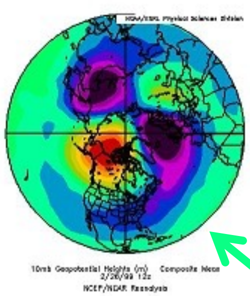
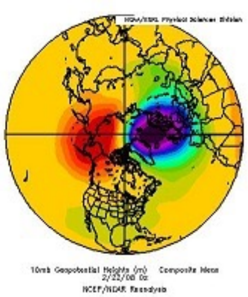
What is the Madden–Julian Oscillation (MJO)?

A planetary-scale, 30–90-day oscillation in zonal wind, surface pressure, and precipitation that propagates slowly eastward.

Wavelength = 12,000–20,000 km **Speed = ~5 m s^{-1}**





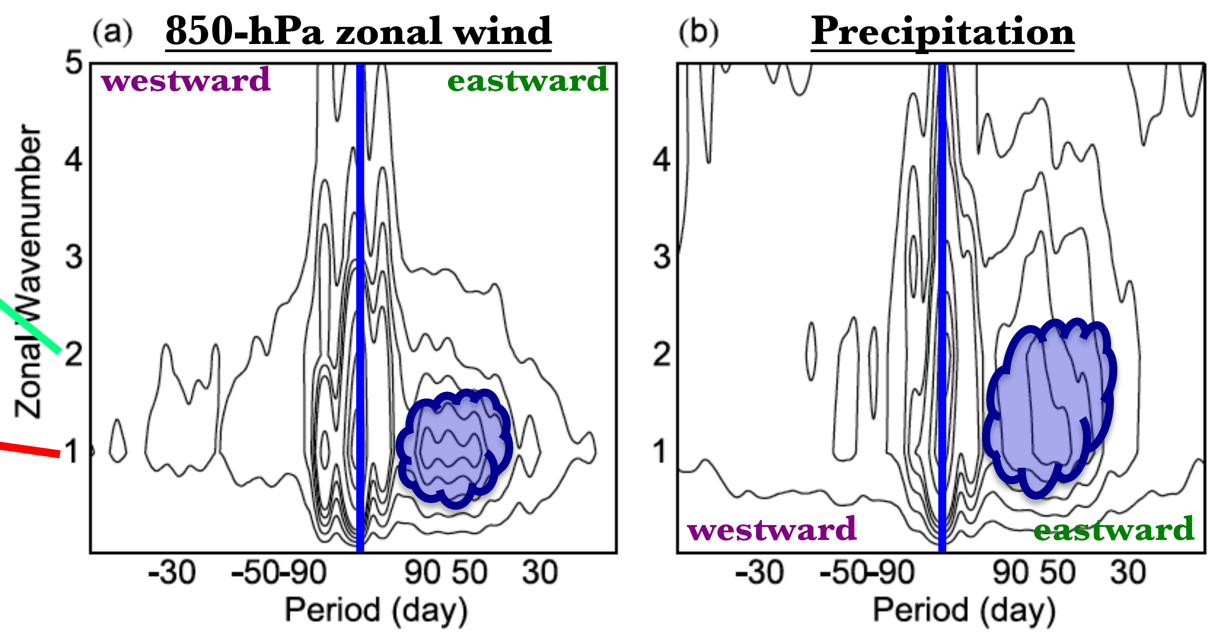
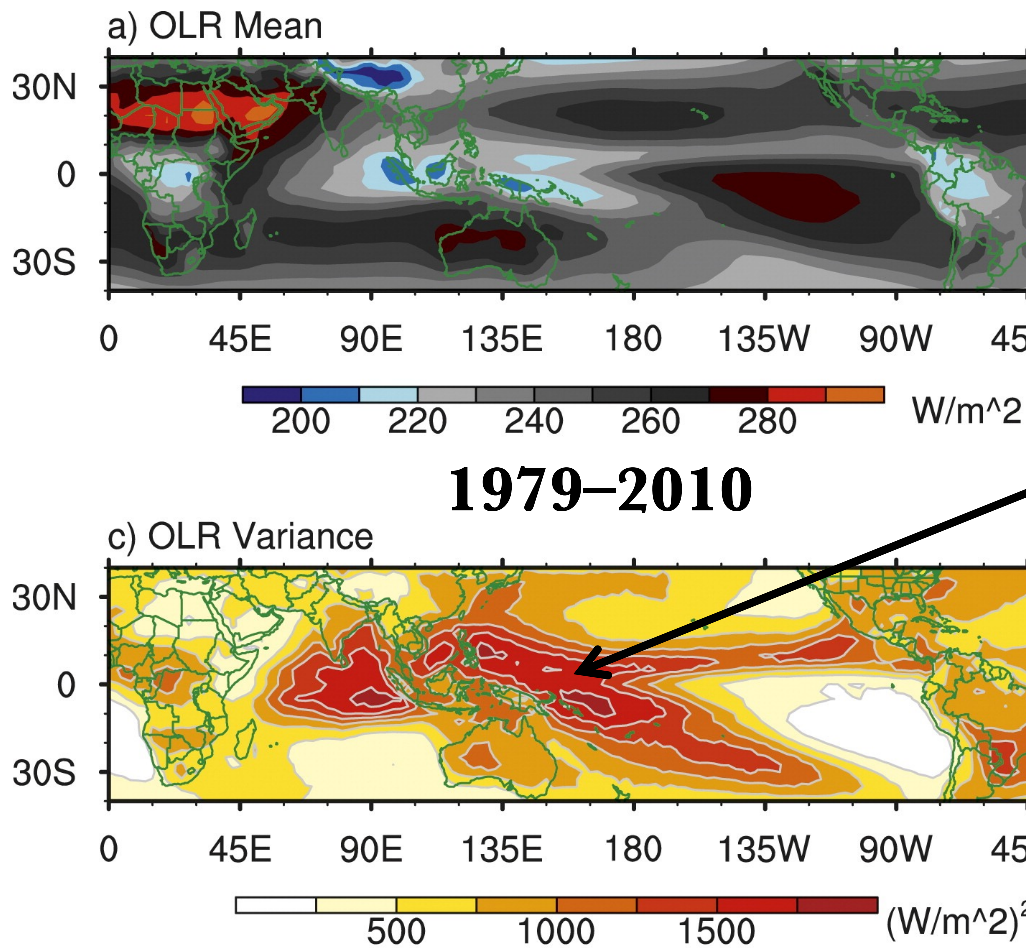


Figure 3. Time-space power spectra of (a) 850 hPa zonal wind (NCEP/NCAR reanalysis) and (b) precipitation [*Xie and Arkin*, 1997] for 1979 through 1998, averaged over 20°N–20°S and 60°–180°E. Positive (negative) periods correspond to eastward (westward) propagating power. Data resolutions for the spectra are pentad in time and 10° in longitude.

Zhang (2005)

What is the Madden–Julian Oscillation (MJO)?

The dominant mode of *intraseasonal* convective variability in the tropics.



How much of this variance can be explained by the MJO?

Schreck et al. (2013)

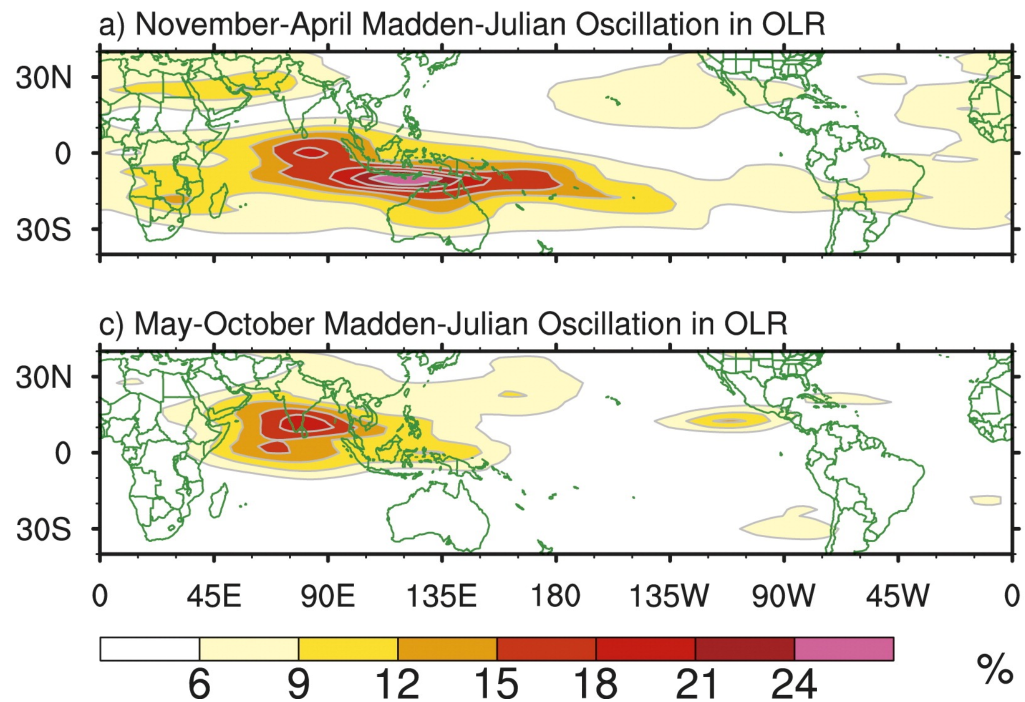
What is the Madden–Julian Oscillation (MJO)?

The dominant mode of *intraseasonal* convective variability in the tropics.

The convective signal of the MJO is strongest over the Indian and Pacific oceans.

The MJO is strongest in the Southern Hemisphere summer.

The convective signature is largest 10–15° north/south of the Equator.



Percentage of OLR variance associated with the MJO (above), ER waves (upper left), and Kelvin waves (lower left)

Schreck et al. (2013)

What is the Madden–Julian Oscillation (MJO)?

