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

Update prepared by
Climate Prediction Center / NCEP
June 15, 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 eastern Indian Ocean and western Maritime Continent.

- Destructive interference between the MJO and the El Niño state continues, with the enhanced phase of the MJO appearing weaker over the Maritime Continent due to a base state favoring suppressed convection. The suppressed phase of the MJO is currently disrupting El Niño-favored convection over the equatorial central and eastern Pacific.

- Most dynamical model MJO index forecasts favor continued eastward propagation of a weaker MJO signal over the Maritime Continent to the West Pacific during the upcoming two weeks. The GFS model indicates a weakening signal during the next two weeks.

- The MJO is expected to play a substantial role in the global tropical convective pattern during the upcoming week, and may contribute to an enhancement of the South Asian Monsoon. The MJO is favored to begin constructively interfering with the low frequency El Niño state by Week-2.

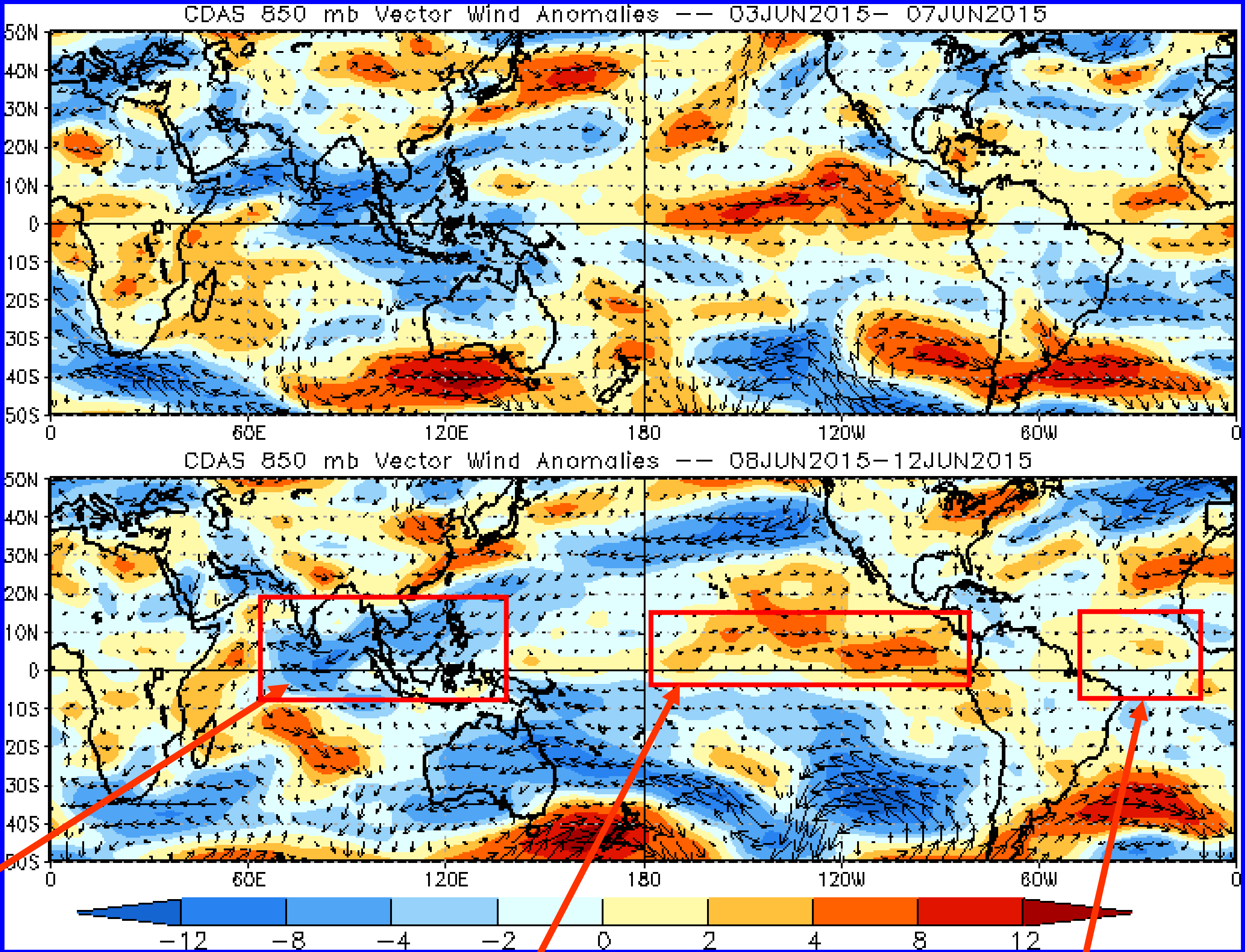
Additional potential impacts across the global tropics and a discussion for the U.S. are available at:
http://www.cpc.ncep.noaa.gov/products/precip/CWlink/ghazards/index.php

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

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies



Easterly anomalies persisted over the Indian Ocean and northwest Pacific, somewhat out of phase with the MJO.

Westerly anomalies persisted across the eastern Pacific, but weakened slightly.

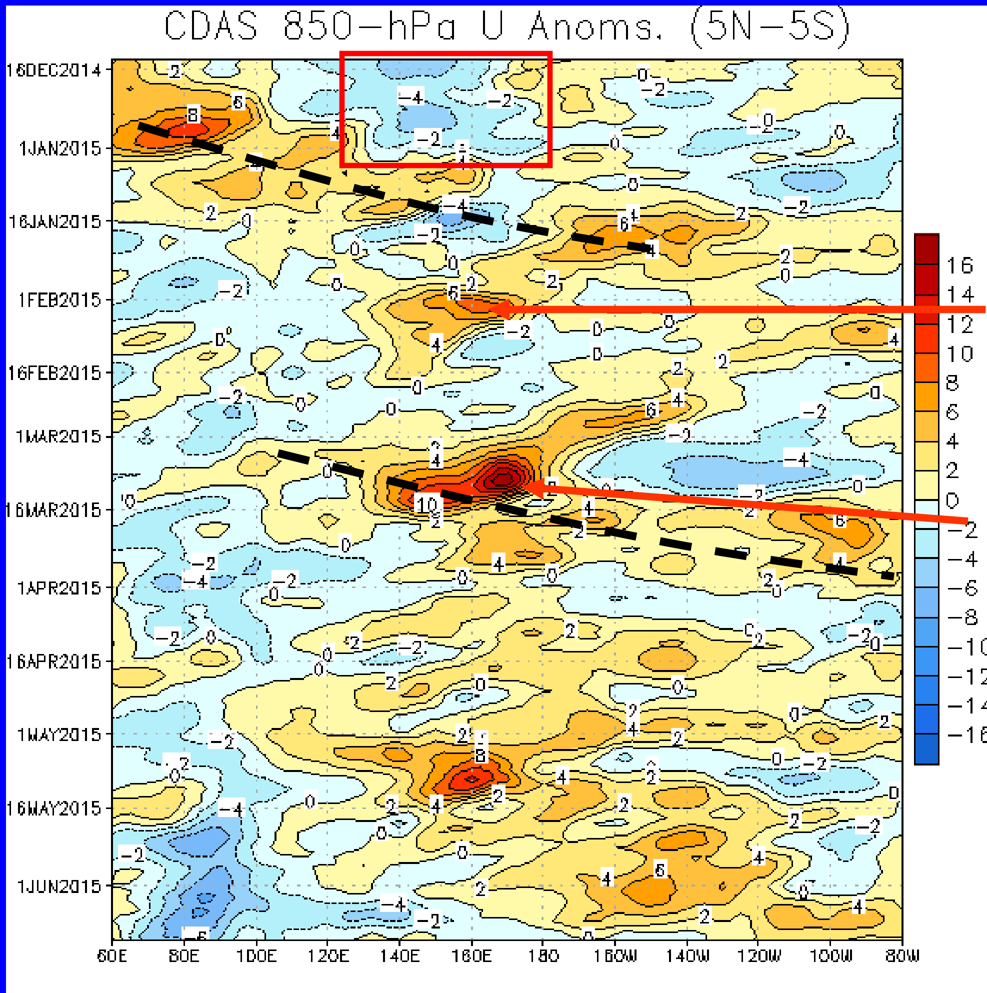
Westerly anomalies weakened over the eastern tropical Atlantic.

