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

Update prepared by: Adam Allgood
Climate Prediction Center / NCEP
24 December 2018

Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

Overview

- The MJO signal continues to remain well organized, but has slowed over the Maritime Continent during the past week due to interactions with strong Rossby wave activity.

- Dynamical models and statistical guidance depict a resumption of canonical MJO eastward propagation, with differences in phase speed and amplitude. The GEFS develops a slow-moving, very high amplitude MJO event over the West Pacific, while the ECMWF shows faster propagation of a weaker signal.

- Given recent observations and the model forecasts, the MJO is anticipated to remain active and be one of the primary influences on the tropical convective pattern over the next two weeks.

- Pacific MJO events can teleconnect to the midlatitudes, and are associated with downstream pattern changes over North America, including troughing over the eastern U.S.

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 $(m\ s^{-1})$

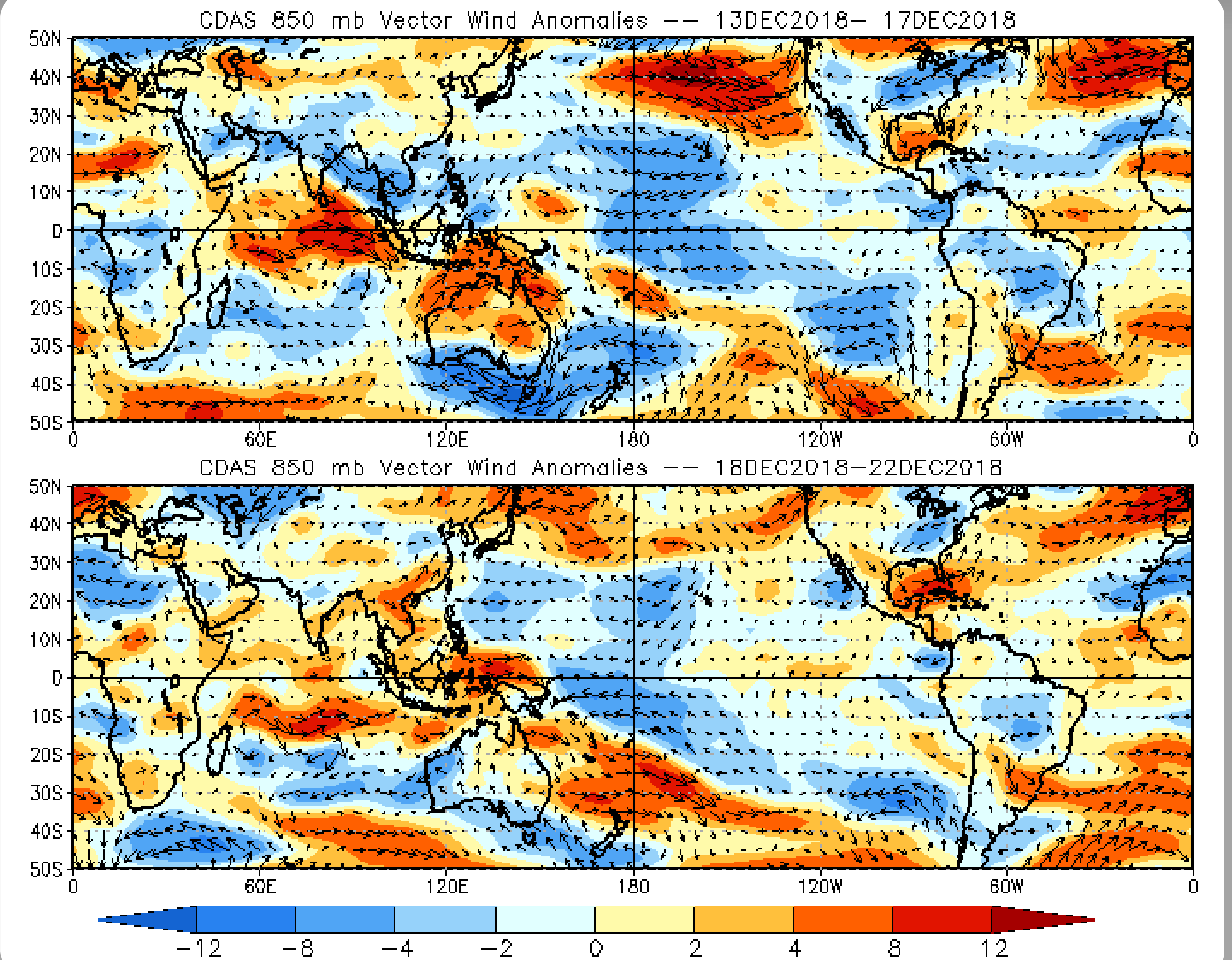
Note that shading denotes the zonal wind anomaly

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

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

The overall pattern of low-level wind anomalies across the tropics showed little change since mid-December.

Anomalous easterlies persisted near the Date Line, while westerly anomalies reappeared across the East Pacific.



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

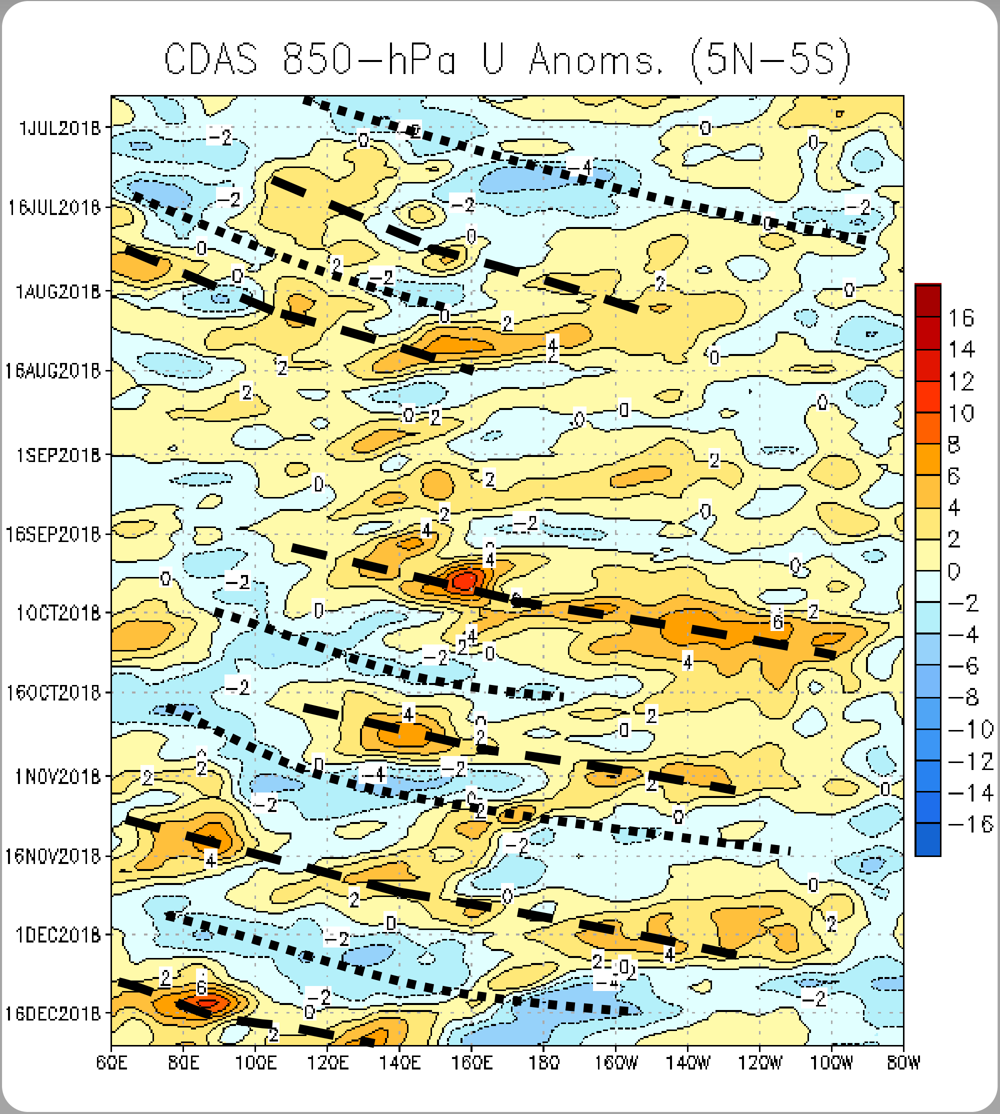
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

A weak intraseasonal signal emerged during mid to late July.

From August through mid-September, other modes, including Rossby wave and tropical cyclone activity, influenced the pattern. Another rapidly propagating intraseasonal feature during late September generated robust westerly wind anomalies across the Pacific.

