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

Update prepared by
Climate Prediction Center / NCEP
July 6, 2015

Outline

- Overview
- Recent Evolution and Current Conditions
- MJO Index Information
- MJO Index Forecasts
- MJO Composites

Overview

- The MJO remains active with the enhanced convective phase currently over the West Pacific.
- Constructive interference among the MJO and the El Niño base state are resulting in continued Pacific convection, with some expansion to the eastern Pacific.
- Dynamical model MJO index forecasts favor a substantial decrease in amplitude with a signal remaining over the western and central Pacific. Some solutions have a slight eastward propagation, while others have a slight westward shift, likely due to differences in the handling of tropical cyclones.
- The MJO is expected to continue influencing the global tropical convective pattern, especially during Week-1, favoring enhanced convection and likely tropical cyclogenesis over the eastern Pacific, and suppressed convection over the Indian Ocean and parts of South Asia.

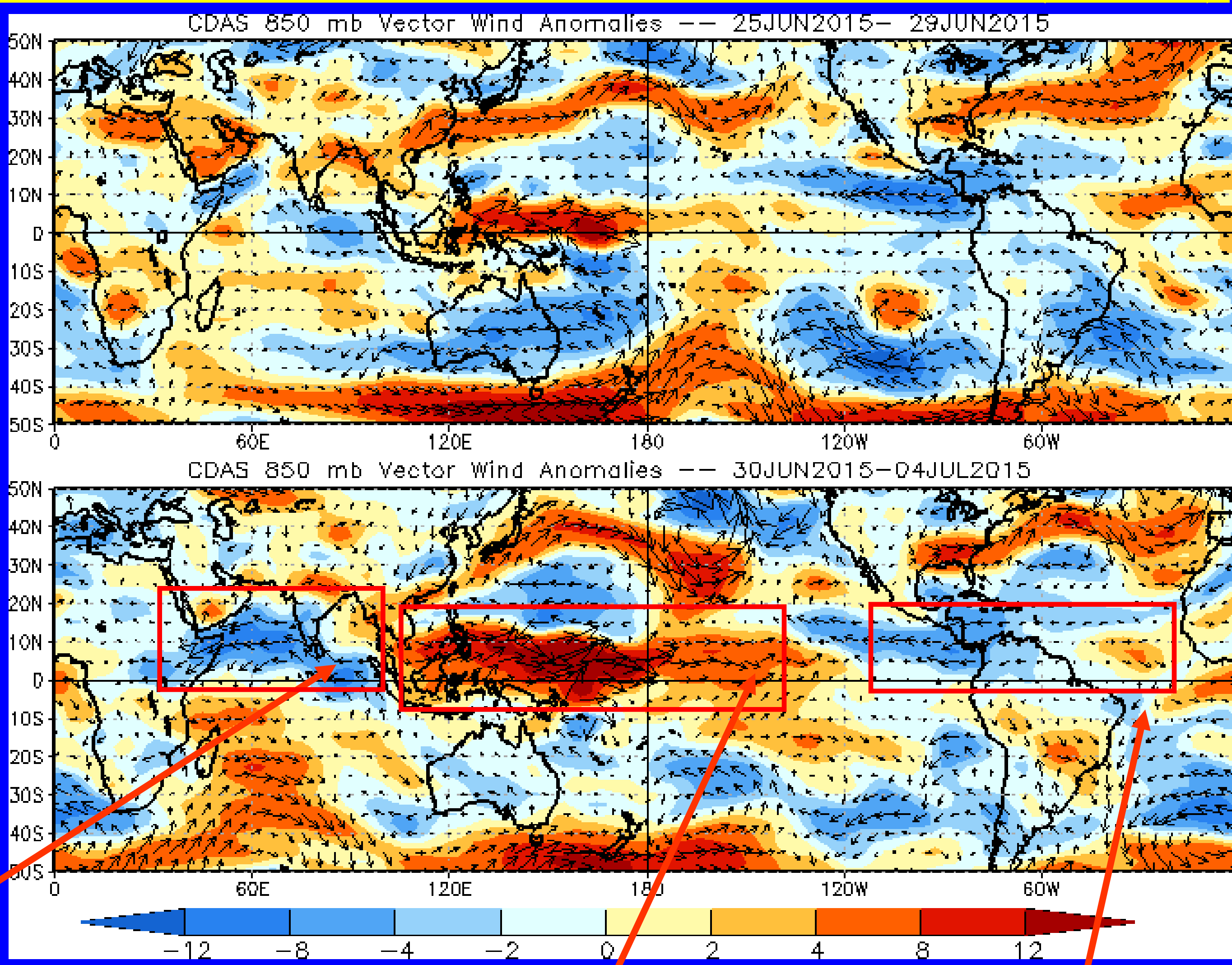
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php

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



Strong easterly anomalies developed over the Arabian Sea and much of the Indian Ocean.

Westerly wind anomalies increased in amplitude and coverage over the western and central Pacific.

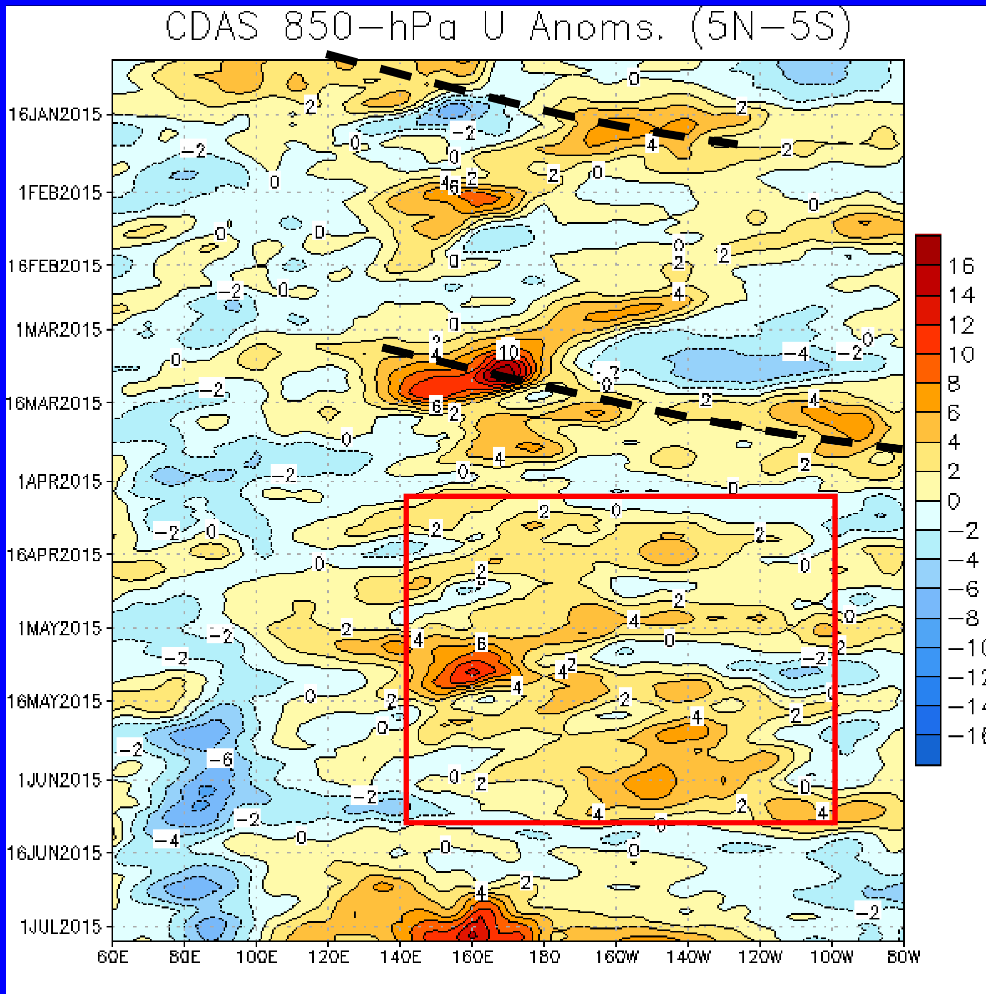
Easterly (westerly) anomalies weakened over the East Pacific (tropical Atlantic).

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

Time



Longitude

Westerly anomalies associated with the MJO propagated eastward (dashed line) during the first half of January. Westerly anomalies returned to the Western Pacific during late January and early February.

Strong westerly anomalies associated with the MJO, an equatorial Rossby wave (ERW) and El Niño base state conditions resulted in strong westerly anomalies propagating west of the Date Line during early March.

