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

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7 January 2019

Outline

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Recent Evolution and Current Conditions

MJO Index Information

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Overview

- The enhanced phase of a robust MJO signal is currently located in Phase 8 (primarily central and eastern Pacific), and a Kelvin wave is near the Brazilian coast.

- Most dynamical models agree on very limited eastward propagation of a rapidly weakening MJO signal during Week-1. During Week-2, there is large disagreement on where a new subseasonal signal may re-emerge. The GEFS and Canadian point to a strengthening signal over the West Pacific; the ECMWF model maintains more eastward propagation throughout the period, hinting at the enhanced phase emerging over the Indian Ocean and propagating to the Maritime Continent.

- Two major uncertainties regarding the MJO forecast for the next two weeks include a) how long will the convection remain stationary near and west of the Date Line, and b) differences between Week-2 RMM forecasts. The enhanced phase crossing over the Pacific favors a transition to a colder pattern over central and eastern North America during mid January. This transition has been forecast by subseasonal climate forecasts initialized over the past couple of weeks.

<u>**Additional potential impacts across the global tropics and a discussion for the U.S. are available at:**</u>
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

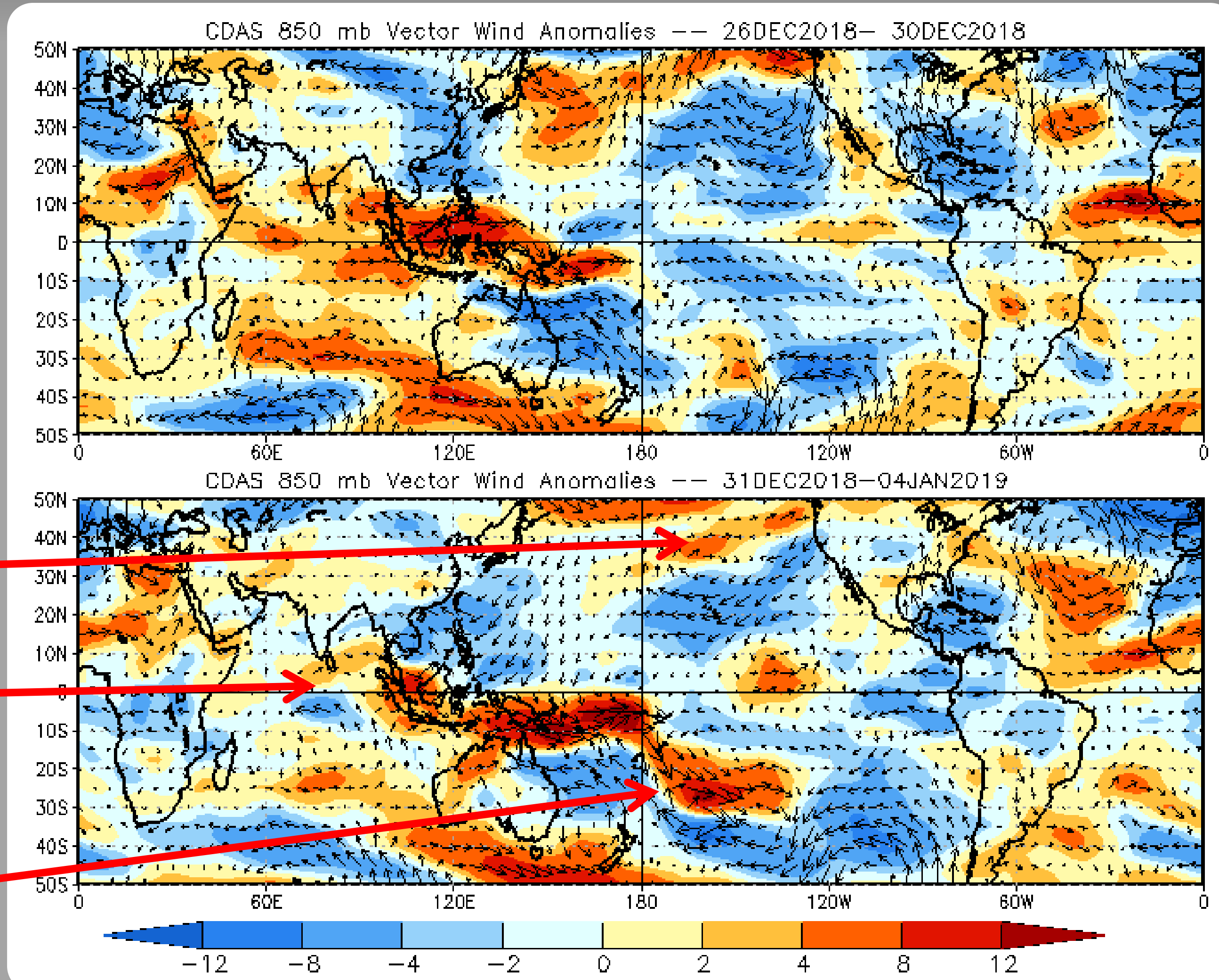
<u>Blue shades</u>: Easterly anomalies

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

Extratropical flow over the North Pacific de-amplified during the past week.

Westerly anomalies have collapsed over the Indian Ocean.

The South Pacific Convergence Zone (SPCZ) has recently become very active.



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

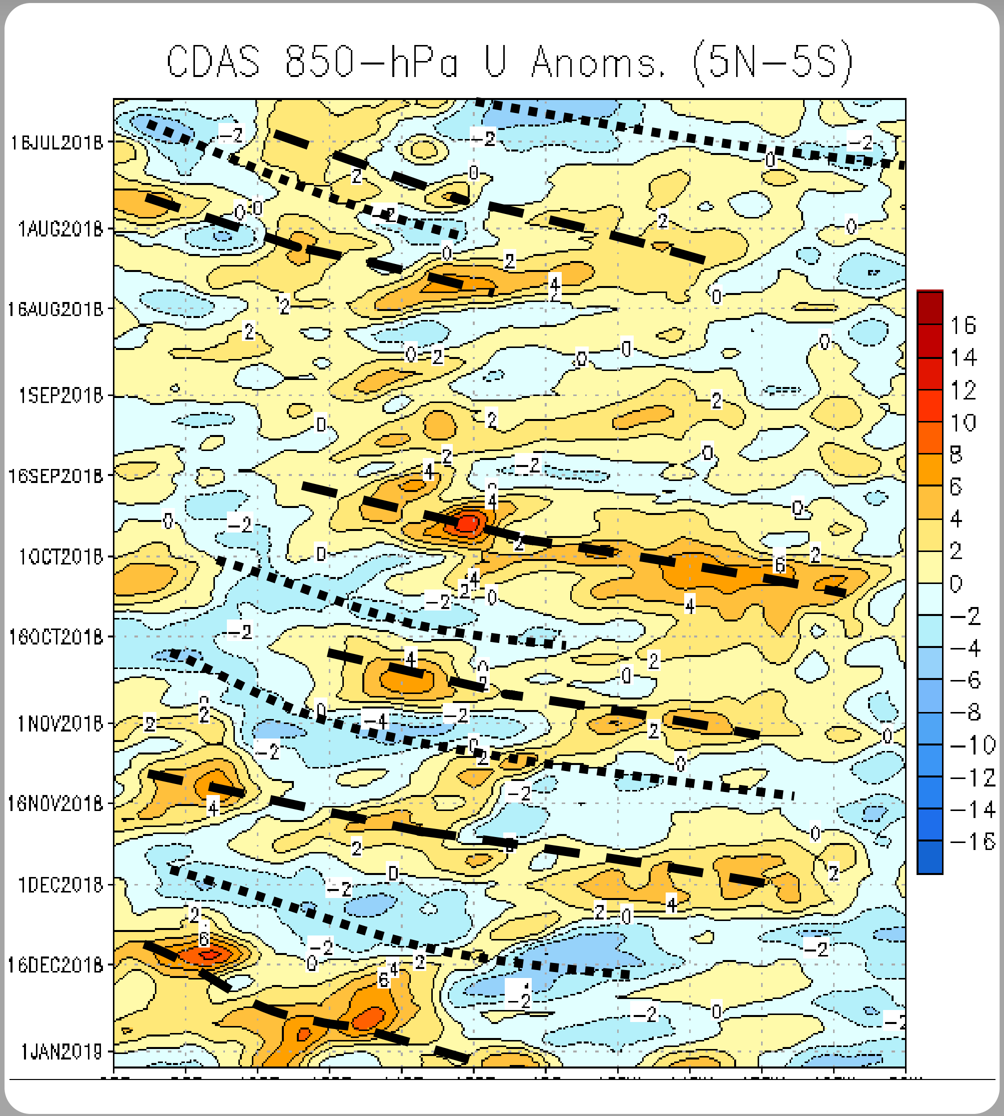
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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

