Module 3: S2S Variability and Prediction

Forecast Timescales

- weather 0-14 Days
- Subseasonal 2 weeks - 3 months
- Seasonal 3-12 months
- Interannual 1 -10 years
- Climate decades – centuries (decadal, multidecadal and longer)

} Subseasonal to seasonal (S2S, 2 weeks – 12 months)

NAS Report 2016, http://www.nap.edu/21873

Outline

- Madden-Julian Oscillation (MJO): characteristics and impacts
- Prediction of the MJO and the MJO as a predictability source
- Weather regimes
- Midlatitude blocking
  - Connections to weather extremes
- Land-atmosphere interaction
  - Soil moisture and Climate Variability/Prediction

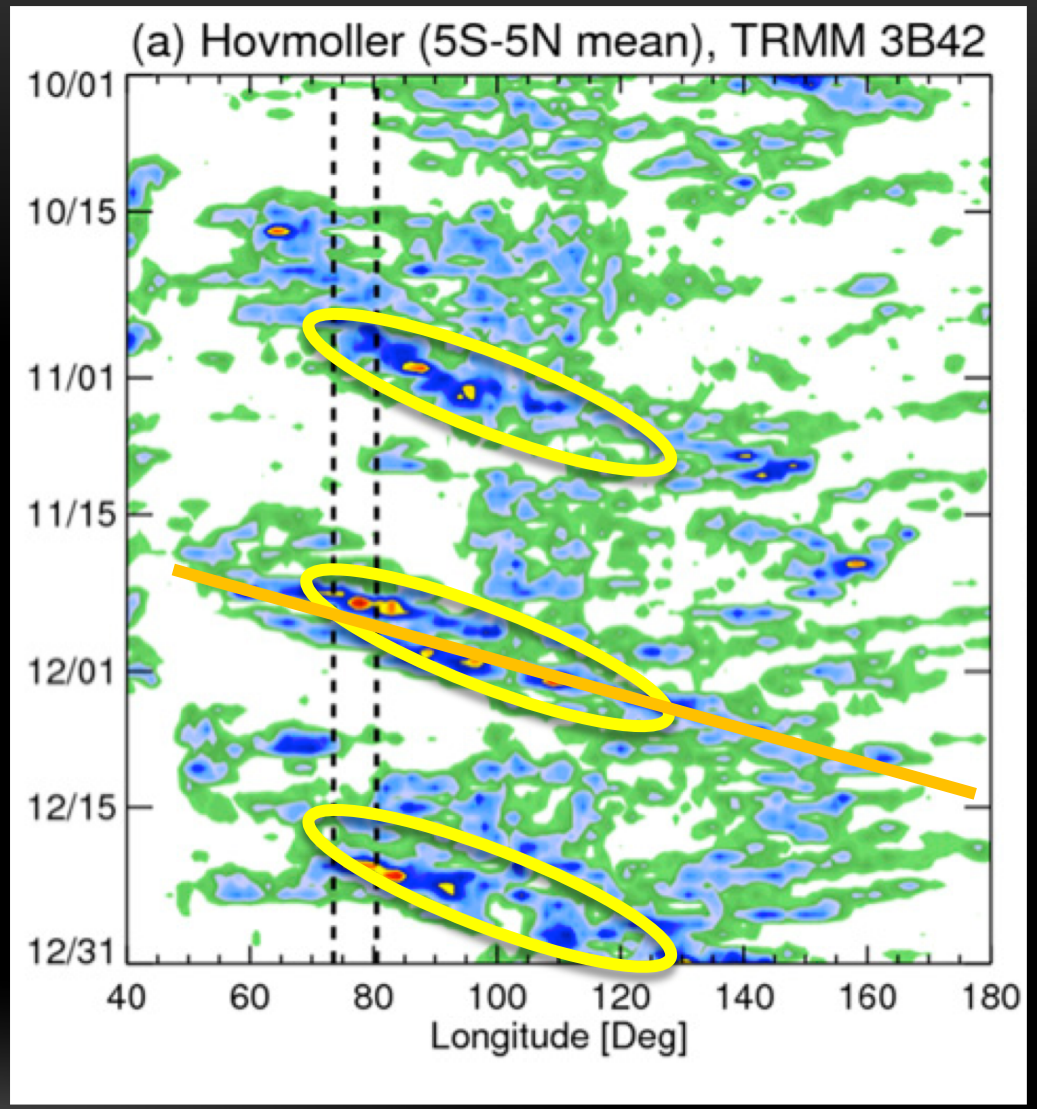
Introduction and Observations of the MJO

Eastward Propagating MJO Signals

Could you describe the major features of variability in this plot?