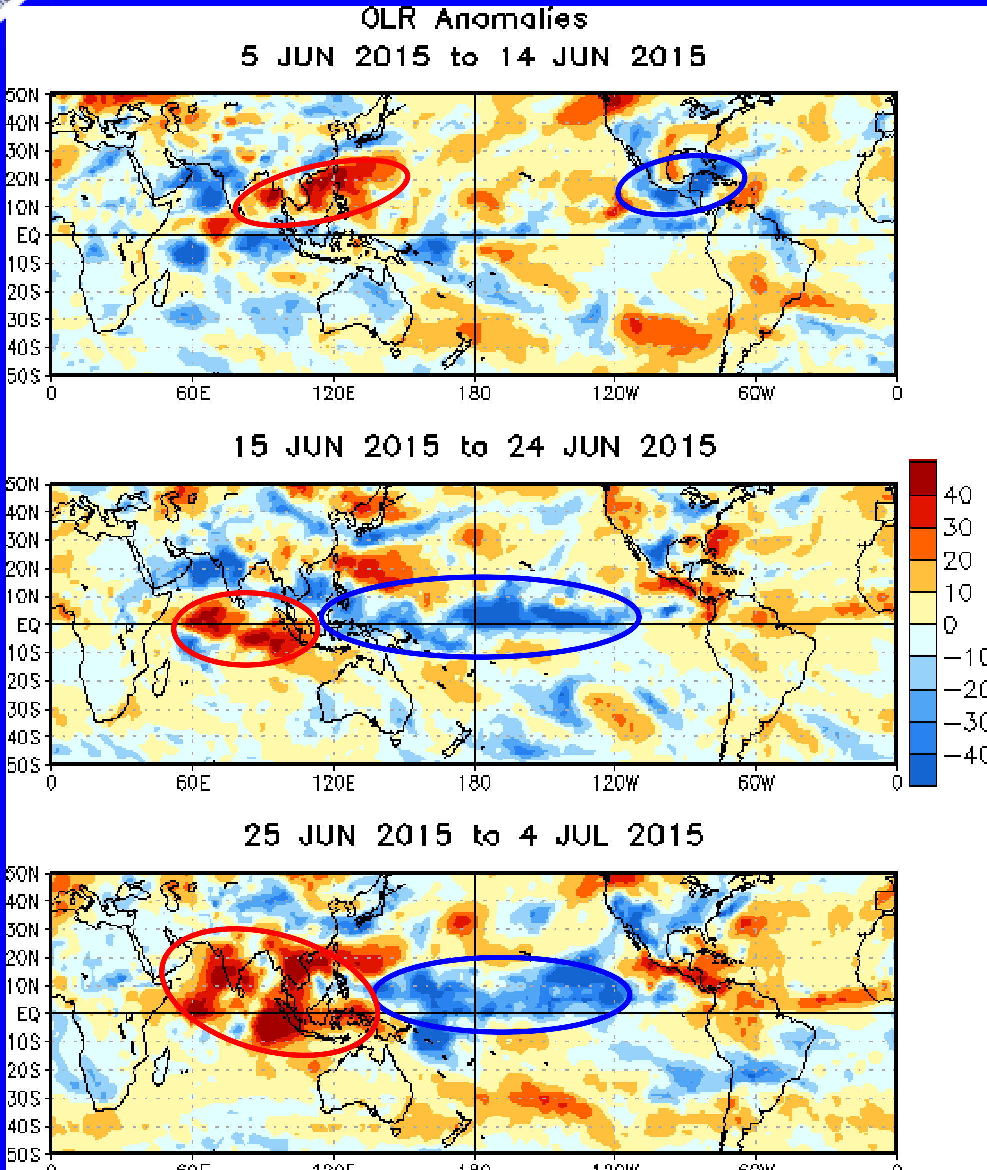
During April and May, westerly anomalies expanded over much of the central and eastern Pacific, consistent with El Nino (red box).

During June, eastward propagation and a brief disruption of the westerly anomalies across the Pacific. Recently, westerly anomalies have strengthened over much of the Pacific, especially the West Pacific.

OLR Anomalies – Past 30 days

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

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



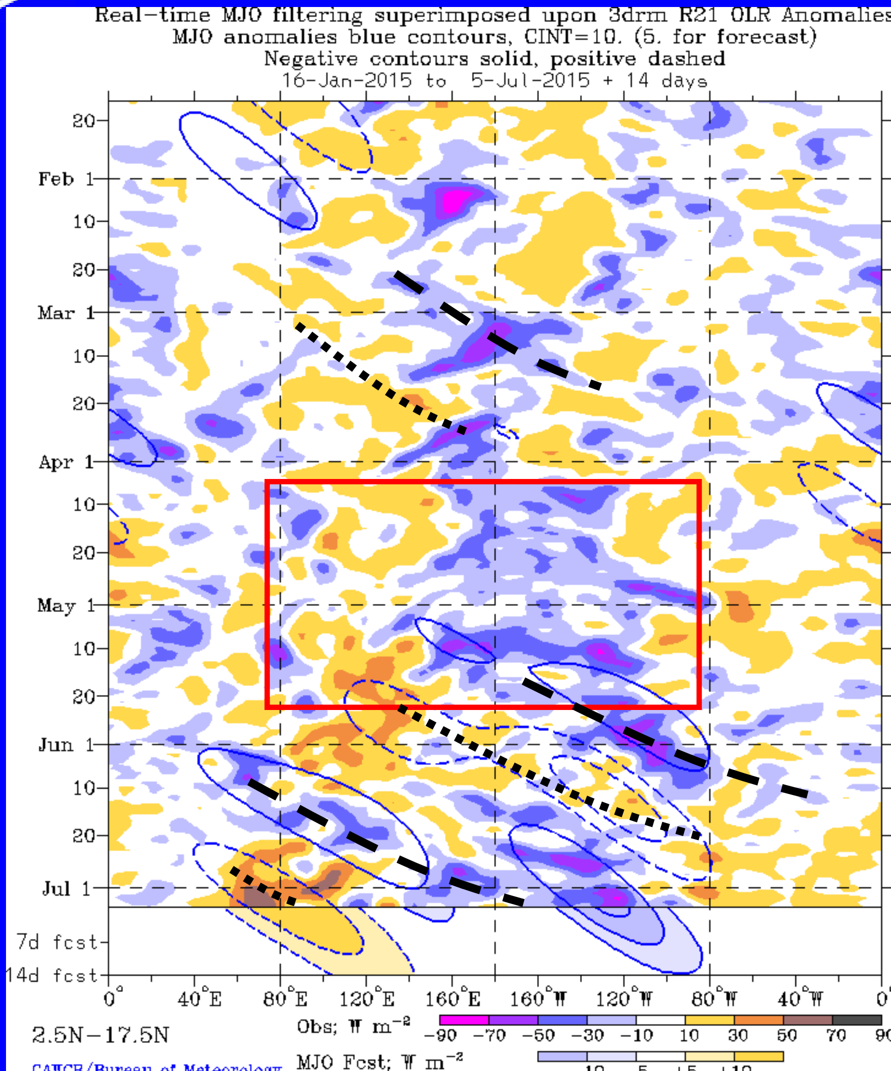
Enhanced (suppressed) convection was present over Central America and the Arabian Sea (Southeast Asia) during early to mid-June. Elsewhere, anomalies were less organized.

During mid to late June, enhanced convection extended from South and Southeast Asia to the western and central Pacific, consistent with MJO influence on the Asian Monsoon. while suppressed convection overspread the equatorial Indian Ocean. Widespread enhanced convection returned to the central Pacific.

Suppressed (enhanced) convection once again developed over much South and Southeast Asia as well as the Maritime Continent (central and eastern tropical Pacific). This pattern is consistent with the low-frequency state and evolving intraseasonal pattern.

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

Time



Longitude

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

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

(Courtesy of CAWCR Australia Bureau of Meteorology)

The MJO became active and strong during March, with eastward propagation of enhanced (suppressed) convective anomalies evident across the Pacific (Indian Ocean and Maritime Continent).

From late March to late May, enhanced (suppressed) convection has dominated at or east of the Date Line (Maritime Continent) (red box), consistent with El Niño conditions. Kelvin Waves were the most prominent subseasonal features during April and May.

