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

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Climate Prediction Center / NCEP
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Outline

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Overview

- The active phase of the MJO continued its slow march across the Pacific during the last week, bogged down by repeated equatorial Rossby wave activity slowing the progression of the eastward-moving envelope. The constructive interference between these modes and El Niño helped convection flare west of the Date Line, with this signal teleconnecting nicely to the extratropics and helping drive the heavy precipitation from multiple atmospheric river events over California in recent days.

- Dynamical models are mixed with some predicting canonical eastward progression towards the Prime Meridian during the next two weeks (ECMWF, CFS), while other models tend to continue emphasizing the equatorial Rossby wave activity, serving to stall and weaken the intraseasonal signal in Phase 8 (GEFS, Canadian, JMA). The former solution is favored here, given that these models are coupled with the ocean and have exhibited greater MJO predictive skill.

- The MJO crossing the Western Hemisphere during the next two weeks would support increased mid-latitude troughing over the Great Lakes and a colder forecast for the Eastern U.S., which model guidance appears to be trending towards.

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})

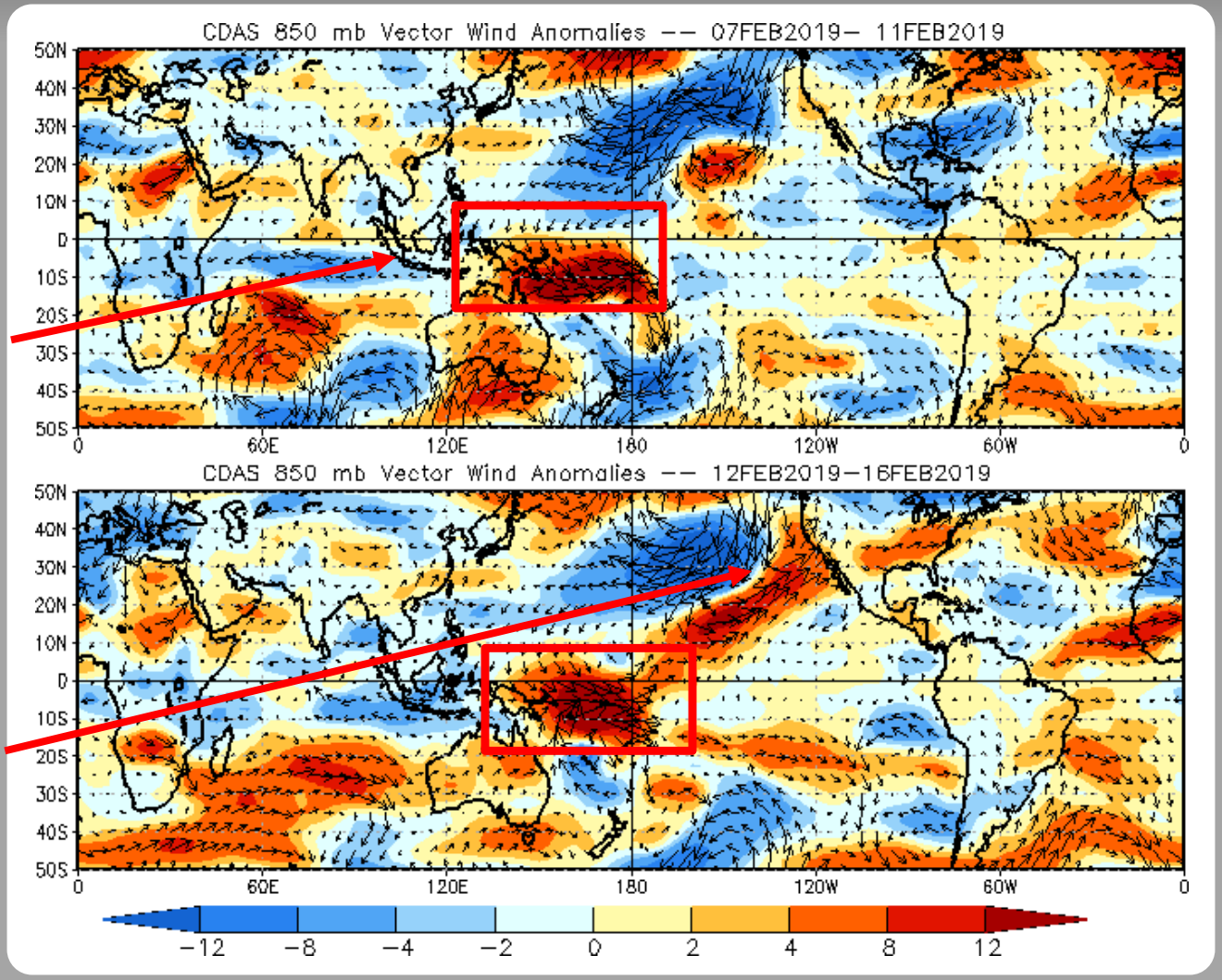
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Constructive interference between the MJO, El Niño, and equatorial Rossby wave activity has resulted in large westerly anomalies near the Antimeridian

The westerlies near the Date Line were recently able to teleconnect to the northeast Pacific in conjunction with troughing near Hawaii, bringing a shot of moisture to California during the last 5 days.



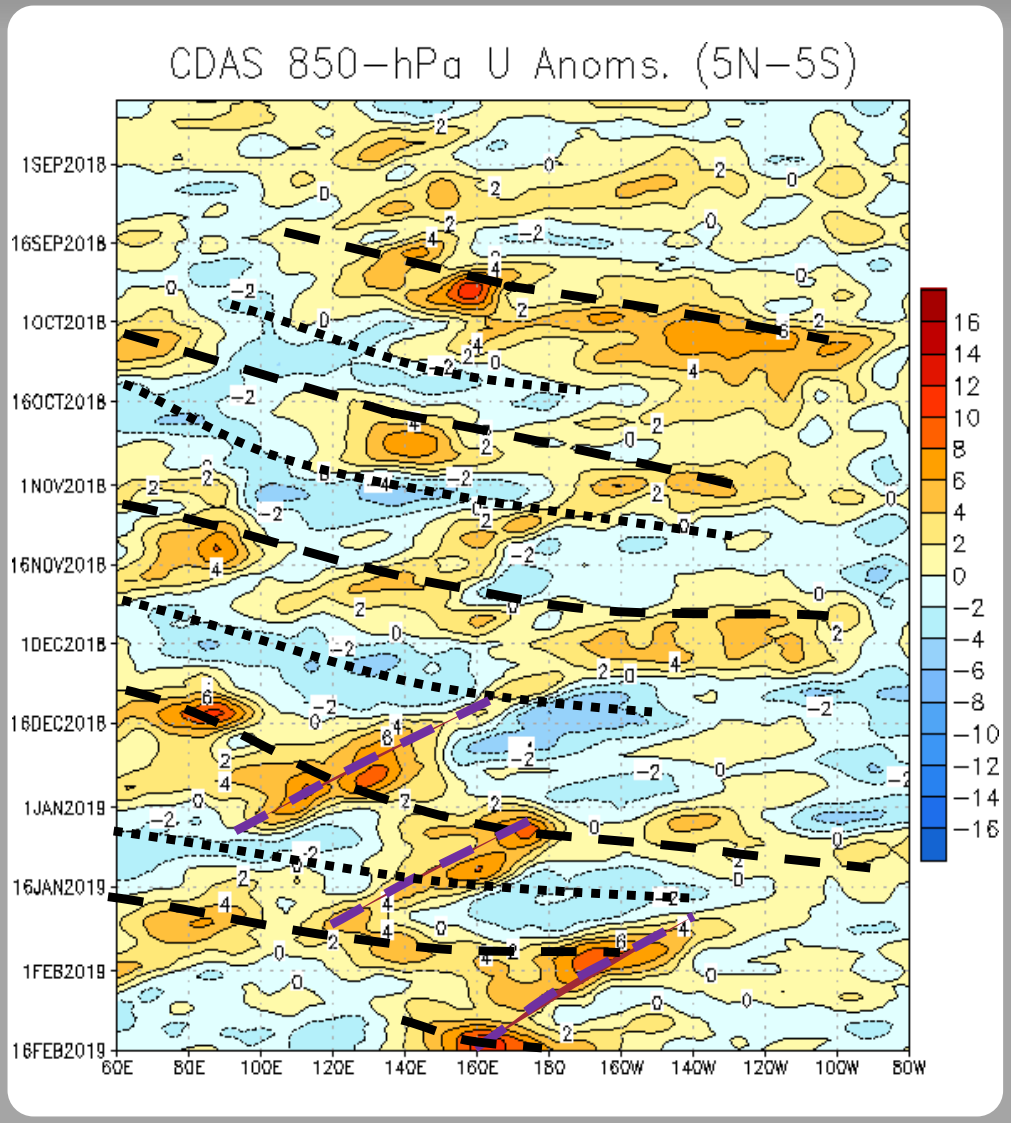
850-hPa Zonal Wind Anomalies (m s^{-1})

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

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

Periodic easterly moving features consistent with the MJO have been evident since mid-September, while westward-moving equatorial Rossby wave activity has increased since early December. Westerly anomalies have been generally present west of the Date Line throughout the period, aside from periods of destructive interference by intraseasonal modes, consistent with El Niño.