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

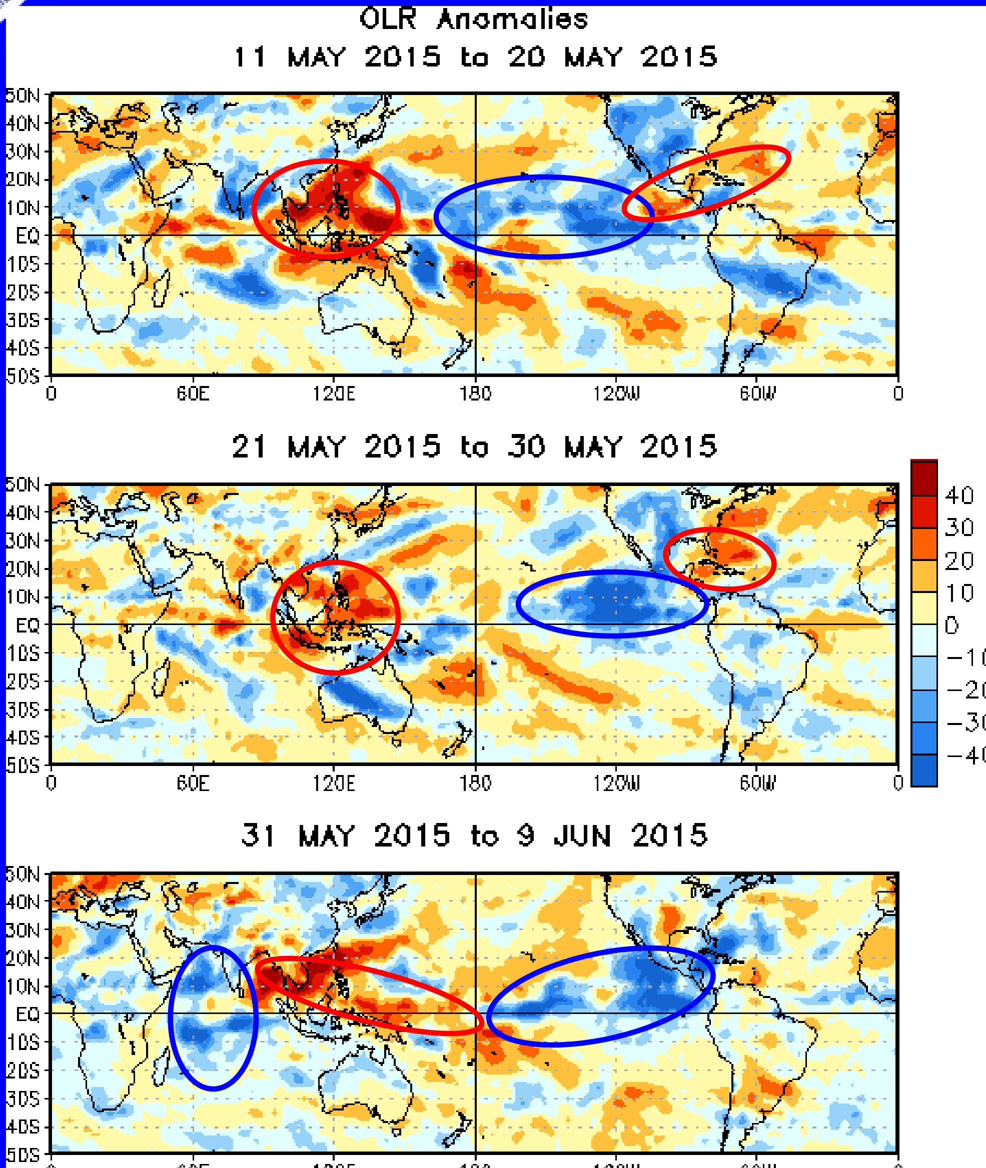
During December, easterly anomalies persisted from 120E to the Date Line (red box).

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. More recently, eastward propagation on the intra-seasonal time scale was observed.

OLR Anomalies – Past 30 days



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

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

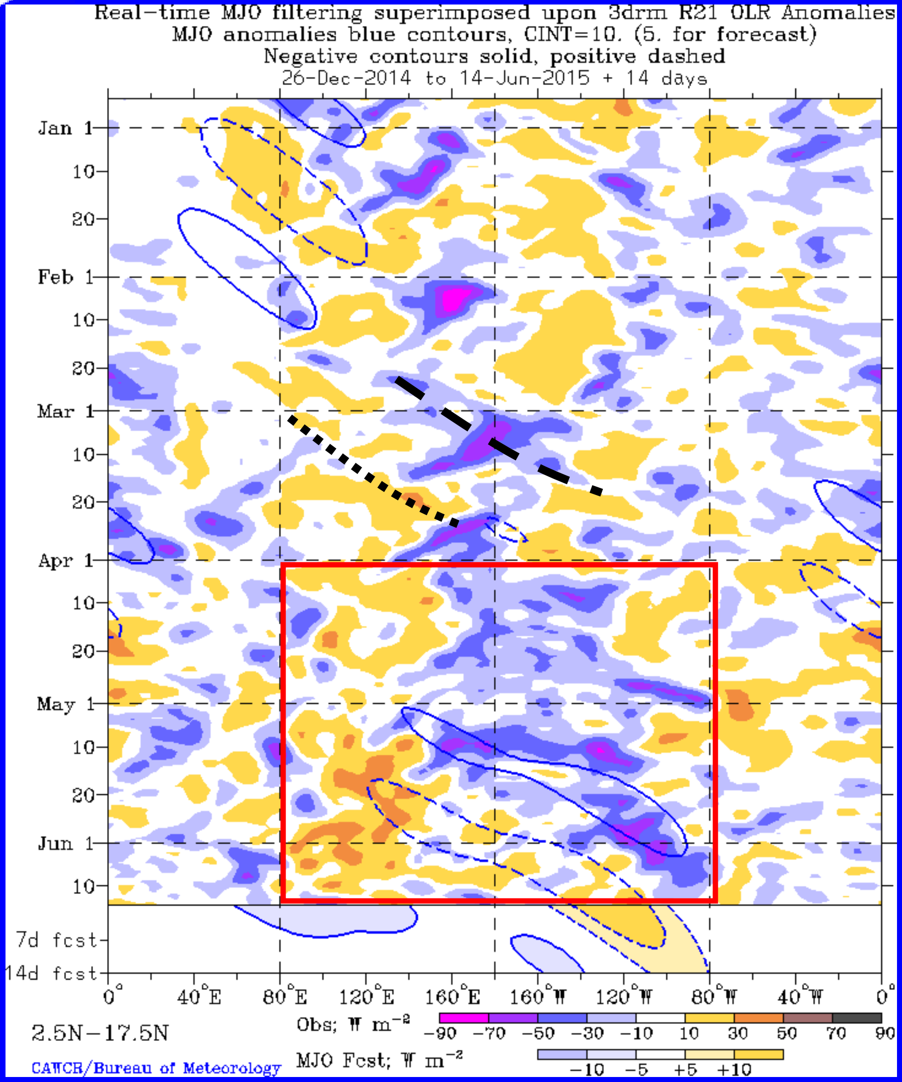
During mid-May enhanced (suppressed) convection was noted over the central Pacific (Southeast Asia, northwestern Pacific, parts of the eastern Pacific and tropical Atlantic).

Convection weakened near the Date Line during late May, with enhanced convection persisting over the eastern Pacific. Suppressed convection continued over southeastern Asia, the western Maritime Continent, and the western Atlantic.

During early June, enhanced convection over the eastern Pacific and Arabian Sea was associated with tropical cyclone activity. The low frequency suppressed convection signal weakened over the southern Maritime Continent, but persisted over Southeast Asia.

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) anomalies evident across the Pacific (Indian Ocean and Maritime Continent).

Since late March, 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.

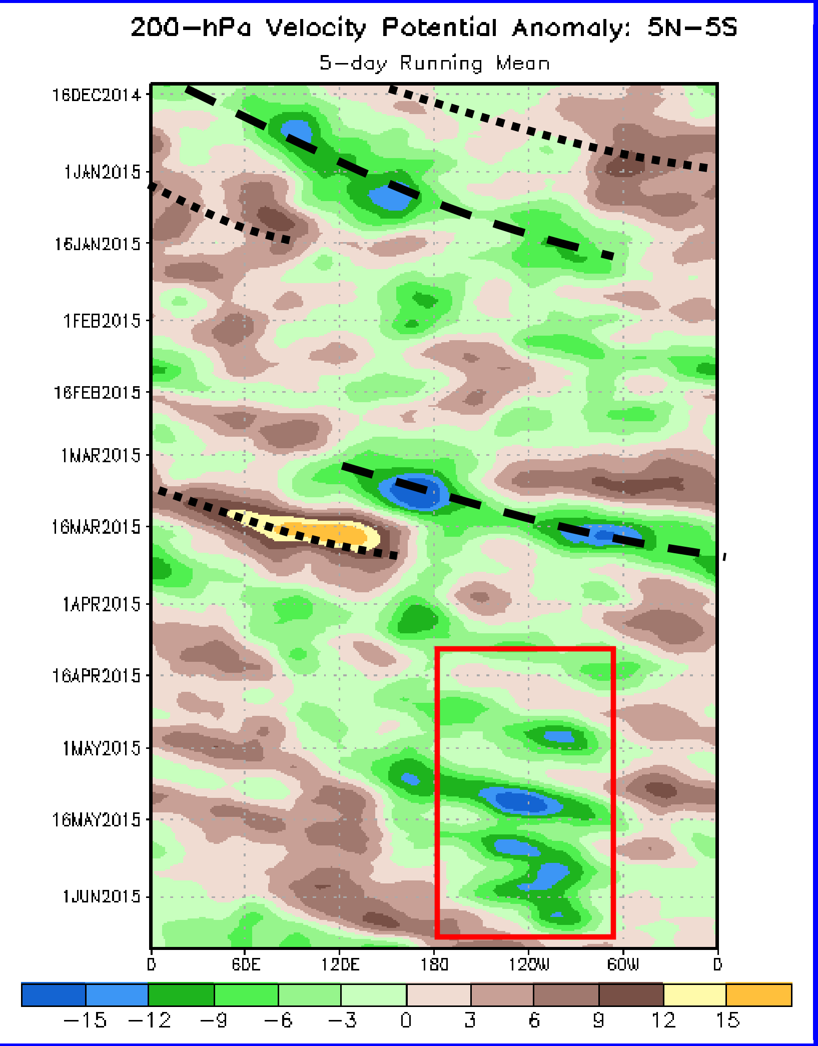
During late May and early June, slower, more robust eastward propagation was evident, consistent with MJO activity.

