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

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Climate Prediction Center / NCEP
10 December 2018

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Overview

- The MJO continued propagating eastward during the last week, emerging over the western Indian Ocean and continuing to its eastern half in the latest observations.

- Model guidance shows the MJO stalling over the Maritime Continent during the next two weeks, although noted model biases in failing to propagate the MJO over the region give some pause to the belief that the signal will actually stall. A combination of RMM Phases 3/4 conditions are anticipated during Week-1, and Phases 4/5 during Week-2.

- Twin tropical cyclones are possible over the Bay of Bengal and the southern Indian Ocean in the wake of the passing intraseasonal envelope. Any Kelvin waves that emanate from the MJO could also help trigger subsequent cyclogenesis over the West Pacific in the next two weeks.

- Contemporaneous composites for Phases 3-5 show a warming signal east of the Rockies, consistent with model guidance during the next two weeks. Dynamical model guidance does support more troughing over the Northeast Pacific than empirical perspectives would support.

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})

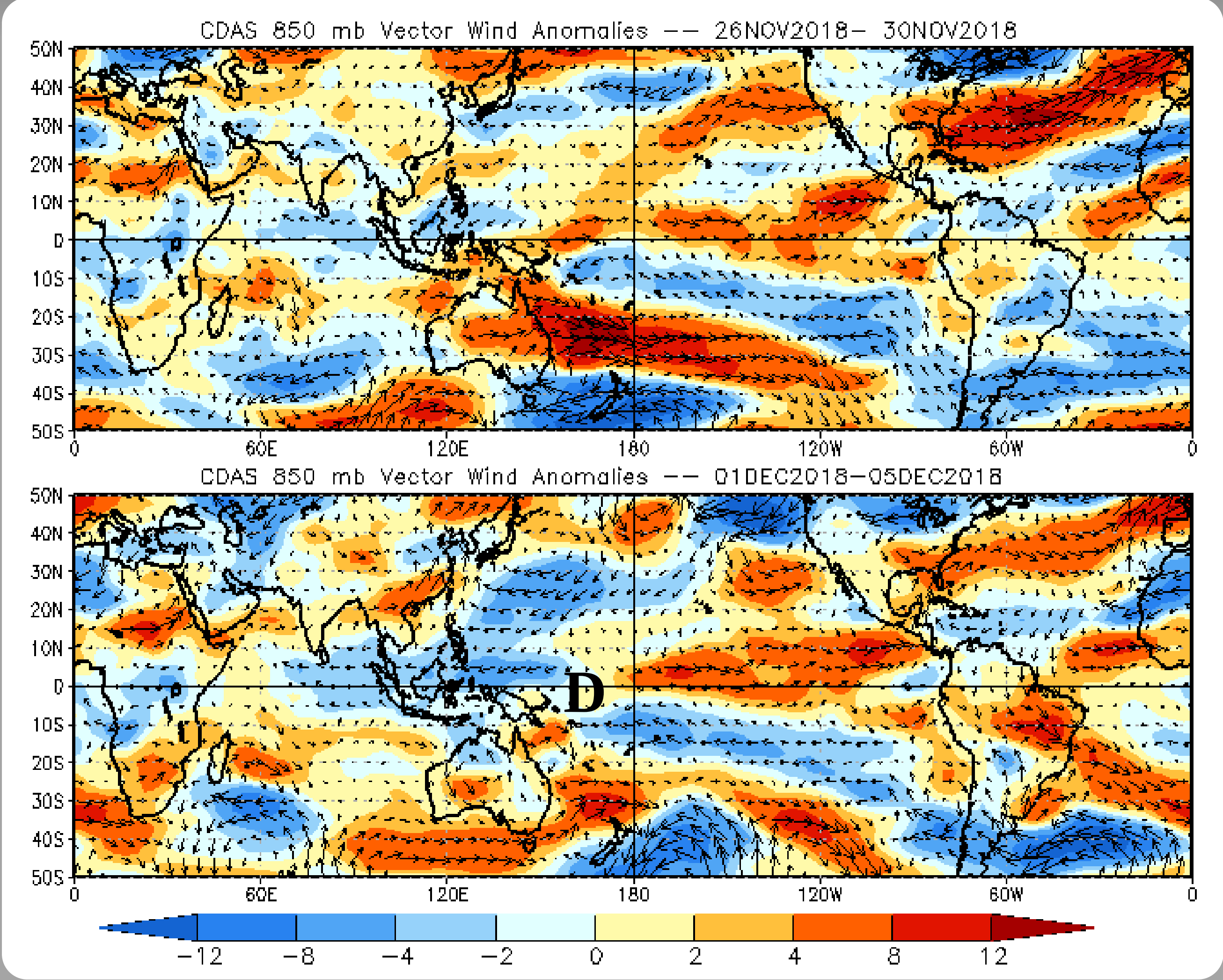
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Anomalous easterlies pushed eastward from the Indian Ocean to the West Pacific.

Despite mid-latitude flow towards the equator, difluence emerged east of New Guinea recently, helping to suppress convection in the equatorial West Pacific.



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

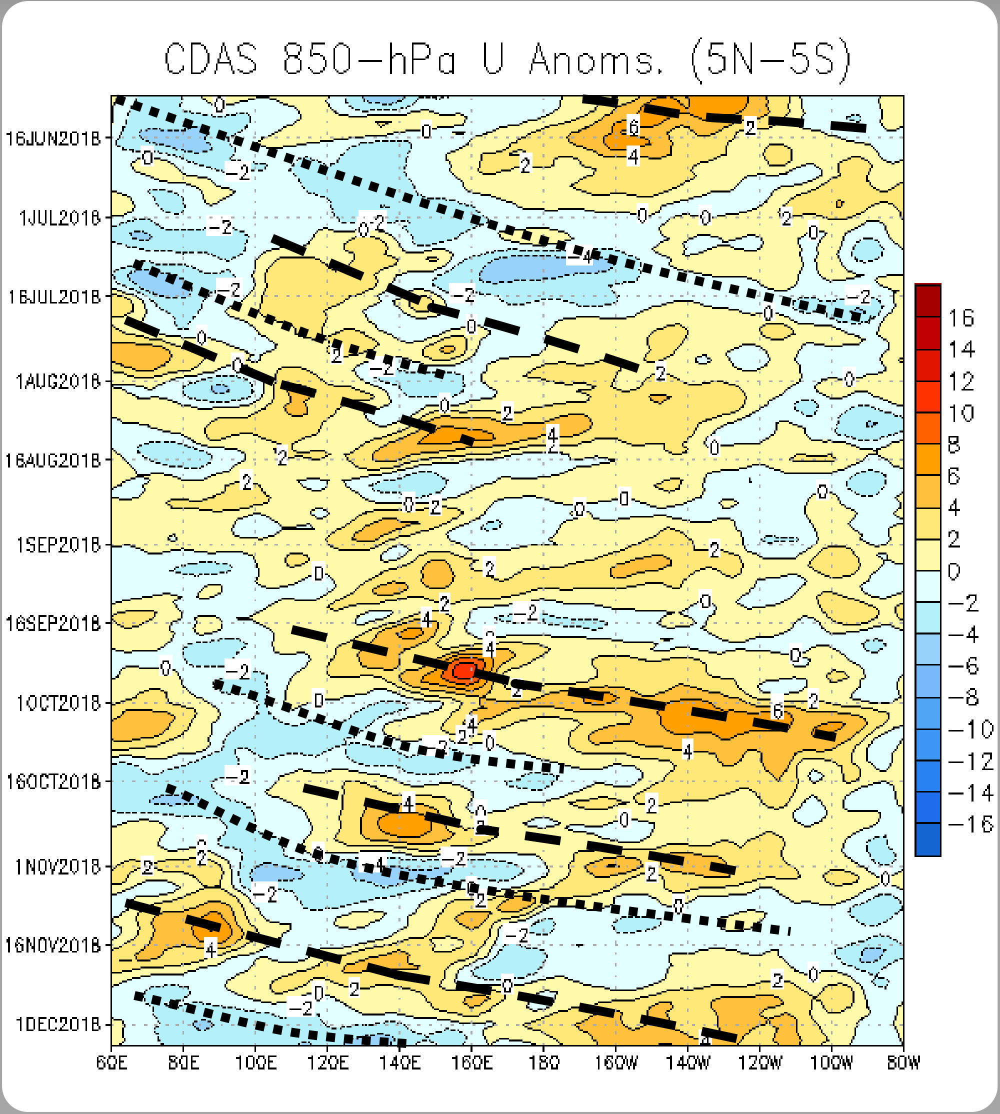
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

Westward moving variability weakened the MJO signal in June. A weak intraseasonal signal re-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, another robust MJO events interfered with the base state. Most recently, anomalous easterlies have shifted across the Indian Ocean towards the Maritime Continent.