Multiple MJO events (yellow ovals) over the Indian Ocean-western Pacific;

1. Eastward propagation 5-8 m/s, as estimated based on the slope of the orange phase line.
2. Convective signal mainly confined in the warm-pool region (eastern Indian Ocean-western Pacific)



Hovmöller diagram of TRMM 3B42 rainfall (mm day21) during October–December 2011 as a function of longitude (5S–5N average) (Xu et al. 2015 © American Meteorological Society. Used with permission)

What is MJO?

- A quasi periodic oscillation of the near-equatorial troposphere, *most noticeable in the zonal wind component in the lower and upper troposphere*.
- The period varies between 30 and 90 days; local wavelength is roughly 12,000-20,000 km.
- The MJO signals propagate eastward with a phase speed of about 5-8 m s^{-1}, much less than that of the Kelvin wave.
- The MJO is coupled with convection over the Indian Ocean and western Pacific; best developed in boreal winter.

AMS Glossary: https://glossary.ametsoc.org/wiki/Madden-julian_oscillation

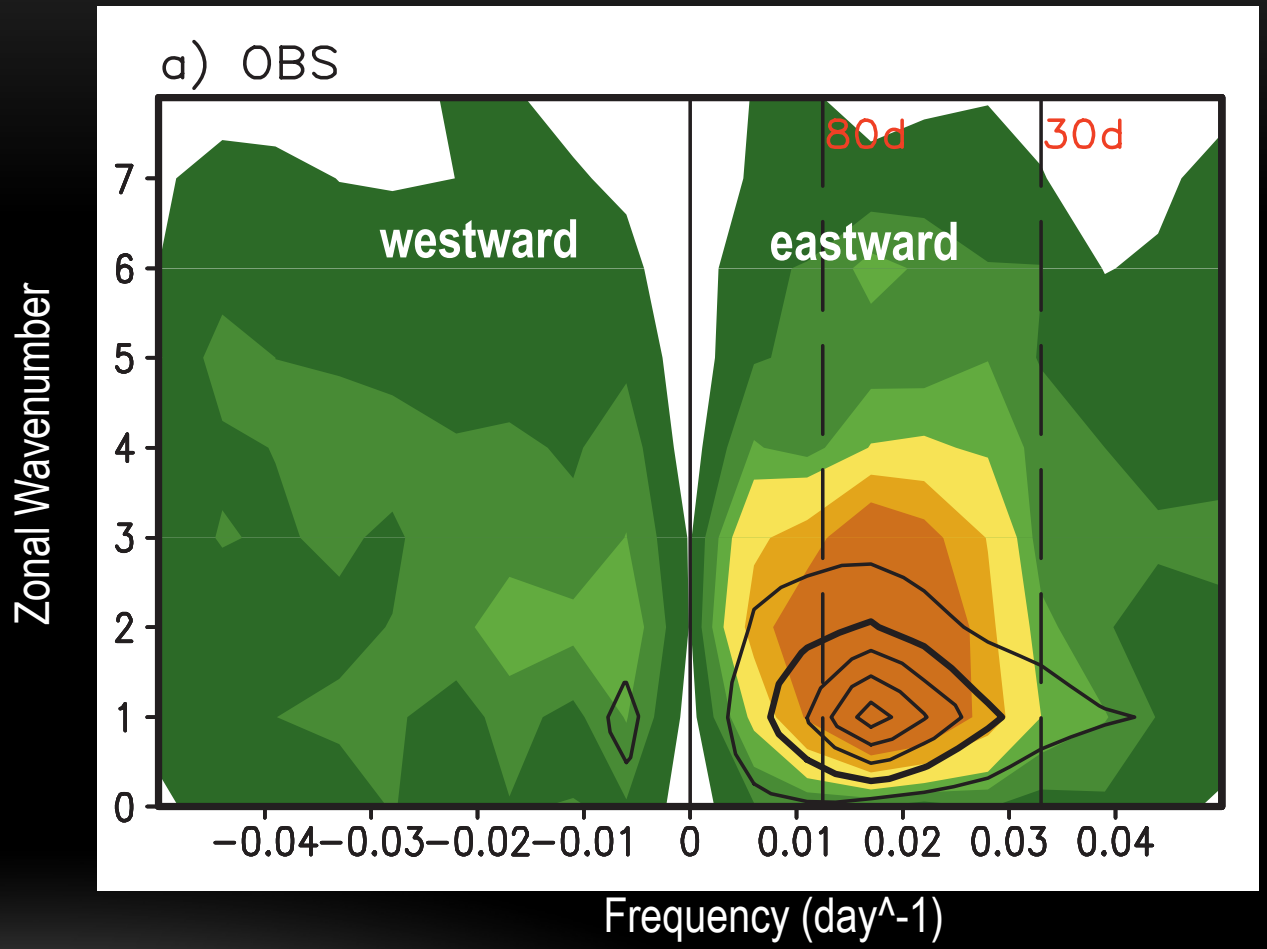
Why are we interested in the MJO?

