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

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Outline

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MJO Composites

Overview

- The MJO rapidly crossed the Western Hemisphere during the past week, albeit at a weakened amplitude. The low frequency state is likely partially to blame for the low amplitude, as enhanced convection east of New Guinea would bias the RMM index towards Phases 6/7. Furthermore, cyclonic extratropical wavebreaking from the Northern Hemisphere helped promote another center of action with anomalous westerlies along the equator in the East Pacific, distinct from the primary MJO envelope, that further muddying interpretation.

- Dynamical model guidance brings the enhanced portion of the MJO envelope into the West Pacific late in Week-1, before models diverge on how much the signal slows due to equatorial Rossby wave activity. The most progressive model, the ECMWF, brings the signal into Phase 7 late in Week-2 is favored here given the constructive interference with the low frequency state anticipated over the West Pacific.

- MJO activity appears unlikely to influence the extratropical circulation in the coming weeks. For North America, the negative phase of the AO is likely tied to the response of the signal crossing the Pacific over the last two weeks, and appears “locked in” for the near future. This is likely to negate any building ridging across the Great Lakes that would typically be the lagged response to the MJO crossing the Maritime Continent.

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})

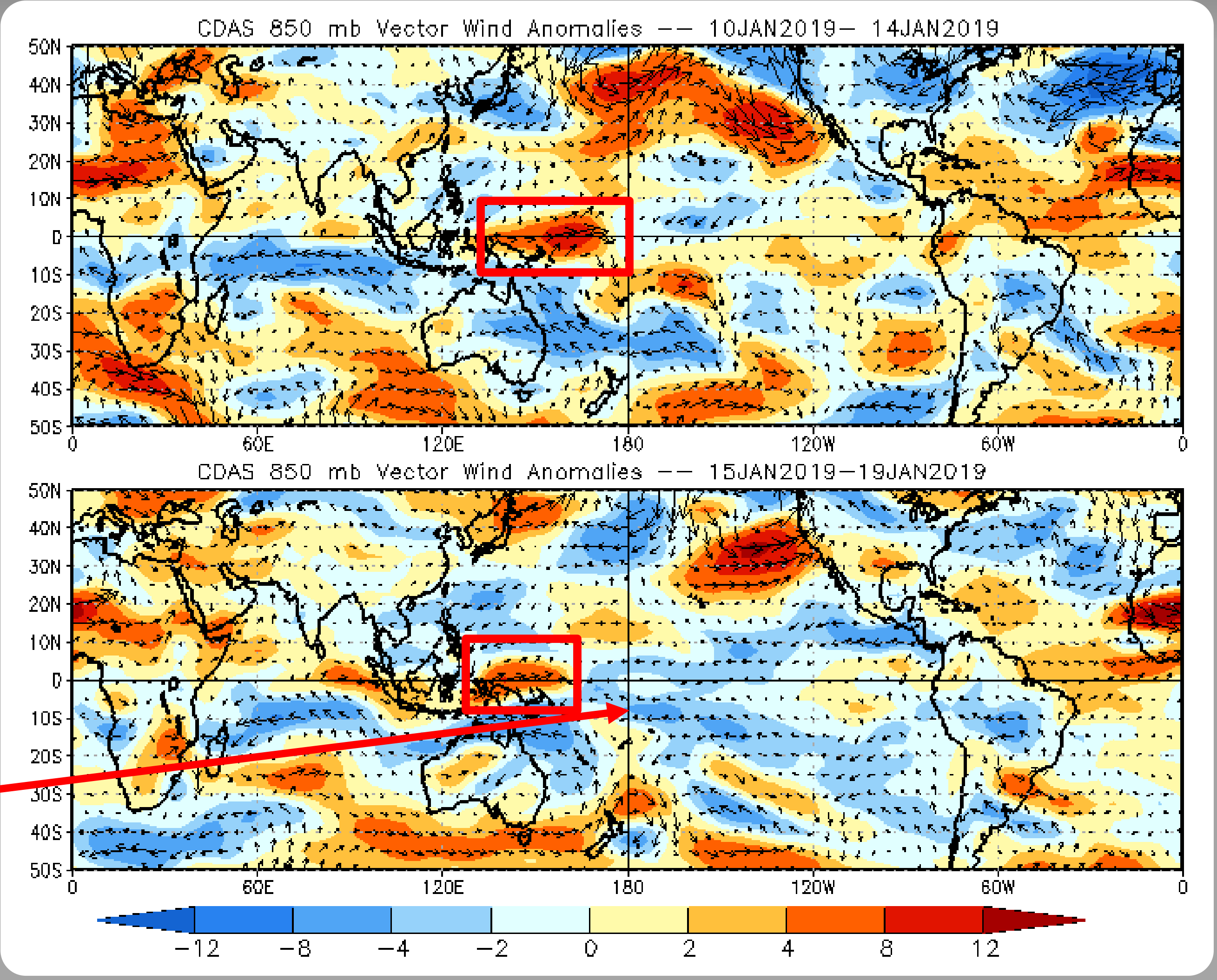
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Anomalous westerlies have persisted to the east of the Maritime Continent, associated with the low frequency state and enhanced convergence/convection near the Antimeridian.

Easterly anomalies strengthened across the Central Pacific, limiting the eastward extent of the anomalous westerlies near New Guinea during the past 5 days.



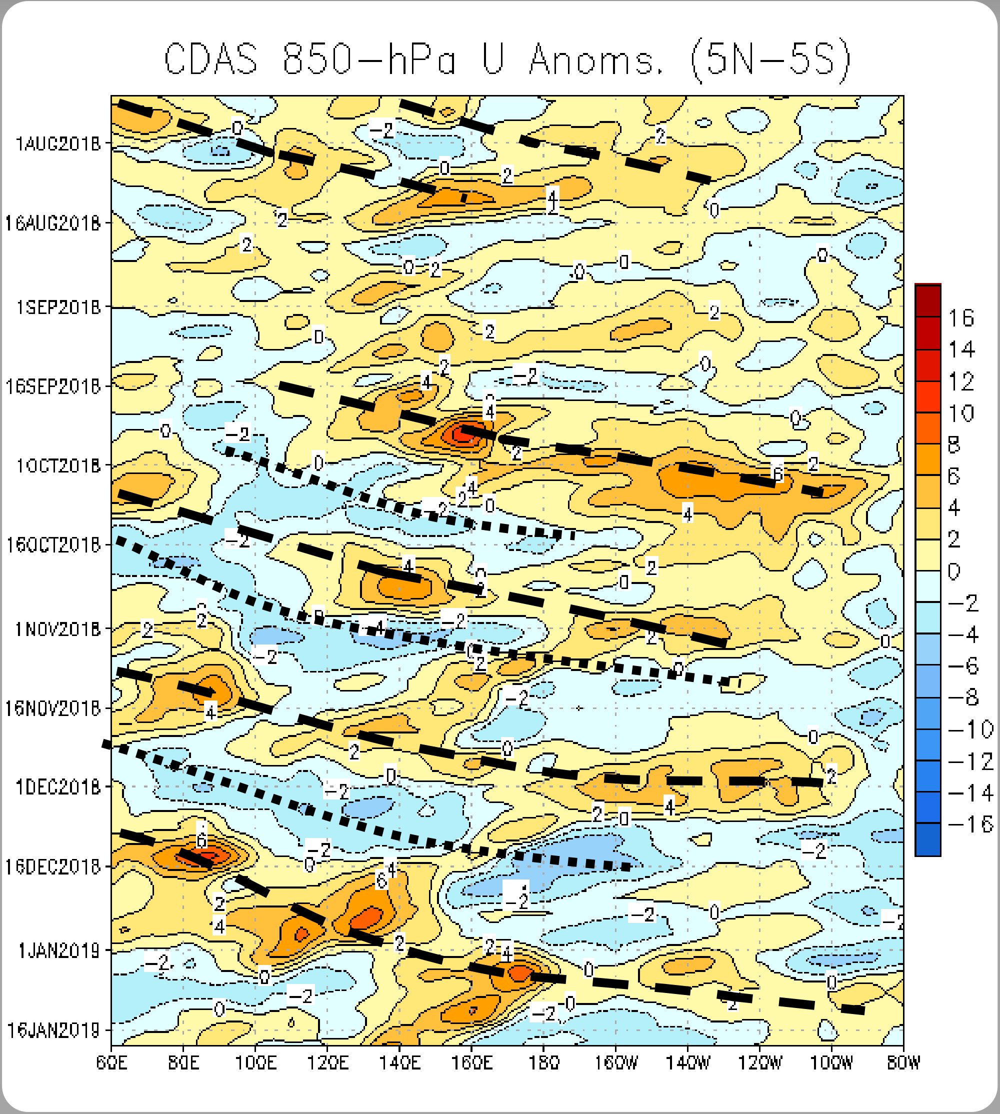
850-hPa Zonal Wind Anomalies (m s^{-1})

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

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

From August through mid-September, other modes, including Rossby waves and tropical cyclones, 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 have interfered with the base state. Since December Rossby wave activity has picked up over the West Pacific and Indian Ocean, resulting in a slowing of the primary eastward moving intraseasonal envelope across these basins and intermittent disruptions of the anomalous westerlies near the Antimeridian.



