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

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Climate Prediction Center / NCEP
23 January 2017

Outline

Overview

- The MJO is active, with both the RMM based and CPC velocity potential based MJO indices depicting robust eastward propagation of an enhanced (suppressed) convective envelope over the Western Hemisphere, Africa, and the western Indian Ocean (central Pacific).

- The low frequency state driven by a weakening La Niña and the Indian Ocean Dipole continues to influence the pattern. Recent destructive interference between this base state and the MJO has waned as the suppressed envelope propagated to the Pacific. Rossby Wave activity is also apparent over the Maritime Continent.

- Dynamical model RMM index forecasts exhibit a range of solutions, with the GEFS weakening the signal before it emerges over the Maritime Continent, and the ECMWF depicting a robust Indian Ocean event that continues across the Maritime Continent, albeit weaker.

- The MJO is anticipated to influence the evolution of the global tropical convective pattern, and may contribute to enhanced convection over the Indian Ocean. The IOD pattern will also continue to play a substantive role.

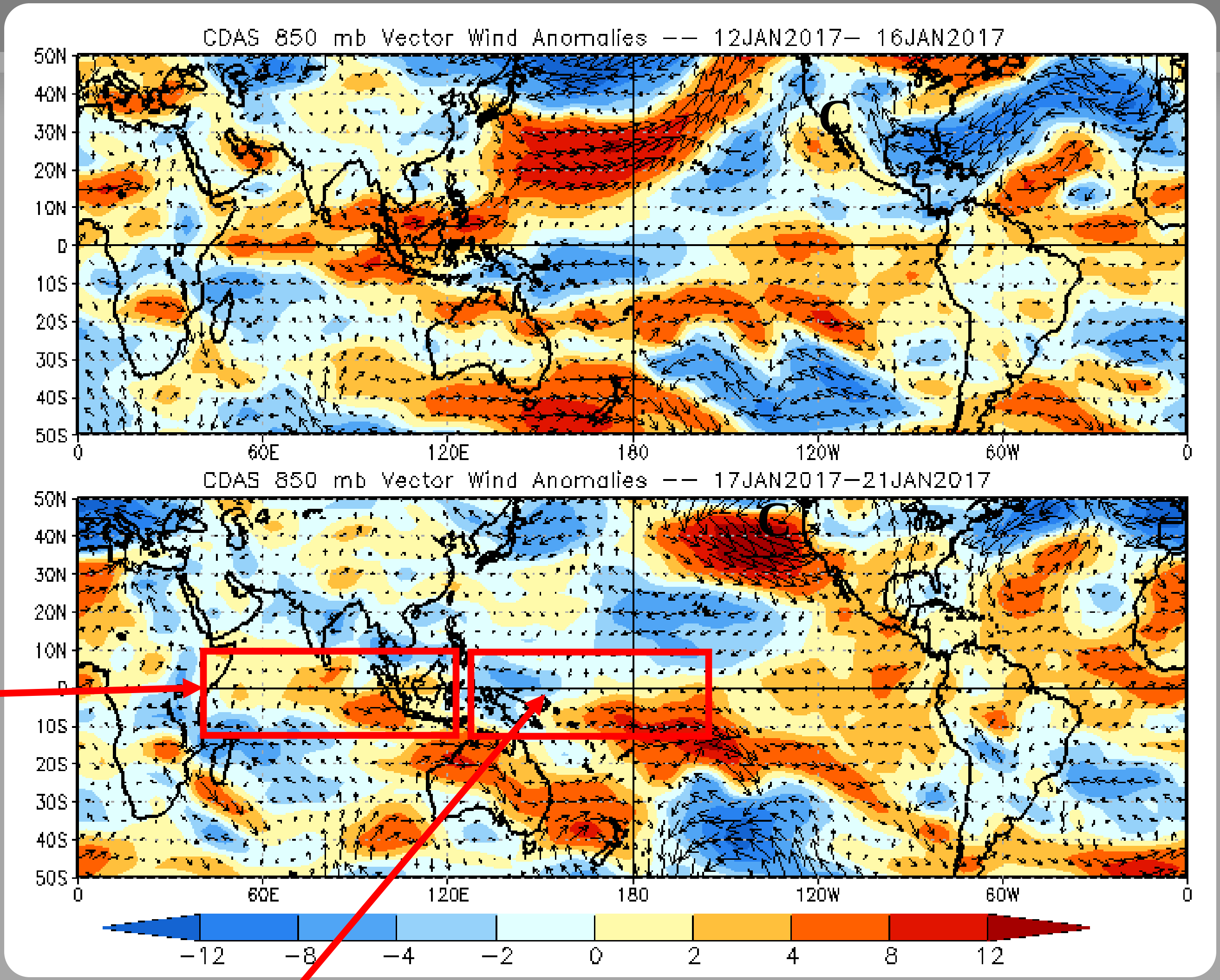
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php

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

Note that shading denotes the zonal wind anomaly

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

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



Westerly anomalies weakened over the Indian Ocean.

Easterly anomalies associated with the low frequency state weakened near the Date Line, with westward propagation evident.

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

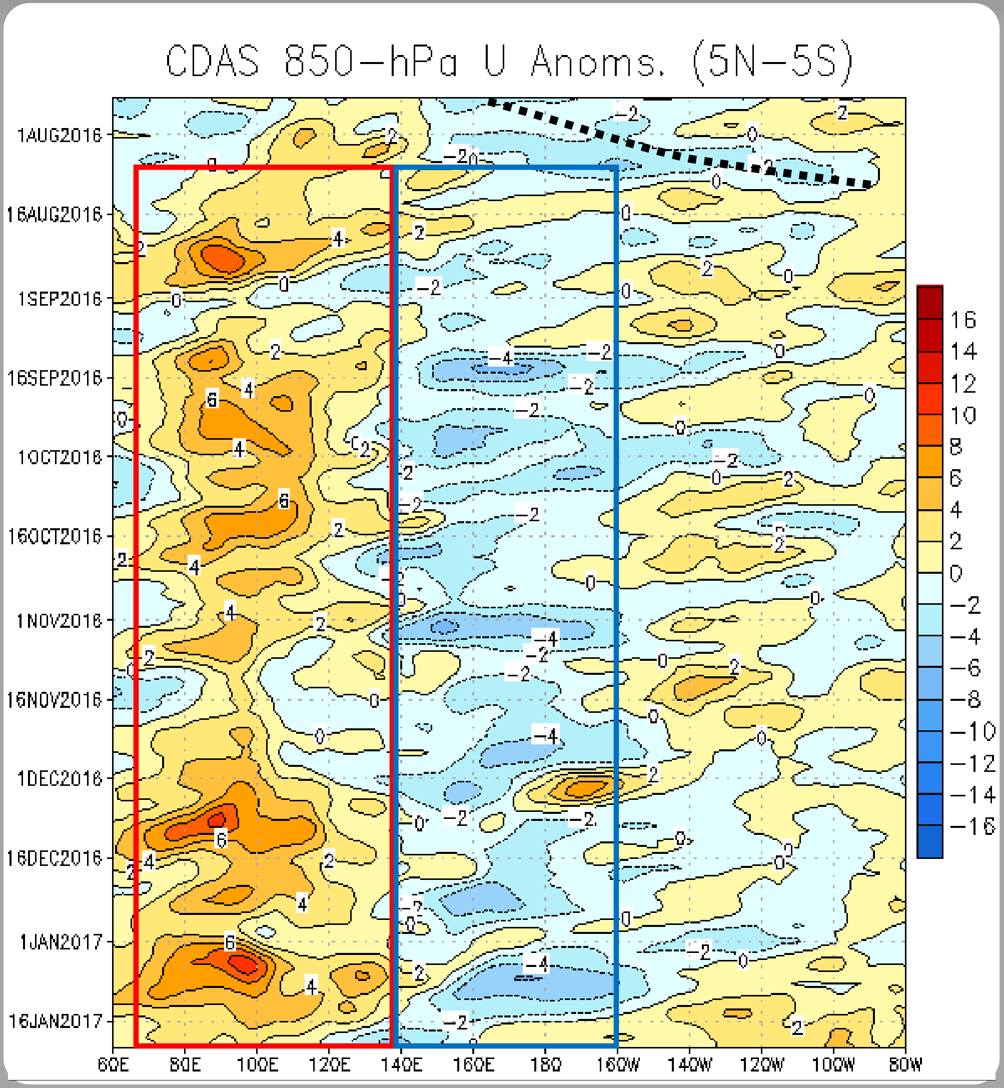
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

Through early August, high frequency, eastward-propagating modes were observed crossing the Pacific.

