

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



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Climate Prediction Center / NCEP
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Overview

A robust MJO continued during the past week, with the enhanced phase over the the eastern Indian Ocean and Maritime Continent.

Dynamical models indicate a weakening of the MJO signal by Week-2. This weakening may be associated with a Kelvin wave ahead of the MJO and a low frequency feature favoring suppressed convection over the western North Pacific.

A Kelvin Wave is likely to contribute to tropical cyclone formation across the eastern Pacific during Week-1. Environmental conditions are expected to remain favorable for additional tropical cyclone formation across the eastern Pacific during Week-2 with an enhancement of low-level moisture over northwest Mexico.

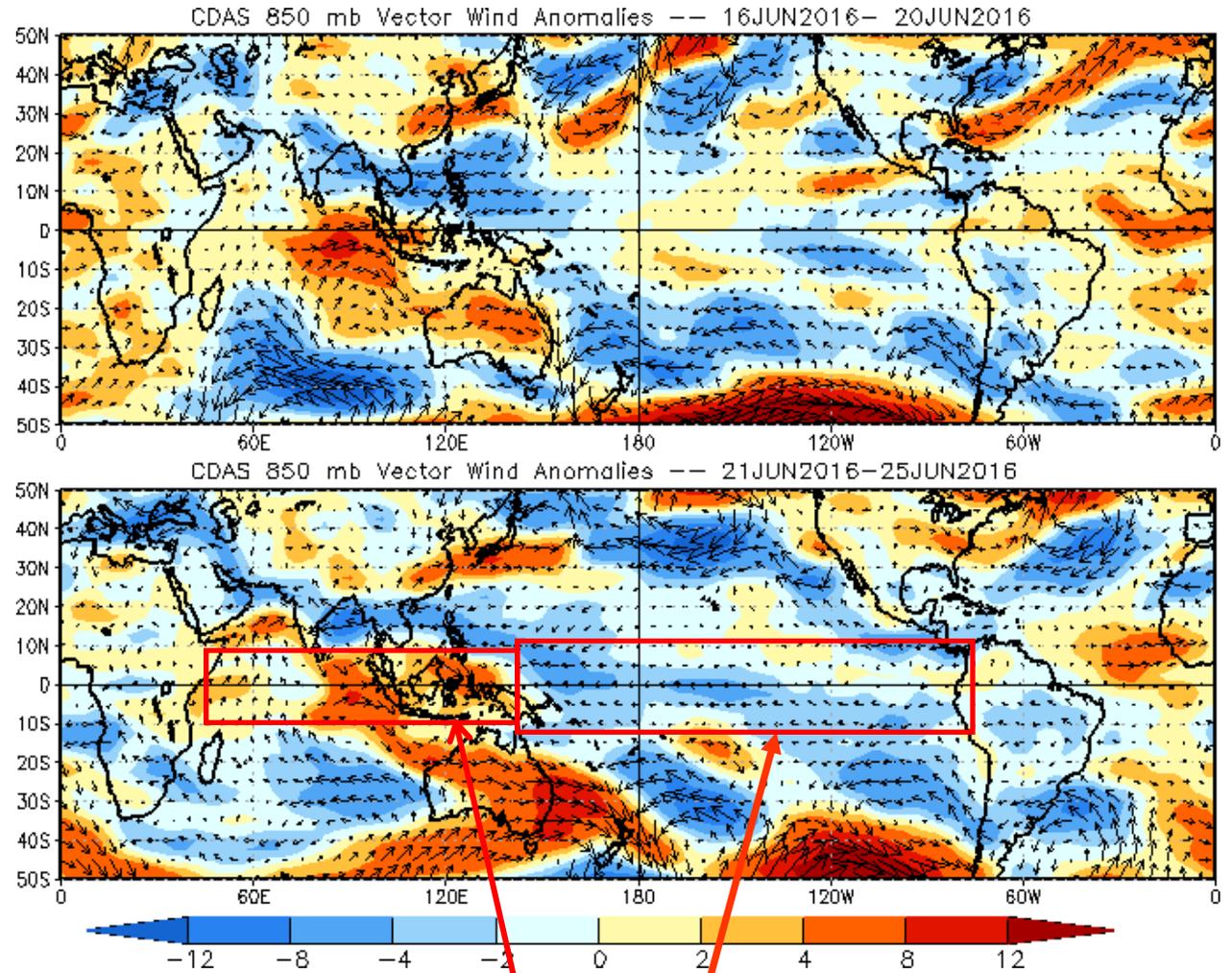
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
<http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php>

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 (easterly)
anomalies expanded across
the Maritime Continent
(equatorial Pacific)

850-hPa Zonal Wind Anomalies (m s⁻¹)

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

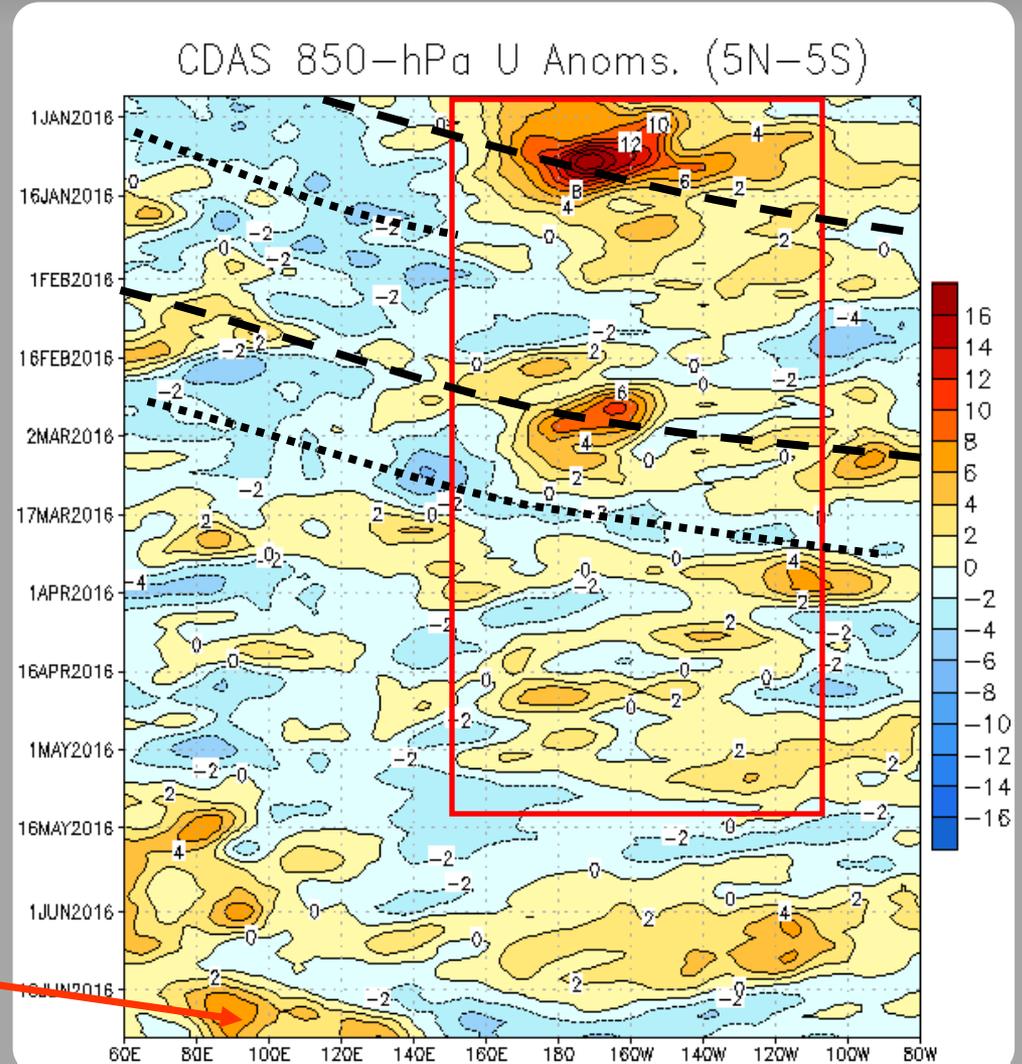
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

Several fast-propagating intraseasonal events modulated the El Niño base state, and are marked using long (short) dashed lines for the enhanced (suppressed) phase of the intraseasonal signal.