- A dominant mode of intraseasonal variability in the tropics.
- MJO influences tropical weather from small-scale tropical convection to planetary-scale circulations.
- MJO has significant impacts on the wintertime atmospheric circulation over the North Pacific and western North America.

Wavenumber-Frequency Diagram

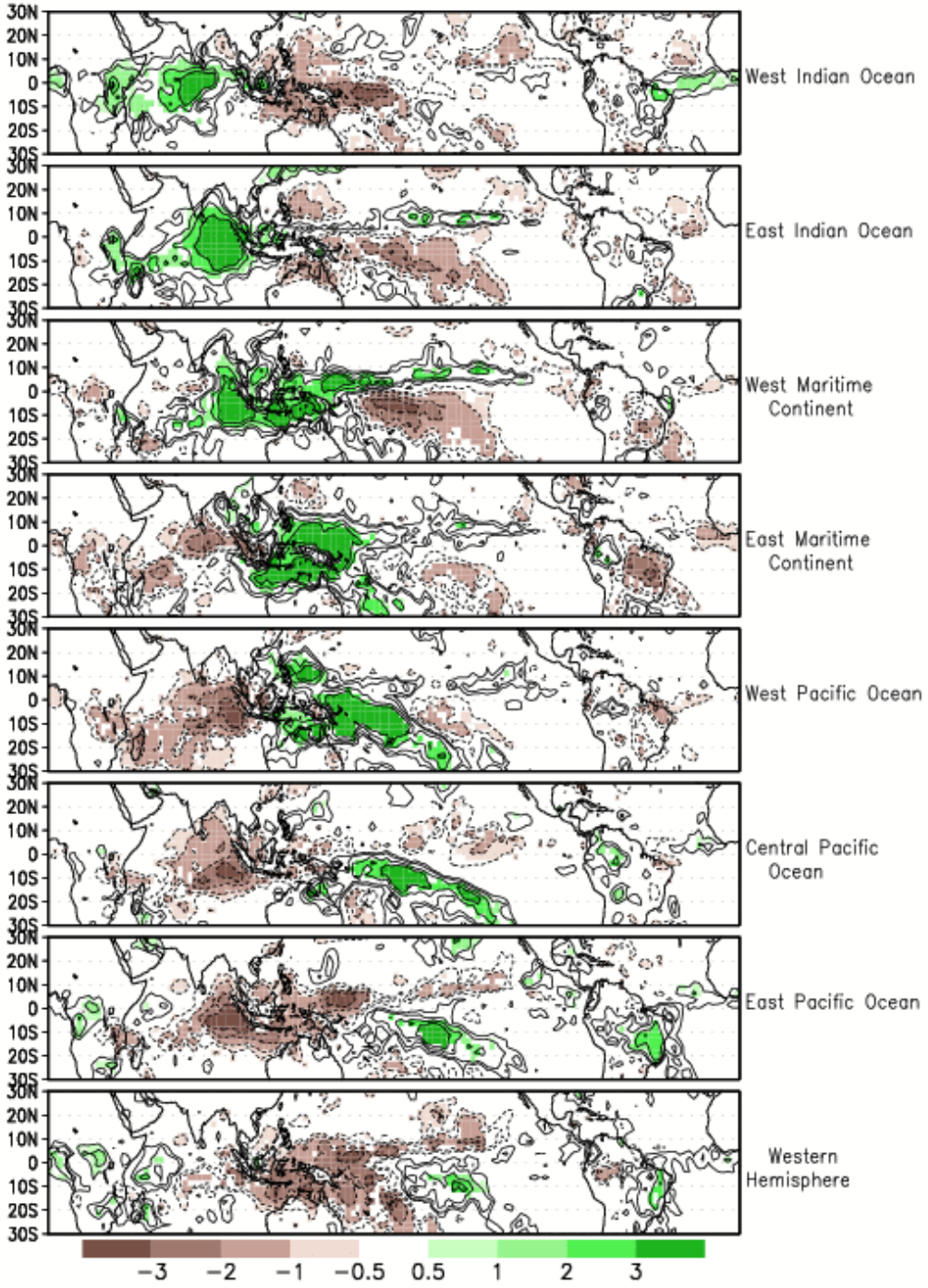
The spatial and temporal characteristics of the MJO can be clearly illustrated using the WV-F diagram.

