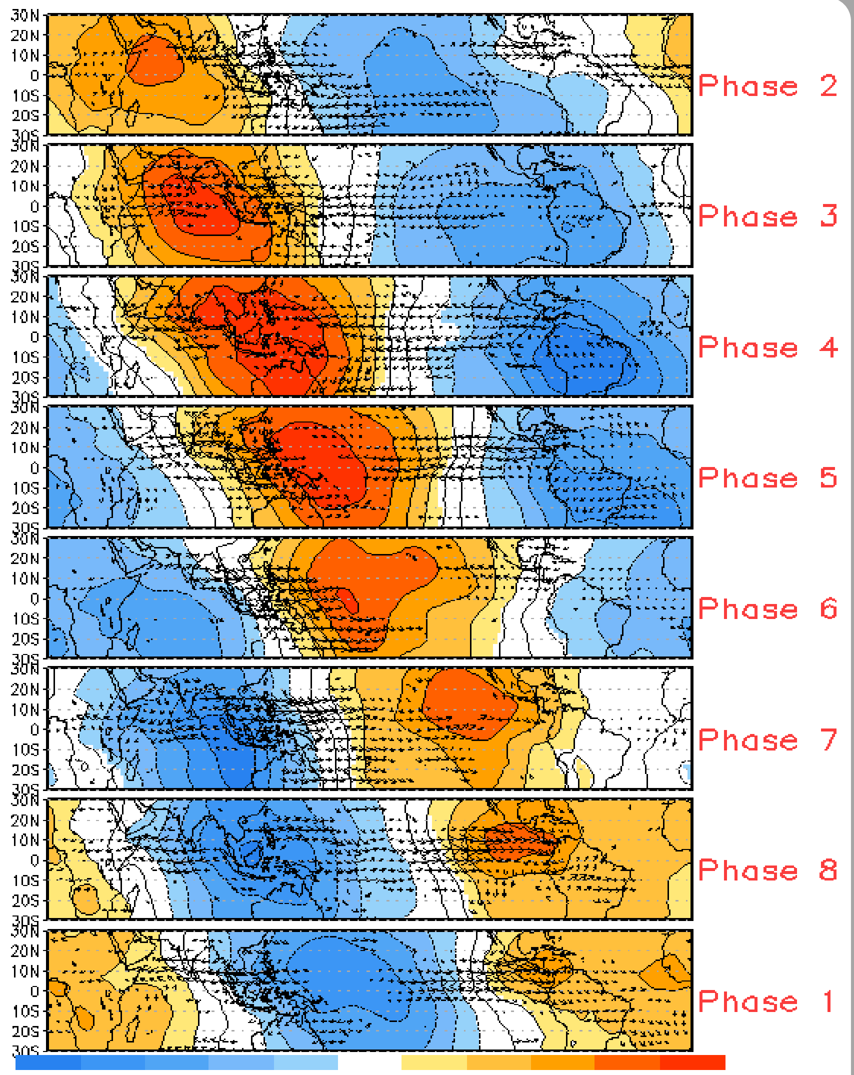


The statistical (Constructed Analog) RMM-based OLR anomaly prediction indicates more robust eastward propagation of the anomaly pattern, with the enhanced phase of the MJO emerging over the Indian Ocean by the end of Week-2.