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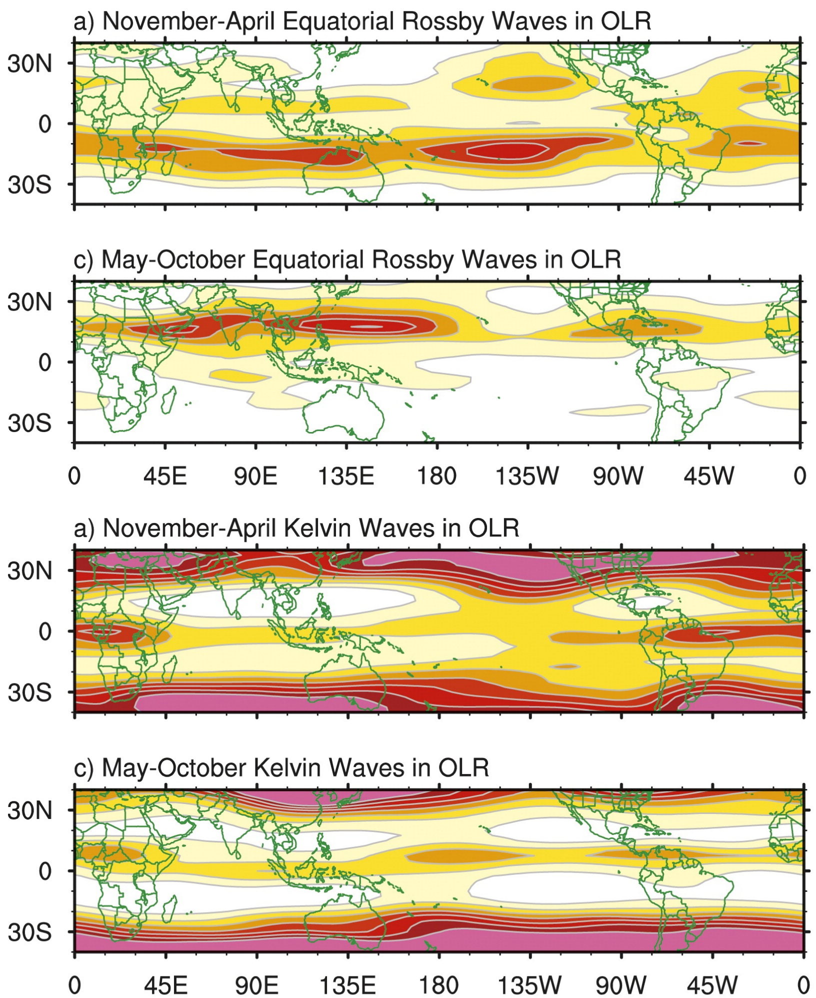
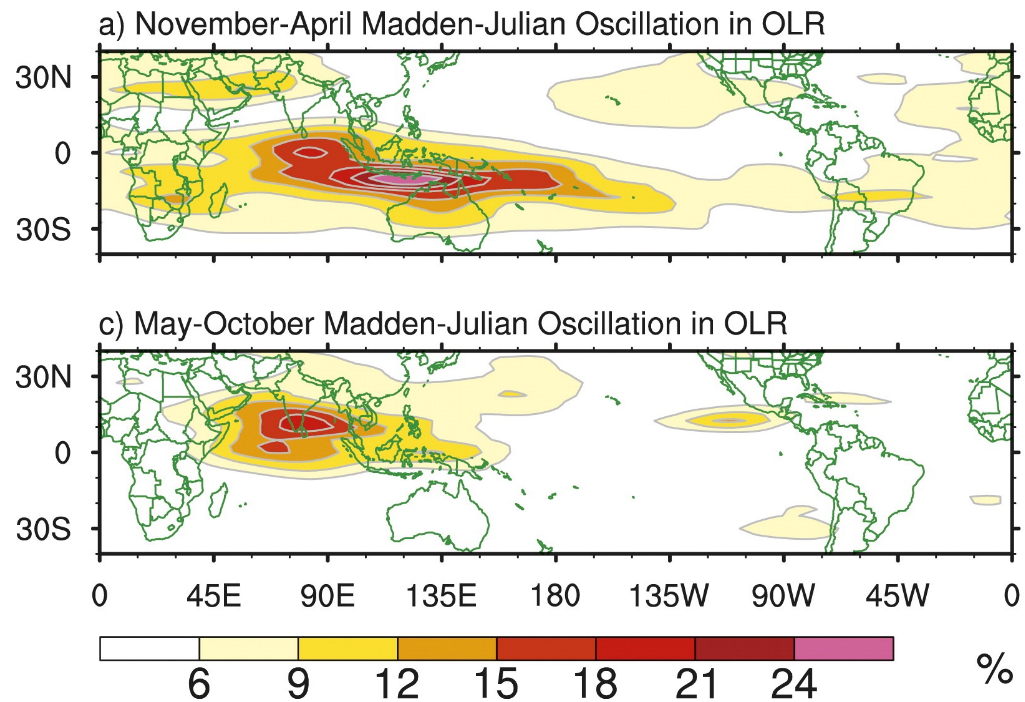




Percentage of OLR variance associated with the MJO (above), ER waves (upper left), and Kelvin waves (lower left)

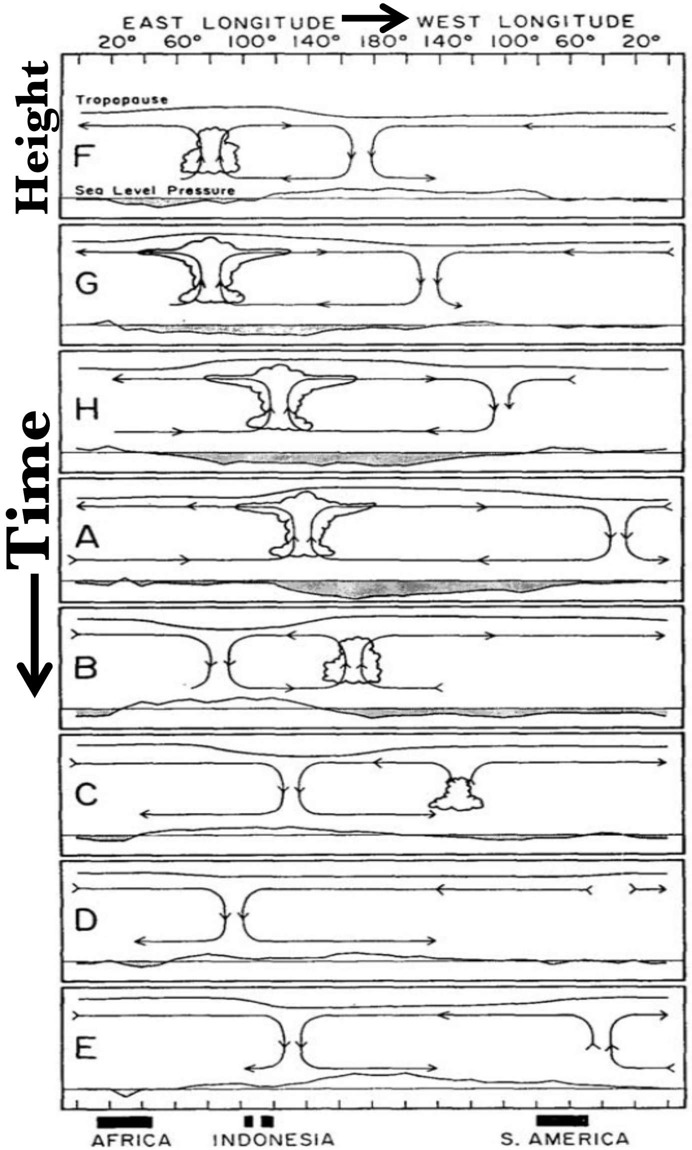
Schreck et al. (2013)

How was the MJO discovered?

In the late 1960s, new computer power at NCAR allowed scientists to look for patterns in weather observations.

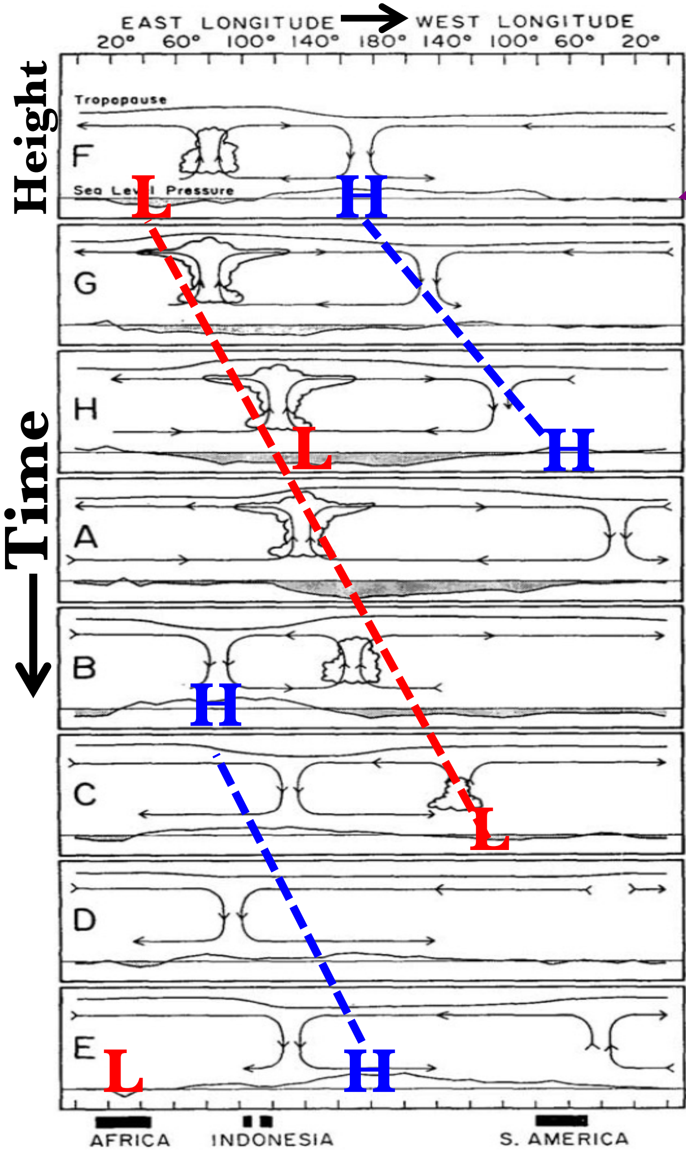
They could only look for patterns in time (at a given location), and not in space (at a given time).

What did Madden and Julian find?



Madden and Julian (1972)

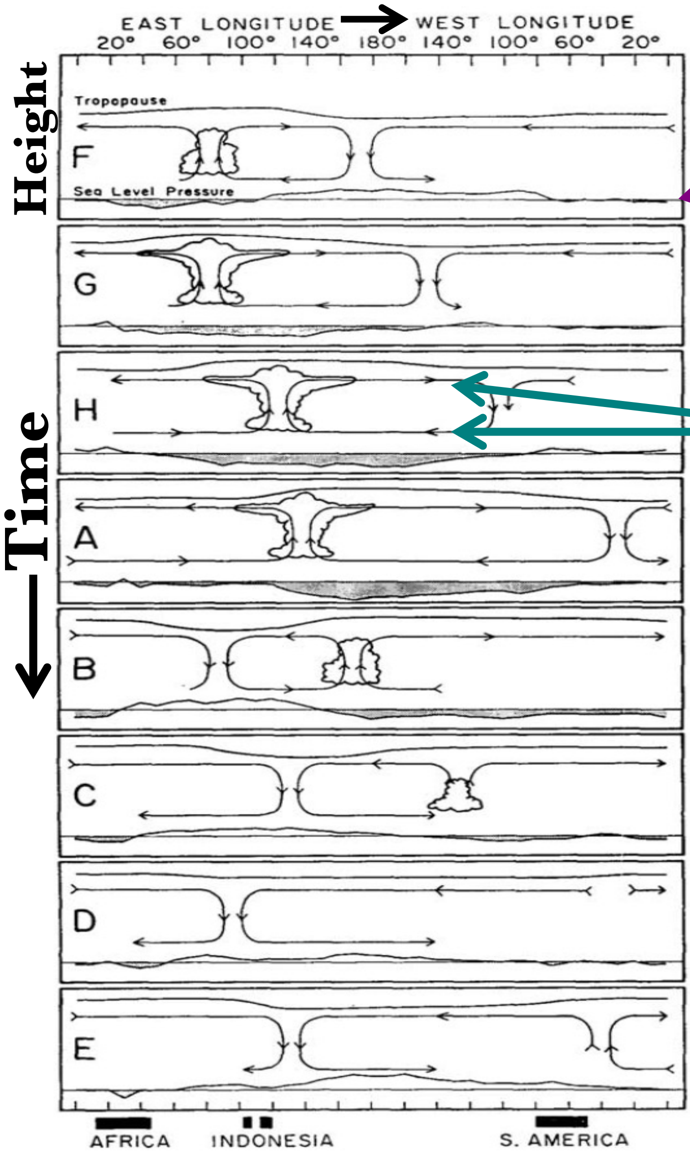
What did Madden and Julian find?