- Positive (negative) periods correspond to eastward (westward) propagating power.
- The power spectra spread over 30-100 days, which suggests that the period of MJO is highly variable.
- The spectral peak is at zonal wave number 1 for the zonal wind but spreads over zonal wave numbers 1–3 for precipitation.



November–April wavenumber–frequency spectra of 10N–108 averaged precipitation (shaded) and 850-hPa zonal wind (contoured) from the CMAP/NCEP/NCAR (From Kim et al. 2009 © American Meteorological Society. Used with permission)

Next, let's look at some 2D horizontal maps

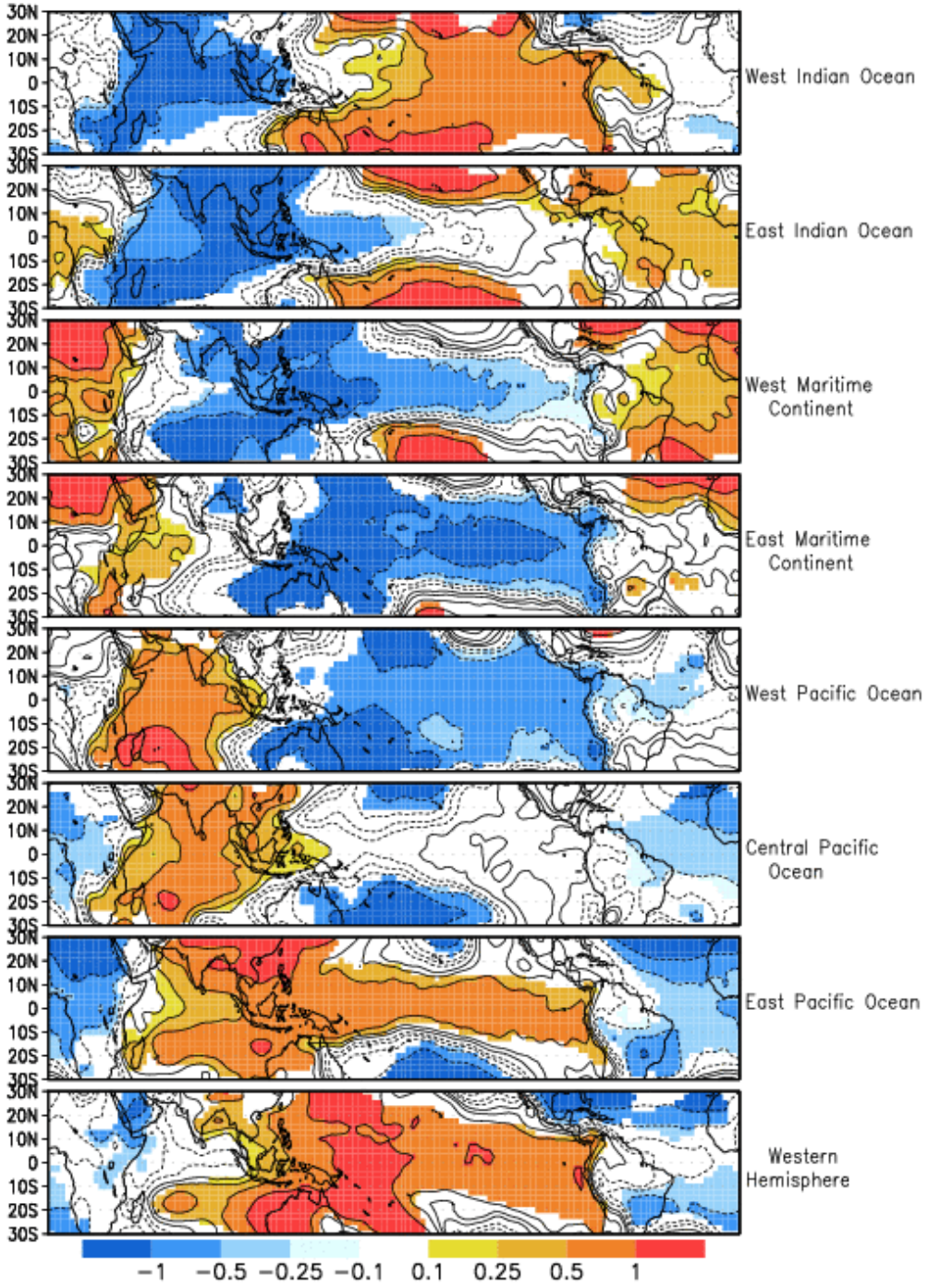


Precipitation (Nov-Mar)

1. Eastward propagation
2. Convective signals weaken significantly east of the dateline
3. Only one fully developed MJO event exists in the tropics at a given time. Occasionally, two or three weak convective centers of the MJO with weak circulations may coexist.

This slide shows a sequence of precipitation maps, with the center of active convection in different locations.