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

Time



Longitude

From December 2014 though January 2015, the MJO was active, as indicated by eastward propagation of alternating anomalies. At times, the signal was dominated by faster-moving variability (likely Kelvin Wave activity).

The signal was weak much of January and during February.

During March, MJO activity was observed, with anomalies becoming strong as they interacted with the developing low frequency state.

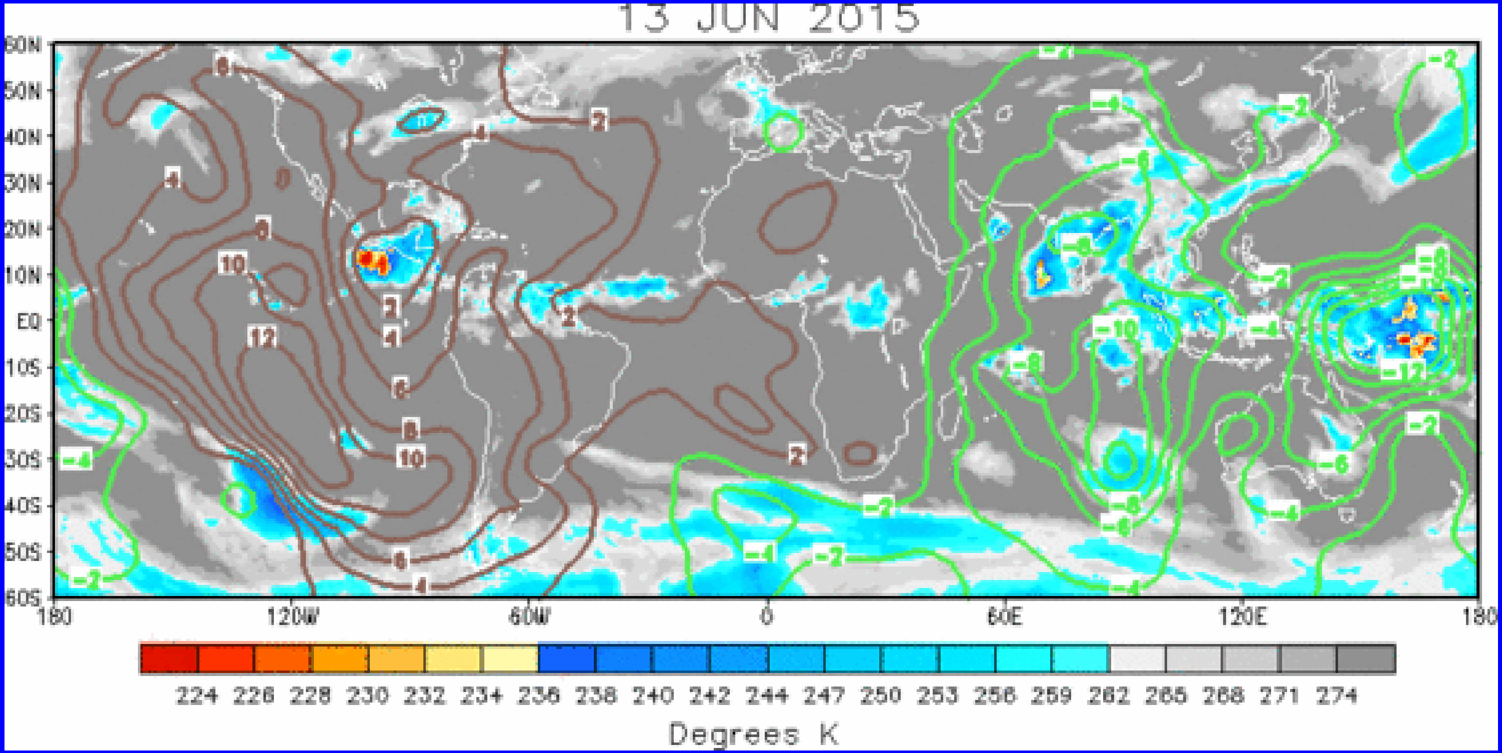
Negative anomalies persisted near the Date Line and to the east since early April due to the El Niño base state. During this time, Kelvin wave activity (fast eastward propagation) has been the primary subseasonal mode of variability evident in this field.

More recently, slower eastward propagation of positive VP anomalies was observed over the West Pacific, while negative anomalies developed over the Indian Ocean, consistent with MJO activity.

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



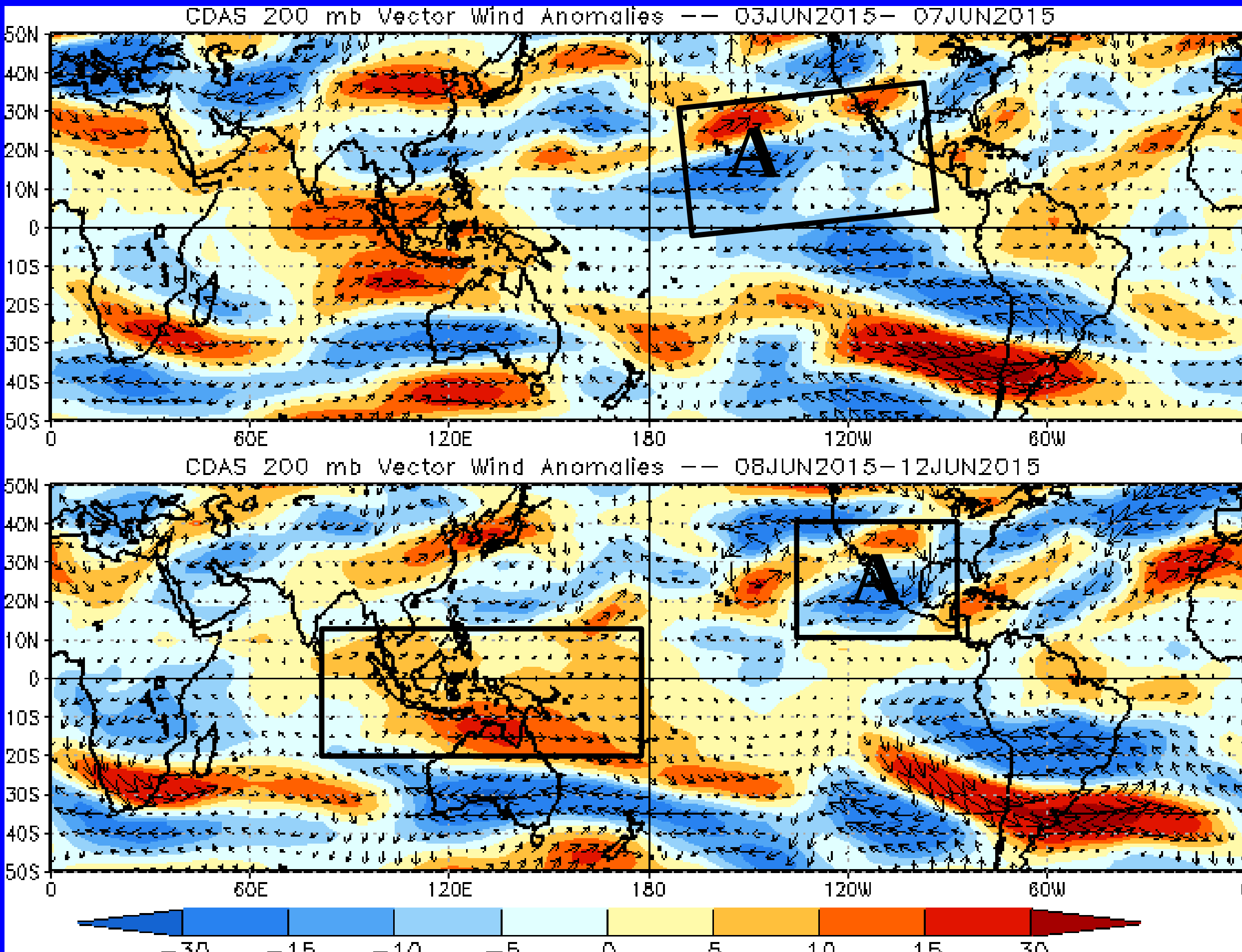
The spatial velocity potential pattern has a coherent Wave-1 structure, with positive anomalies (associated with suppressed convection) over the eastern Pacific as the MJO interferes with the El Niño state, and negative anomalies (associated with enhanced convection) propagate over the eastern Indian Ocean and Maritime Continent. Enhanced convection developing over the western Pacific is associated with a Kelvin Wave emerging ahead of the primary MJO envelope constructively interacting with the base state.