1) **Surface pressure oscillates with a period of 40–50 days.**

Madden and Julian (1972)

What did Madden and Julian find?

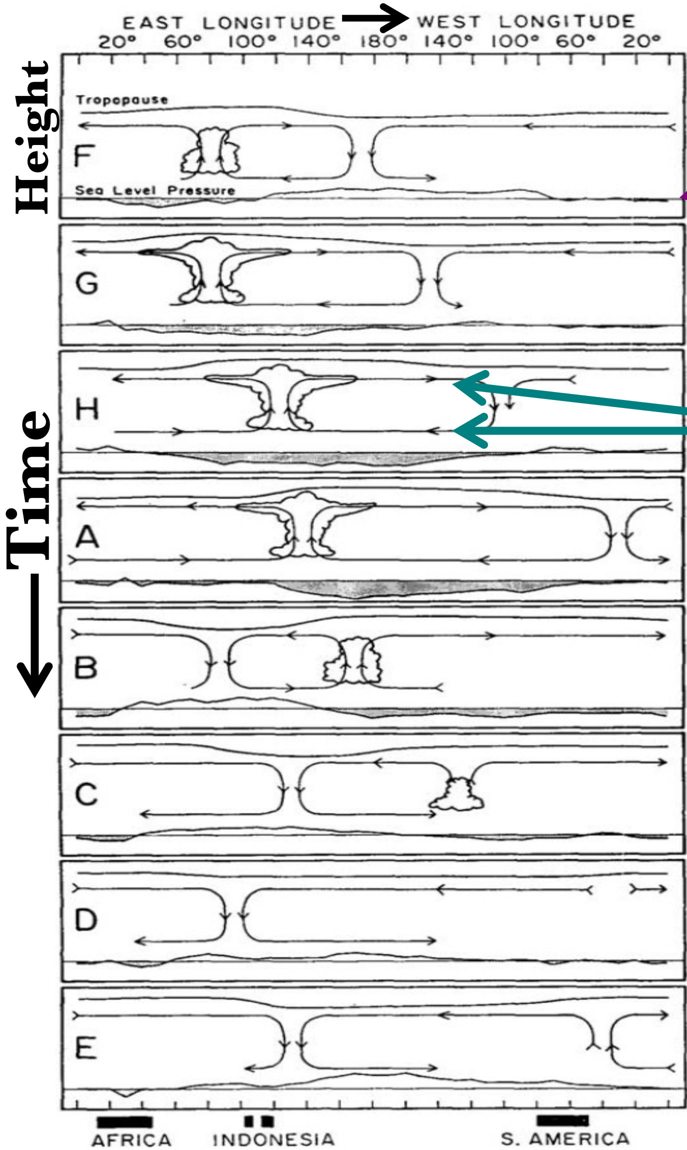


1) **Surface pressure oscillates with a period of 40–50 days.**

2) **Zonal winds in the lower and upper troposphere also oscillate at this frequency, but are 180° out of phase.**

Madden and Julian (1972)

What did Madden and Julian find?



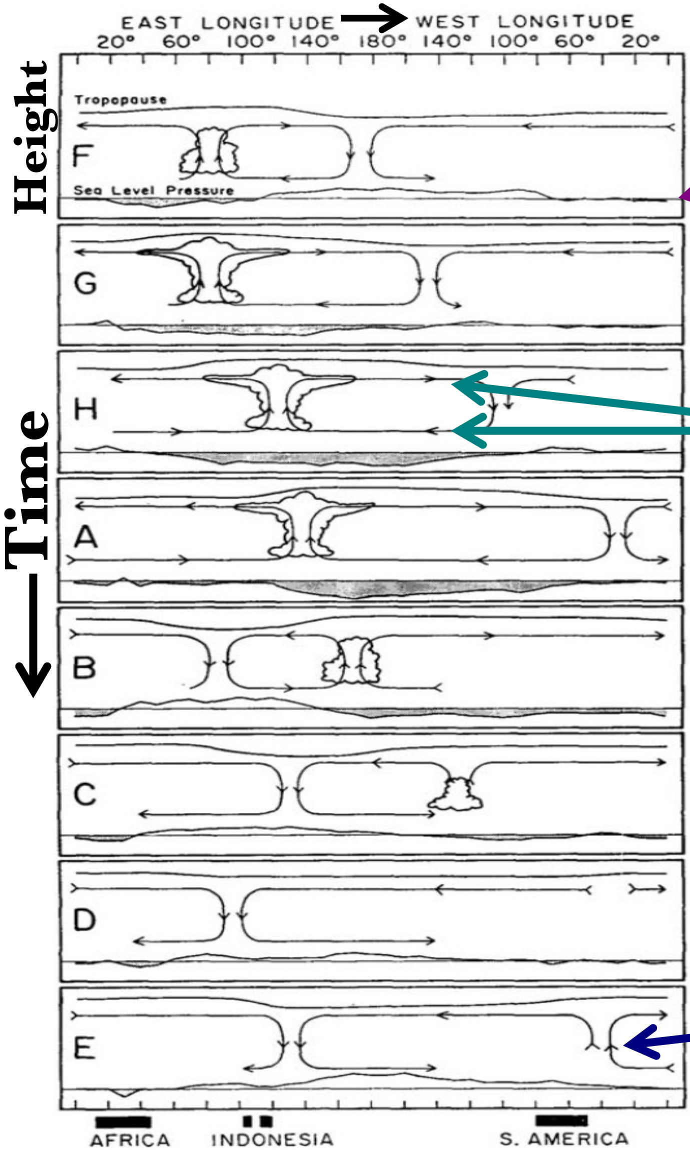
1) **Surface pressure** oscillates with a period of 40–50 days.

2) **Zonal winds** in the **lower and upper troposphere** also oscillate at this frequency, but are 180° out of phase.

3) The signal was **limited** to the deep tropics.

Madden and Julian (1972)

What did Madden and Julian find?



1) Surface pressure oscillates with a period of 40–50 days.

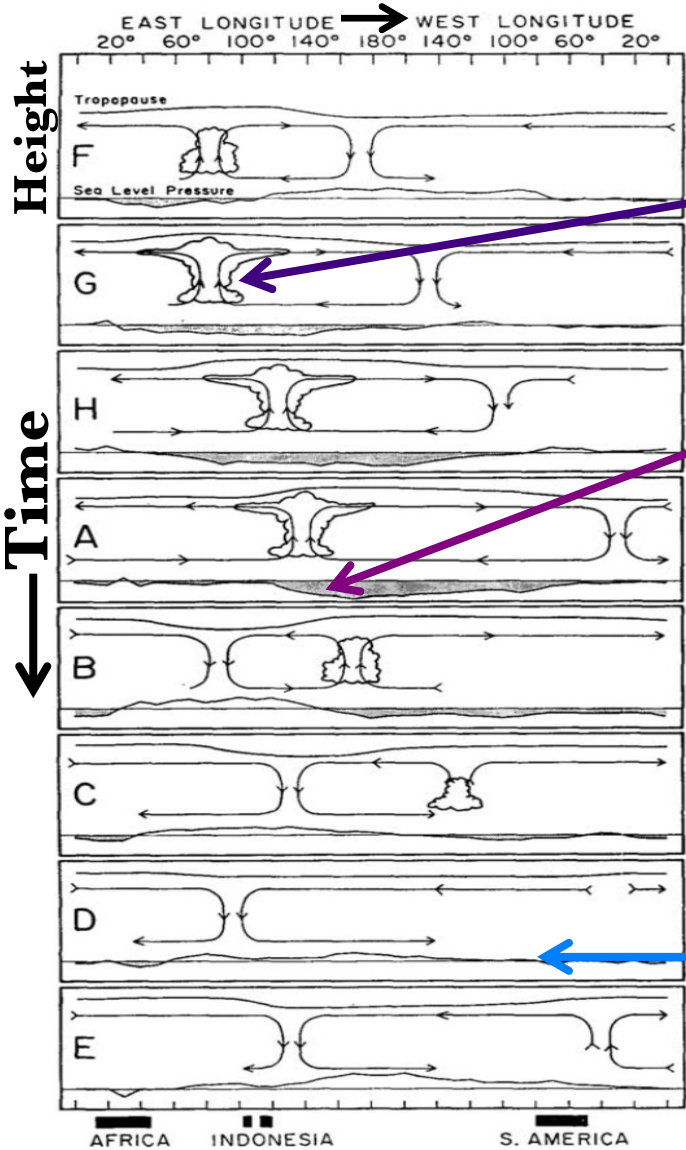
2) Zonal winds in the lower and upper troposphere also oscillate at this frequency, but are 180° out of phase.

3) The signal was limited to the deep tropics.

4) There was little signal in the meridional winds and in the zonal winds in the mid-troposphere.

Madden and Julian (1972)

How did they interpret their findings?



1) The MJO is a region of low-level **convergence** and, thus, **convection**.

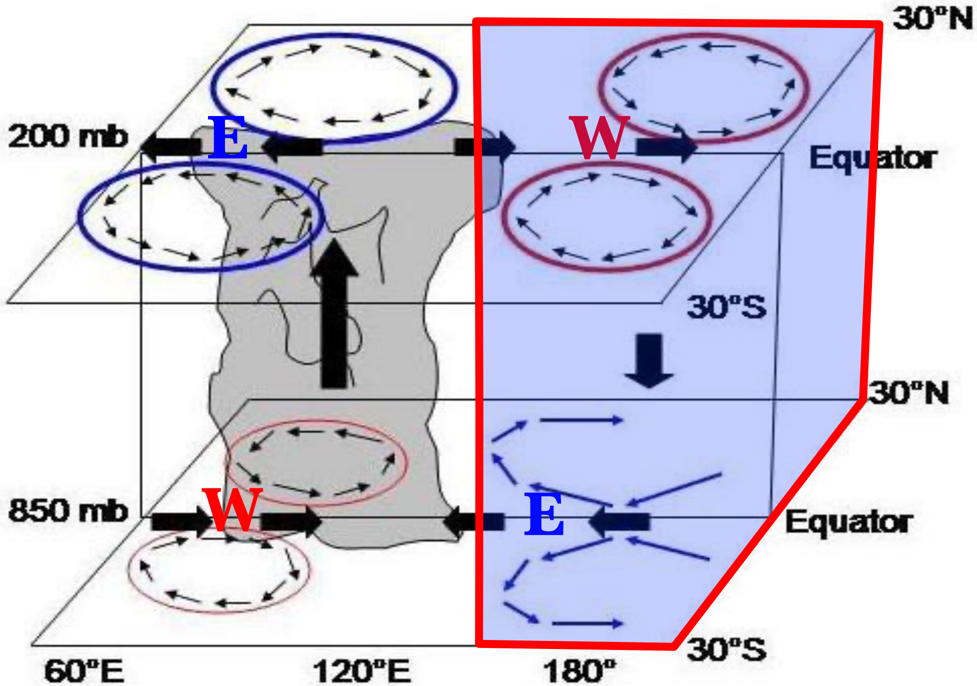
2) **Pressure** is low in the regions of strong **convection**.