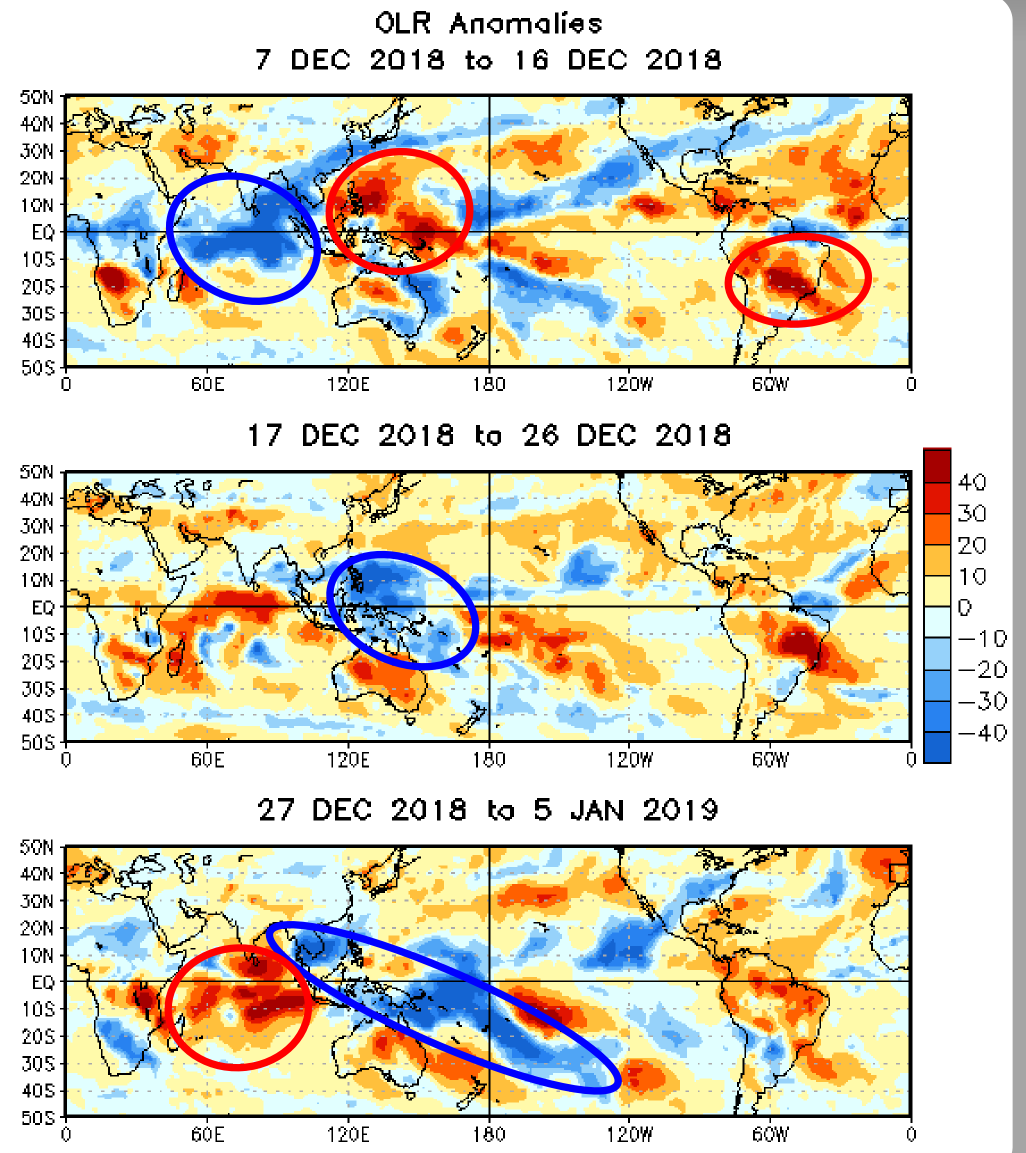
Drier-than-normal conditions, positive OLR anomalies (yellow/red shading)

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

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. Suppressed convection emerged over 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.

By late December and early January, some of the convective activity associated with the MJO extended along the SPCZ into the southern mid-latitudes. Suppressed convection prevailed over the Indian Ocean.



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

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

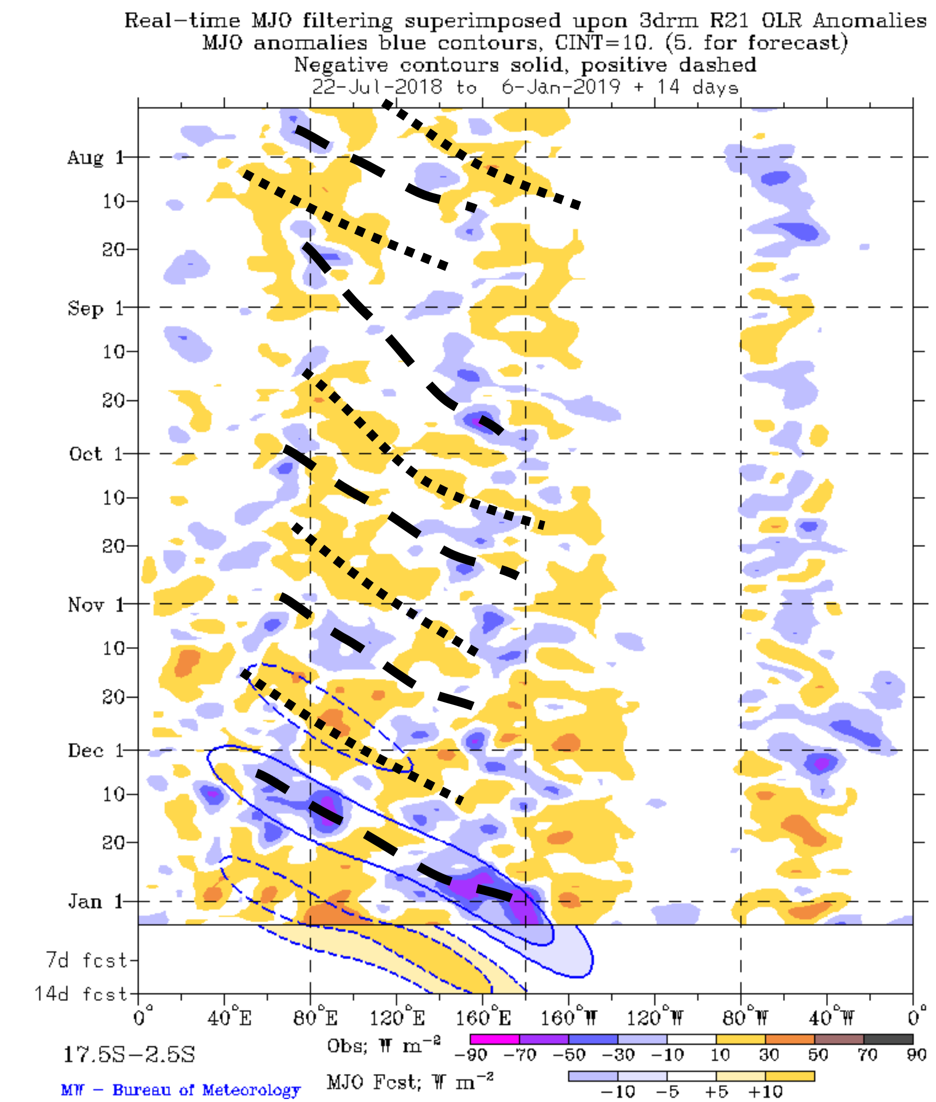
Wetter-than-normal conditions, negative OLR anomalies (blue shading)

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, there may be some constructive interference between the MJO and the low-frequency state near the Date Line.



