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

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25 February 2019

# Outline

Overview

Recent Evolution and Current Conditions

MJO Index Information

MJO Index Forecasts

MJO Composites

# Overview

- Interference from equatorial Rossby wave activity continued over the past week and the meandering active MJO signal remains at the edge of Phase 8 on the Wheeler-Hendon diagram, making its way toward the Western Hemisphere. The upper-level 200-hPa VP field appears to be a phase ahead of the lower level wind field.

- Dynamical models are in better agreement this week, where all support a fairly fast progression for the MJO signal of Week-1 across the Western Hemisphere and re-emerging over the Indian Ocean. The signal is forecast to slow slightly moving into Week-2, but continue eastward progression toward the Maritime Continent.

- The MJO crossing the Western Hemisphere during the next week would support increased mid-latitude troughing over the Great Lakes and a colder forecast for the Eastern U.S. Model guidance currently supports cold temperatures for a large portion of the U.S.; however, the troughing is centered over the central U.S., so the cold is focusing further west.

**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 $s^{-1}$)

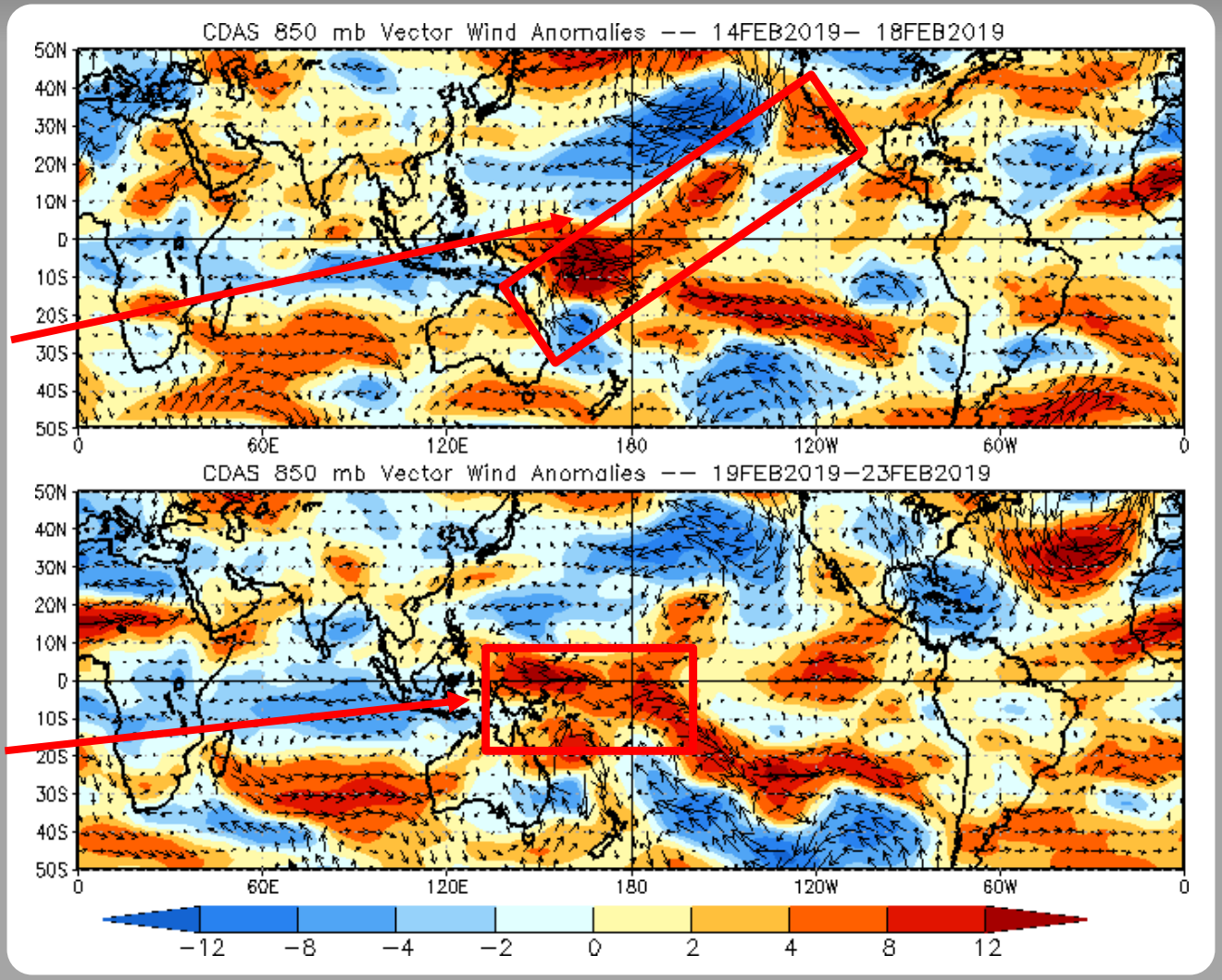
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

The westerlies near the Date Line were recently able to teleconnect to the northeast Pacific in conjunction with troughing near Hawaii, advecting moisture to California mid-February.

Constructive interference between the MJO, El Niño, and equatorial Rossby wave enhances low level westerlies. Transport from the tropics into the southern hemisphere has increased.



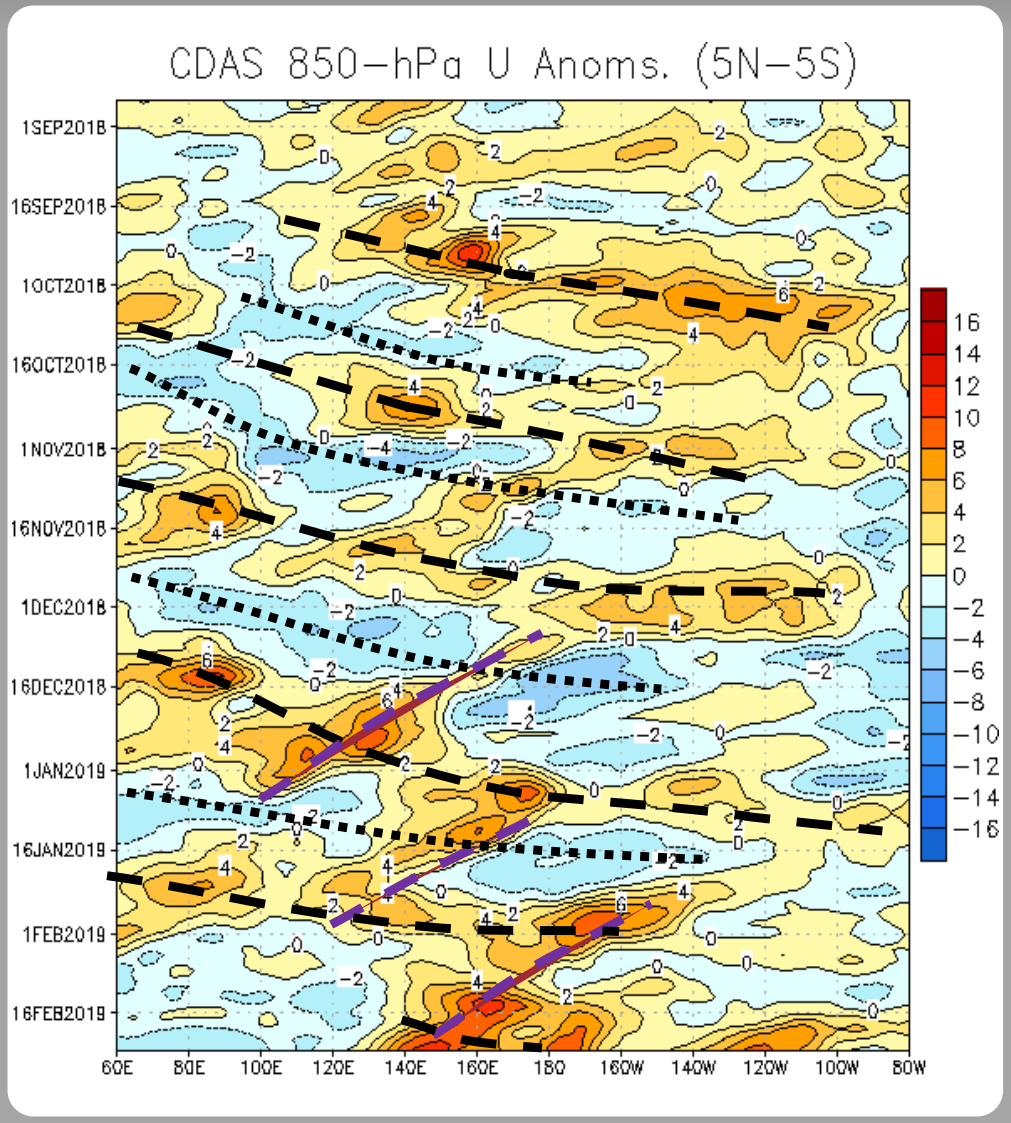
# 850-hPa Zonal Wind Anomalies (m $s^{-1}$)

**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.

In the past week, a westerly wind burst event was centered near 160°E. This was tied to constructive interference between the base state, MJO, and an equatorial Rossby wave. The persistent westerlies in the West Pacific have strengthened since late January.