Within the past week, a westerly wind burst near 160°E emerged. This is tied to constructive interference between the base state, MJO, and an equatorial Rossby wave.



OLR Anomalies – Past 30 days

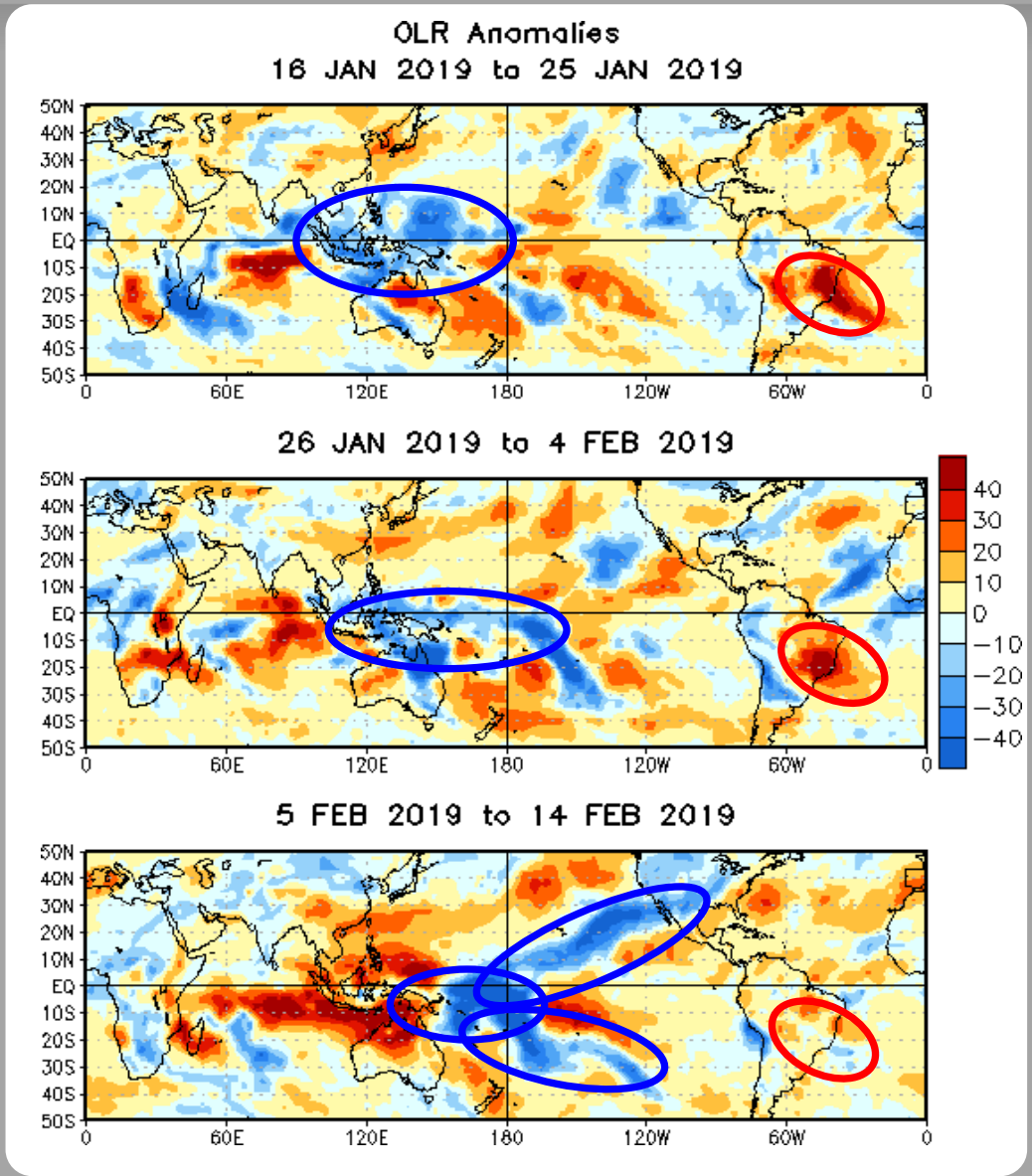
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

During mid- to late January, enhanced convection across the Maritime Continent was tied to the active phase of the MJO. Suppressed convection persisted over parts of Brazil and the South Atlantic (all panels).

During late January and early February, enhanced convection linked to the active phase of the MJO continued driving east from the Maritime Continent into the West Pacific.

By early to mid-February, robust enhancement of convection was observed east of the Maritime Continent, linked to constructive interference of El Nino, equatorial Rossby wave activity, and the MJO. This enhanced convection extended poleward and eastward in both hemispheres.



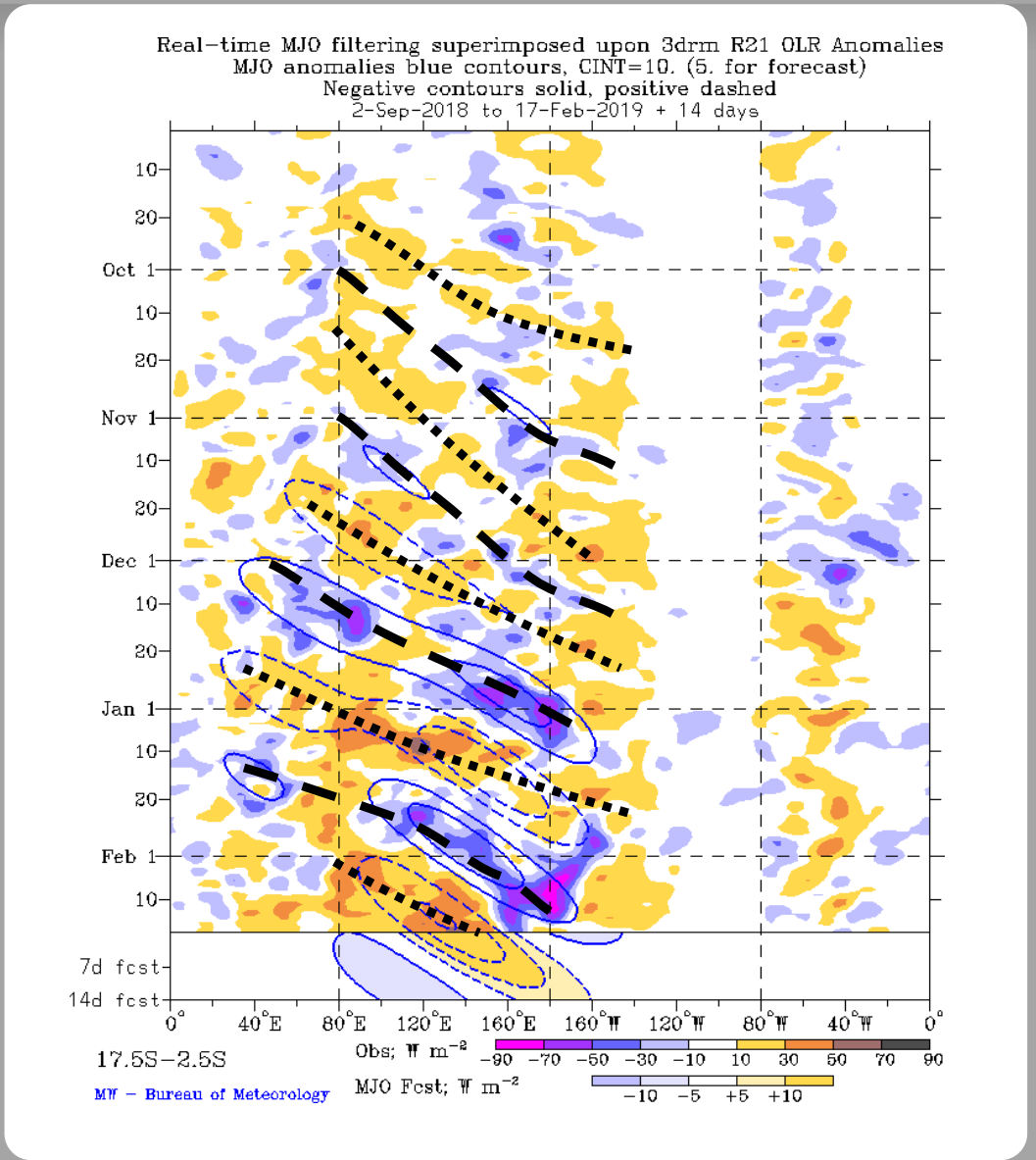
Outgoing Longwave Radiation (OLR) Anomalies (2.5°S - 17.5°S)

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

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

Since September, the MJO signal has seen alternative active and inactive phases crossing the Indian Ocean through the Central Pacific and influencing the convection for these regions.

Beginning in late January a robust equatorial Rossby wave is apparent near 155°W that has drifted slowly westward. The most anomalous enhanced convection occurred near the Antimeridian around 10 February, when this signal constructively interfered with the active phase of the MJO.