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

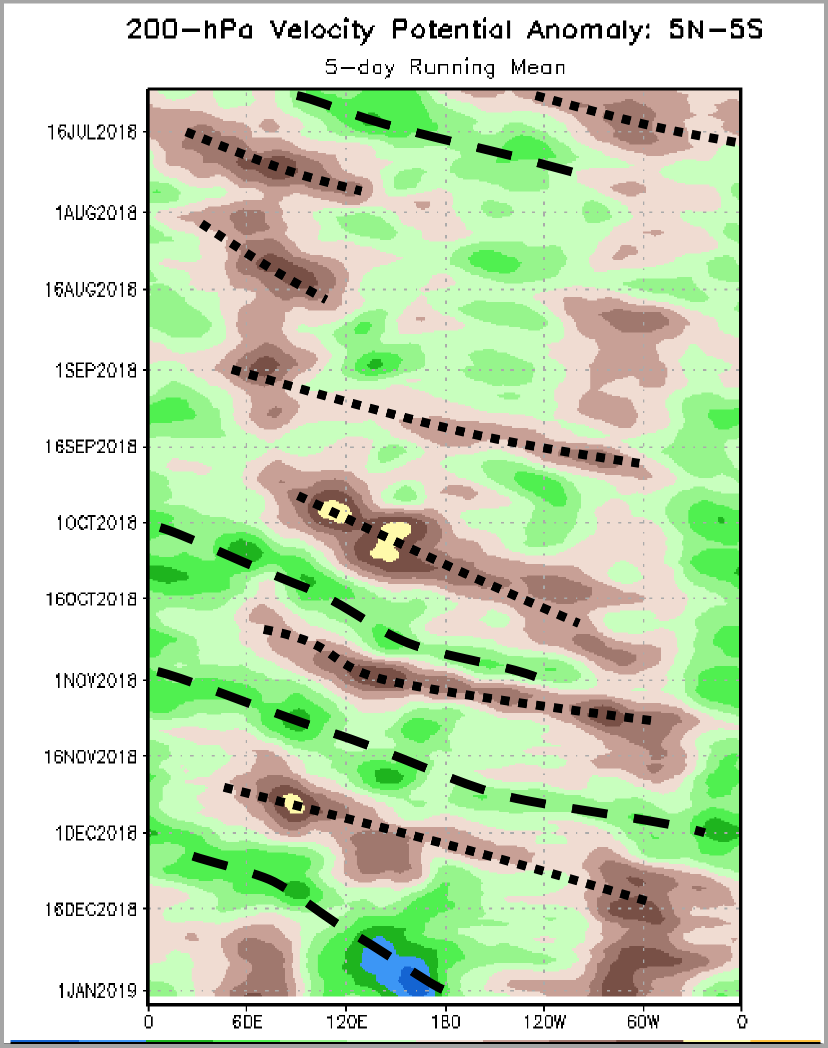
Positive anomalies (brown shading) indicate unfavorable conditions for precipitation

Negative anomalies (green shading) indicate favorable conditions for precipitation

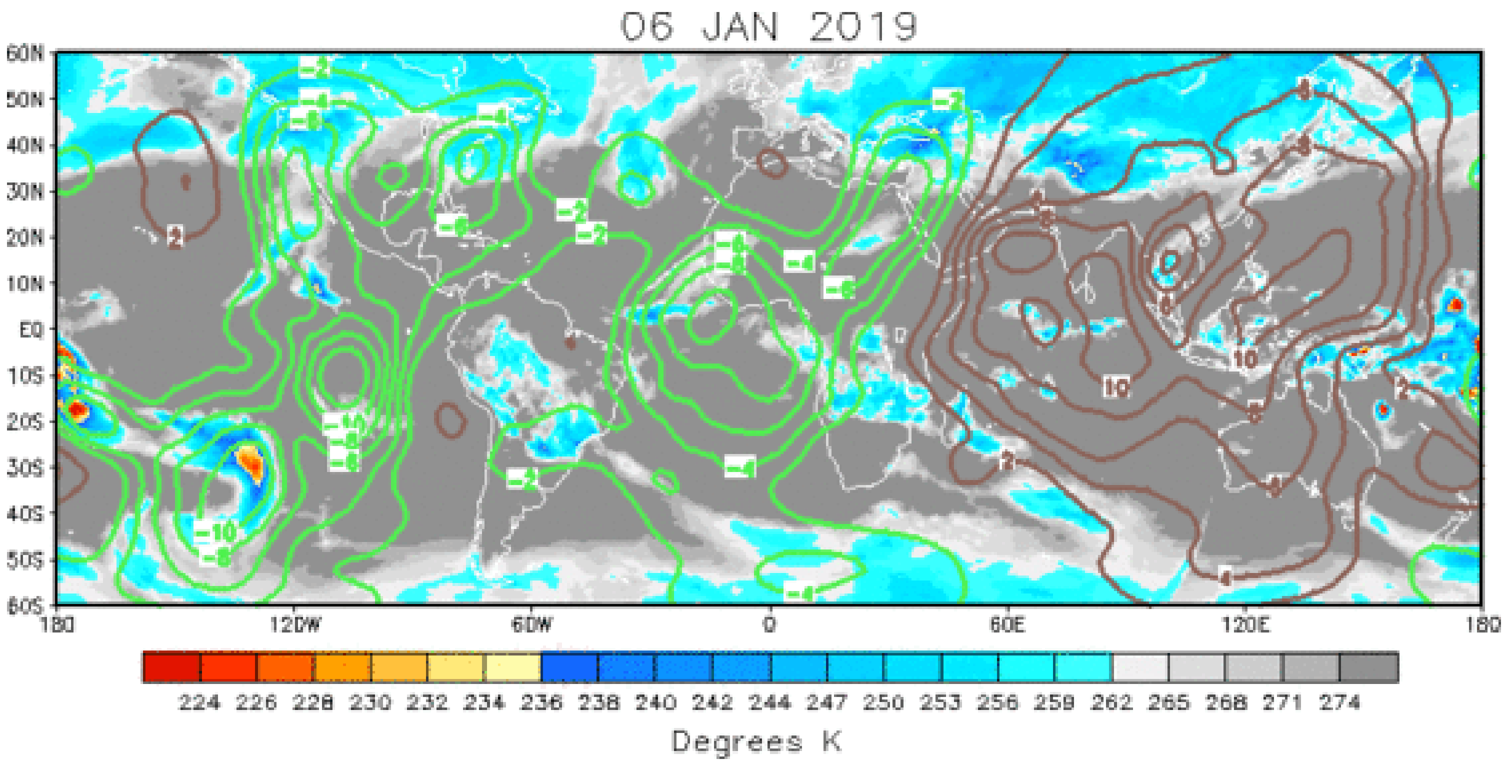
Eastward propagation of broad suppressed convection was apparent throughout early July. The upper-level footprint of the MJO re-emerged during mid-July, with a broad divergent signal propagating from the Maritime Continent to the central Pacific.

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 were apparent in the upper-level VP, but the overall envelope of enhanced divergence aloft continued propagating eastward to the West Pacific until mid-December. Convection has since become more stationary due to Rossby wave activity and the low-frequency state.



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



The upper-level VP anomaly pattern exhibits a Wave-1 pattern; upper-level divergence is primarily noted over the Western Hemisphere, while upper-level convergence dominates much of the Eastern Hemisphere.

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})

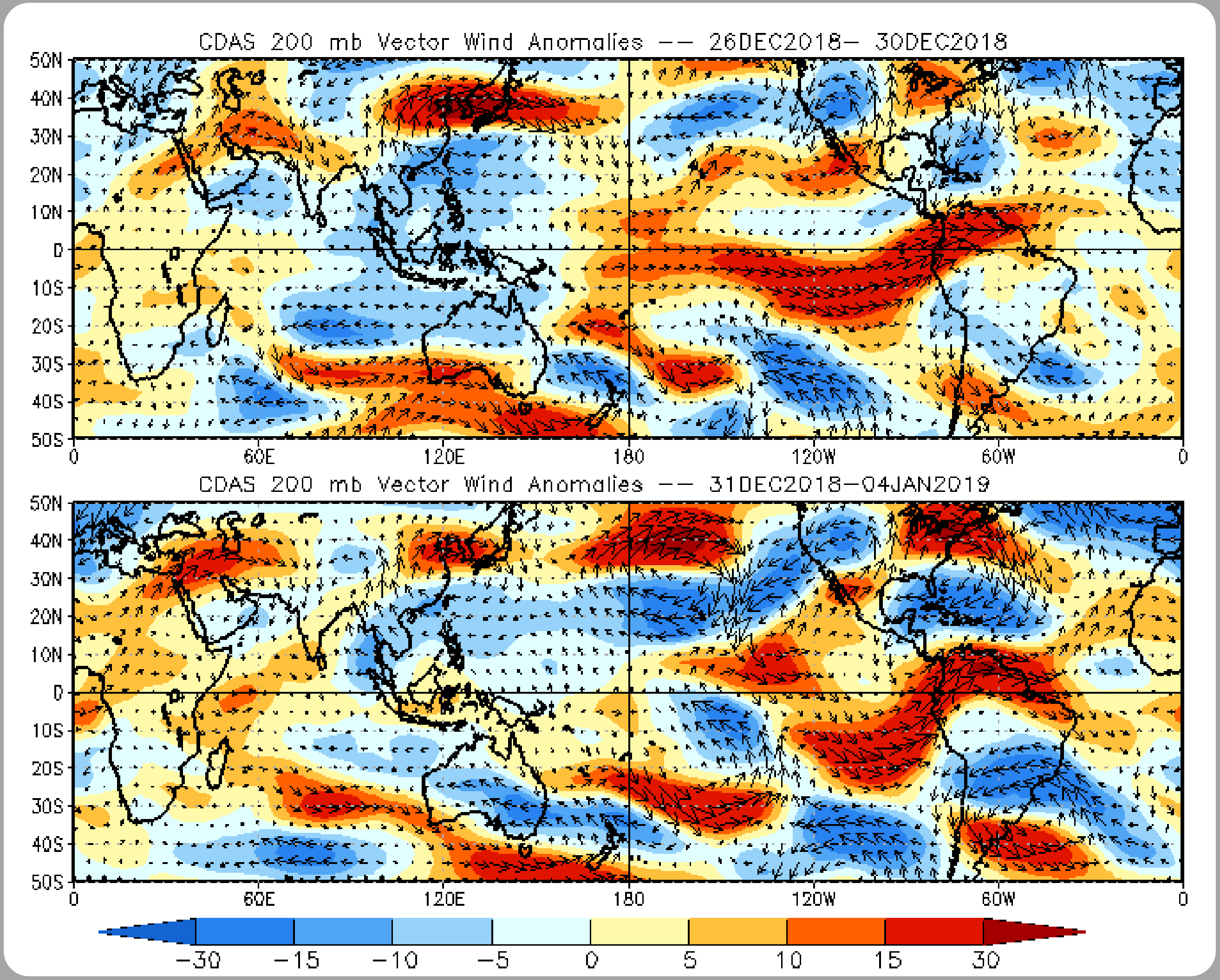
Note that shading denotes the zonal wind anomaly