OLR Anomalies – Past 30 days

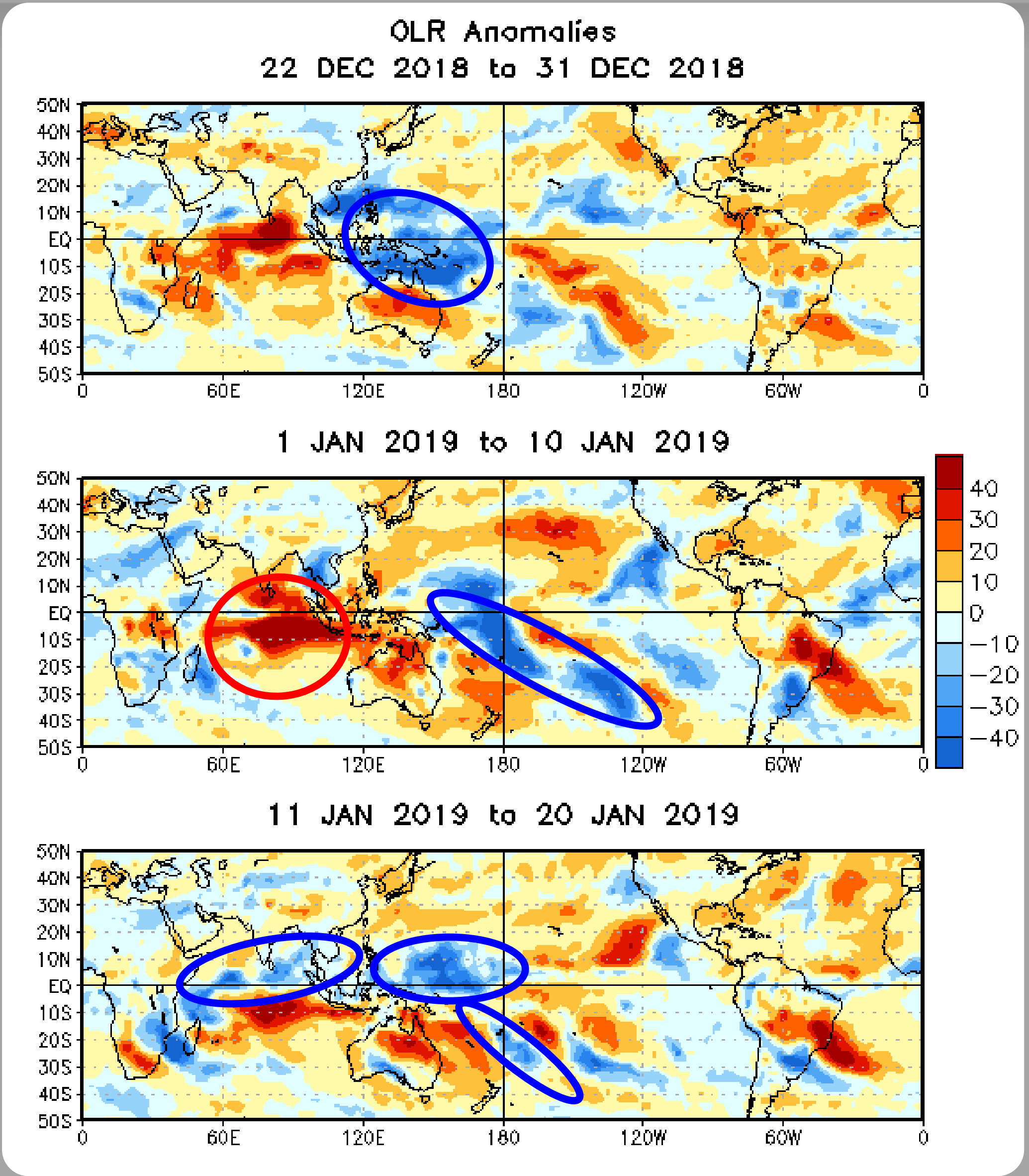
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

In late December, the MJO propagated out of the Indian Ocean, towards the Maritime Continent and West Pacific. Suppressed convection over the central Pacific weakened. Pronounced Rossby wave activity supported TC activity over the western Pacific.

By early January, some of the convective activity associated with the MJO extended along the SPCZ into the southern mid-latitudes. In addition, suppressed convection over the Indian Ocean strengthened.

During mid-January, enhanced convection across the Indian Ocean (West and South Pacific) was tied to the active phase of the MJO (Rossby wave activity).Convection persisted between New Guinea and the Date Line, consistent with the low frequency state.



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

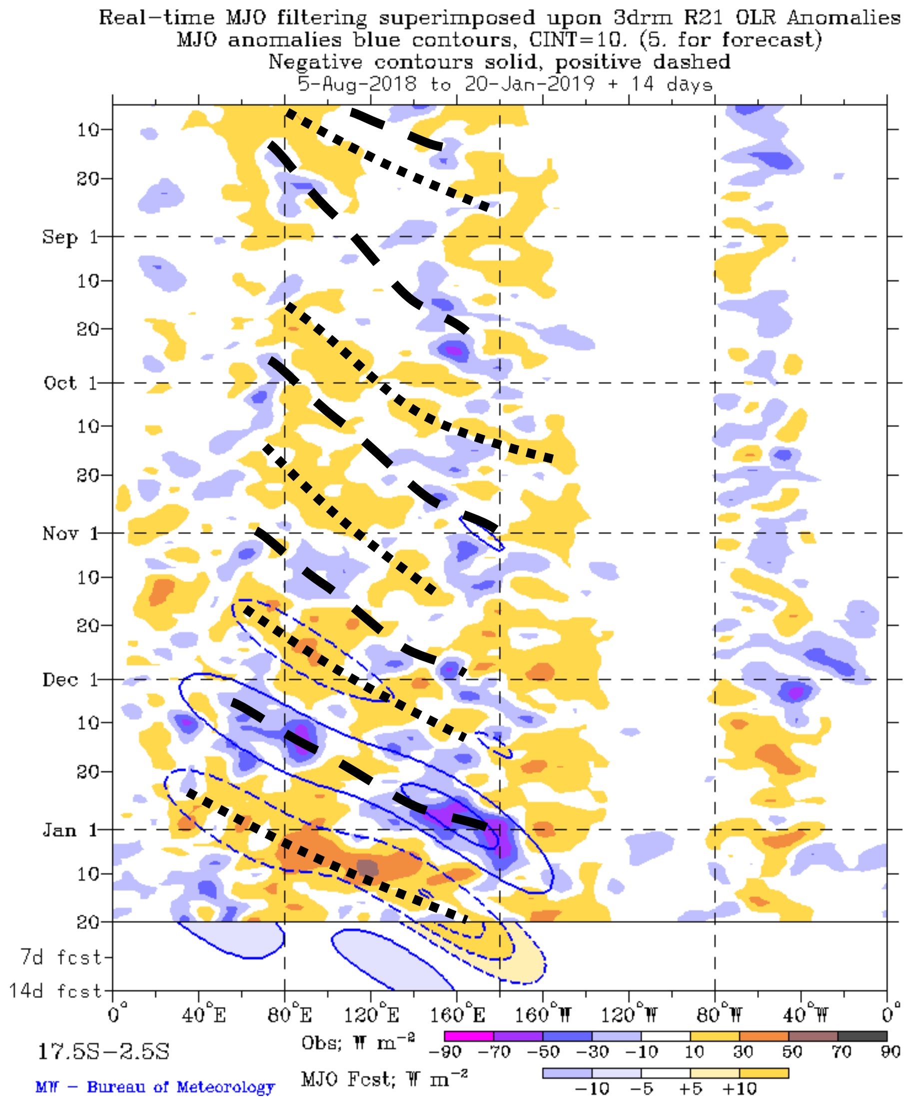
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During August, other modes of tropical (Kelvin waves, Rossby waves and tropical cyclones) variability dominated, with weak OLR anomalies continuing until mid-September. These variabilities also interfered with the emerging base state.

Limited anomalous convection has been observed east of 140W during the past several months, suggesting if El Niño does develop it may be of the Modoki variety.

Since the end of September, the MJO signal has seen alternative active and inactive phases crossing the Indian Ocean through Central Pacific and influencing the convection for these regions. The suppressed phase of the MJO recently interfered with low frequency convection east of New Guinea.