During April, the wind field became less coherent as El Niño conditions weakened. Westerly anomalies strengthened over the Indian Ocean in late May, with some eastward propagation.

During late June, westerly anomalies increased over the eastern Indian Ocean and Maritime Continent with easterly anomalies returning to the Pacific Ocean.



OLR Anomalies - Past 30 days

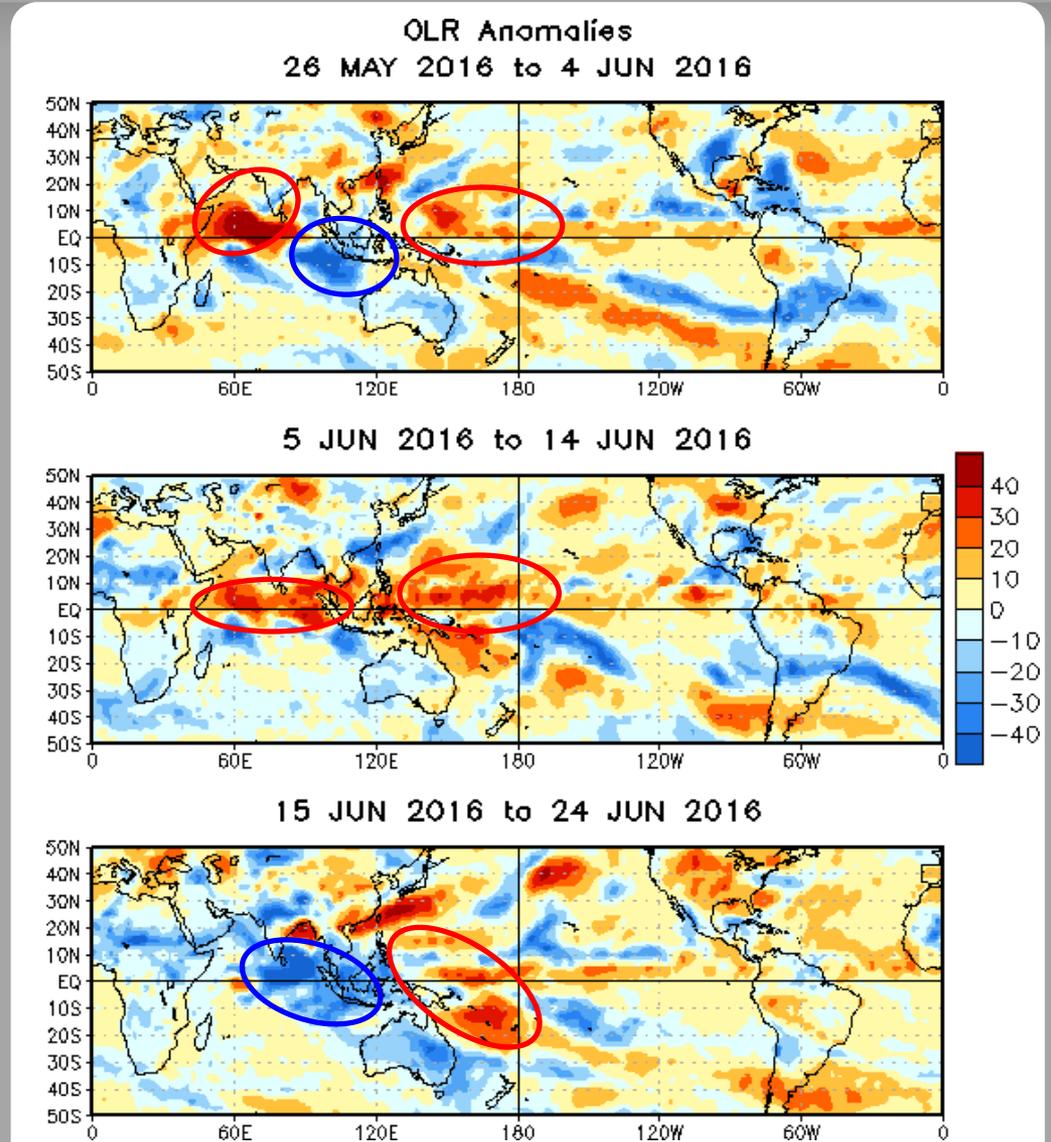
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late May and early June, enhanced convection encompassed the western Maritime Continent, with suppressed convection across the western Indian Ocean. Suppressed convection was also observed over much of the equatorial Pacific.

During early and mid-June, suppressed convection overspread the equatorial Indian Ocean. The enhanced convective envelope over the Maritime Continent weakened, however, and did not enter the West Pacific.

Enhanced convection returned to the eastern Indian Ocean and western Maritime Continent during mid to late June, while suppressed convection persisted over the western equatorial Pacific.



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

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

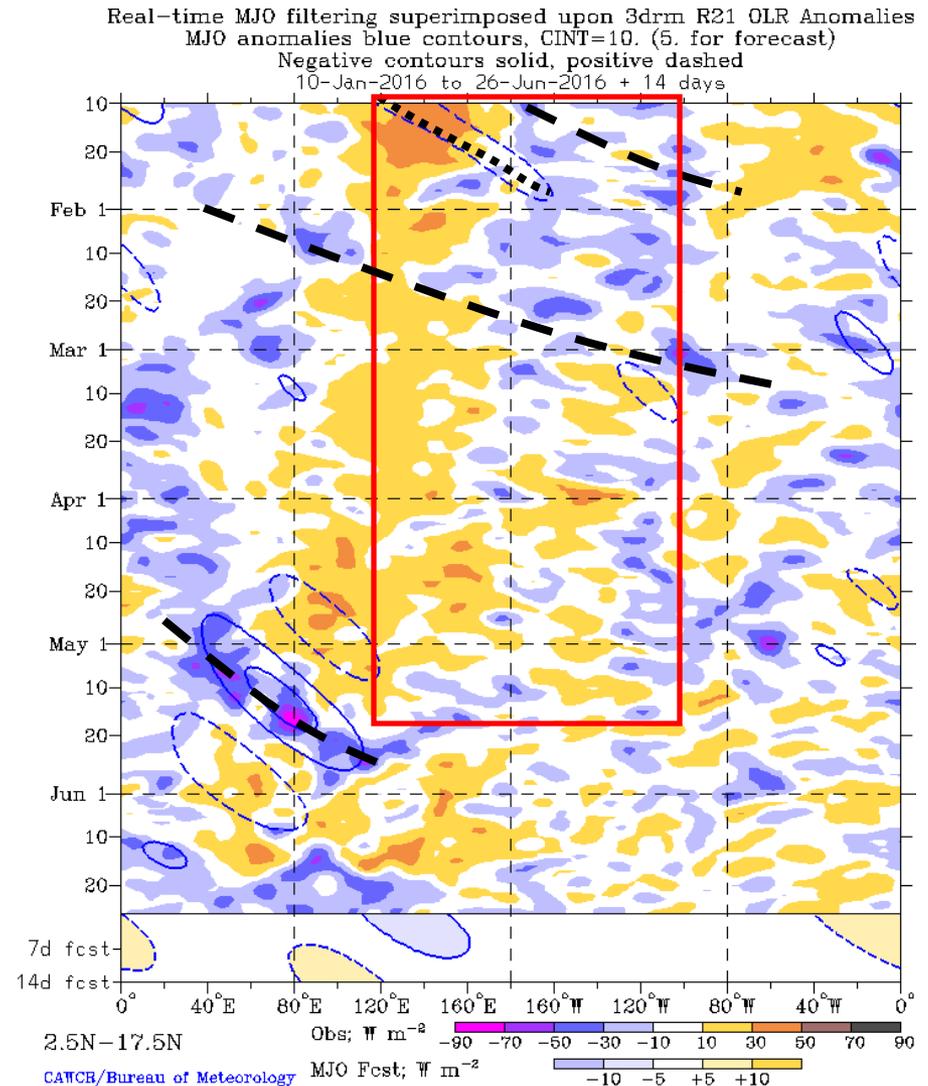
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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. The signal weakened steadily during the past several months.