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 ridging persisted over the subtropical central and eastern Pacific, consistent with El Niño conditions. This anomalous circulation has allowed moisture to impact the continental U.S. at times during the period.

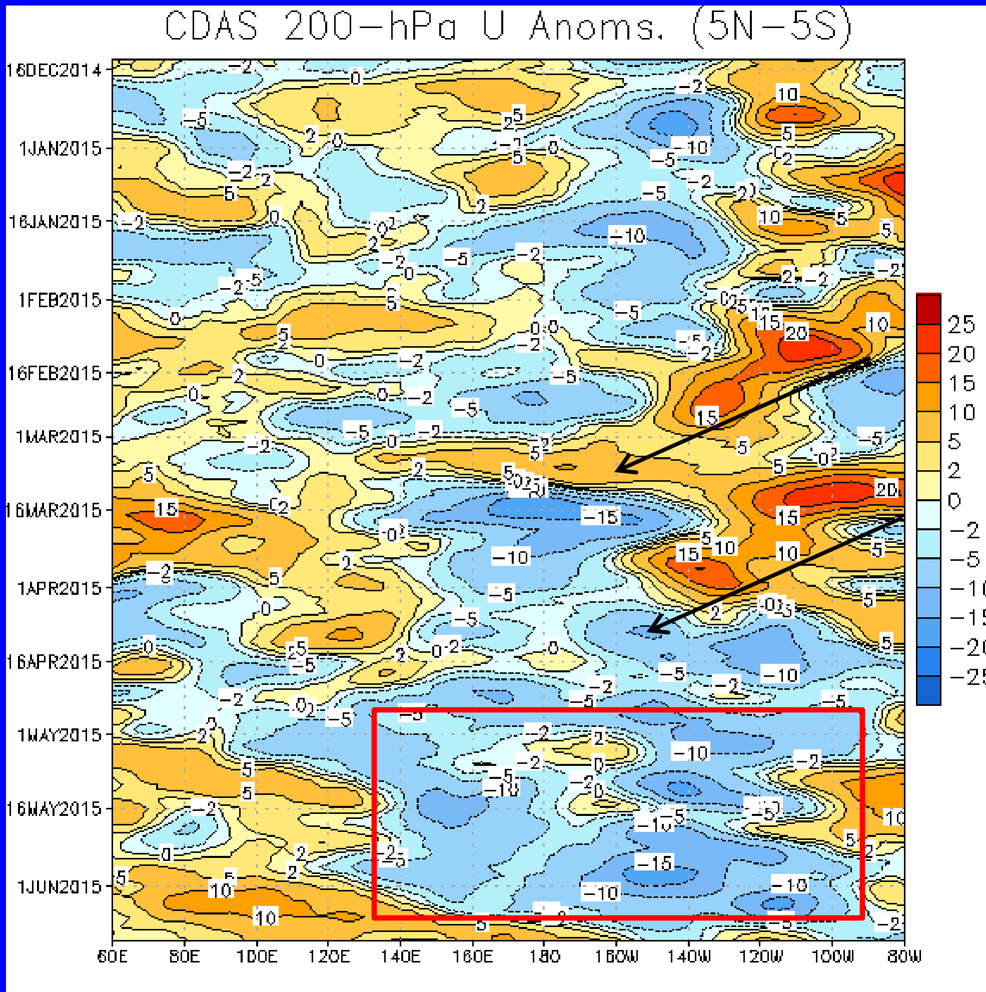
More recently, the pattern was disrupted by MJO activity, with the subtropical ridge shifting eastward over the eastern Pacific, and westerly anomalies propagating eastward to the Date Line.

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

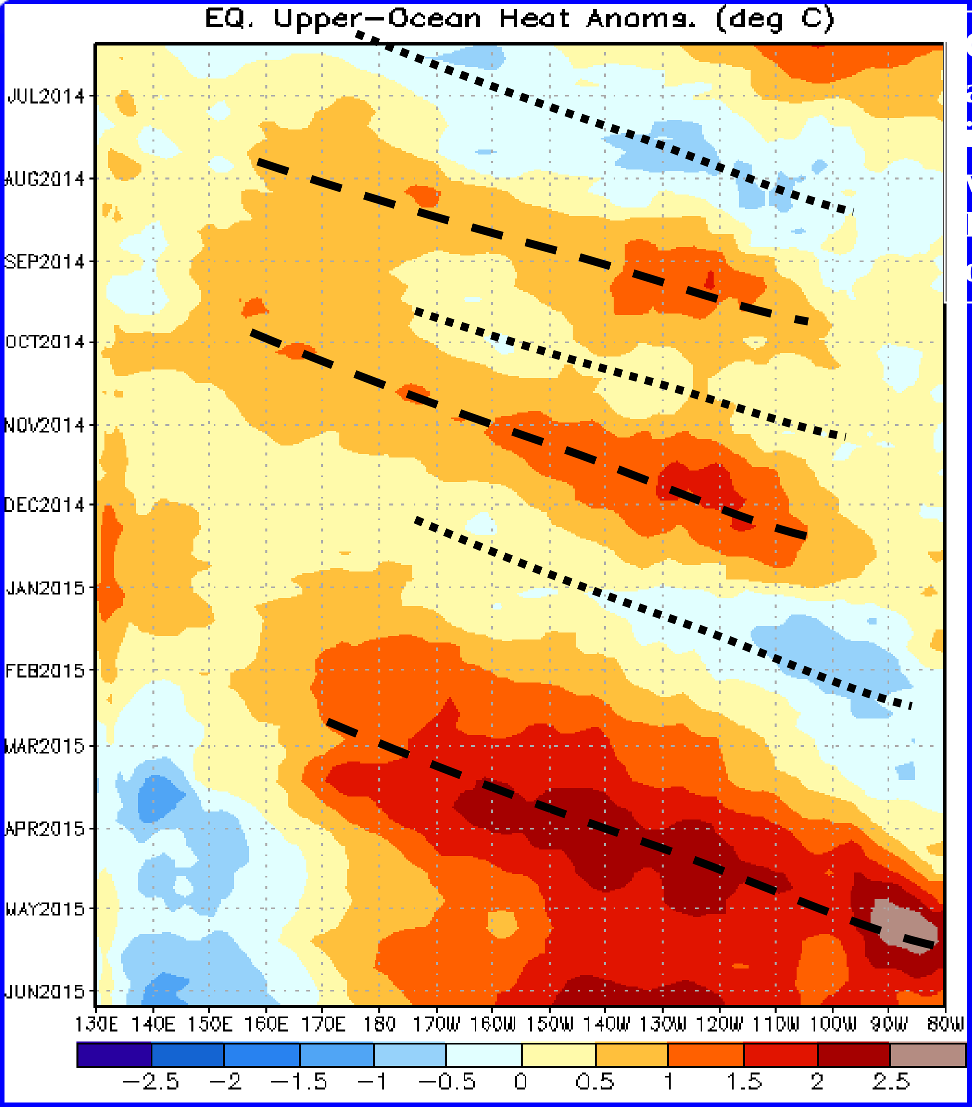
Westward propagation of westerly anomalies was evident over the eastern Pacific during late February and again in March (black arrows).

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

More recently, westerly anomalies propagated from the Maritime Continent to the west-central Pacific, consistent with MJO activity.

Weekly Heat Content Evolution in the Equatorial Pacific

Time



Longitude

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).