3) The **convection** only propagates eastward.

4) The circulation associated with the MJO circumnavigates the globe in ~40 days, but the convection **weakens** as it moves into the Western Hemisphere.

Madden and Julian (1972)

Schematic of MJO structure

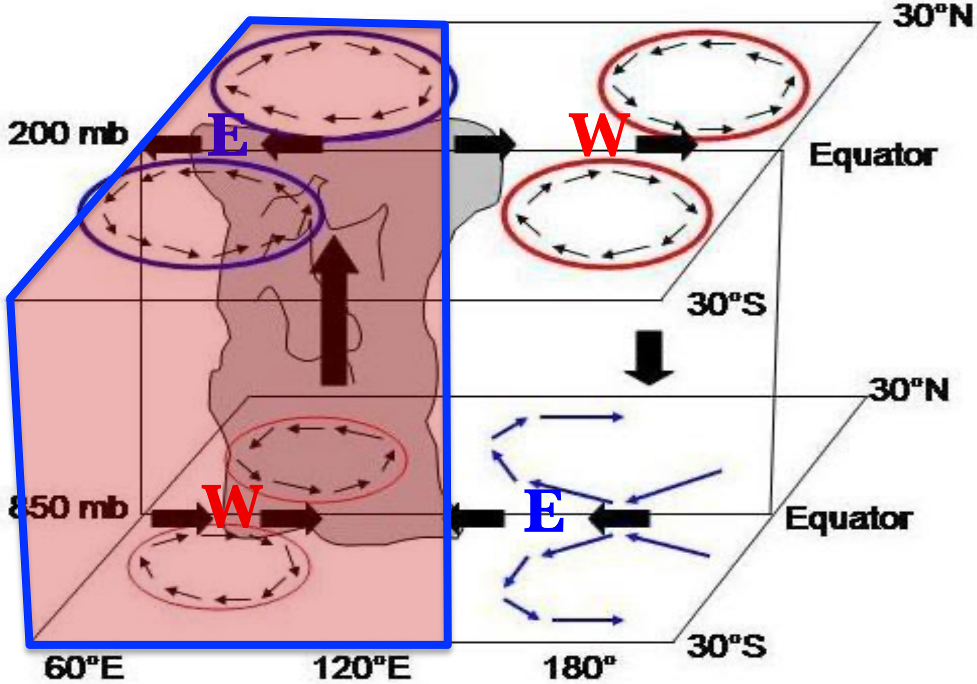


As the convection approaches, easterly (westerly) trade winds are enhanced at the Equator at low levels (aloft).

This enhanced flow creates counter-rotating vortices to the north and south = shear vorticity!

Anticyclones @ low levels   Cyclones @ upper levels

Schematic of MJO structure

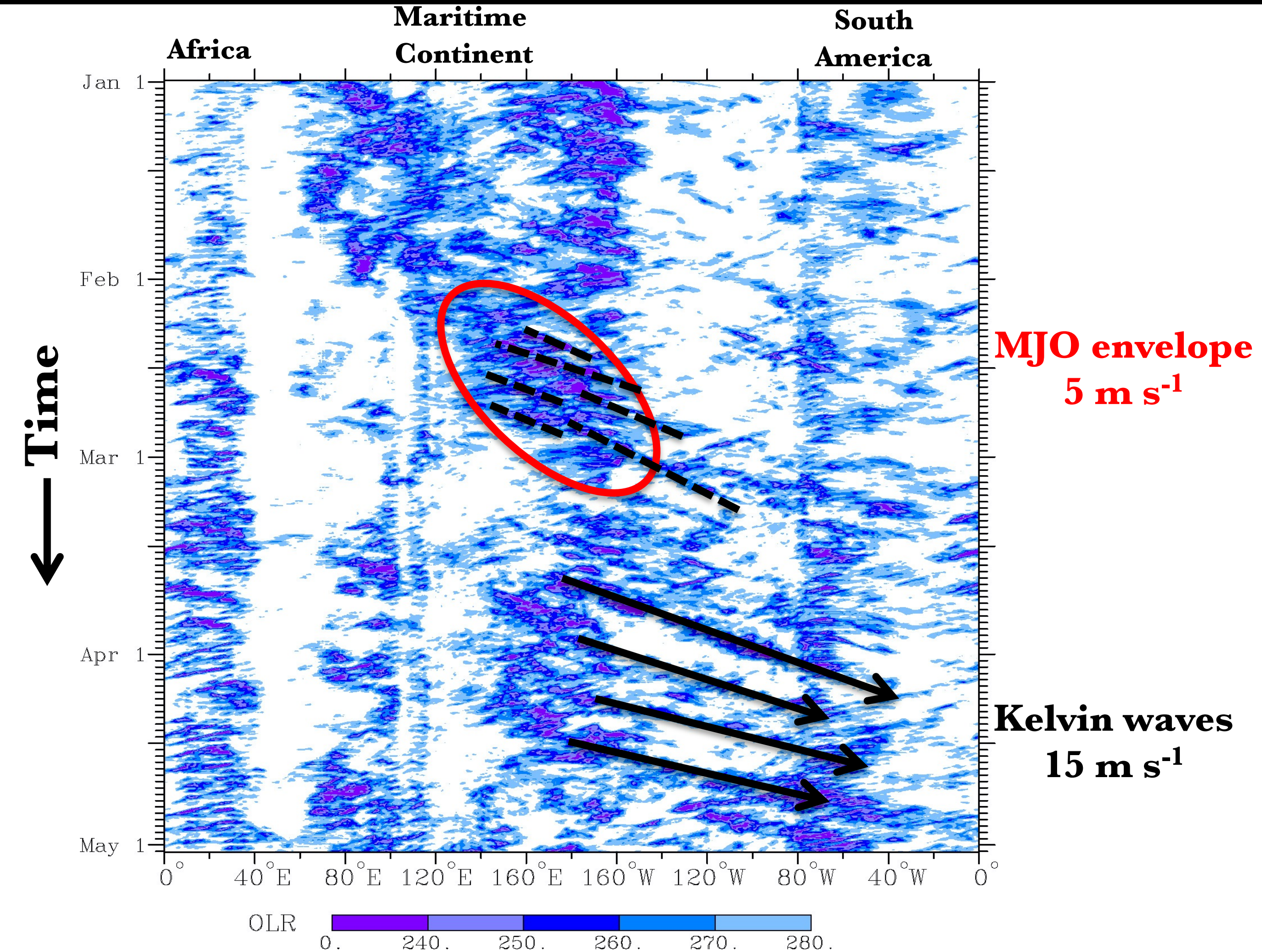


Associated with, and behind the convection, are strong westerly (easterly) winds at low levels (aloft).

Twin cyclones @ low levels   Anticyclones @ upper levels

This structure is reminiscent of a *Rossby wave* to the west of the convection, and of a *Kelvin wave* to the east of the convection.