Blue shades: Easterly anomalies

Red shades: Westerly anomalies

Anomalous easterlies were noted over the eastern Indian Ocean, Maritime Continent, and Southeast Asia; a large anomalous anticyclone centered near the East Asian coast is also apparent (Dec 26-30).

Anomalous anticyclones are indicated over east Asia/far western Pacific, and the north-central Pacific. Anomalies over the Western Hemisphere are significantly more amplified than those over the Eastern Hemisphere at 200 hPa.



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

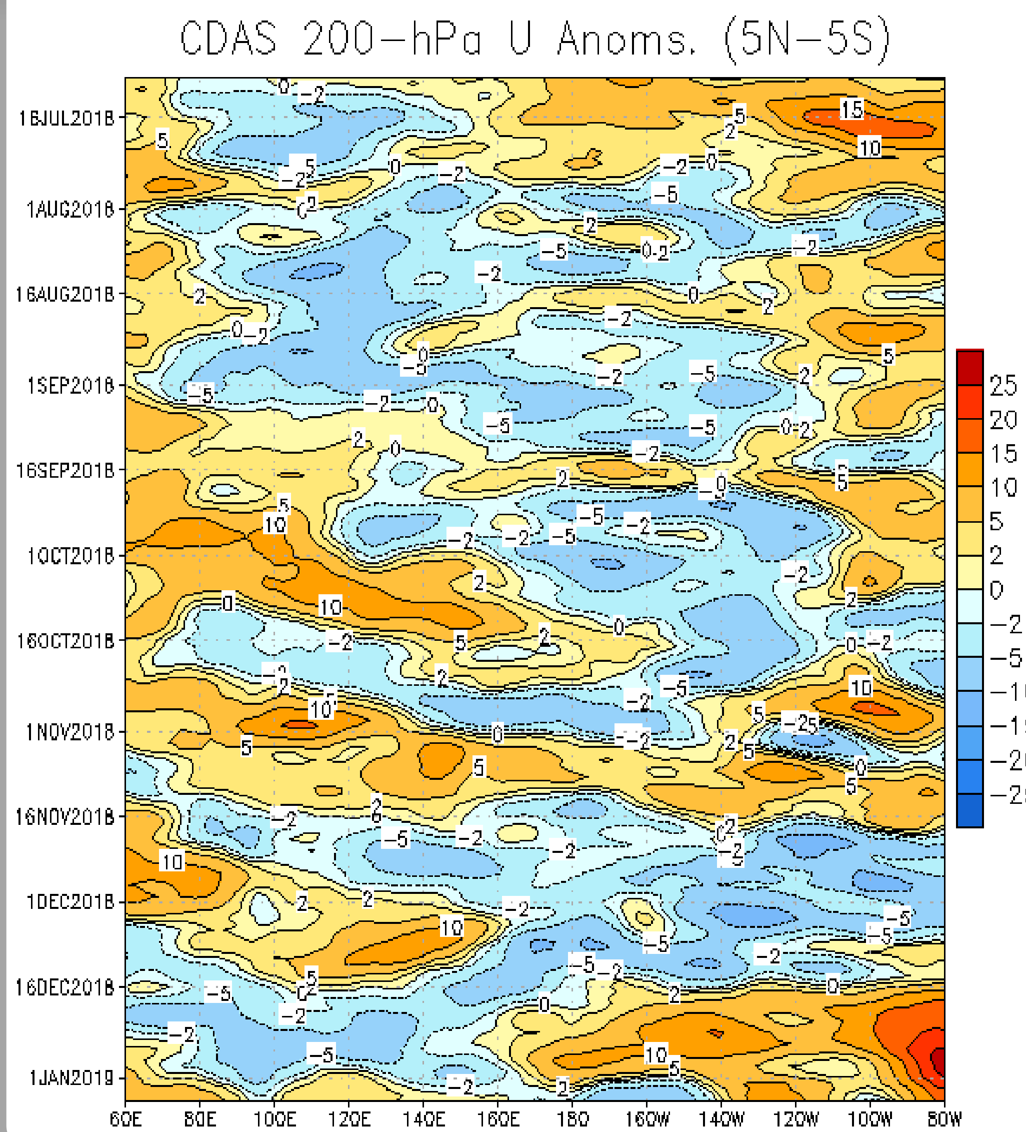
Westerly anomalies (orange/red shading) represent anomalous west-to-east flow

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.

From mid-November to mid-December, an envelope of westerly anomalies shifted from the Indian Ocean to the Pacific, with the signal briefly interrupted by Rossby wave activity during early to mid-December. Most recently, another area of westerly anomalies is depicted over the Indian Ocean and the Maritime Continent.



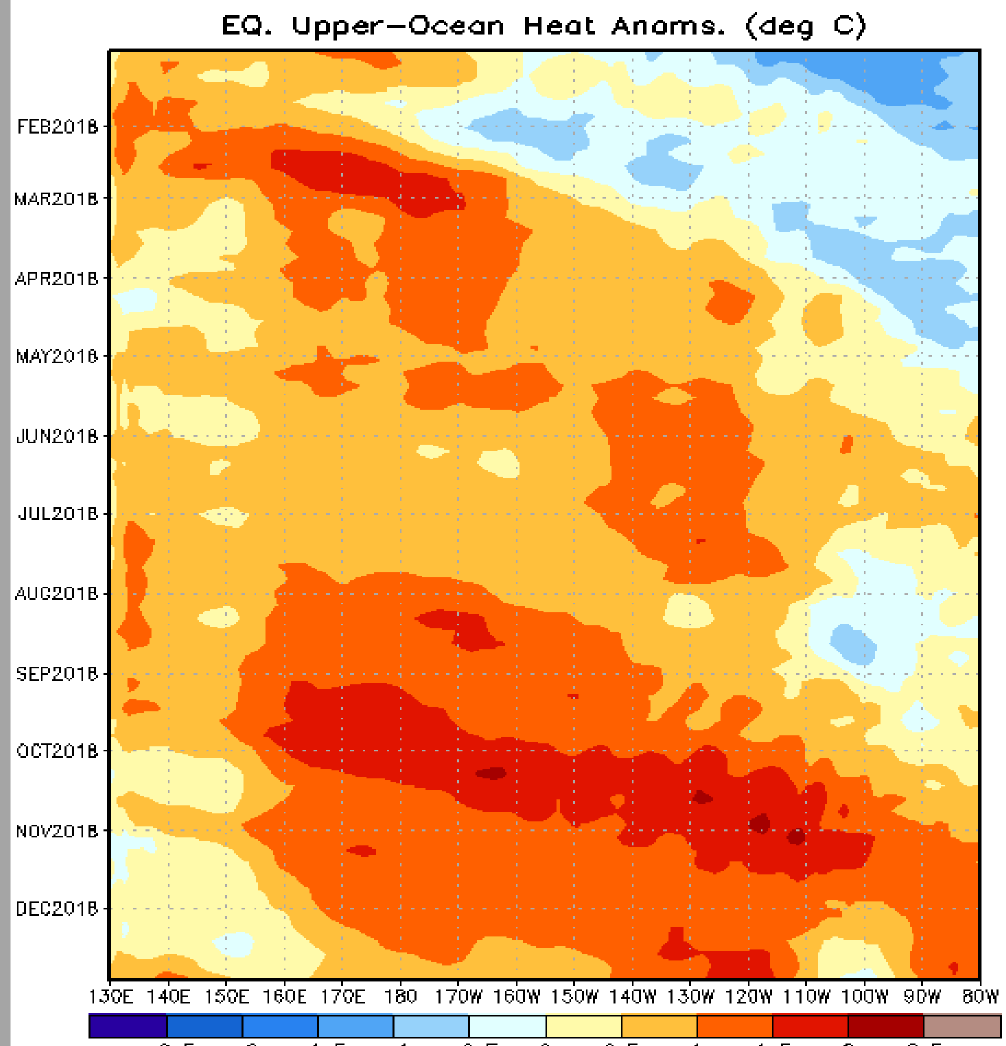
Weekly Heat Content Evolution in the Equatorial Pacific

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 at the start of 2018. 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 recently.