OLR Anomalies – Past 30 days

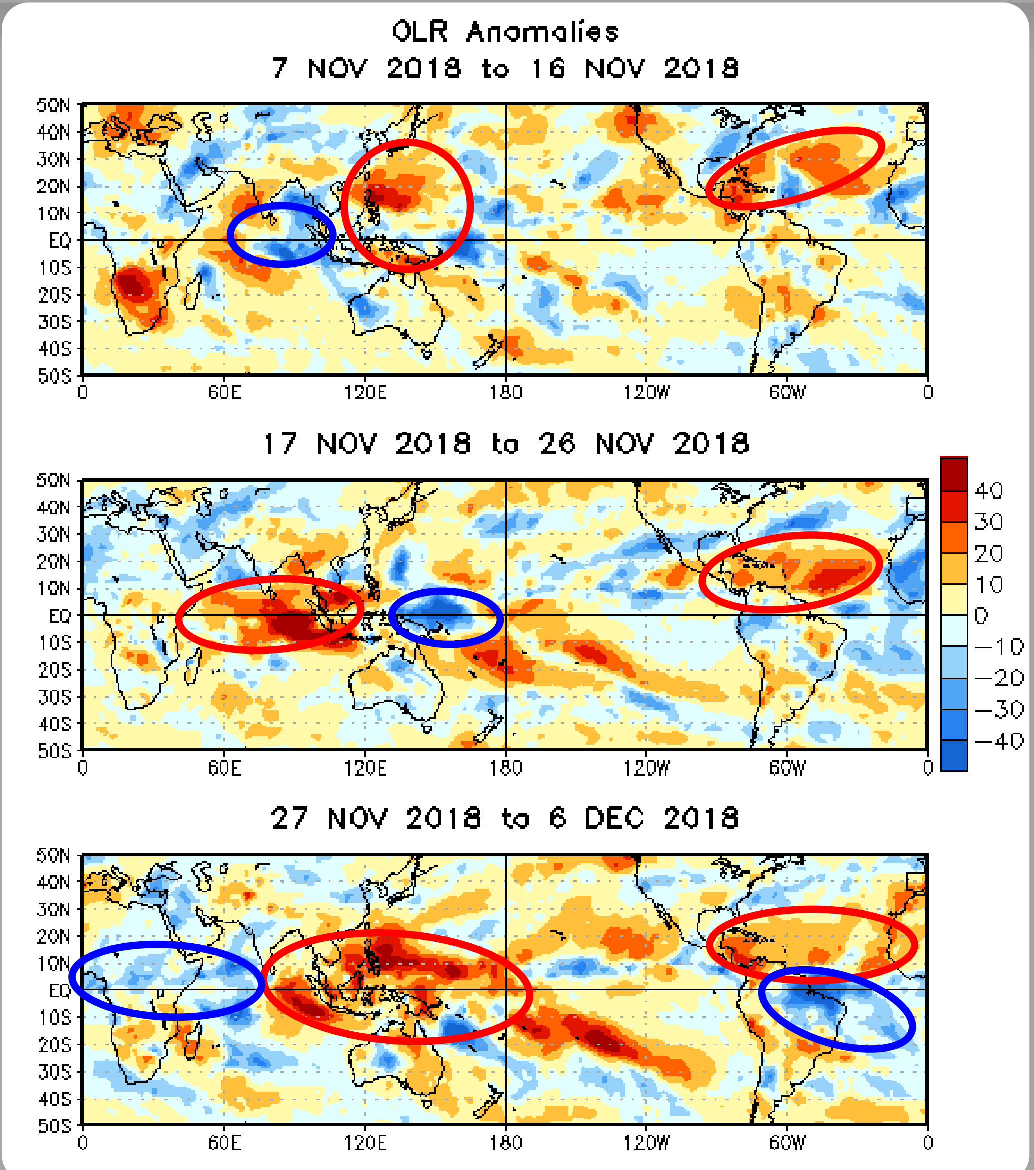
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

In early November, the active MJO was helping to enhance (suppress) convection over the eastern Indian Ocean (West Pacific). The western Caribbean and tropical Atlantic have had persistent suppressed convection through the end of the hurricane season.

During mid- to late November, the MJO crossed the Maritime Continent and entered the West Pacific. This acted to enhance convection east of New Guinea, while suppressing convection over the Indian Ocean.

During late November through early December the MJO decoupled from convection and the ocean, racing across the Western Hemisphere and back to the western Indian Ocean. The increase (decrease) in convection across eastern Brazil, Africa, and the western Indian Ocean (eastern Indian Ocean and Maritime Continent) is consistent with this progression.



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

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

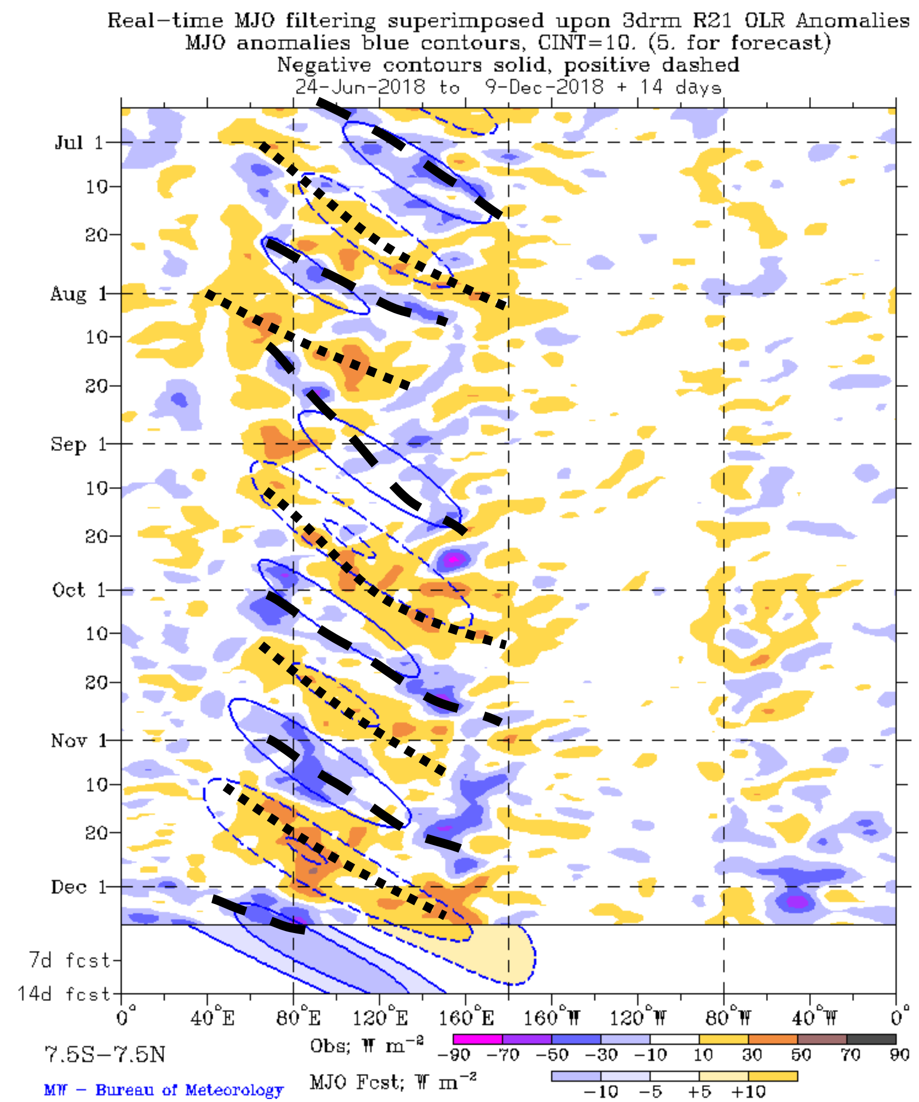
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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

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

Most recently, the suppressed phase of the MJO was apparent east of New Guinea, while the enhanced phase was working across the Indian Ocean.

Limited enhancement of convection near the Date Line has been observed, suggestive of the lack of coupling of the anomalously warm sea surface temperatures from the possible El Niño event with the atmosphere.