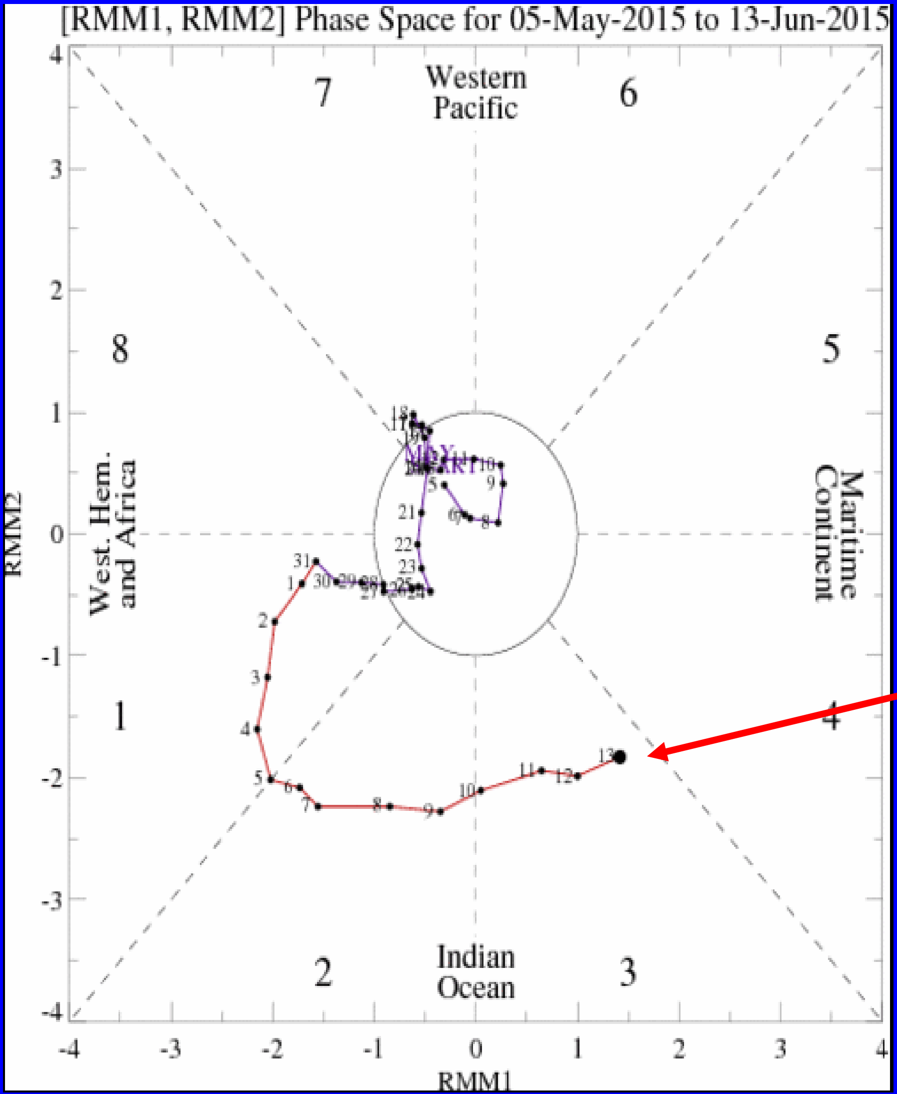
Wheeler M. and H. Hendon, 2004: An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction, *Monthly Weather Review,* 132, 1917-1932.

• 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).

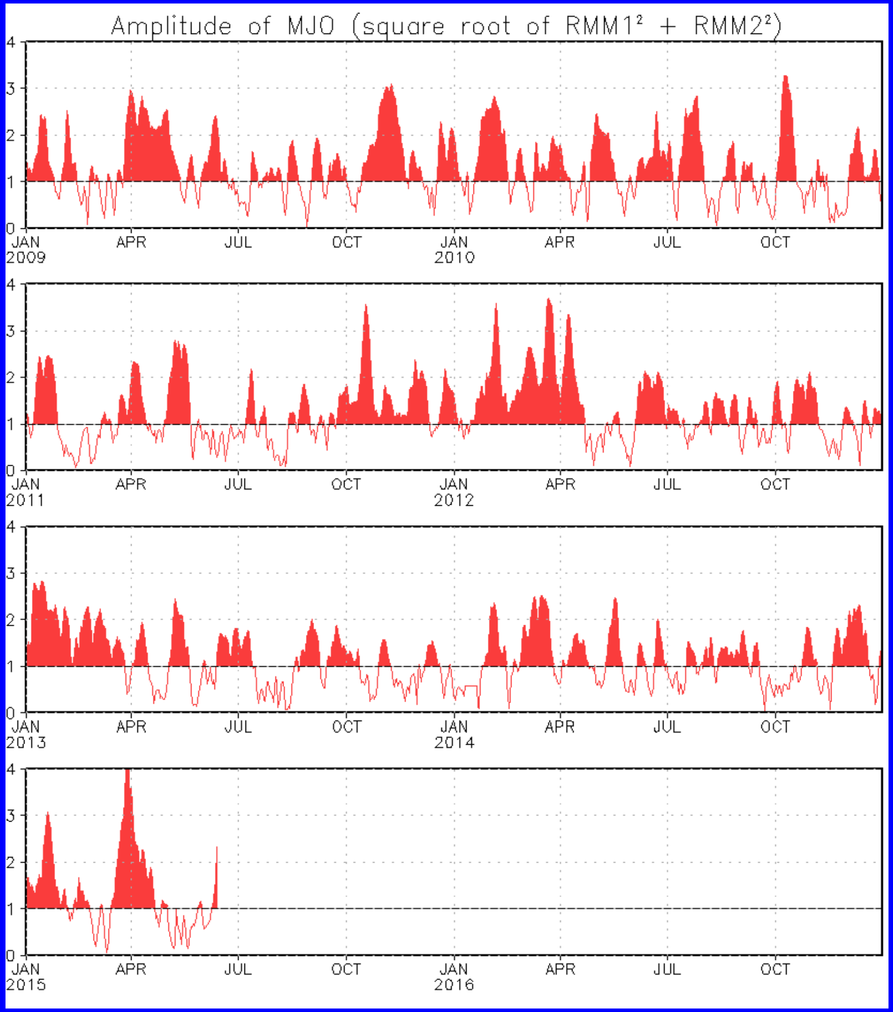
MJO Index -- Recent Evolution



- 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

Eastward propagation of a MJO signal was evident during the past two weeks, with the enhanced phase crossing the Indian Ocean.

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.