# OLR Anomalies – Past 30 days

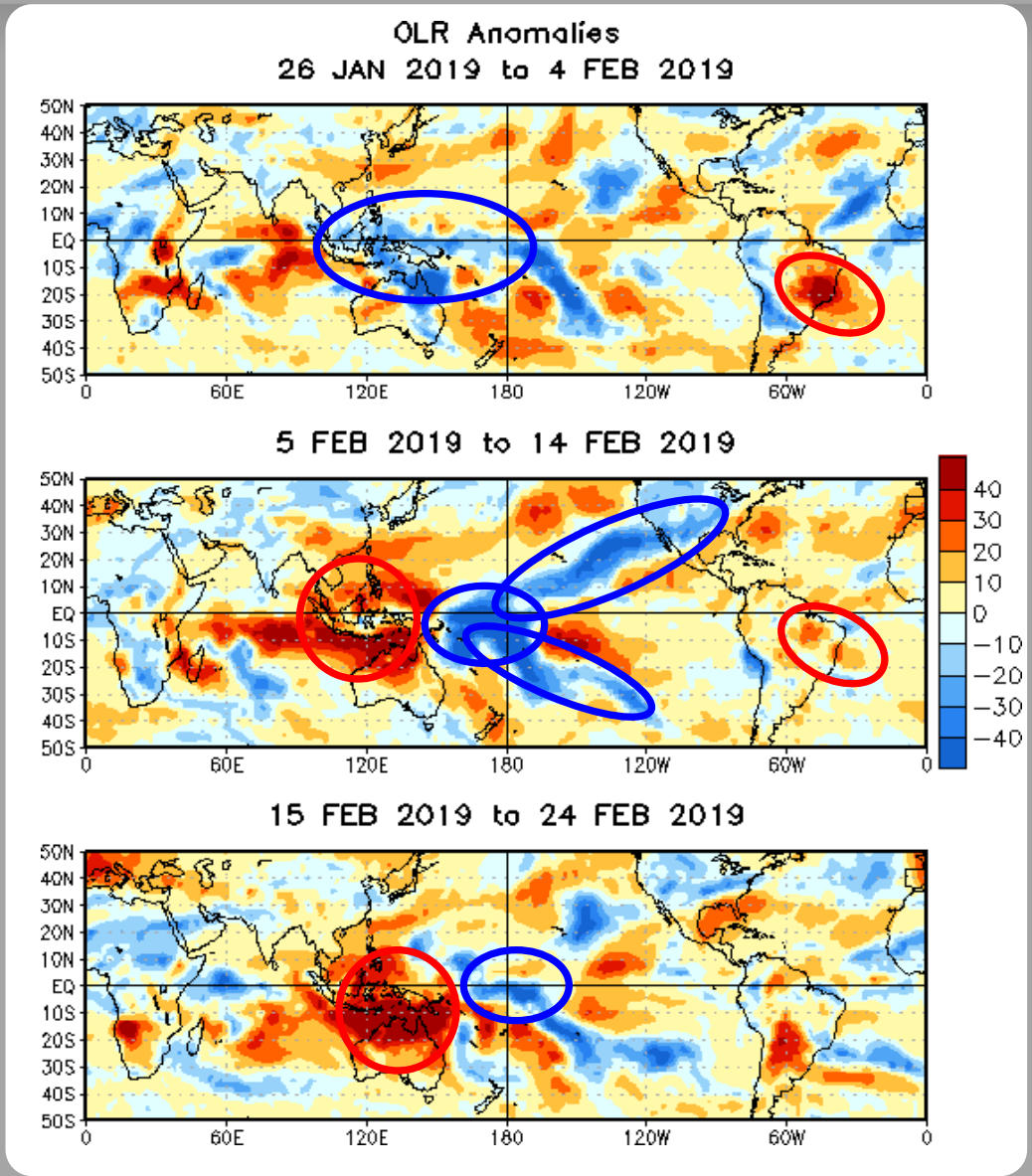
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

By early February, 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 until mid-February.

Mid-February, robust enhancement of convection was observed in the West Pacific, linked to constructive interference of El Nino, equatorial Rossby wave activity, and the MJO. This enhanced convection extended poleward and eastward in both hemispheres. A suppressed convective signal grew over the eastern Indian Ocean and Maritime Continent.

Over the past week, the suppressed convection has strengthened over the Maritime Continent and the enhanced convection has weakened over the Pacific as the MJO continued to propagate into Phase 1.



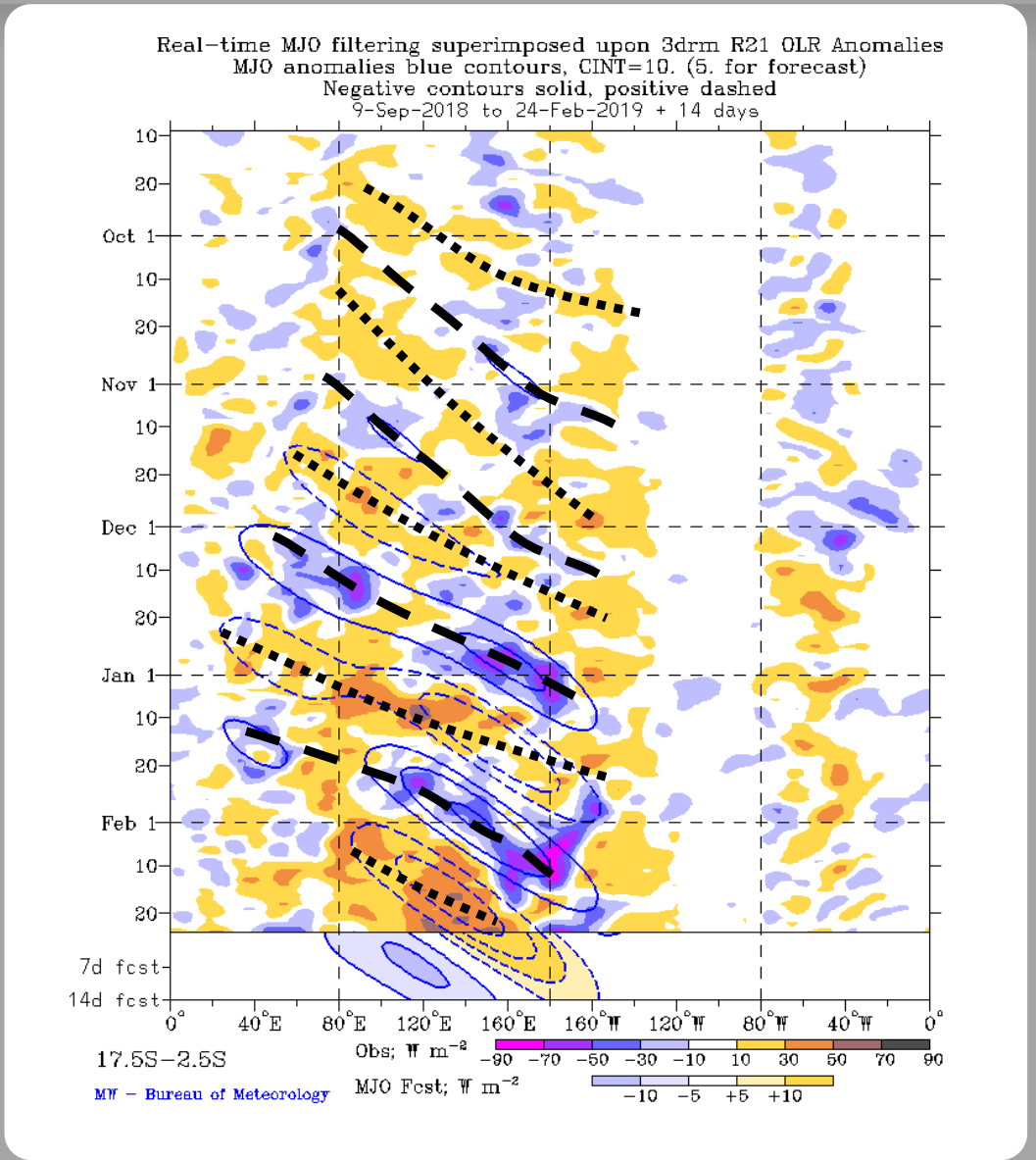
# Outgoing Longwave Radiation (OLR) Anomalies (2.5°S - 17.5° S)

**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 Date Line around February 10, when this signal constructively interfered with the active phase of the MJO. The suppressed phase over the Maritime Continent has strengthened since mid February and is likely to destructively interfere with the enhanced convective signal near the Date Line over the next week.