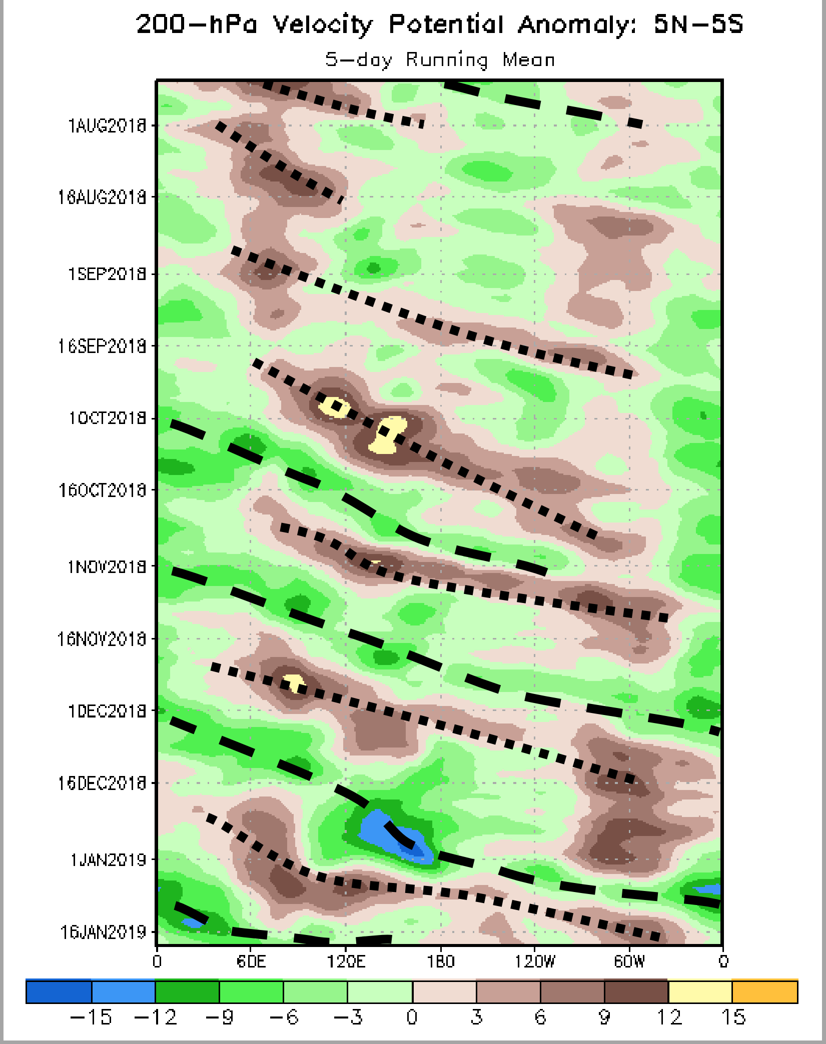
200-hPa Velocity Potential Anomalies (5ºS - 5ºN)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

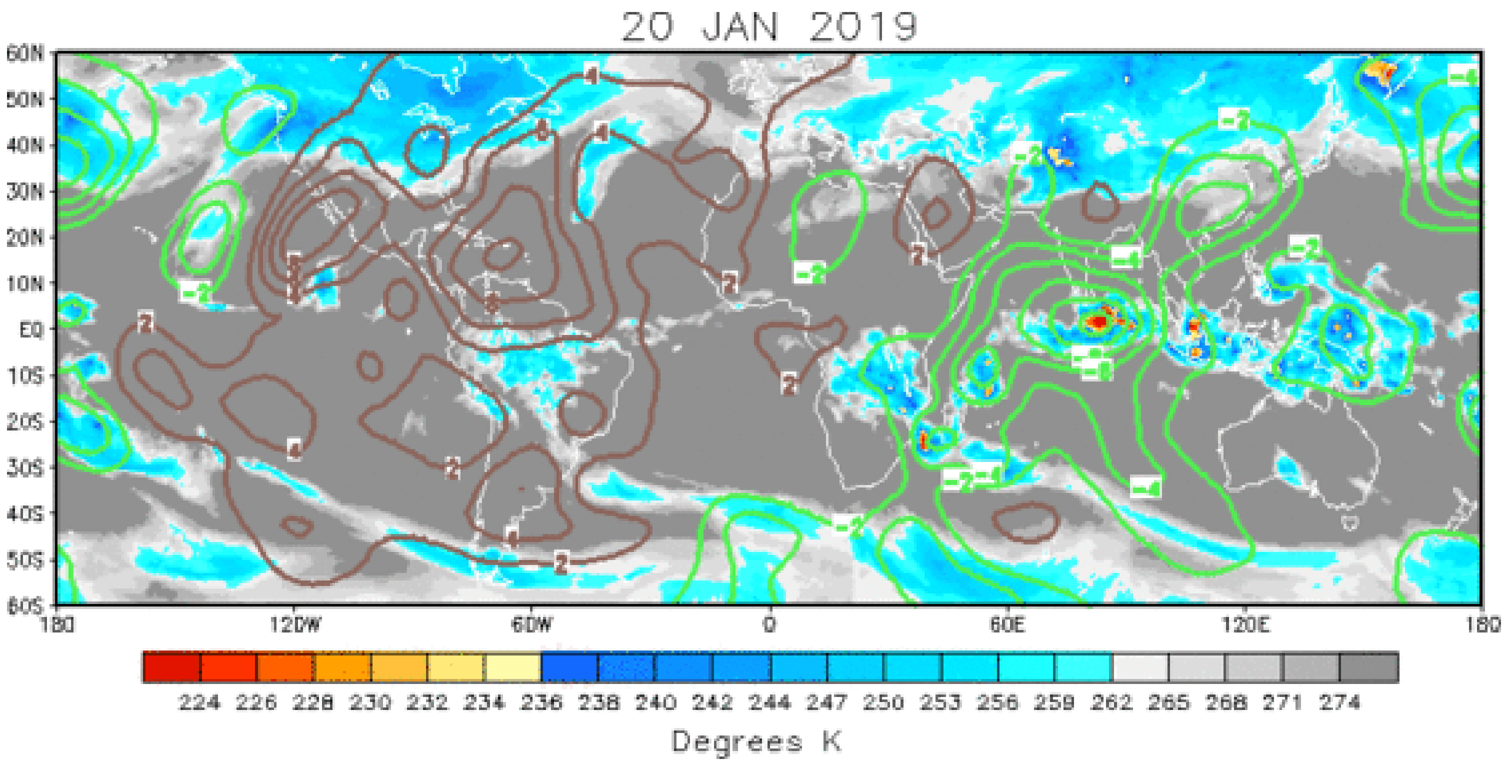
Negative anomalies (green shading) indicate favorable conditions for precipitation

The upper-level footprint of the MJO emerged during mid-July, with a broad divergent signal propagating from the Maritime Continent to the central Pacific. Around the same time, a low-frequency dipole favoring enhanced (suppressed) convection over the east-central Pacific (Indian Ocean) emerged, consistent with a gradual transition towards possible El Niño conditions. An active MJO pattern since September has overwhelmed this signal at times.

The enhanced divergent envelope continued propagating eastward to the West Pacific through late-December before slowing tied to Rossby wave activity and the low frequency state. This envelope then continued across the Western Hemisphere early in 2019, with conditions favorable for enhanced convection tied to the MJO rapidly crossing from the Prime Meridian through the Maritime Continent during the past week.



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



The upper-level VP anomaly pattern exhibits a fairly coherent wave-1 pattern tied to the active (inactive) phase of the MJO crossing the Indian Ocean (Western Hemisphere) and acting to enhance (suppress) convection for these regions.

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})