Since late September westerly anomalies increased in amplitude and duration over the equatorial Pacific, consistent with a gradual transition towards El Niño conditions. Over the last two months, other robust MJO events interfered with the base state. Most recently, pronounced Rossby wave activity interfered with the MJO, resulting in a slowing of the eastward propagating convective signal.



OLR Anomalies – Past 30 days

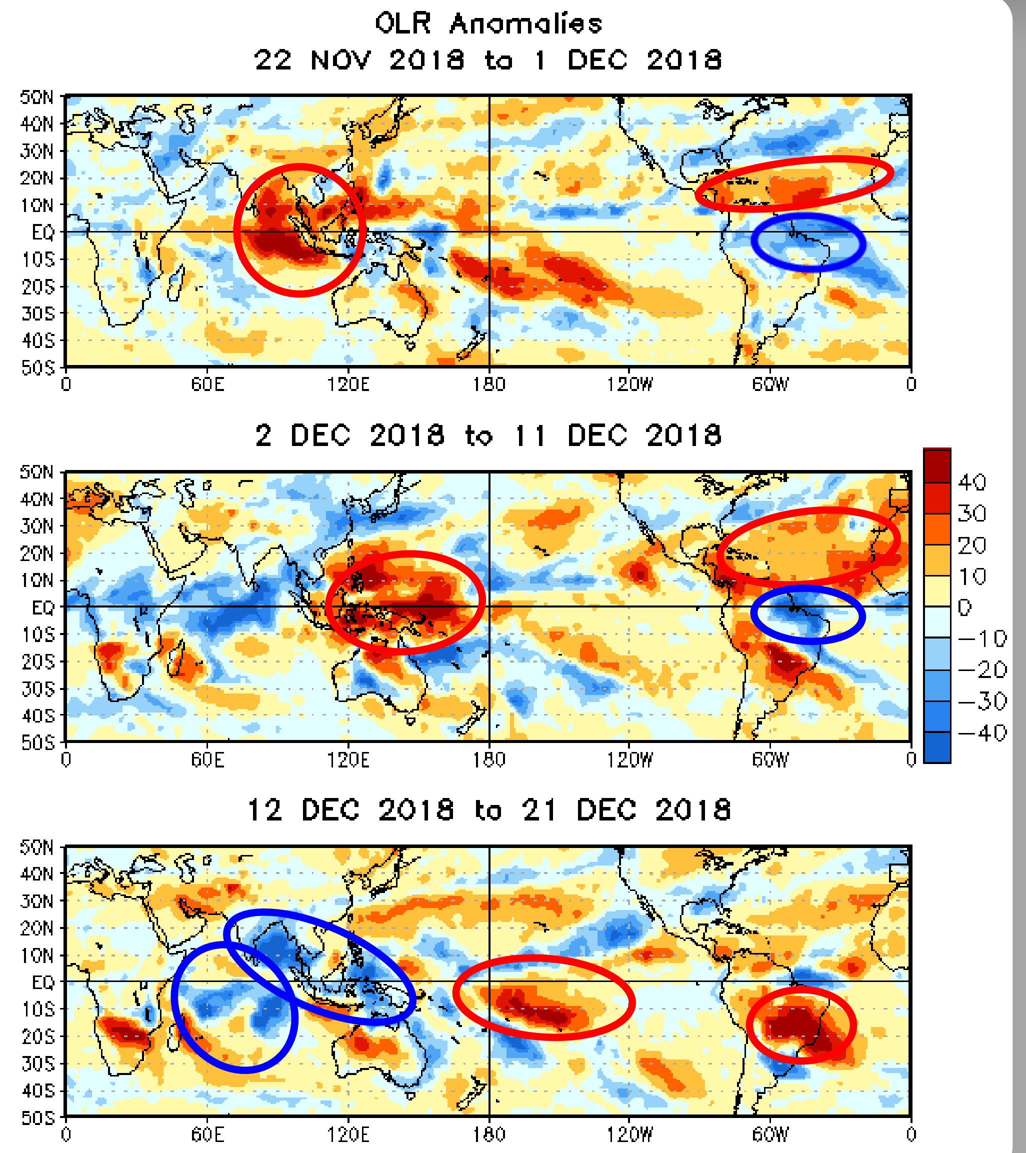
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During late November, the MJO rapidly moved across the Western Hemisphere, with reduced coverage of convective anomalies. The strongest signal was suppressed convection over the eastern Indian Ocean.

The MJO signal emerged over the Indian Ocean in early December, resulting in widespread enhanced convection, while the suppressed signal moved from the eastern Indian Ocean to the West Pacific. Enhanced convection persisted over northeastern Brazil.

During mid-December, the MJO propagated to the Maritime Continent, and destructive interference with the base state reduced the coverage of the anomalous convective envelopes. Pronounced Rossby wave activity helped engender tropical cyclogenesis over the Indian Ocean, which resulted in a slowdown of the MJO signal.



Outgoing Longwave Radiation (OLR) Anomalies (7.5ºS - 7.5ºN)

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

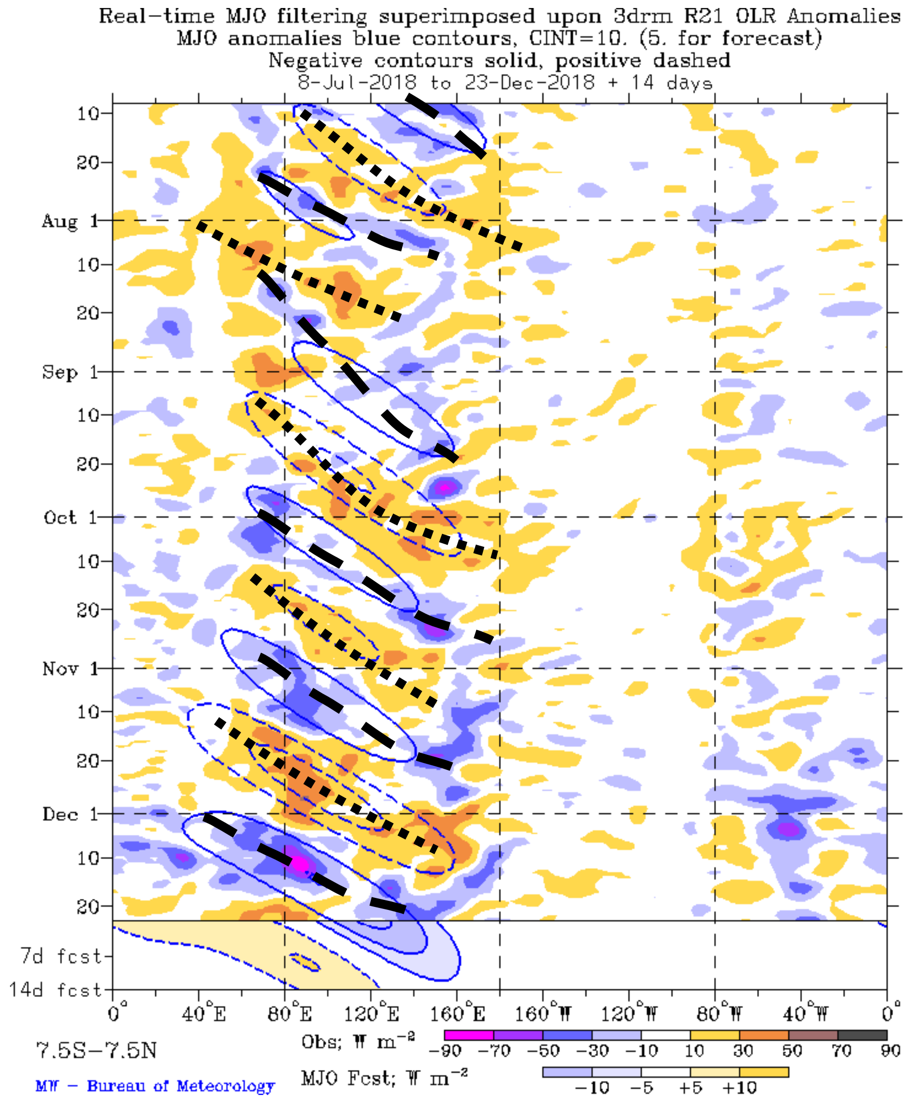
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

The MJO has been apparent since July, with alternating periods of enhanced and suppressed convection evident from the Indian Ocean through the Date Line.

Other modes of variability (Kelvin waves, Rossby waves, and tropical cyclones) interfered with the primary intraseasonal signal during the past several months.

There is limited anomalous convection over the eastern Pacific, which suggests that the atmosphere has not coupled with the anomalously warm waters in the equatorial Pacific associated with the developing El Niño.

Most recently, robust Rossby wave activity has modulated the MJO signal over the Maritime Continent.