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

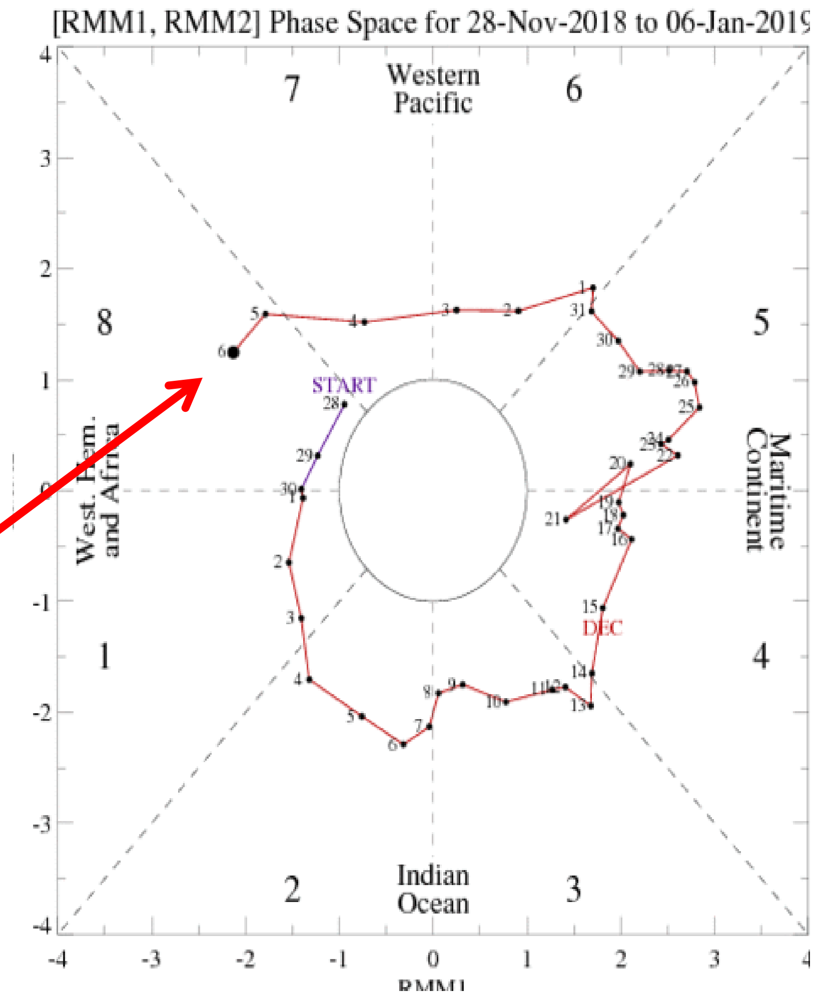
The triangular areas indicate the location of the enhanced phase of the MJO

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

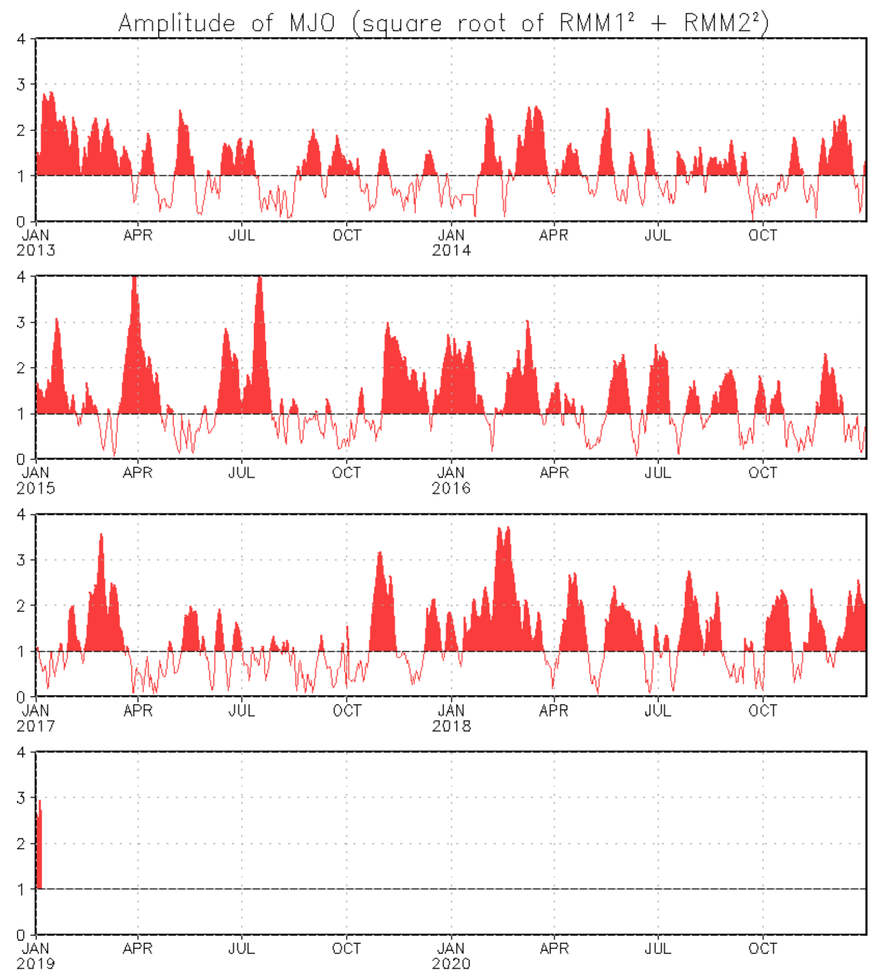
Since its interference with a strong equatorial Rossby wave over the Maritime Continent region between Christmas and New Year's, the MJO signal has propagated rapidly eastward across western and central Pacific.



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

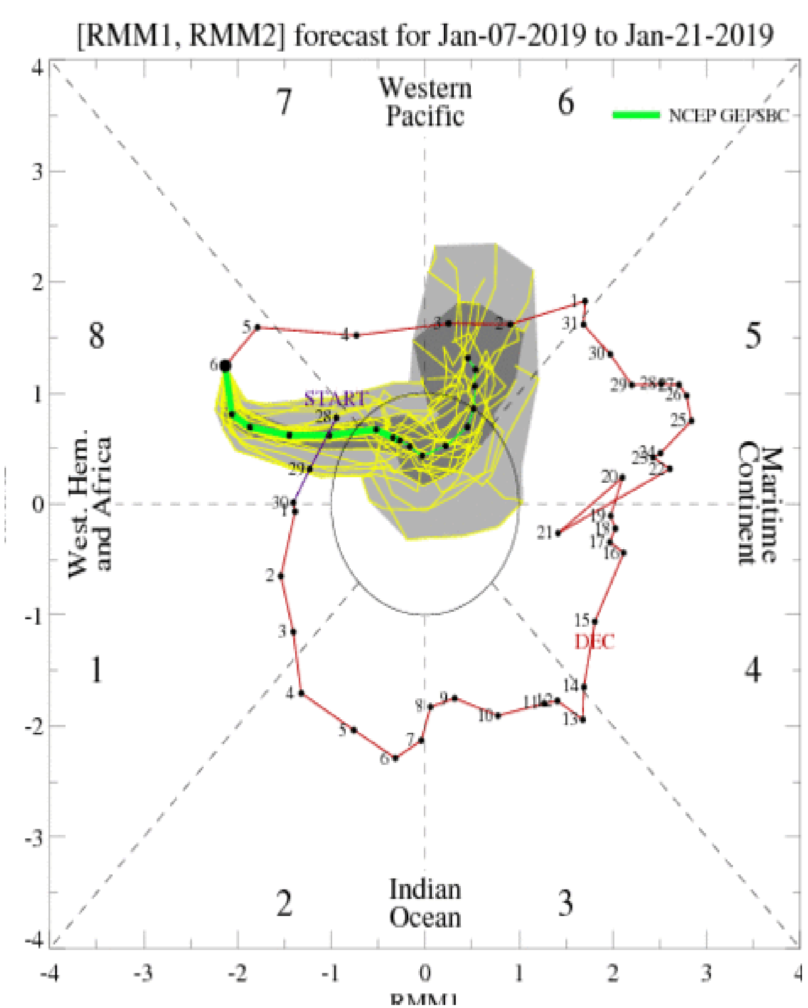
Yellow Lines - 20 Individual Members
Green Line - Ensemble Mean

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 weaken rapidly with little eastward propagation during Week-1. During Week-2, the GEFS predicts the re-emergence of a subseasonal signal over the Western Pacific, with fairly moderate ensemble spread.