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

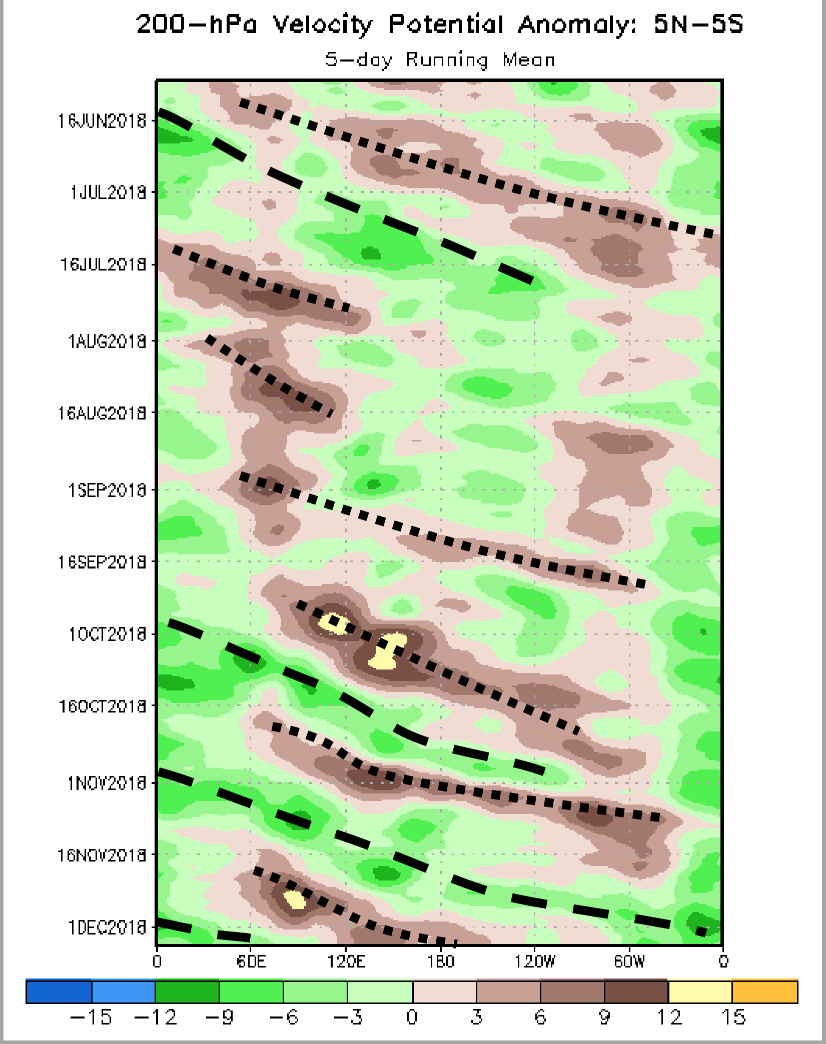
Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

Negative anomalies (green shading) indicate favorable conditions for precipitation

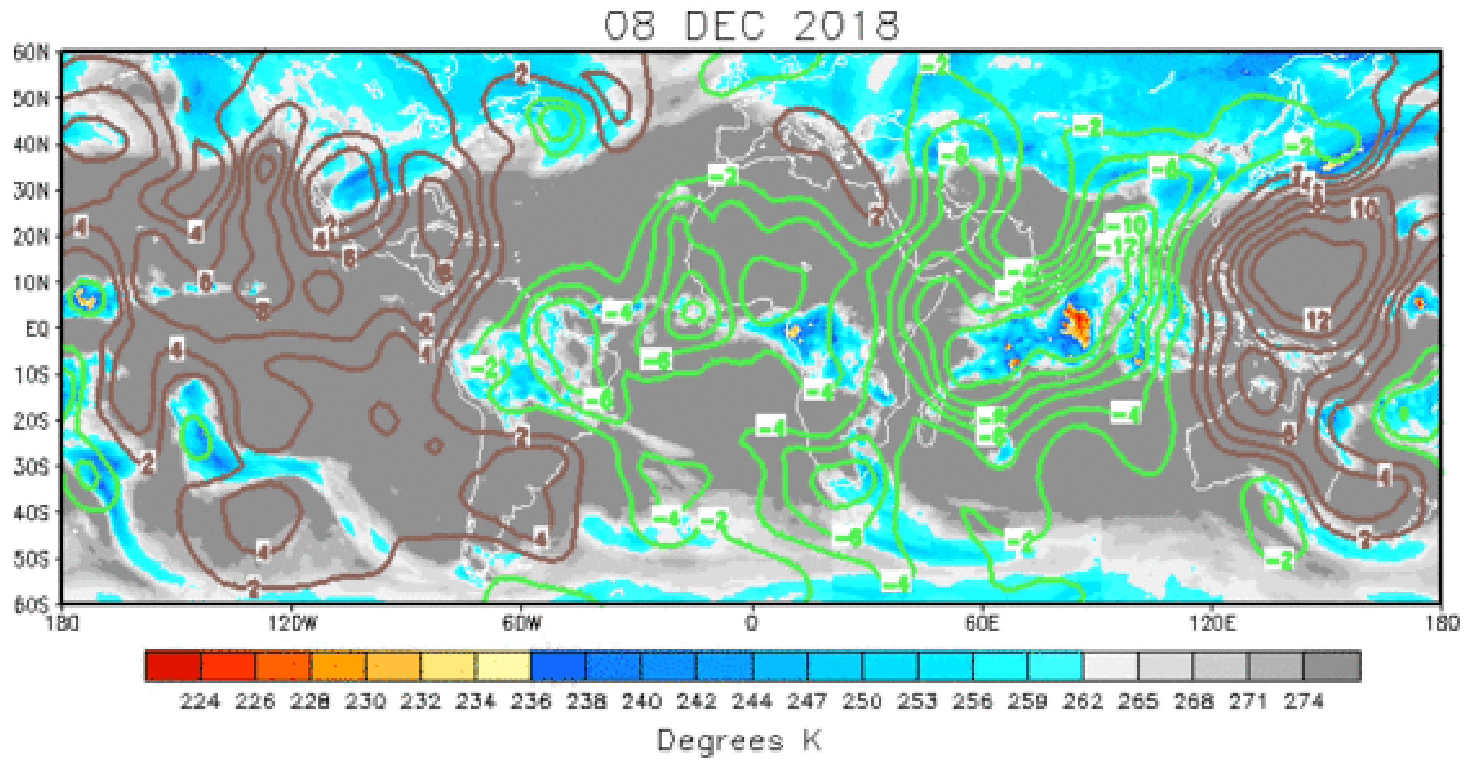
The enhanced phase of the MJO weakened east of the Date Line during June. Eastward propagation of broad suppressed convection continued into early July. The upper-level footprint of the MJO re-emerged during mid-July, with a broad divergent signal propagating from the Maritime Continent to the central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

During mid-September, a robust intraseasonal signal constructively interfered with the base state over the Maritime Continent. The MJO signal persisted into October, and destructively interfered with the base state. Most recently, the active phase of the MJO was over the Western Indian Ocean, and the suppressed phase was located near the Date Line.



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



There is a mostly Wave-1 pattern in the upper-troposphere, with enhanced convection from the Atlantic, Africa, and the Indian Ocean, and suppressed convection from the West Pacific through the Americas.

Positive anomalies (brown contours) indicate unfavorable conditions for precipitation

Negative anomalies (green contours) indicate favorable conditions for precipitation