Alternating periods of constructive and destructive interference with El Niño are evident. A fast eastward propagating signal raced across the Pacific during February.

During early May, an eastward-propagating convective envelope associated with the MJO developed east of the Prime Meridian. This OLR signal weakened over the Pacific.

Recently, convection has redeveloped over the Indian Ocean and expanded east to the Maritime Continent.



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.

MJO activity was evident during January, and again in late February and March, alternatively constructively and destructively interfering with the ENSO background state.

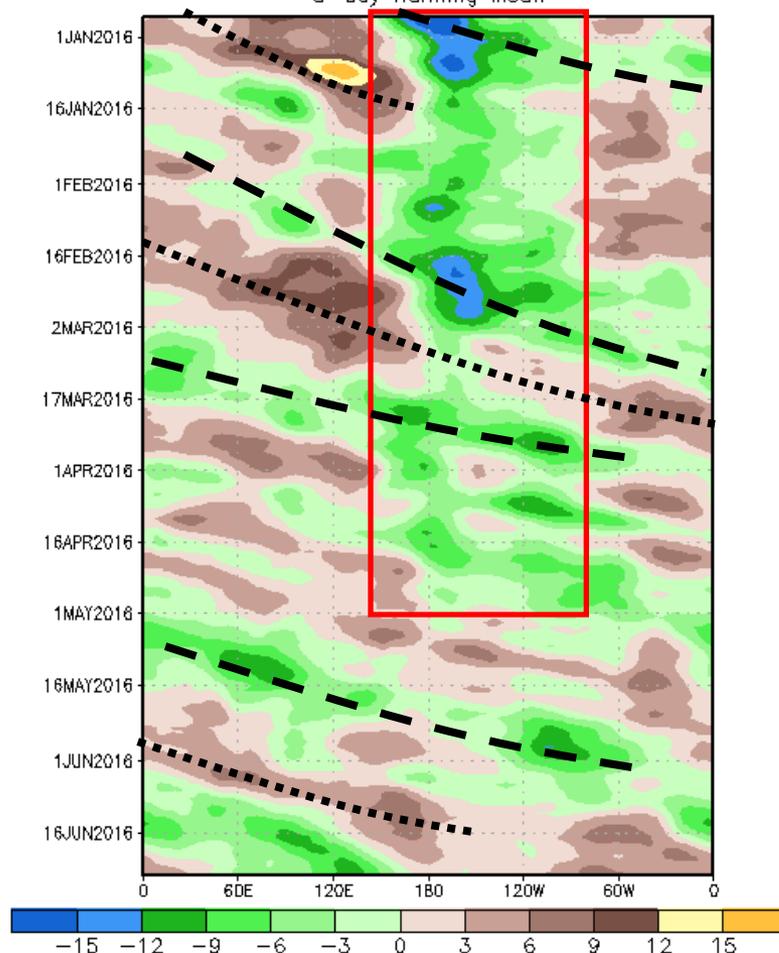
The upper-level velocity potential pattern became less coherent as the El Niño waned during April.

During May and early June, an eastward propagating signal was evident in the upper-level velocity potential field. This signal was more coherent than the low-level MJO indicators.

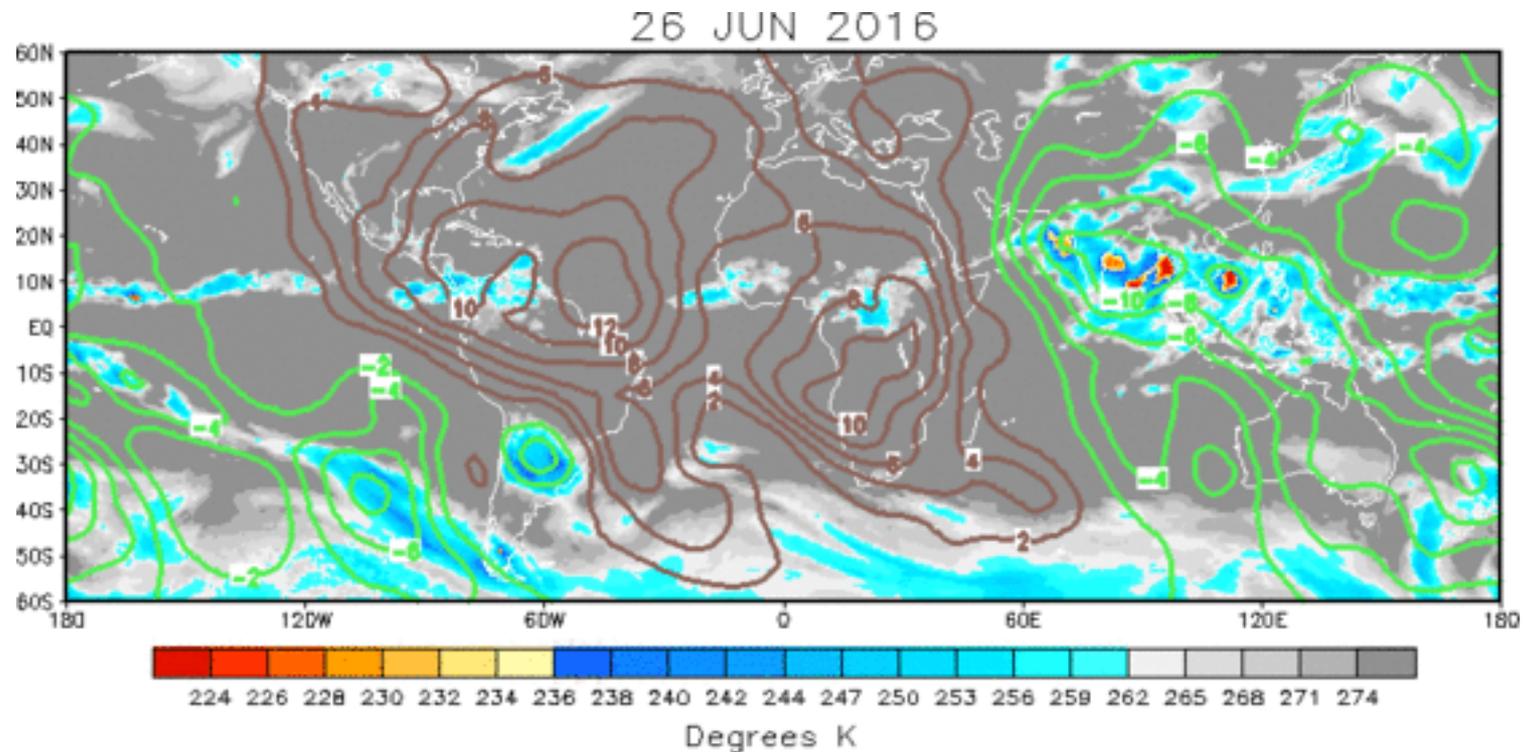
More recently, anomalous divergence returned to the Indian Ocean and western Maritime Continent.