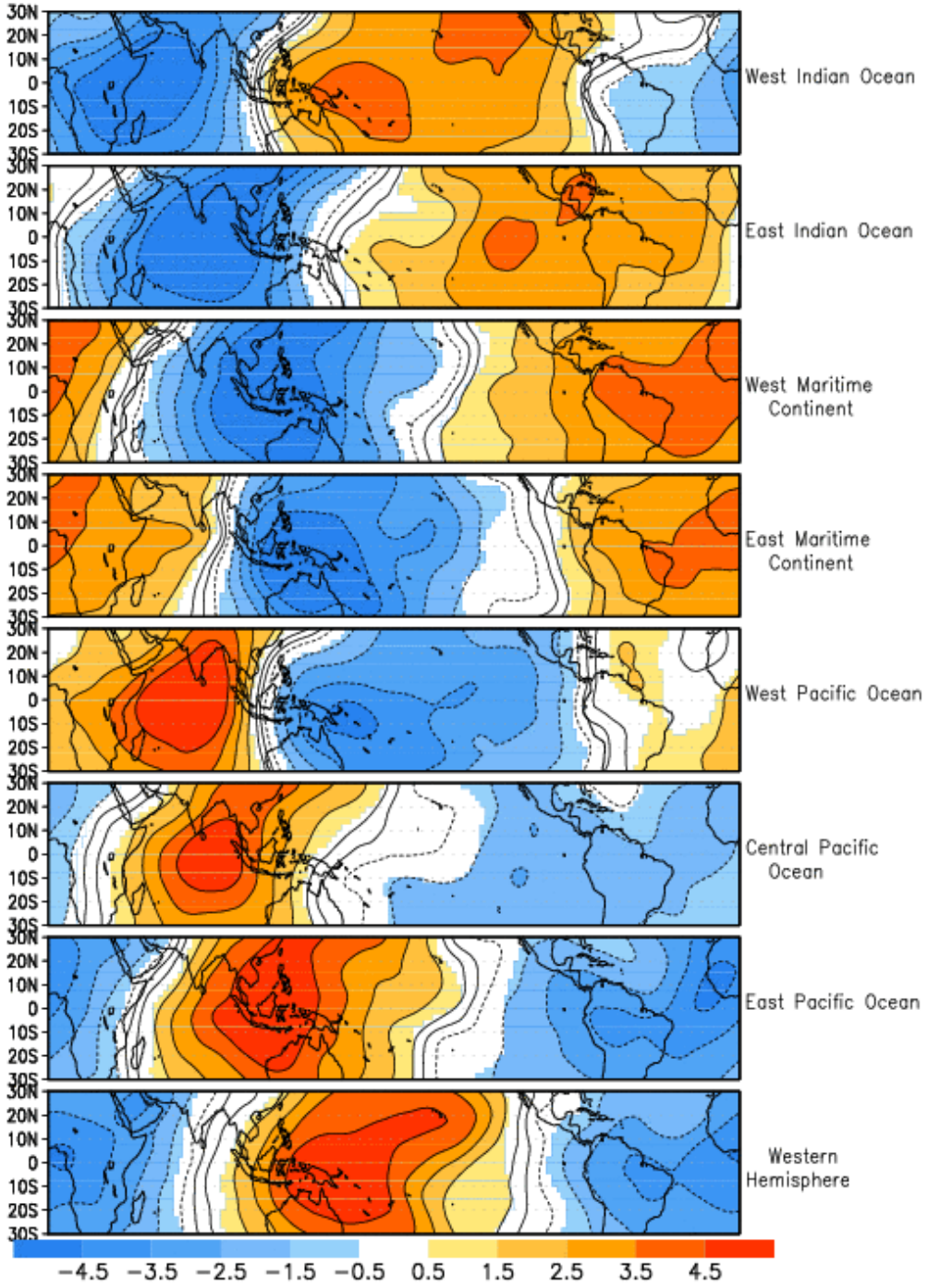
From NOAA CPC



SLP (Nov-Mar)

- The zonal scale of the circulation component is much larger than that of the convection; dominated by wavenumber-1 pattern
- Regions of active convection are associated with reduced SLP.