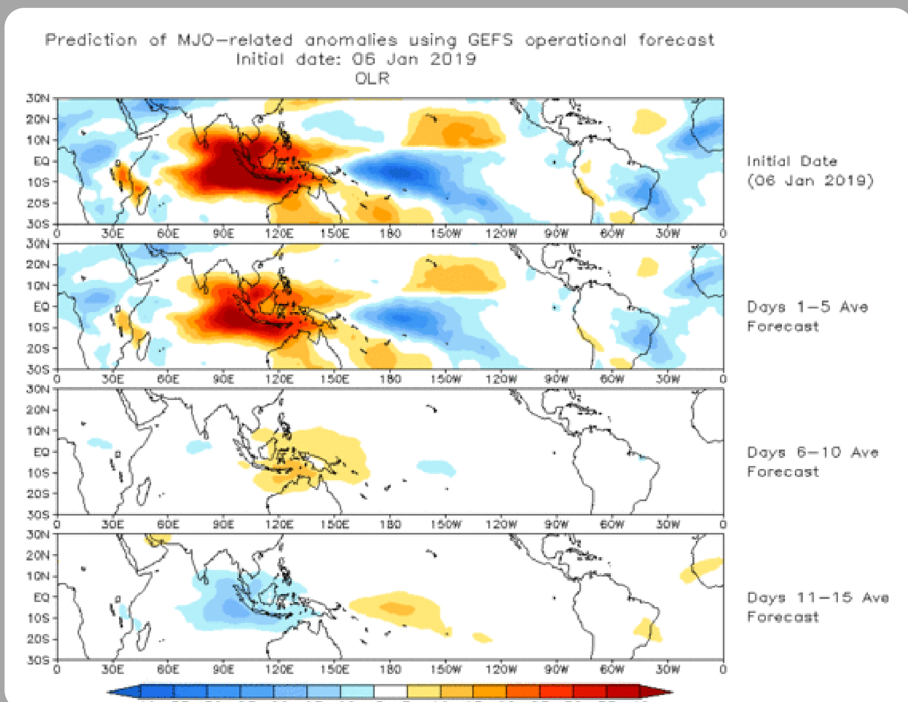


Ensemble GFS (GEFS) MJO Forecast

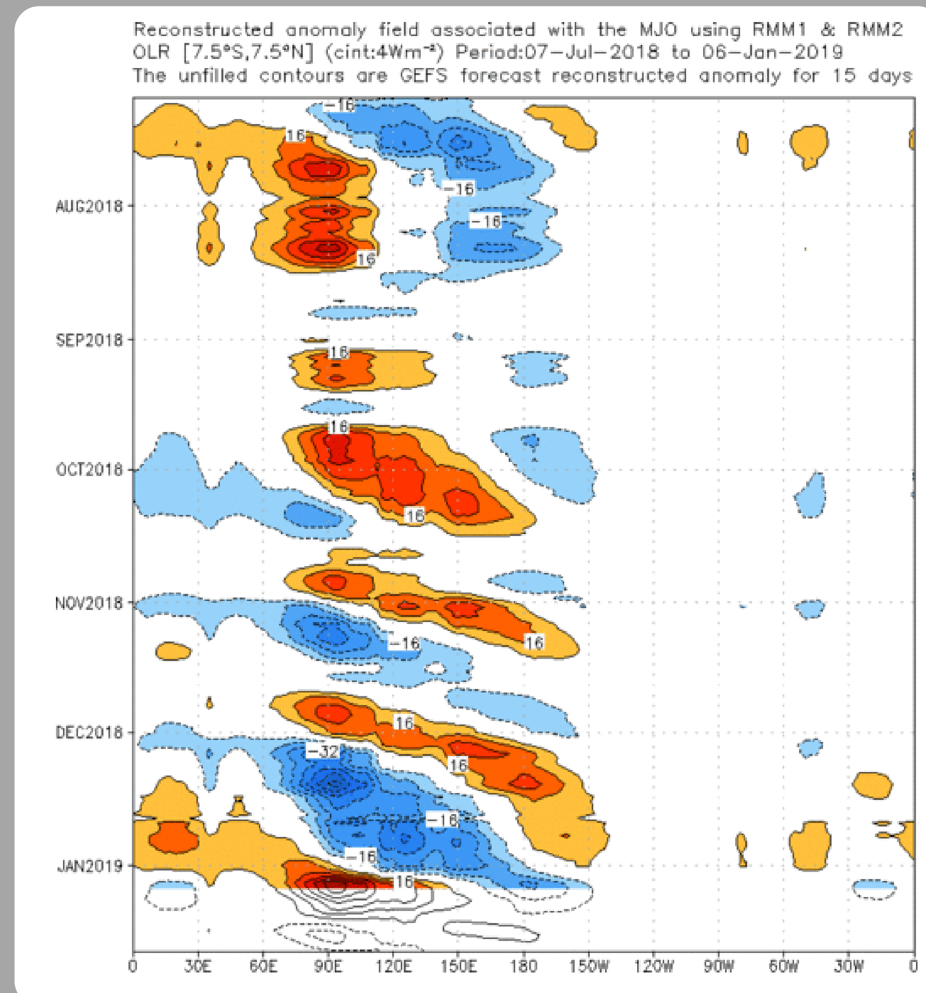
Figures below show MJO associated OLR anomalies only (reconstructed from RMM1 and RMM2) and do not include contributions from other modes (*i.e.*, ENSO, monsoons, etc.)

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



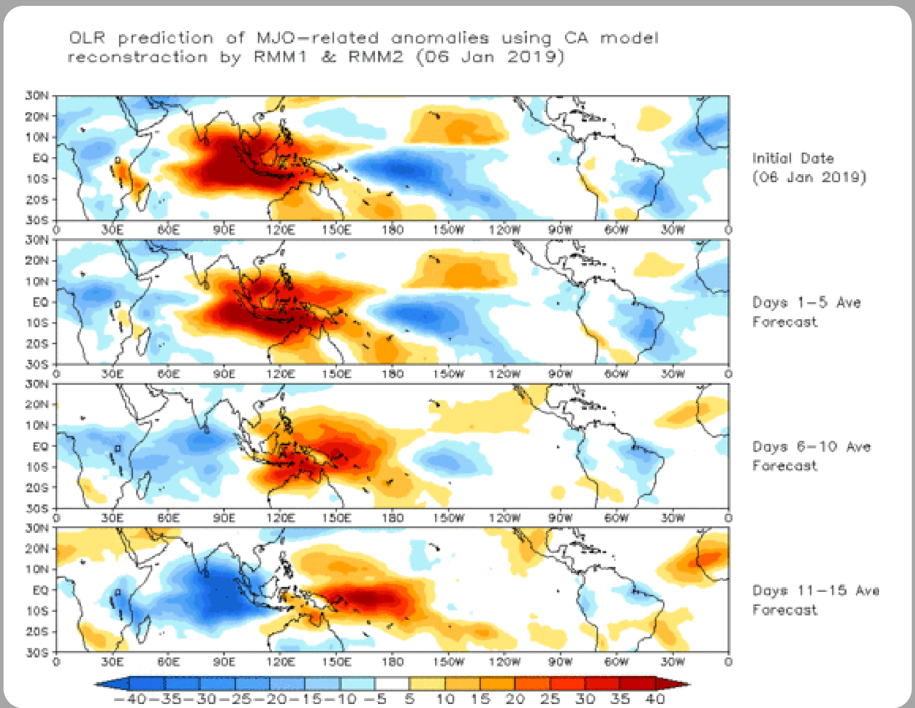
OLR anomalies based on the GEFS RMM-index forecast depict MJO-related convection over the central Pacific during Week-1, while weakening thereafter.