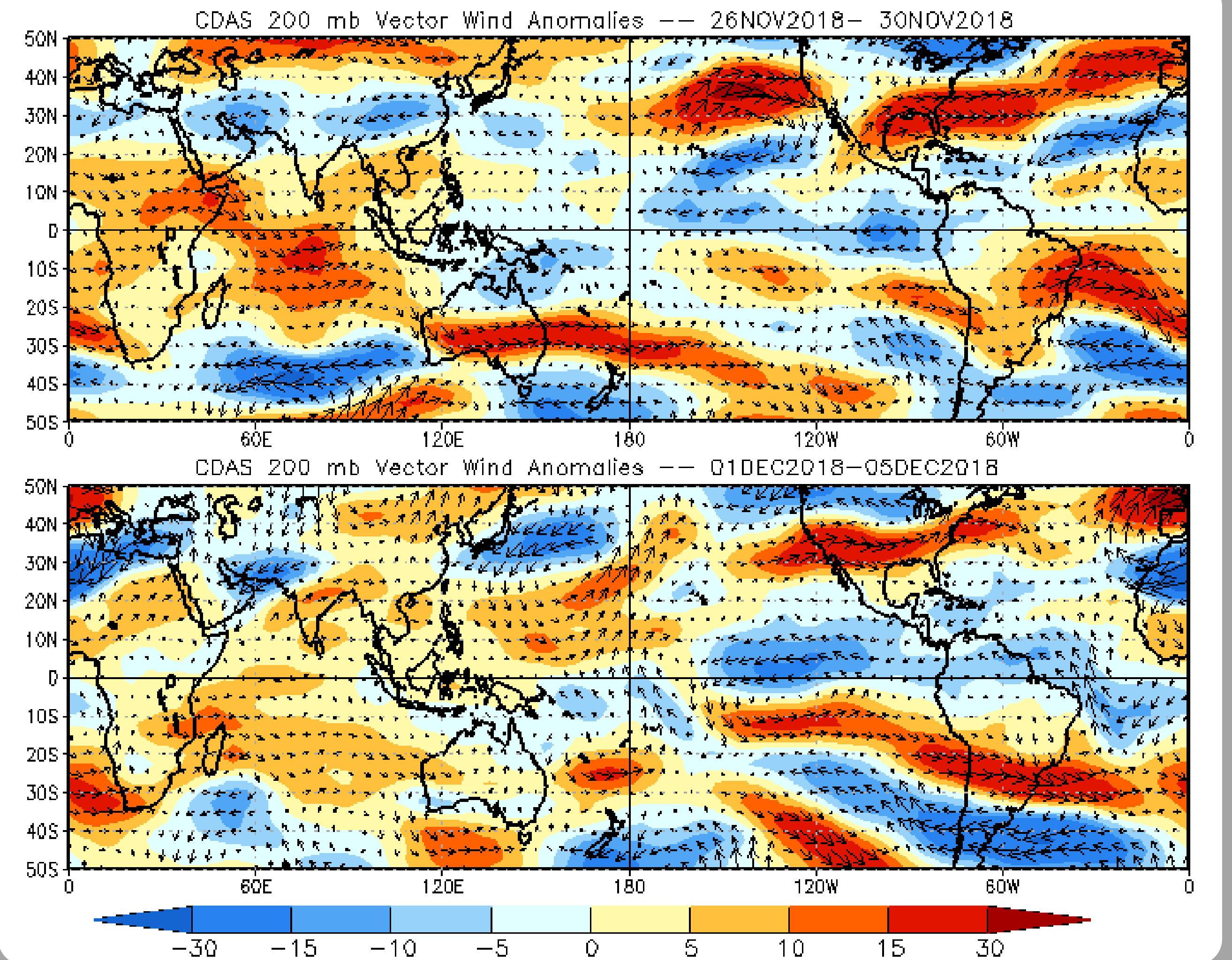
200-hPa Vector Wind Anomalies (m s^{-1})

Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

The subtropical jetstream in the northern hemisphere was displaced southward, yielding wet conditions across the southern US in recent days.



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

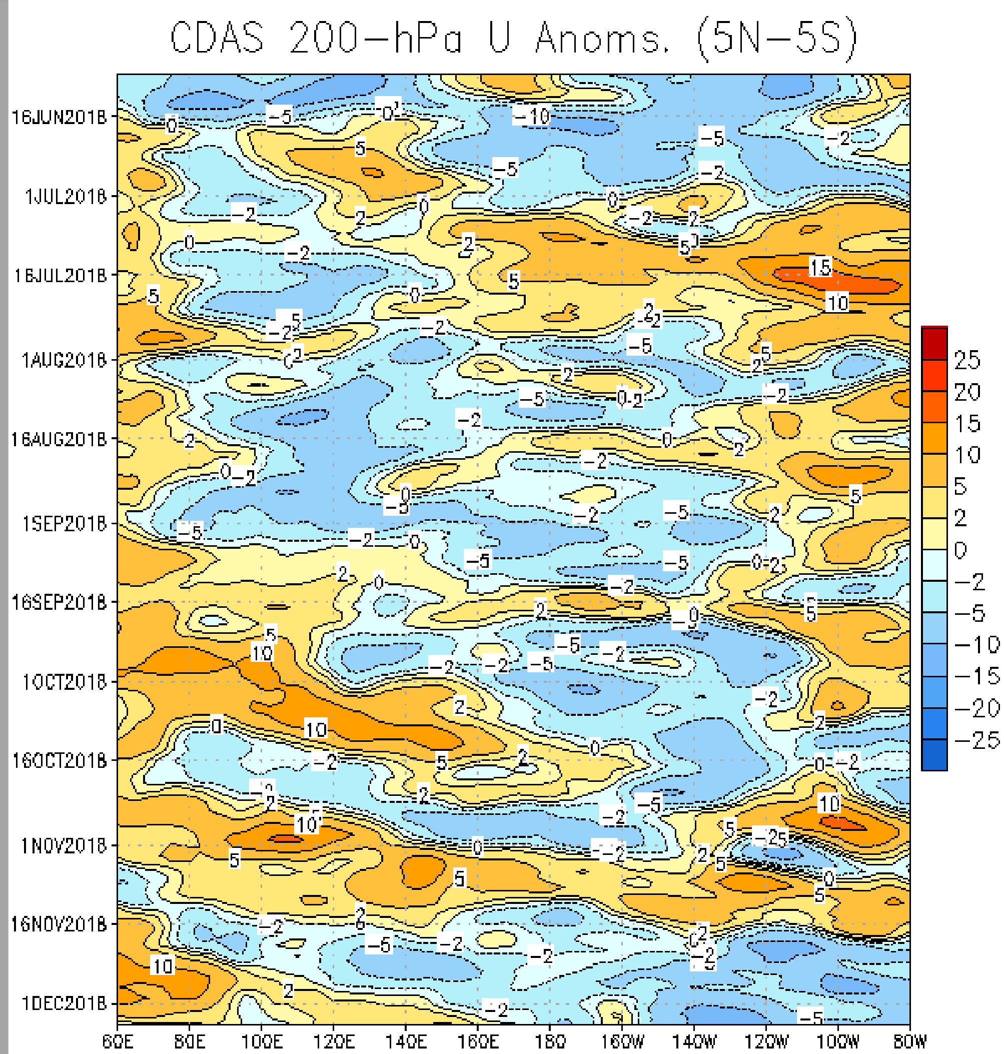
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

Anomalous westerlies amplified over the Maritime Continent in mid-June and propagated eastward at MJO-like phase speeds.

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

Toward the end of October, anomalous westerlies strengthened over the Indian Ocean and since early November, have shifted east, persisting across the entire tropical Pacific. Thereafter, easterly anomalies returned to this broad area. Most recently, westerly anomalies re-emerged over the Indian Ocean.



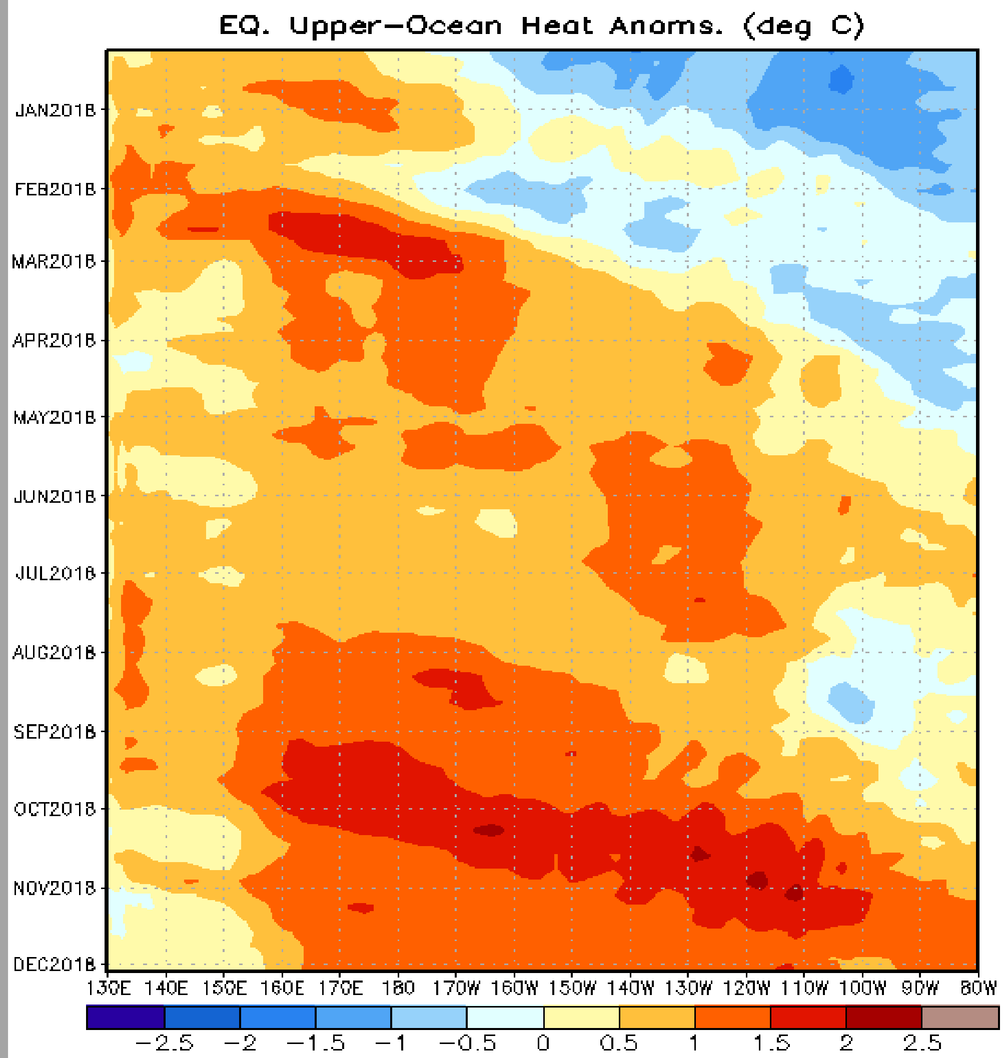
Weekly Heat Content Evolution in the Equatorial Pacific

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.