200-hPa Velocity Potential Anomalies (5°S - 5°N)

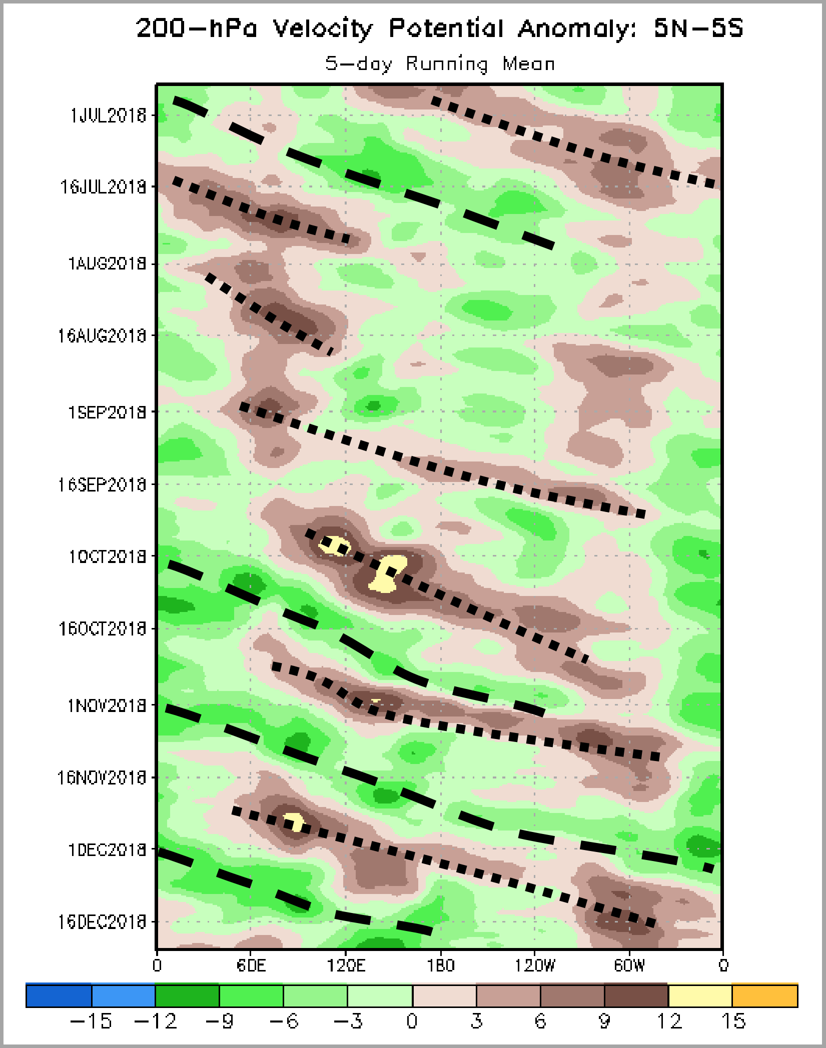
Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

Negative anomalies (green shading) indicate favorable conditions for precipitation

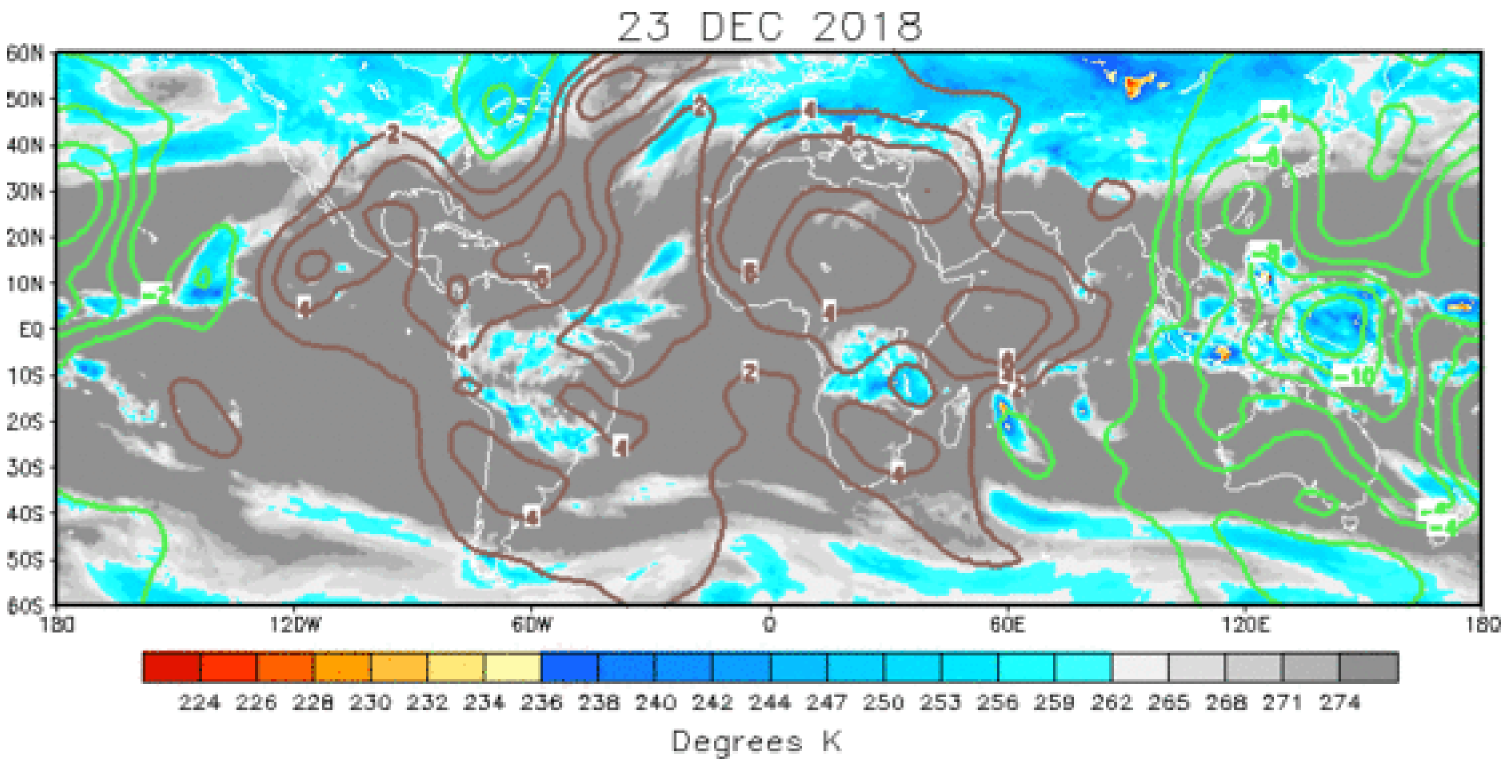
The enhanced phase of the MJO weakened east of the Date Line during June. Eastward propagation of broad suppressed convection continued into early July. The upper-level footprint of the MJO re-emerged during mid-July, with a broad divergent signal propagating from the Maritime Continent to the central Pacific.

Starting in mid-July, a low-frequency dipole favoring enhanced (suppressed) convection over the east-central Pacific (Indian Ocean) emerged, consistent with a gradual transition towards El Niño conditions. An active MJO pattern since September has overwhelmed this signal at times.

More recently, the interactions between the MJO and robust Rossby wave activity is apparent in the upper-level VP field in addition to the low-level fields discussed earlier, but the overall envelope of enhanced divergence aloft has continued propagating eastward to the West Pacific.



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



The upper-level VP anomaly pattern continues to exhibit a classic Wave-1 pattern, with the enhanced divergent envelope emerging over the West Pacific.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

Negative anomalies (green contours) indicate favorable conditions for precipitation