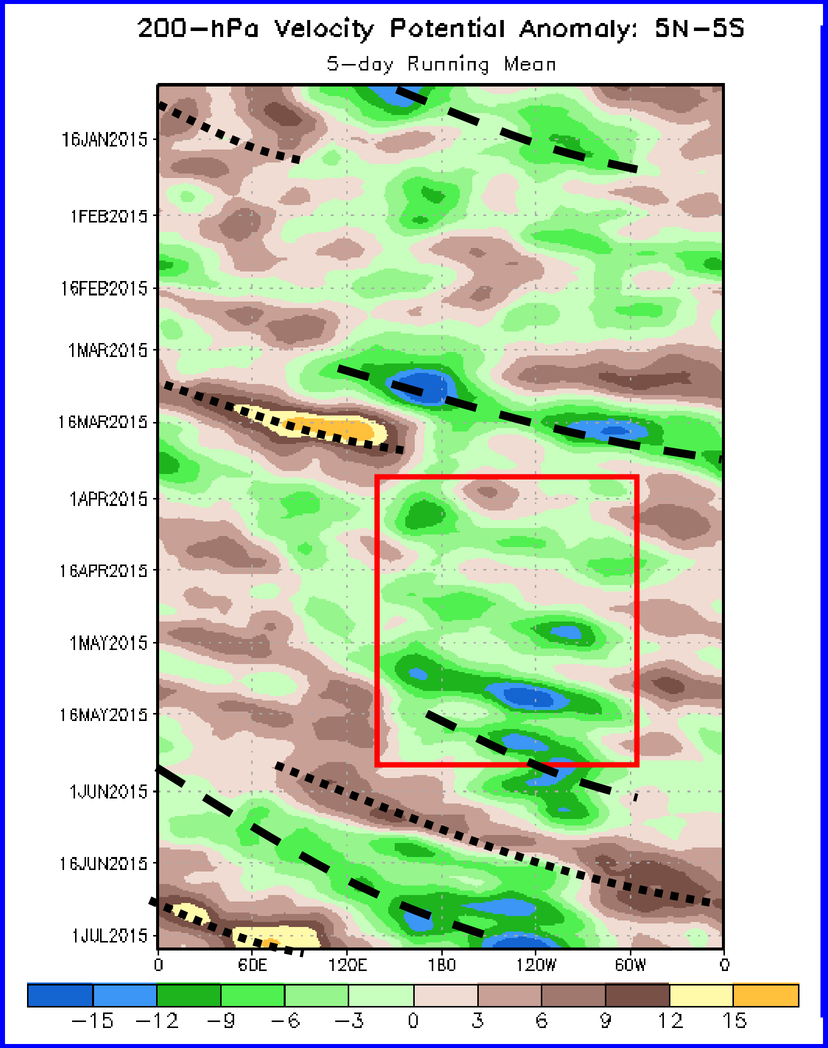
During late May and June, slower, more robust eastward propagation was evident, consistent with MJO activity. Kelvin Wave activity over the east-central Pacific ahead of the MJO enhanced envelope constructively interfered with the El Niño signal.

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

Time



Longitude

The MJO was active at the start of 2015, indicated by eastward propagation of alternating anomalies. At times, the signal was dominated by faster-moving variability (likely Kelvin Wave activity).

The signal became weak during late January and February, then strengthened again during March, as anomalies became strong as they interacted with the developing low frequency state.

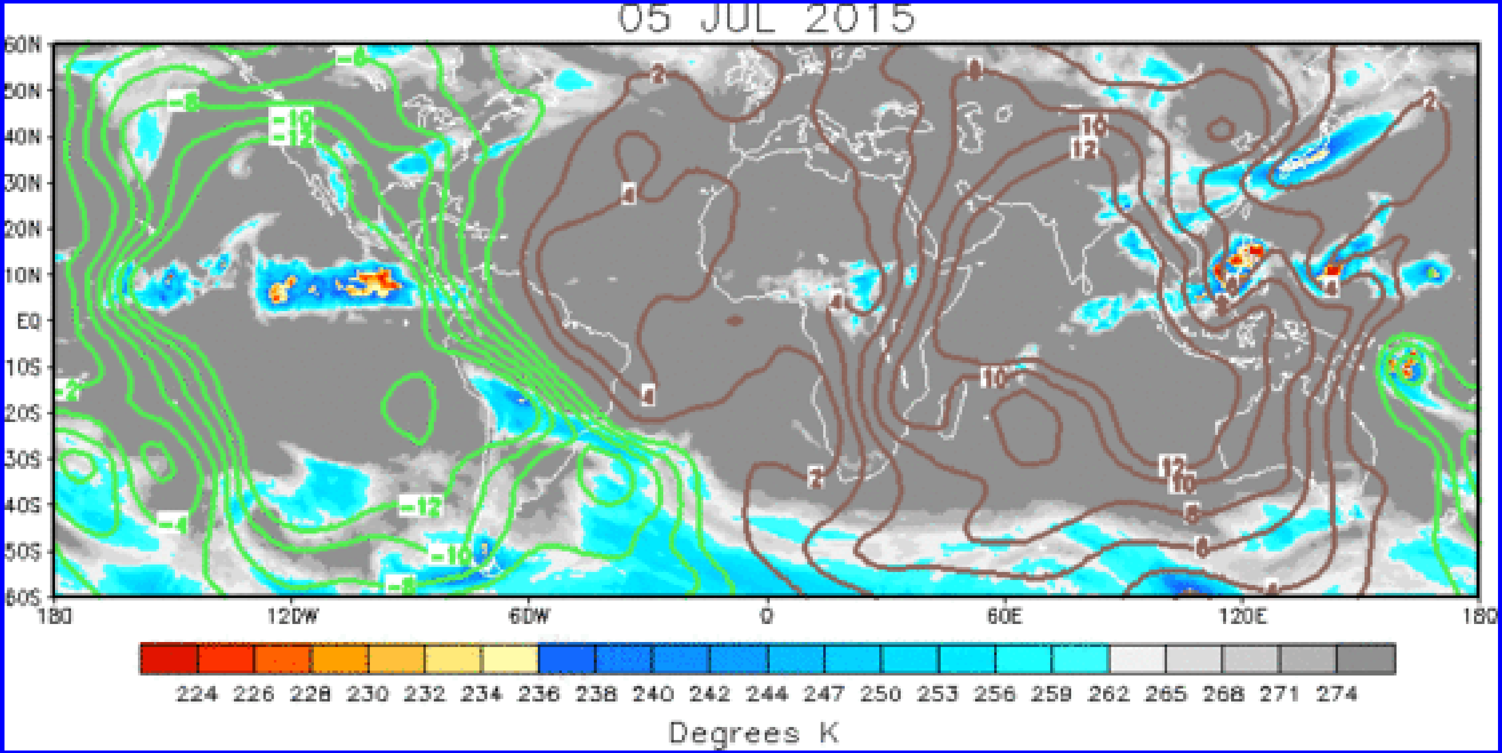
Negative anomalies persisted near the Date Line and to the east from early April through May due to the El Niño base state. During this time, Kelvin wave activity (fast eastward propagation) has been the primary subseasonal mode of variability evident in this field.

During late May and June, slower eastward propagation of an anomaly couplet was observed, consistent with an MJO event. More recently, the amplitude of the anomaly field has increased as the intraseasonal signal begins constructively interfering with the El Niño base state.

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

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

Negative anomalies (green contours) indicate favorable conditions for precipitation



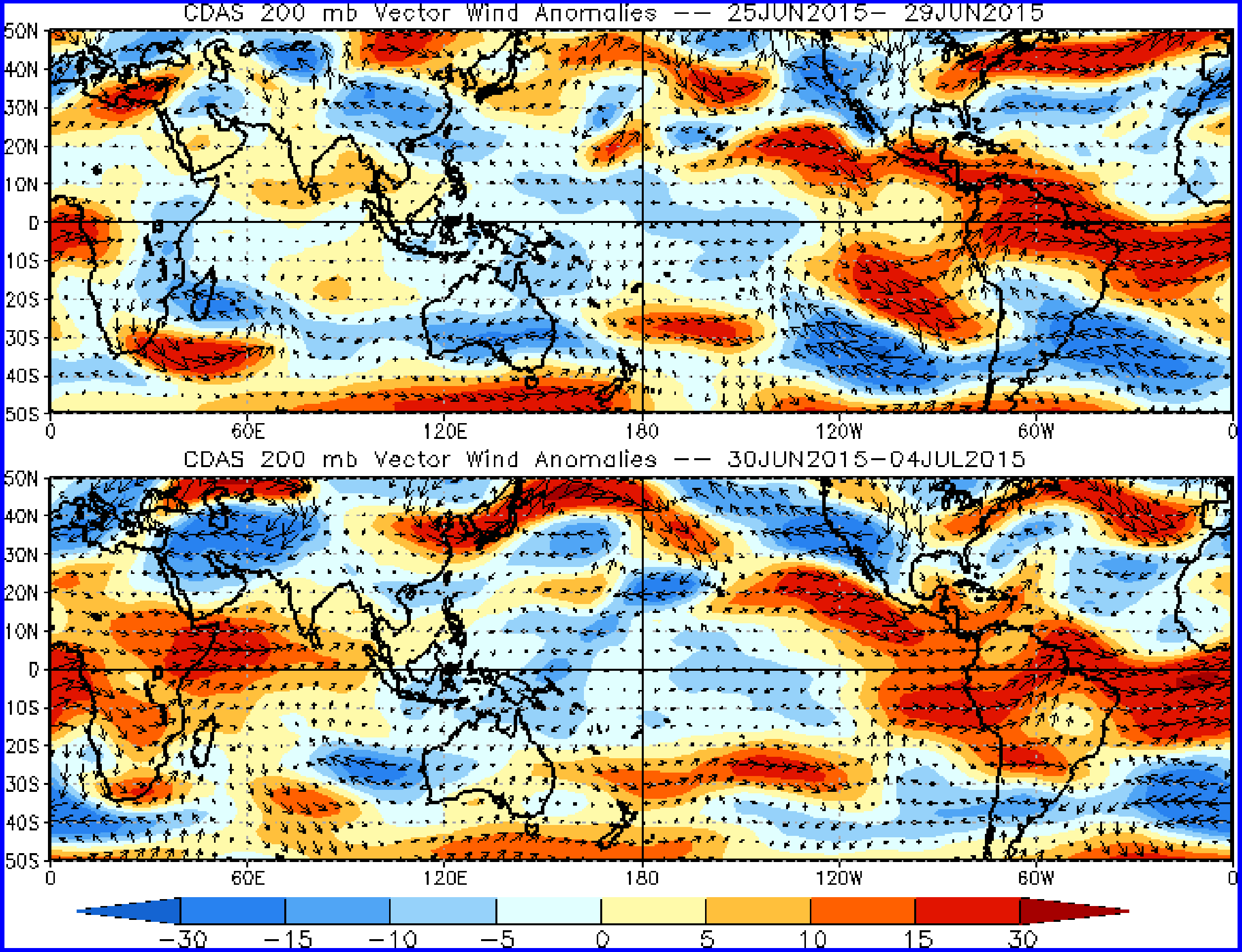
The spatial velocity potential pattern continues to maintain a robust and coherent Wave-1 structure, consistent with MJO activity. The suppressed phase is currently over the Atlantic, Africa, and the Indian Ocean, while negative VP anomalies associated with the enhanced phase overspread the entire Pacific basin.