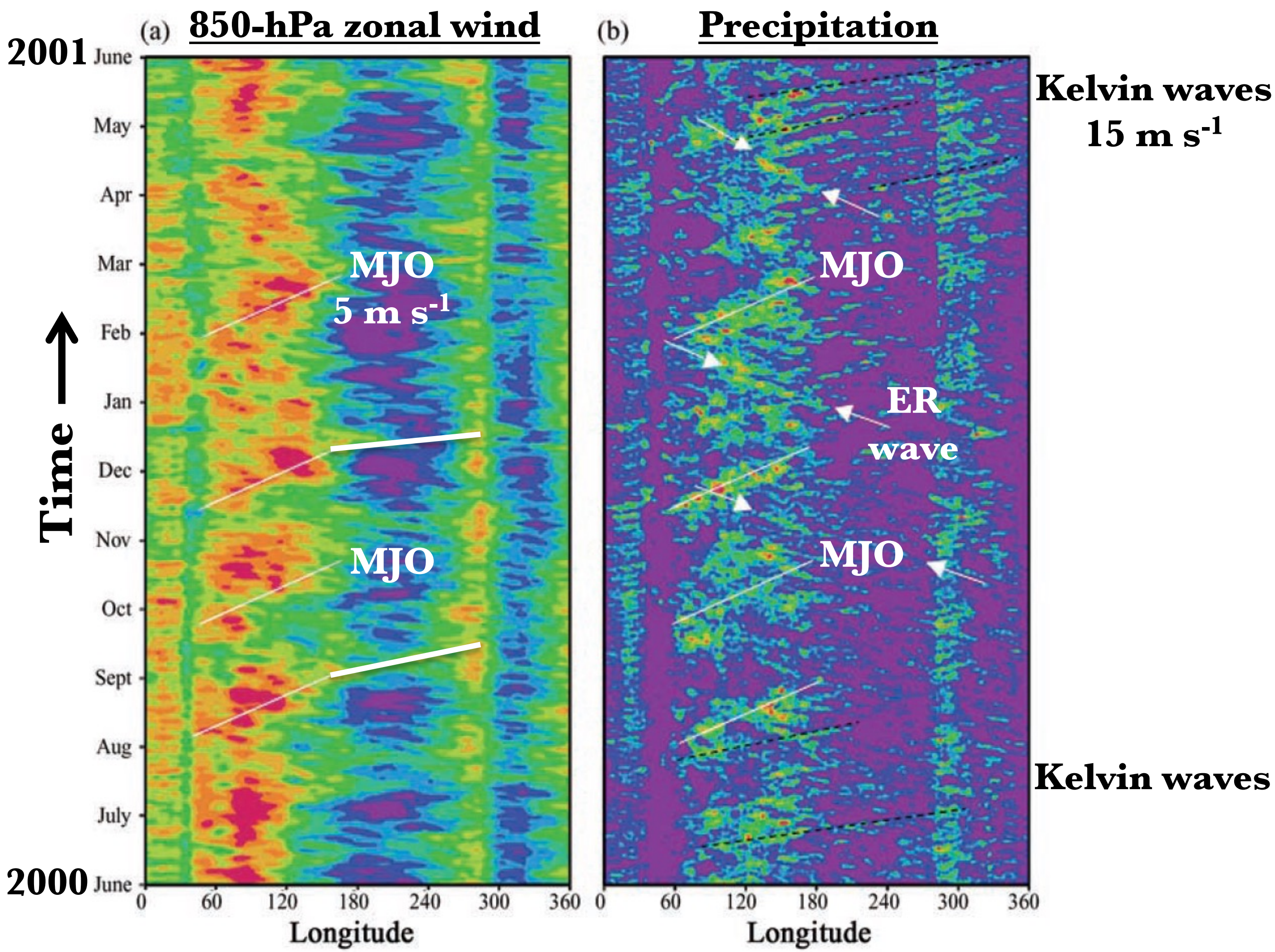
Observations of the MJO: Unfiltered



1 January – 1 May 1987

CLAUS Brightness Temperature averaged 2.5° S–7.5° N

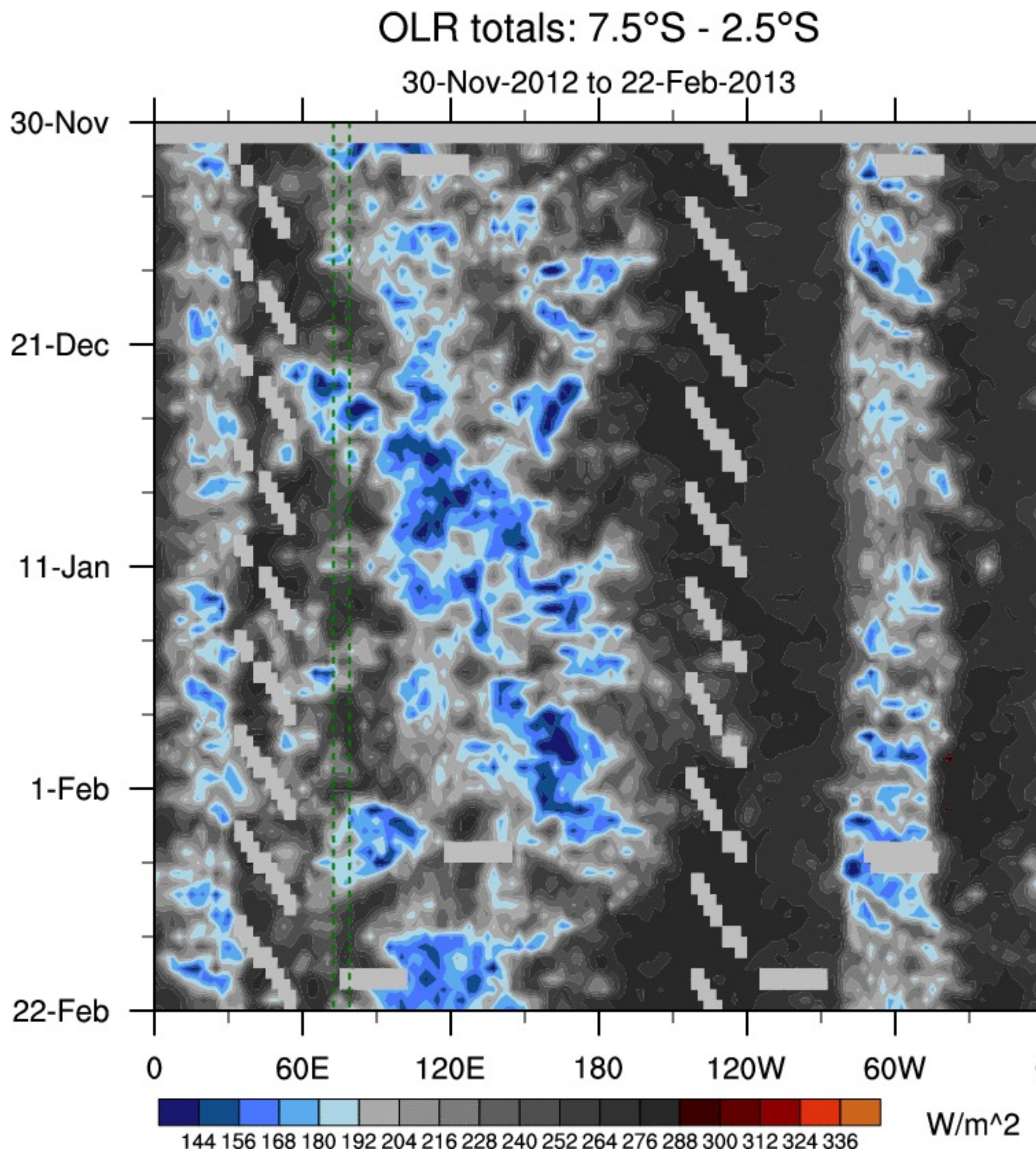
Observations of the MJO: Unfiltered



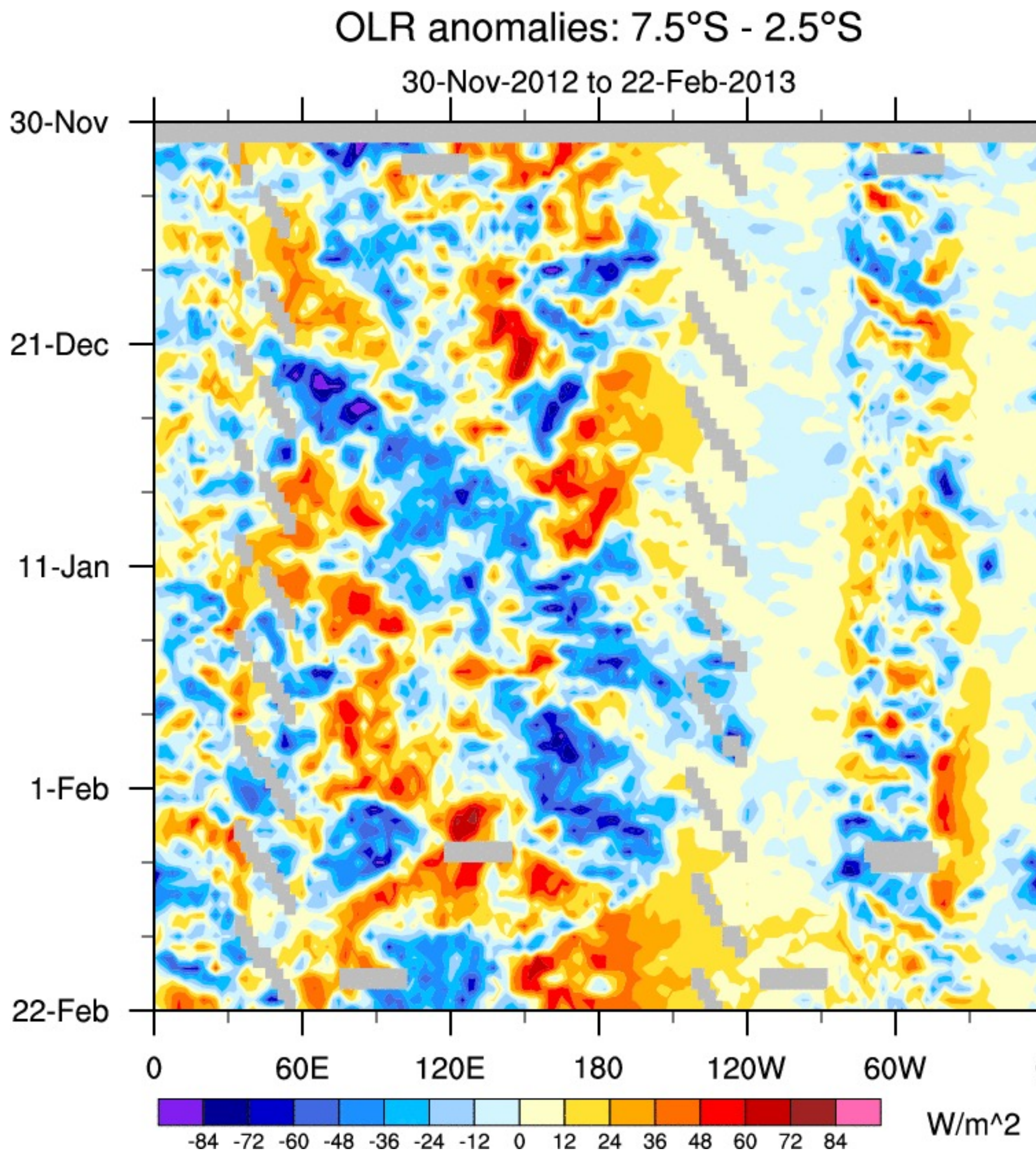
Warm colors = westerly winds and heavy rainfall
Cool colors = easterly winds and no rain

Zhang (2005)