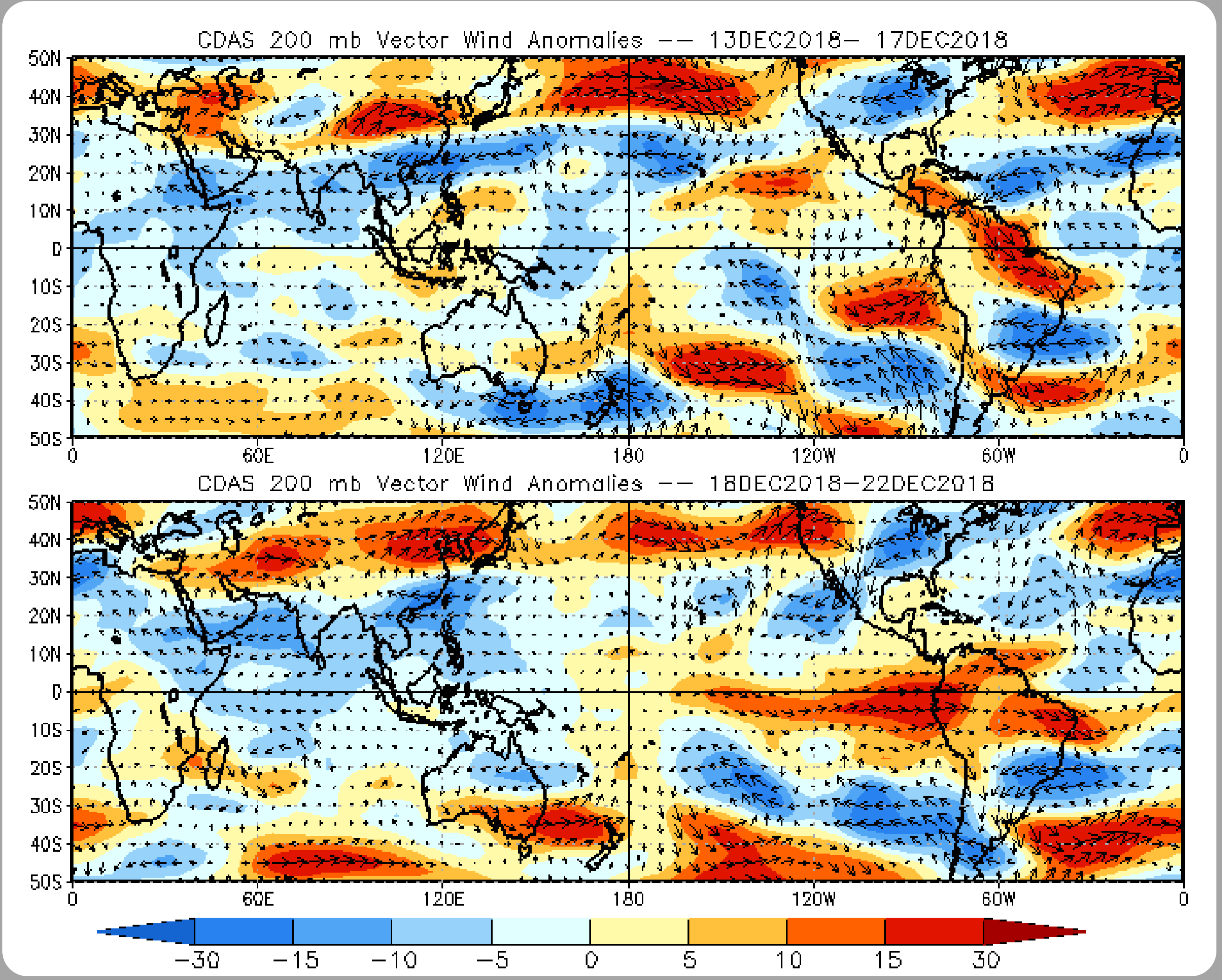
200-hPa Vector Wind Anomalies (m s^{-1})

Note that shading denotes the zonal wind anomaly

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

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

The upper-level wind field appears more consistent with canonical MJO activity over the West Pacific, with easterly anomalies to the west over the Indian Ocean and Maritime Continent, and westerly anomalies to the east over the East Pacific and Western Hemisphere.



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

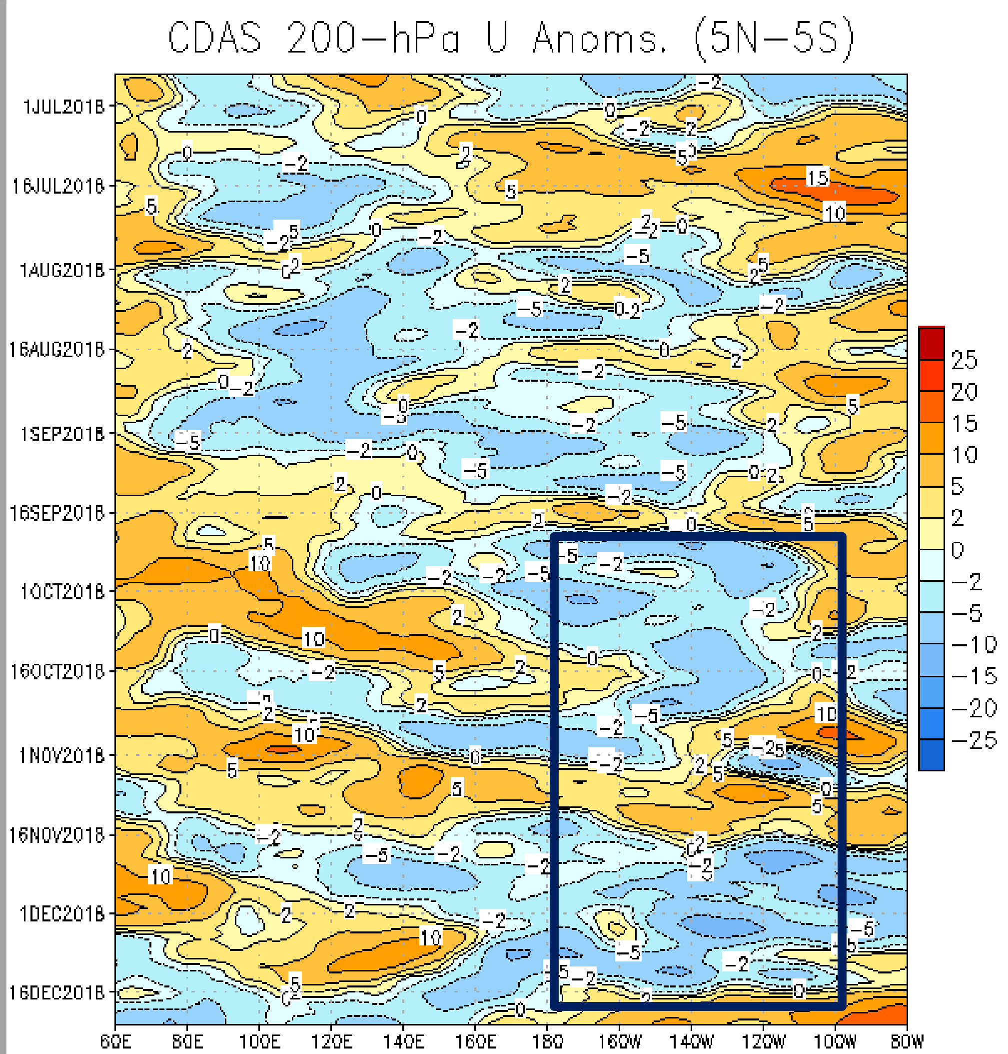
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

During August the intraseasonal pattern weakened, with Rossby wave activity influencing the West Pacific pattern.

Since early October, the upper-level wind field has been marked by pronounced intraseasonal activity, interrupted at times by Rossby waves. A trend towards more persistent easterly anomalies over the Pacific (boxed area) may be associated in part with the base state.

Recently, an envelope of westerly anomalies shifted from the Indian Ocean to the Pacific during December, with the signal briefly interrupted by Rossby wave activity during early December.



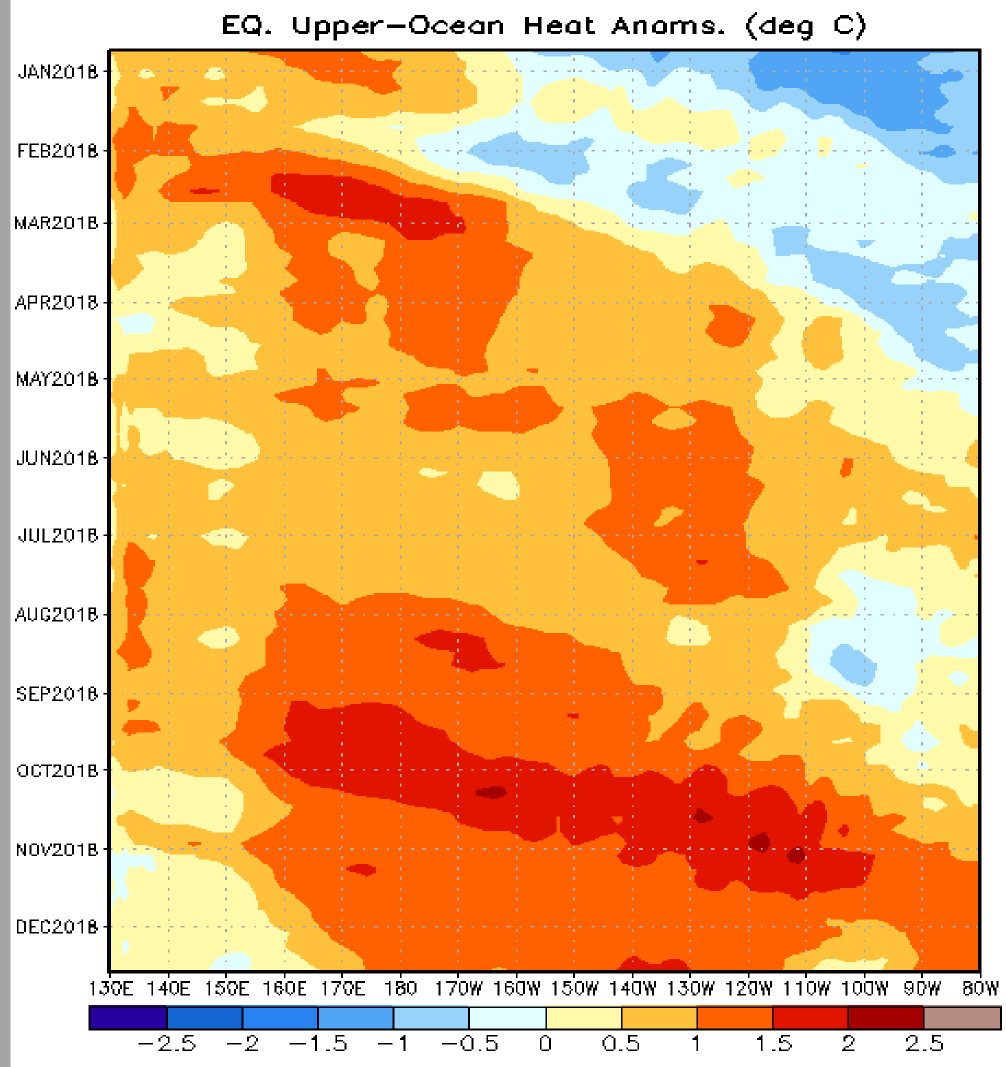
Weekly Heat Content Evolution in the Equatorial Pacific