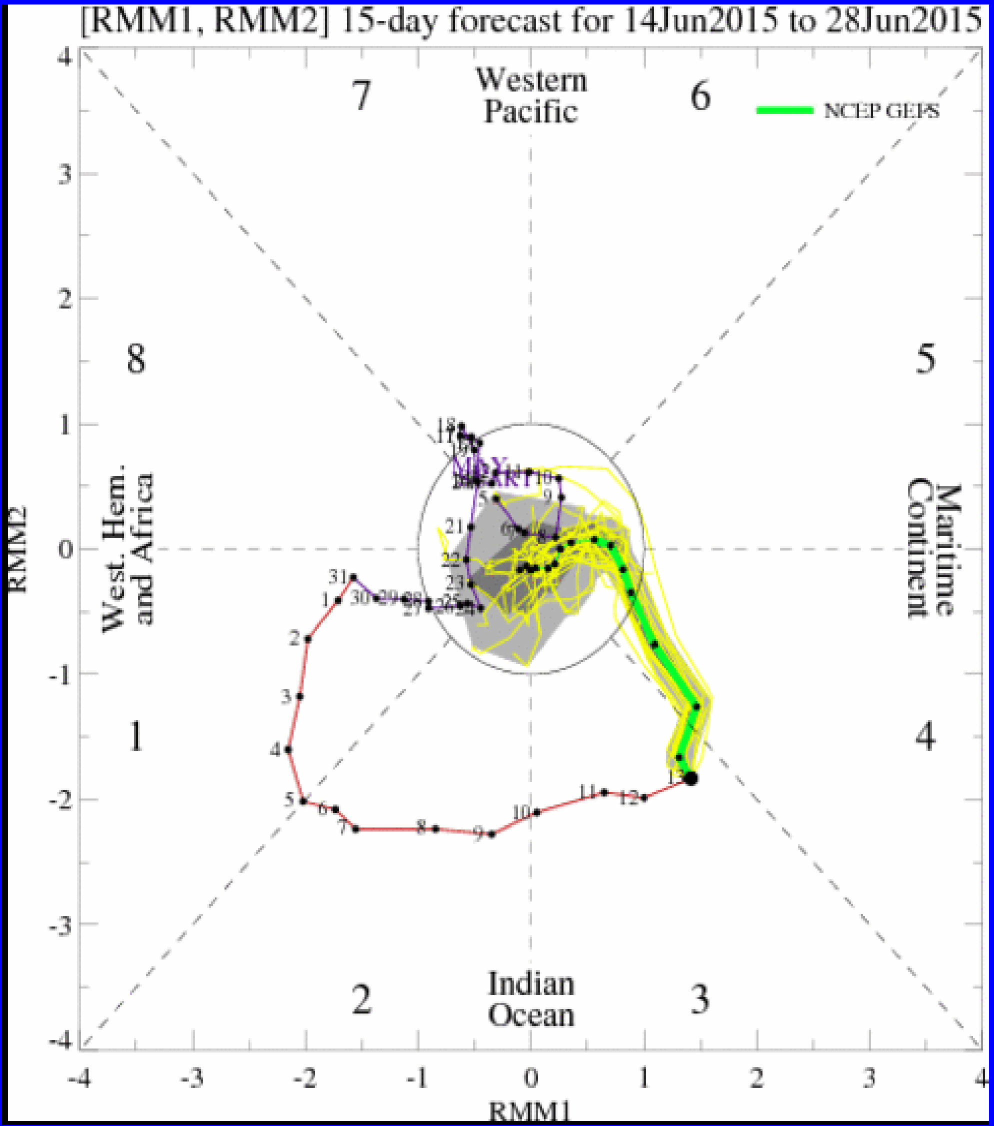
Ensemble GFS (GEFS) MJO Forecast

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

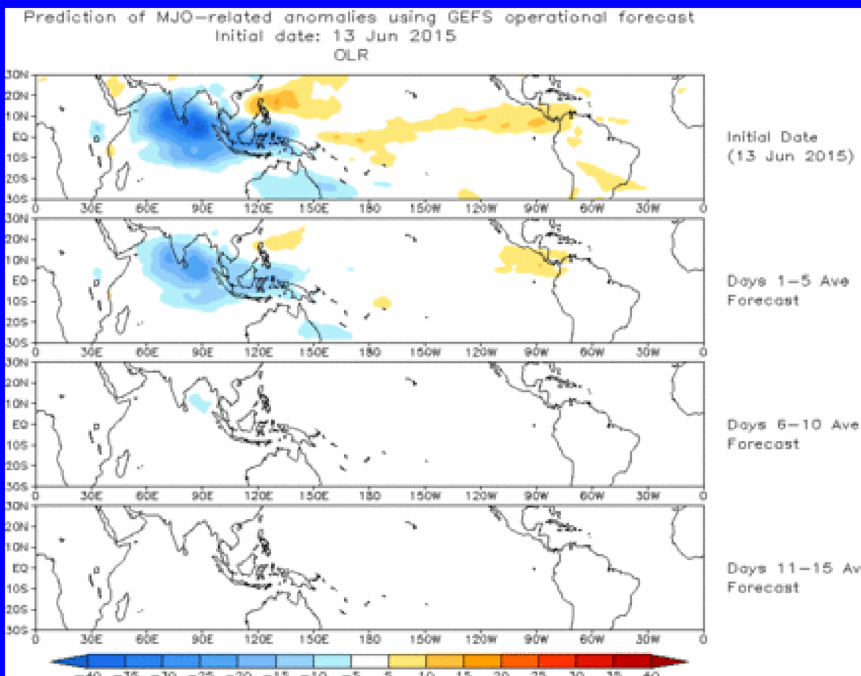
The GFS ensemble MJO index forecast depicts limited eastward propagation of a weakening MJO signal during Week-1, with no signal during Week-2. Other dynamical model MJO index forecasts depict continued eastward propagation of the signal to the western Pacific.



Ensemble Mean GFS MJO Forecast

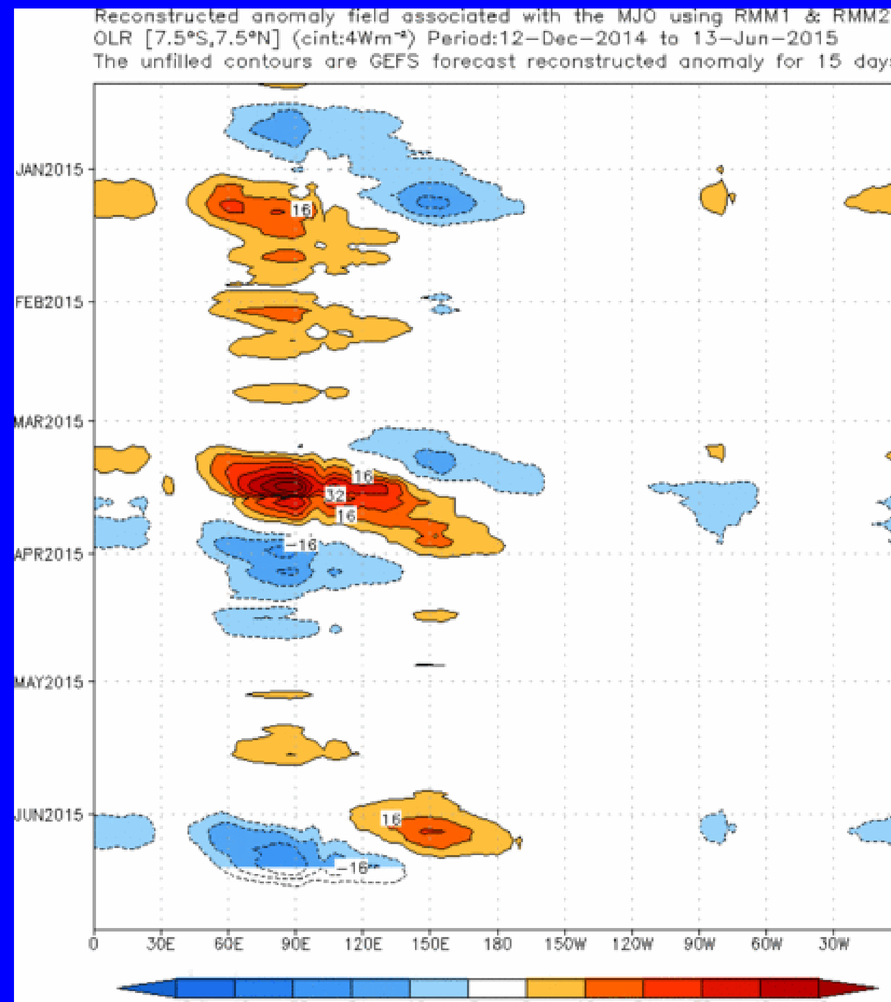
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



The GEFS MJO index based OLR anomalies forecast depicts a weakening enhanced convective signal over the northern Indian Ocean and Maritime Continent during Week-1, with no signal by Week-2.

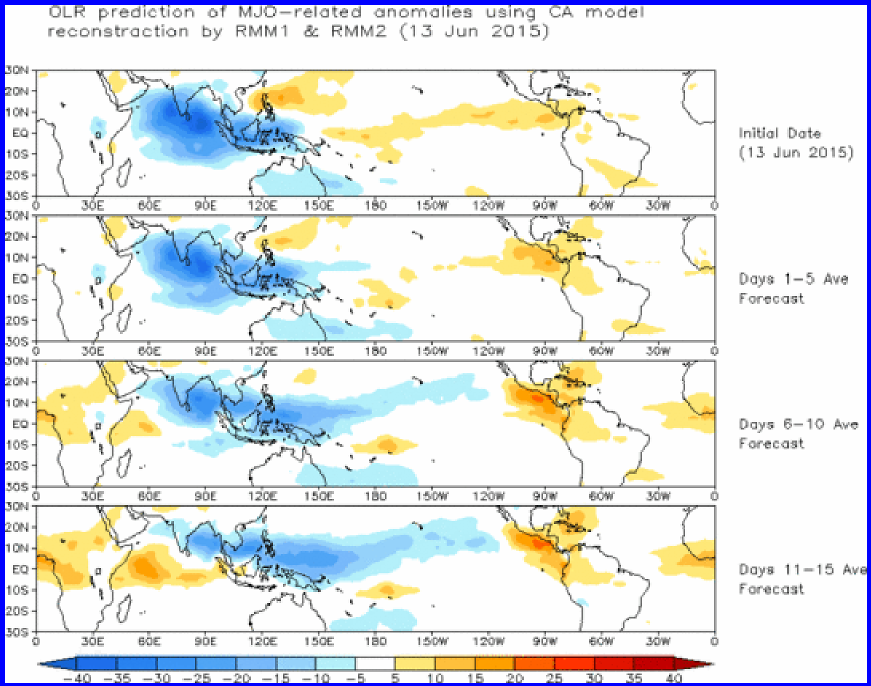
Time-longitude section of (7.5°S-7.5°N) OLR anomalies for the last 180 days and for the next 15 days