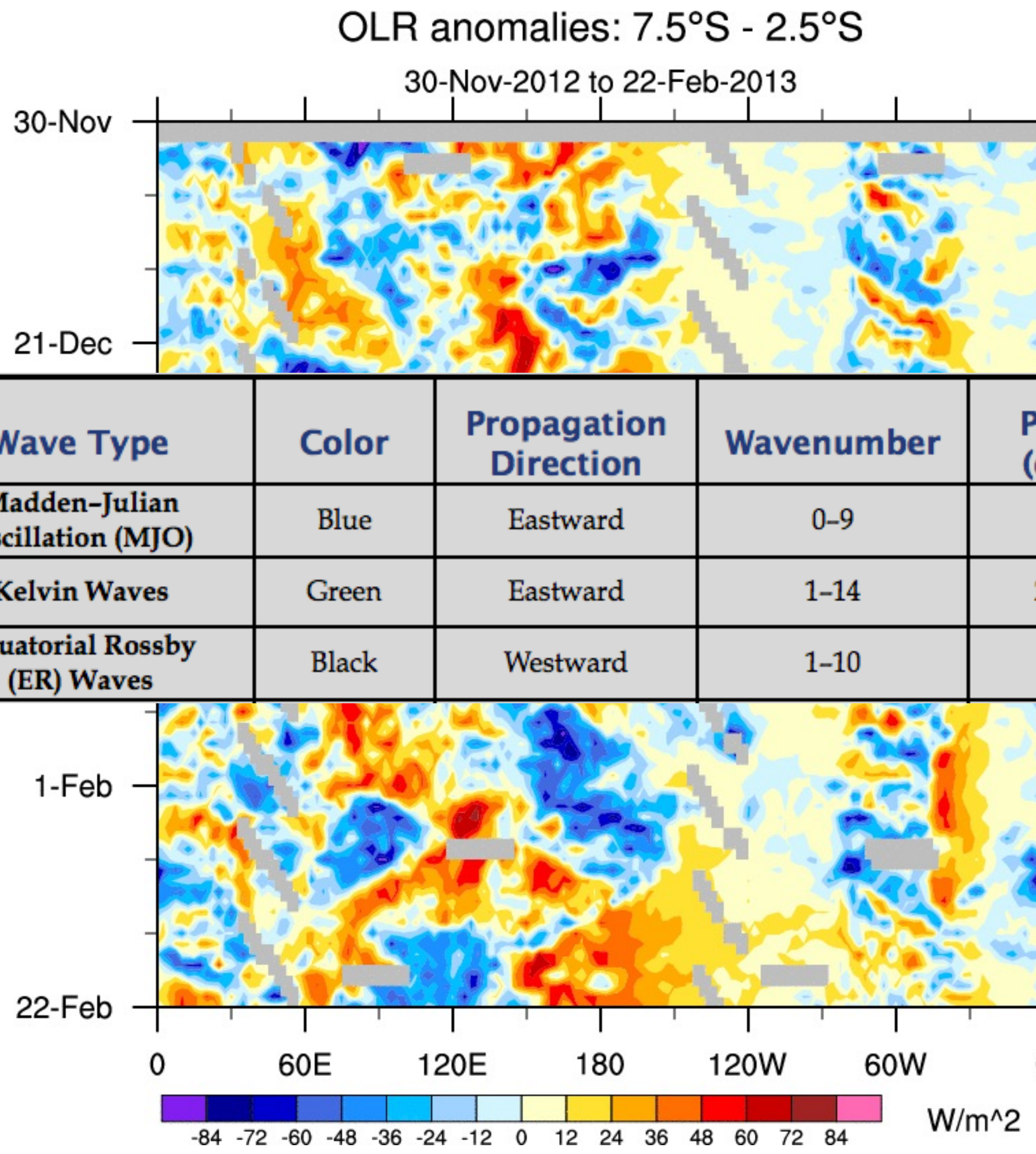
Observations of the MJO: Filtered



Observations of the MJO: Filtered

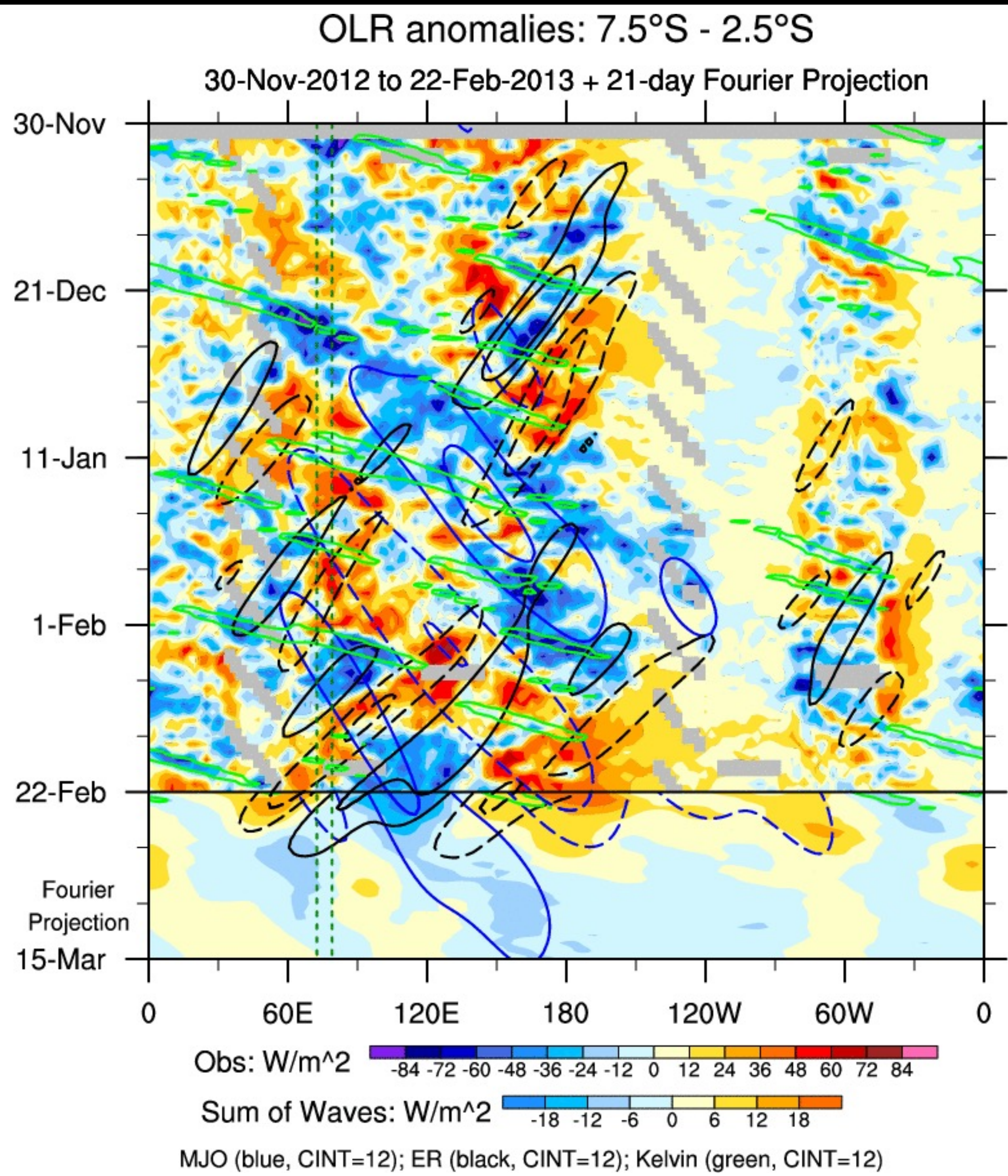


Observations of the MJO: Filtered

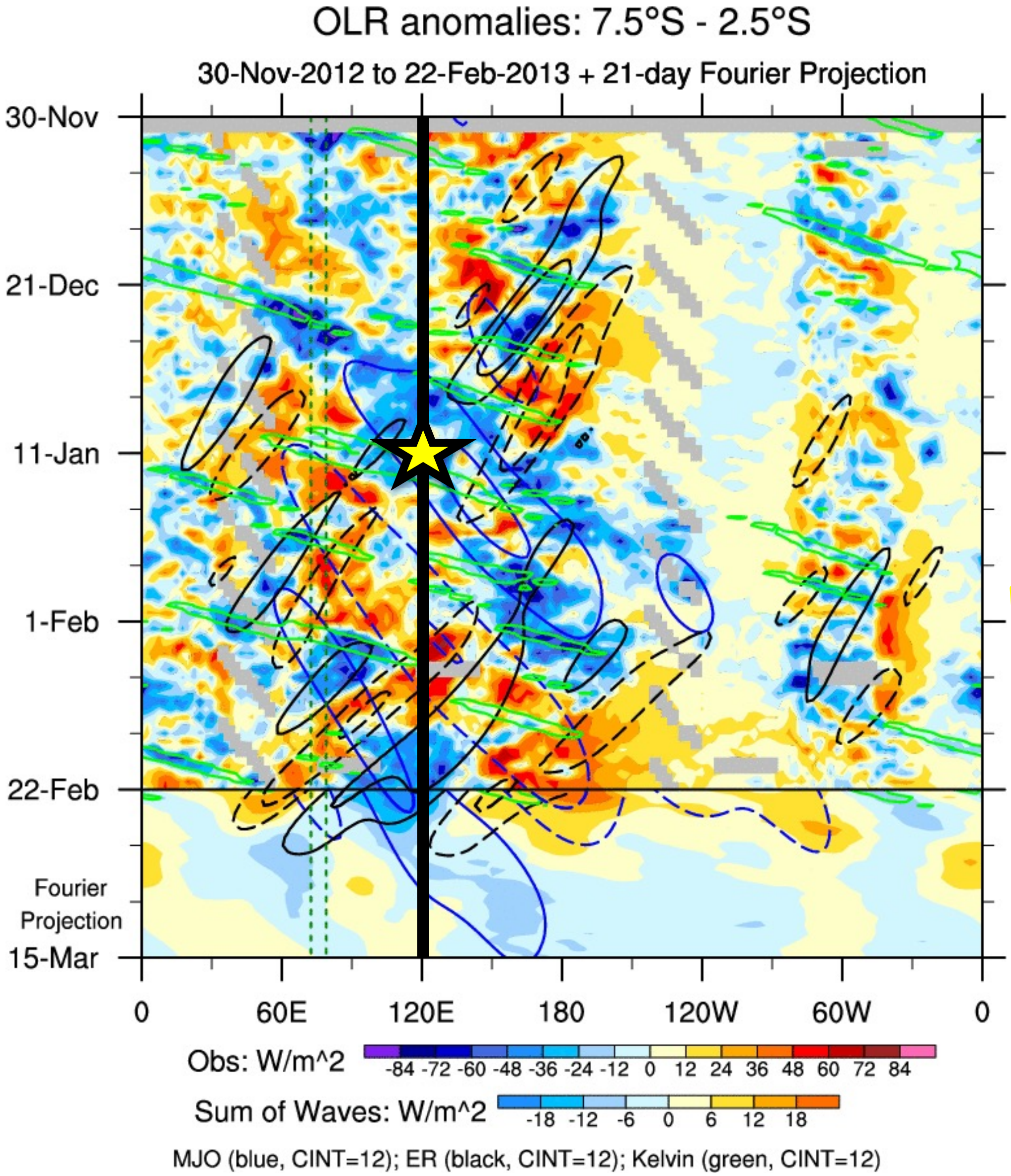


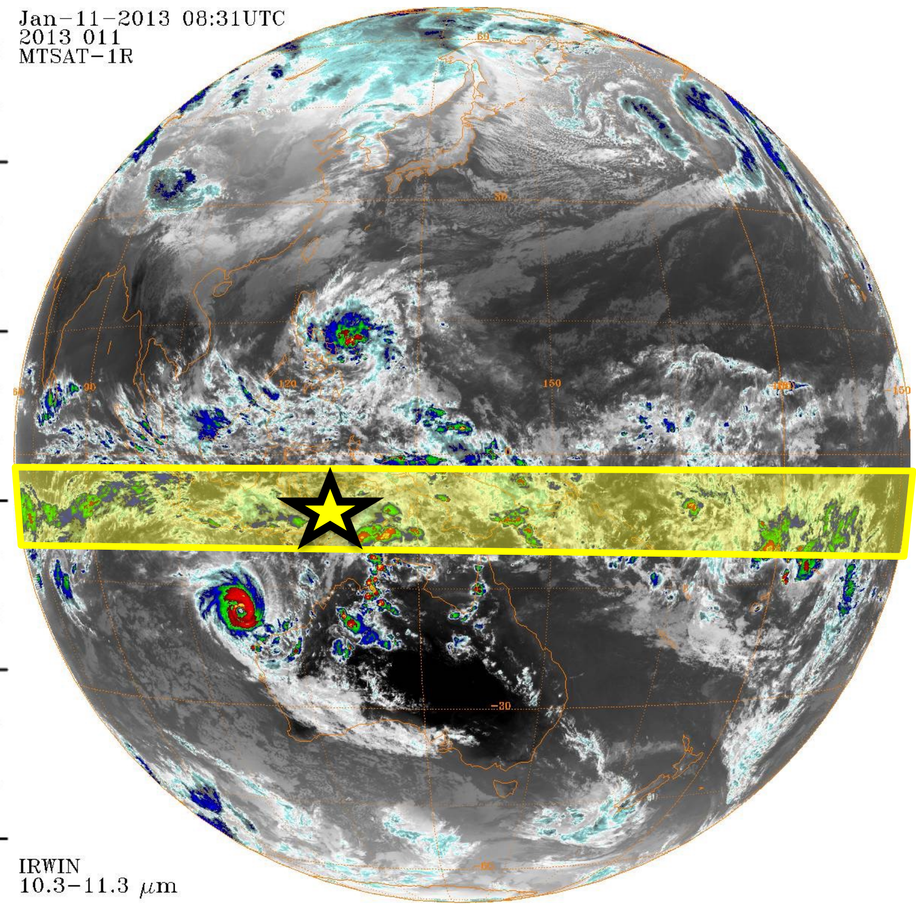
Wave Type	Color	Propagation Direction	Wavenumber	Period (days)
Madden-Julian Oscillation (MJO)	Blue	Eastward	0–9	30–96
Kelvin Waves	Green	Eastward	1–14	2.5–17
Equatorial Rossby (ER) Waves	Black	Westward	1–10	9–72