Since late July, persistent westerly (easterly) anomalies were evident over the eastern Indian Ocean and western Maritime Continent (central and western Pacific) as shown by the red (blue) box at right. These anomalies are low frequency in nature, associated with the negative phase of the Indian Ocean Dipole (IOD), and later, La Niña.

More recently, Rossby Wave activity was evident in the low-level wind field, destructively interfering with the base state.



OLR Anomalies - Past 30 days

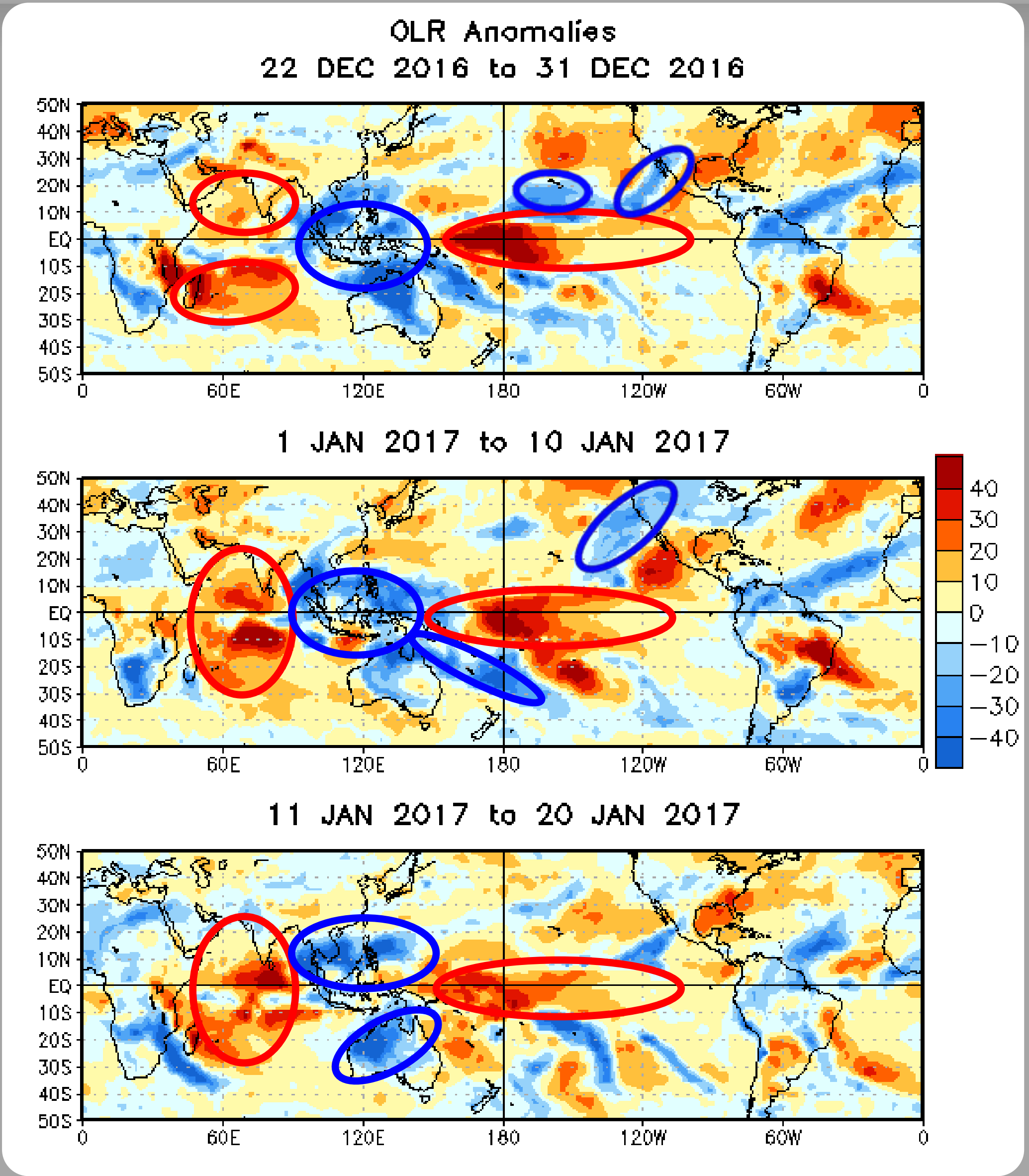
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

From late December through early January, the low frequency state remained evident, with enhanced (suppressed) convection persisting over the Maritime Continent (central Pacific). The pattern was influenced by higher frequency modes, such as equatorial Kelvin Wave activity over the Indian Ocean in late December.

Periodic surges of tropical moisture into western North America were evident in the OLR field, particularly during late December and early January.

During mid-January, Rossby Wave activity was evident over the West Pacific.



Outgoing Longwave Radiation (OLR) Anomalies (2.5ºS - 17.5º S)

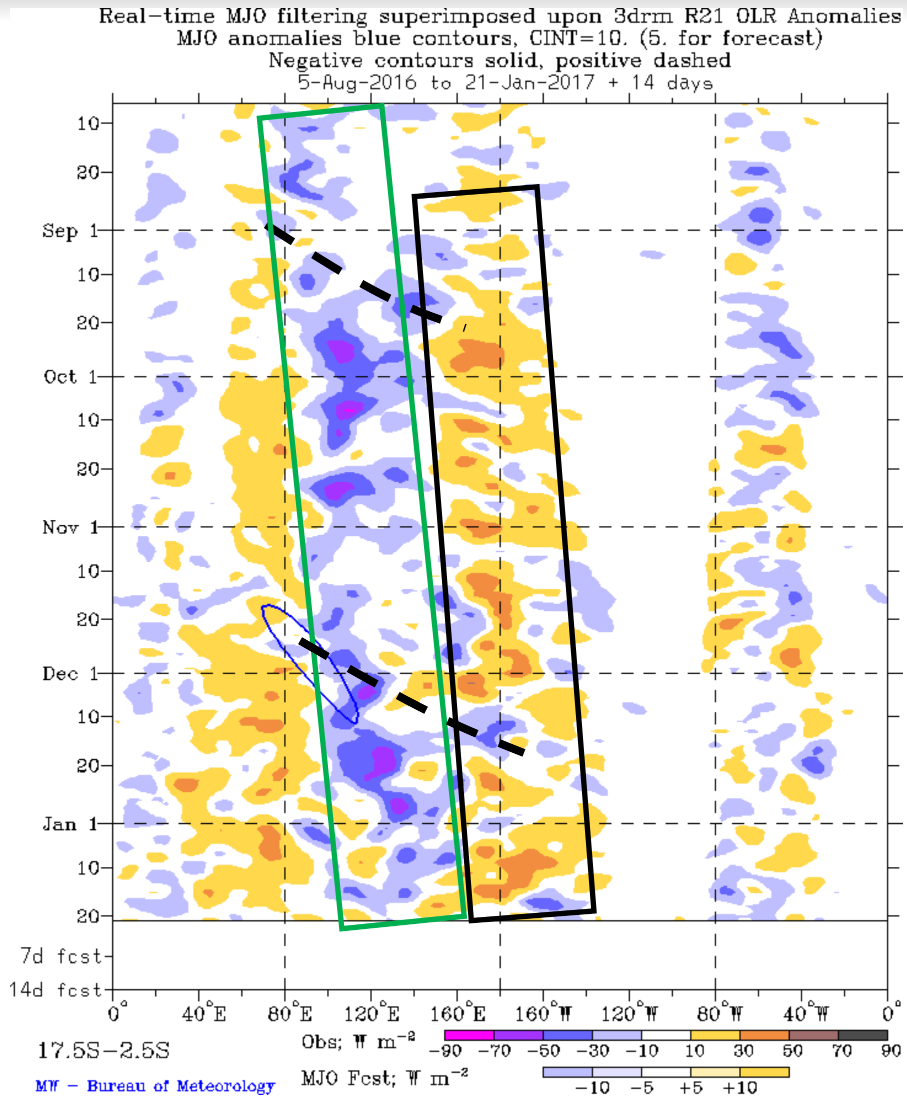
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

A low frequency state favoring enhanced convection shifting slowly east from the eastern Indian Ocean to the Maritime Continent has been evident since July (green box). Low frequency suppressed convection, tied to La Niña conditions, has been apparent near the Date Line since August (black box).

A fast eastward propagating convective envelope was evident during early September, and briefly disrupted the pattern. Another intraseasonal event occurred during late November and early December.

During January, faster modes (Kelvin waves and a Rossby wave) have influenced the pattern.