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.

Negative upper-ocean heat content anomalies persisted in the central and eastern Pacific through December. A downwelling Kelvin wave associated with the intraseasonal signal weakened the negative anomalies across the east-central Pacific during late January and early February.

Several downwelling oceanic Kelvin waves contributed to the eastward expansion of relatively warm subsurface water during February. Positive anomalies have now been observed over most of the basin since April.

The westerly wind burst east of New Guinea in September triggered another oceanic Kelvin wave and round of downwelling, helping to reinforce the warm water availability for a potential El Niño event. Heat content anomalies have decreased in magnitude over the West 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

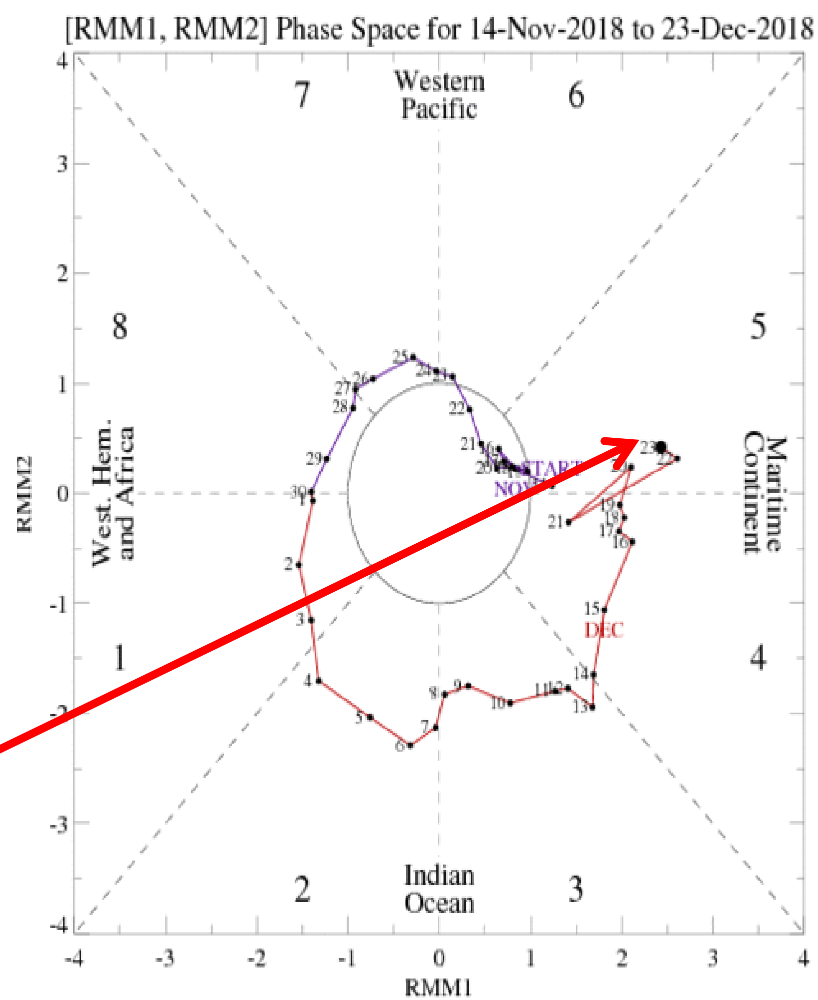
The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes

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

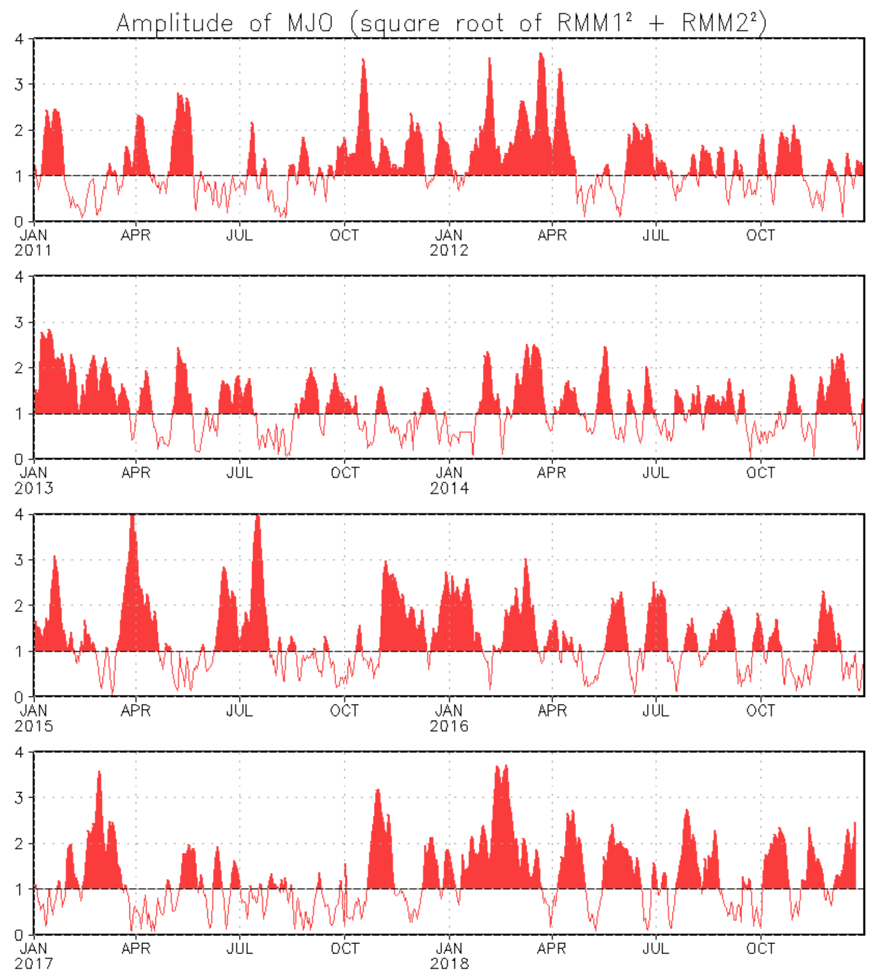


The MJO signal slowed over the Maritime Continent over the past week as the intraseasonal signal interacted with strong Rossby wave activity.

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.