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.



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

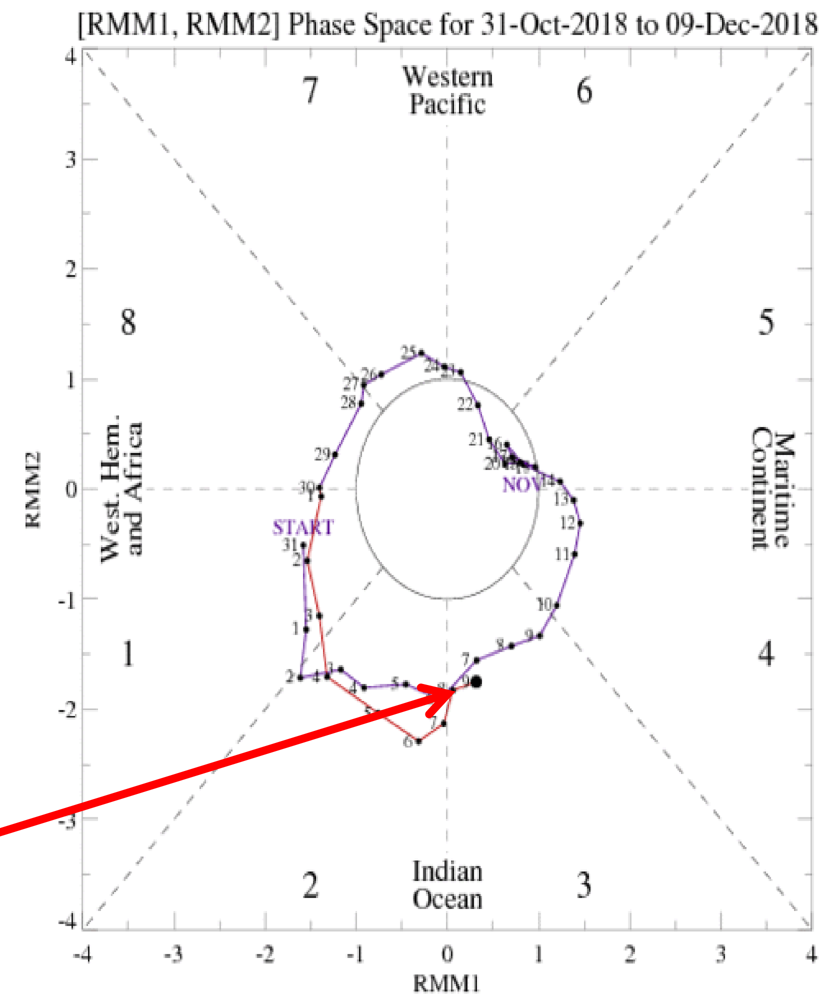
The axes (RMM1 and RMM2) represent daily values of the principal components from the two leading modes

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



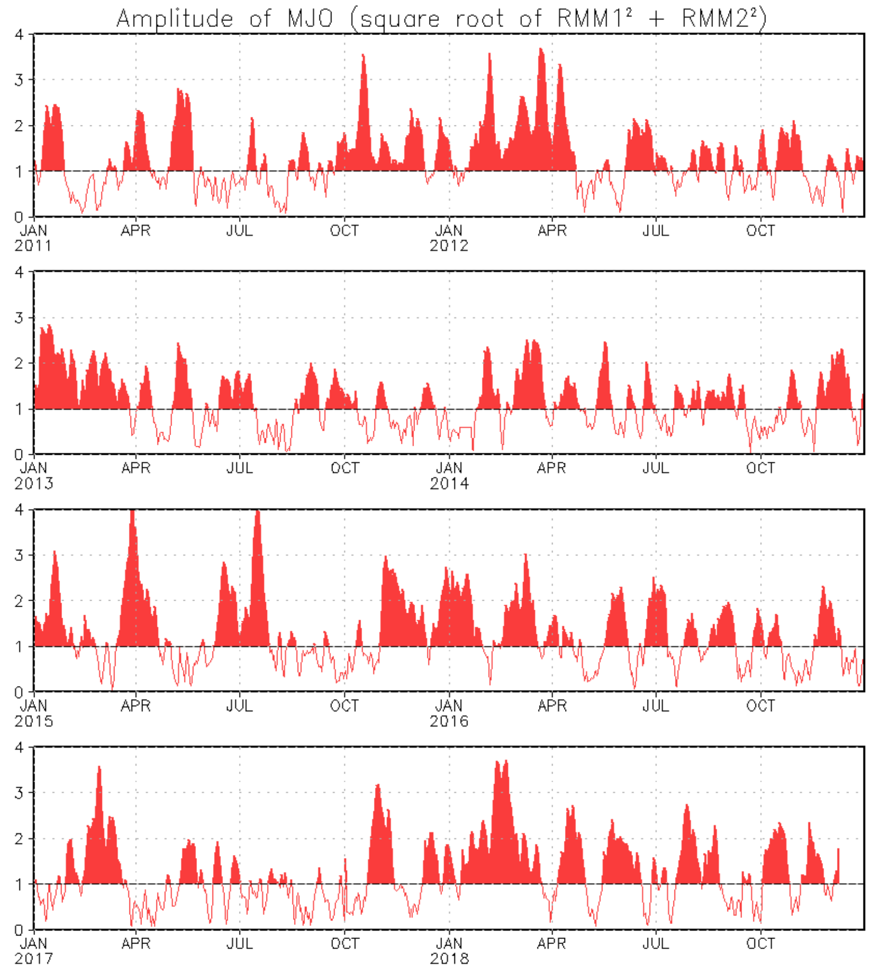
During the past week the RMM index shows the MJO entering the Indian Ocean and shifting into its eastern half.

The present MJO event was last in this location 32 days ago, putting it on the faster end of typical MJO event phase speeds.

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

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

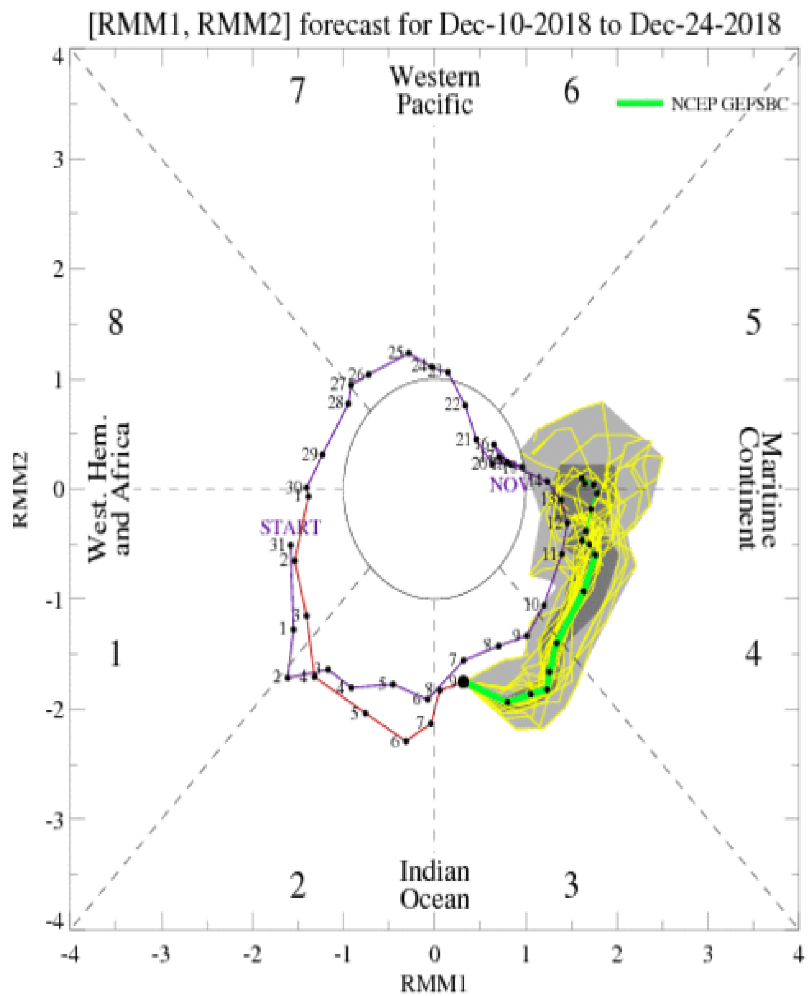
<u>light gray shading</u>: 90% of forecasts

<u>dark gray shading</u>: 50% of forecasts

The GEFS forecast of the RMM index portrays continued eastward propagation of the current MJO event towards the Maritime Continent the next two weeks, with the signal slowing substantially late in Week-2.