200-hPa Vector Wind Anomalies (m s^{-1})

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies



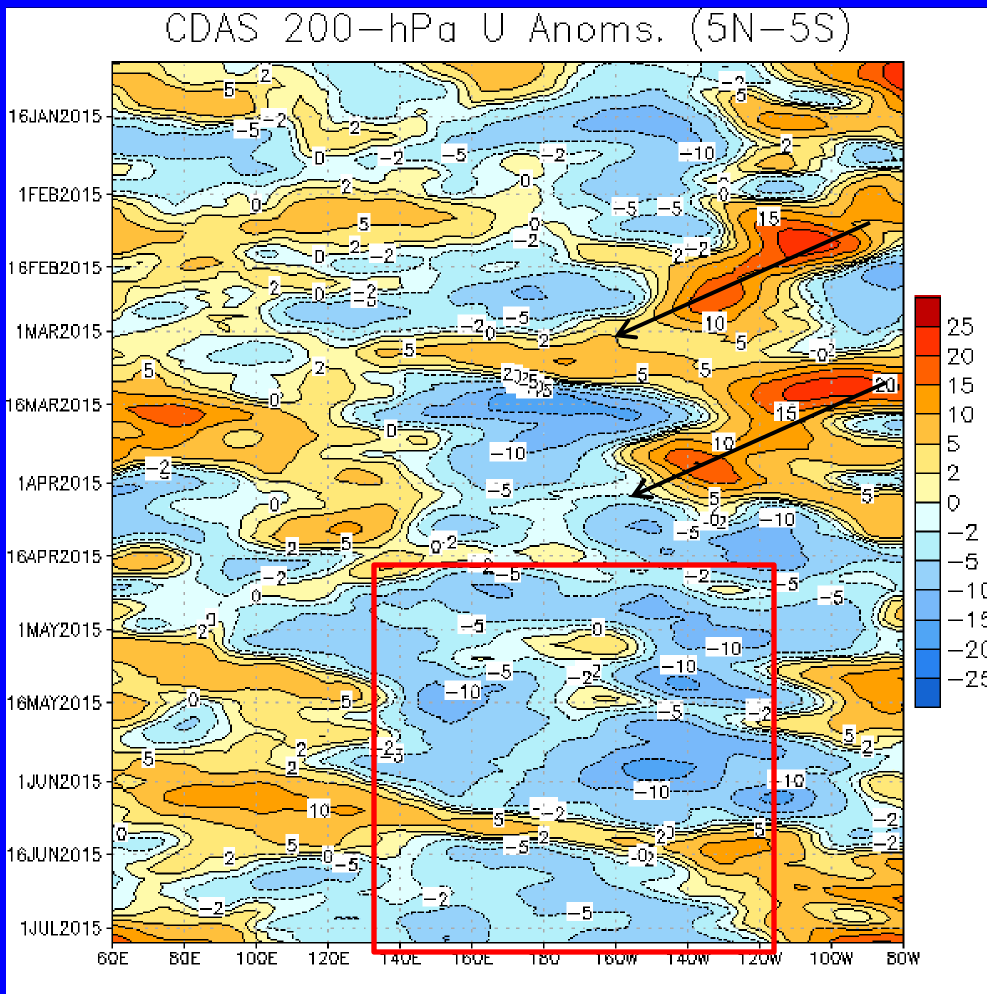
Westerly anomalies strengthened over the Americas during the ten days, while easterly anomalies developed near the Date Line. Westerly anomalies also developed over the Arabian Sea and Africa.

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

Time



Longitude

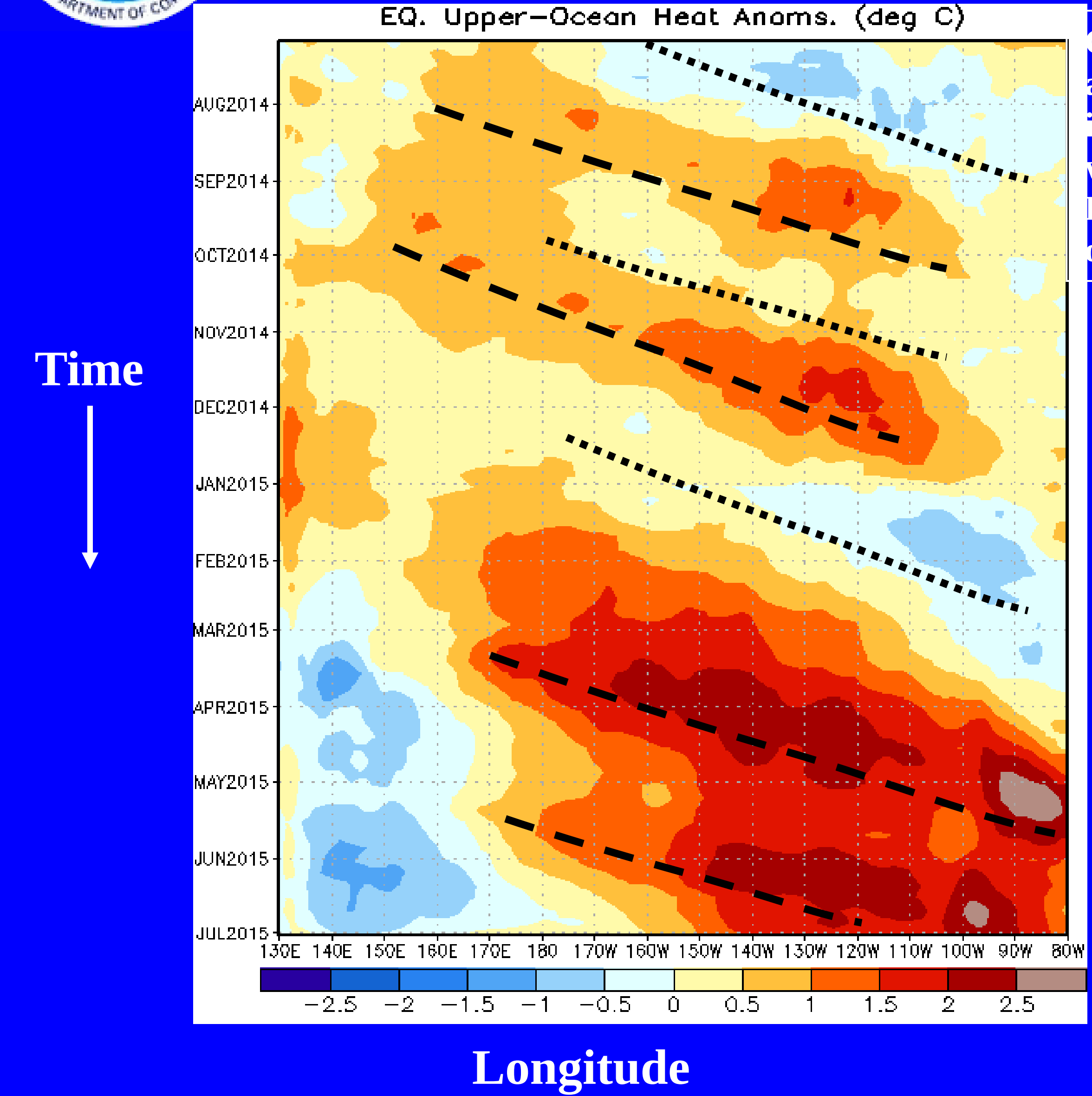
During January through the mid-April, westerly anomalies increased in coverage and intensity from 120W to 80W.

Westward propagation of westerly anomalies was evident over the eastern Pacific during late February and again in March (black arrows).

Easterly anomalies have generally persisted over the central and eastern Pacific (red box) consistent with El Nino since early May.

During June, westerly anomalies propagated eastward from the Maritime Continent to the western Hemisphere, consistent with MJO activity. Easterly anomalies developed near the Date Line and have expanded over most of the Pacific basin.

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.