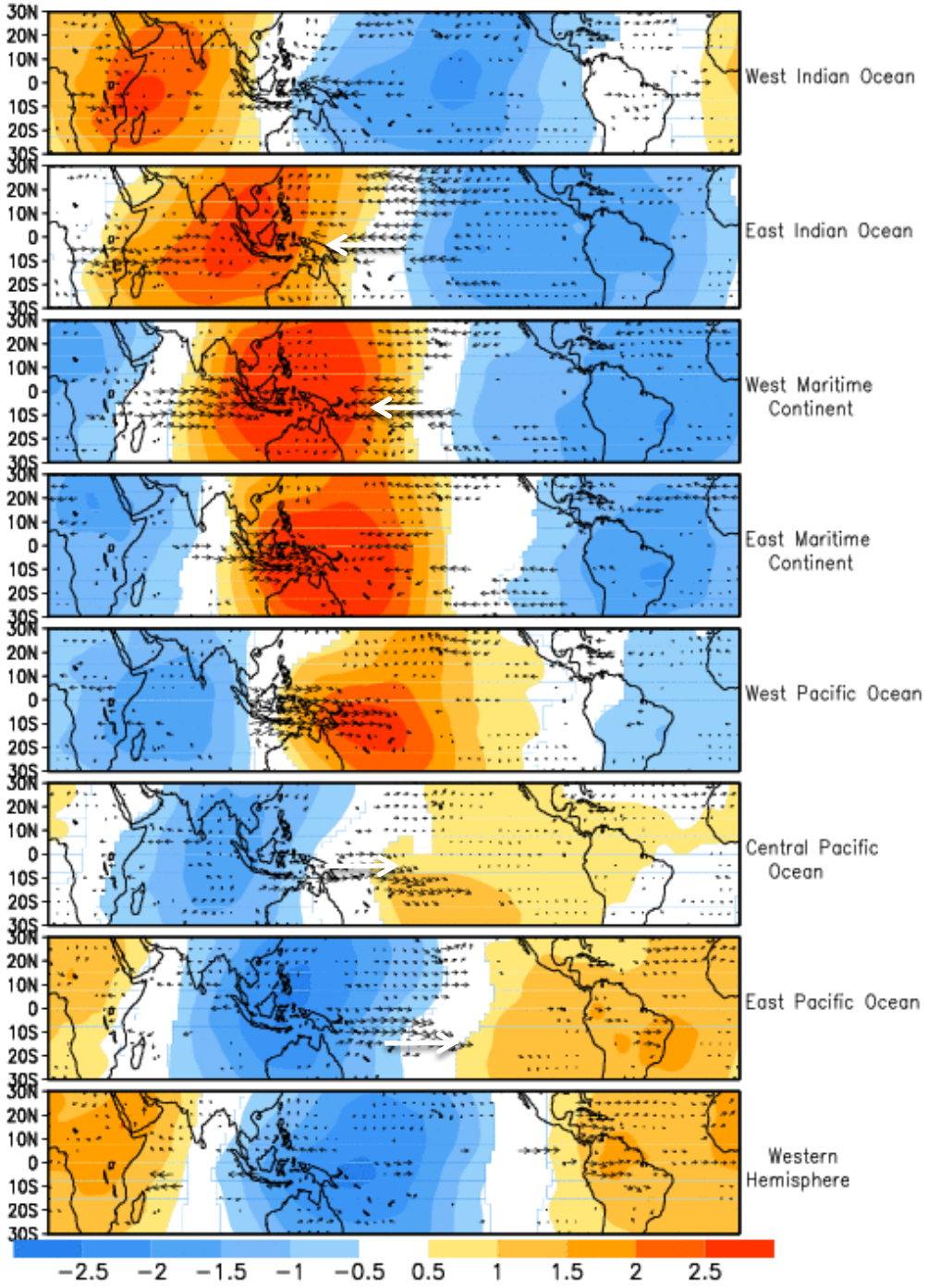
From NOAA CPC



250 hPa Velocity Potential (Nov-Mar)

- Velocity Potential represents the irrotational component of the horizontal flow. A local minimum -- divergence
- Different from precipitation, the upper-level VP shows a continuous eastward propagation across the global tropics (weakens east of the dateline).
- dominated by wavenumber-1 pattern