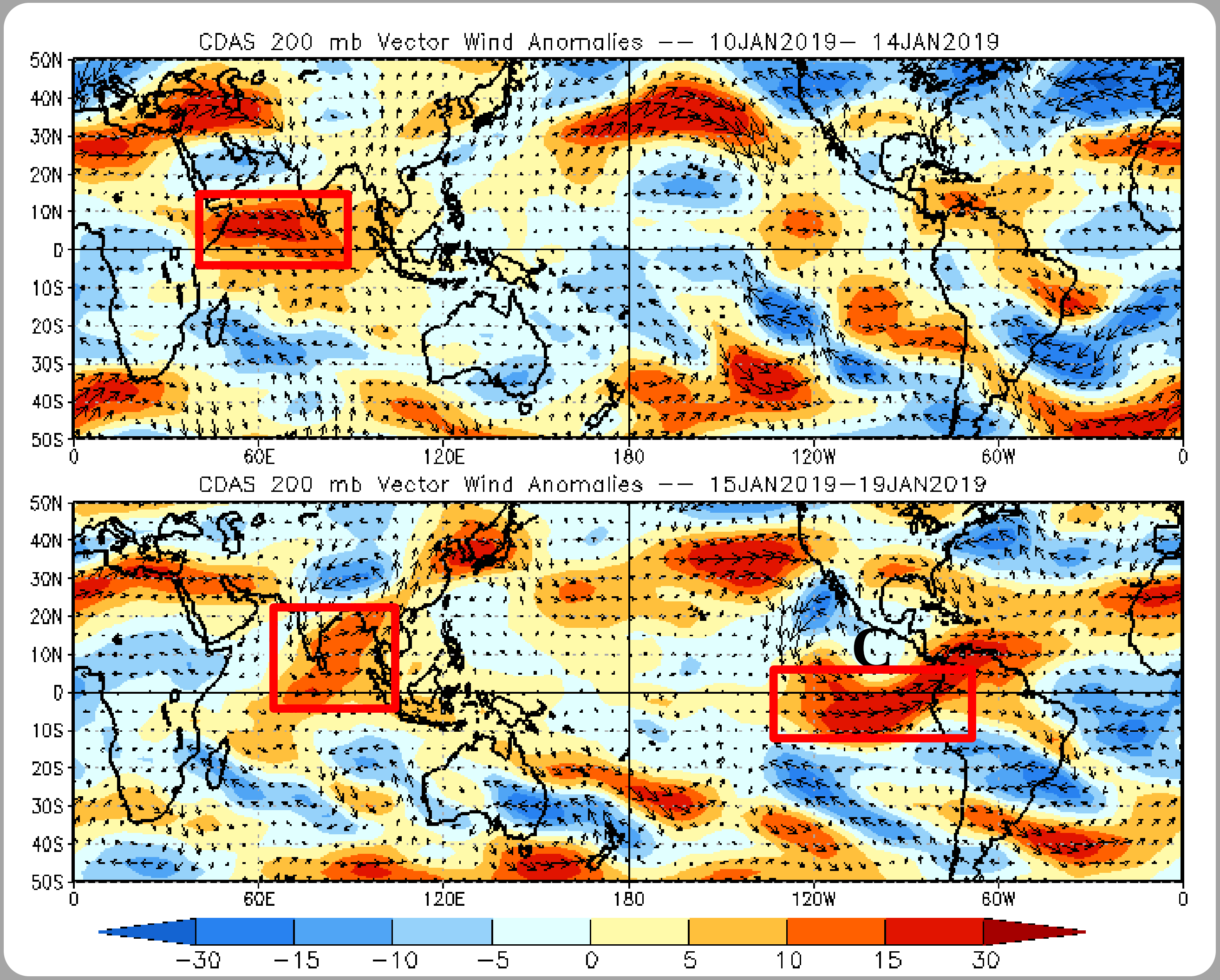
Note that shading denotes the zonal wind anomaly

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

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

Anomalous westerlies shifted from the western Indian Ocean towards the Bay of Bengal, tied to the active phase of the MJO pushing eastward.

Cyclonic wavebreaking over the East Pacific from the Northern Hemisphere is helping to yield strong westerlies along the equator, which could be muddying MJO tracking indices such as the RMM index due to the two competing centers of action over the Indian Ocean and East Pacific.



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

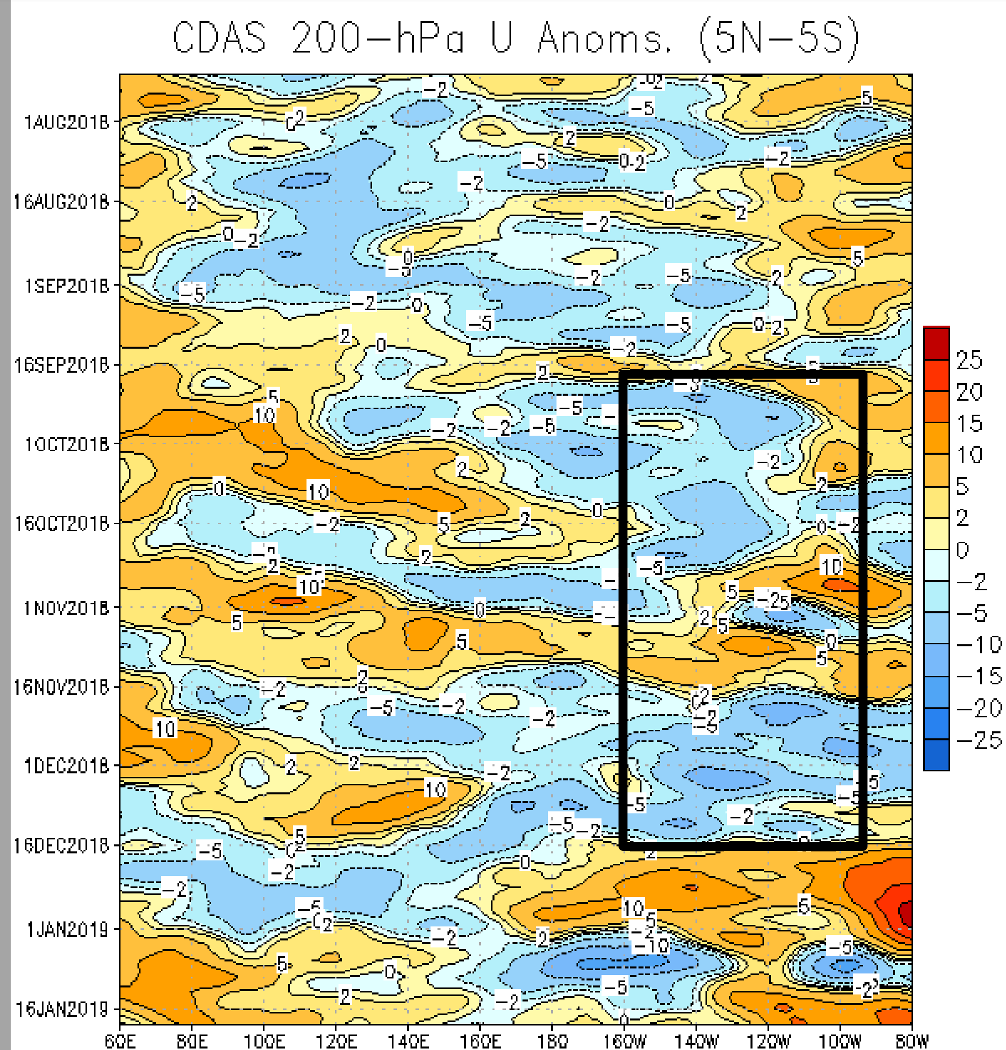
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

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

Since mid-September through mid-December, upper-level winds have been marked by pronounced intraseasonal activity, interrupted by Rossby waves. A trend towards more persistent easterly anomalies over the Pacific (boxed area) may have been associated in part with the base state.

In mid-December, the MJO signal, along with Rossby wave activity interrupted the persistent easterlies over the eastern Pacific that briefly re-established early in 2019, before a return to westerly anomalies over the past week associated with the cyclonic wavebreaking from the Northern Hemisphere noted on the previous slide.



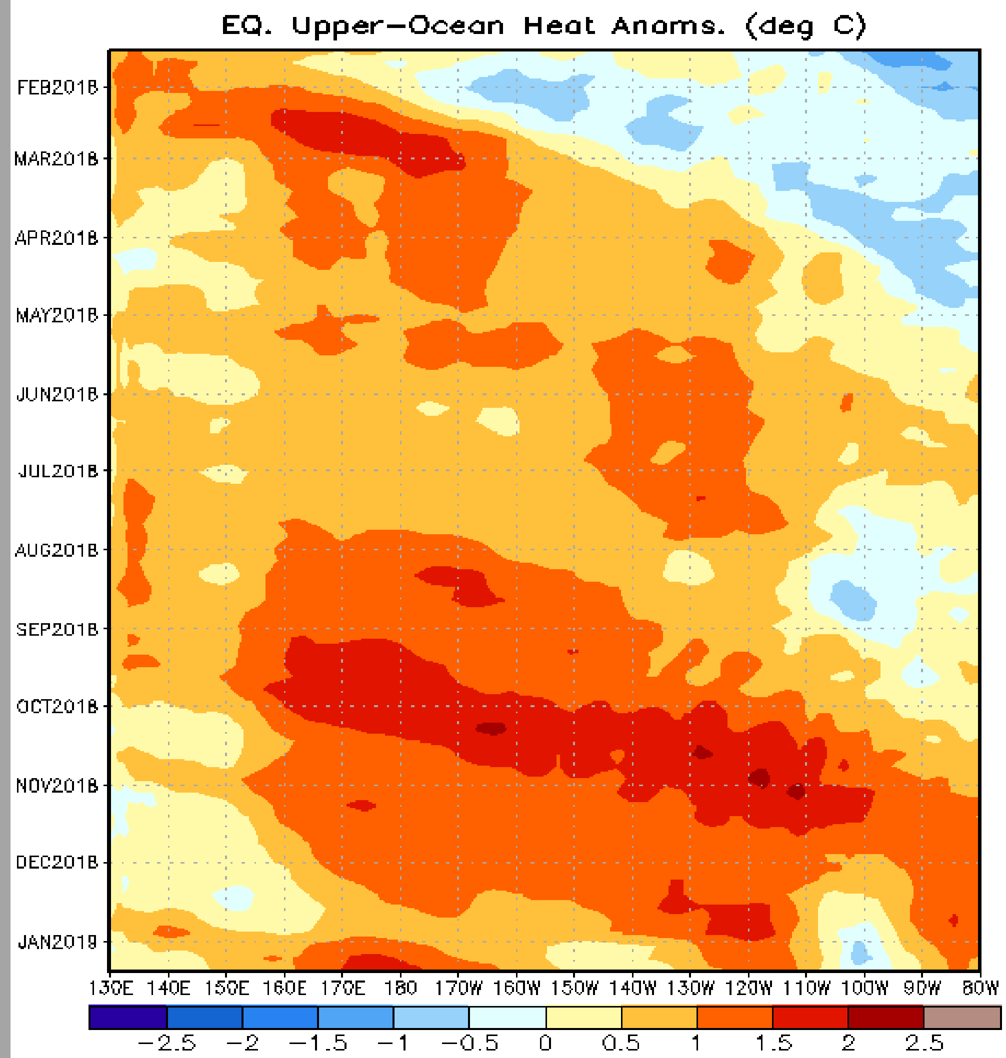
Weekly Heat Content Evolution in the Equatorial Pacific