The upwelling phase of a Kelvin wave went through during May-July 2014.

During October-November, positive subsurface temperature anomalies increased and shifted eastward in association with the downwelling phase of a Kelvin wave.

During November - January, the upwelling phase of a Kelvin wave shifted eastward.

During January through April, a very strong downwelling Kelvin Wave was observed..

Positive anomalies persisted over the central and Eastern Pacific, with evidence of a potential second downwelling Kelvin Wave evident during late May and early June.

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).

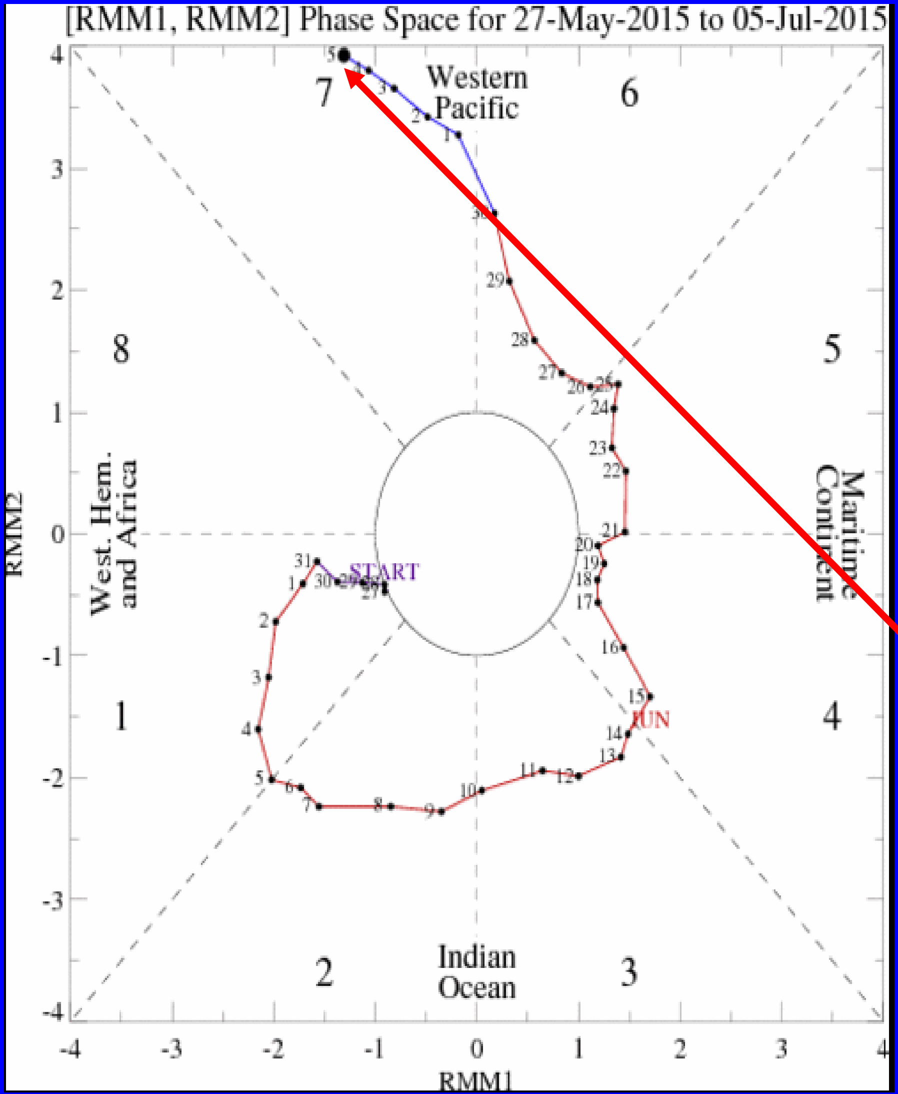
Wheeler M. and H. Hendon, 2004: An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction, *Monthly Weather Review,* 132, 1917-1932.

• 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).

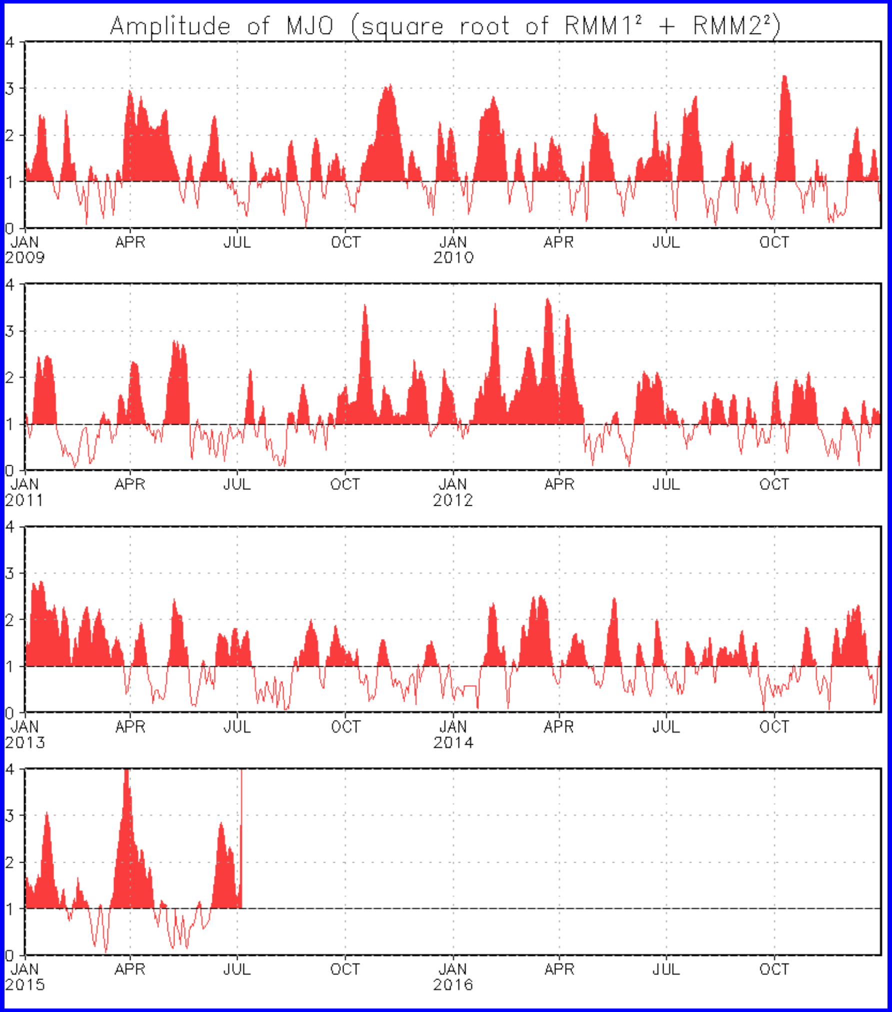
MJO Index -- Recent Evolution



- 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 RMM based MJO index indicates a very strong signal, likely due to many factors, including tropical cyclone activity and constructive interference between modes of intraseasonal and interseasonal variability.

MJO Index – Historical Daily Time Series



Time series of daily MJO index amplitude from 2007 to present.

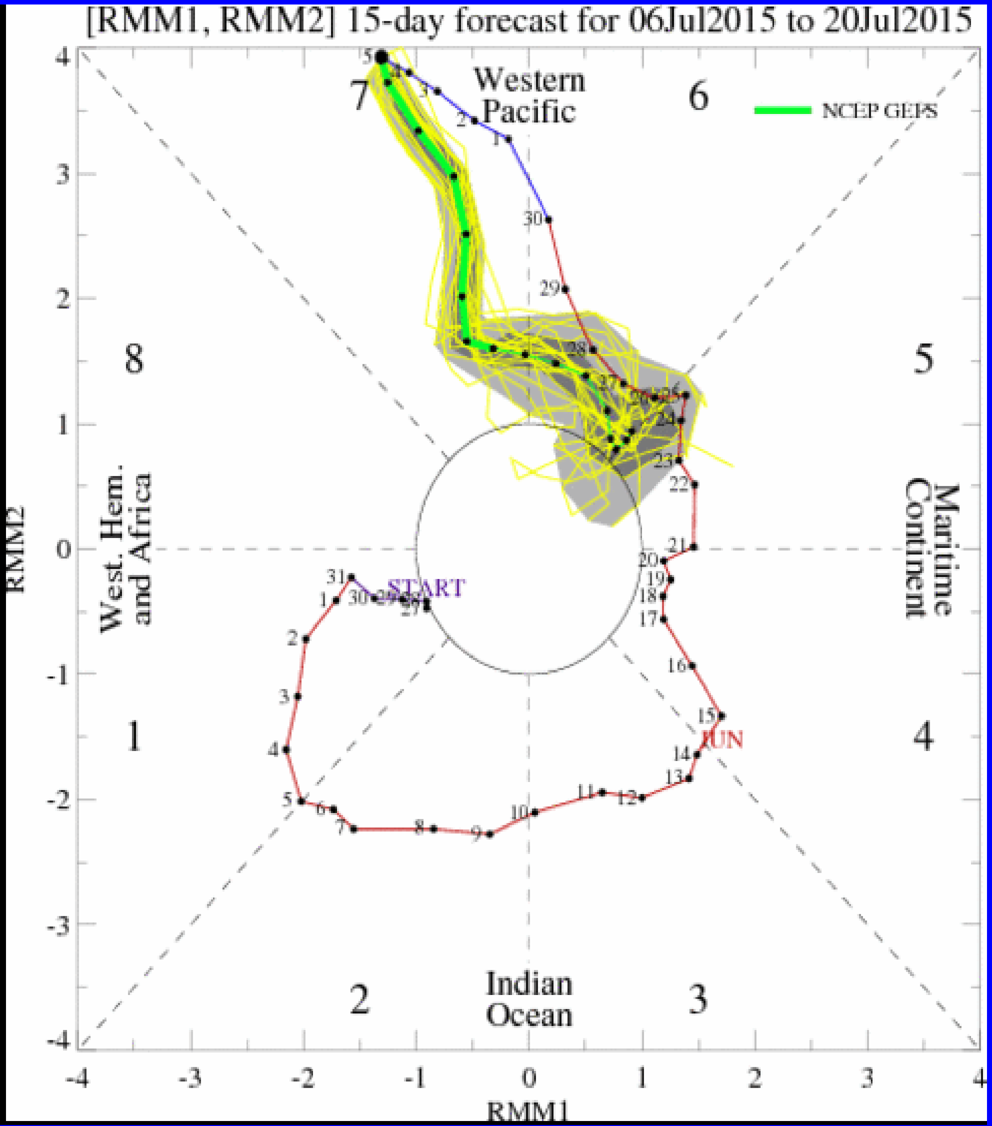
Plot puts current MJO activity in recent historical context.