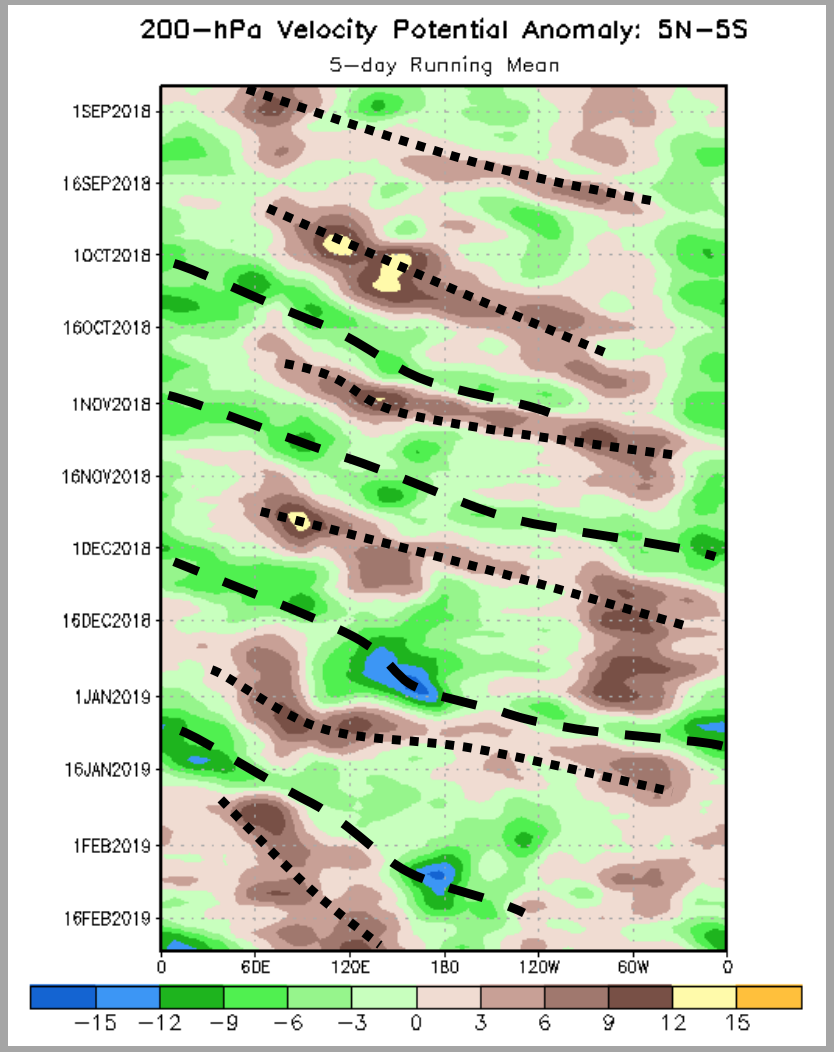
# 200-hPa Velocity Potential Anomalies (5°S - 5°N)

Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

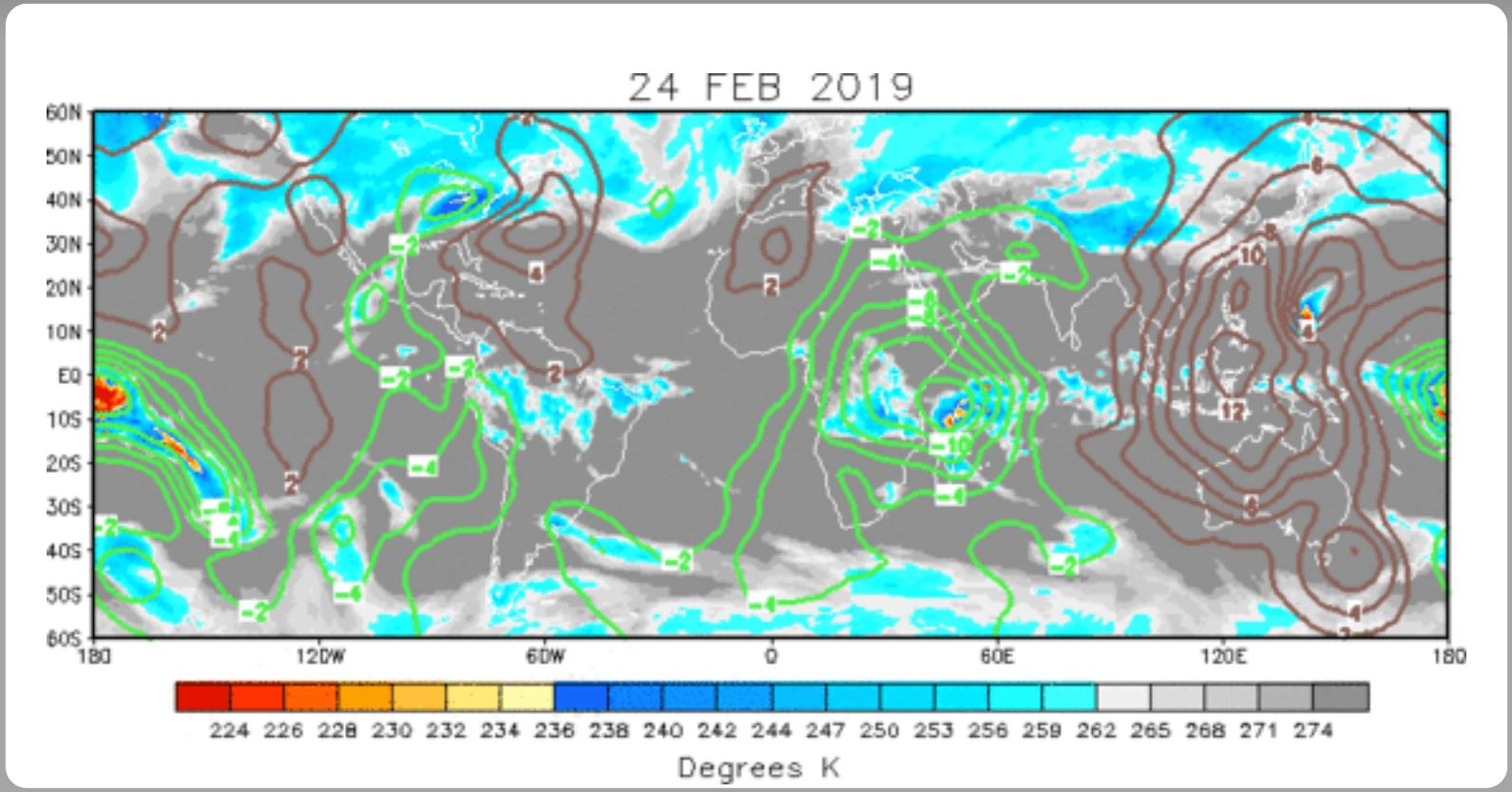
Negative anomalies (green shading) indicate favorable conditions for precipitation

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).

Equatorial 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 Date Line around the 10th of February.



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




The upper-level VP field is noisy, with no apparent Wave 1 or 2 pattern. Suppressed (enhanced) convection over the Maritime Continent (western Indian Ocean) is consistent with the MJO in Phase 1. Rossby and Kelvin wave activity add noise to the pattern.

| |
|---|
| Positive anomalies (brown contours) indicate unfavorable conditions for precipitation |
| Negative anomalies (green contours) indicate favorable conditions for precipitation |