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 decayed across the central and eastern Pacific during the first half of 2018 tied to multiple downwelling oceanic Kelvin waves. 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 recently decreased in magnitude over much of the Pacific, with the warmest near-surface water focused just west of the Antimeridian. The strengthening meridional oceanic heat content gradient may be tied to the more robust appearance of low frequency convection in recent weeks 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

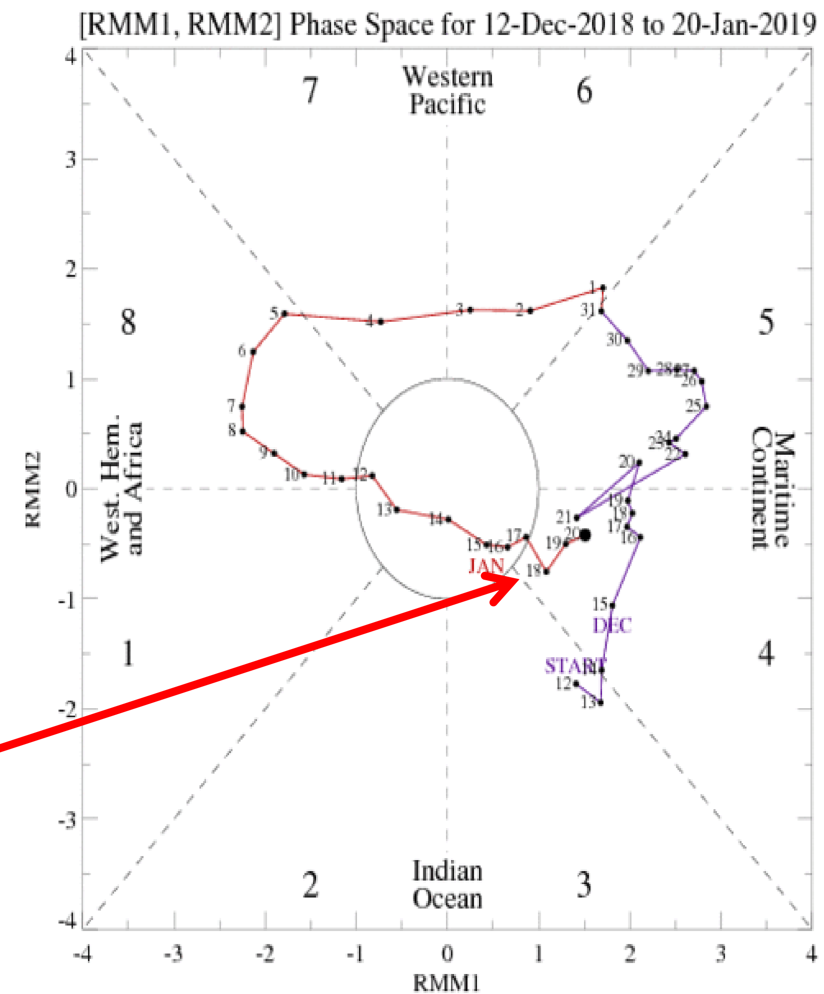
Counter-clockwise motion is indicative of eastward propagation. Large dot most recent observation.

Distance from the origin is proportional to MJO strength

Line colors distinguish different months

Over the 7 days, the MJO signal rapidly crossed from a weak signal centered over Africa to emerging across the Maritime Continent.

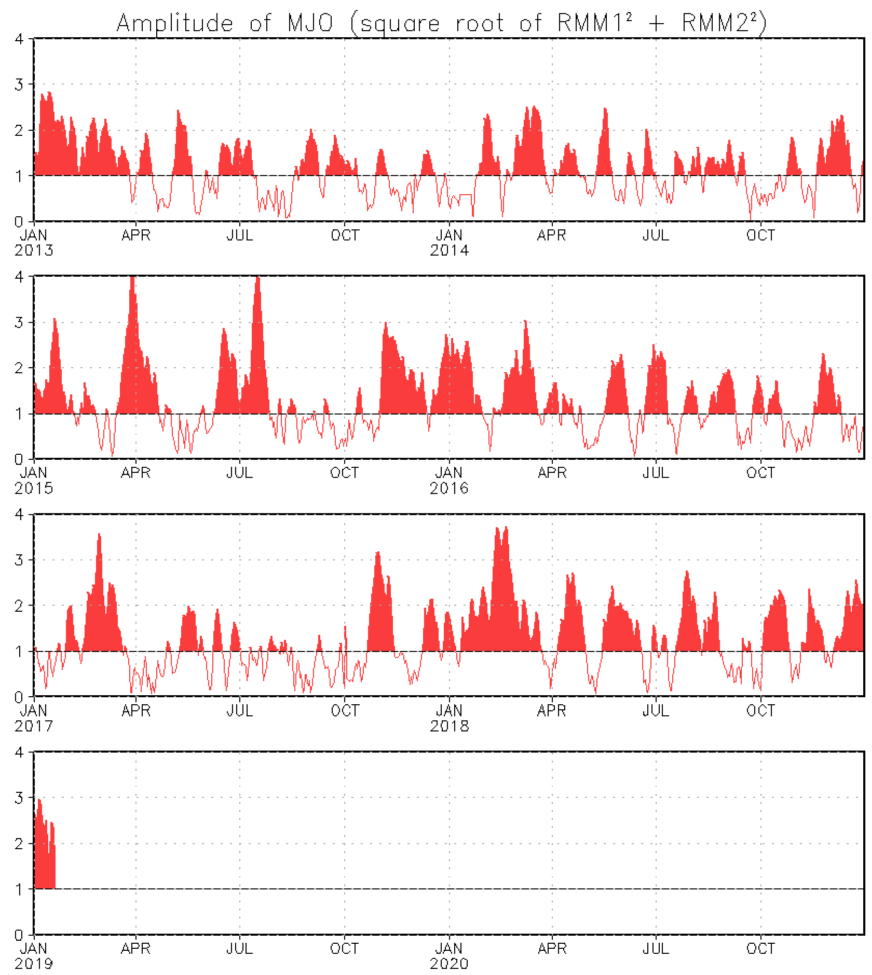
Anomalous equatorial westerlies from extratropical influences over the Western Hemisphere and persistent enhanced convection over the West Pacific may have both played a role in the lack of a robust signal across the Indian Ocean, despite the obvious influences on convection and the circulation noted earlier in this presentation.