Observations of the MJO: Filtered

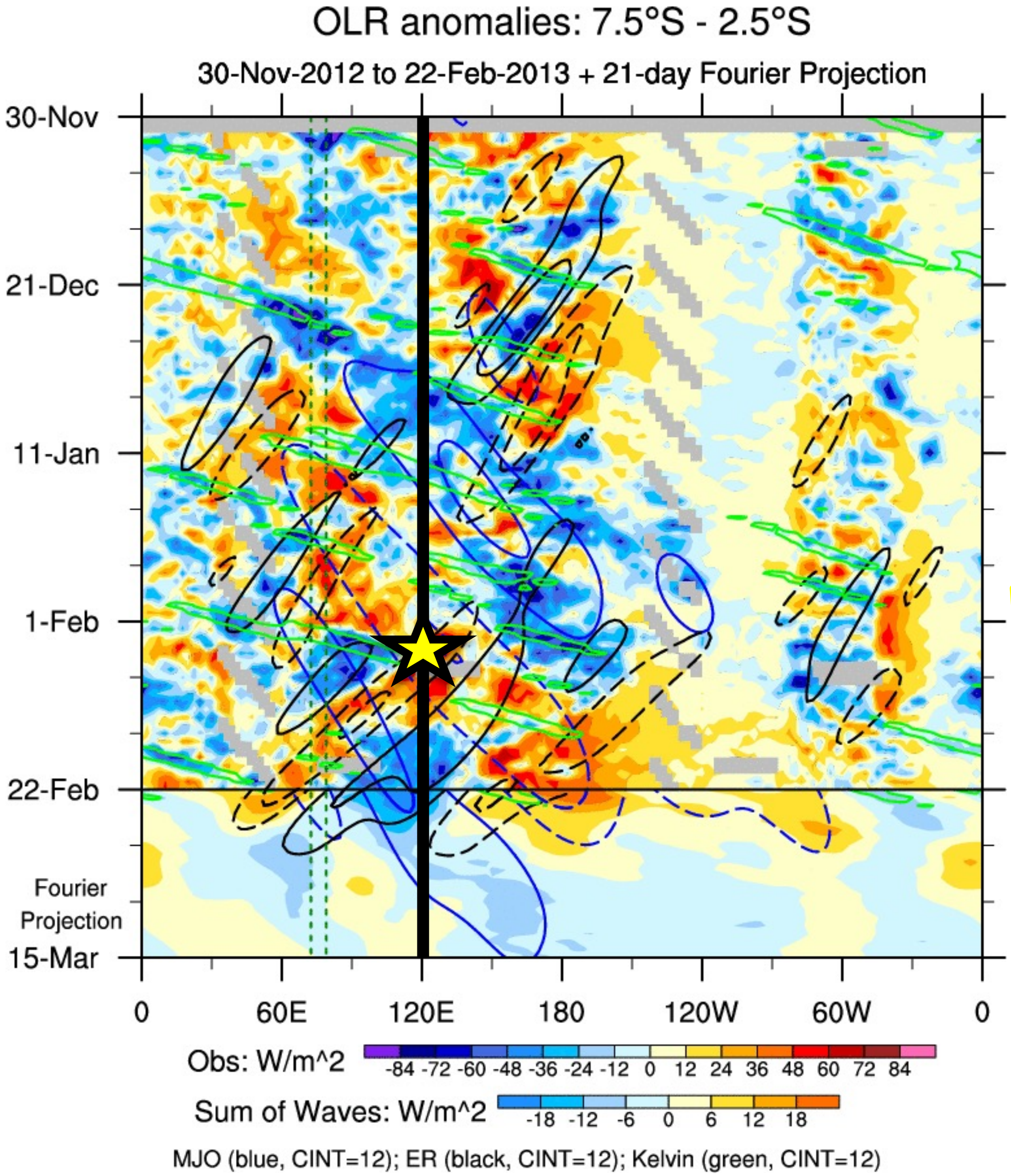


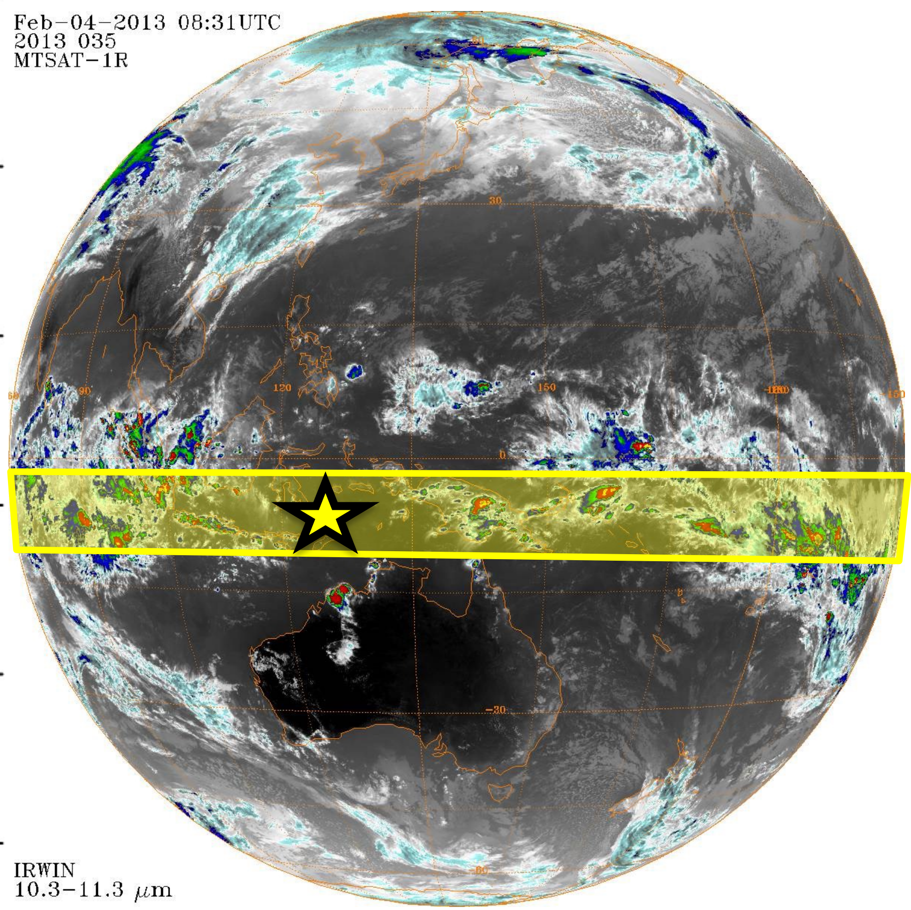
Observations of the MJO: Filtered





Observations of the MJO: Filtered





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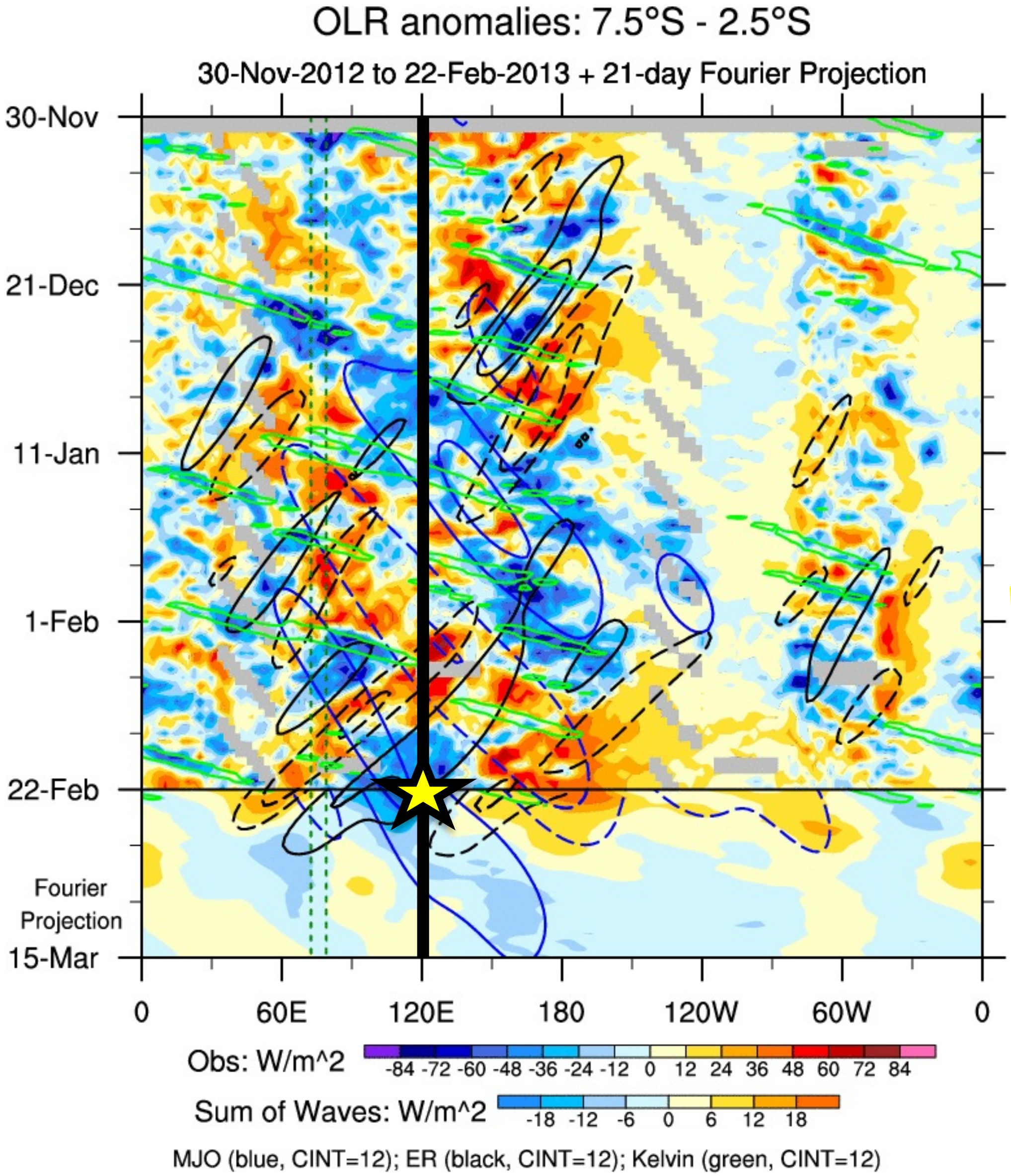