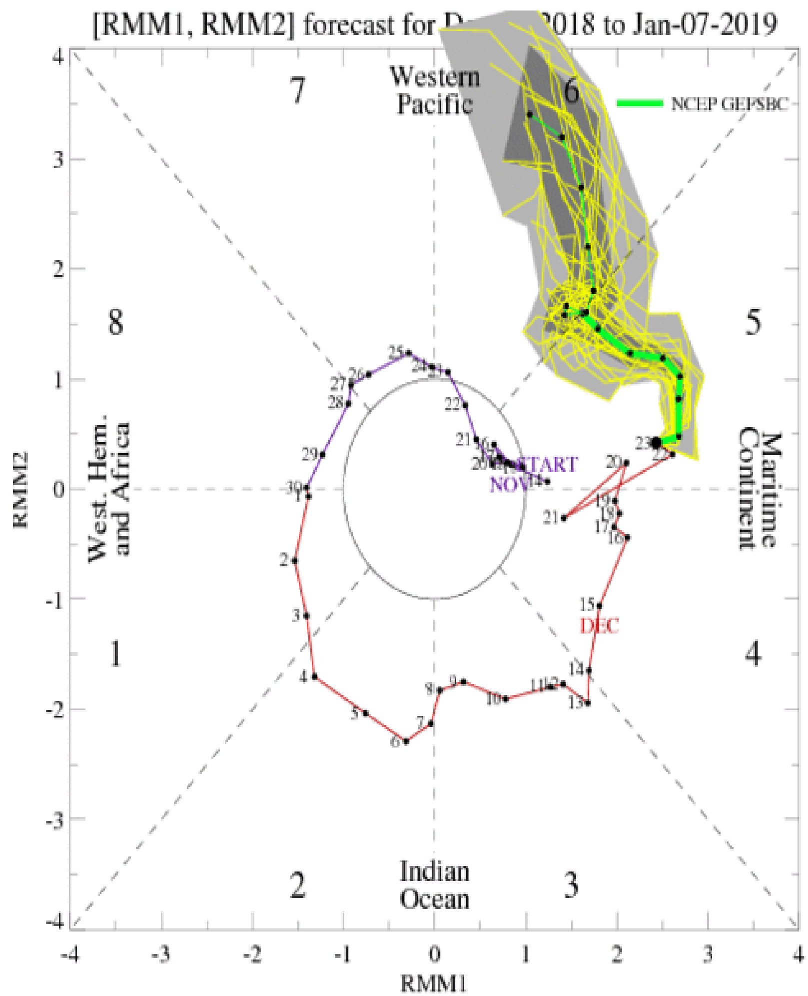
GFS Ensemble (GEFS) MJO Forecast

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

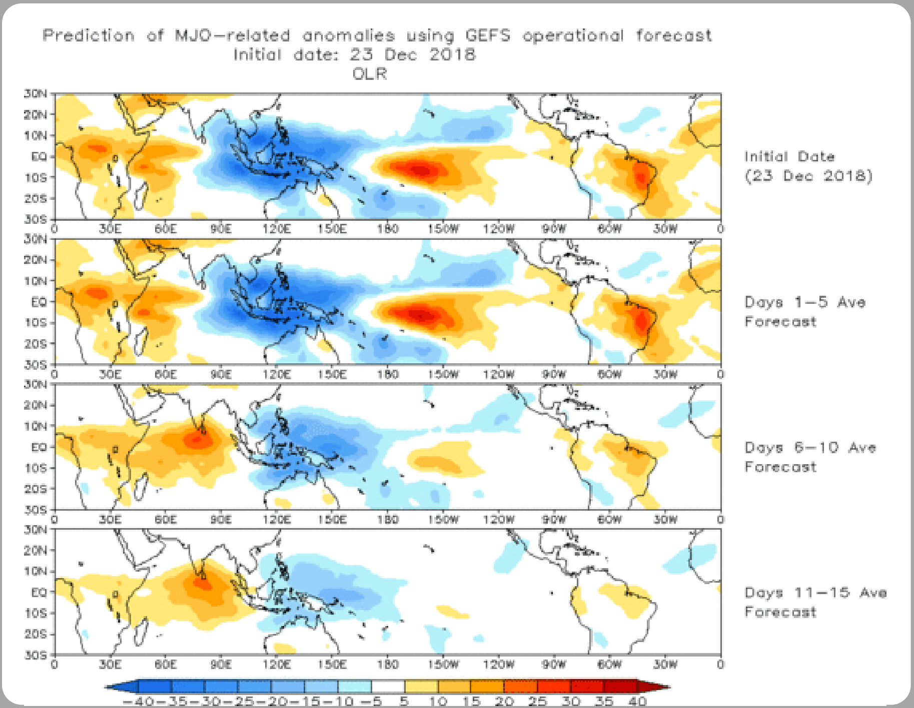


The GEFS forecasts the MJO to resume eastward propagation over the next two weeks, with a rapid amplification of the signal over the West Pacific.

Ensemble GFS (GEFS) MJO Forecast

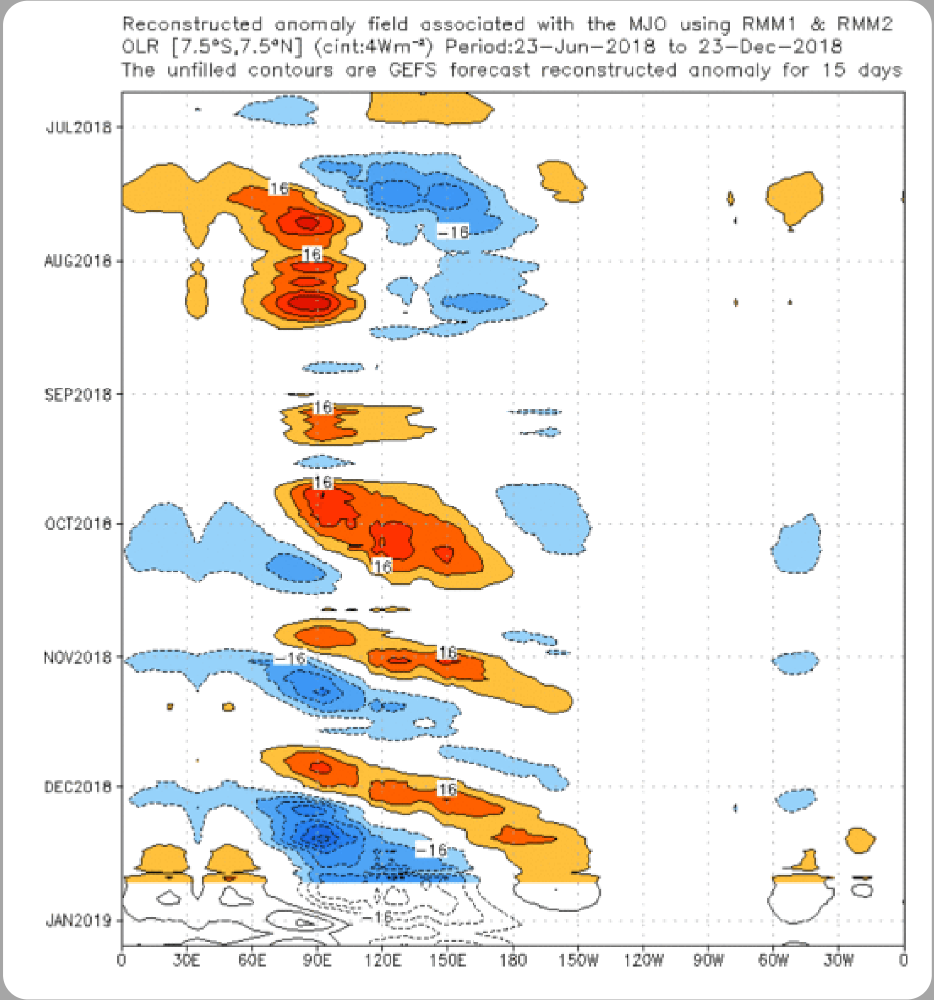
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



OLR anomalies based on the GEFS RMM-index forecast depict slow propagation to the West Pacific over the next two weeks.

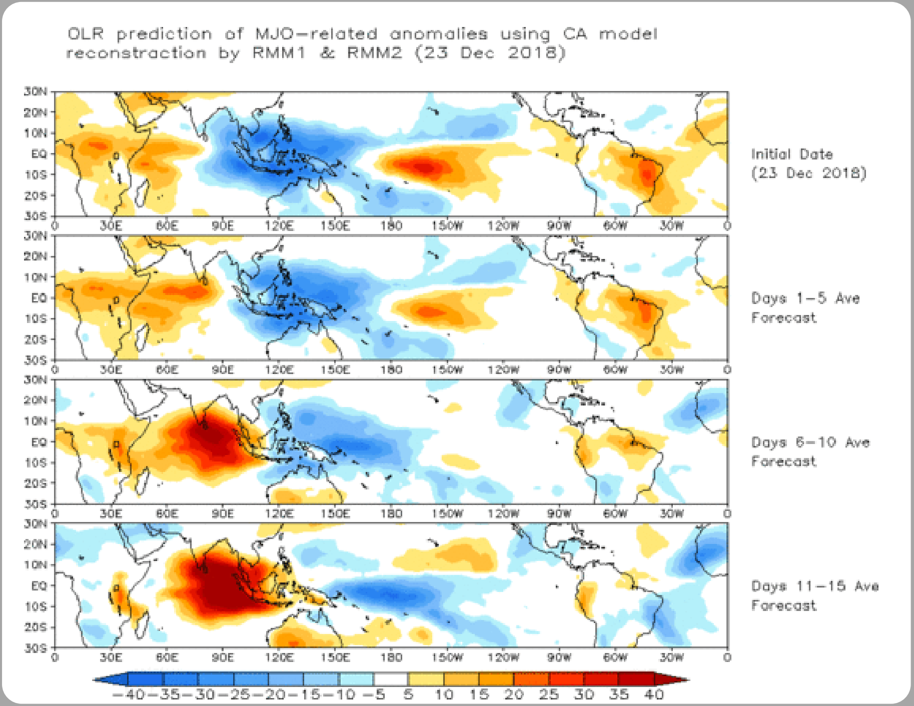
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