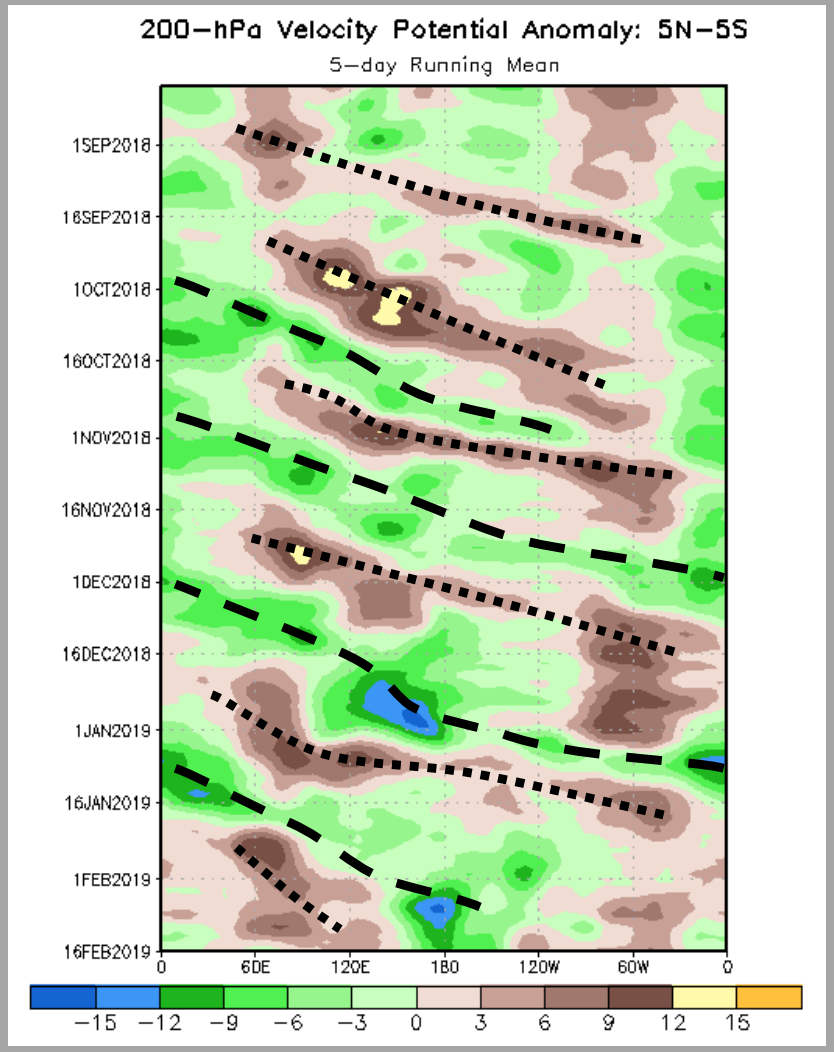
200-hPa Velocity Potential Anomalies (5°S - 5°N)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

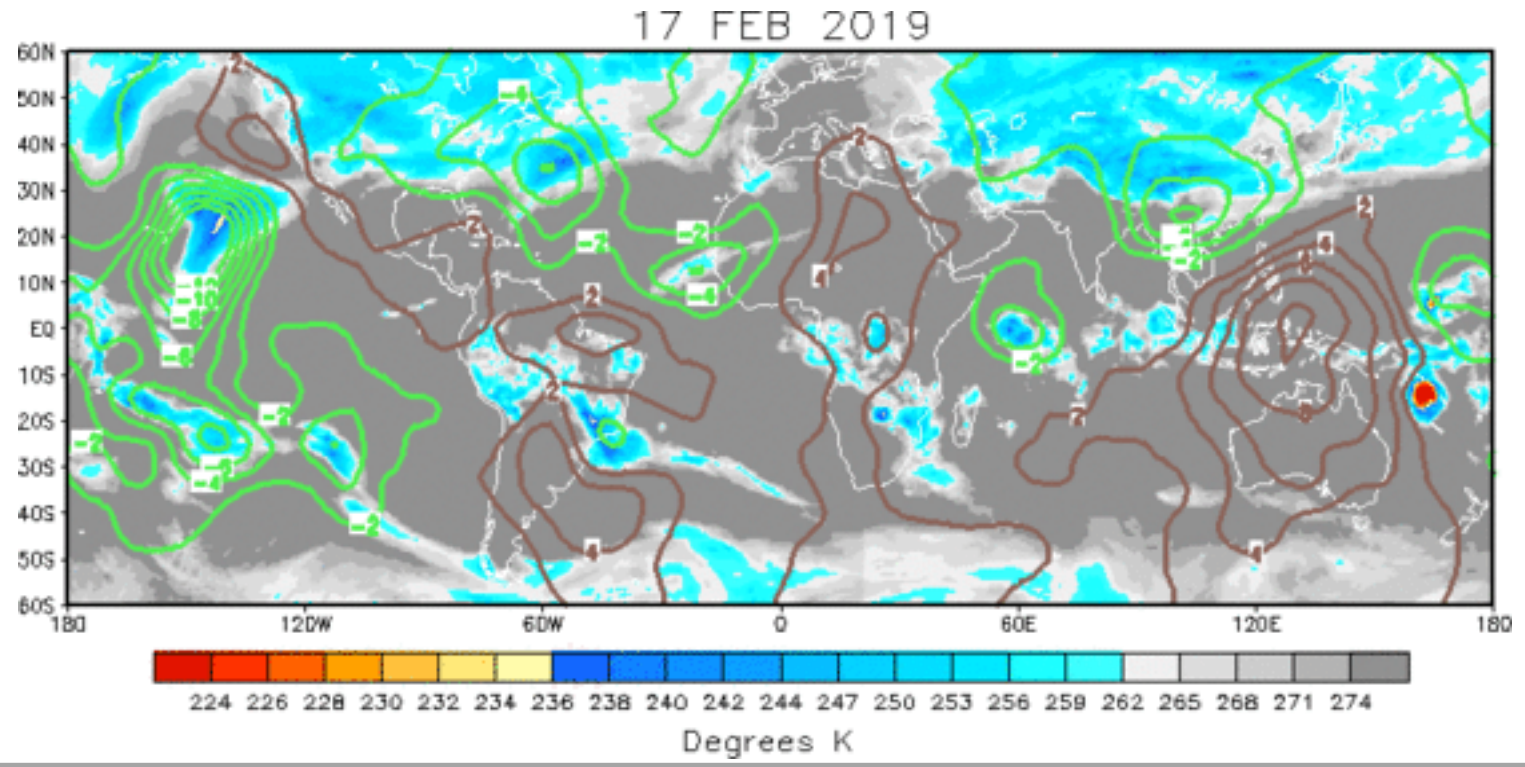
Negative anomalies (green shading) indicate favorable conditions for precipitation

The intraseasonal MJO activity since early September continues to be apparent, as does the persistent conditions tied to El Niño that favor convection near the Date Line (aside from when the inactive envelope of the MJO is present).

Rossby wave activity also shows up here, with constructive interference of the MJO and Rossby wave activity resulting in the most prominent enhancement of observed velocity potential signatures near 160°E in late December and near the Antimeridian around the 10th of February.



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



The present anomalous convective pattern is fairly incoherent, tied to multiple modes being present (El Niño and the active MJO envelope in the Pacific, a Kelvin wave over the western Indian Ocean, extratropical influences over the Atlantic).

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})