Some of this slowdown appears due to varying phase speeds of the individual ensemble members, although only a handful bring the signal into Phase 5. Model difficulties in propagating the MJO across the Maritime Continent are well documented, leading this solution to be taken cautiously.

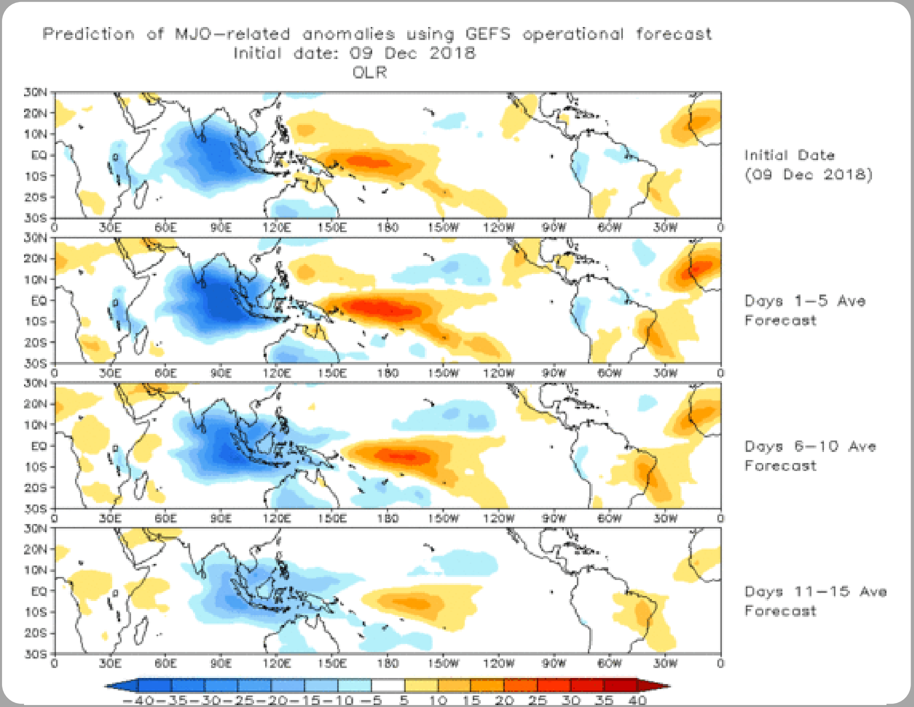
<u>Yellow Lines</u> - 20 Individual Members
<u>Green Line</u> - Ensemble Mean



Ensemble GFS (GEFS) MJO Forecast

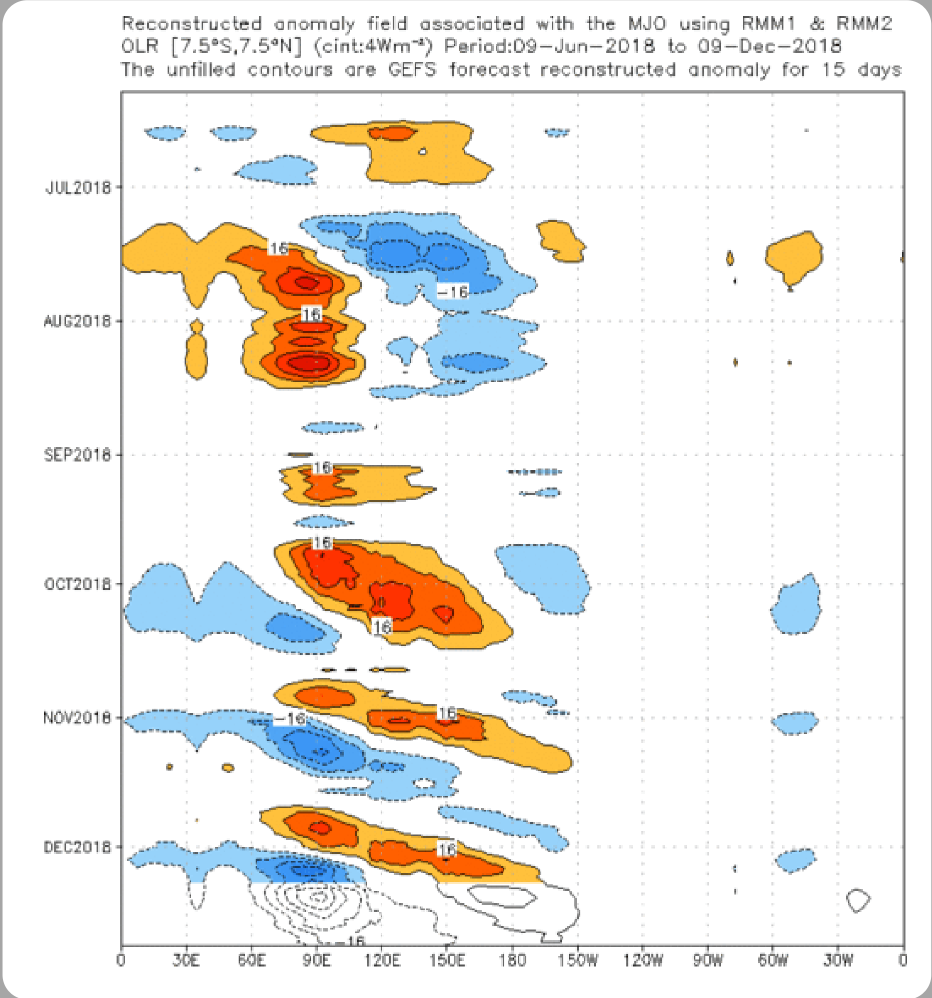
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



The GEFS RMM-based OLR forecast shows minimal eastward propagation of the convective couplet during the next two weeks, and instead slowly weakens the enhanced and suppressed convective signals.

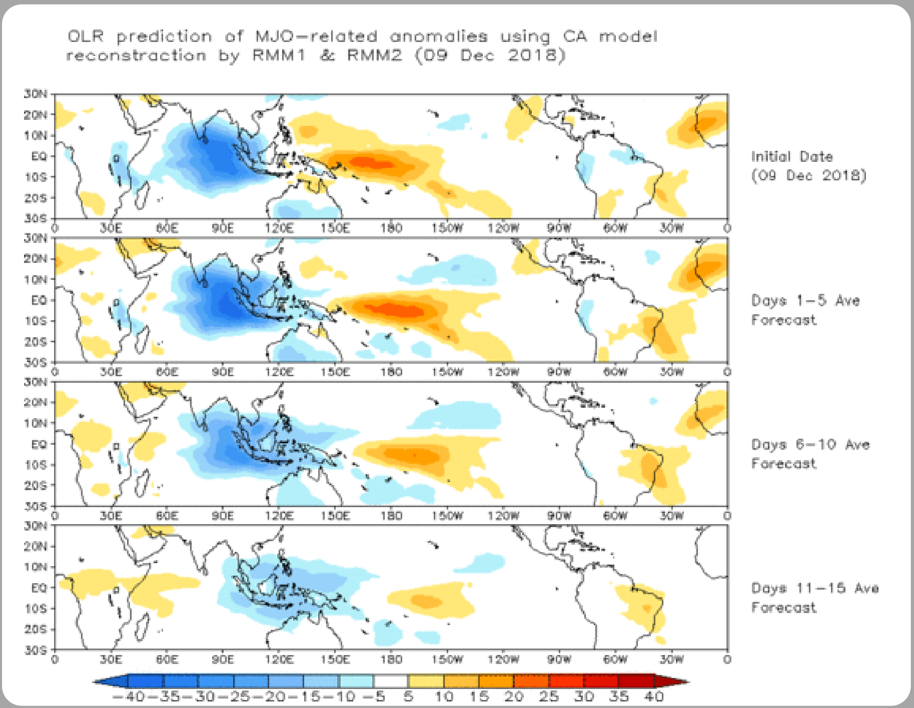
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