Constructed Analog (CA) MJO Forecast

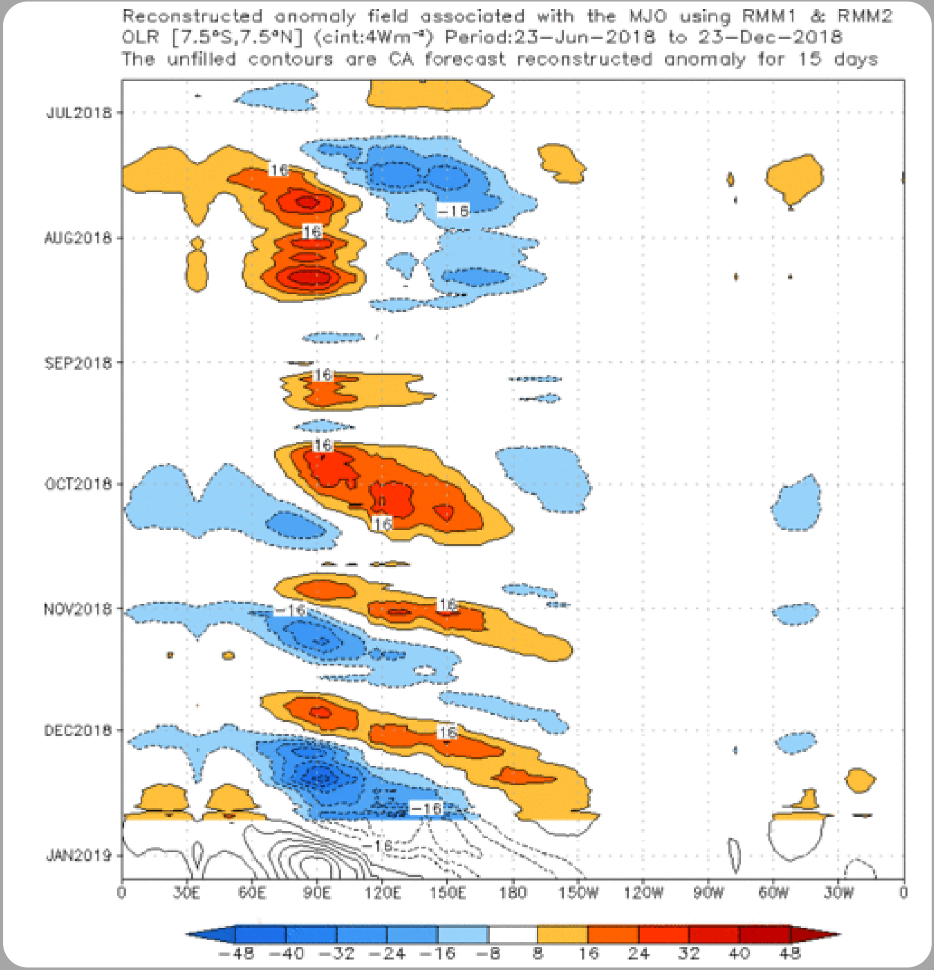
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



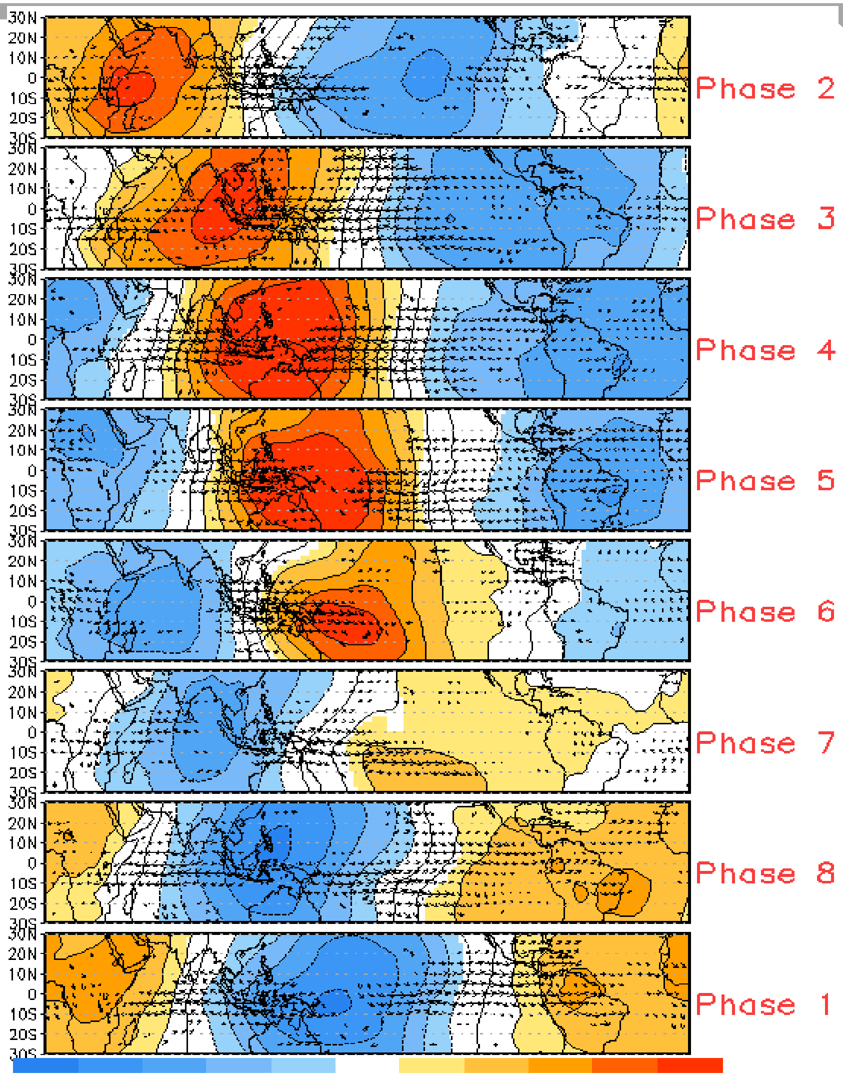
The constructed analog forecast also depicts robust MJO activity, with a faster phase speed than the GEFS forecast.