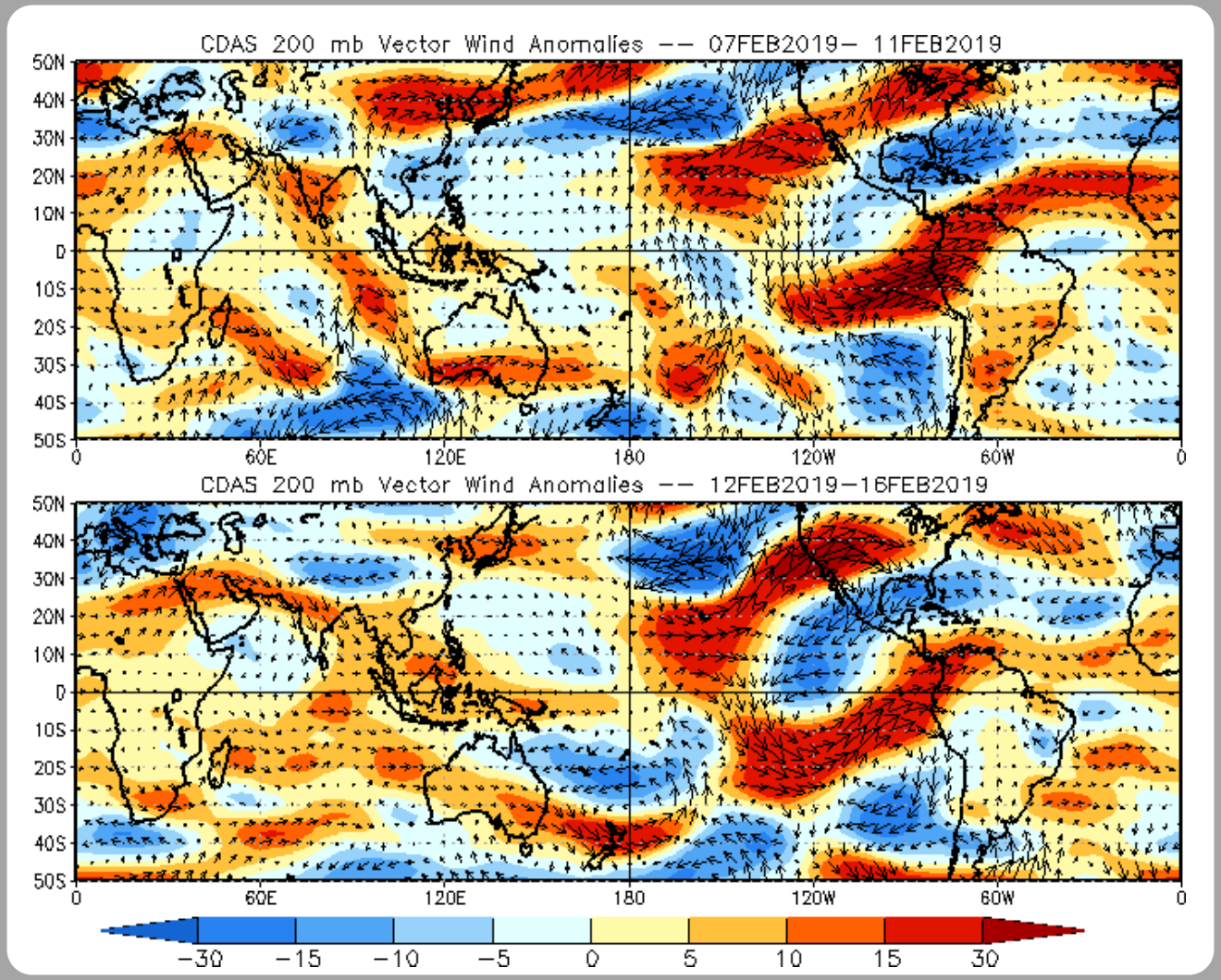
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

The subtropical jet in the Northern Hemisphere has been greatly enhanced, and oriented from Hawaii through California, during the last 10 days. This yielded multiple atmospheric river events for the Western U.S.

During the most recent 5 days, tropical and subtropical anomalies over the eastern (western) hemisphere were largely muted (pronounced). This is tied to the anomalous convection near the Date Line from the constructive interference among multiple modes of tropical convection.



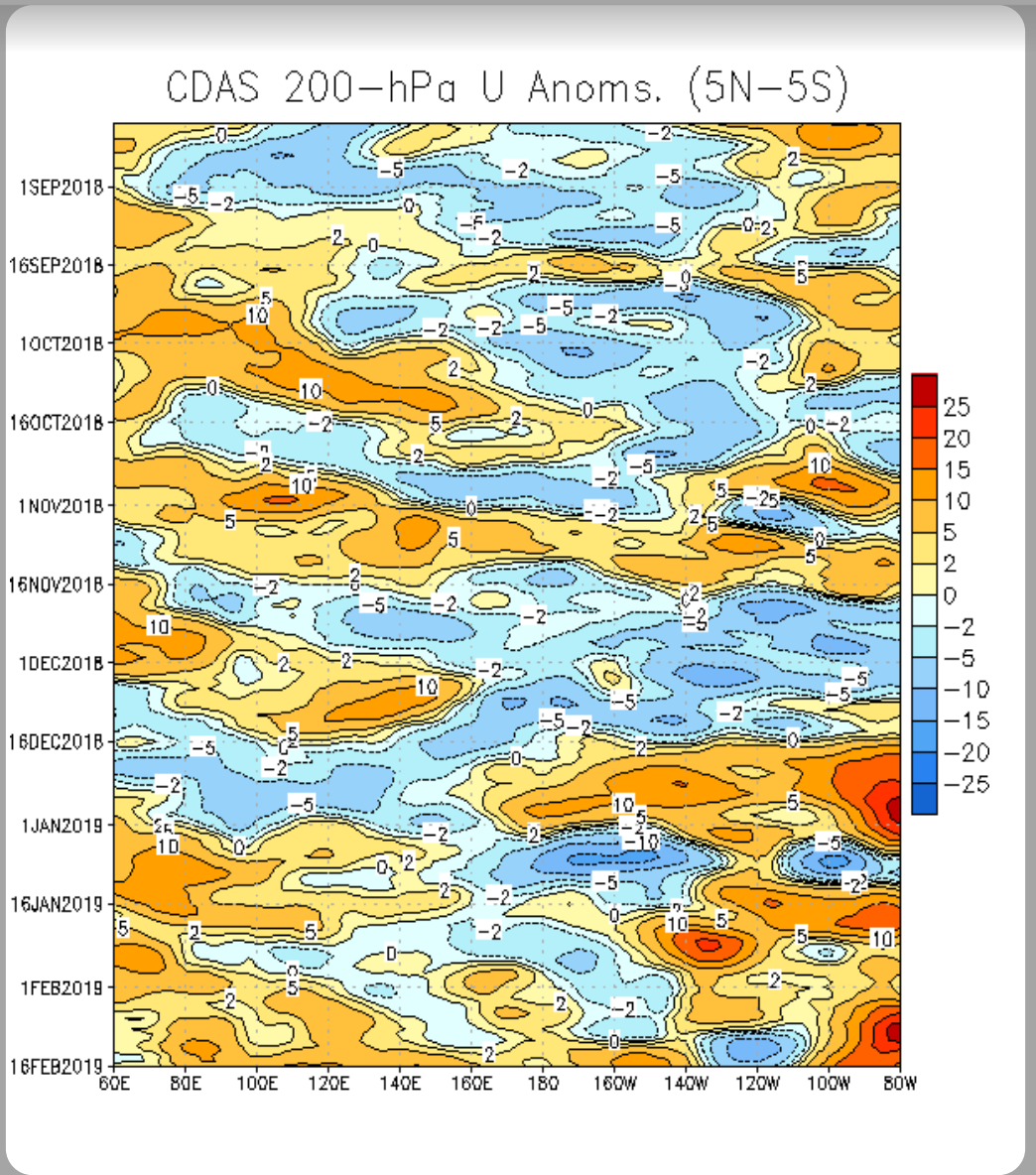
200-hPa Zonal Wind Anomalies (m s^{-1})

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

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

From mid-September through mid-December, upper-level winds have been marked by pronounced eastward-moving intraseasonal activity, interrupted by westward-propagating Rossby waves.

Most recently, westerly anomalies have grown in coverage to encompass most areas between the Indian Ocean and East Pacific, with the exception of a small area between 130-110°W that is associated with the suppressed phase of an equatorial Rossby wave.



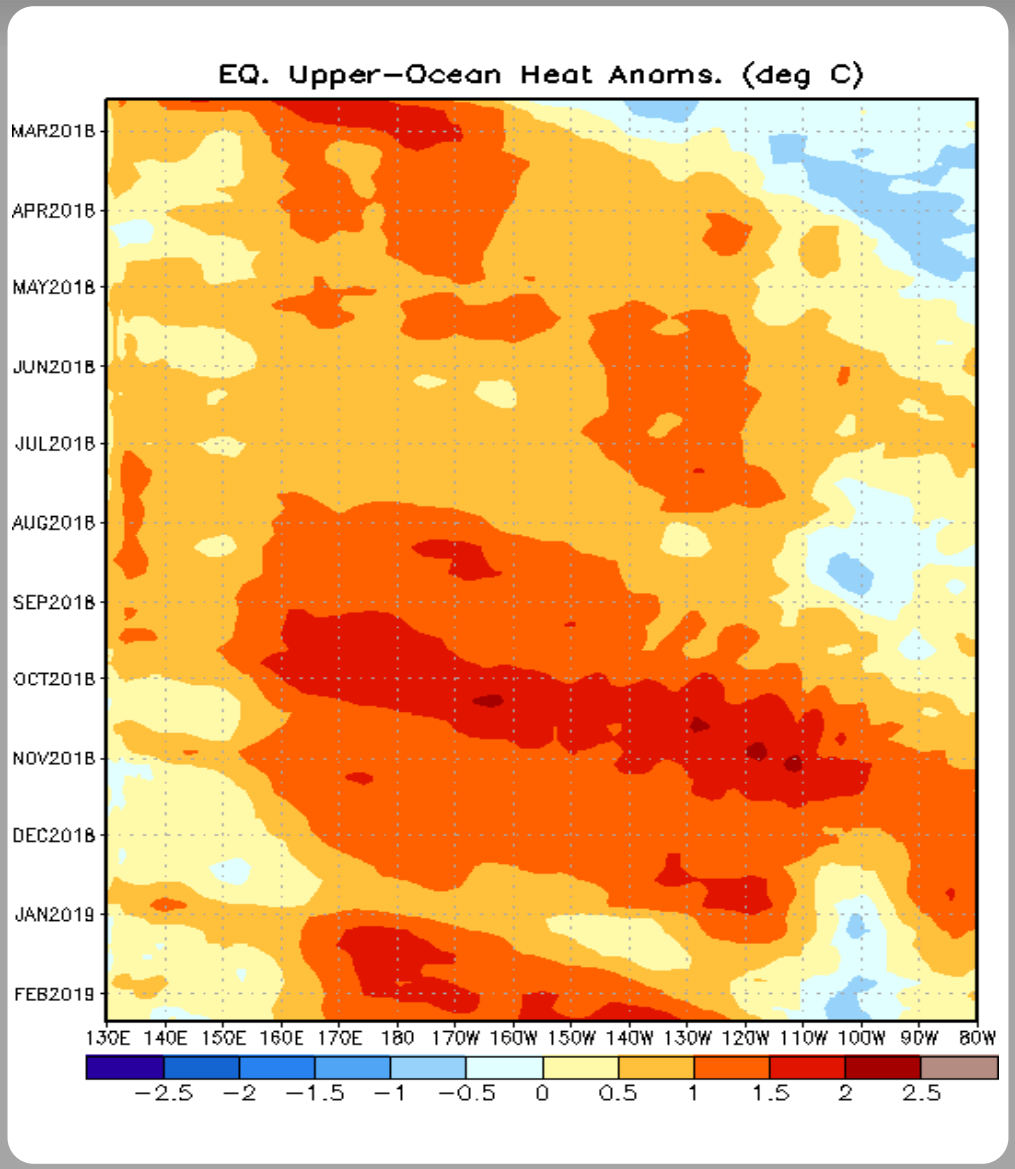
Weekly Heat Content Evolution in the Equatorial Pacific