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 is a coherent Wave-1 field with negative (positive) anomalies over the eastern Indian Ocean and Maritime Continent (Americas, Atlantic Ocean, and Africa).

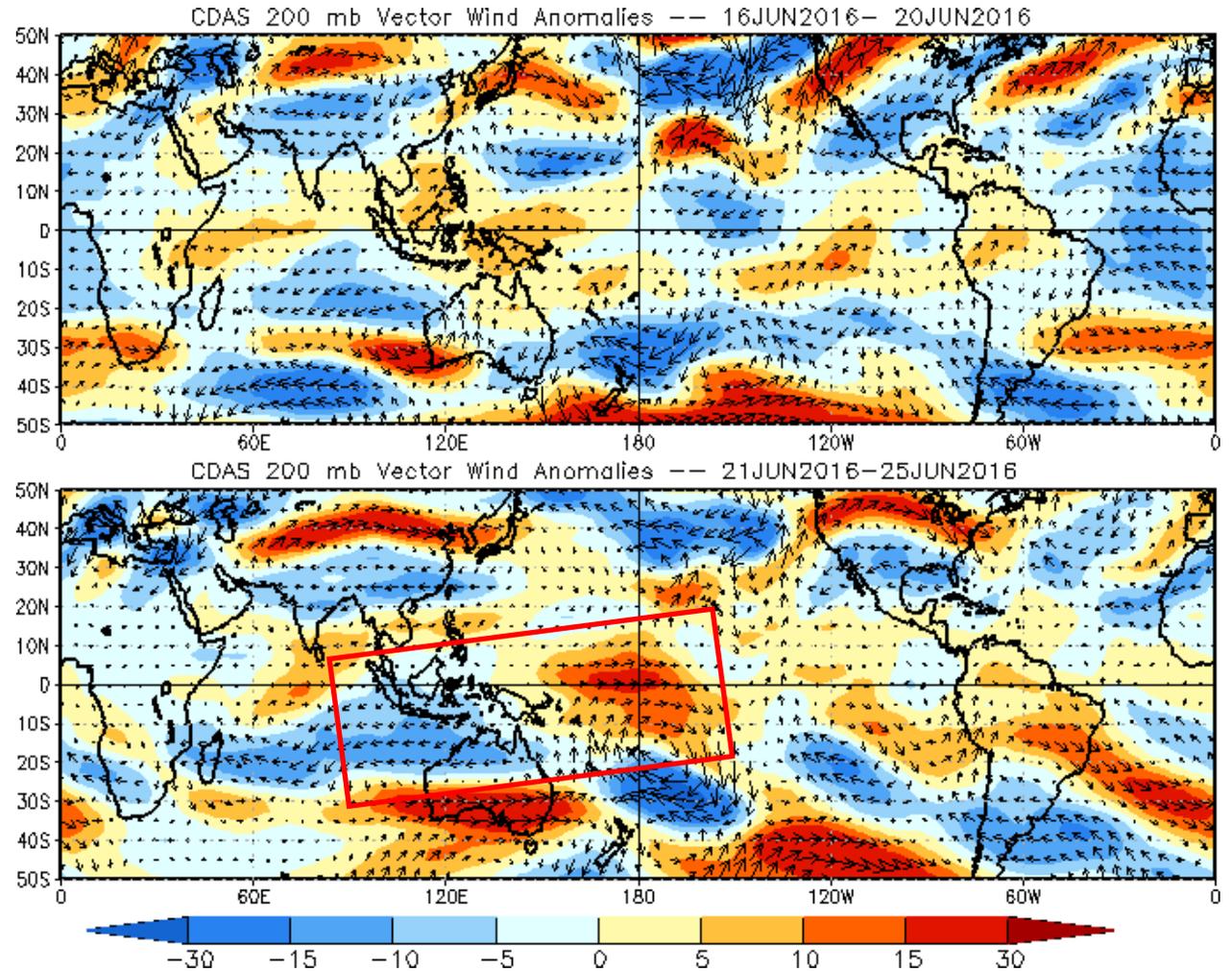
Positive anomalies (brown contours) indicate unfavorable conditions for precipitation
Negative anomalies (green contours) indicate favorable conditions for precipitation

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 couplet of easterly (westerly) anomalies over the Maritime Continent (equatorial central Pacific) strengthened during the past five days.

200-hPa Zonal Wind Anomalies (m s⁻¹)

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

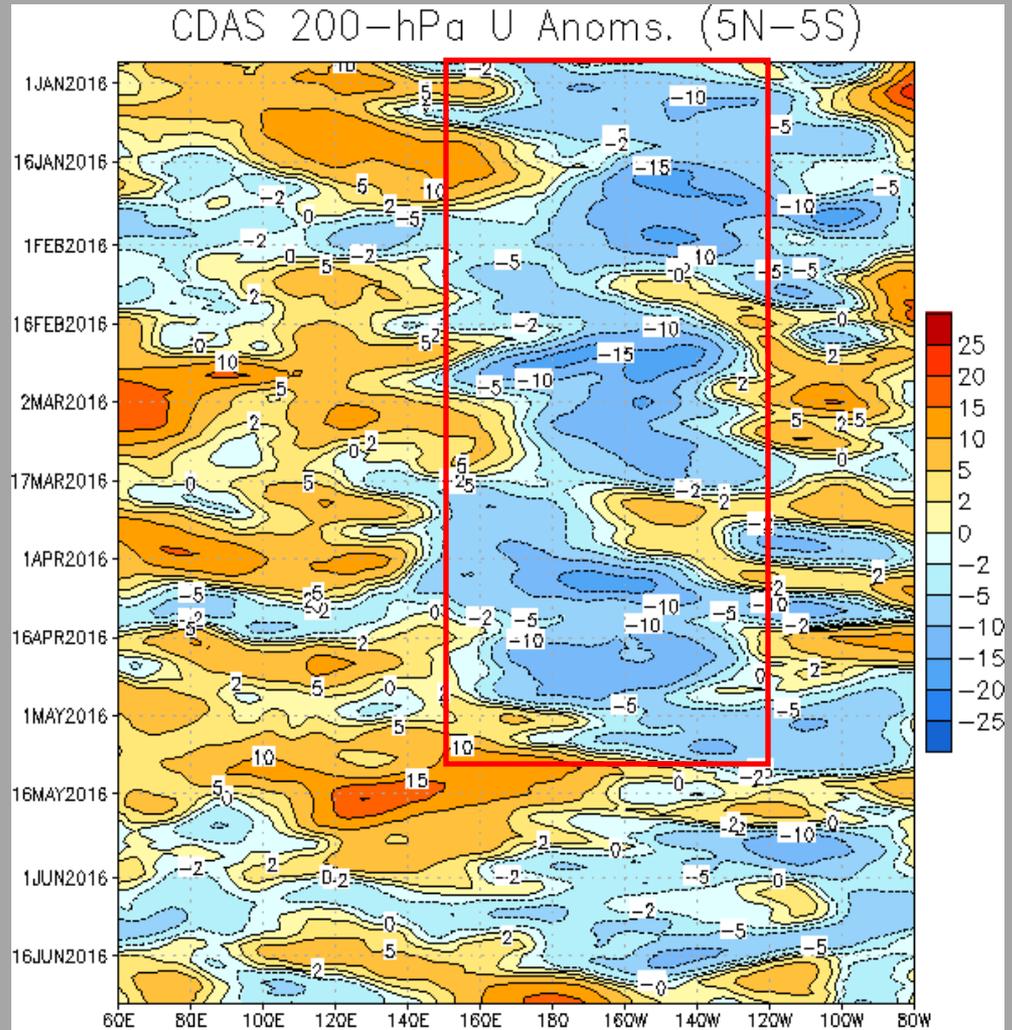
Easterly anomalies (blue shading) represent anomalous east-to-west flow

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

During May, westerly anomalies expanded eastward to the Date Line as the ENSO event weakened. Faster modes were evident in the upper-level wind field.