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

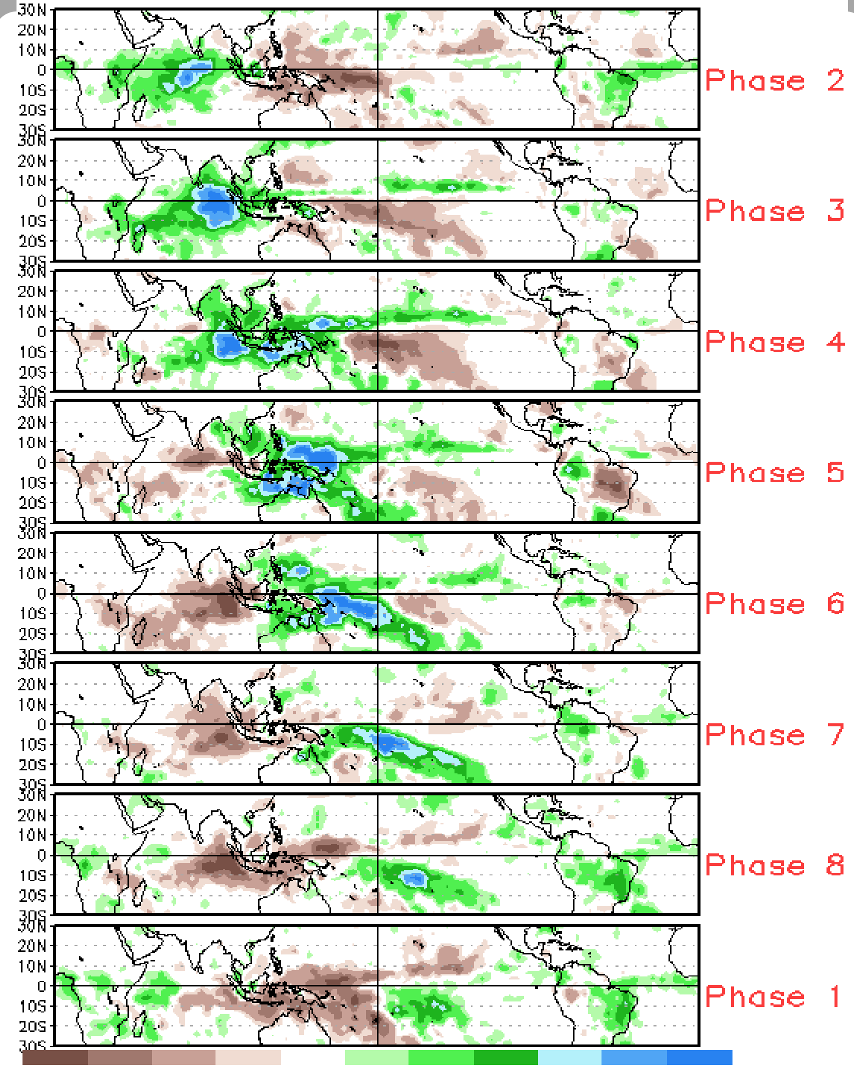


MJO Composites - Global Tropics

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



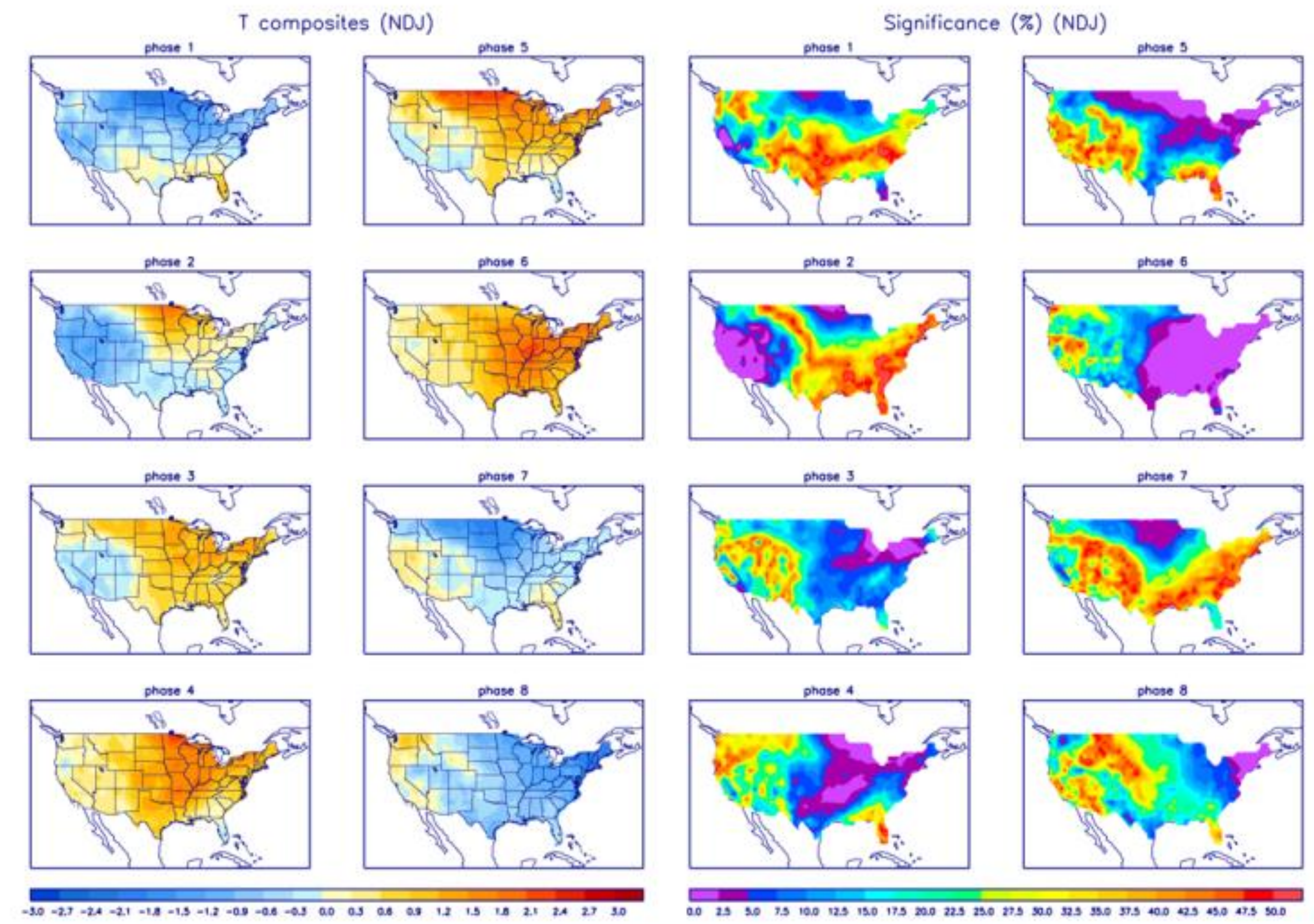
Precipitation Anomalies (Nov - Mar)



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.



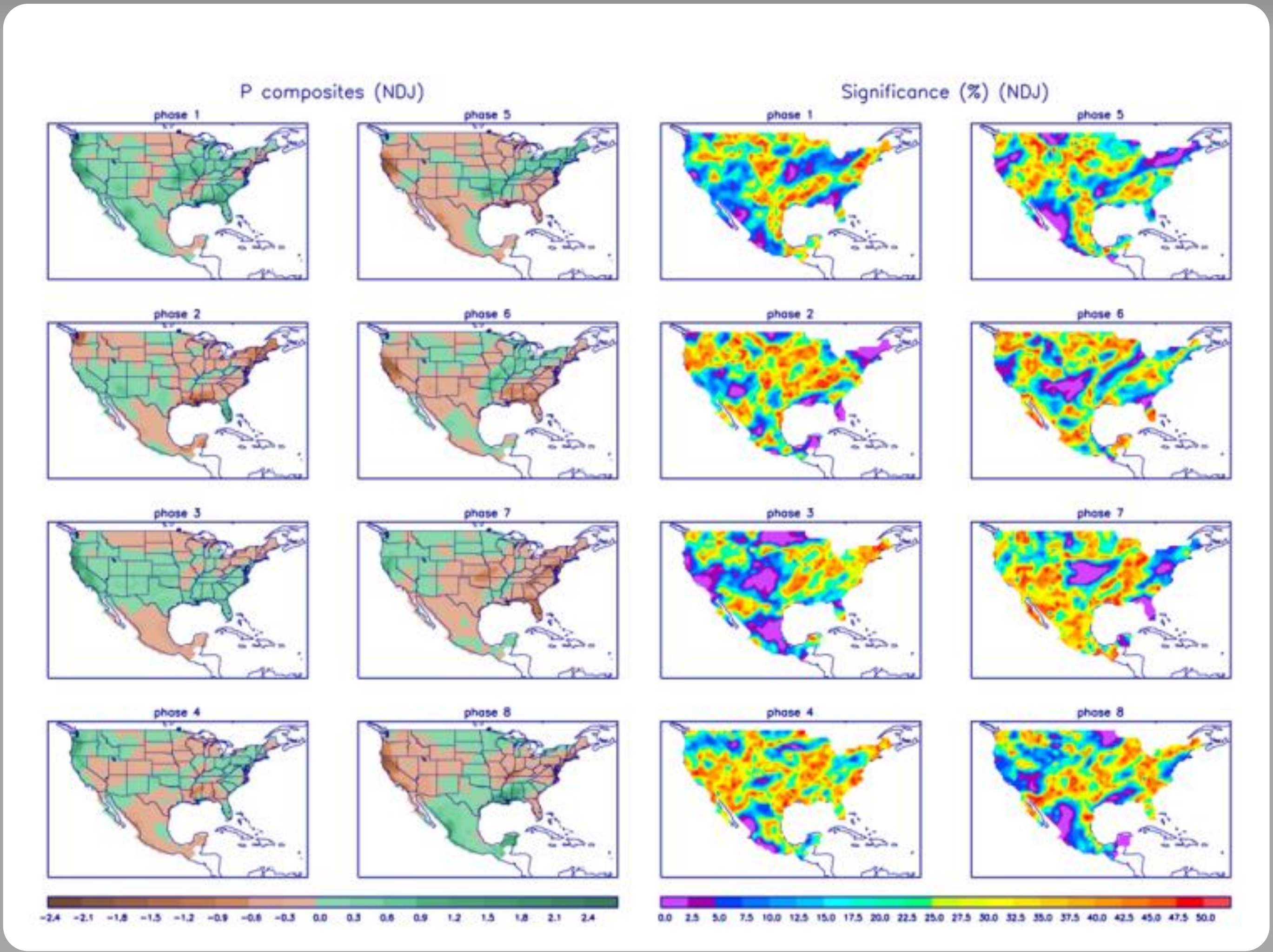
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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.



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