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 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 the current El Niño event.

Another downwelling Kelvin wave is evident since the start of 2019. The strengthened meridional oceanic heat content gradient may be tied to the more robust appearance of low frequency convection since the start of the new year to the east of New Guinea.



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

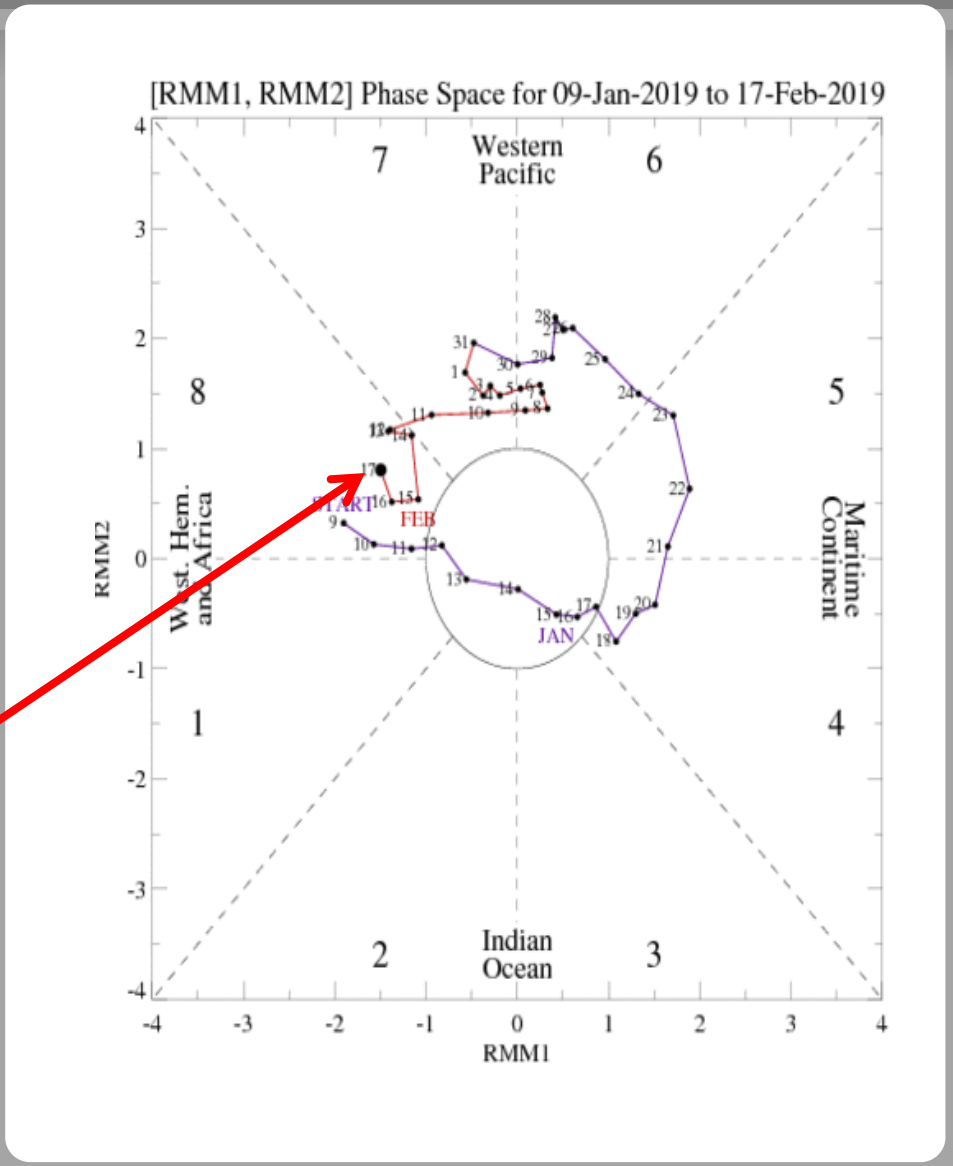
Counter-clockwise motion is indicative of eastward propagation. Large dot most recent observation.

Distance from the origin is proportional to MJO strength

Line colors distinguish different months

The enhanced envelope of the MJO has slowly meandered across the Pacific during the last 2-3 weeks due to multiple equatorial Rossby waves helping to slow its progression.

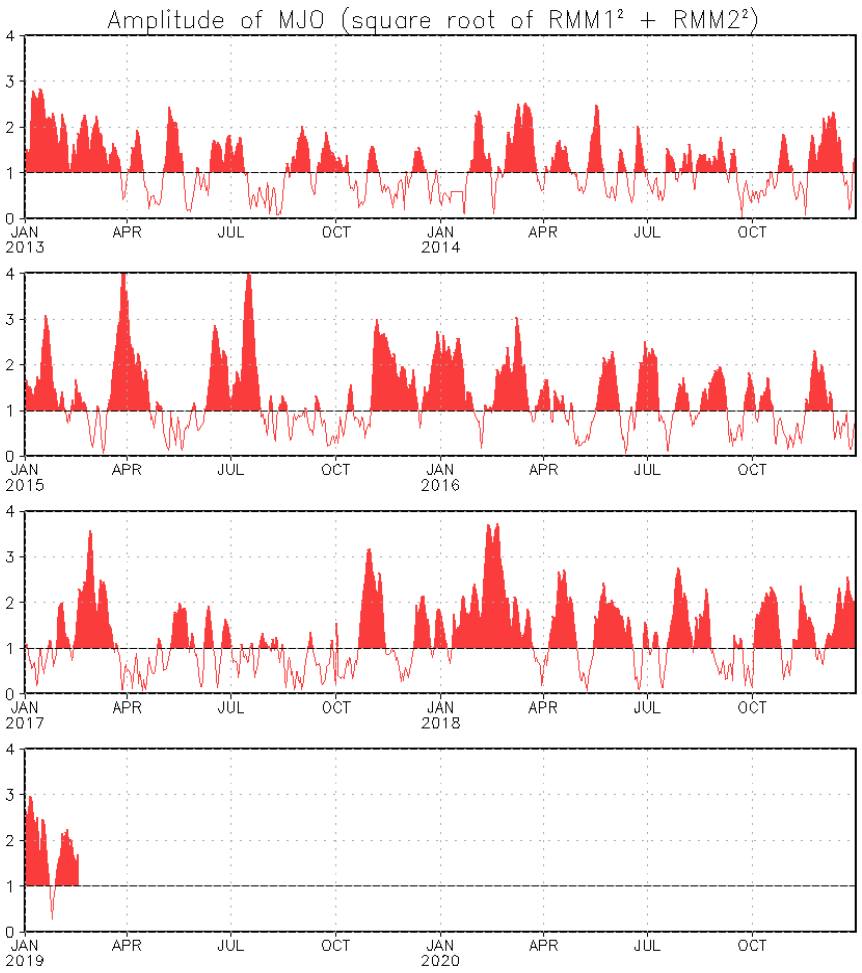
The signal presently exists over the Central Pacific.