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

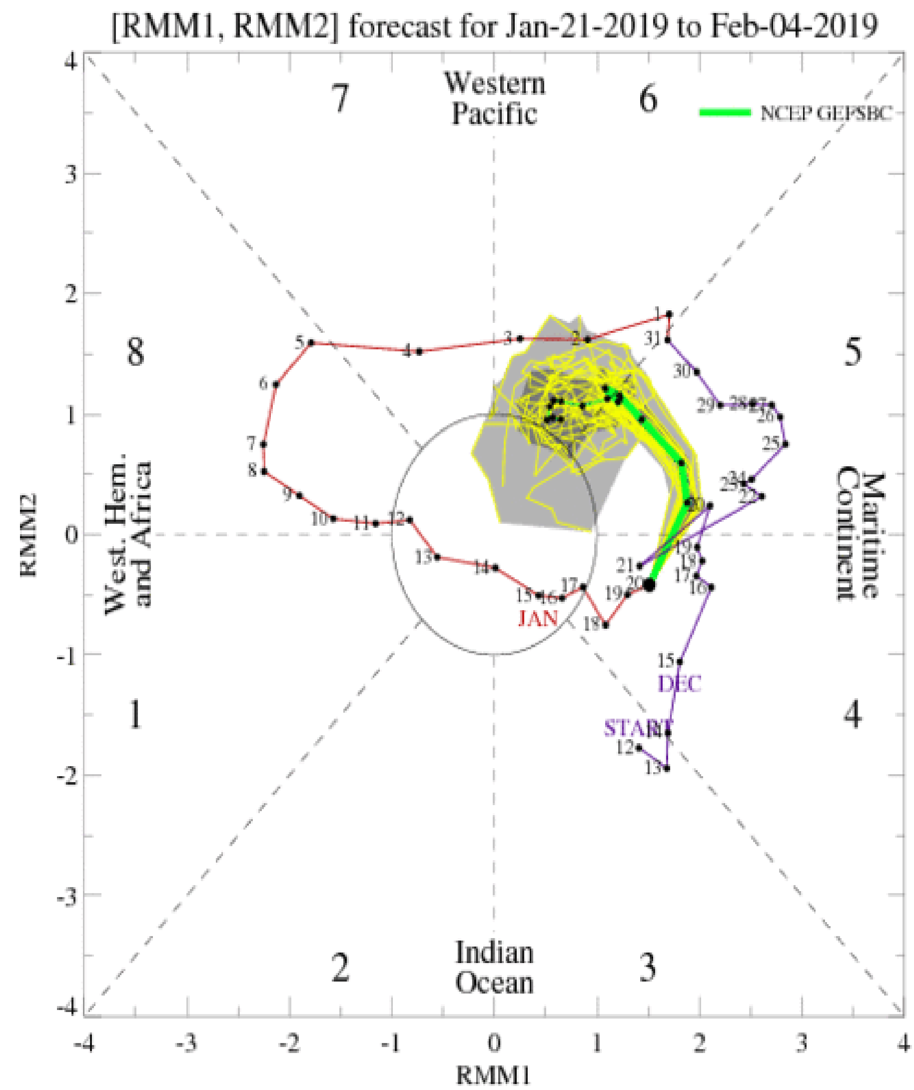
RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS forecasts the MJO to reach the West Pacific during the next week, before stalling out with the intraseasonal signal weakening and tracking towards the unit circle. This progression is notably consistent across all GEFS ensemble members.

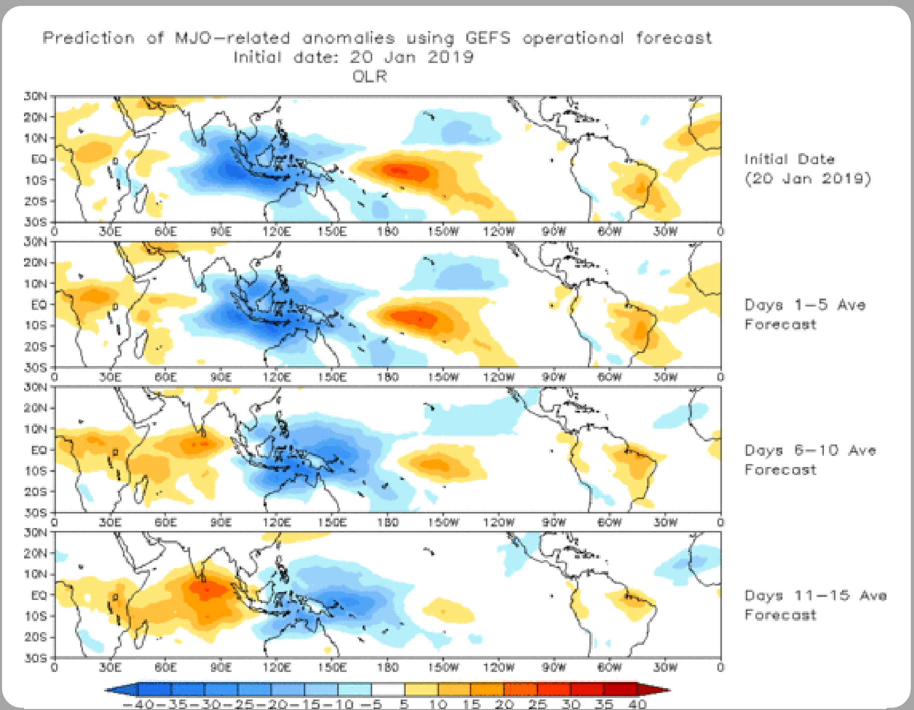
The cause for this decrease in amplitude is not tied to differences in MJO phase speed, but instead to forecast equatorial Rossby wave activity, which the GEFS is known to overdo. There may be some slowing of the intraseasonal signal during Week-2, but the low frequency state would further support the signal pushing toward the Date Line in early February.



Ensemble GFS (GEFS) MJO Forecast

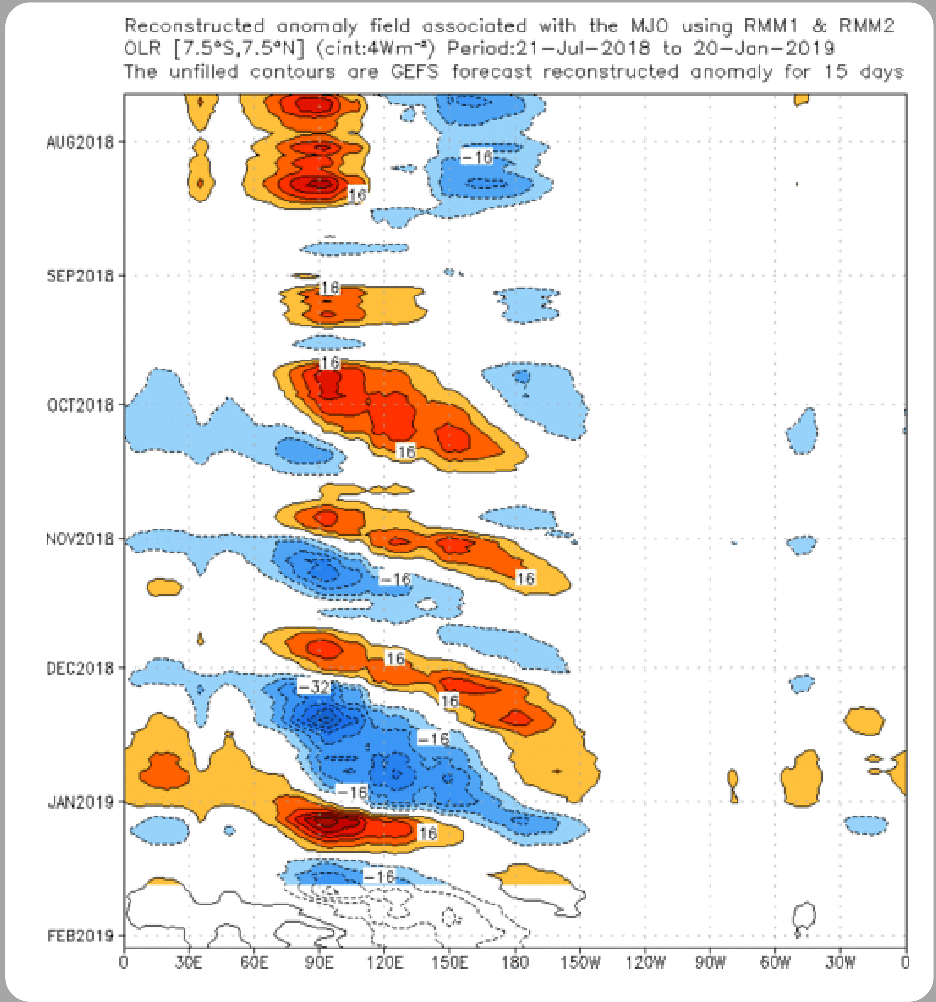
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

Spatial map of OLR anomalies for the next 15 days



OLR anomalies based on the GEFS RMM-index forecast depict MJO-related convection strengthening over the Indian Ocean and Maritime Continent in Week-1, with propagation eastward over the Western Pacific in Week-2. Suppressed convective anomalies push eastward and grow (weaken) over the Indian Ocean (Central Pacific).

