

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



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Outline

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Overview

The MJO signal propagated eastward across the Indian Ocean during the last week, aiding development of Tropical Cyclone Roanu. During the coming week a complex pattern is expected with multiple interfering modes of tropical variability existing jointly with an evolving background state associated with the waning El Niño.

Most dynamical models suggest that the MJO signal will decay during week-1, and become incoherent during week-2.

Enhanced tropical rainfall is likely across the Maritime Continent during week-1. No regions are explicitly favored for tropical cyclogenesis at this time.

Any extratropical impacts of the MJO on the U.S. are anticipated to be negligible, given the typically weak teleconnections during this time of year.

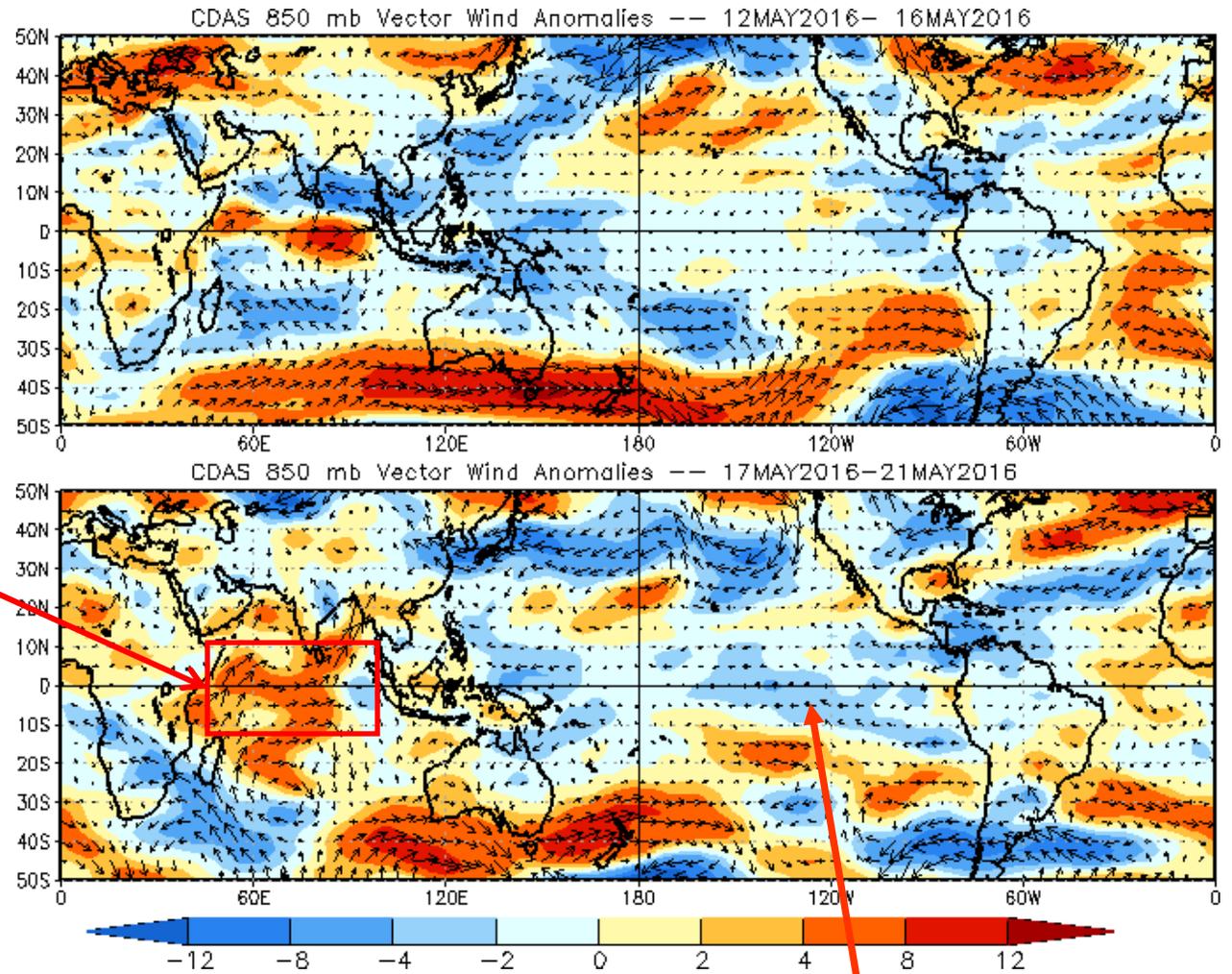
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php>

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 associated with the MJO signal have spread across much of the Indian Ocean. Cross-equatorial flow is also apparent here.

Weak easterly anomalies are evident from near 90 W to the Maritime Continent.

850-hPa Zonal Wind Anomalies (m s⁻¹)

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

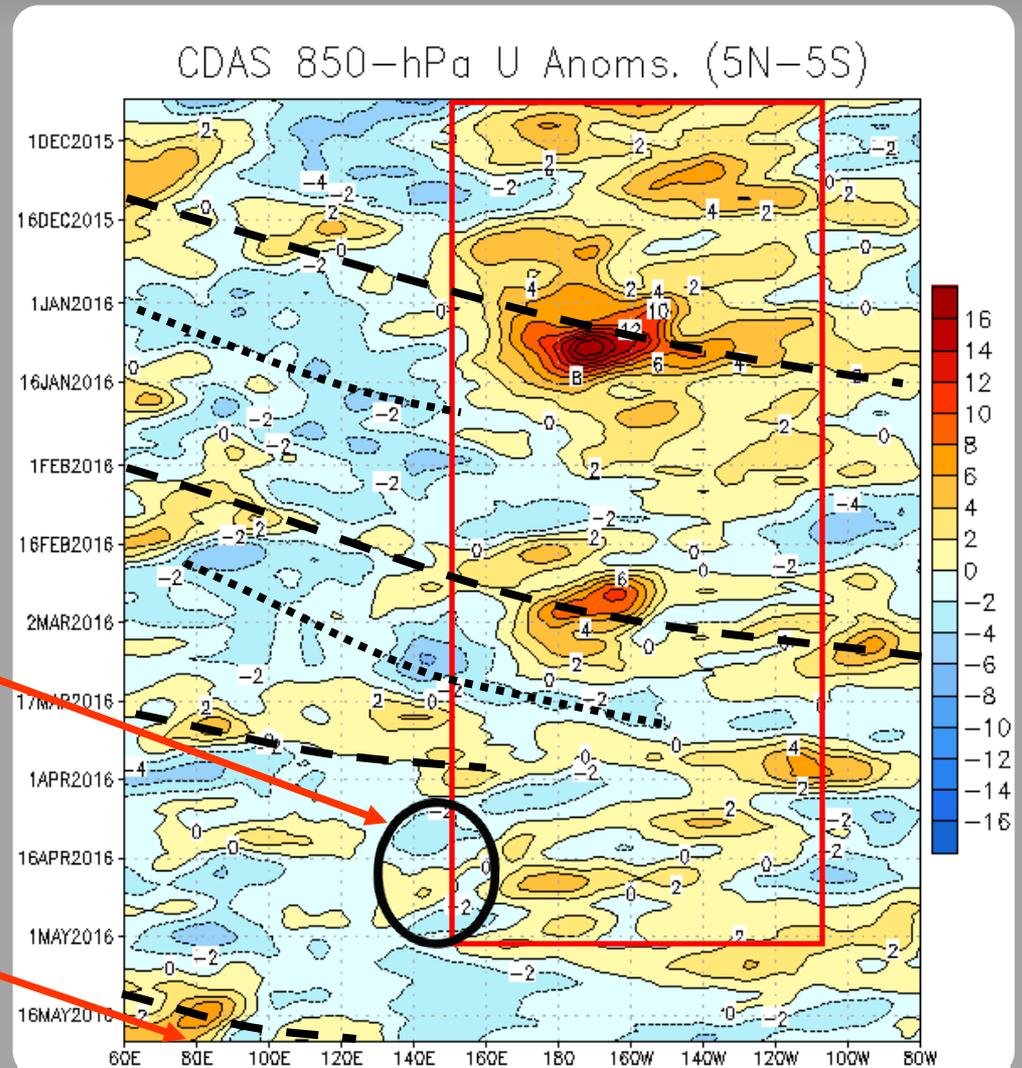
Easterly anomalies (blue shading) represent anomalous east-to-west flow

The red box highlights the persistent low-frequency westerly wind anomalies associated with the 2015-2016 El Niño background state.

During March, a fast eastward propagating intraseasonal signal crossed the Pacific.