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

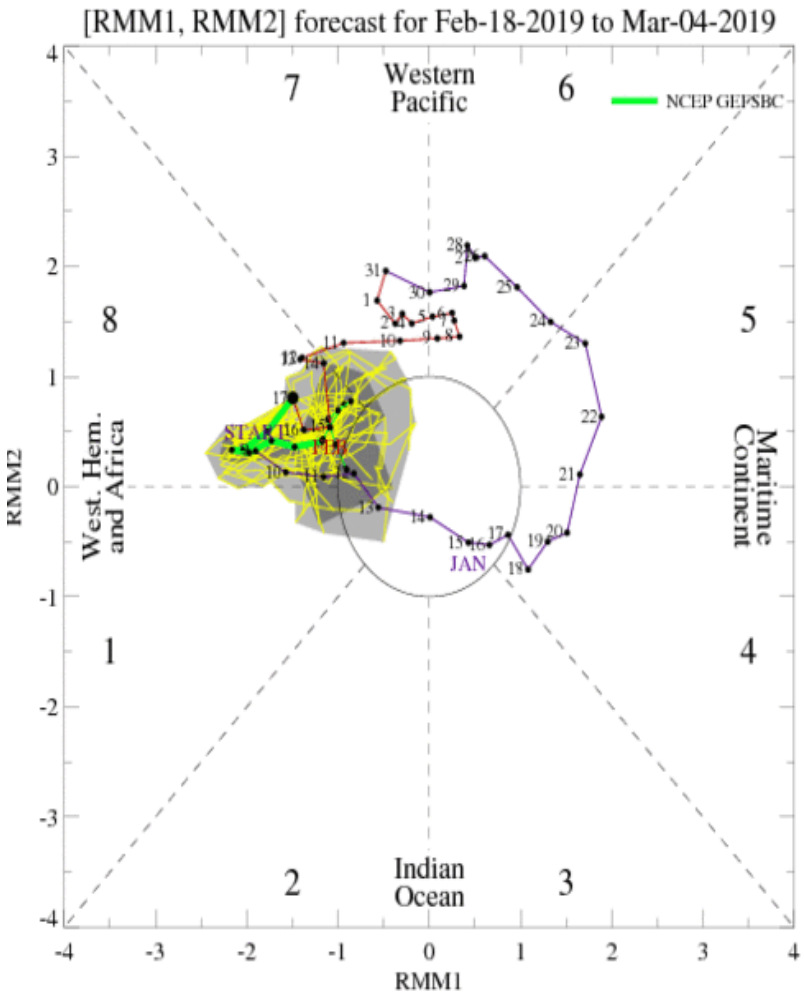
RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days

light gray shading: 90% of forecasts

dark gray shading: 50% of forecasts

The GEFS forecasts continued interactions with multiple equatorial Rossby waves during the next two weeks and little to no eastward propagation as a result. The MJO signal weakens with time across most ensemble members.

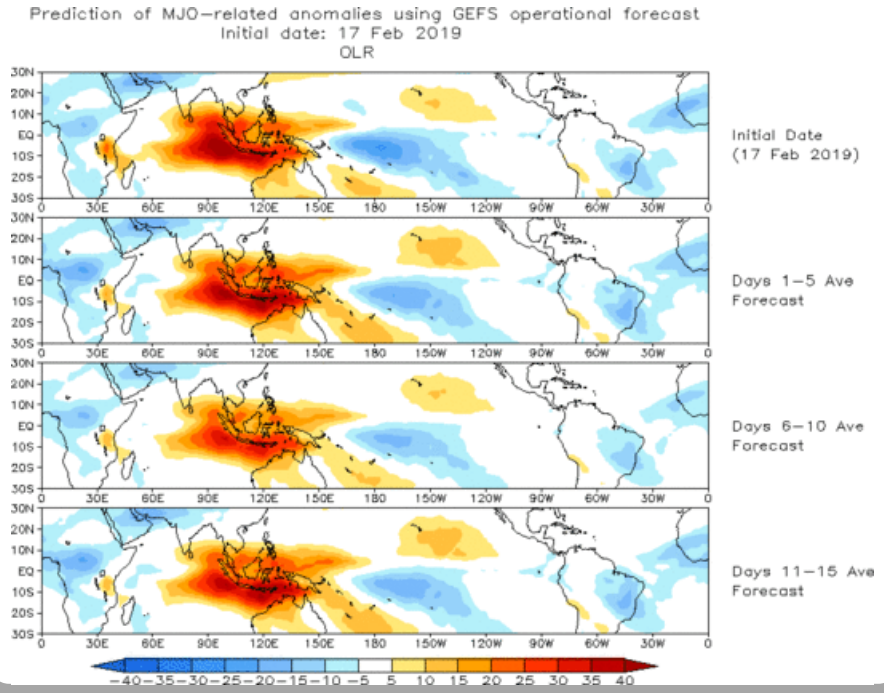
Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean



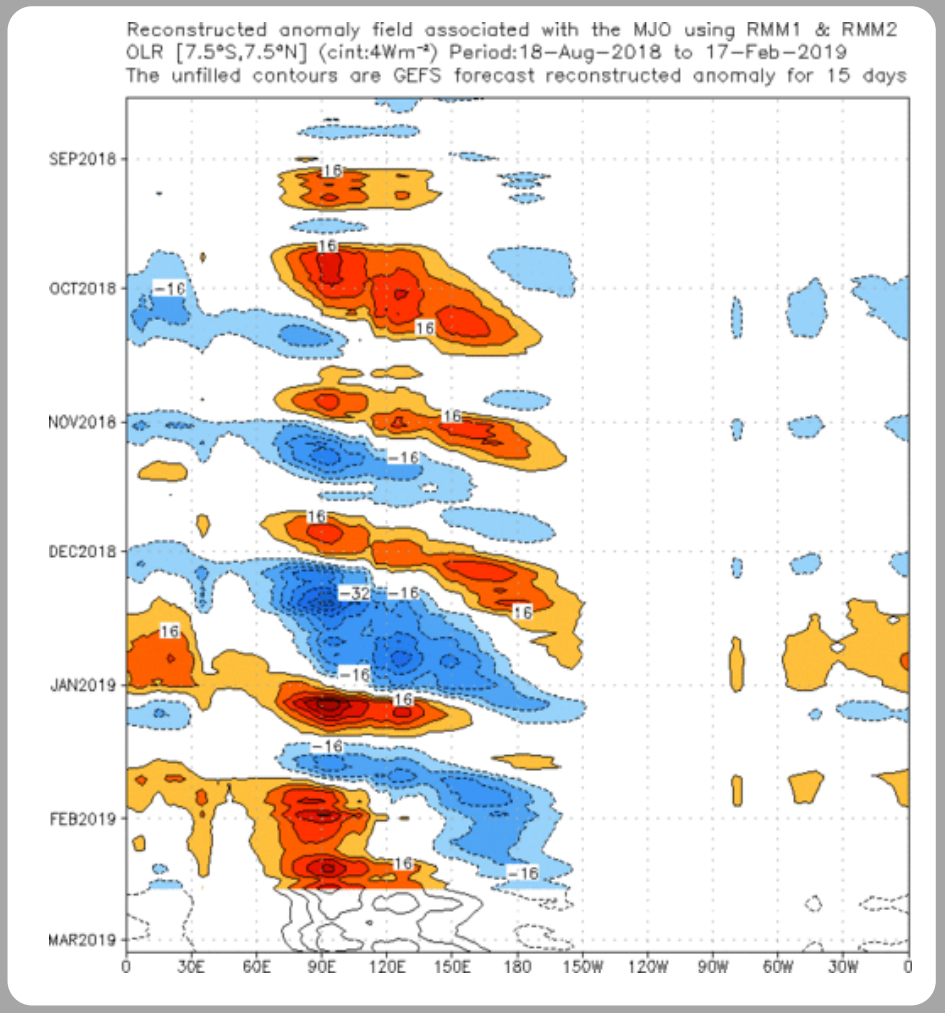
Ensemble GFS (GEFS) MJO Forecast

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



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



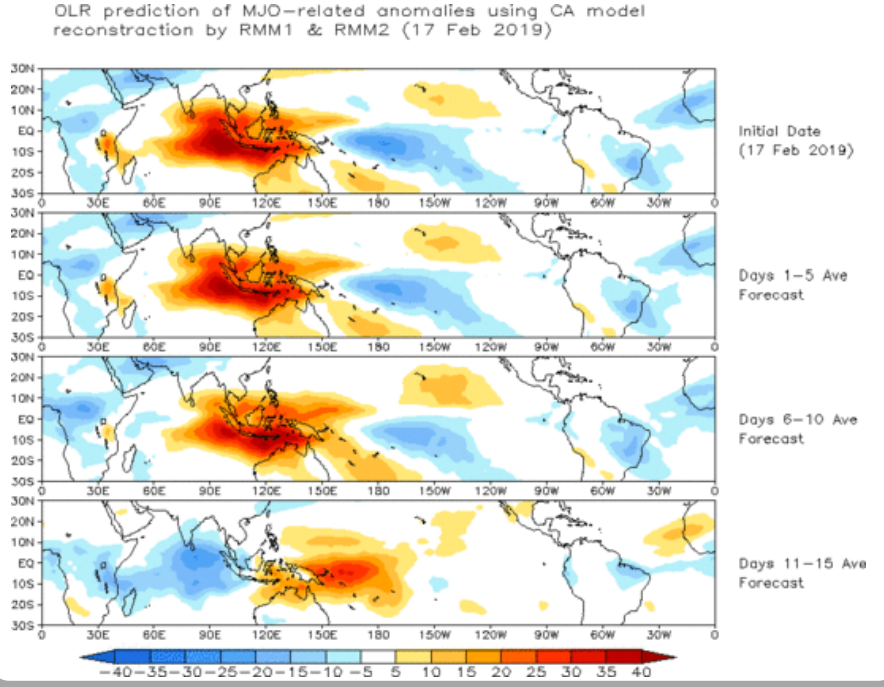
The GEFS indicates quasi-stationary convective anomalies tied to the MJO during the next 15 days, with slow weakening in place.