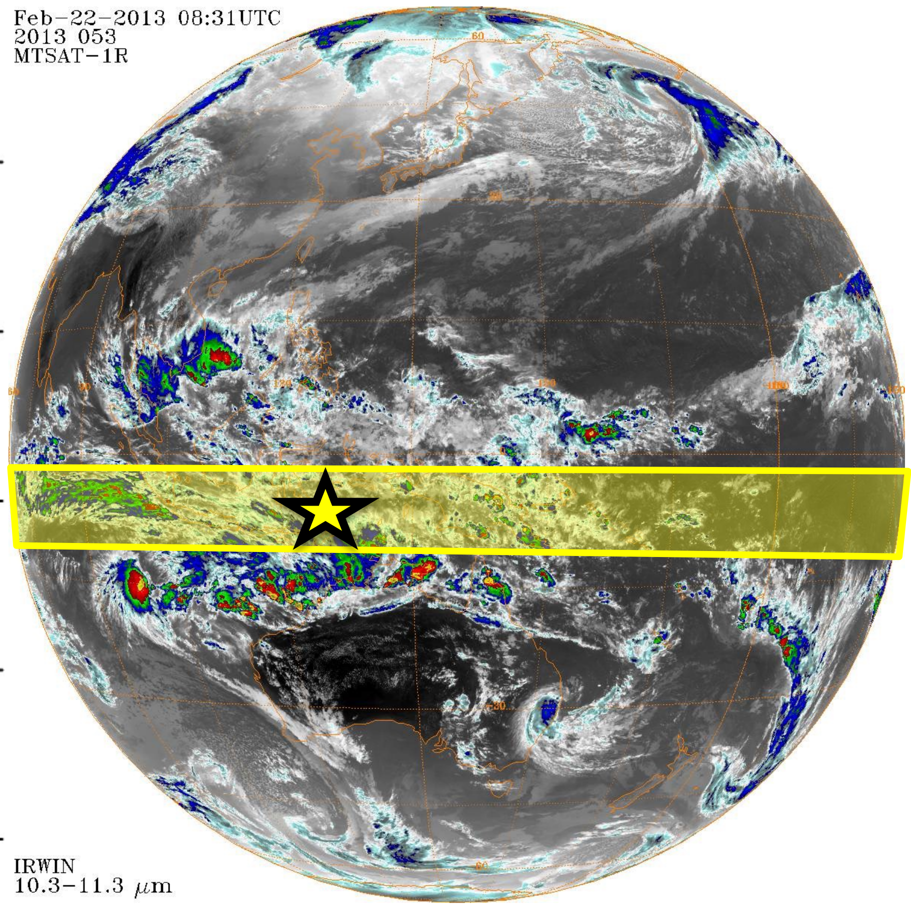

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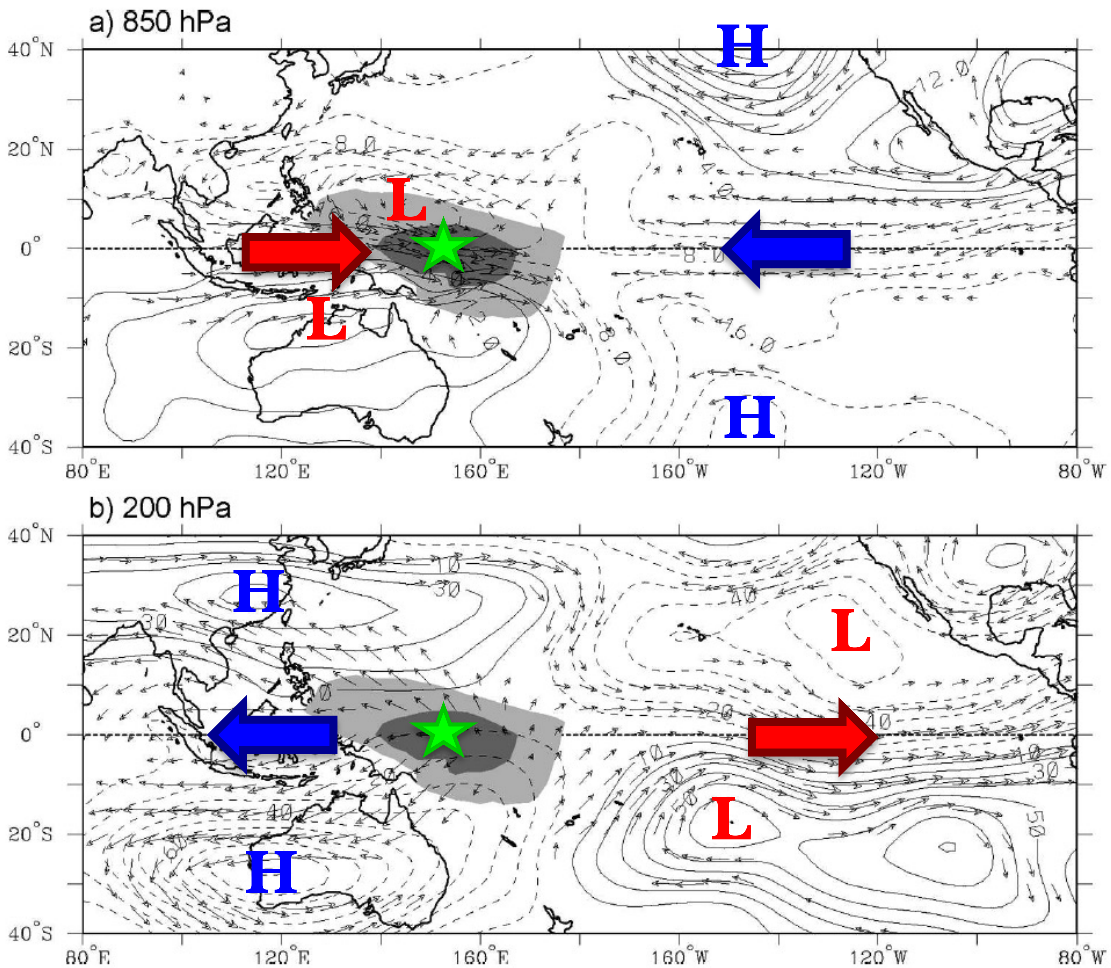
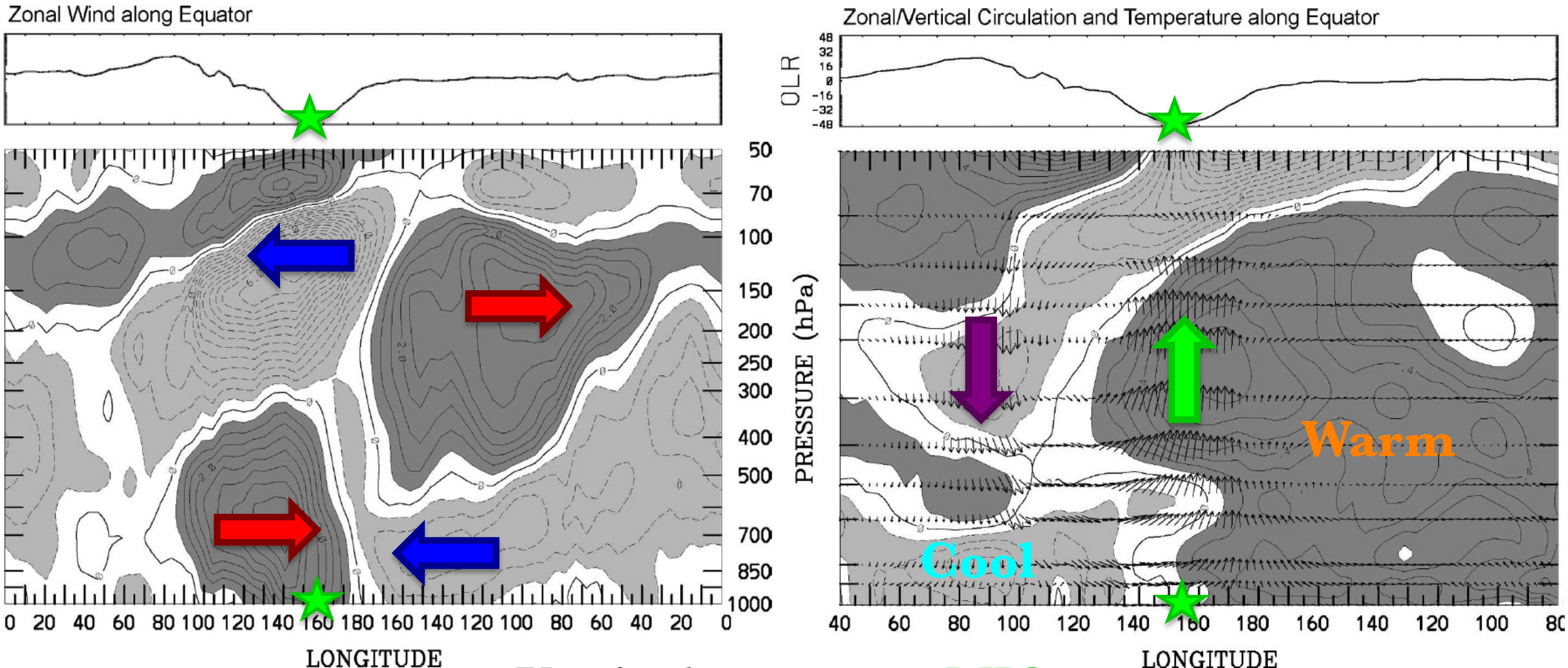


FIG. 2. Anomalous OLR and circulation from ERA-15 reanalysis on day 0 associated with a −40 W m^{-2} perturbation in MJO-filtered OLR at the equator, 155°E for the period 1979–93, all seasons included; (a) 850 and (b) 200 hPa. Dark (light) shading denotes OLR anomalies less than −32 W m^{-2} (−16 W m^{-2}). Streamfunction contour interval is (a) 4×10^5 m^2 s^{-1} and (b) 10×10^5 m^2 s^{-1}. Locally statistically significant wind vectors at the 95% level are shown. The largest vectors are about 2 m s^{-1} in (a) and around 5 m s^{-1} in (b).

Kiladis et al. (2005)

Observations of the MJO: Filtered



<u>Vertical structure</u>: MJO

<u>Top</u>: Anomalous **OLR** associated with the **MJO**

<u>Bottom left</u>: Longitude–height composite of anomalous **zonal wind**

<u>Bottom right</u>: Longitude–height composite of anomalous **temperature** and **zonal/vertical circulation**

Kiladis et al. (2005)