During April, the pattern included more high frequency variability including an equatorial Rossby Wave activity (ERW) that shifted westward from near the Date Line to 130 E.

Low-level westerlies have emerged across much of the Indian Ocean during mid-May.



OLR Anomalies - Past 30 days

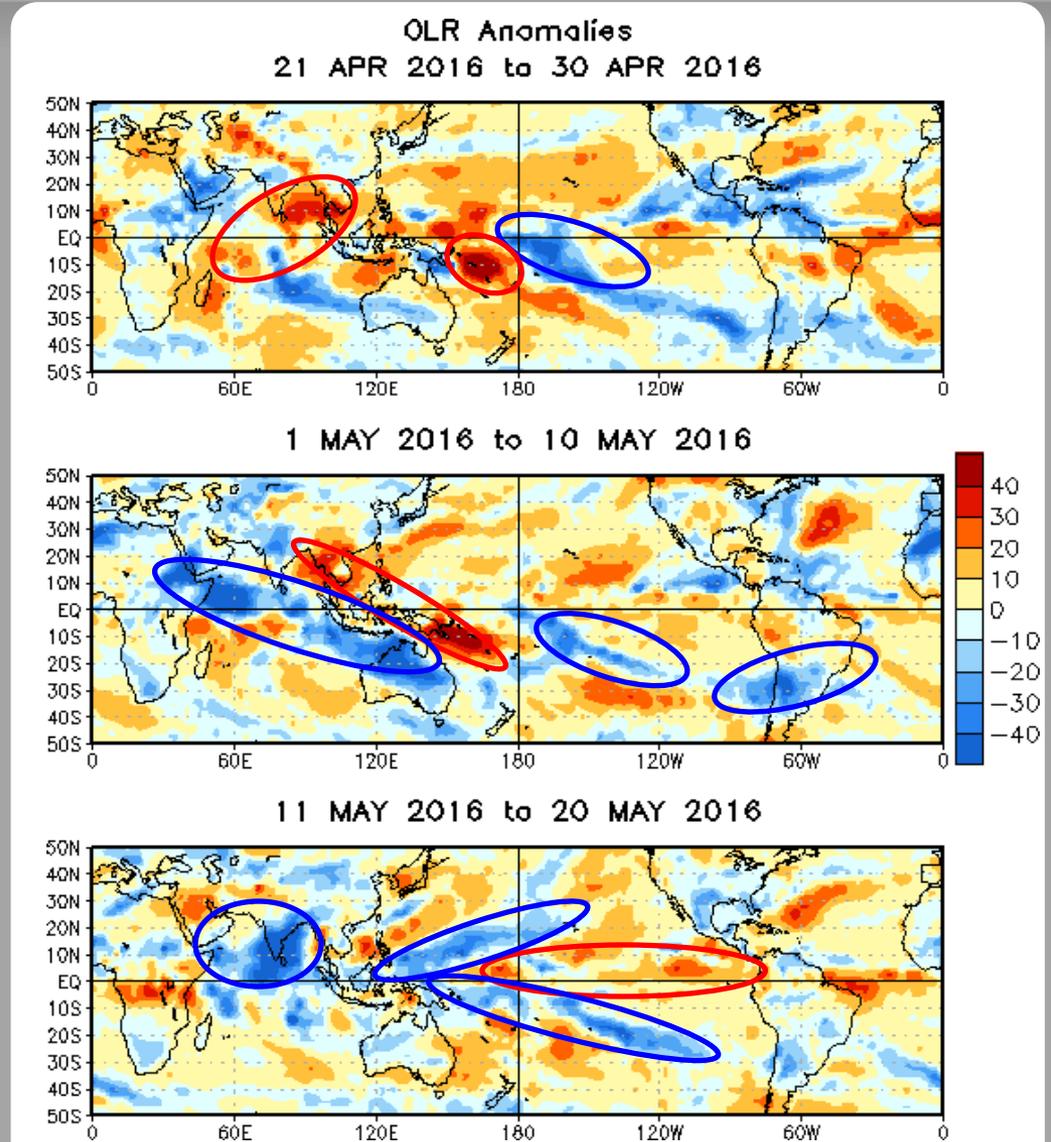
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late April to early May, suppressed convection remained over the eastern Indian Ocean, while the signal became more mixed over the Maritime Continent. SPCZ convection waned.

During early to mid-May, enhanced convection filled in over the Indian Ocean, while generally suppressed convection developed over the eastern Pacific. Some convection remained over the South Pacific.

During mid-May, enhanced convection was focused across the Northern Indian Ocean and Indian subcontinent. Continued suppression of convection occurred over the East Pacific. Anomalous convection remained in a horseshoe-like pattern around the Date Line periphery.



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

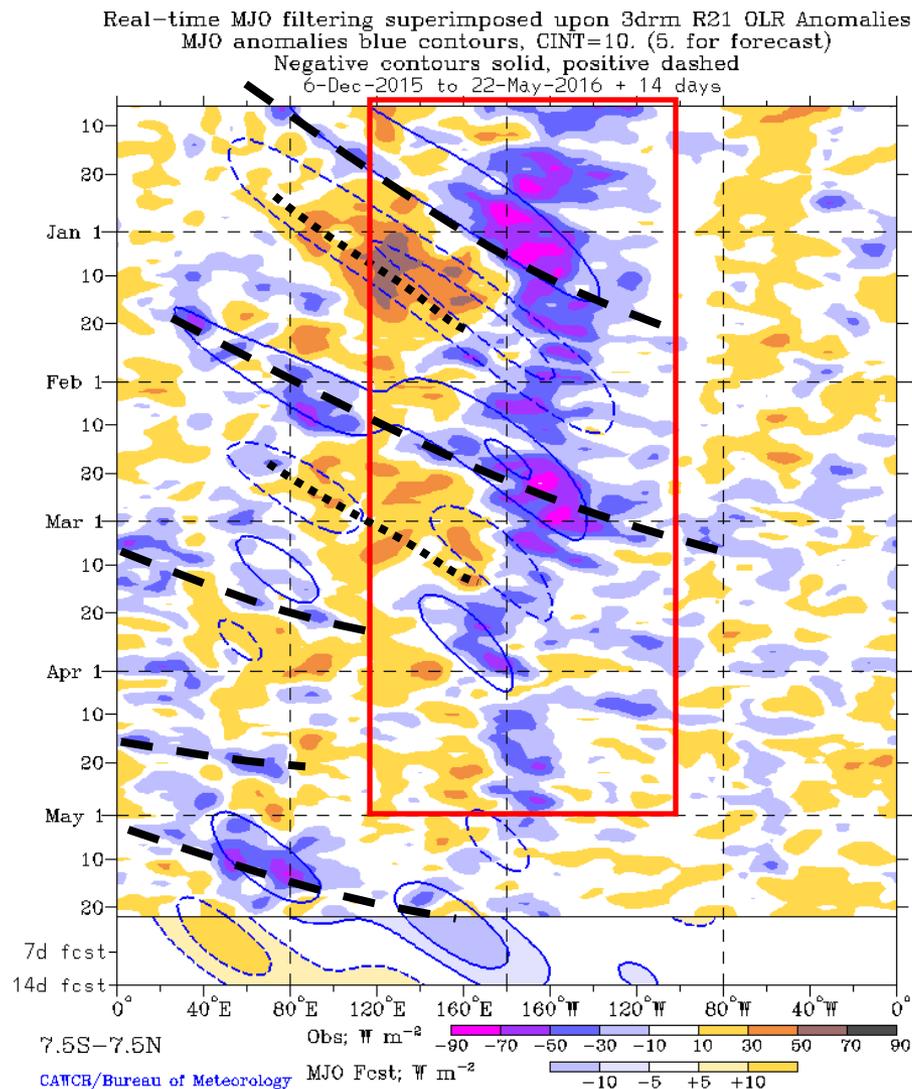
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

The 2015-2016 El Niño background state is observed (red box) as a dipole of anomalous convection extending from the Maritime Continent to the East Pacific.

Alternating periods of constructive/destructive interference with ENSO is evident. A fast eastward propagating signal raced across the Pacific during mid-March.

Since early May an eastward-propagating convective envelope associated with the MJO has developed east of the Prime Meridian. Negative OLR anomalies linked to this feature have lessened relative to the prior week, and propagated over the Maritime Continent. A weakness near 150E appears tied to equatorial Rossby wave activity.