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

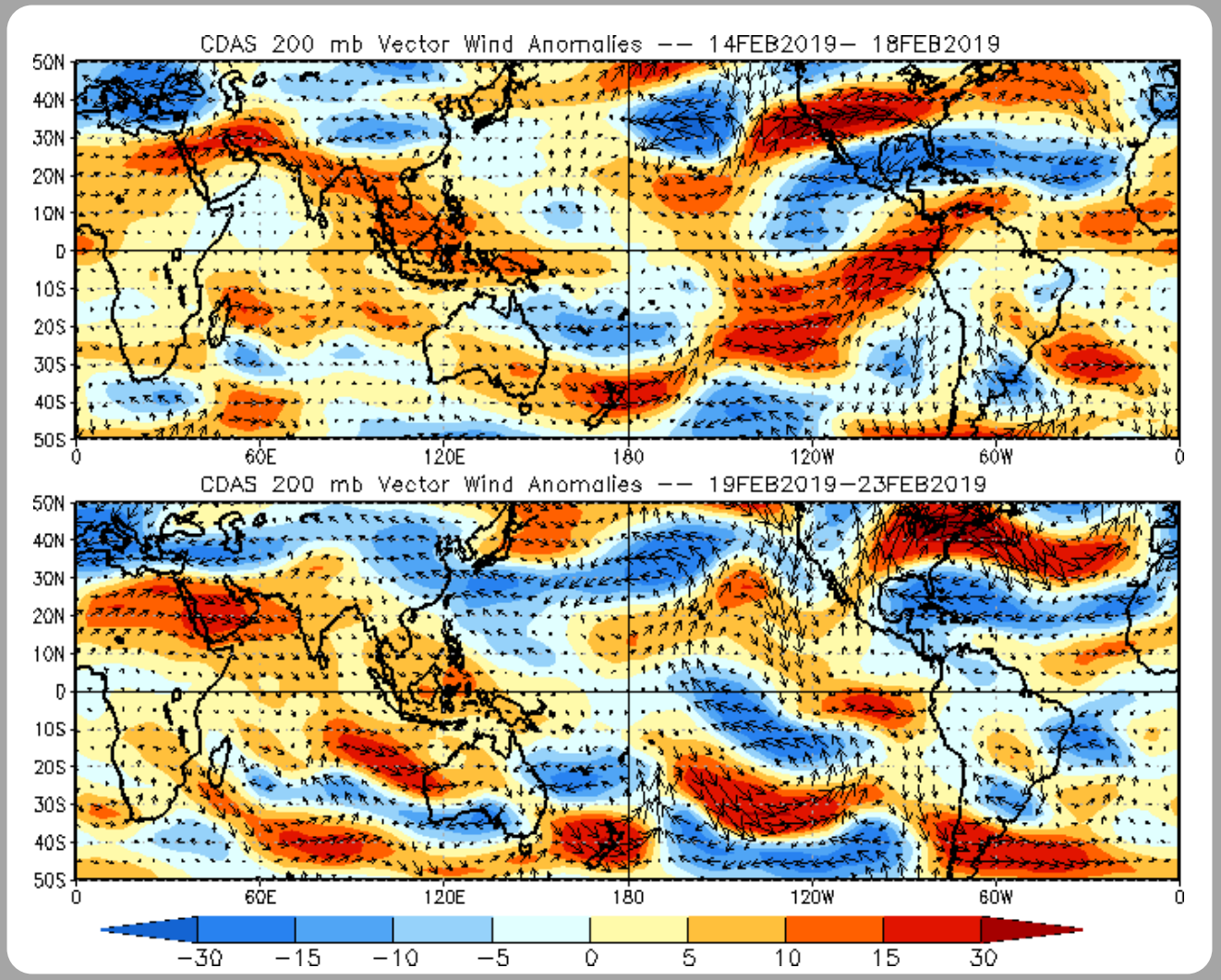
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

The enhancement of the subtropical jet seen in mid February has broken down over the past 5 days, cutting off the robust flow into the southwestern U.S.

Convergence on the Equator between 120W and the Date Line is tied to the base state as well as the eastward progressing MJO. Return flow from the subtropical jet is enhanced over the North Pacific toward Asia.



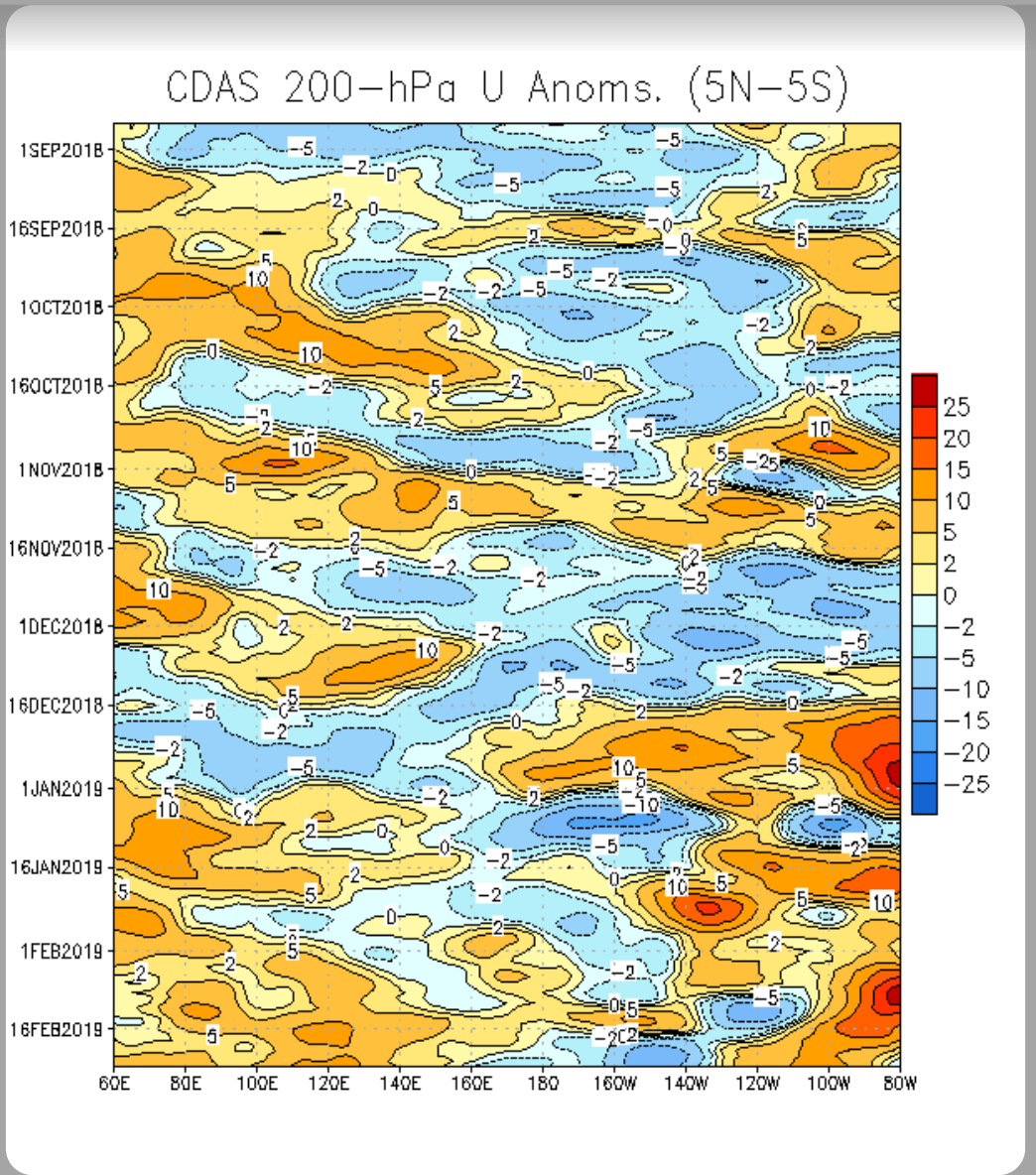
# 200-hPa Zonal Wind Anomalies (m $s^{-1}$)

**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. However, westward moving Rossby wave activity is still evident, with the suppressed phase centered now between 160-140W.



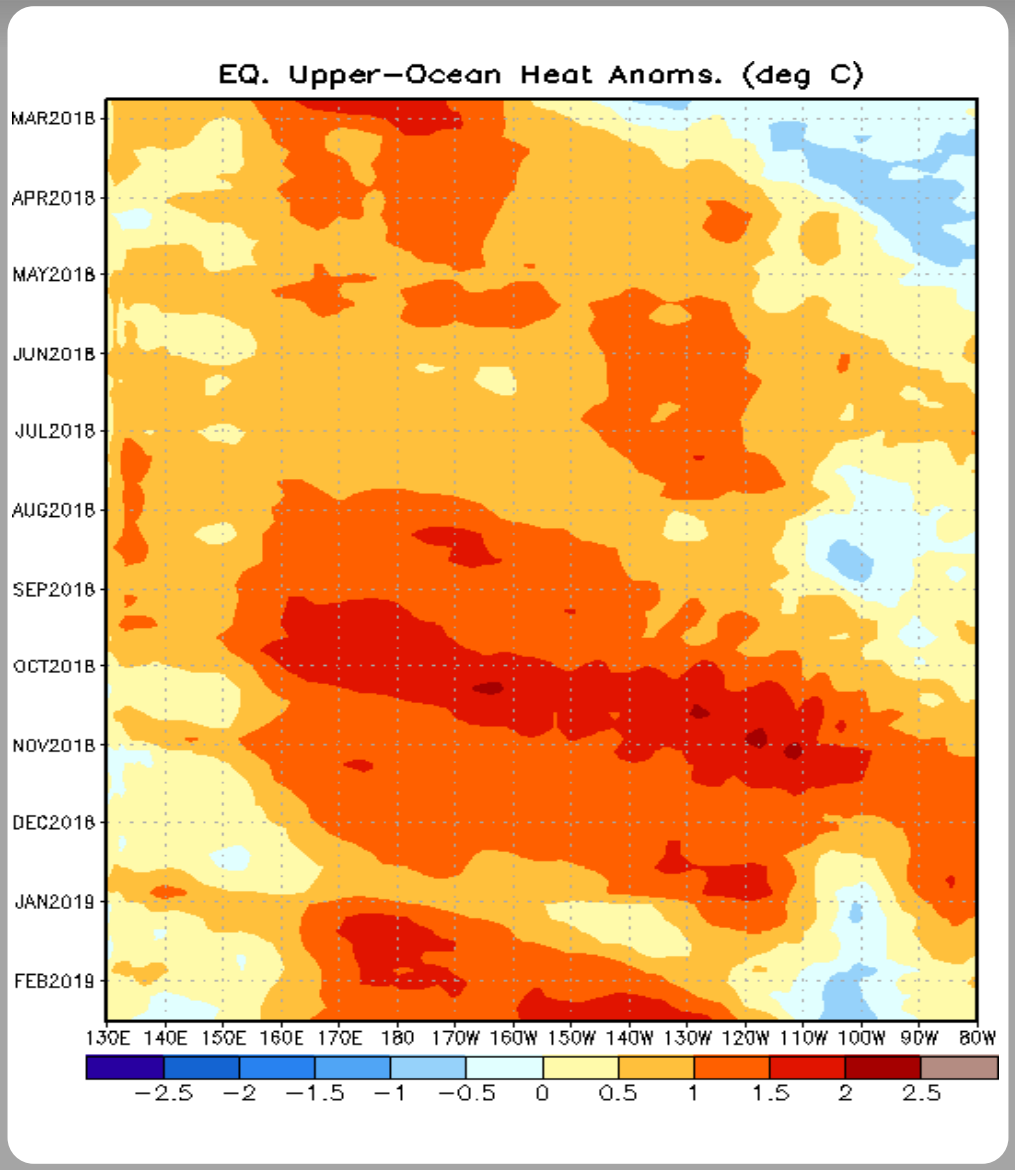
# Weekly Heat Content Evolution in the Equatorial Pacific