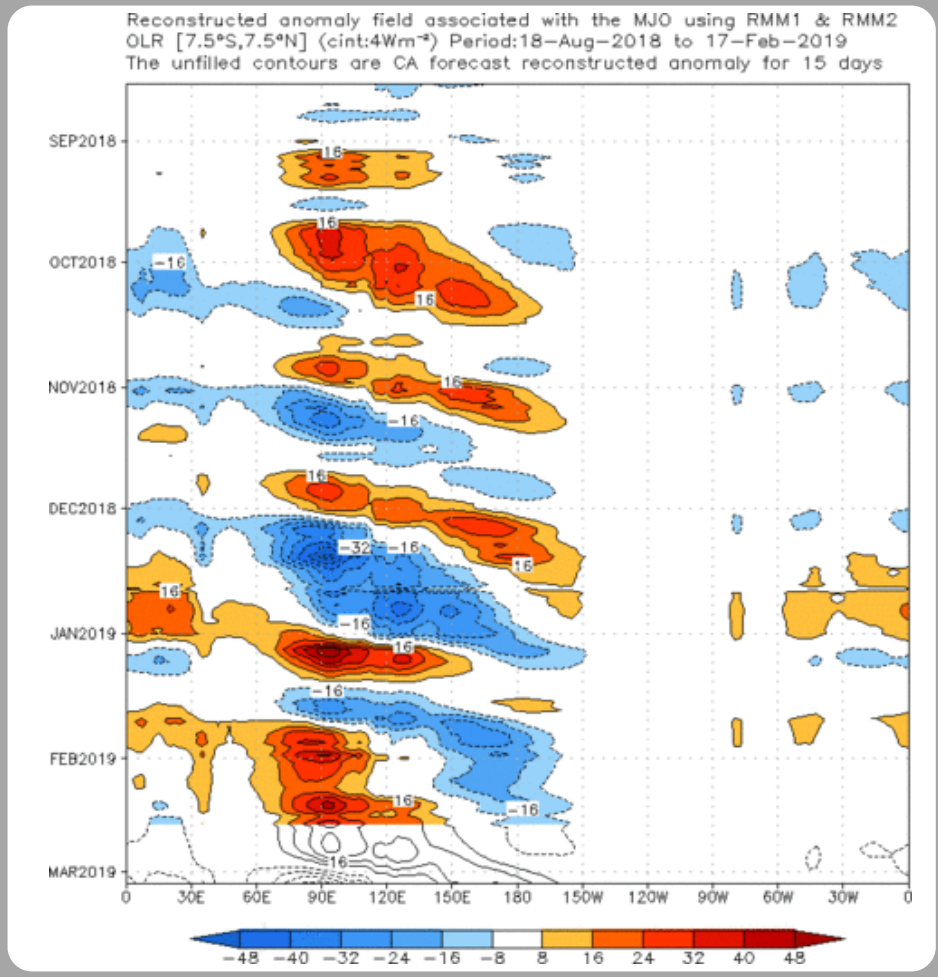
Constructed Analog (CA) MJO Forecast

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

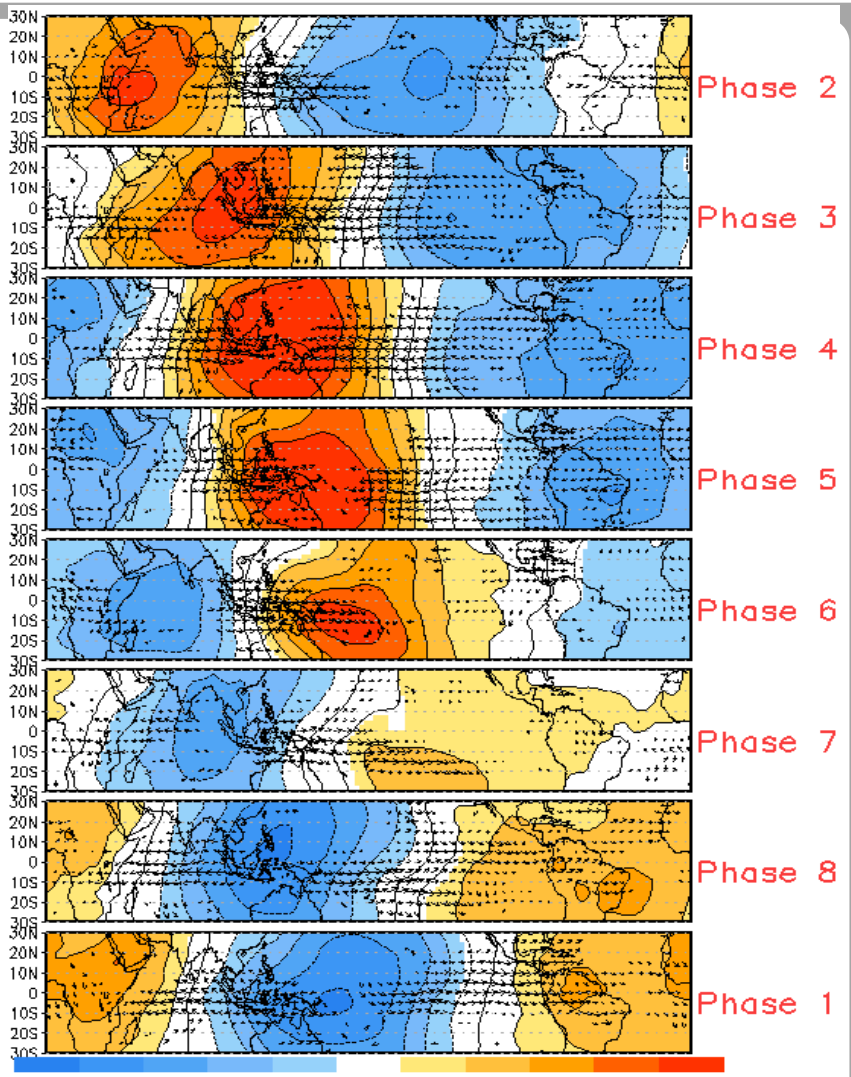




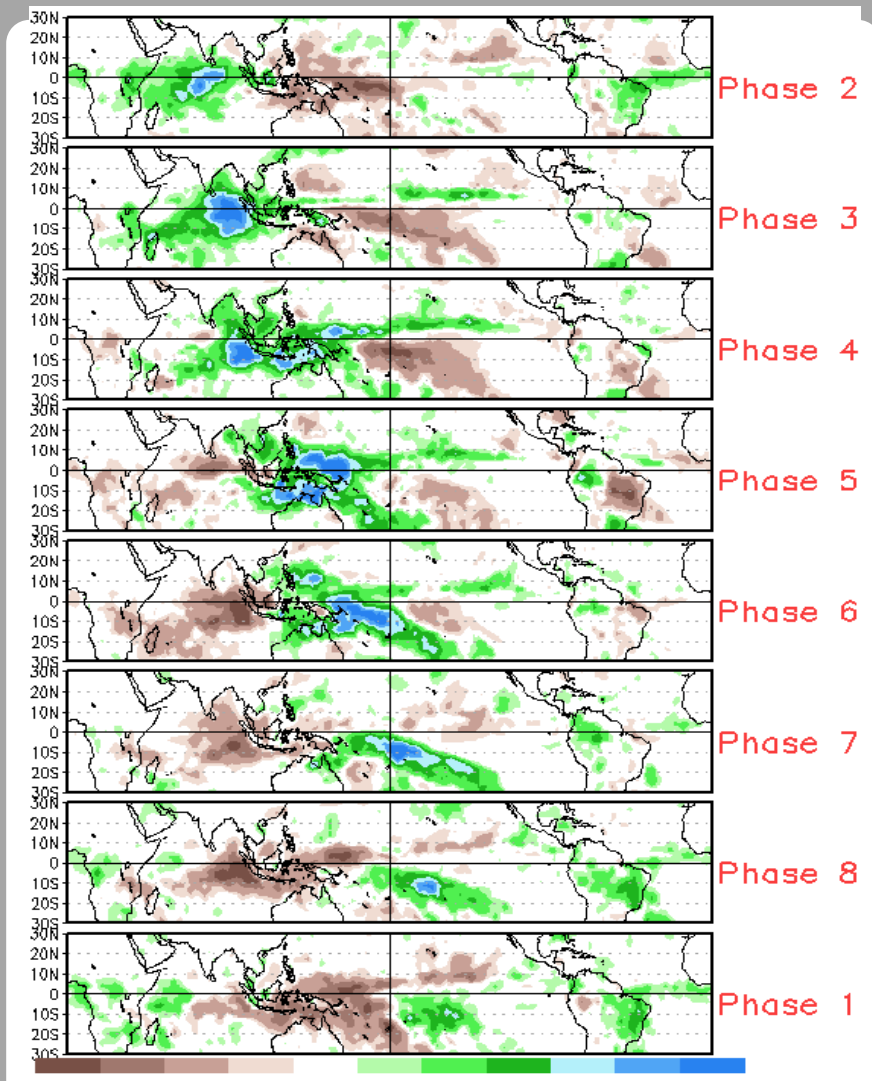
The constructed analog depicts a more progressive pattern than the GEFS, with suppressed (enhanced) convection shifting into the West Pacific (Indian Ocean) by late in Week-2.