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

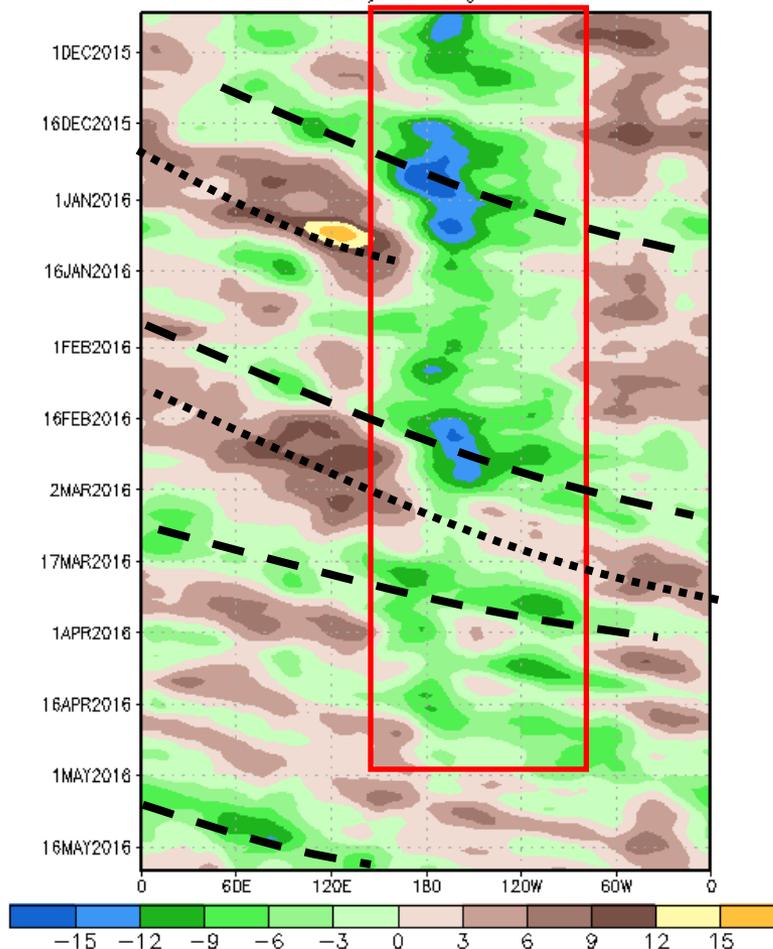
The 2015-16 El Niño background state is highlighted by the red box, showing anomalous divergence over the central and eastern Pacific.

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

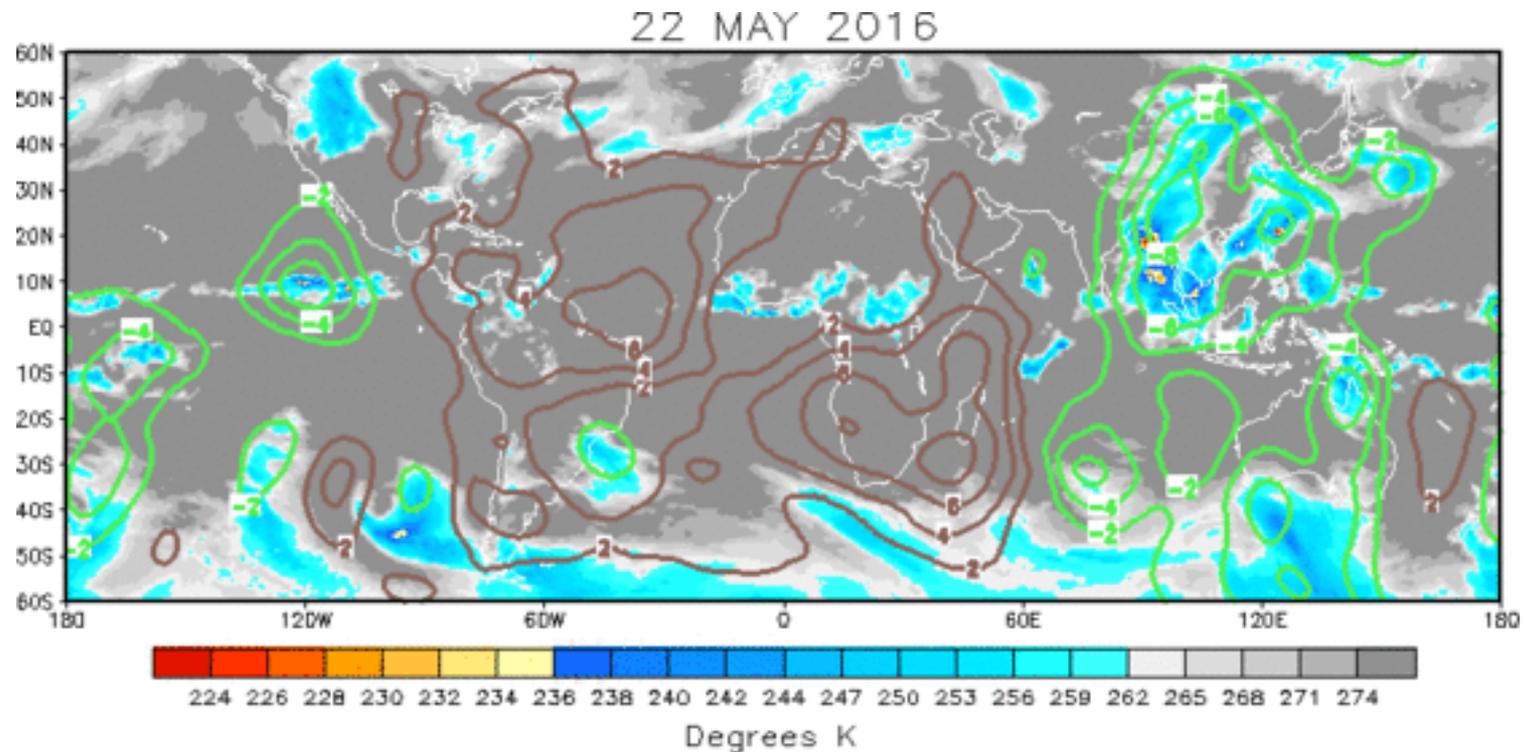
In April, the pattern in upper-level velocity potential anomalies was incoherent with respect to MJO activity, and more reflective of other modes of tropical variability.

During the past 2-3 weeks, an area of upper-level divergence has moved into the region between the Prime Meridian and Date Line with the MJO. Upper-level convergence is noted over much of the Western Hemisphere and building in across Africa.

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



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



The large scale upper-level velocity potential anomaly pattern indicates a wave-1 structure, with upper-level divergence (convergence) eastward from about 60E to 100W (100W to 60E). Two Kelvin waves are present in the E. Pacific (160W and 120W) with another over Africa near the Prime Meridian.