**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.**

Positive upper-ocean heat content anomalies have been observed over most of the basin since April 2018.

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. The downwelling event has failed to reach the far East Pacific however, which retains negatively anomalies.



# 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**

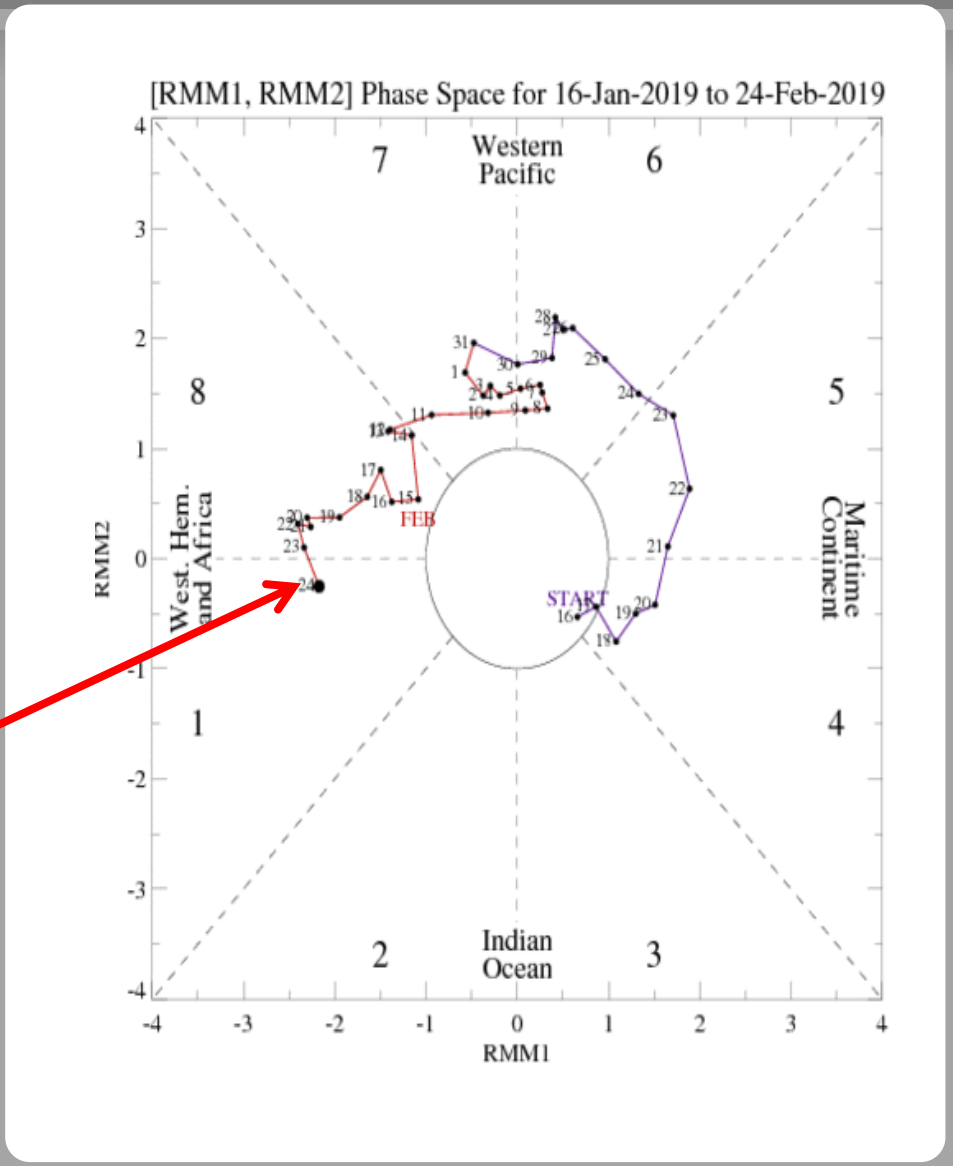
**Counter-clockwise motion is indicative of eastward propagation. Large dot most recent observation.**

**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 as multiple equatorial Rossby waves helped slow its progression.

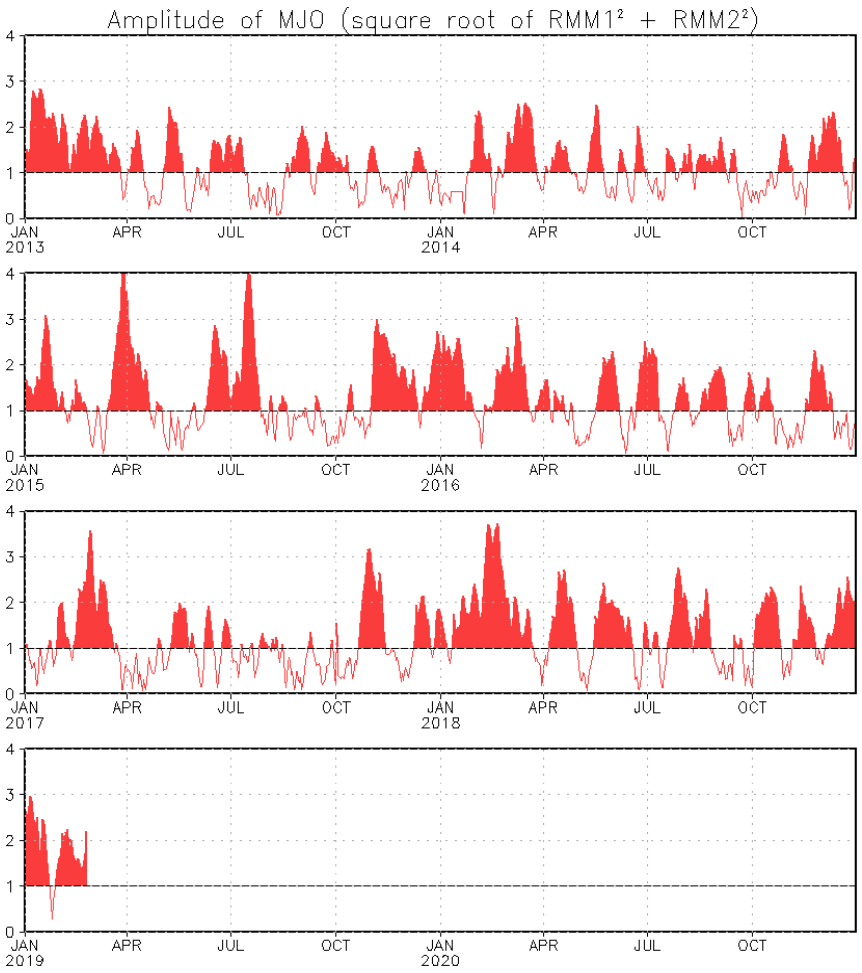
The MJO is now shifting into the Western Hemisphere/western Indian Ocean.