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

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

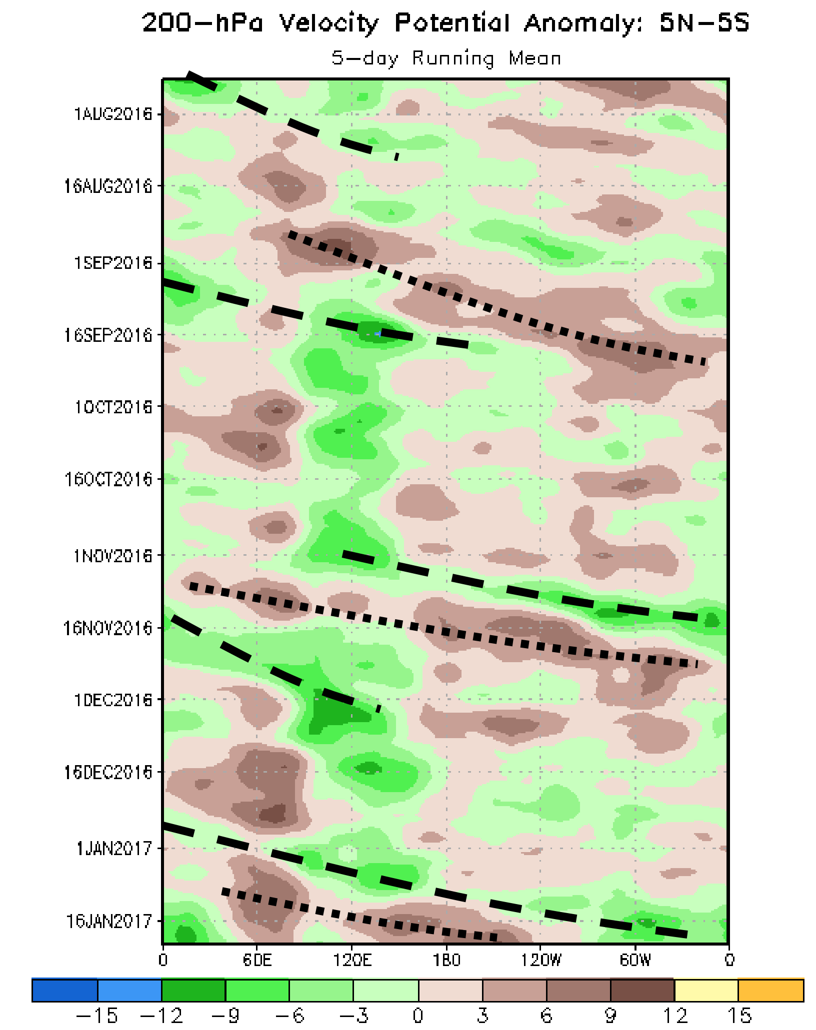
Negative anomalies (green shading) indicate favorable conditions for precipitation

During 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.

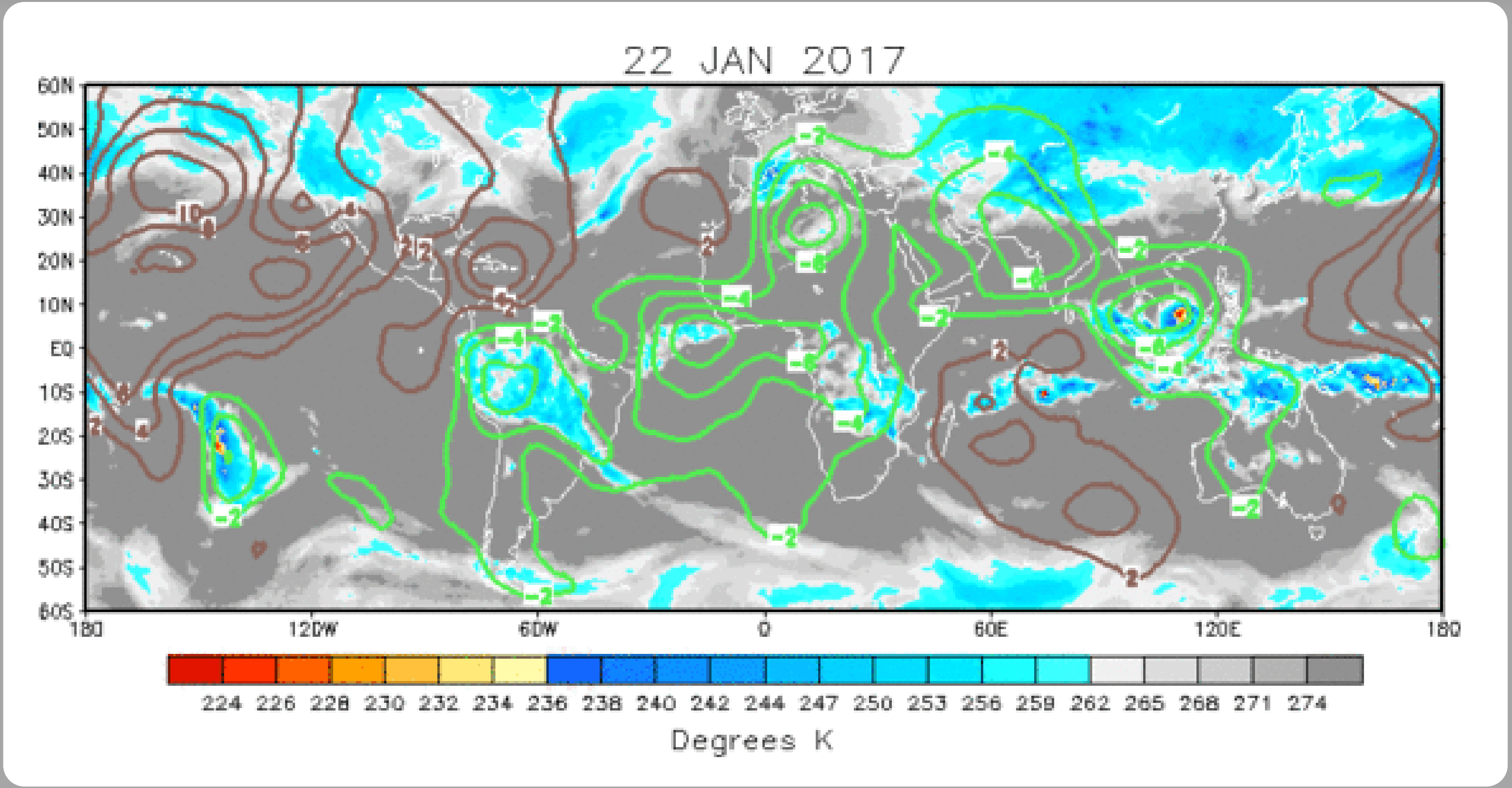
From mid-September to late October, the low frequency signal dominated the pattern. During November, eastward propagation was observed consistent with MJO activity on the fast end of the intraseasonal spectrum.

During December, the IOD/La Niña influenced base state re-emerged as the dominant mode. The intraseasonal signal returned during January.

Recently, the enhanced (suppressed) phase of the intraseasonal signal was over the Western Hemisphere and Africa (Pacific).



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



Upper-level velocity potential anomalies remain fairly coherent, with a clear enhanced (suppressed) convective envelope over the Western Hemisphere and Africa (central Pacific). Constructive interference between the base state and a Rossby wave is evident with strong negative anomalies over the Maritime Continent that are out of phase with the MJO.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