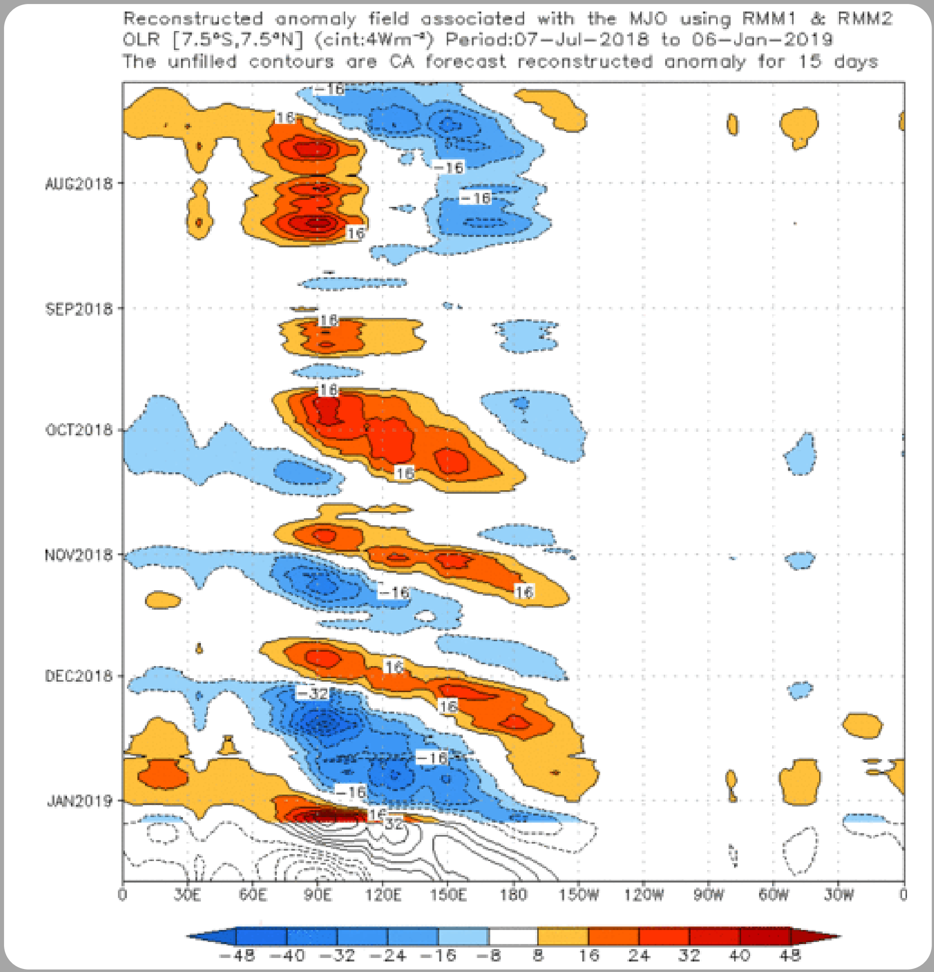
Constructed Analog (CA) MJO Forecast

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



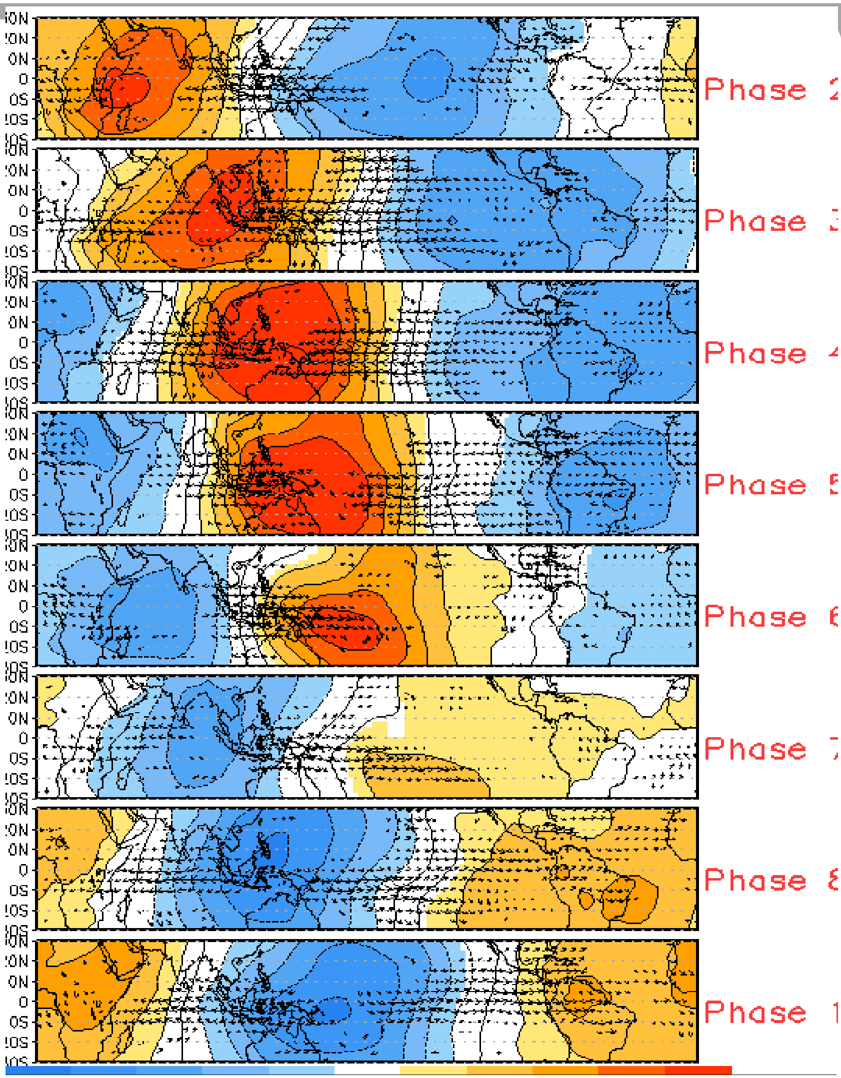
Time-longitude section of (7.5° S-7.5° N) OLR anomalies - last 180 days and for the next 15 days



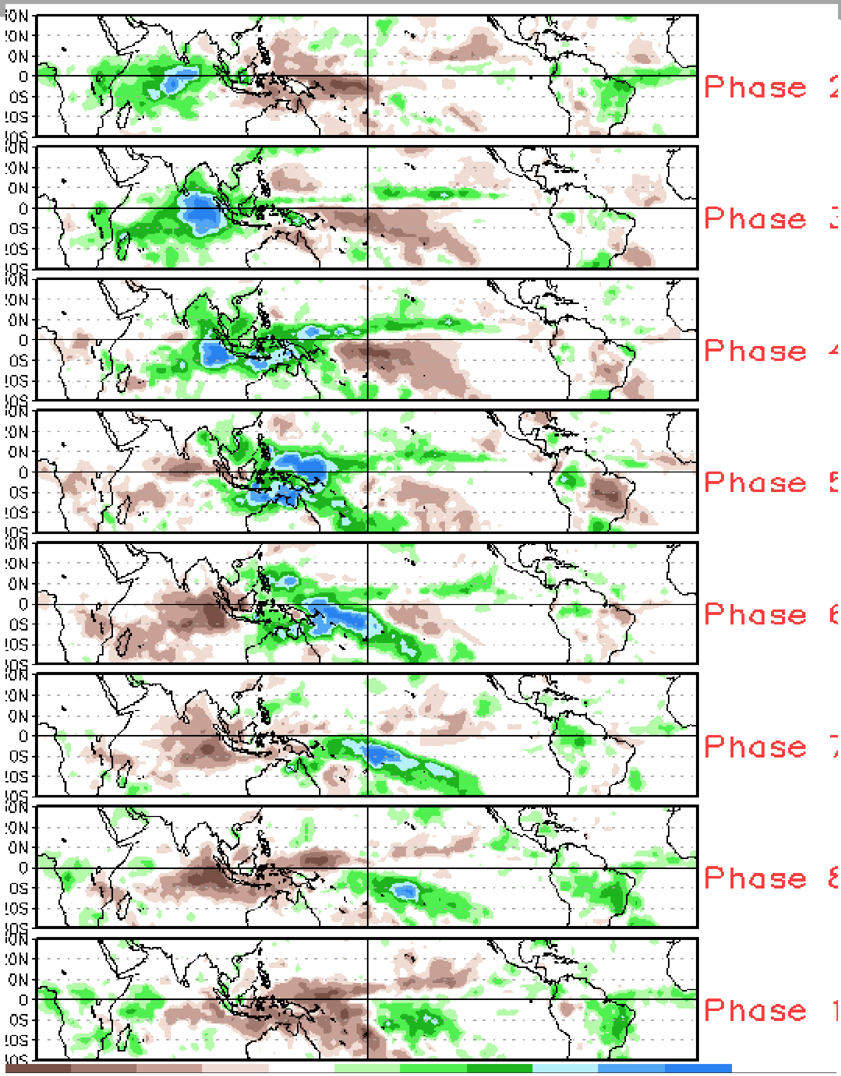
The constructed analog forecast also depicts MJO-related convection over the central Pacific during Week-1 which weakens somewhat with time. This statistical model maintains eastward propagation of the signal back to the Indian Ocean during Week-2.