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

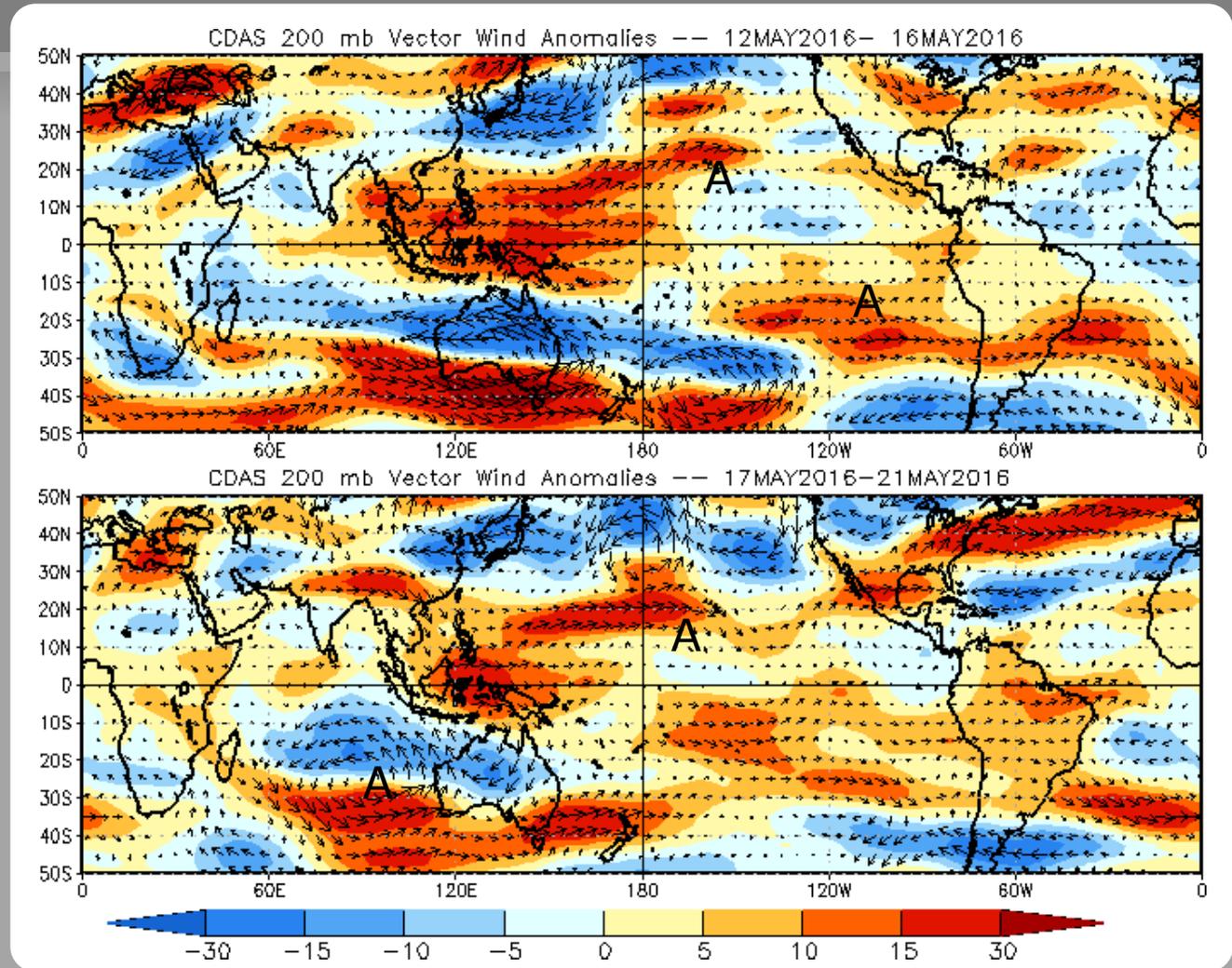
Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Only one anomalous anticyclone is evident this week associated with El Niño, as westerly anomalies have filled in over the South Pacific. Convergence prevails near the Date Line.

Upper-level equatorial westerlies extend across the entire Eastern Hemisphere, with peak values focused across the Maritime Continent.

A well-defined anomalous anticyclone is also apparent west of Australia.



200-hPa Zonal Wind Anomalies (m s⁻¹)

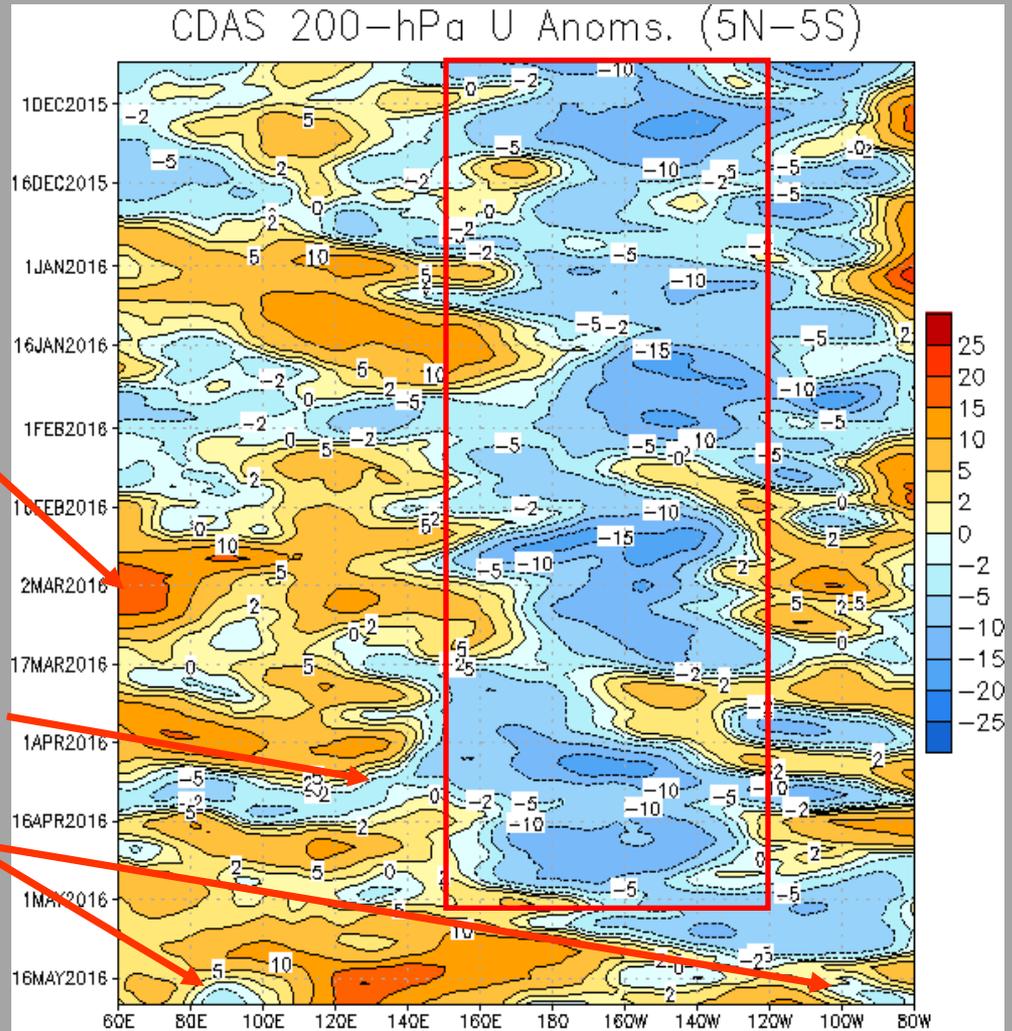
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

Easterly anomalies have persisted over the central and eastern Pacific from June 2015 through May 2016 associated with El Niño (red box).

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

Since mid April, westerly anomalies weakened and then re-strengthened over the Indian Ocean & Maritime Continent. These westerlies now extend through the Central Pacific. Easterly anomalies are confined to east of 100W and between 80-100E.



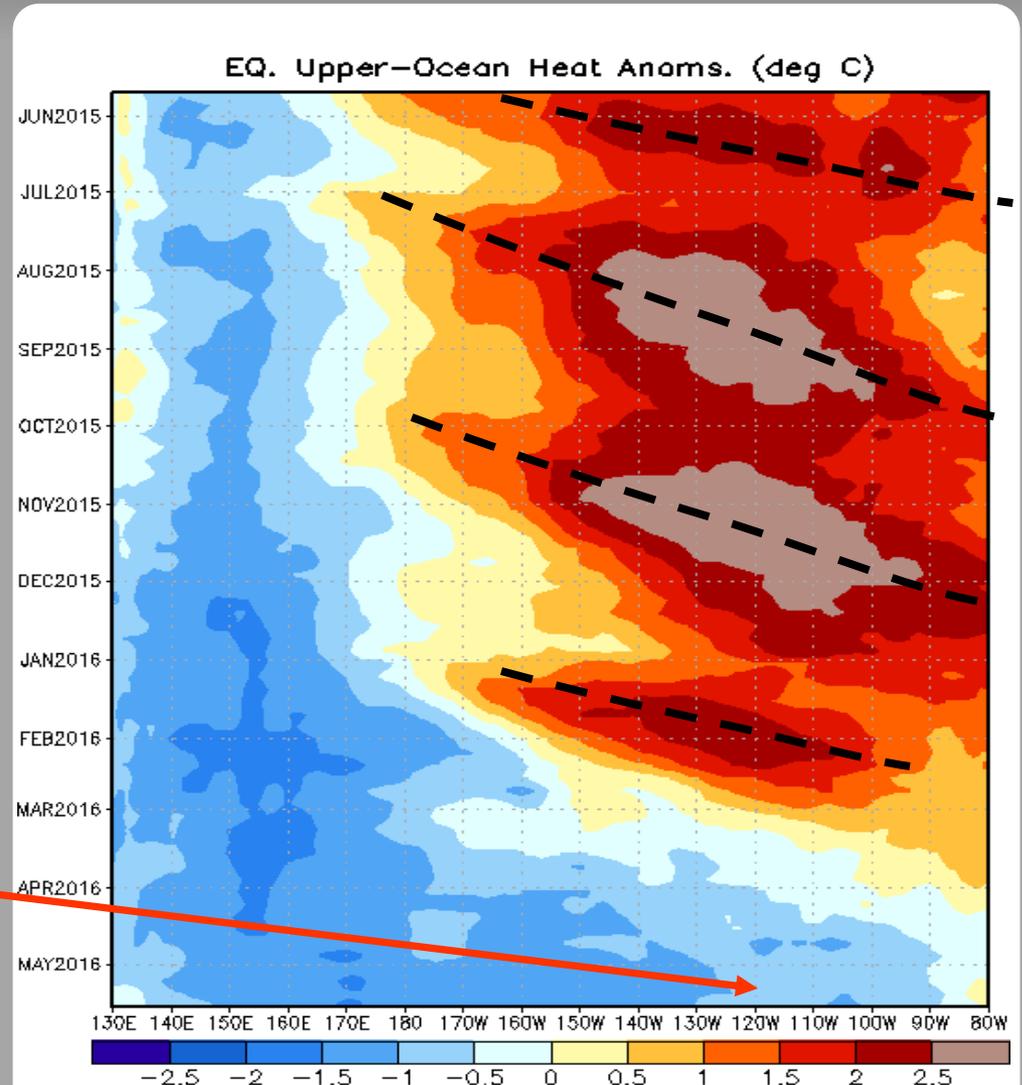
Weekly Heat Content Evolution in the Equatorial Pacific

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.