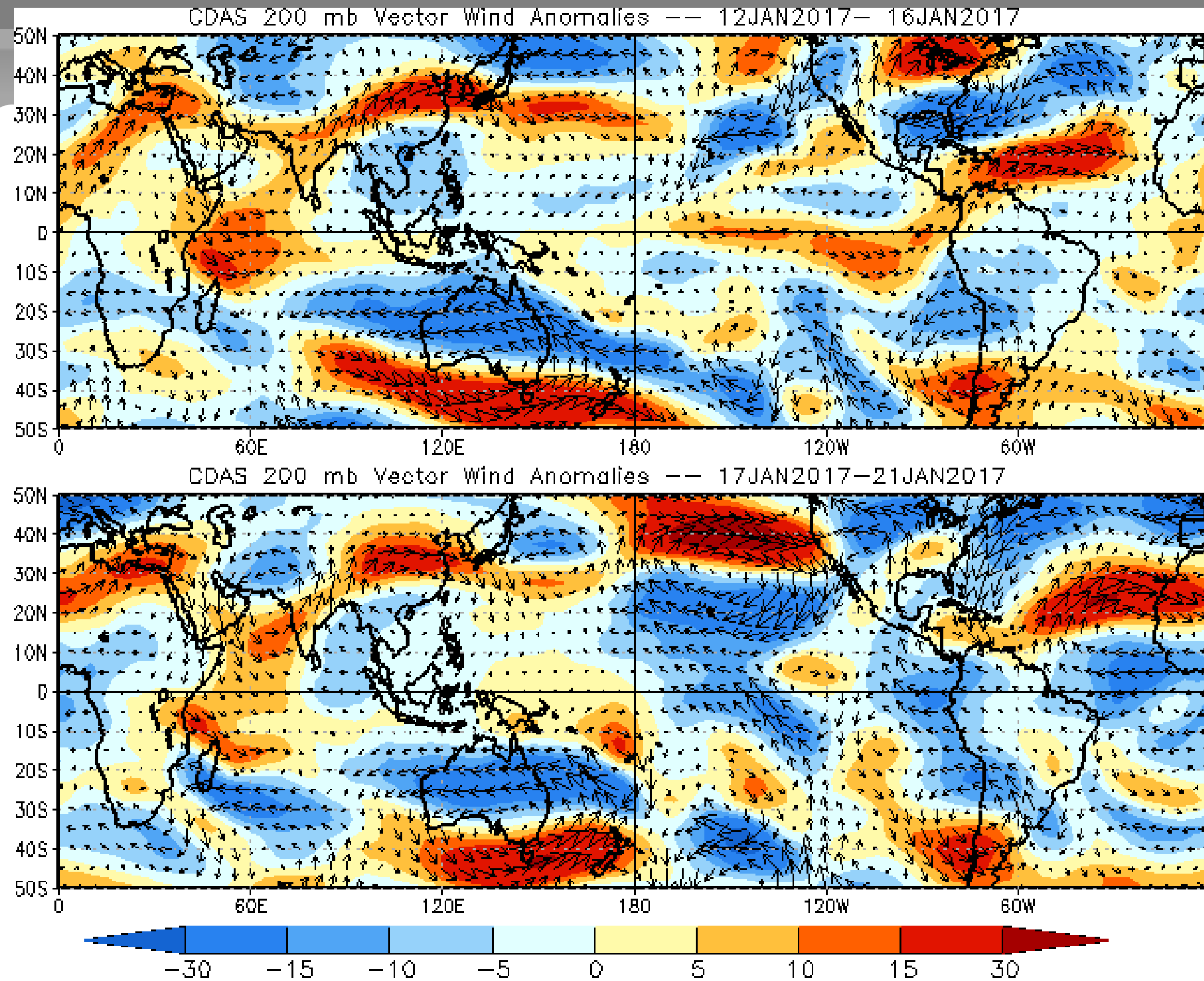
Negative anomalies (green contours) indicate favorable conditions for precipitation

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

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies



Anomalous anticyclonic flow remains evident over southeastern Asia, consistent with continued enhanced convection over the Maritime Continent.

Easterly anomalies developed along the equatorial east-central Pacific, with substantial cross-equatorial flow.

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

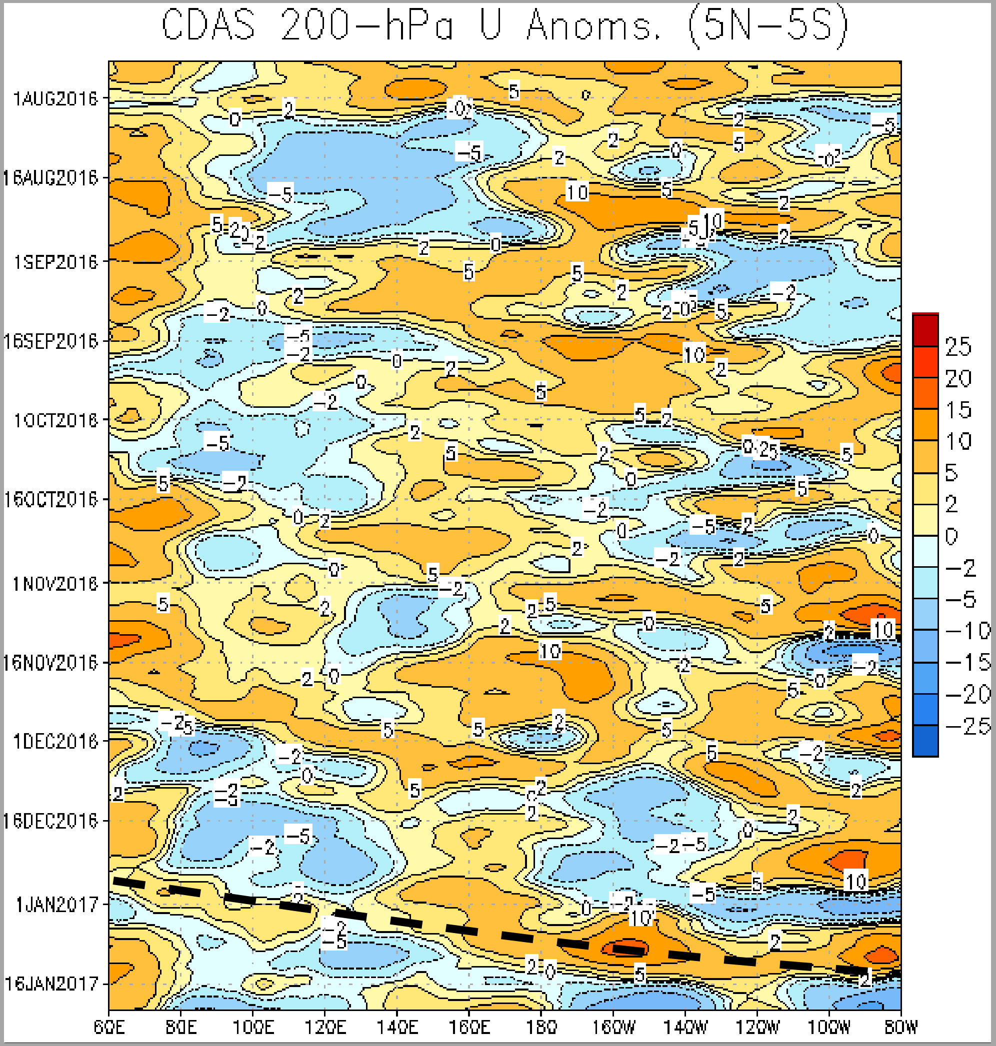
After a quiet August, eastward propagation of westerly anomalies was broadly consistent with organized MJO activity during September.

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.

More recently, the low frequency state has re-emerged as destructive interference with the intraseasonal signal waned.

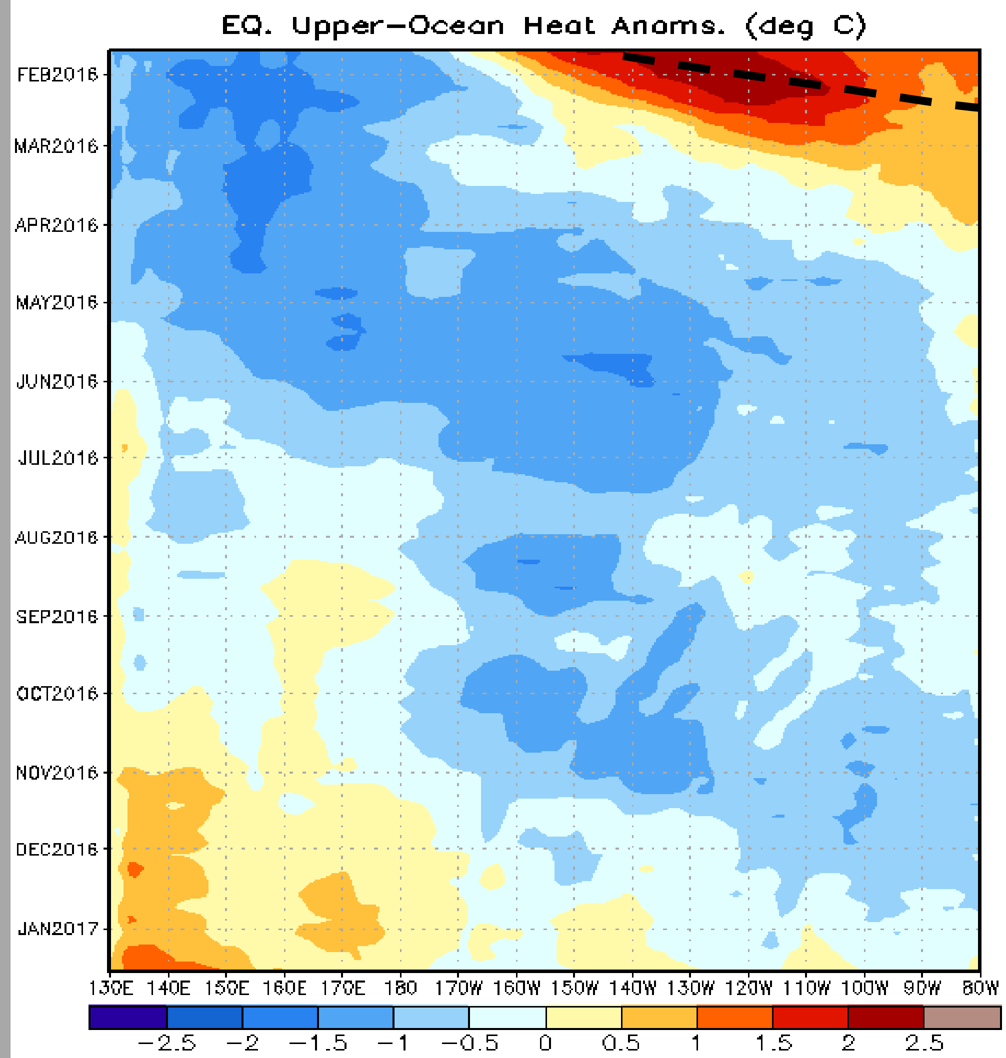


Weekly Heat Content Evolution in the Equatorial Pacific

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 April, with widespread negative anomalies building across the Pacific over the course of the spring and summer months.