Ensemble GFS (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 ensemble Global Forecast System (GEFS) for the next 15 days

light gray shading: 90% of forecasts
dark gray shading: 50% of forecasts

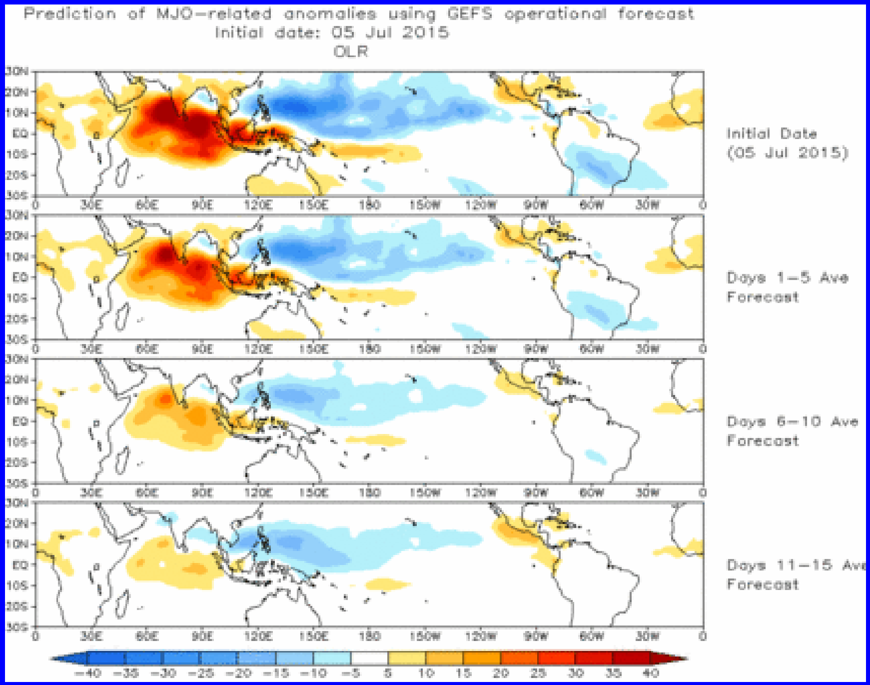


The GFS ensemble MJO index forecast depicts a substantial decrease in amplitude during the two week outlook period, along with some retrogression of the signal.

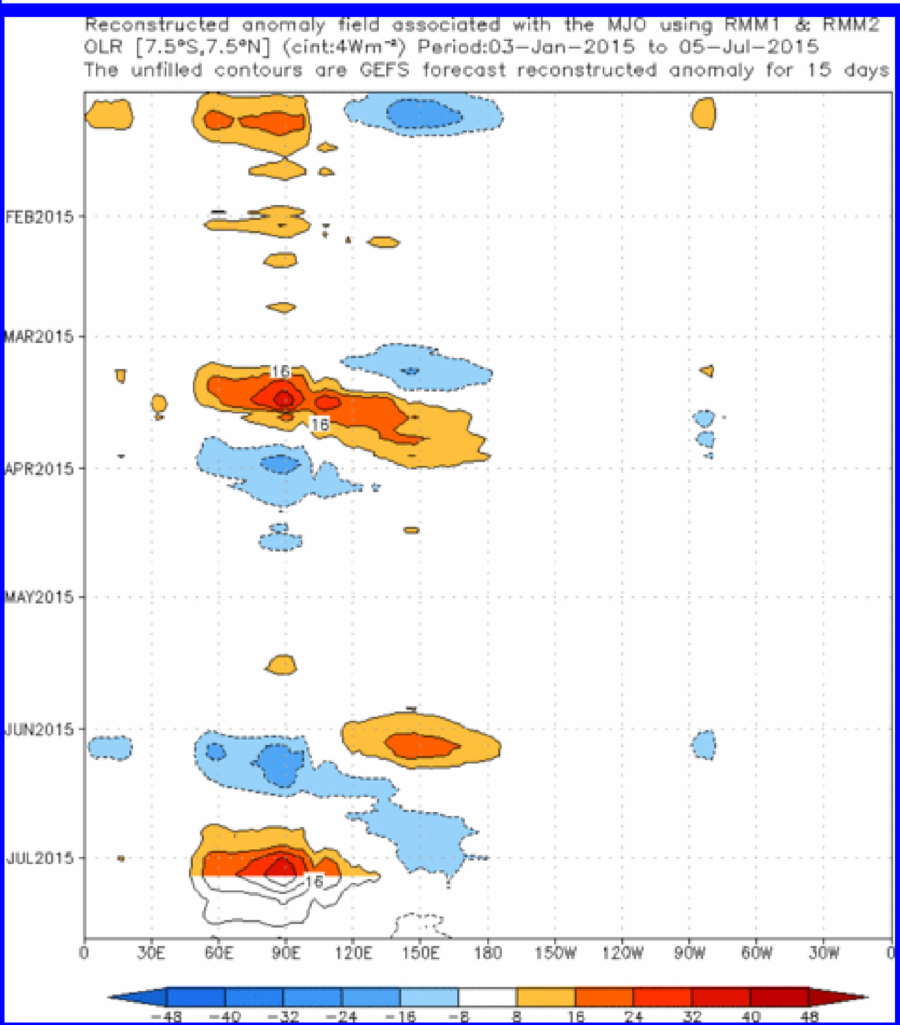
Ensemble Mean GFS MJO Forecast

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 for the last 180 days and for the next 15 days

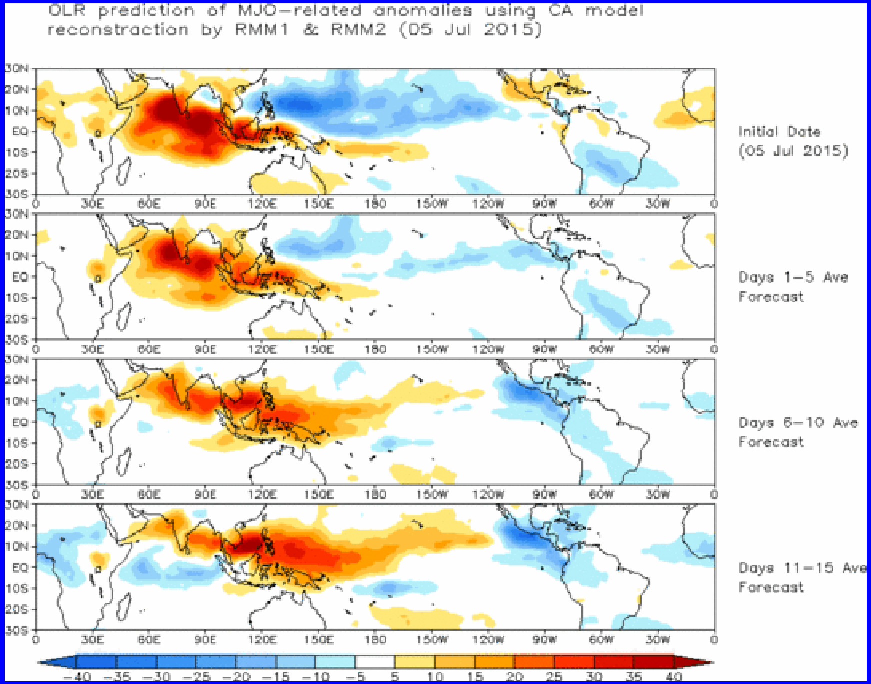


The ensemble GFS MJO index based forecast depicts robust enhanced (suppressed) convective anomalies over the western Pacific (Indian Ocean and southern Asia), with little to no eastward propagation.