Reinforcing downwelling events were observed during the second half of 2015, 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, with negative anomalies beginning to spread east of the Date Line.

In the last two months, there has been a rapid eastward expansion of below-average oceanic heat content across the central and eastern Pacific. Negative anomalies now extend across the entire equatorial Pacific with the exception of just off the Peruvian coast.



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

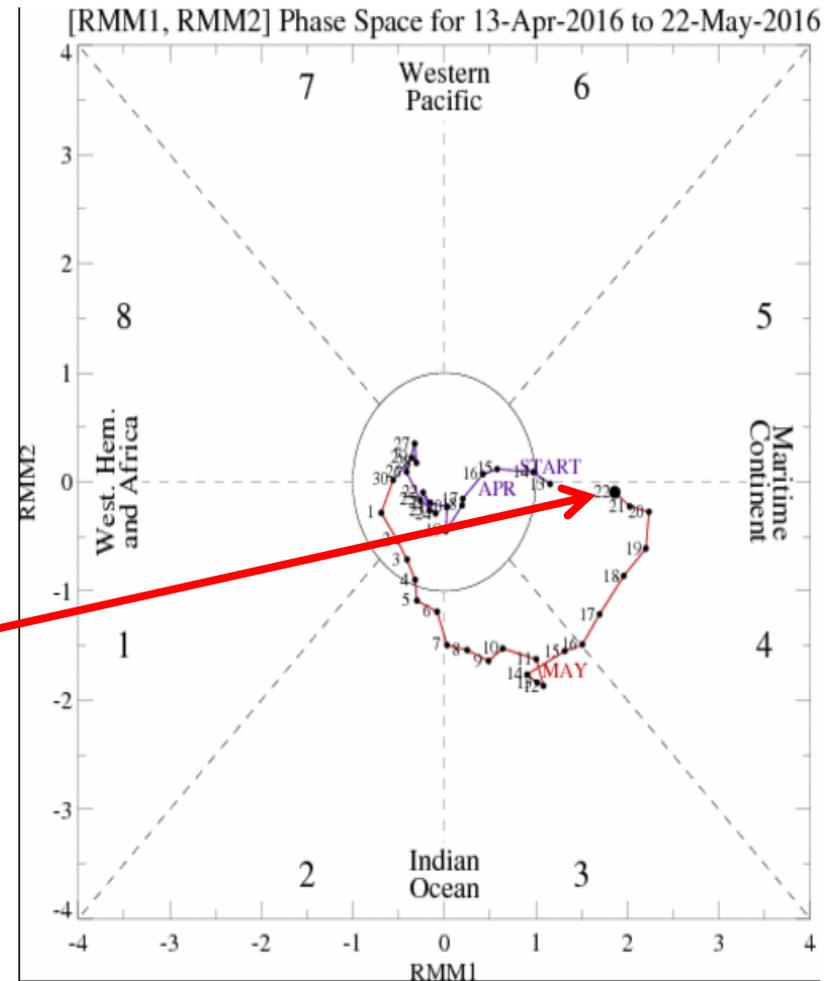
The triangular areas indicate the location of the enhanced phase of the MJO

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

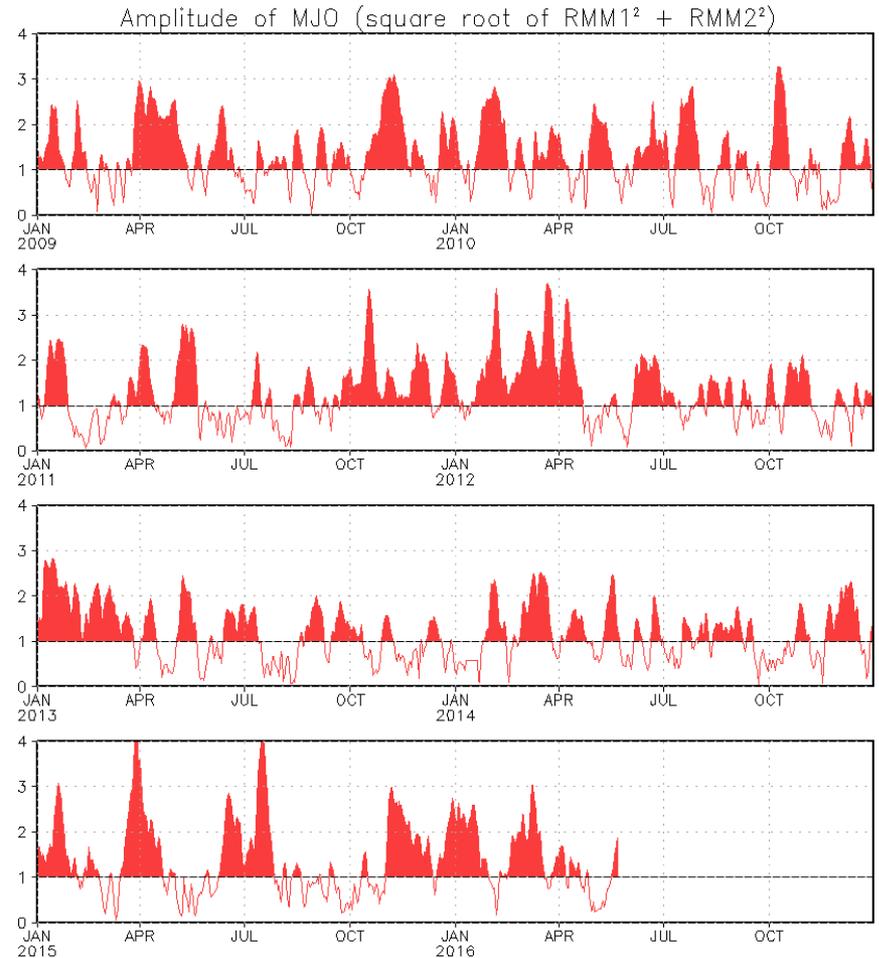
A strong MJO signal continues to persist across the eastern Indian Ocean. Eastward propagation was apparent over the past week, however at the end of the week the signal stagnated somewhat and weakened slightly, possibly due to destructive Rossby wave interference.