Most recently, upper-ocean heat content anomalies have been low amplitude, consistent with the forecast transition to ENSO-neutral conditions over the coming months.



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.

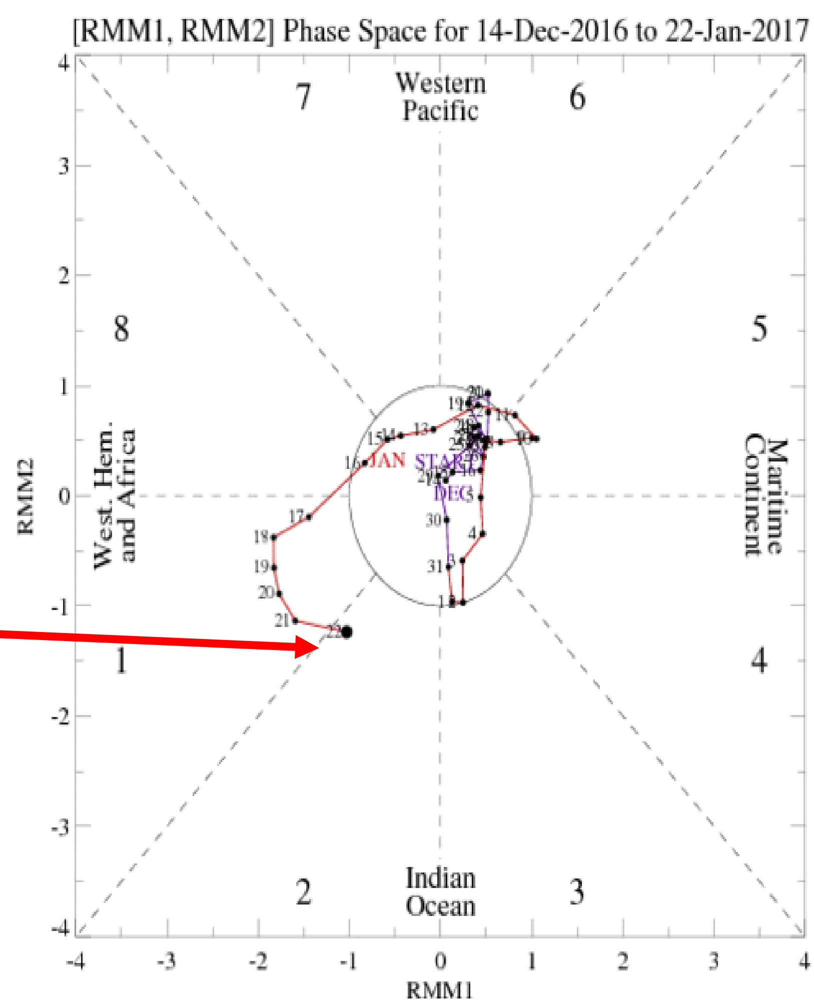
Gottschalck et al. 2010: A Framework for Assessing Operational Madden-Julian Oscillation Forecasts: A CLIVAR MJO Working Group Project, *Bull. Amer. Met. Soc*., 91, 1247-1258.

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**

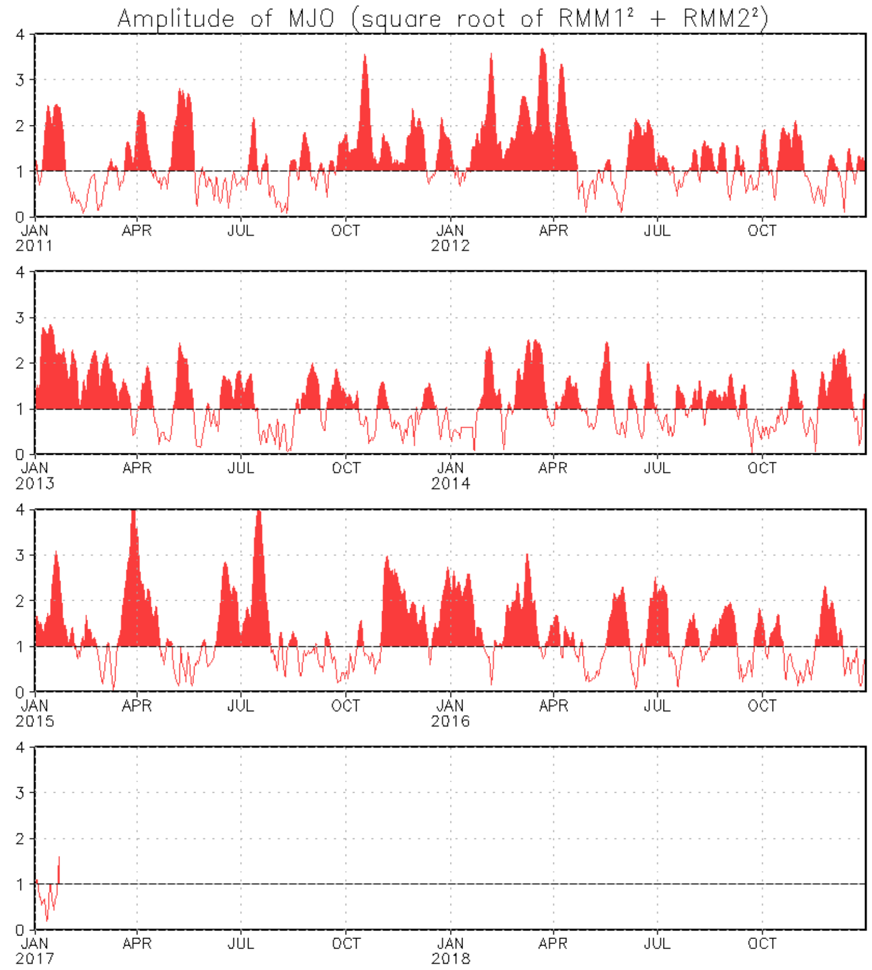
During the past week, eastward propagation of a robust MJO signal was evident over the Western Hemisphere. Most recently, the signal appears to be emerging over the western Indian Ocean.



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

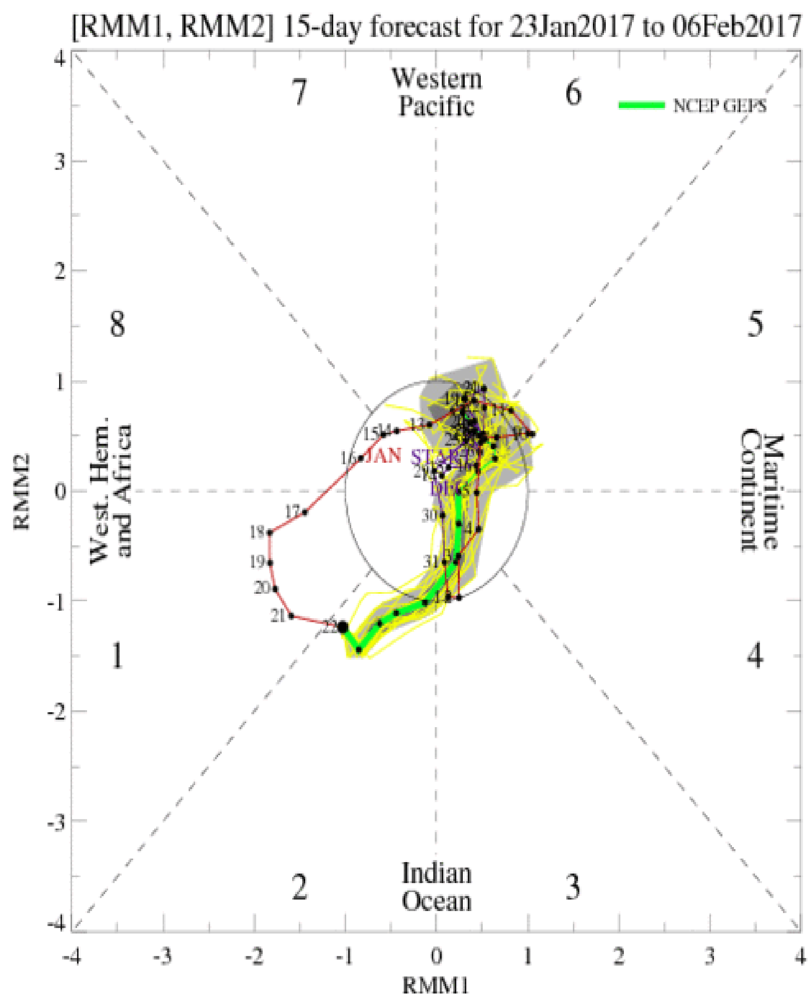
RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS depicts continued eastward propagation over the next several days, followed by a weakening of the signal before it reaches the Maritime Continent.