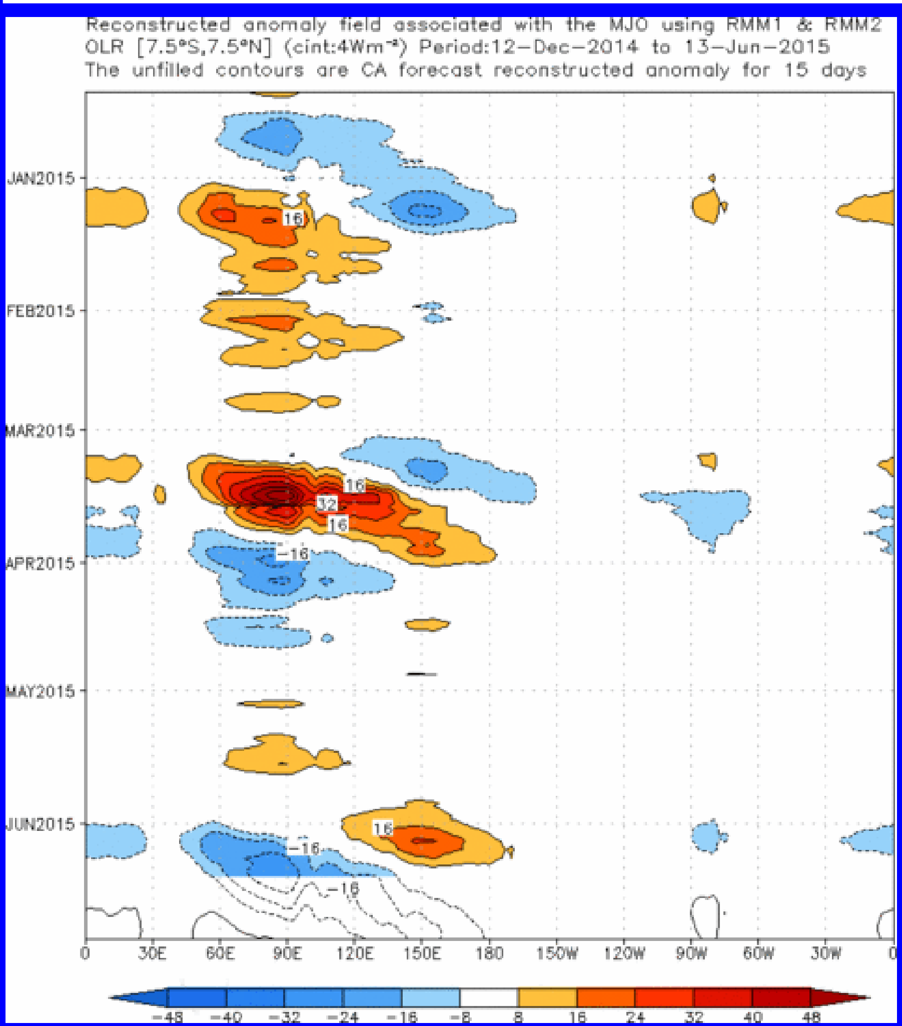
Constructed Analog (CA) MJO Forecast

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



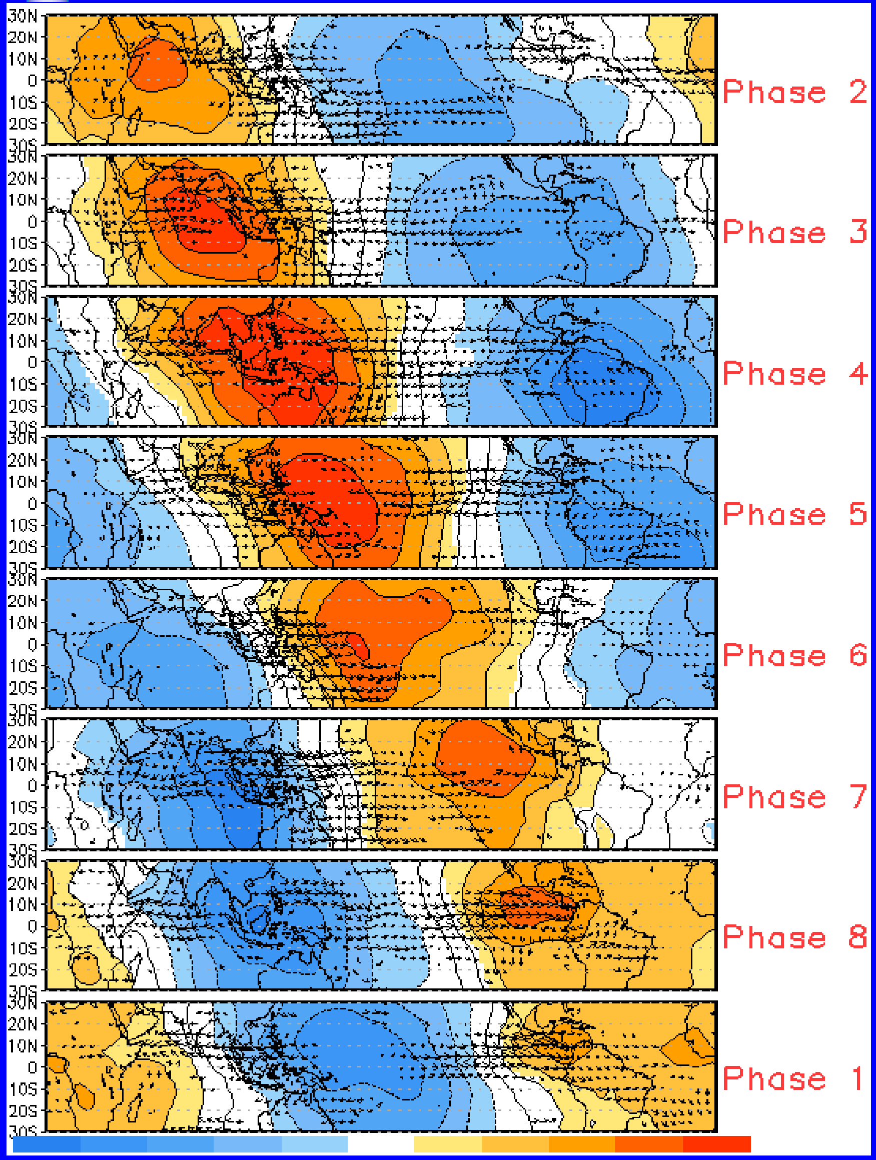
Time-longitude section of (7.5°S-7.5°N) OLR anomalies for the last 180 days and for the next 15 days



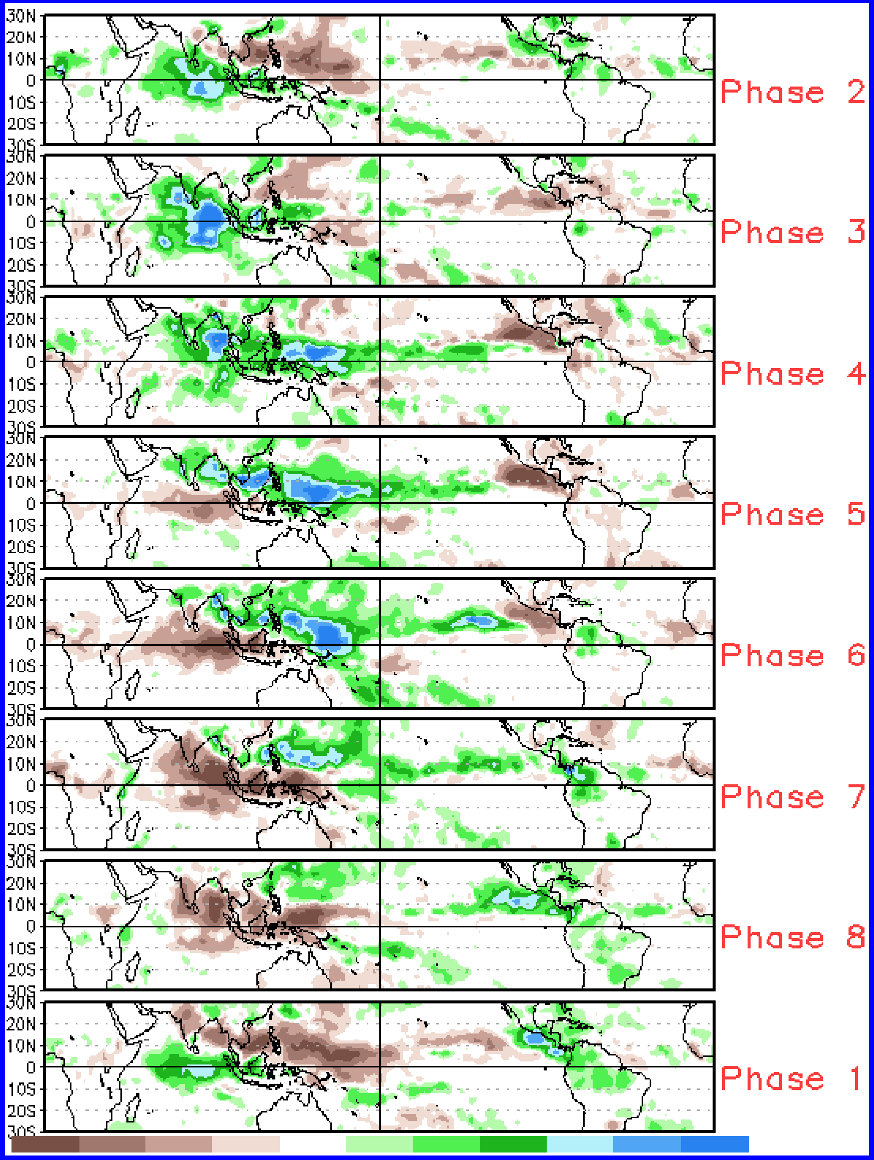
The statistical forecast depicts more robust MJO signal propagation, with enhanced convection returning to the western Pacific by Week-2.