Constructed Analog (CA) MJO Forecast

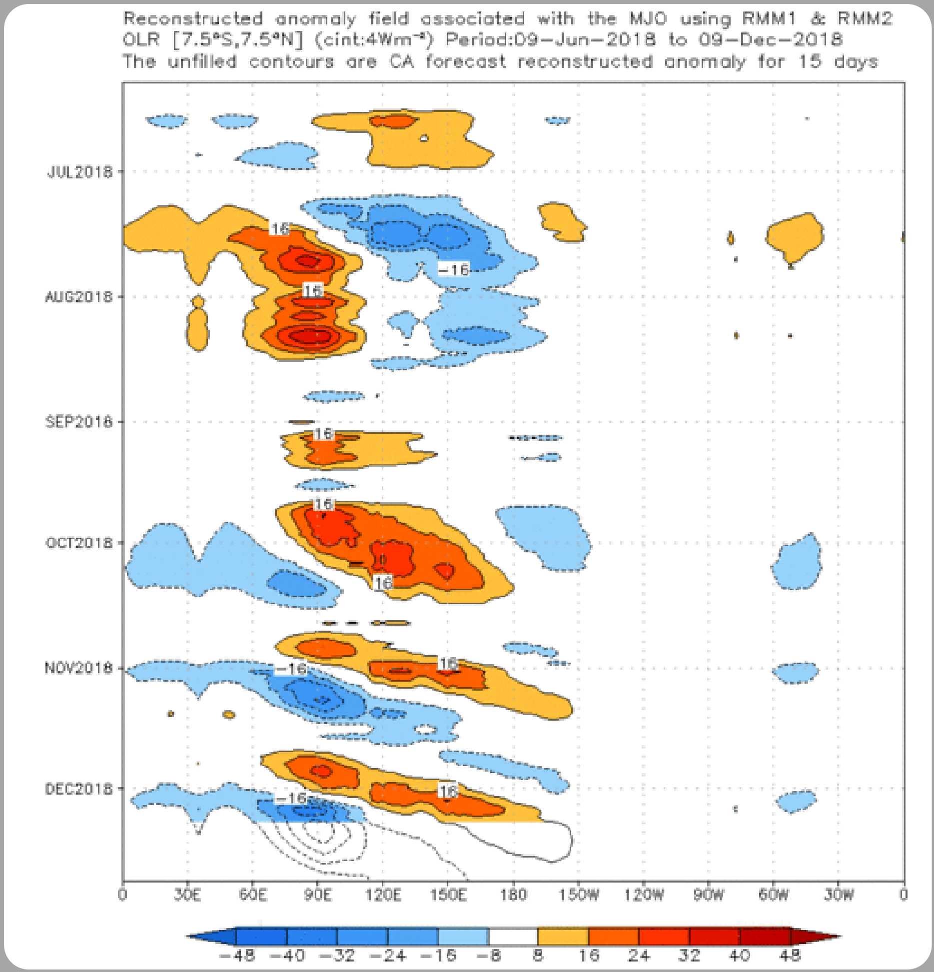
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



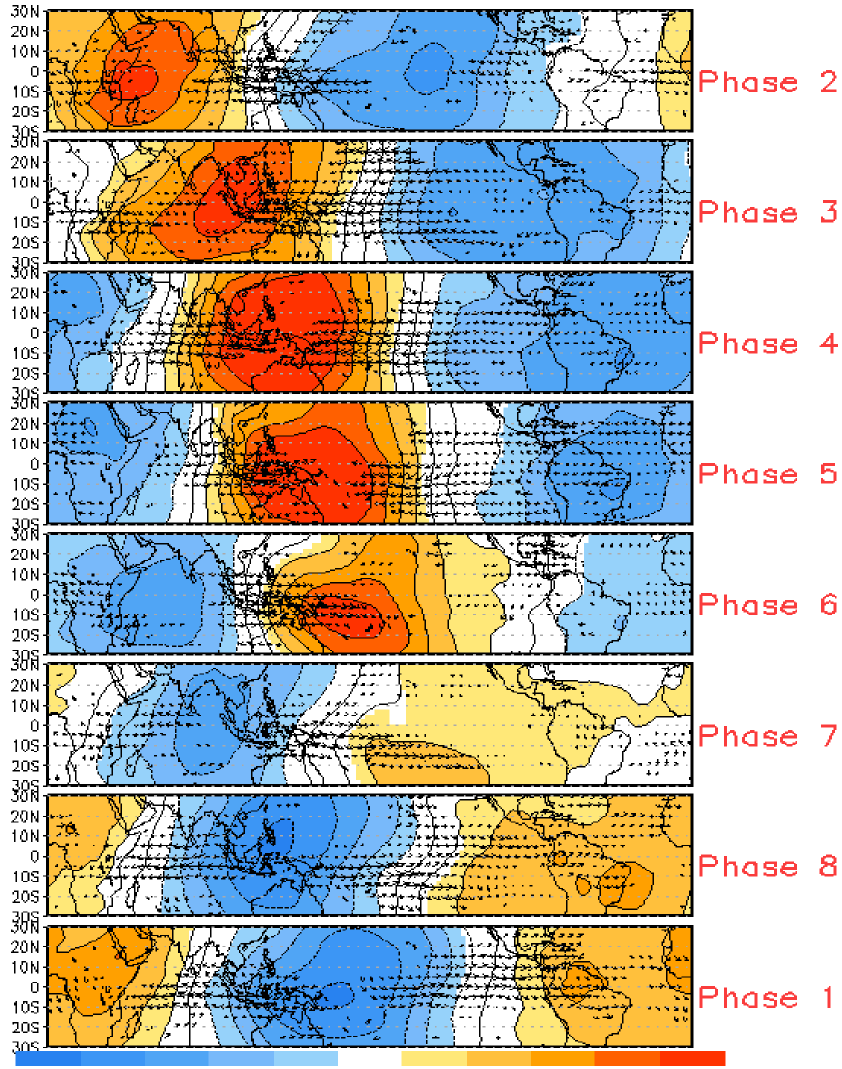
The constructed analog forecast is similar to the GEFS, with minimal eastward propagation of the intraseasonal signal, and instead a slow weakening that is largely stationary.