The upper-level wind field became less coherent during late May and early June.

More recently, westerly anomalies strengthened over the equatorial Pacific with eastern anomalies shifting east to the Indian Ocean.



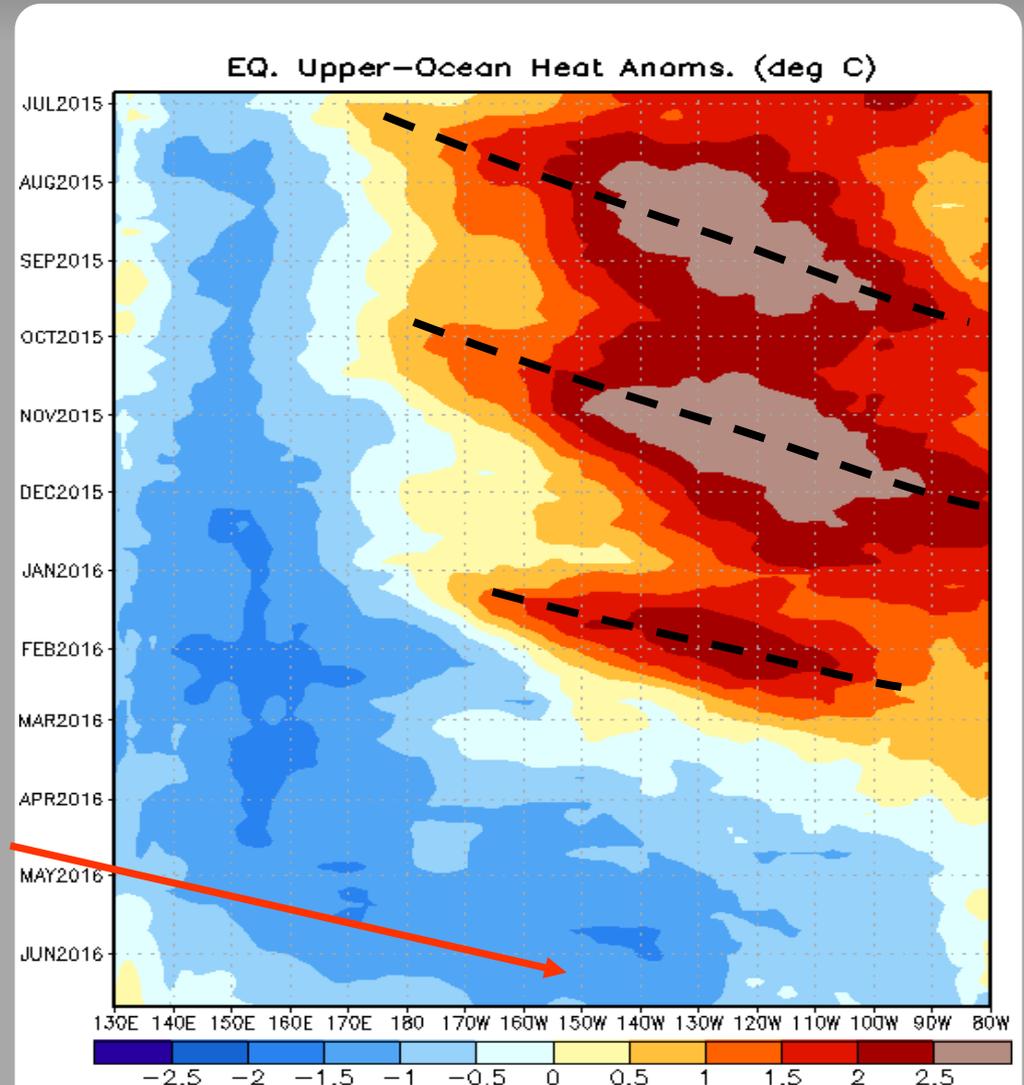
Weekly Heat Content Evolution in the Equatorial Pacific

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.

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 three 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.



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

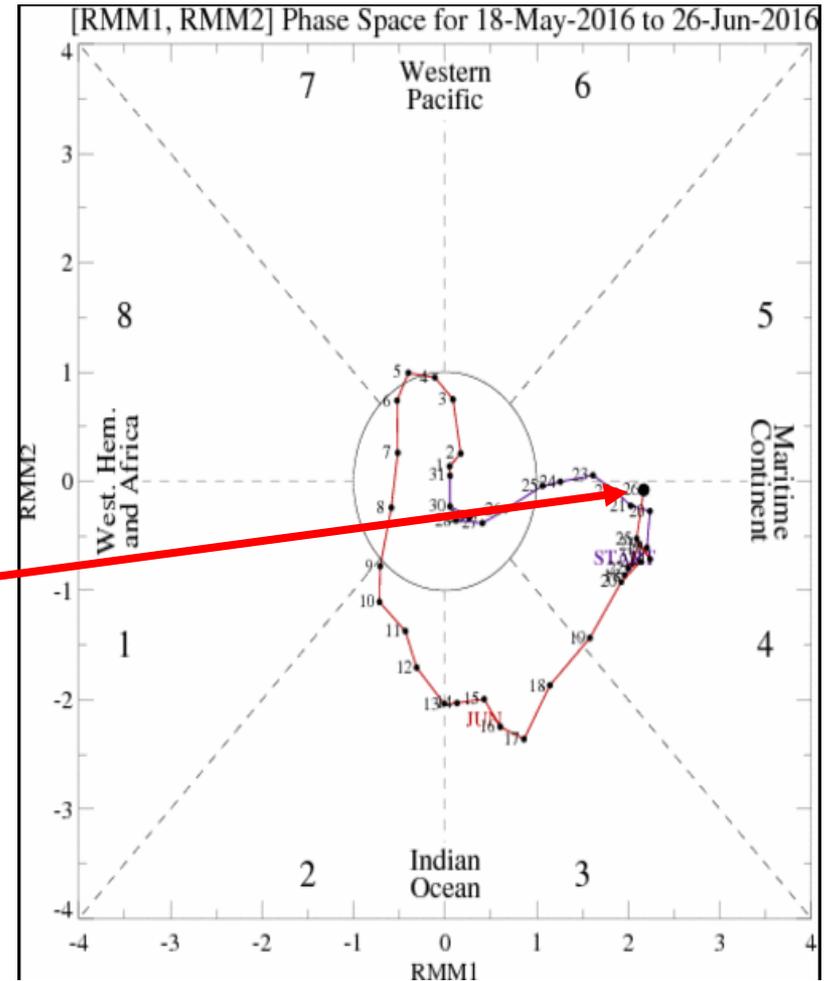
The triangular areas indicate the location of the enhanced phase of the MJO