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

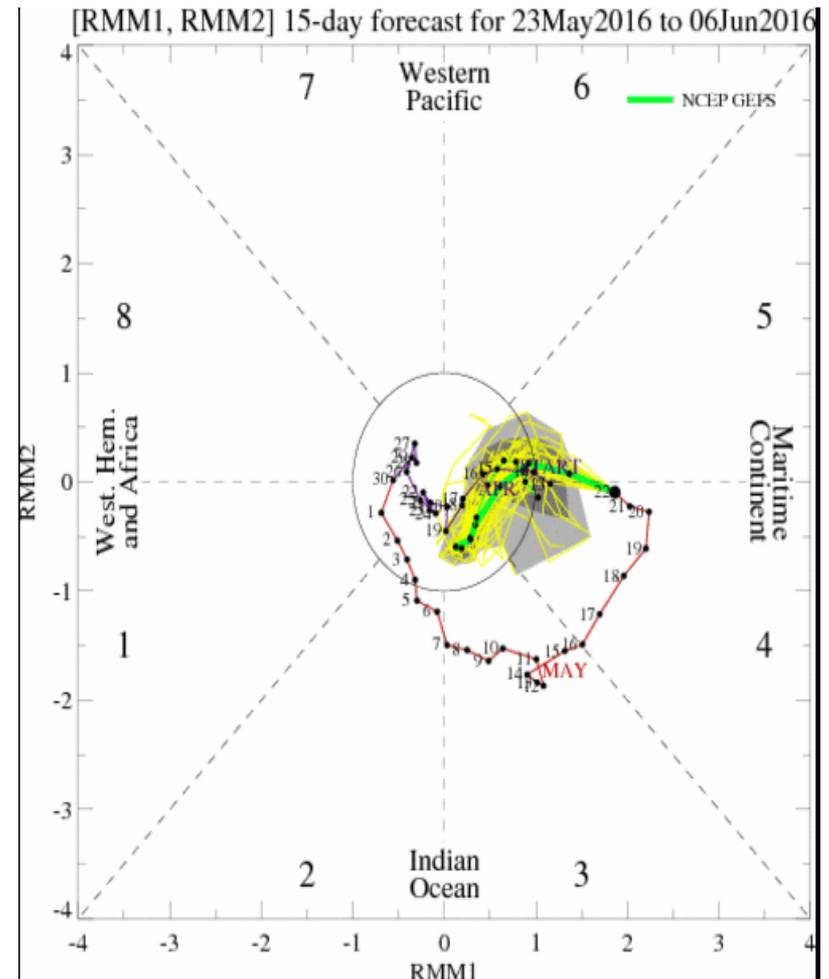
light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

During the next two weeks, the GFS ensemble MJO index forecast depicts the MJO signal to weaken, before some ensemble members suggest re-emergence during week-2 over the Maritime Continent.

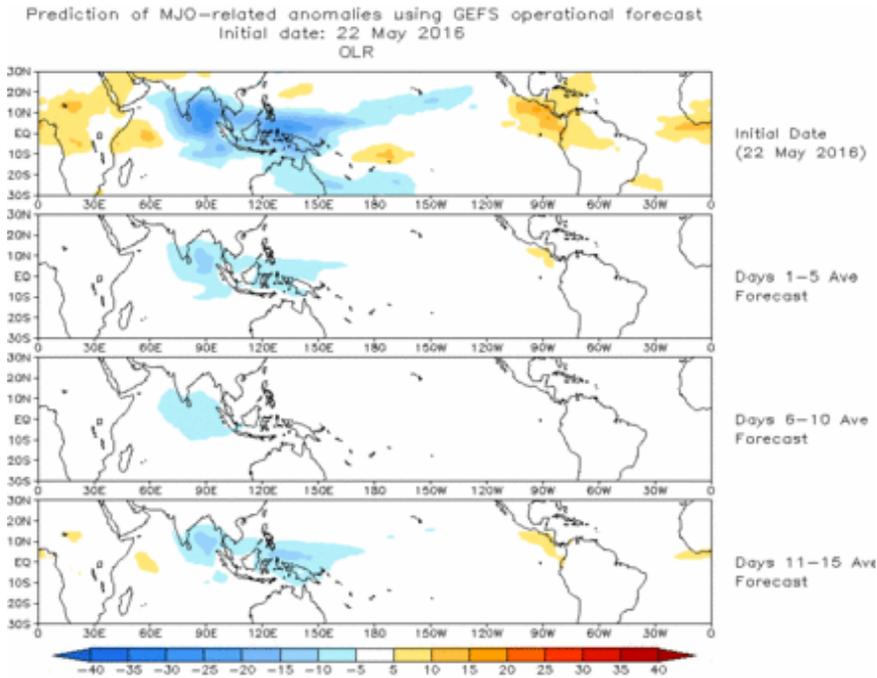
Some of this complicated signal may be due to the decaying El Niño event being aliased into the RMM indices through the changing of the background 120-day mean state.

Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean



Ensemble GFS (GEFS) MJO Forecast

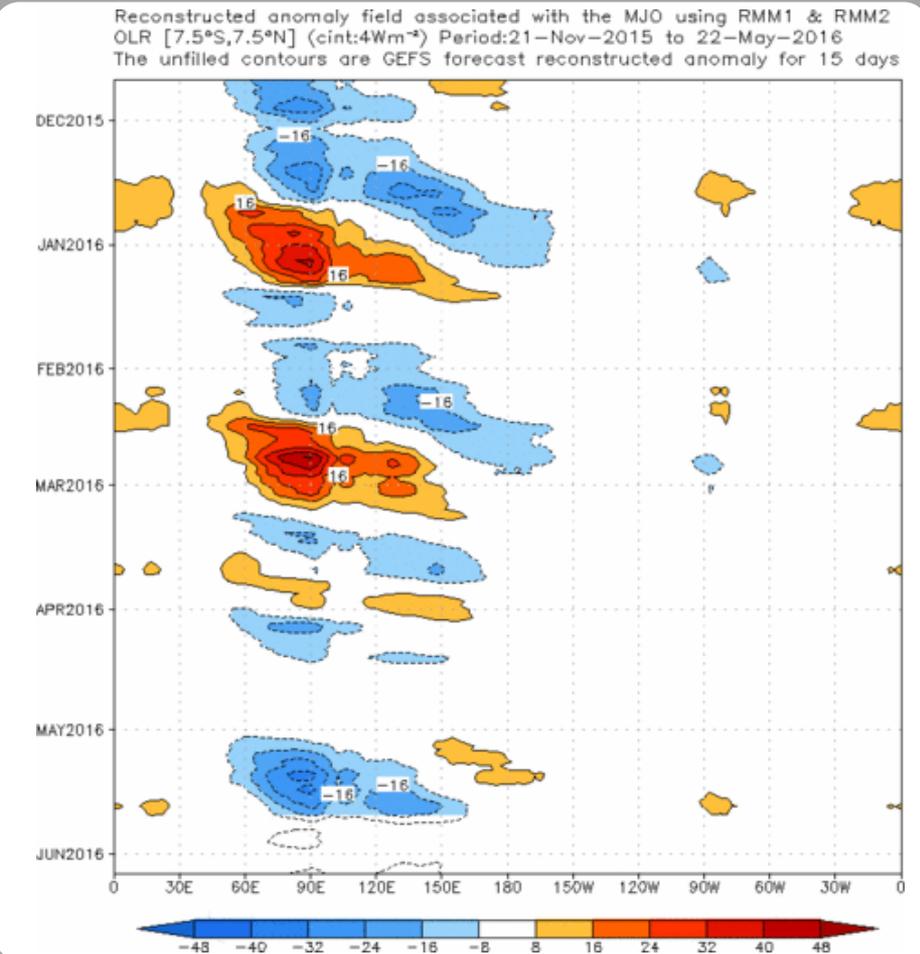
Spatial map of OLR anomalies for the next 15 days



The GEFS OLR forecast based on the RMM Index depicts a relatively stable and weakening solution with enhanced (suppressed) convection over the Indian Ocean and Maritime Continent (East Pacific).

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.)

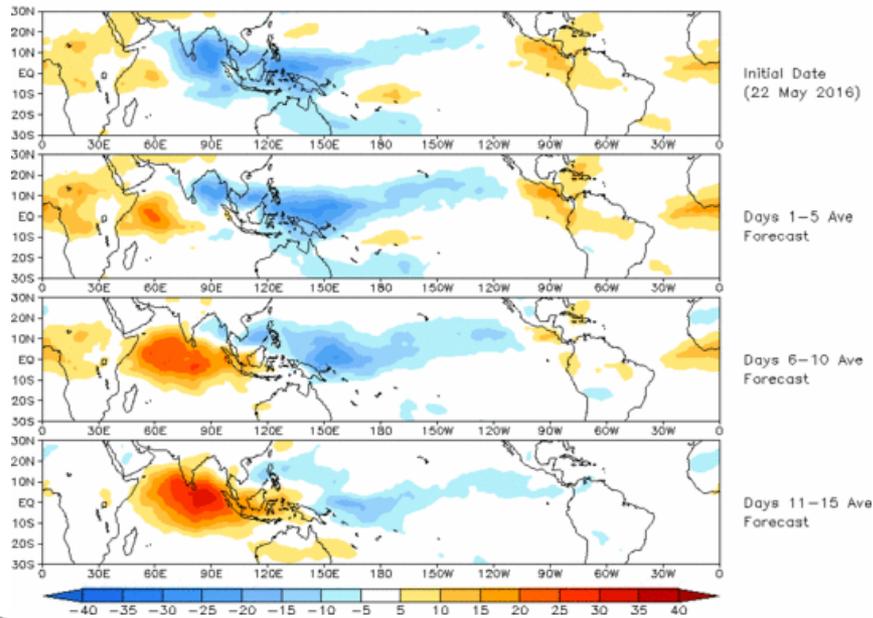
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