From NOAA CPC



850 hPa Wind and Velocity Potential (Nov-Mar)

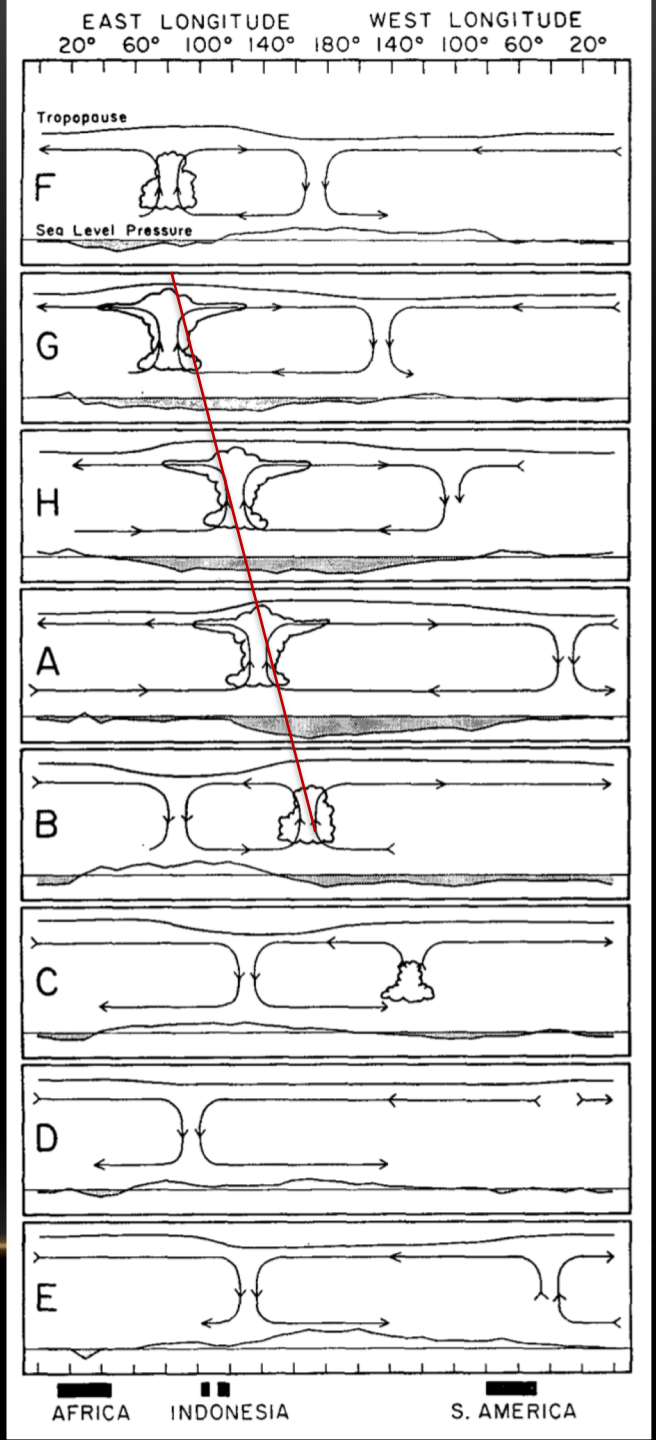
- The pattern is nearly opposite to 250VP. This baroclinic structure corresponds to modulations of the Walker cells around the tropics.
- Strong signals in U850.
- The VP signals weaken east of the dateline when the circulation field is not strongly coupled with convection.