# 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

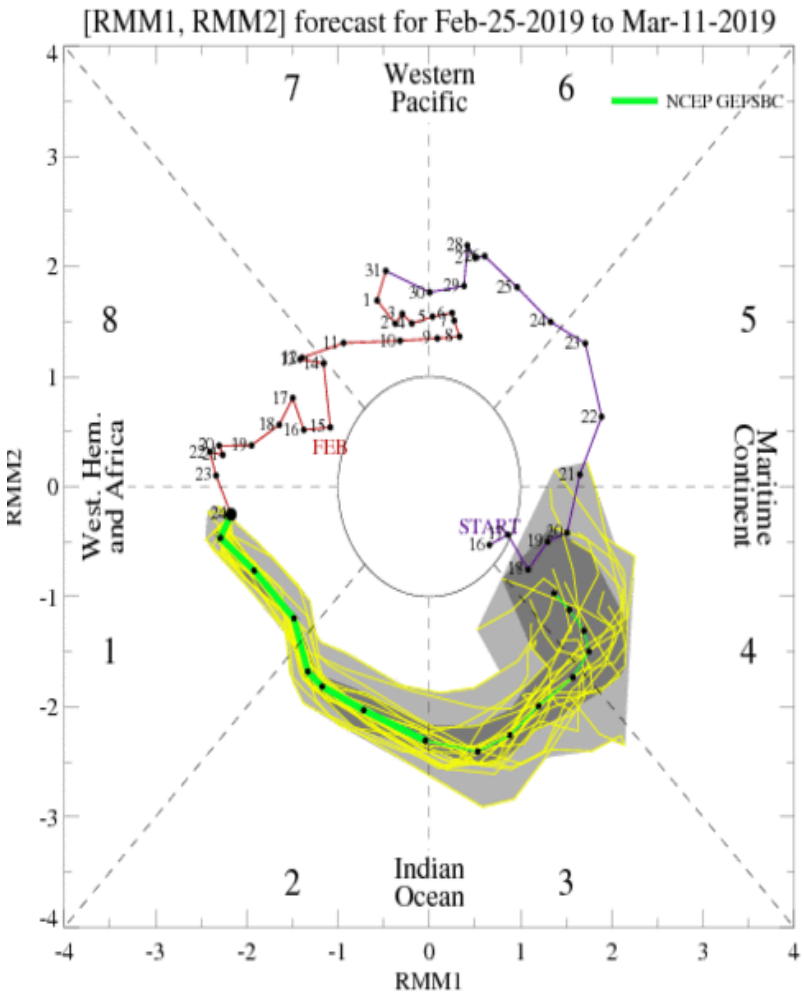
**RMM1 and RMM2 values for the most recent 40 days and forecasts from the GFS ensemble system (GEFS) for the next 15 days**

**light gray shading: 90% of forecasts**

**dark gray shading: 50% of forecasts**

The GEFS forecast shows strong eastward progression, well into the Indian Ocean during Week-1. In Week-2, the eastward progression continues, though not quite as fast as the previous week, likely due to continued interactions with equatorial Rossby waves and interactions with the El Nino state. The MJO signal weakens toward the end of Week-2.

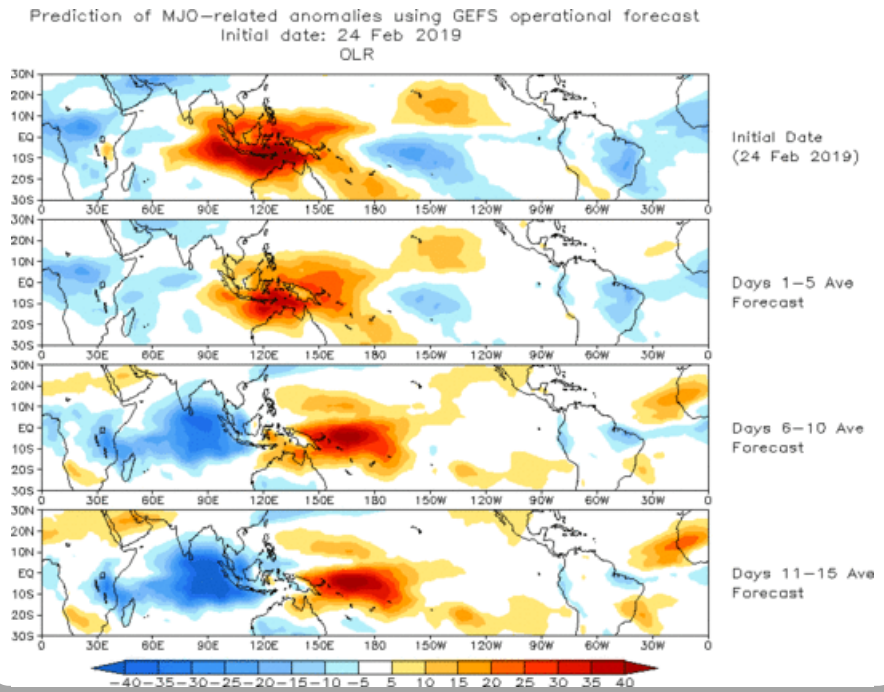
**Yellow Lines - 20 Individual Members**
**Green Line - Ensemble Mean**



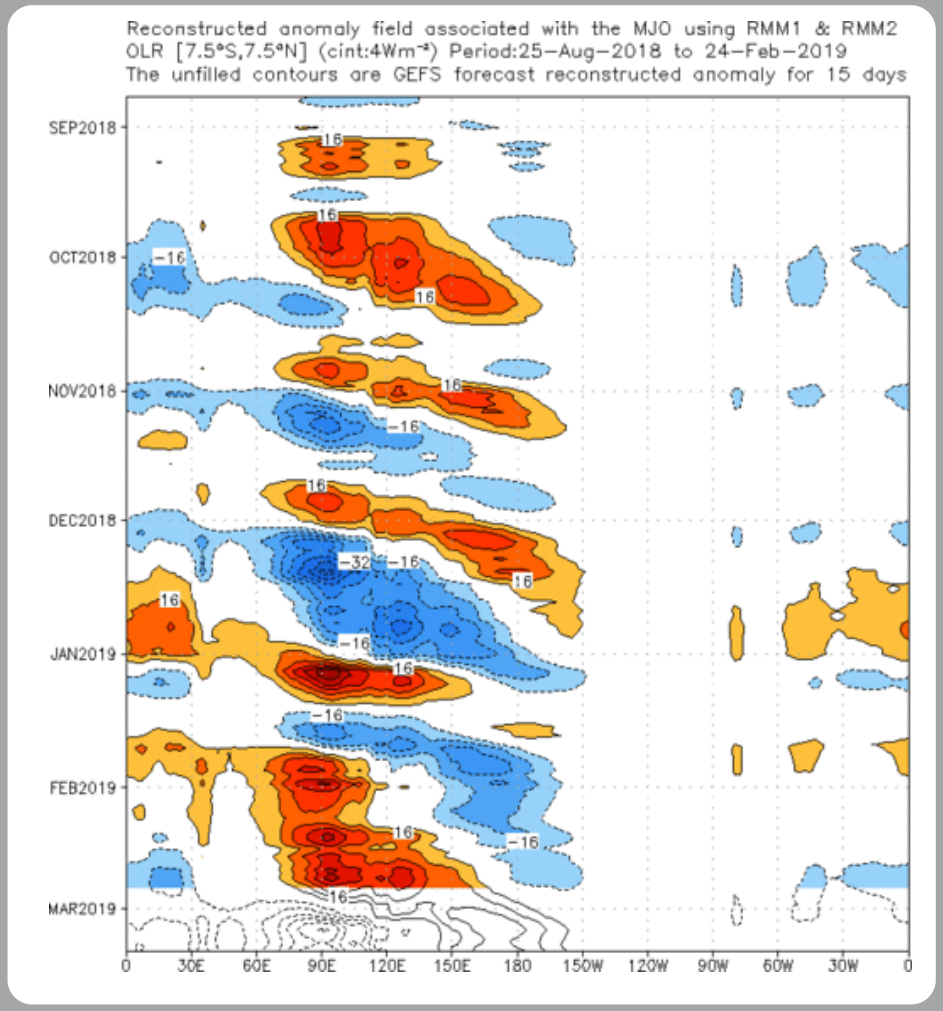
# Ensemble GFS (GEFS) MJO Forecast

**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**



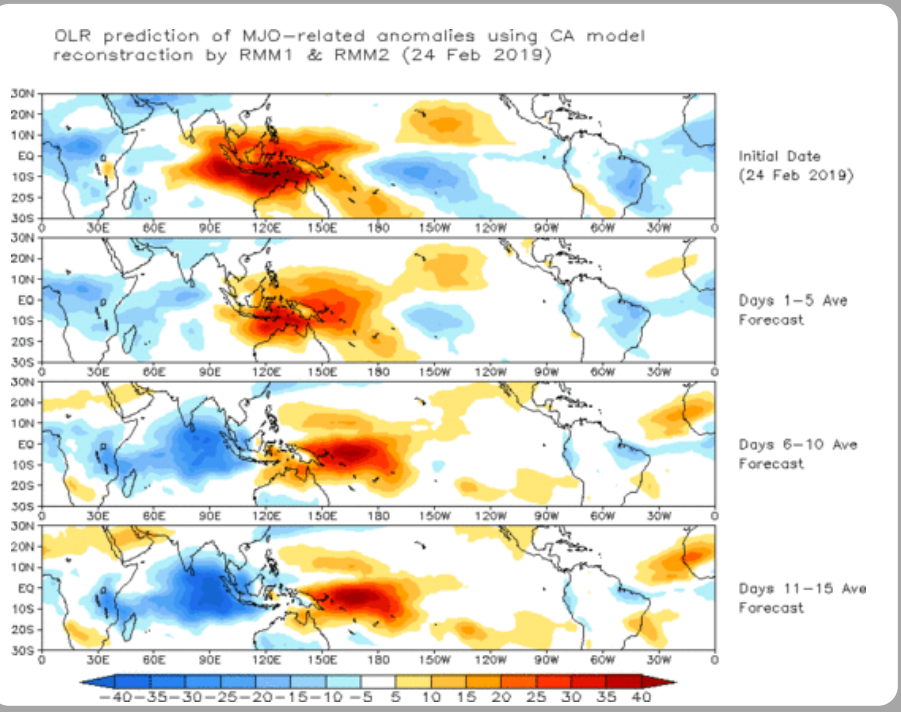

The GEFS indicates eastward progression of the MJO signal, with the enhanced phase really strengthening in the Indian Ocean toward the end of Week-1. The signal remains fairly robust through the next two weeks.