Constructed Analog (CA) MJO Forecast

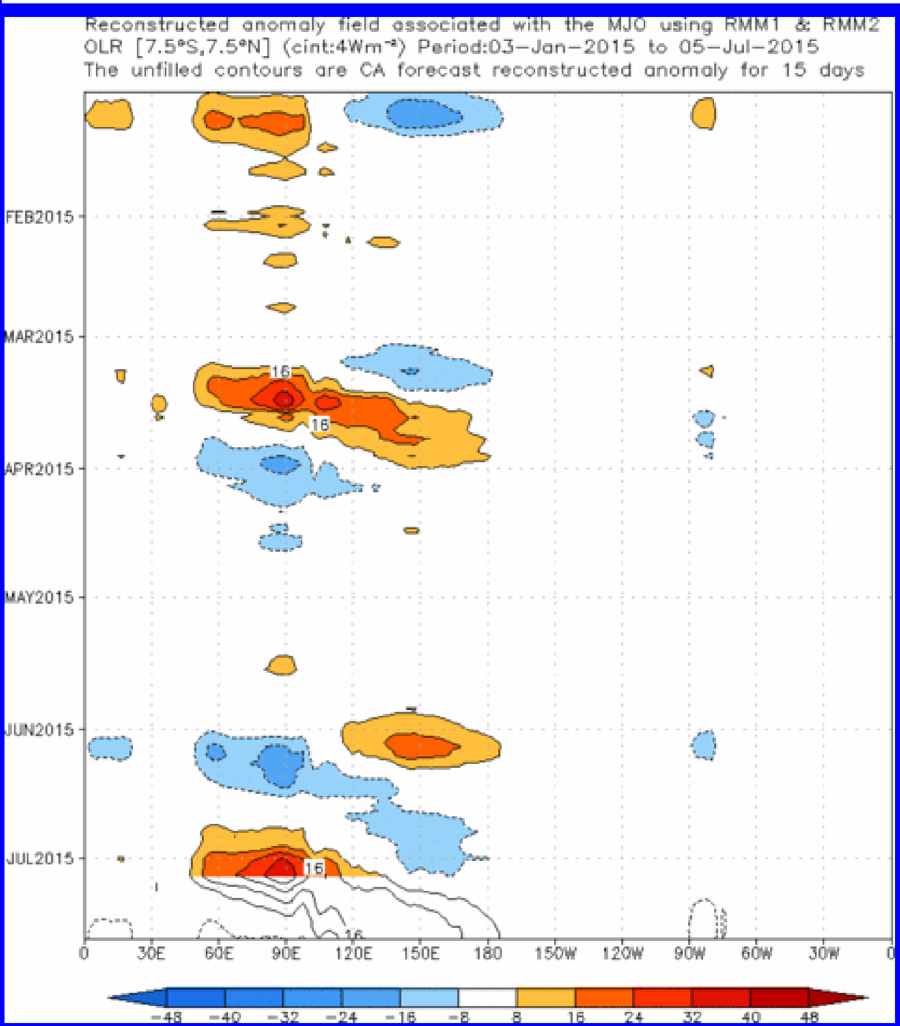
Figure below shows MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



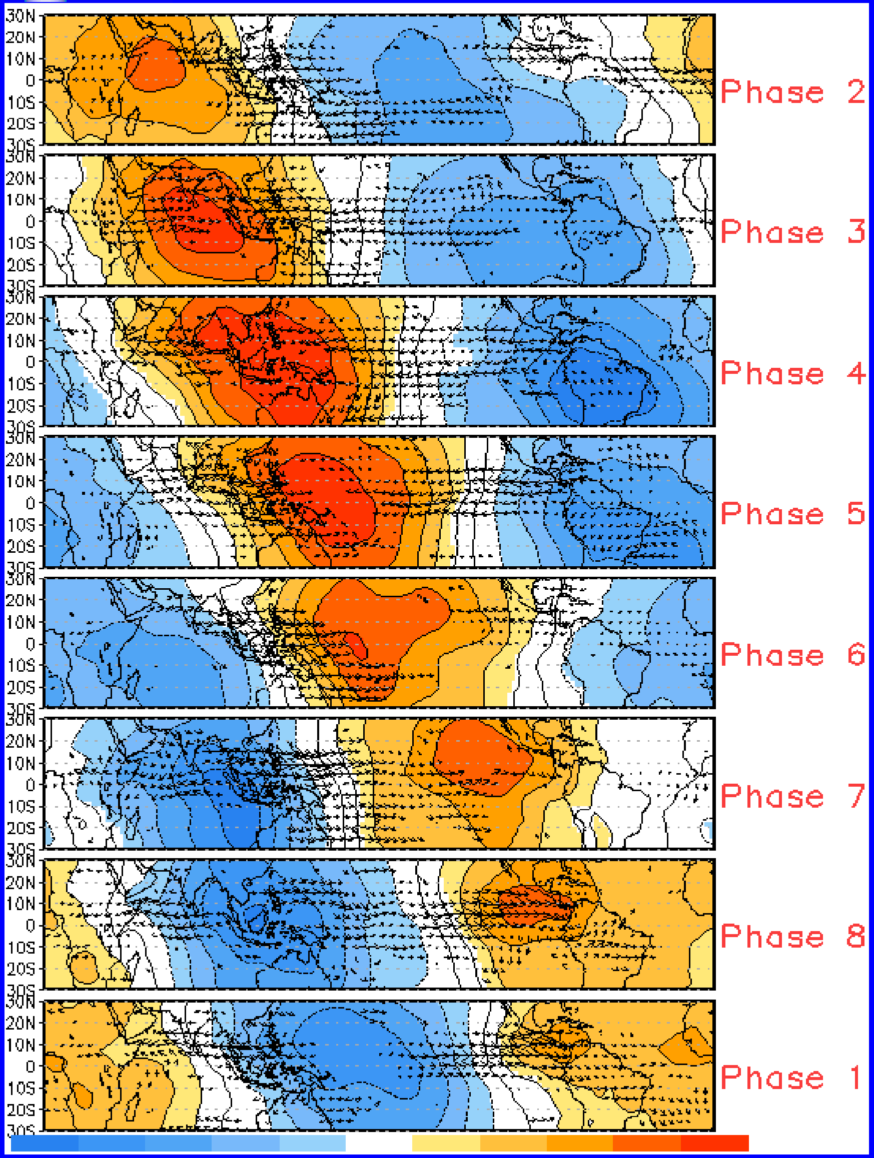
The statistical forecast depicts a continued eastward propagation of a moderate amplitude signal during the next two weeks.