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 (22 May 2016)

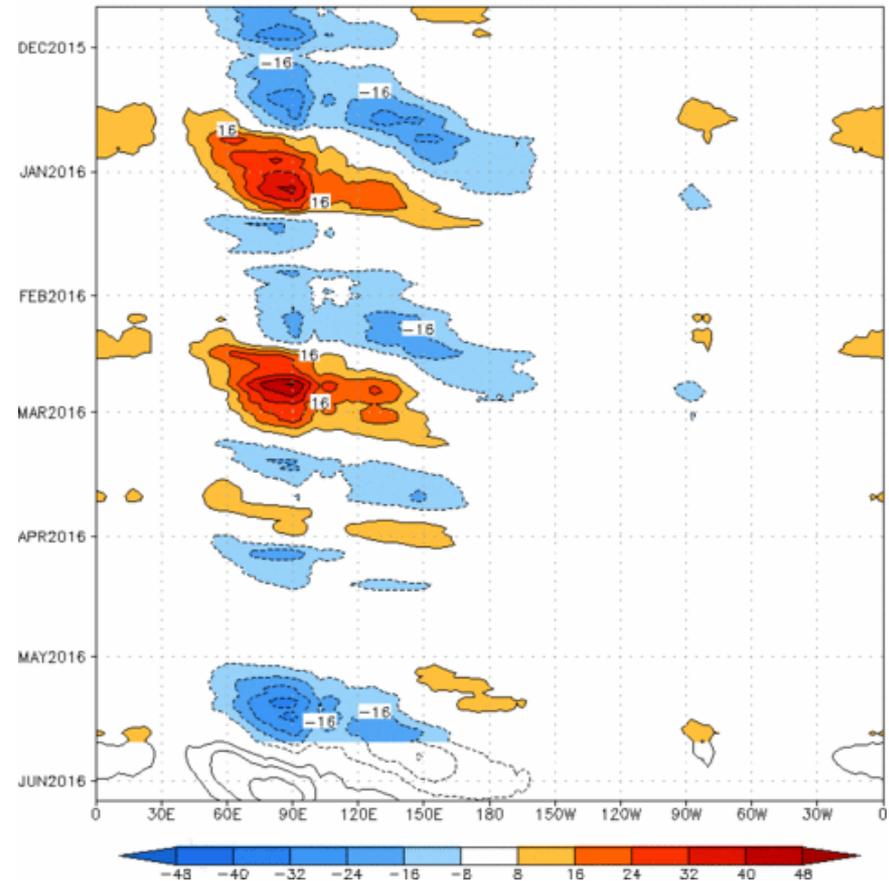


The Constructed Analog (CA) model predicts a weakening and eastward propagating intraseasonal signal during the next two weeks with strongly suppressed convection developing across the Indian Ocean.

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.)

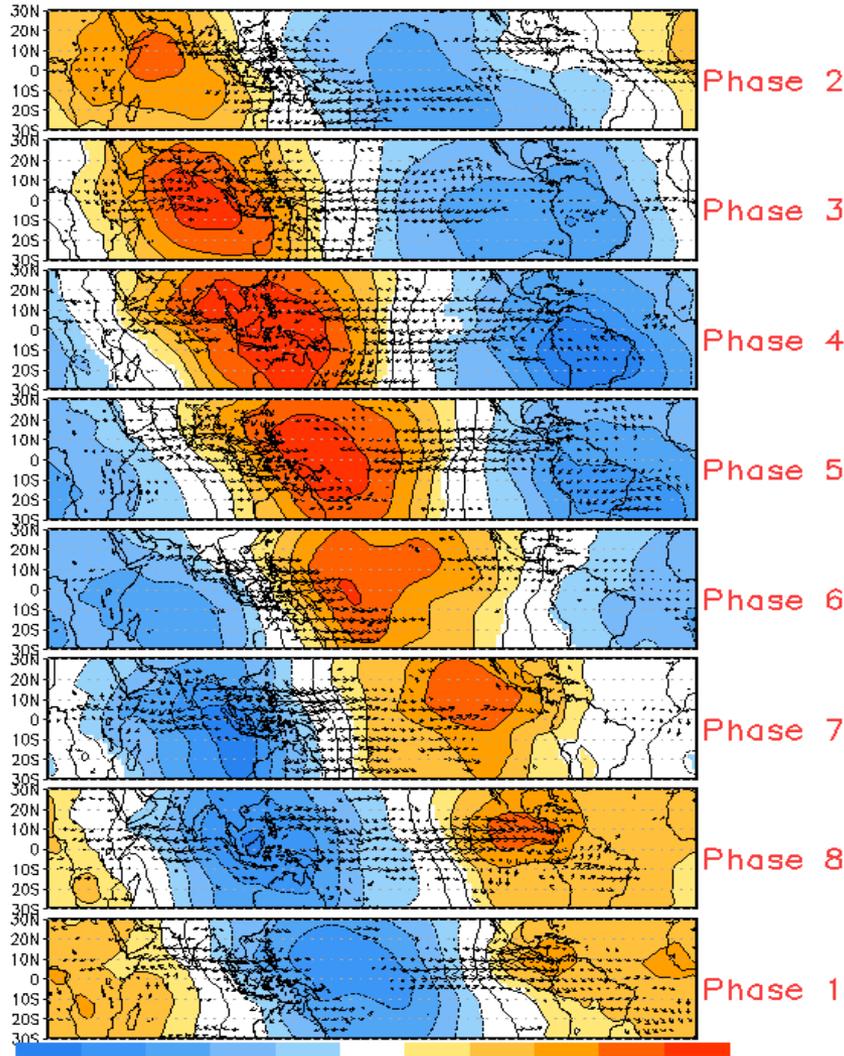
Time-longitude section of (7.5° S- 7.5° N) OLR anomalies - last 180 days and for the next 15 days

Reconstructed anomaly field associated with the MJO using RMM1 & RMM2 OLR [7.5° S, 7.5° N] (cont:4Wm⁻²) Period:21-Nov-2015 to 22-May-2016
The unfilled contours are CA forecast reconstructed anomaly for 15 days

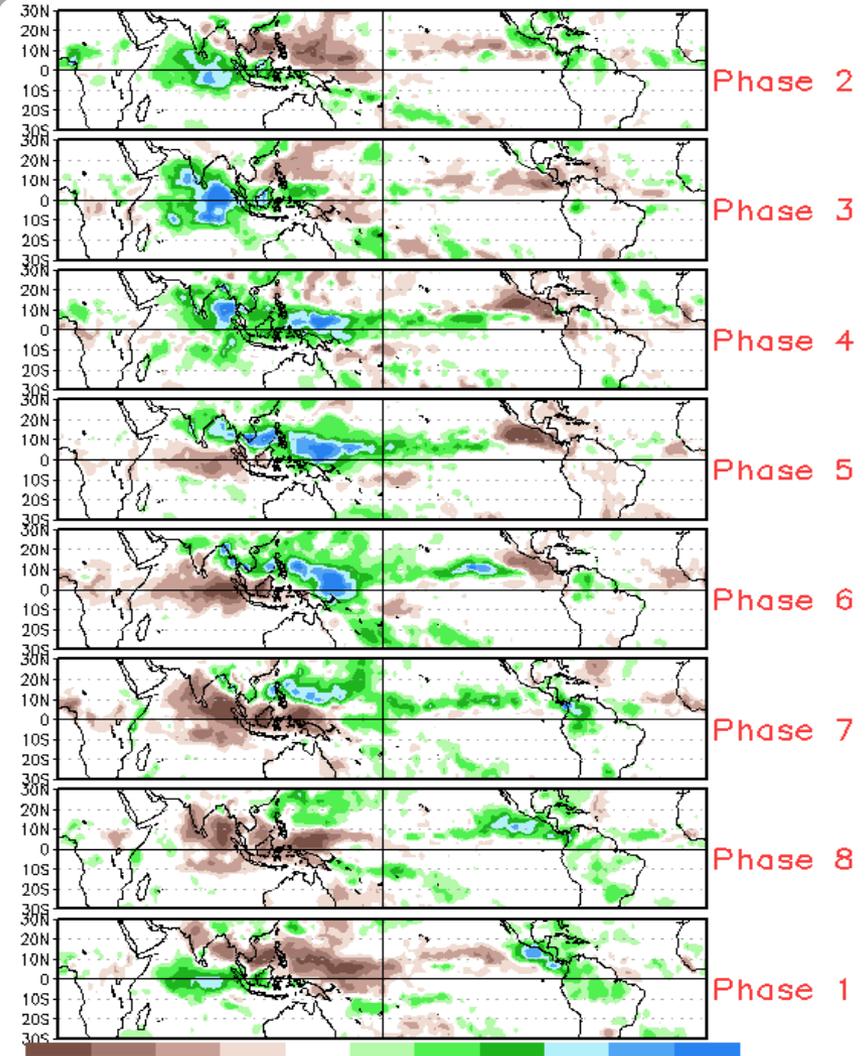


MJO Composites - Global Tropics

850-hPa Velocity Potential and
Wind Anomalies (May - Sep)