MJO Composites - Global Tropics

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



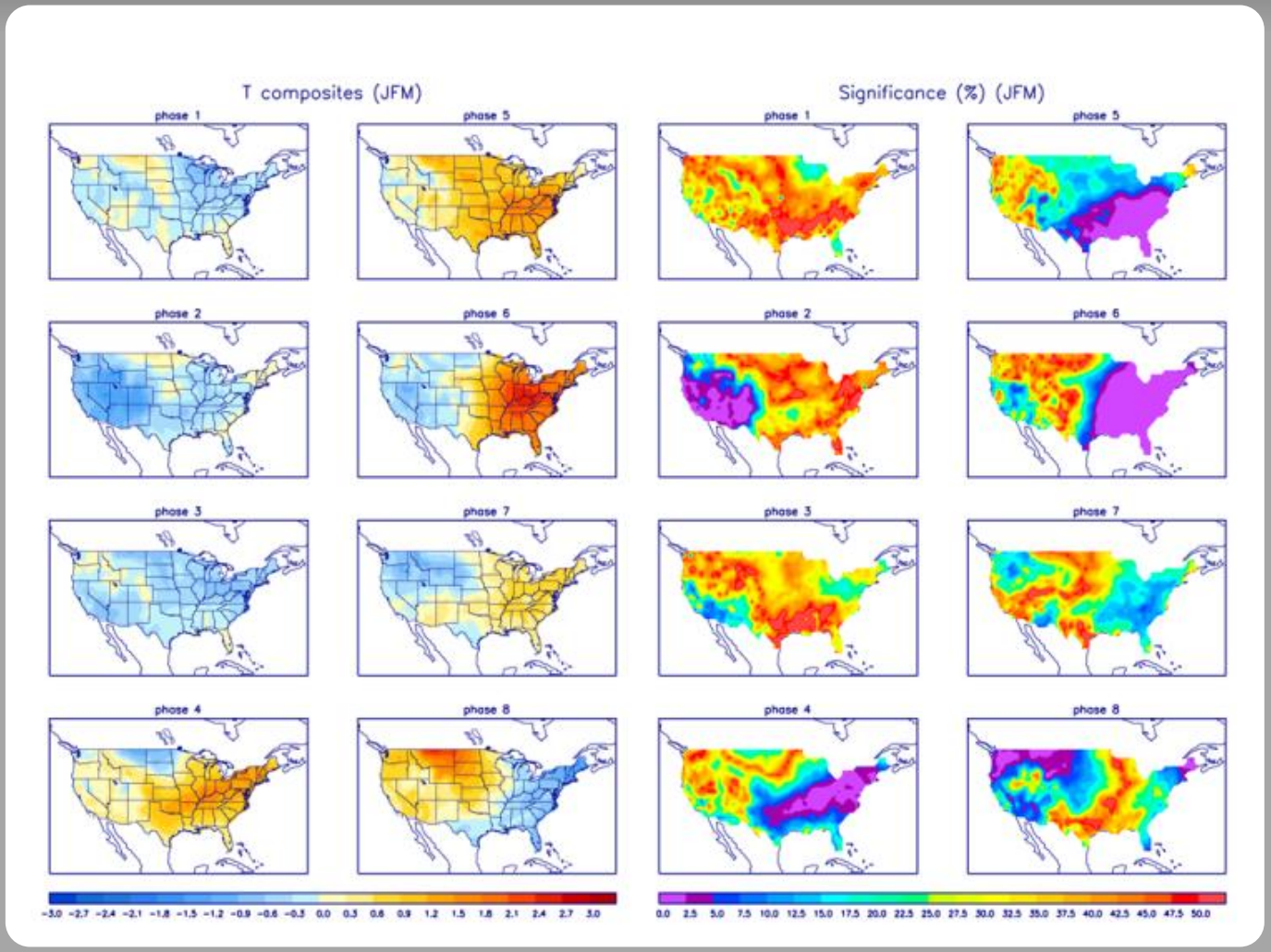
Precipitation Anomalies (Nov - Mar)



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.



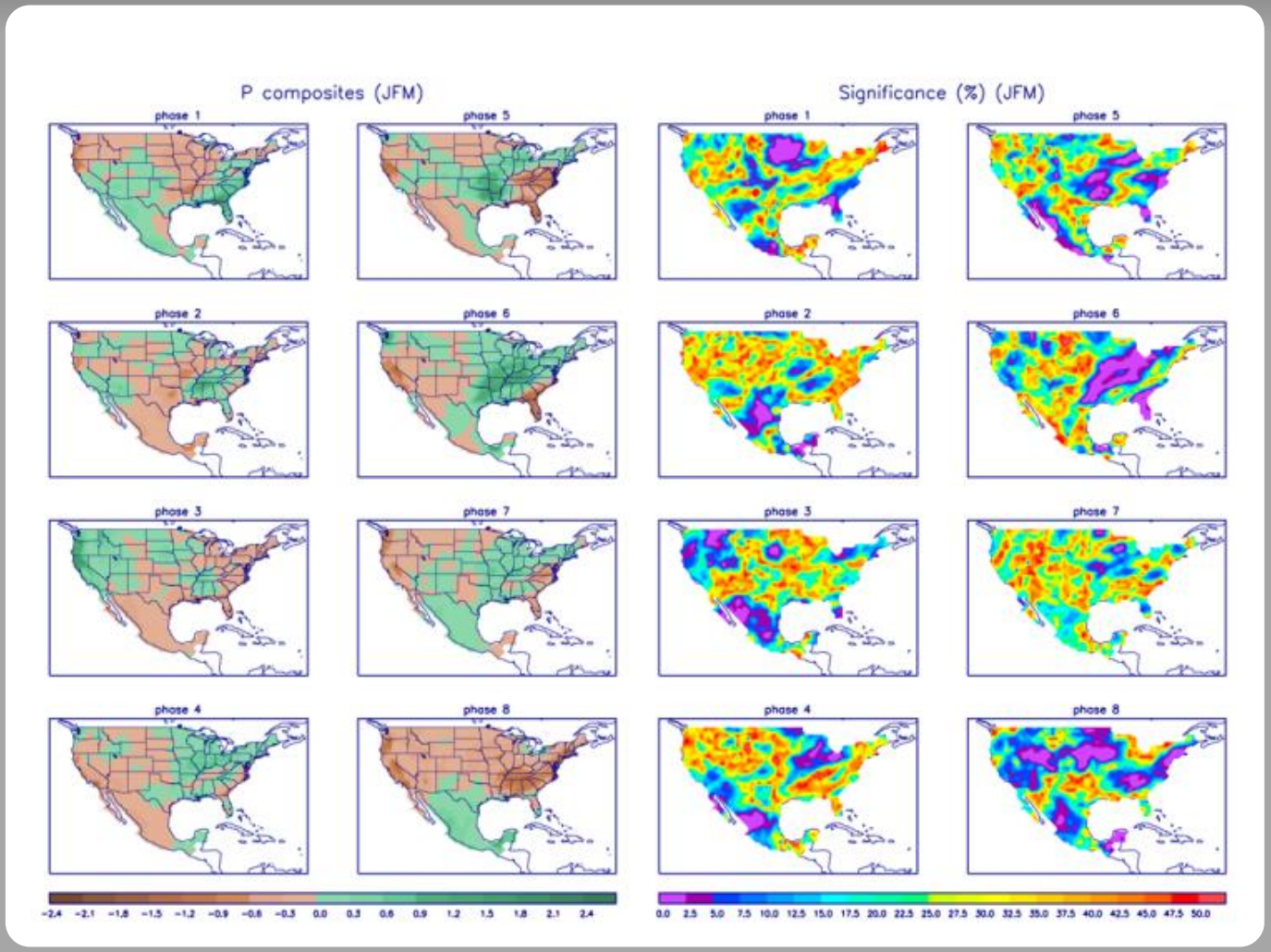
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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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