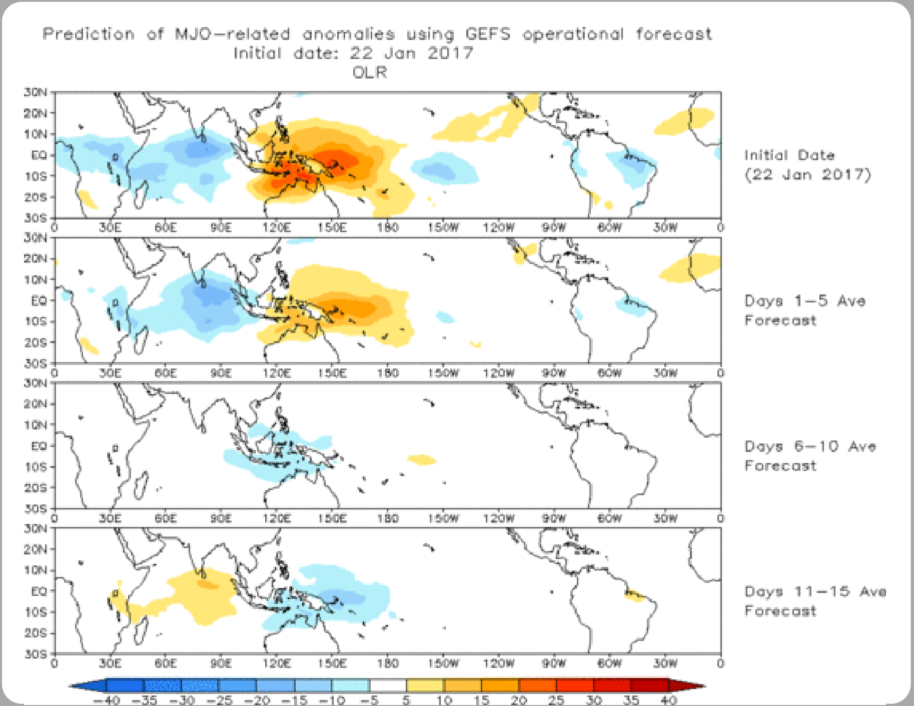
Note: The 120-day period mean is removed from this product, so the low frequency state favoring enhanced convection over the Maritime Continent may be playing a role in the forecast amplitude of the MJO.



Ensemble GFS (GEFS) MJO Forecast

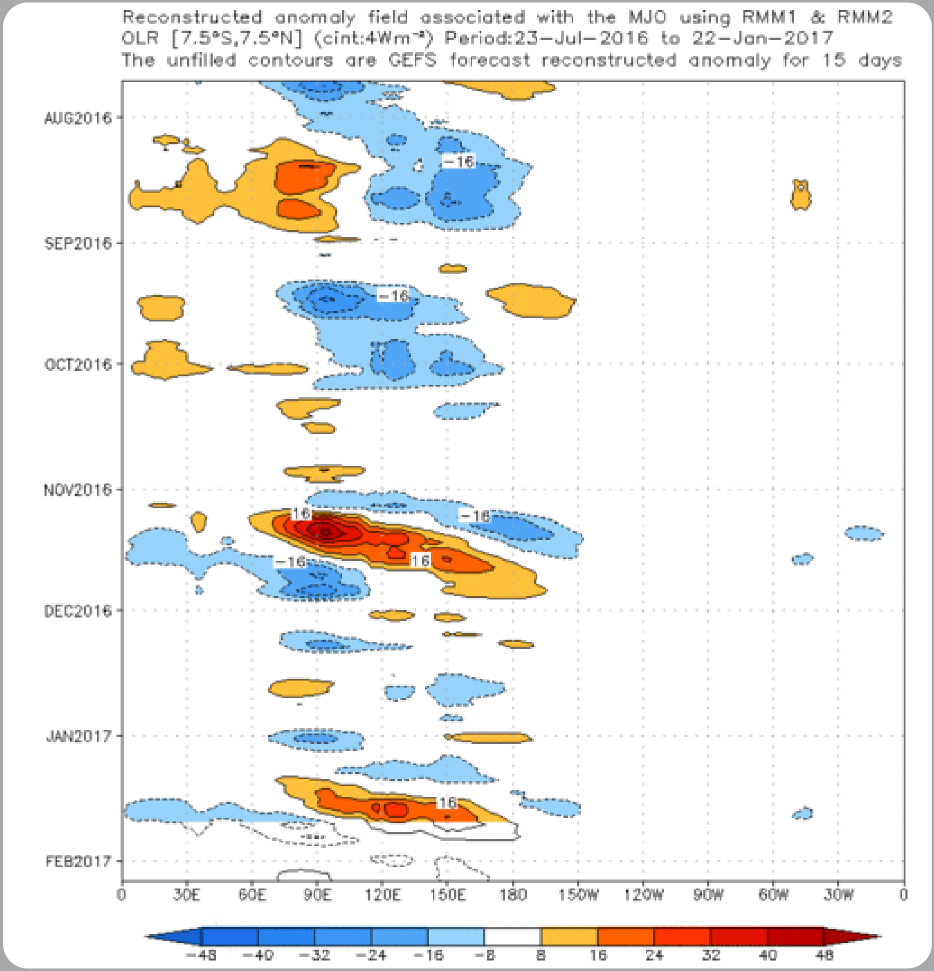
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



The GEFS prediction for RMM Index-based OLR anomalies over the next two weeks depicts robust eastward propagation of weakening OLR anomaly envelopes.

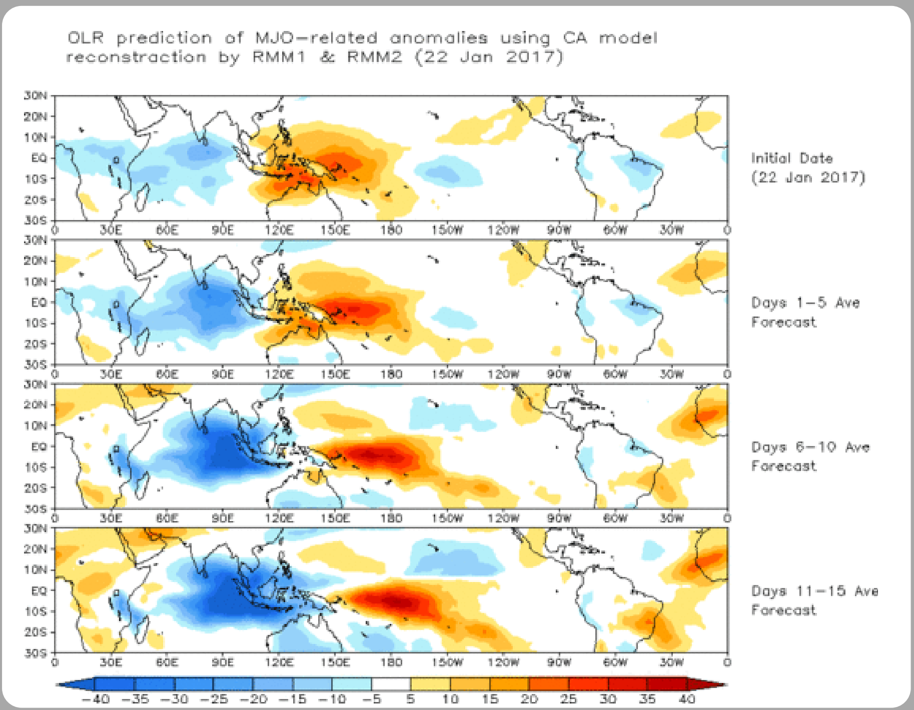
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