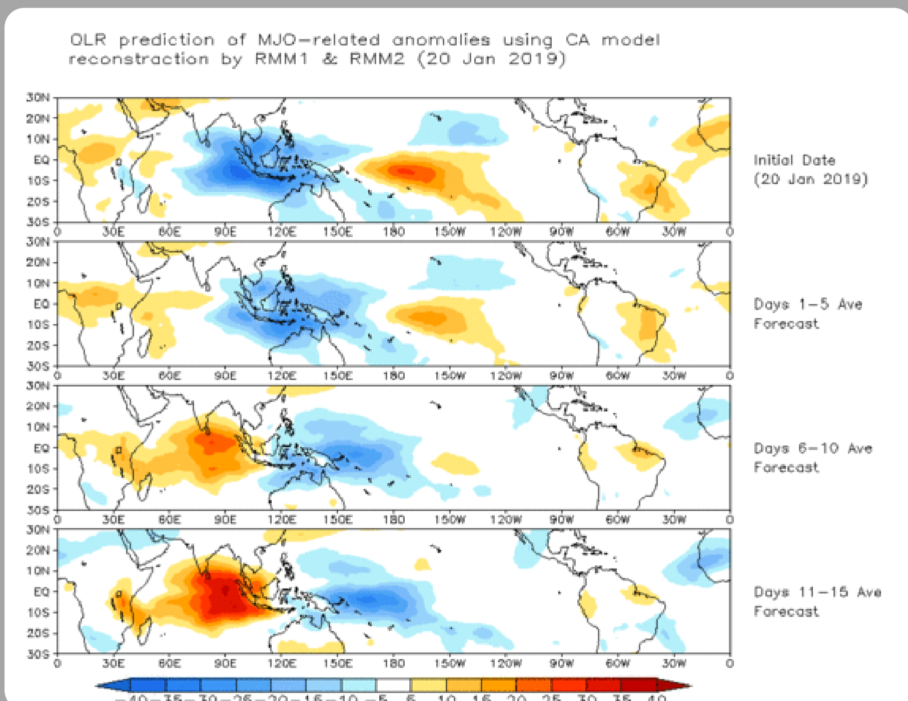
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



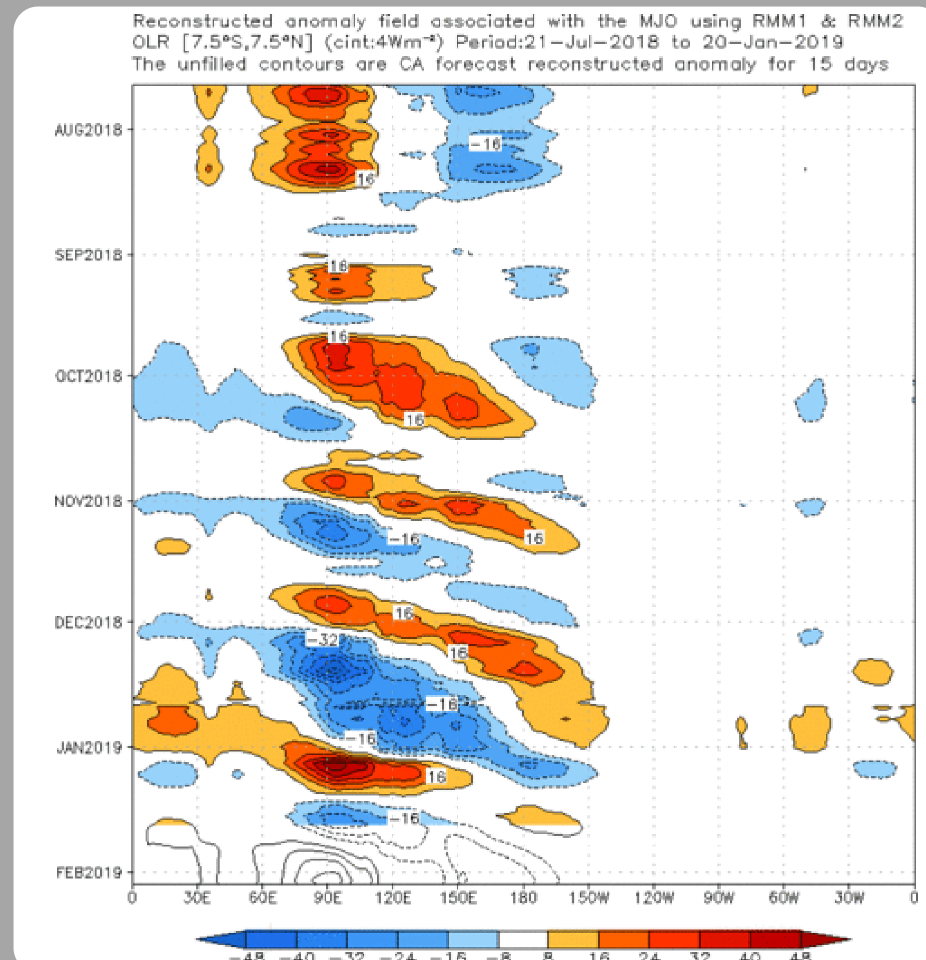
Constructed Analog (CA) MJO Forecast

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



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

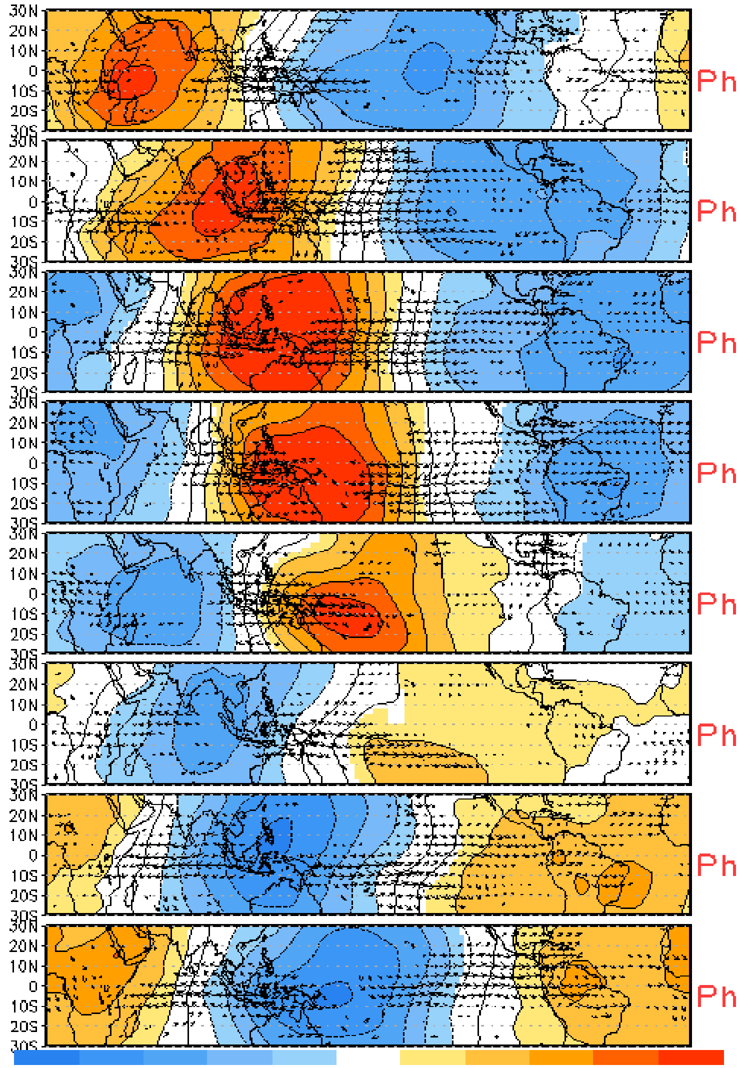


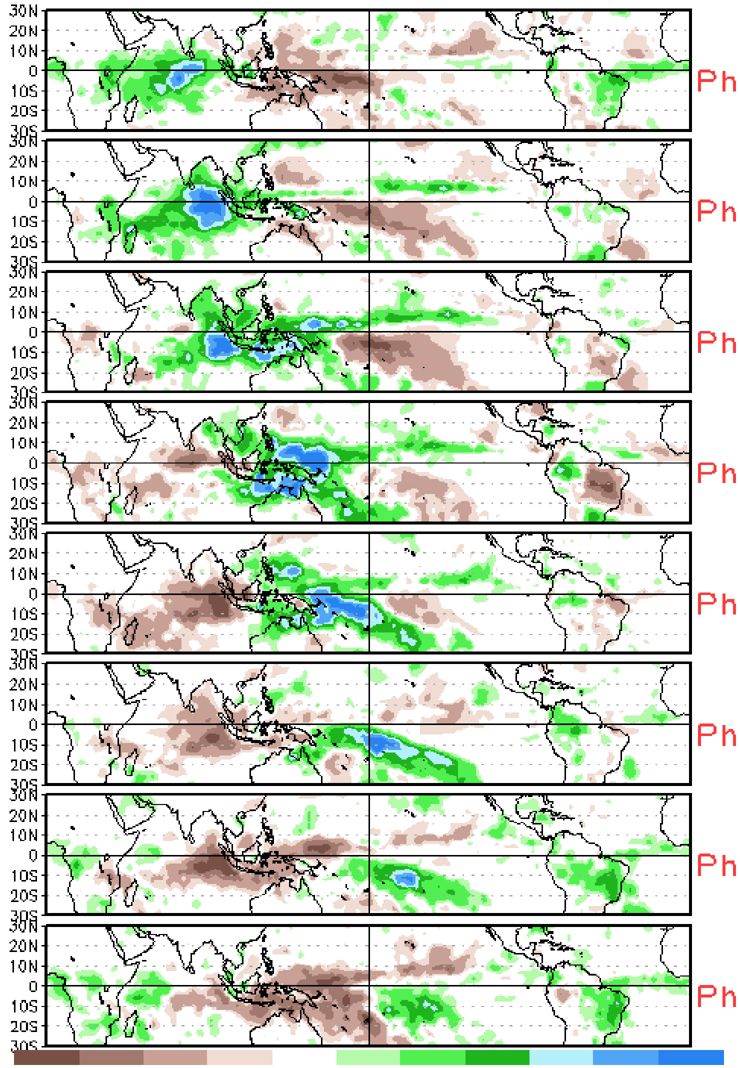
The constructed analog forecast is similar to that of the GEFS, with a more progressive MJO envelope over the West Pacific late in Week-2 and greater suppression of convection across the eastern Indian Ocean.