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

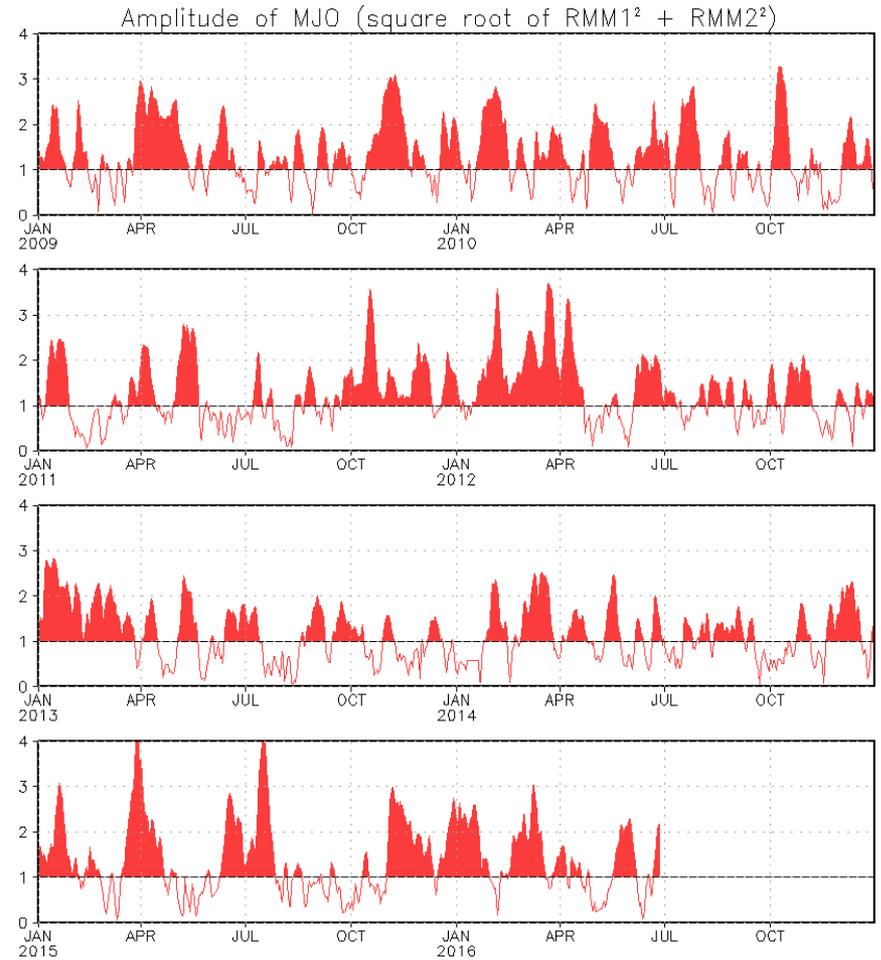
During the past week, the RMM index depicts a robust MJO signal propagating east from the Indian Ocean to the Maritime Continent.



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

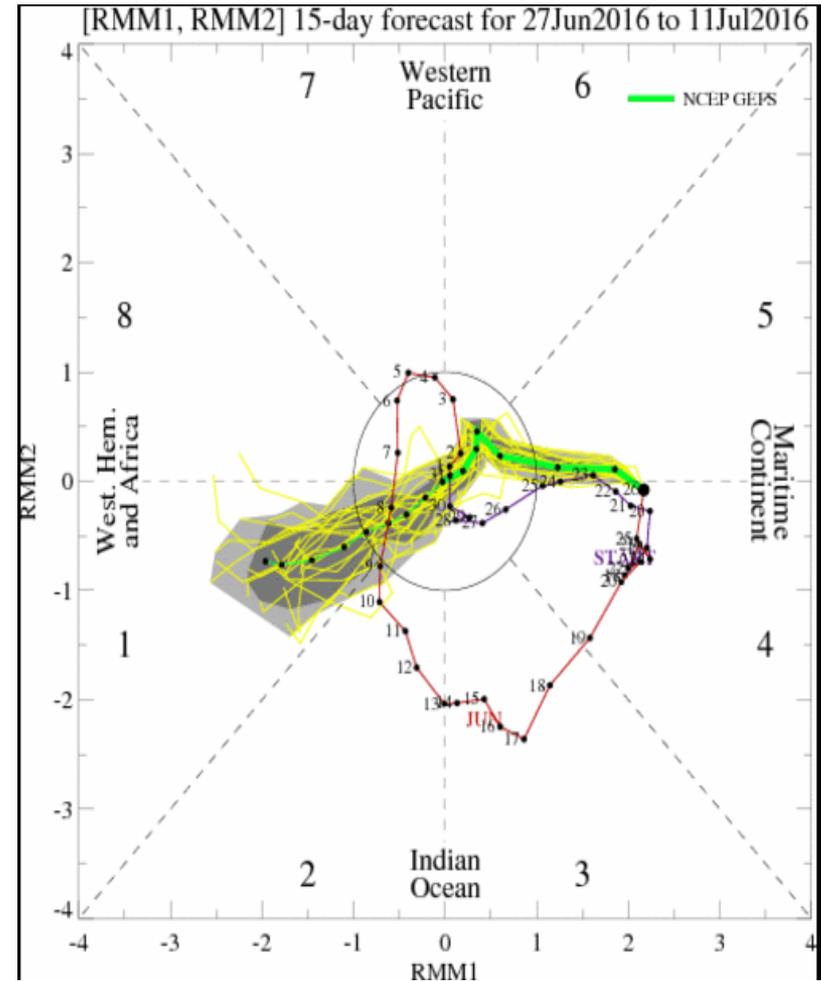
light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

During the next two weeks, the GFS ensemble indicates rapid weakening of the MJO signal over the Maritime Continent, with a reversal of the convective signal during Week-2.

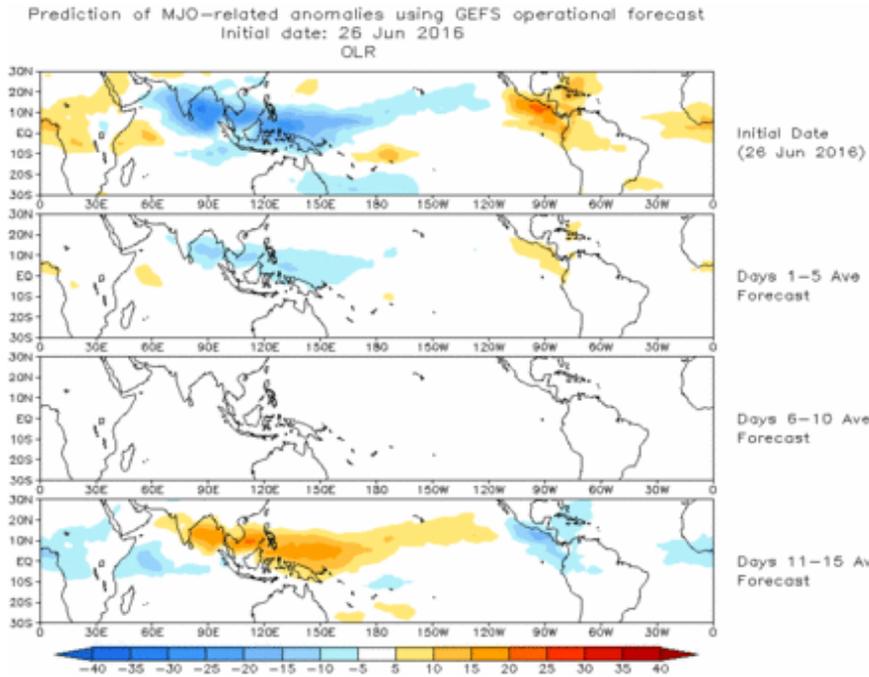
However, changes in the background state with the decaying El Niño event are being aliased into the 120-day mean state.

Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean



Ensemble GFS (GEFS) MJO Forecast

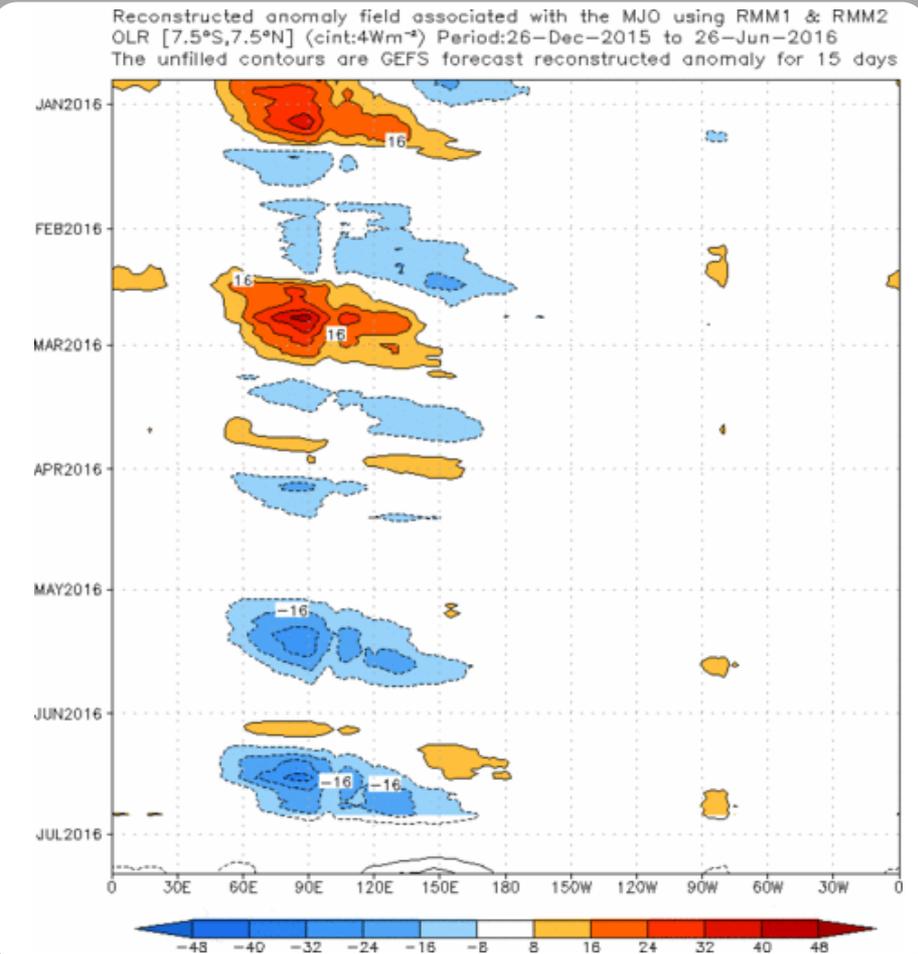
Spatial map of OLR anomalies for the next 15 days



The GEFS OLR forecast based on the RMM Index depicts rapid weakening of robust convective anomalies during the next week, and a reversal of the pattern during Week-2.

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.)

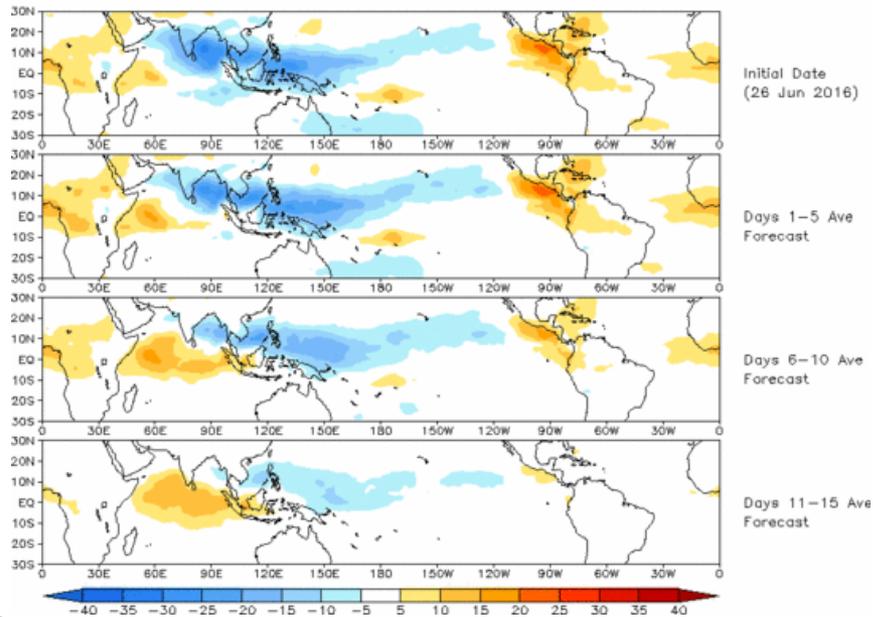
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



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 Jun 2016)

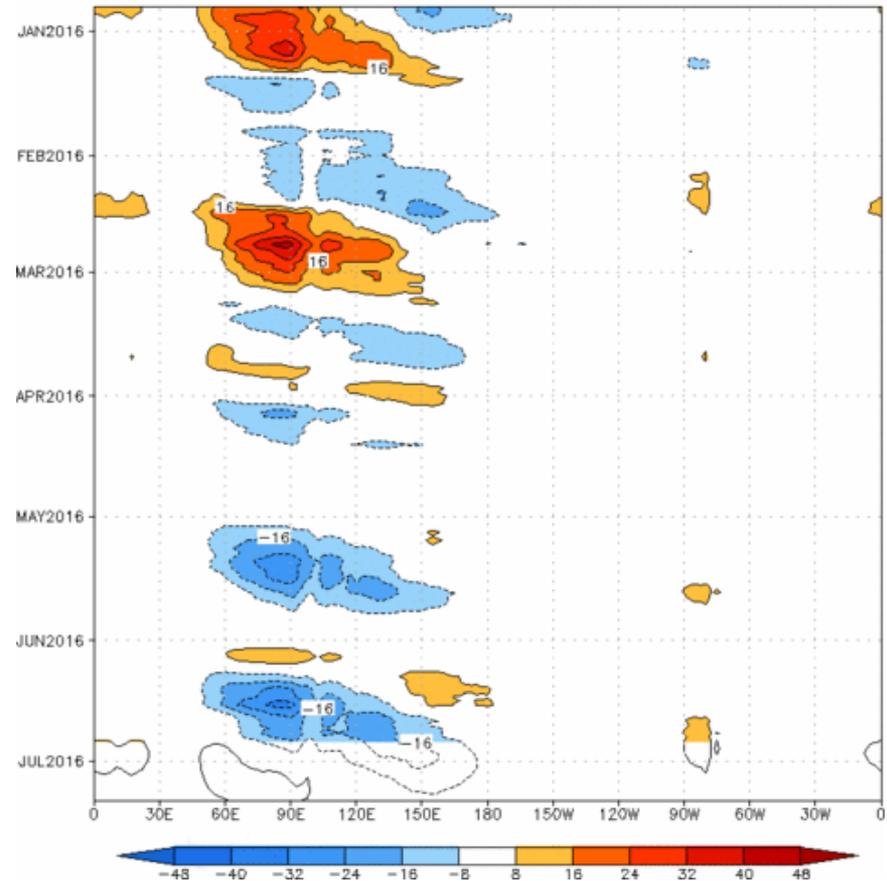


The Constructed Analog (CA) model predicts continued eastward propagation of the MJO signal to the Maritime Continent and West Pacific during the next two weeks.