MJO Composites - Global Tropics

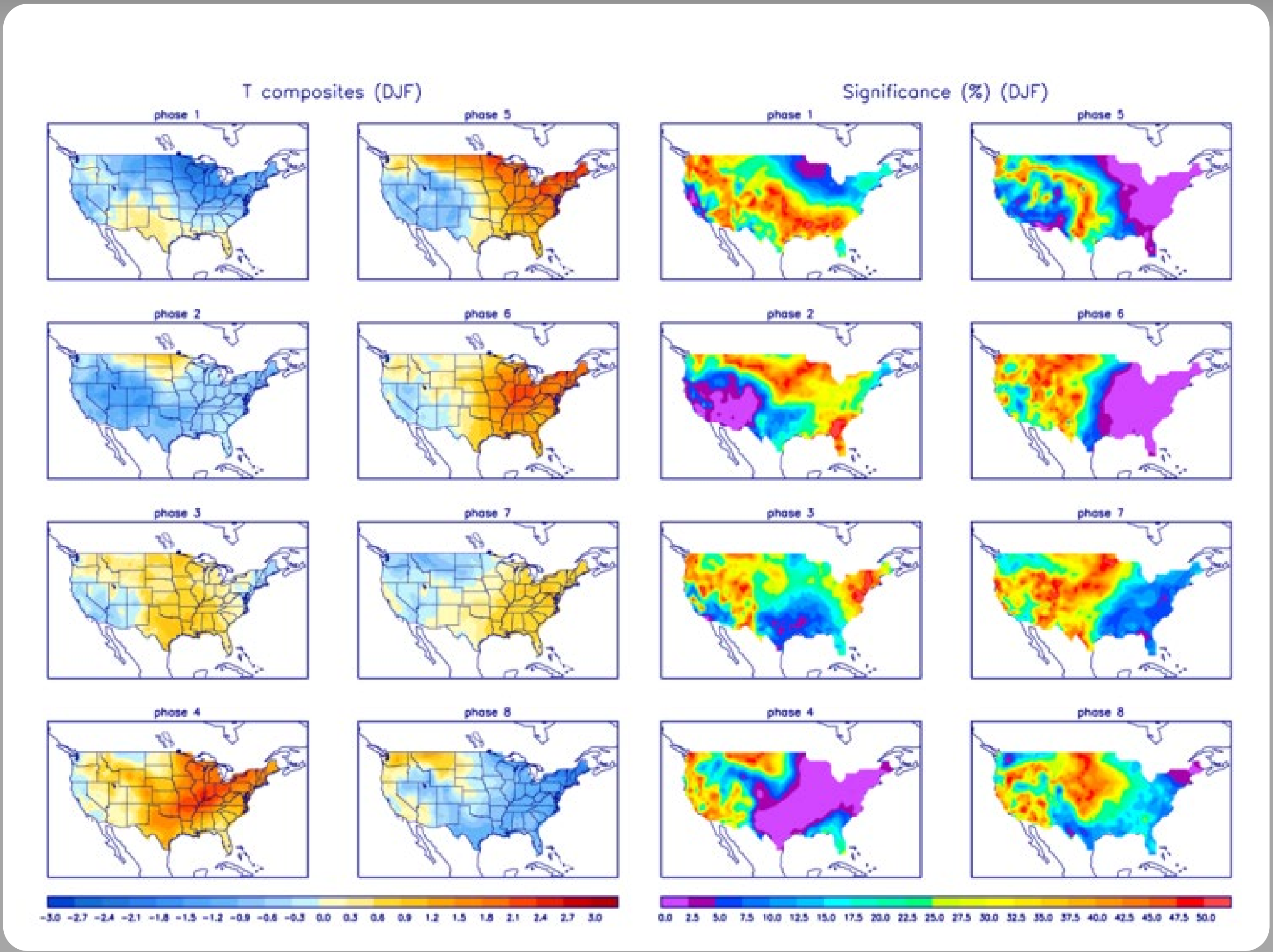
850-hPa Velocity Potential and Wind Anomalies (Nov - Mar)



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.

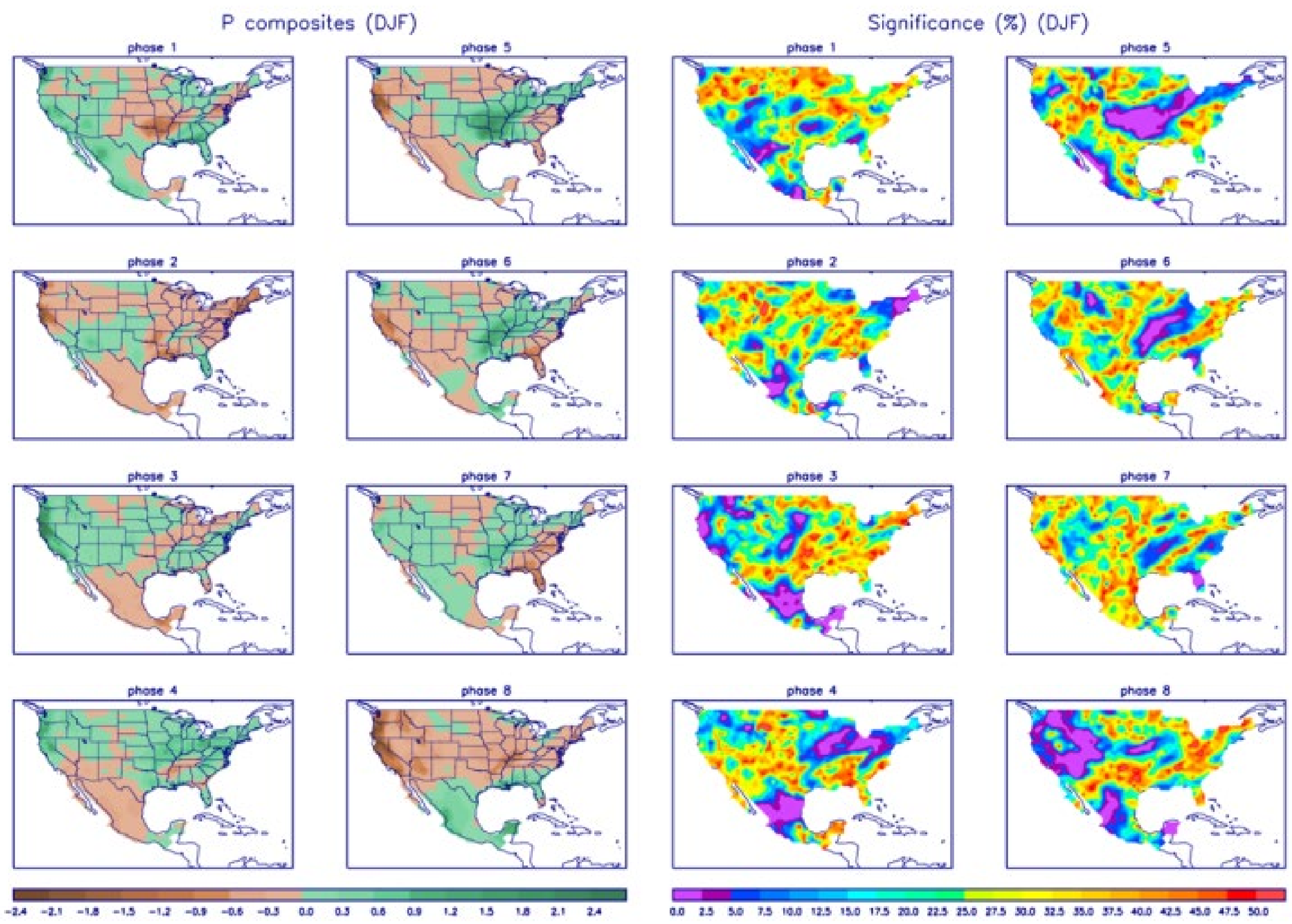
Zhou et al. (2011): A composite study of the MJO influence on the surface air temperature and precipitation over the Continental United States, *Climate Dynamics*, 1-13, doi: 10.1007/s00382-011-1001-9

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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