MJO Composites – Global Tropics

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



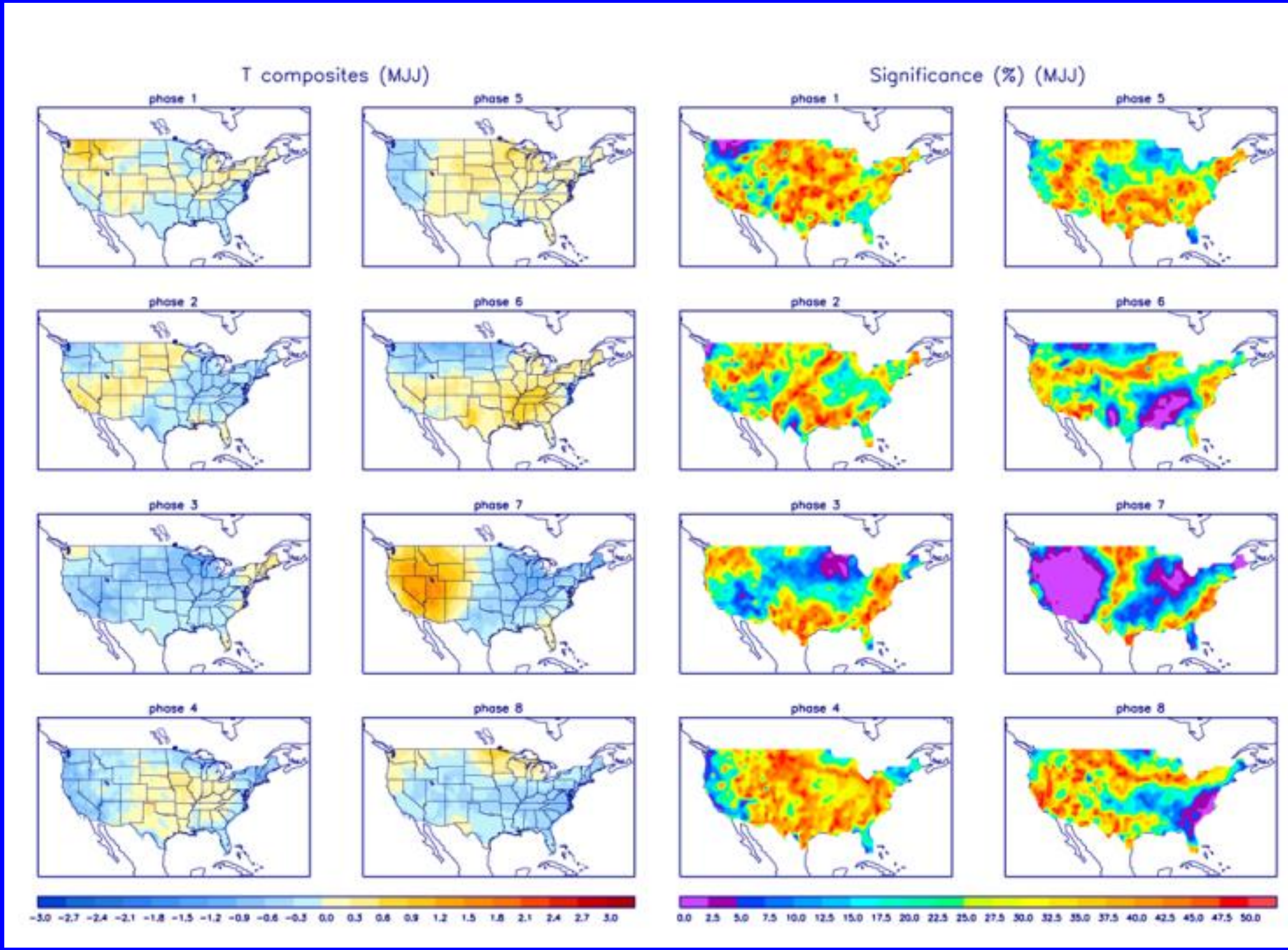
Precipitation Anomalies (May-Sep)



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.

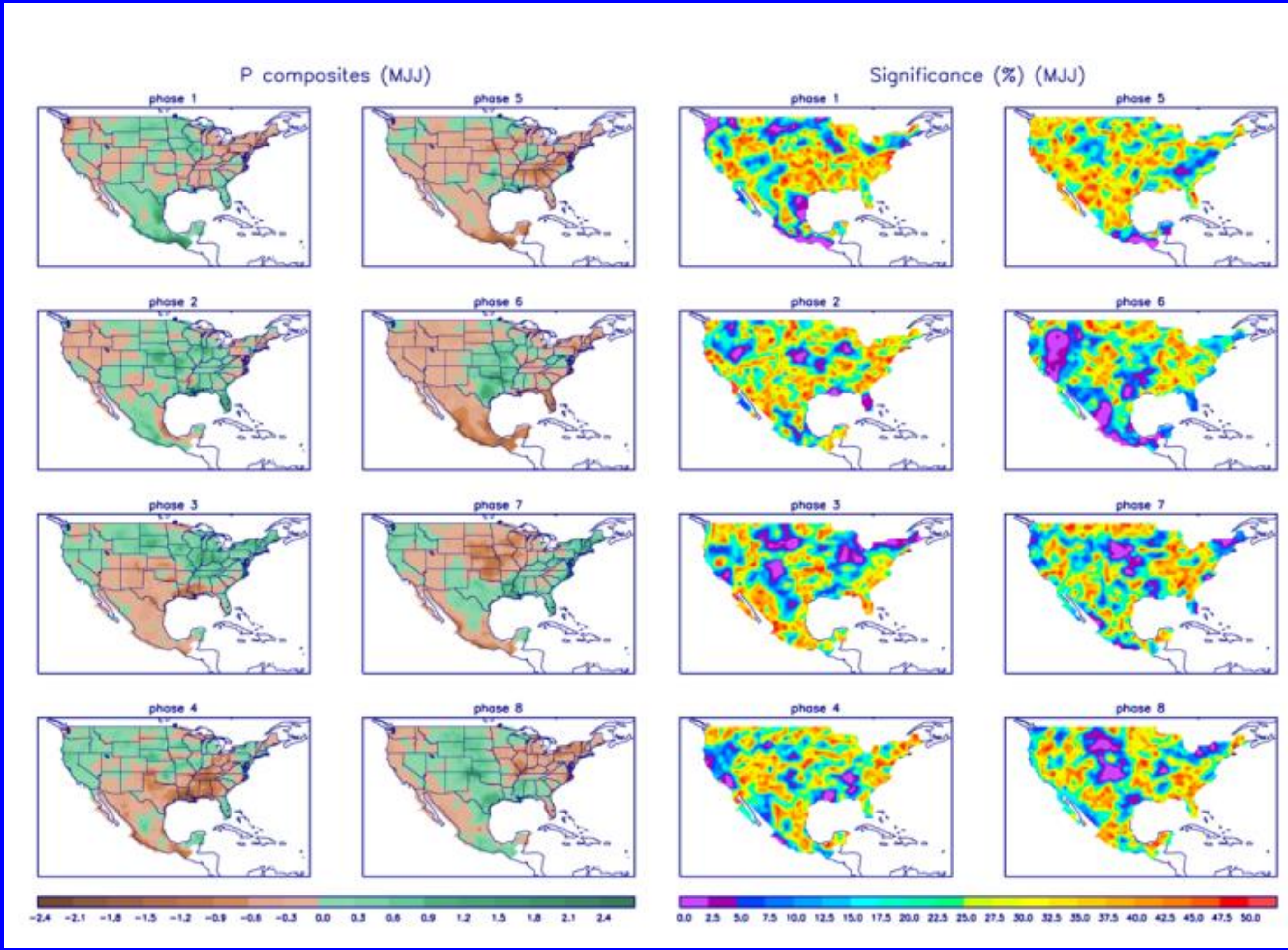
▪ Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.



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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