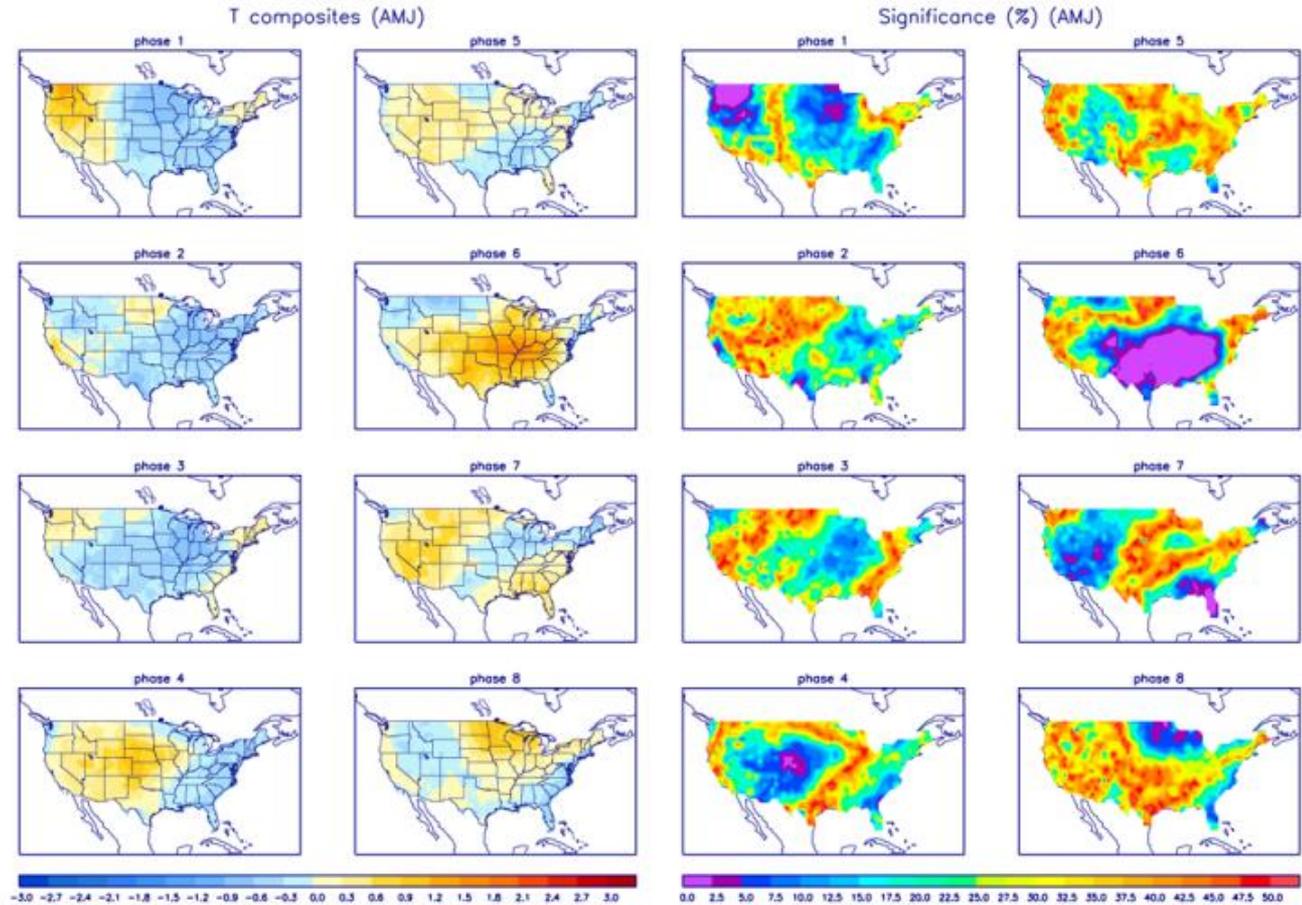
Precipitation Anomalies (May - Sep)



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.



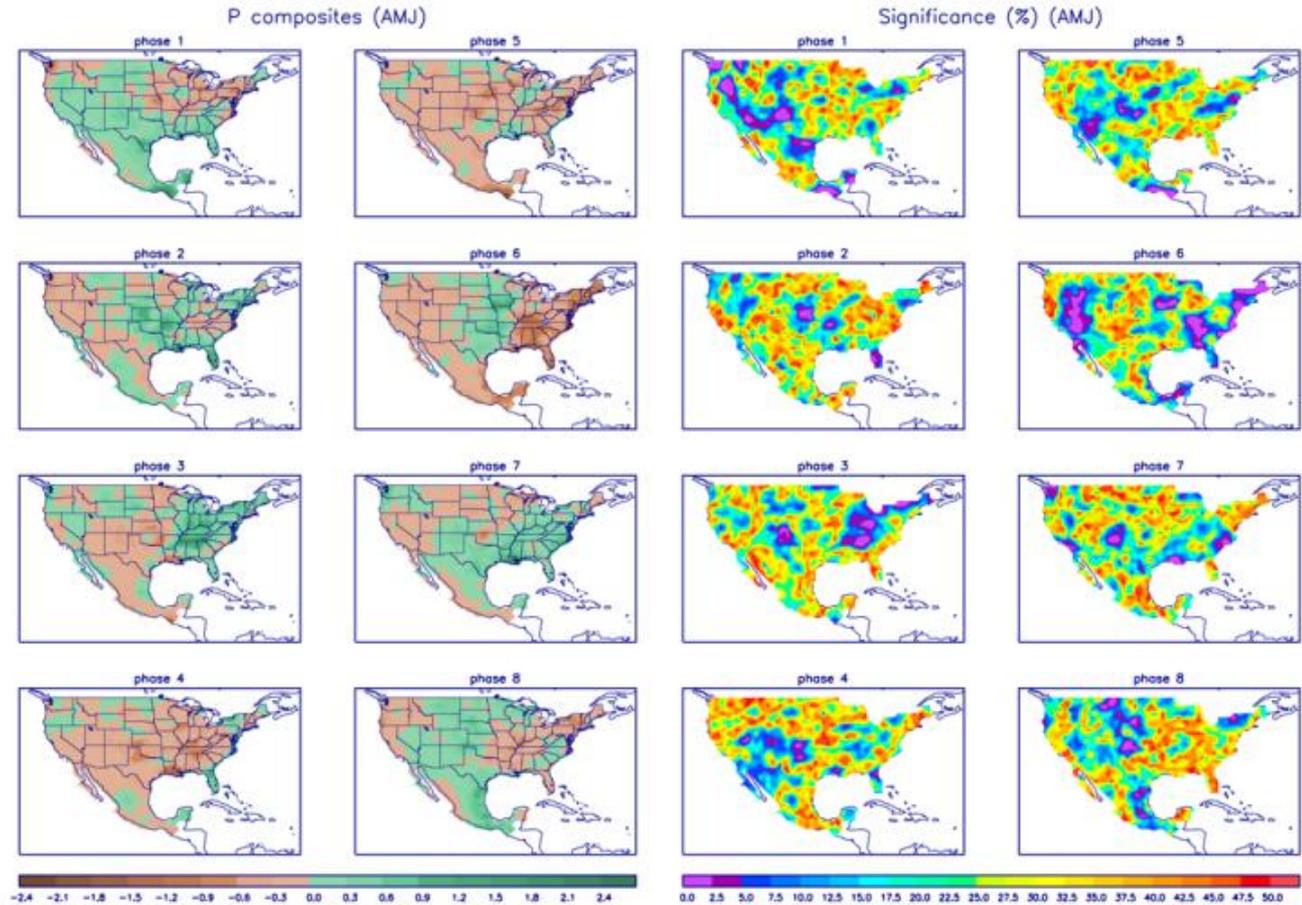
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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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