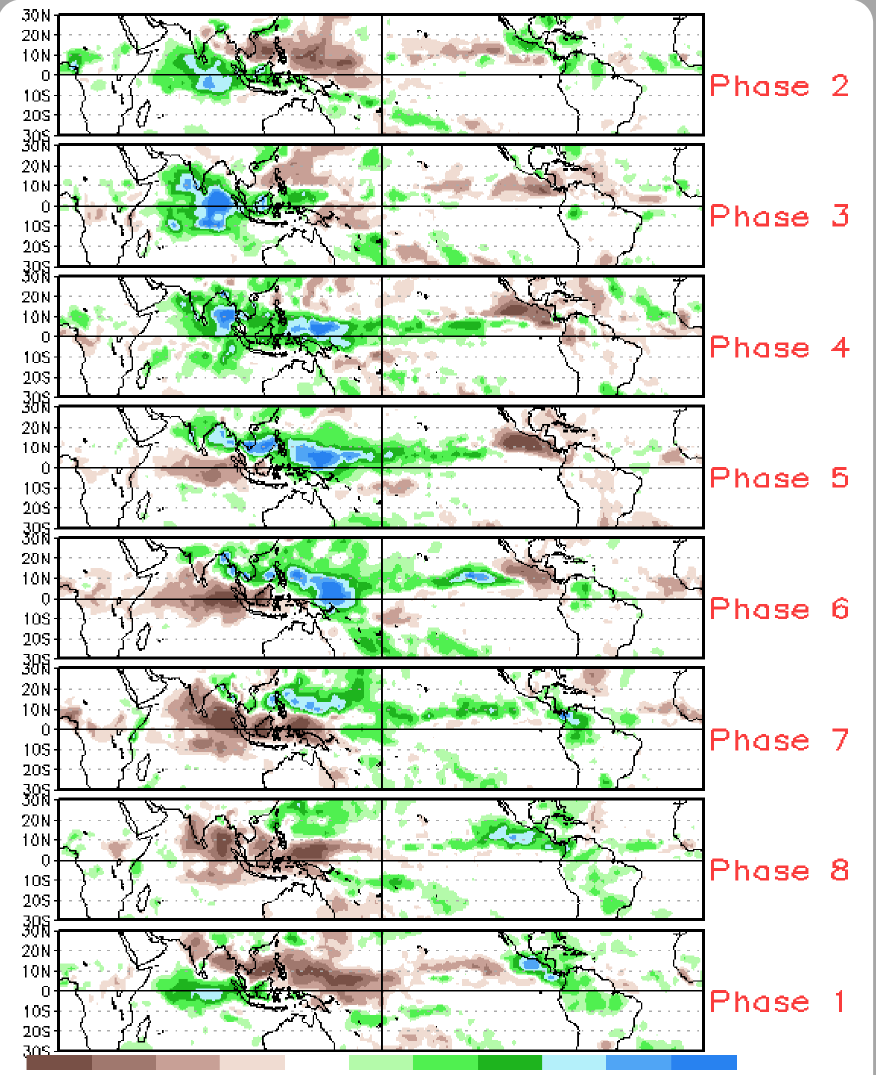
MJO Composites - Global Tropics

850-hPa Velocity Potential and

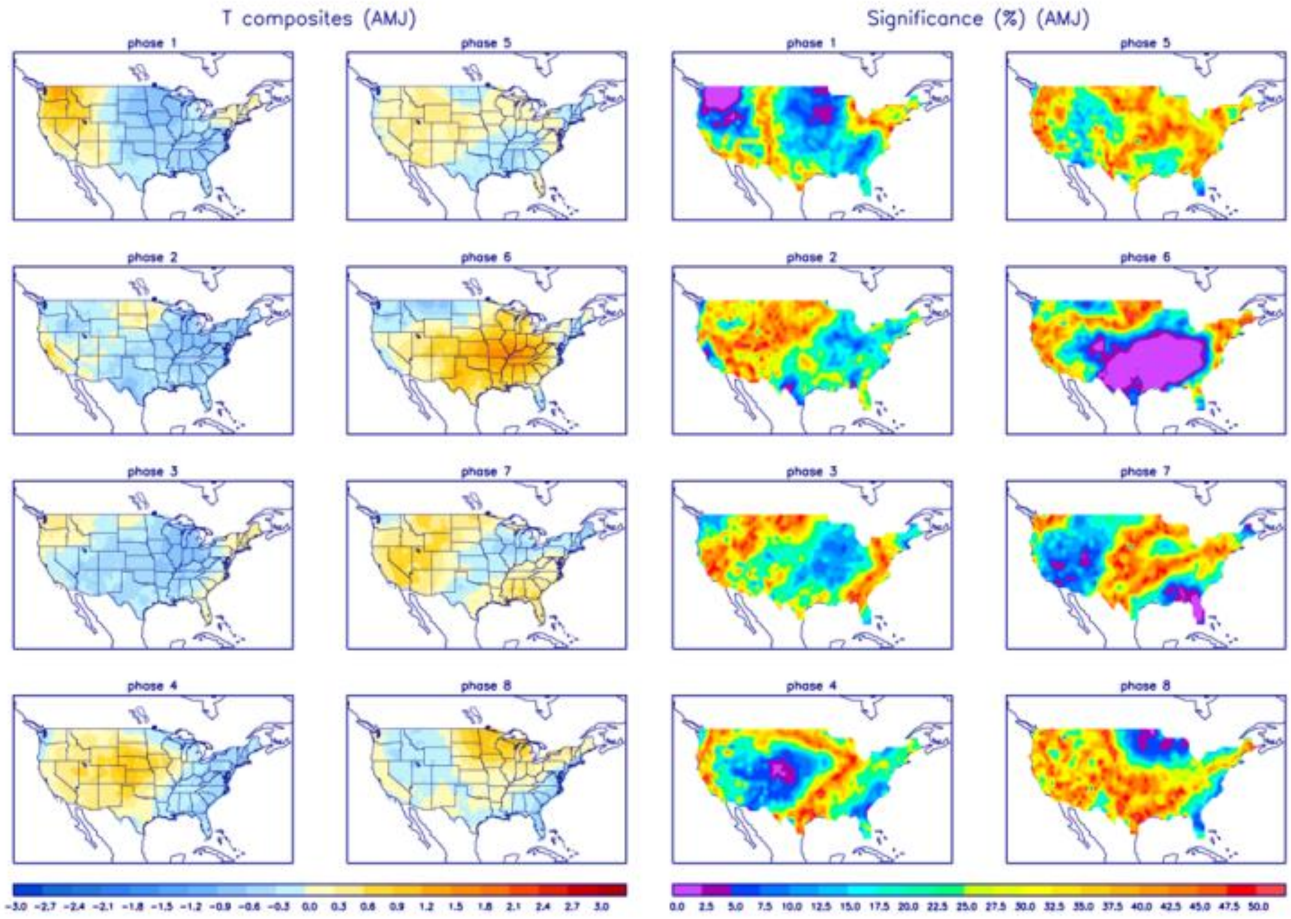
Wind Anomalies (Nov - Mar)