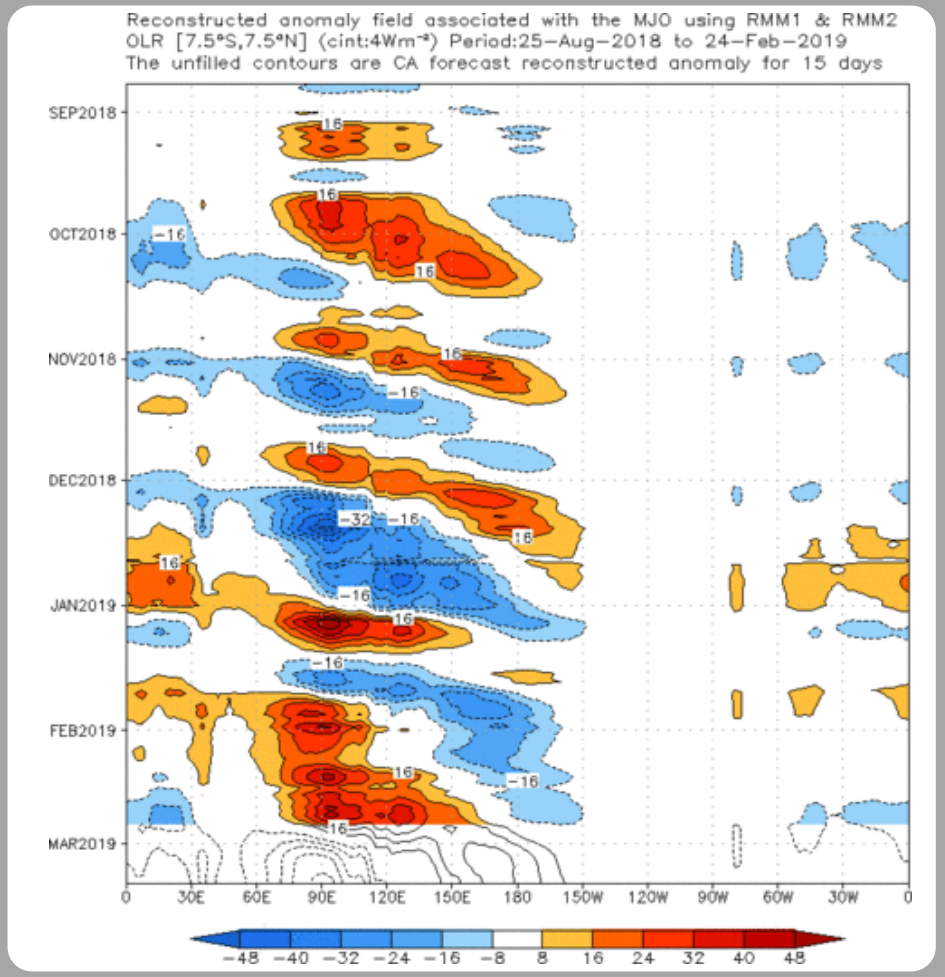
# Constructed Analog (CA) MJO Forecast

**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

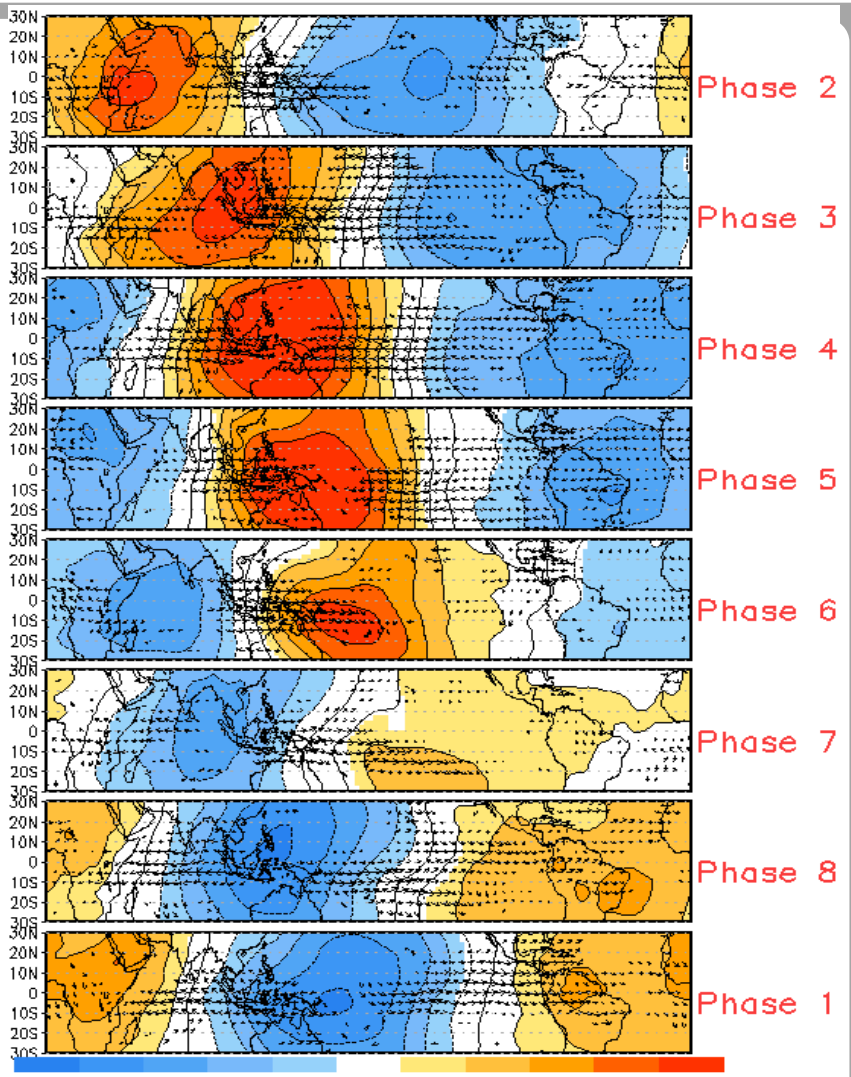


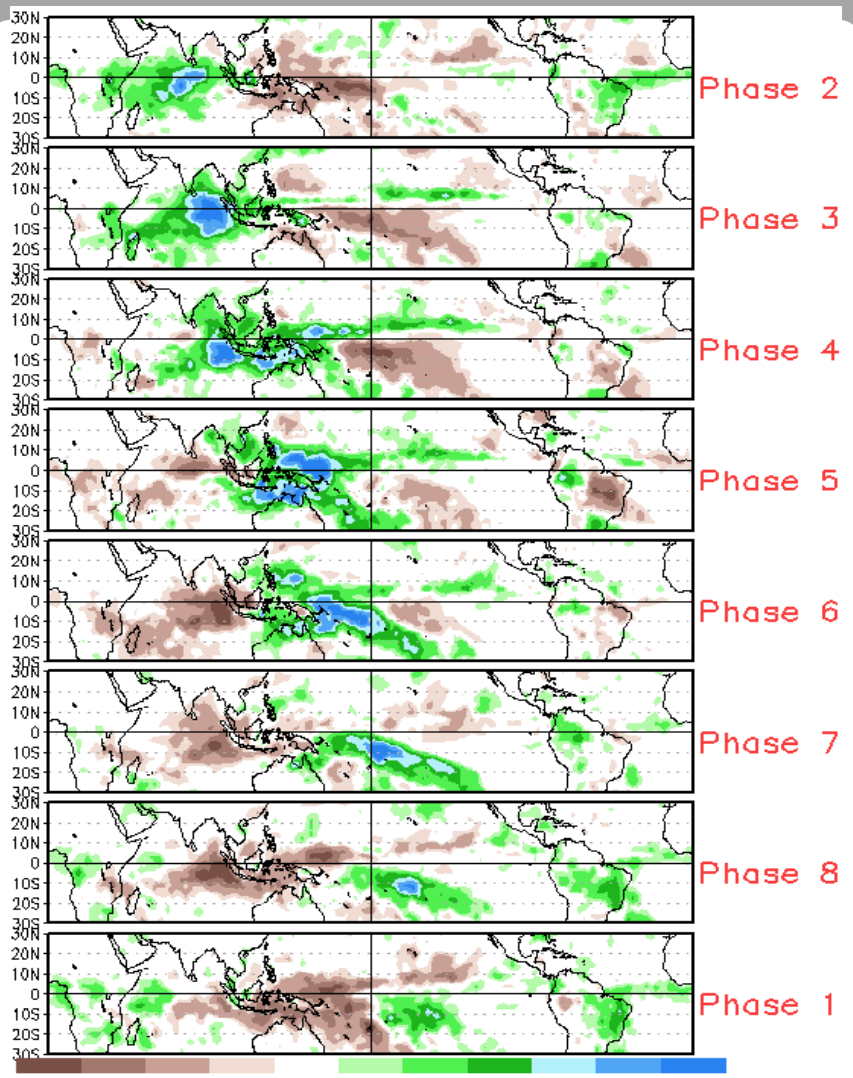

The constructed analog depicts a very similar phase speed as the GEFS forecast, with the enhanced envelope overspreading the western hemisphere in Week-1, strengthening in the Indian Ocean end of Week-1 and into Week-2.