Constructed Analog (CA) MJO Forecast

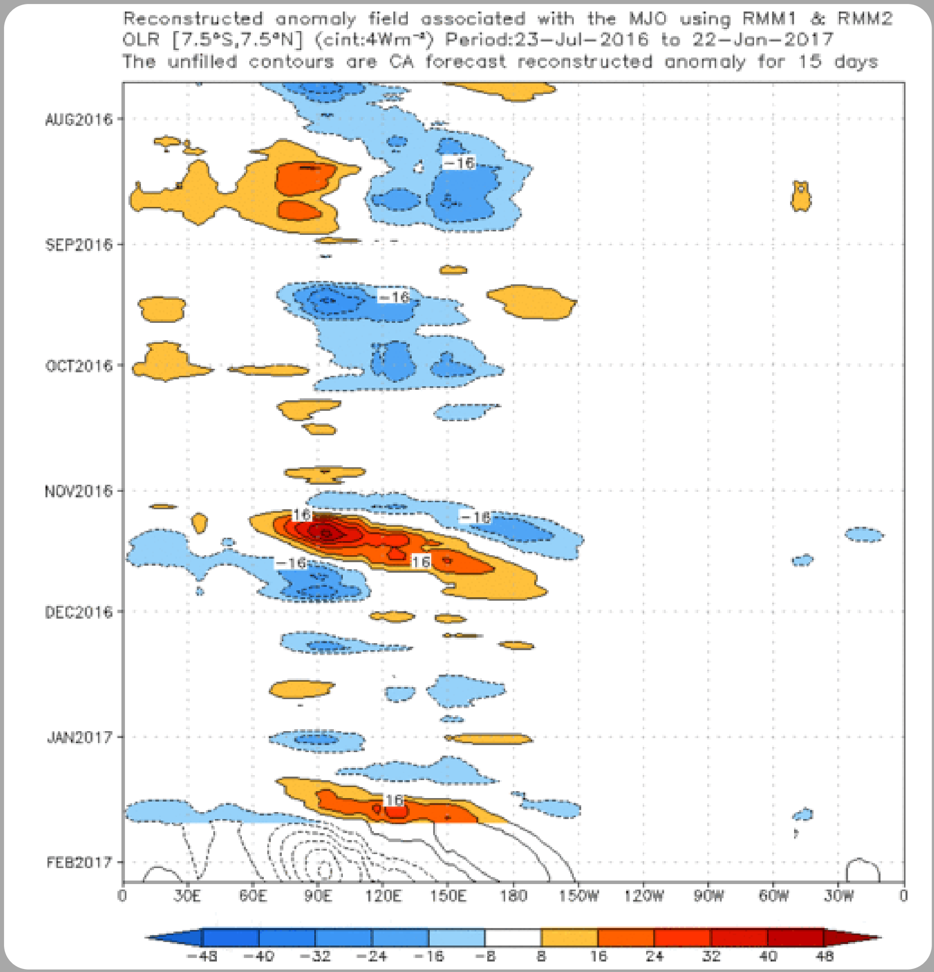
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



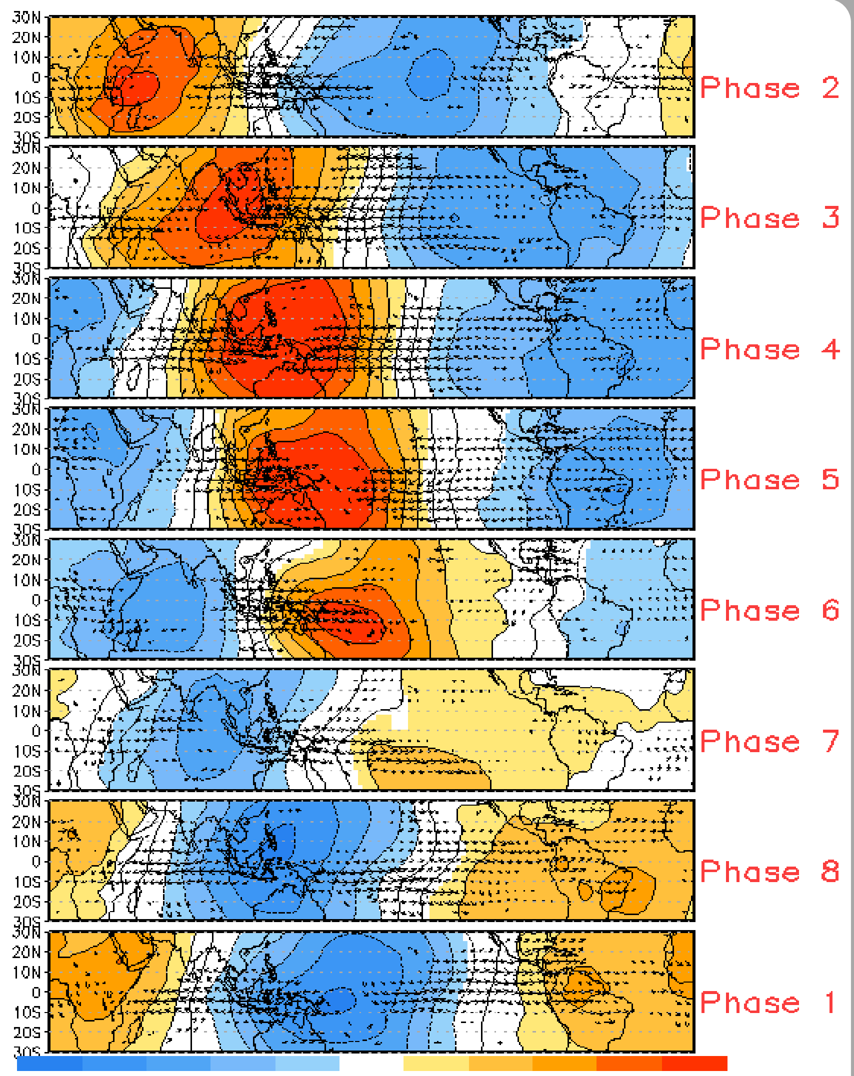
The statistical (Constructed Analog) RMM-based OLR anomaly prediction depicts a robust Indian Ocean MJO event propagating to the Maritime Continent by the end of the period.