MJO Composites - Global Tropics

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

Precipitation Anomalies (Nov - Mar)

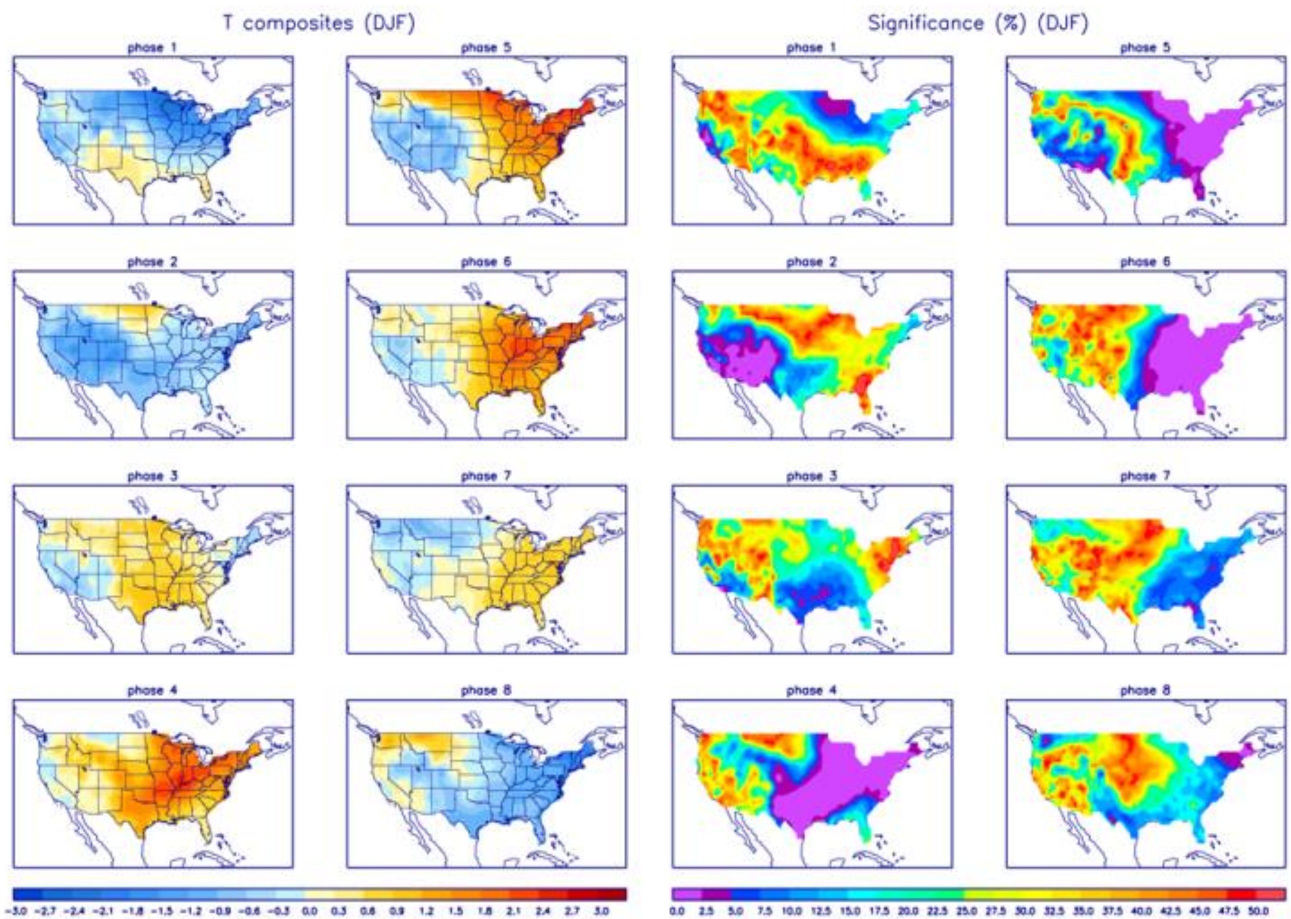




U.S. MJO Composites – Temperature

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.

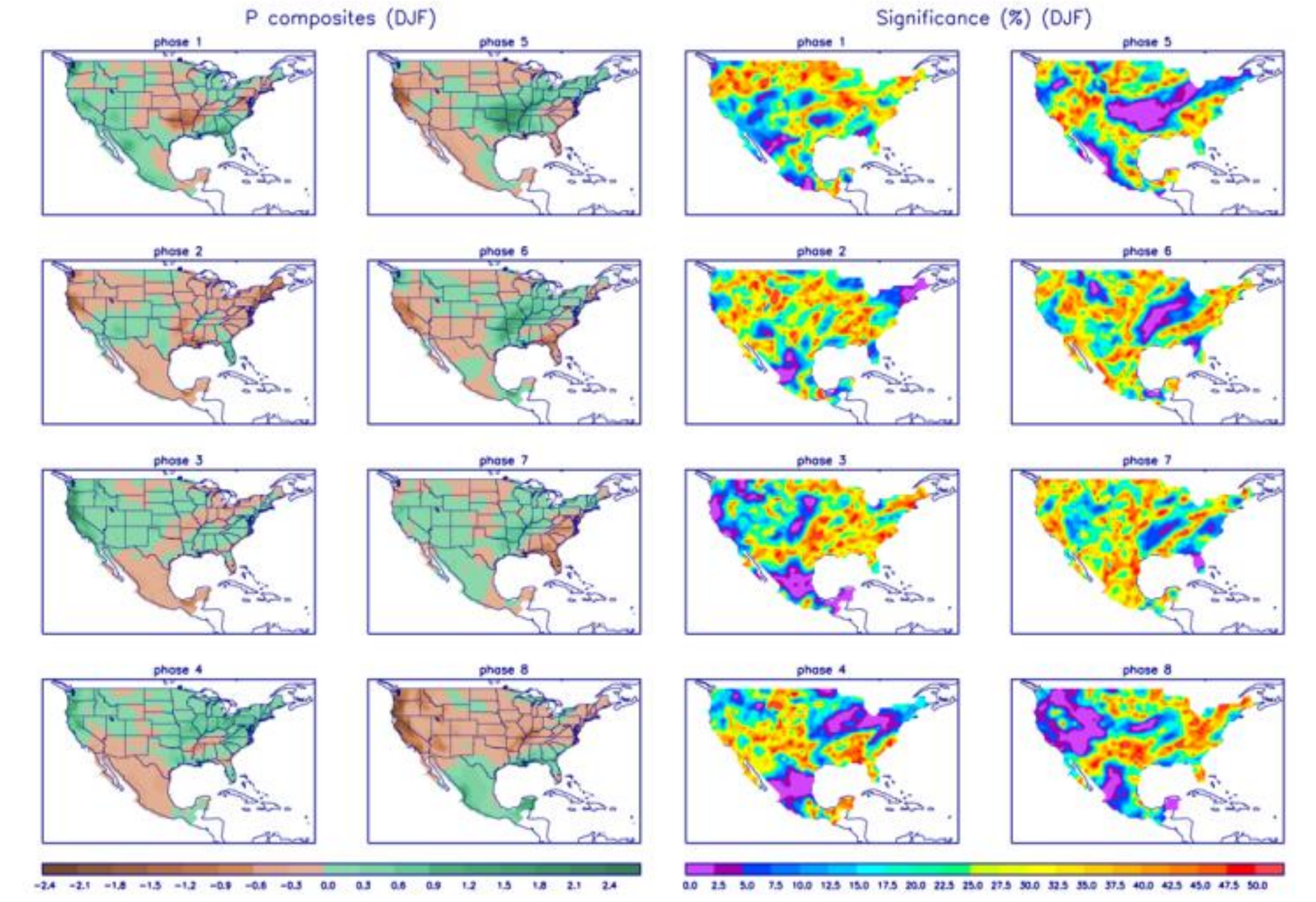
Right hand side plots show a measure of significance for the left hand side anomalies. Purple shades indicate areas in which the anomalies are significant at the 95% or better confidence level.



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

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