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

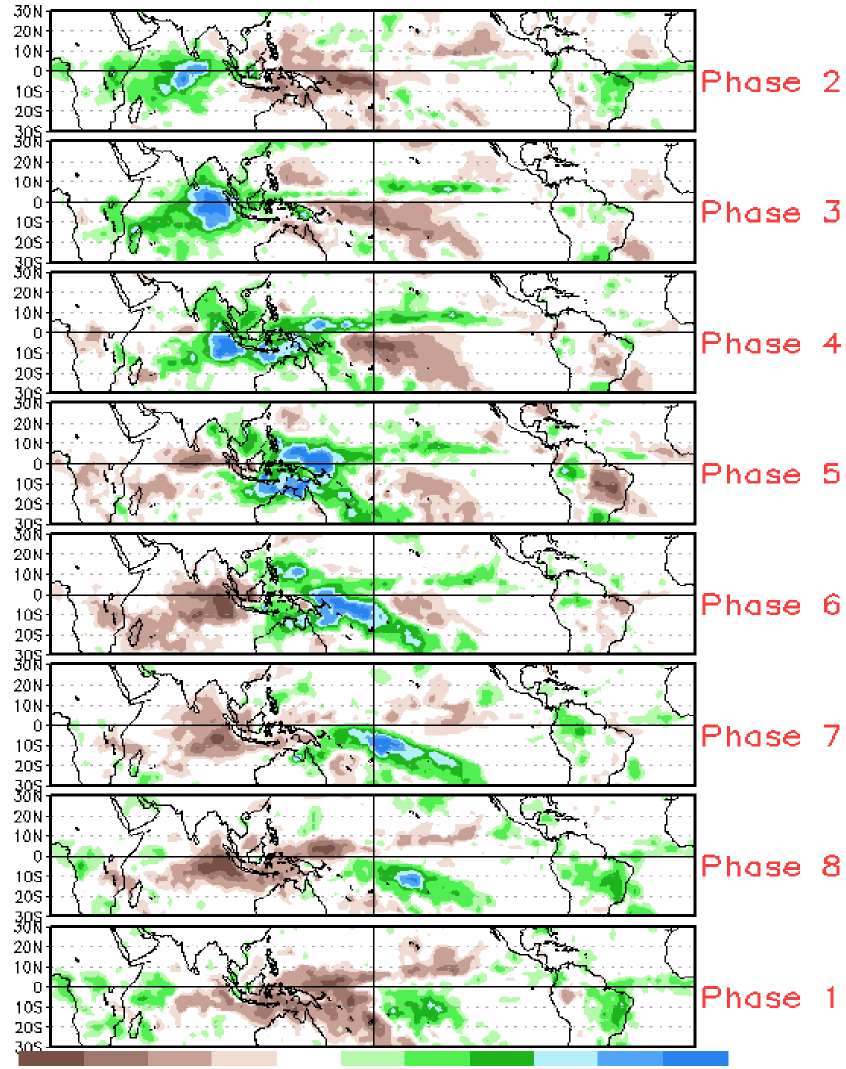


MJO Composites – Global Tropics

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



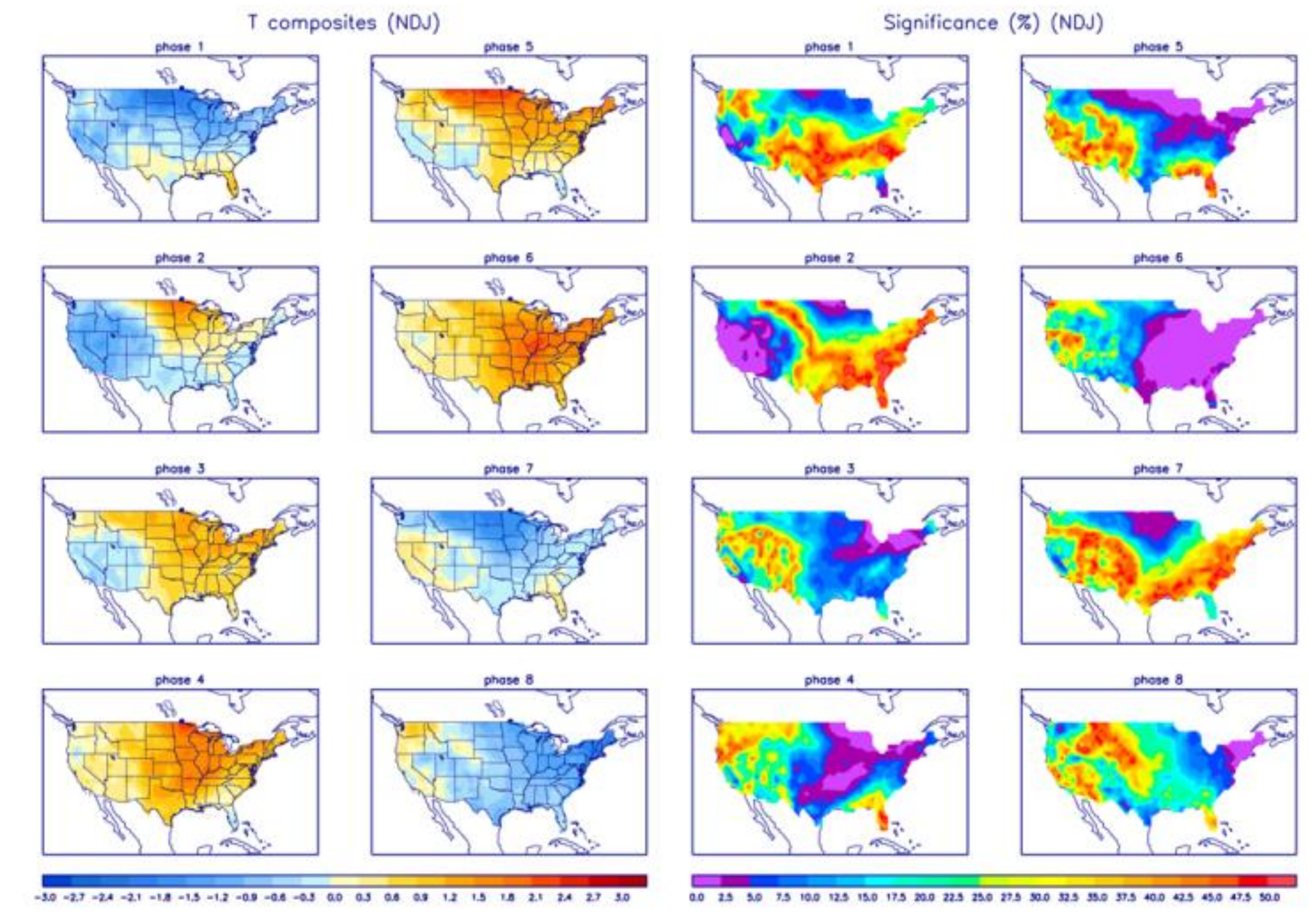
Precipitation Anomalies (Nov - Mar)



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.



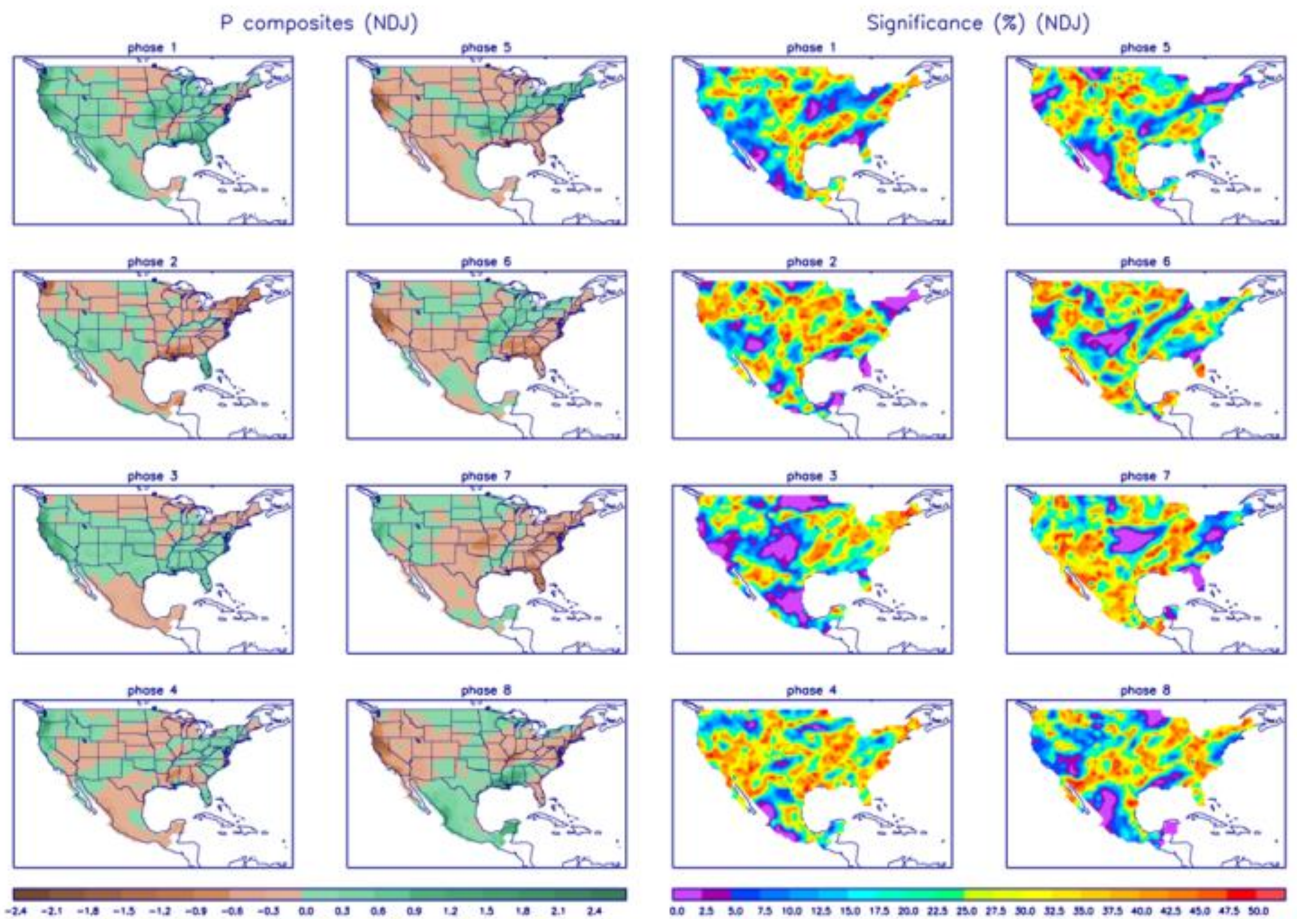
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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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