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

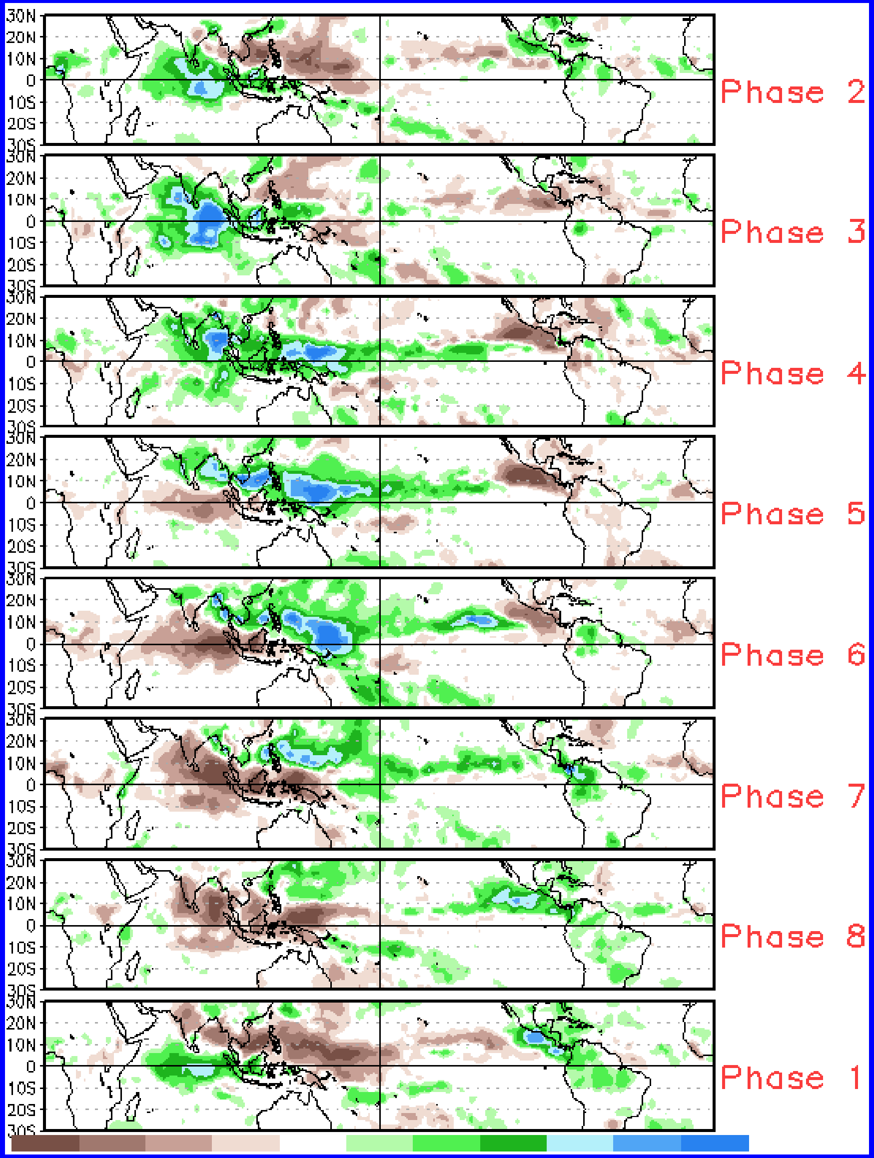


MJO Composites – Global Tropics

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

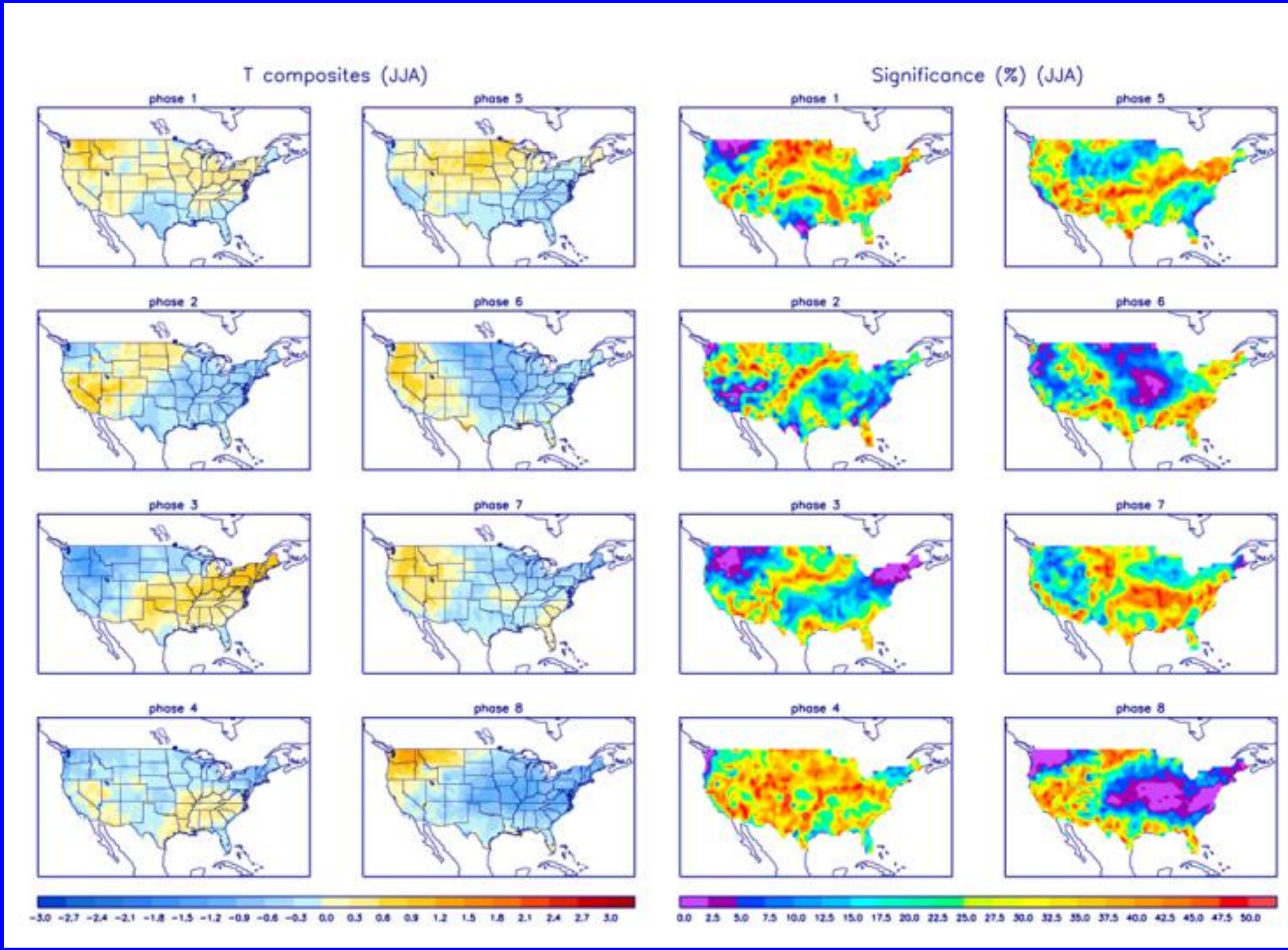


Precipitation Anomalies (May-Sep)



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.

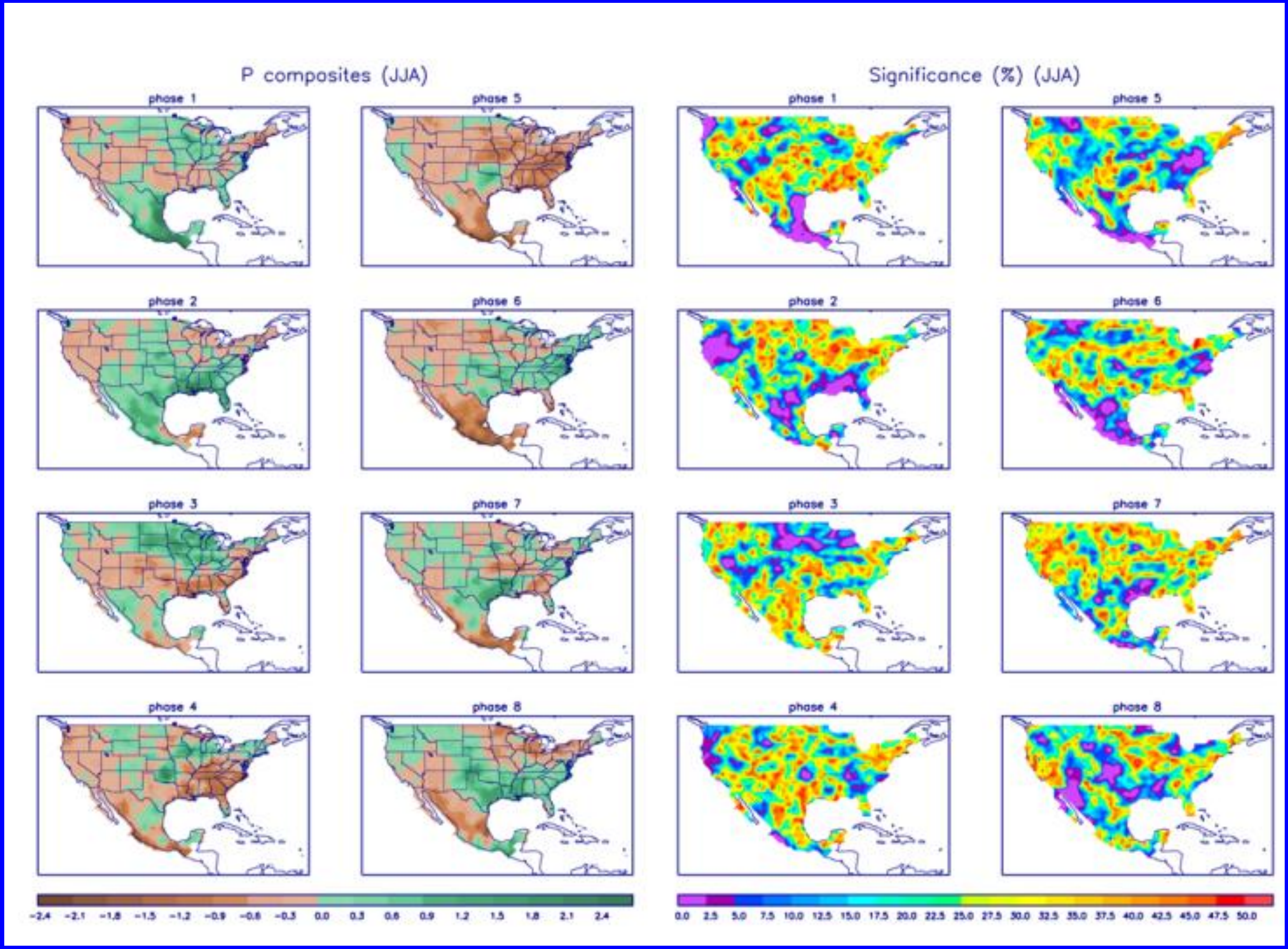


Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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.**



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