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.

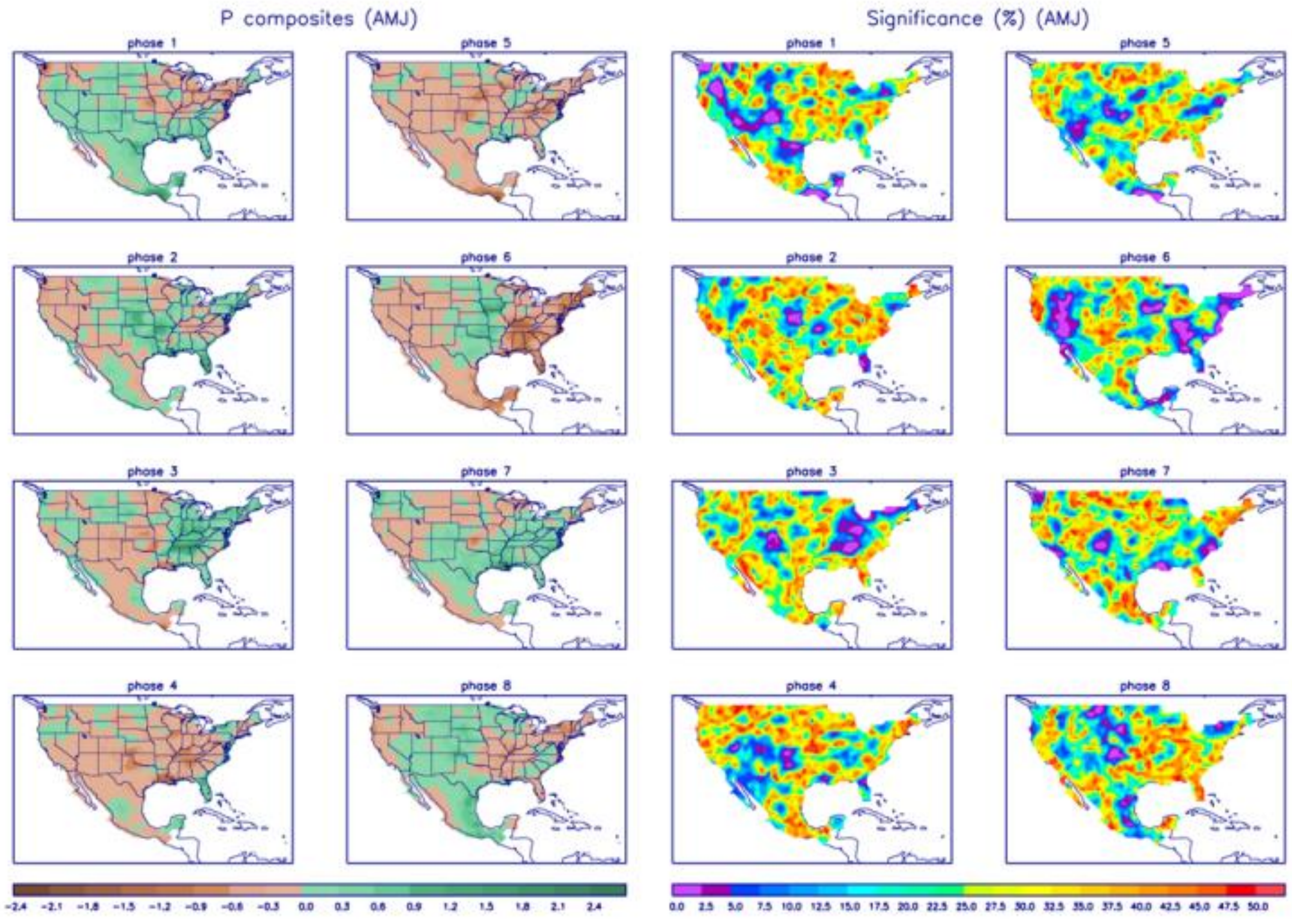
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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