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

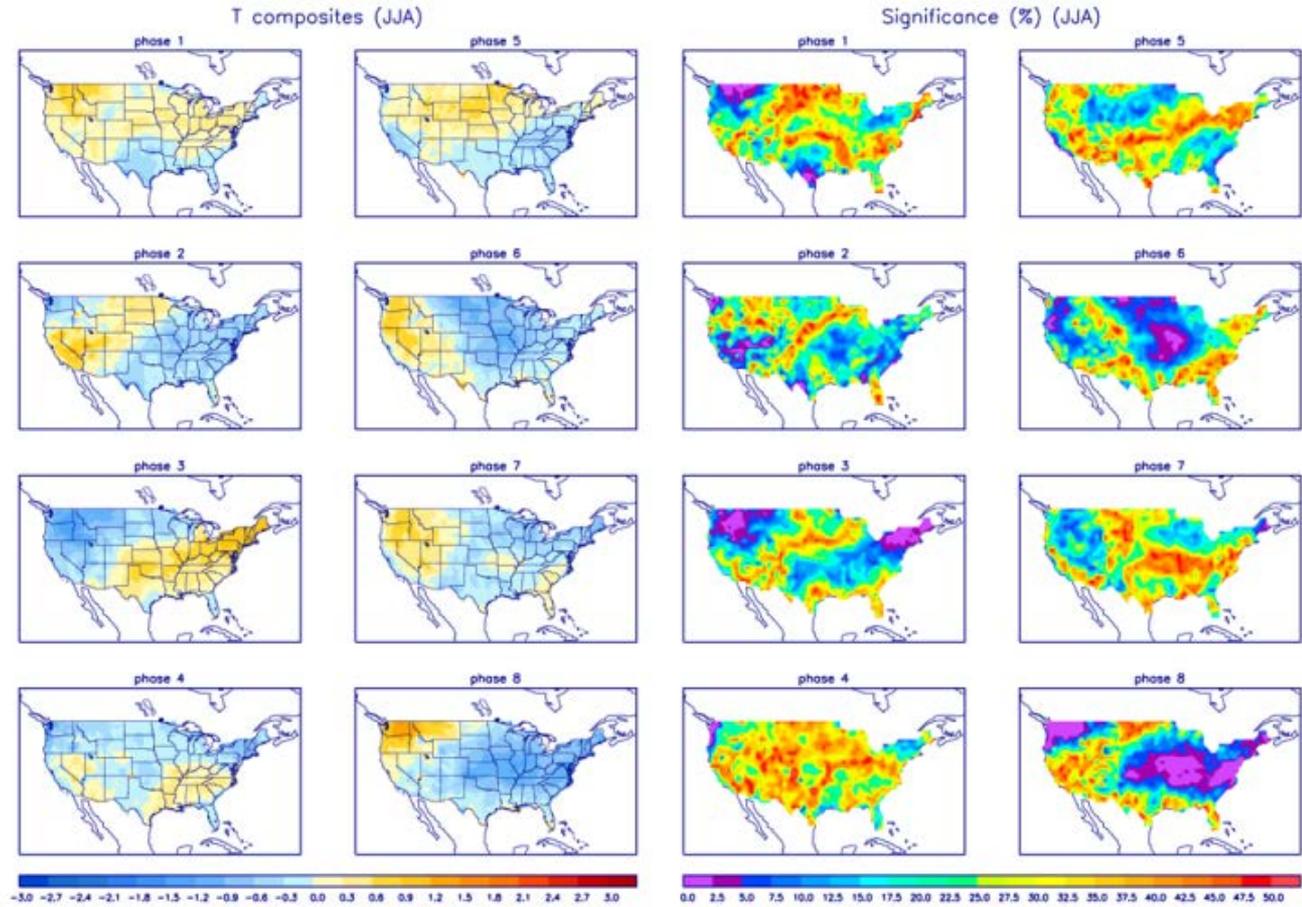
Reconstructed anomaly field associated with the MJO using RMM1 & RMM2 OLR [7.5°S,7.5°N] (cont:4Wm⁻²) Period:26-Dec-2015 to 26-Jun-2016
The unfilled contours are CA forecast reconstructed anomaly for 15 days



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.



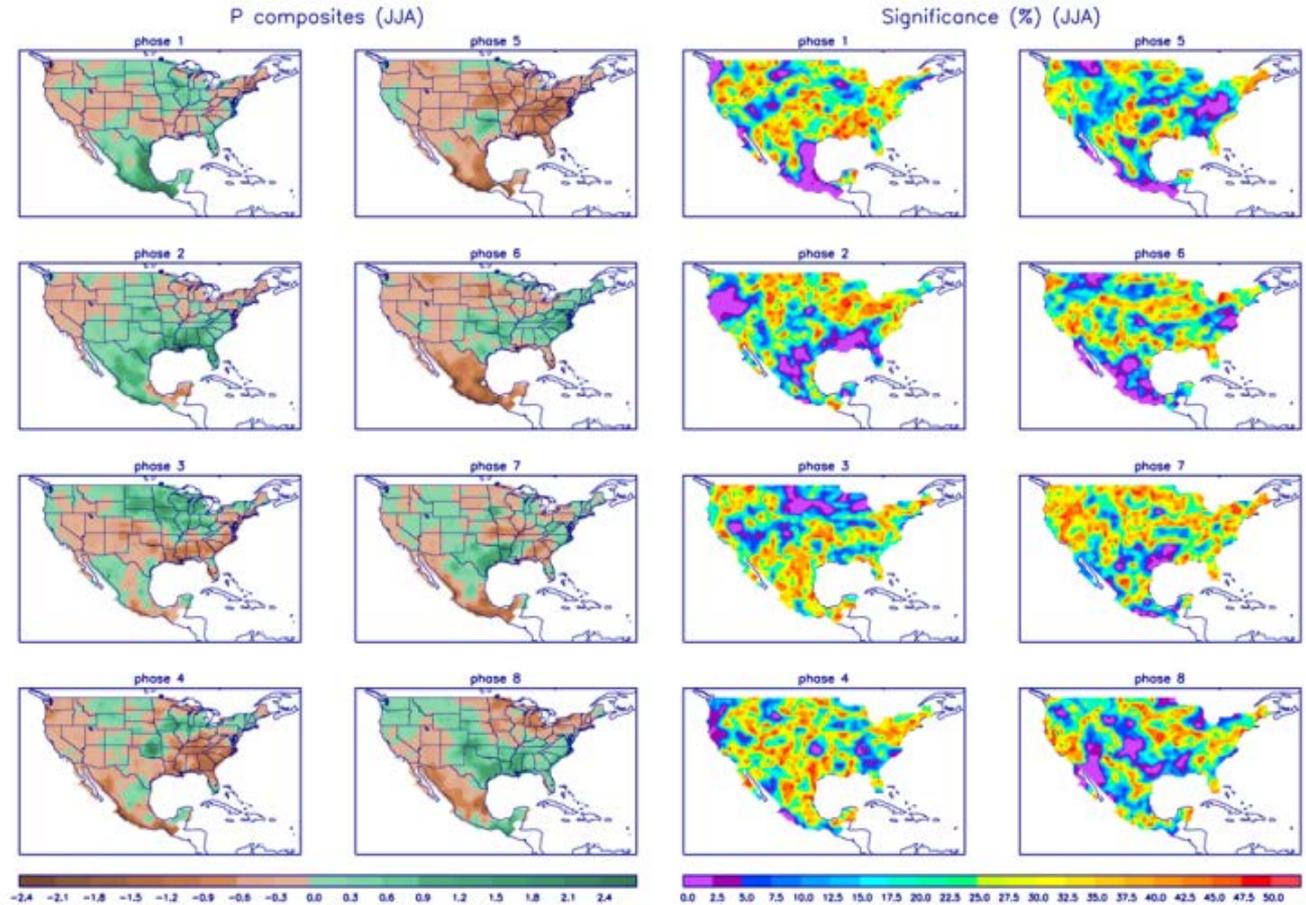
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

<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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