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

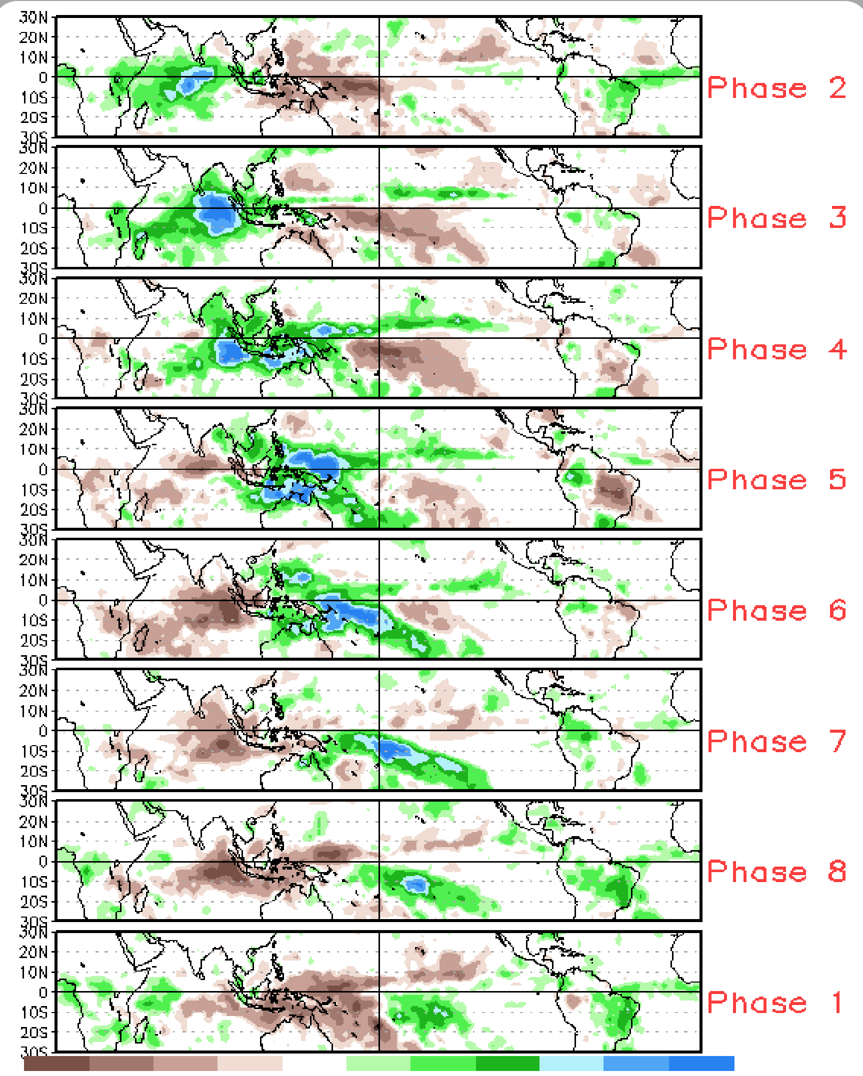


MJO Composites - Global Tropics

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



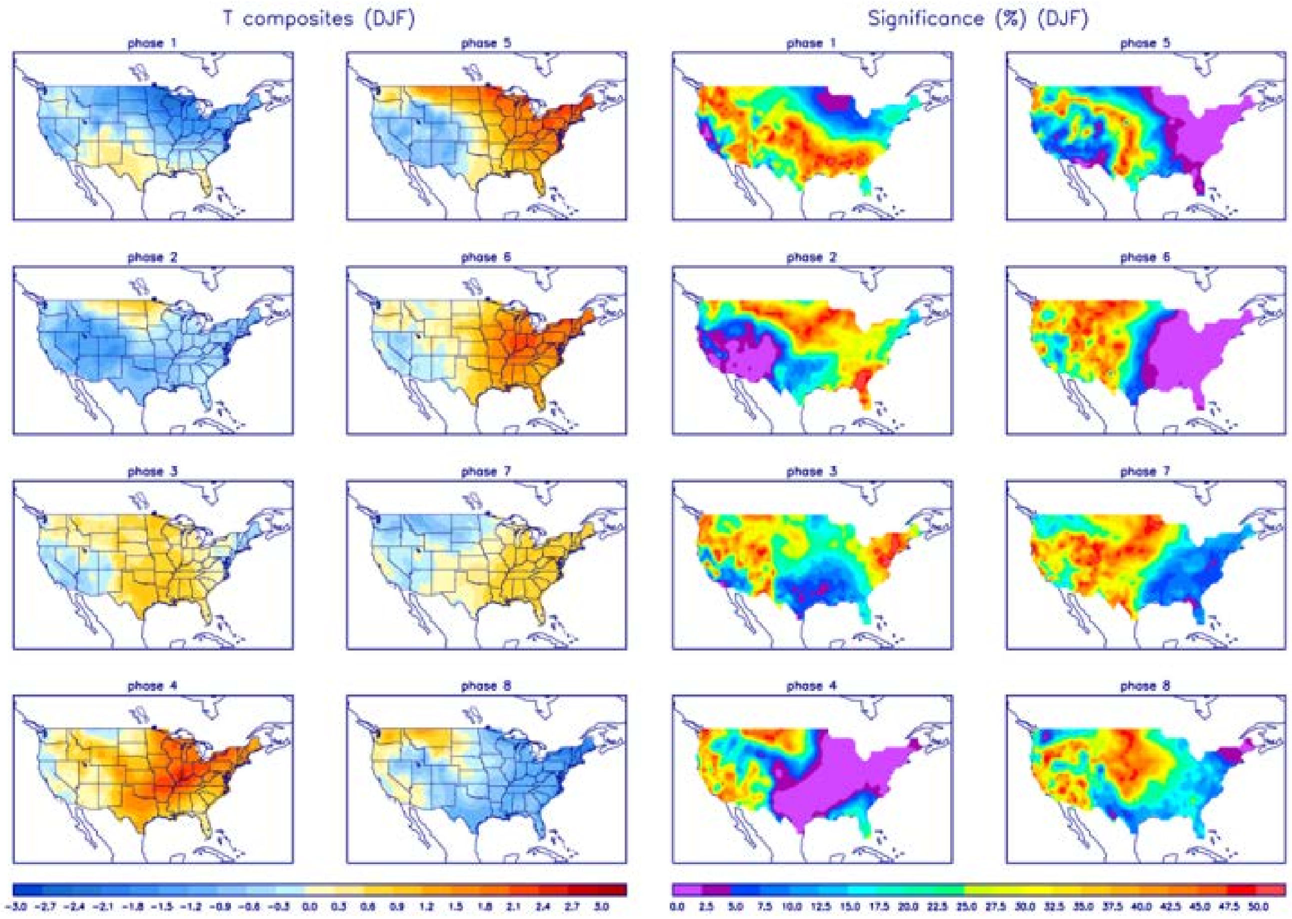
Precipitation Anomalies (Nov - Mar)



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.

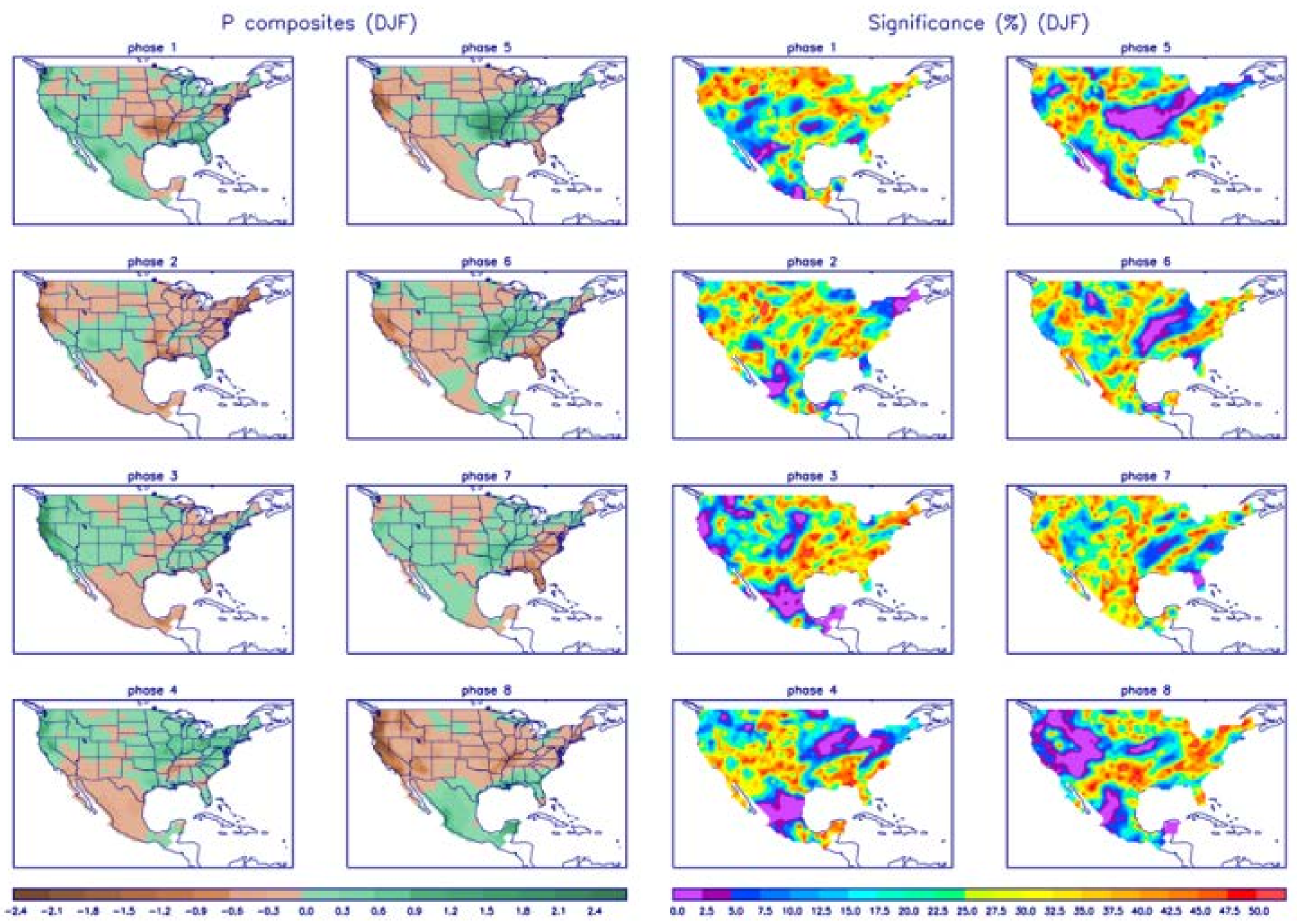
Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.



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.

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