# MJO Composites - Global Tropics

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



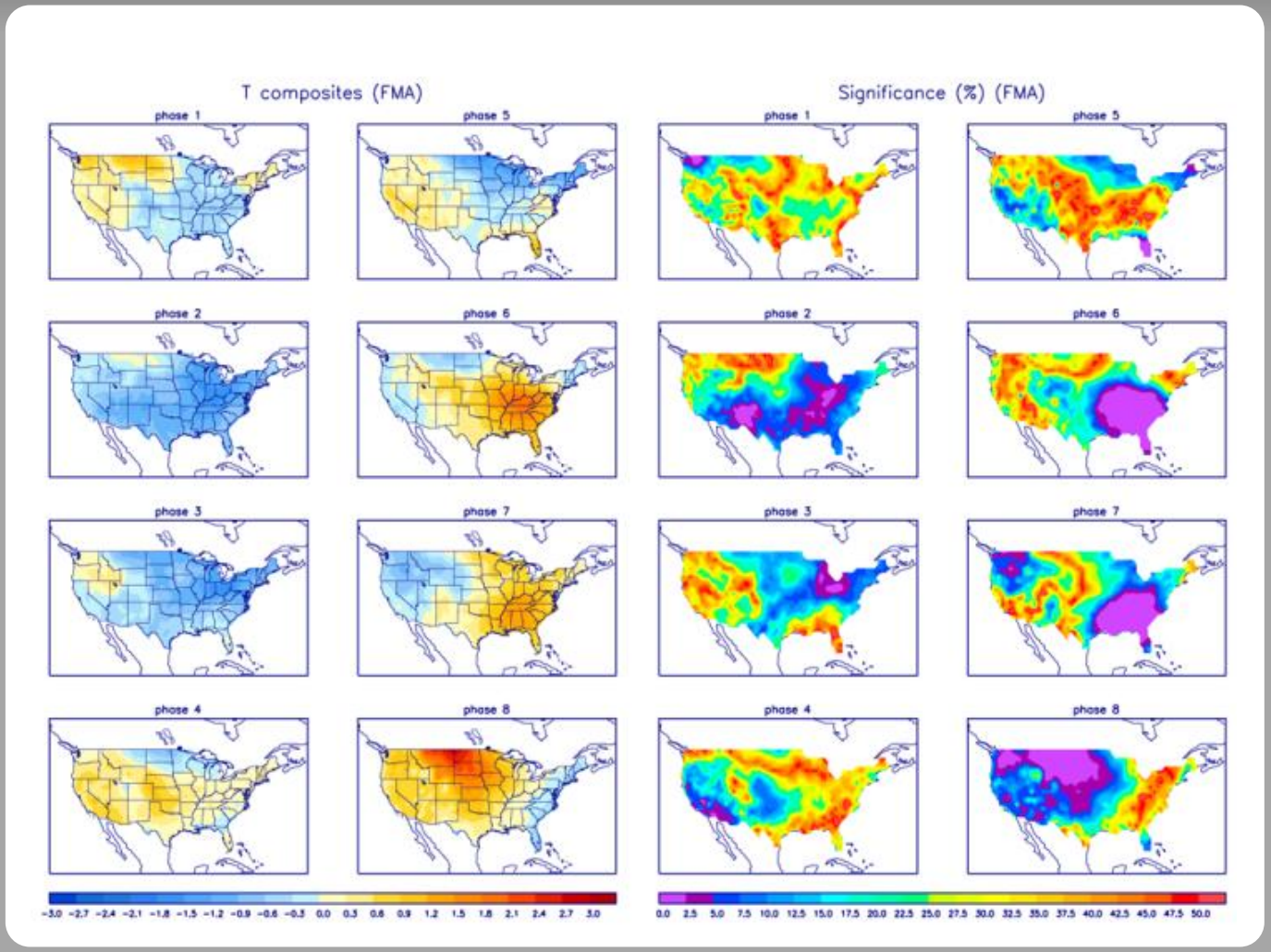

**Precipitation Anomalies (Nov - Mar)**



# 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.**



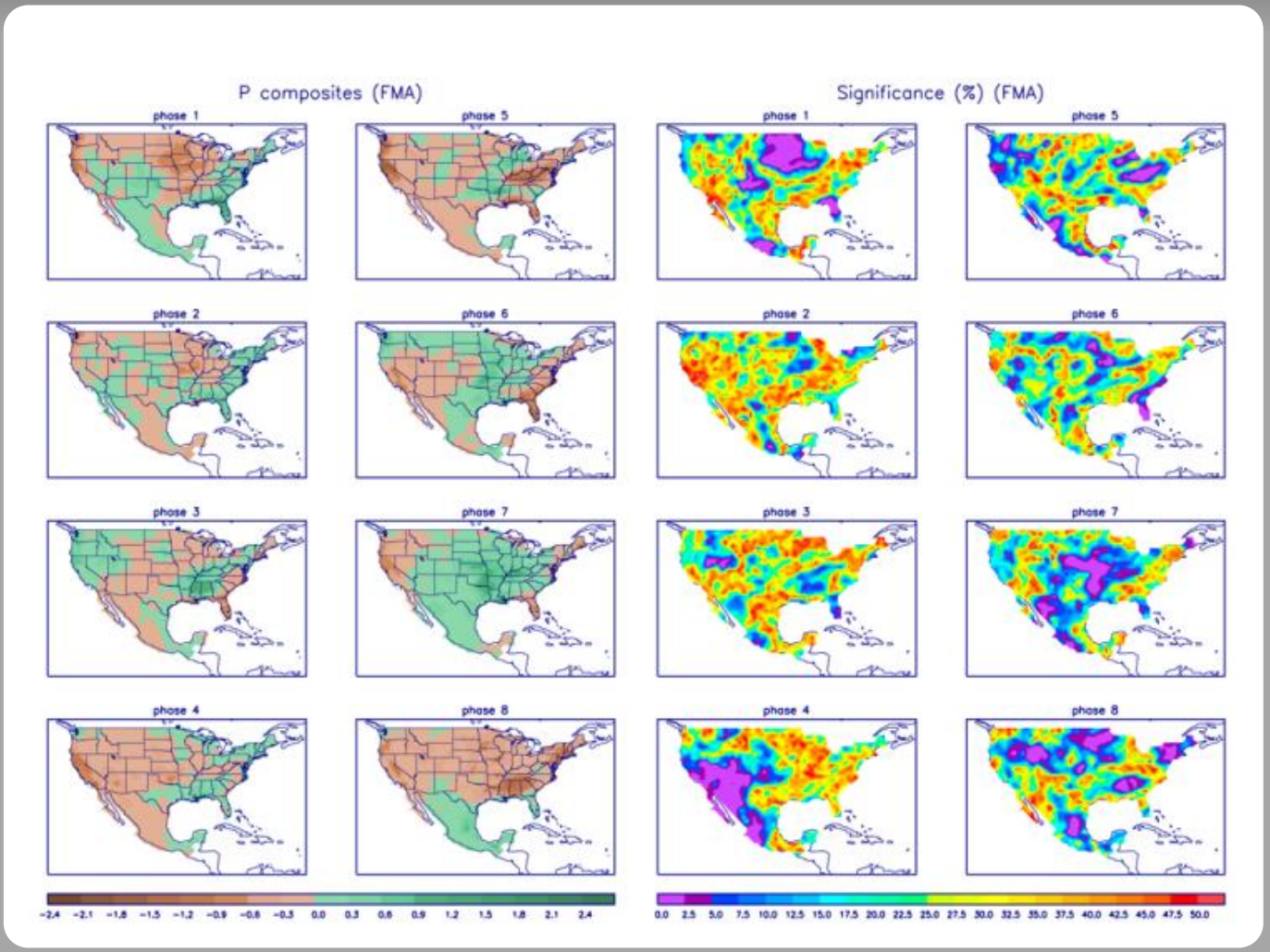

Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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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