Velocity Potential represents the irrotational component of the horizontal flow. A local minimum – divergence. Active convection – low-level convergence

From NOAA CPC

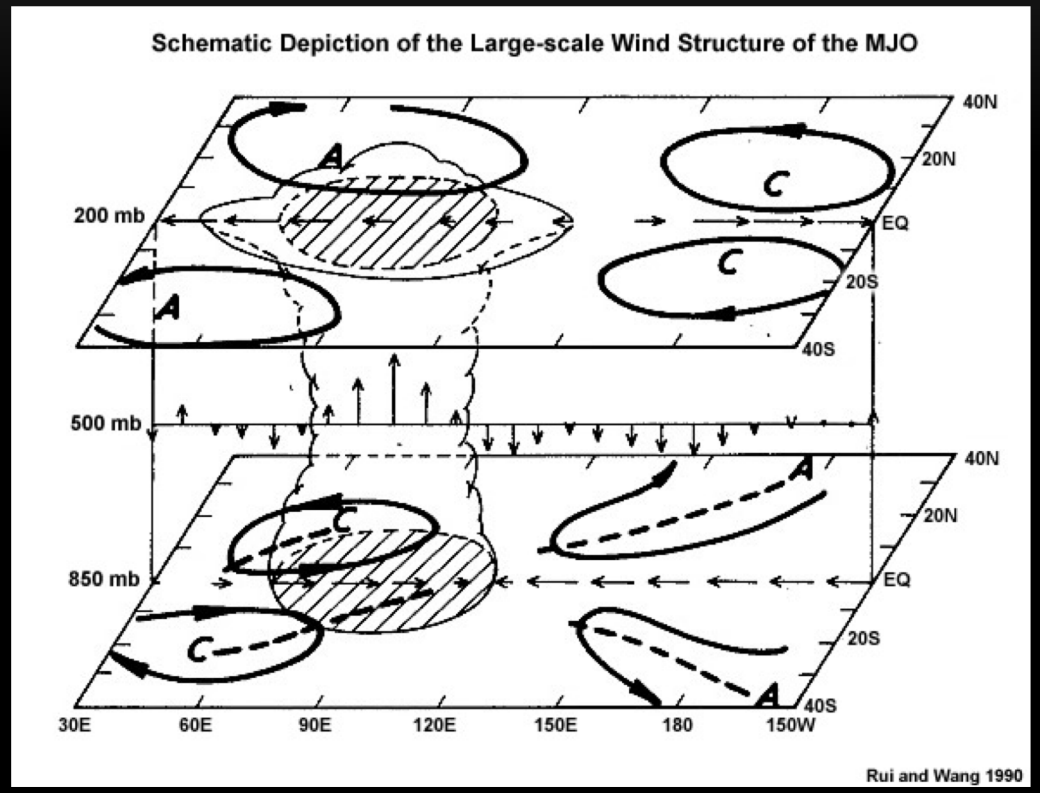
MJO: A schematic

- The atmospheric signature is evident in the surface pressure, the lower and upper tropospheric wind (or divergence) and in fields representative of deep convection
- The westerly phase of the MJO is characterized by eastward propagation of convection, anomalously low surface pressure, westerly lower-tropospheric zonal wind anomalies and easterly upper-tropospheric zonal wind anomalies.
- The atmospheric circulation associated with the MJO has a baroclinic structure with a top-heavy heating profile during the westerly phase.
- The convective signals of the MJO weaken east of the dateline



Longitude-height schematic diagram along the equator illustrating the fundamental large-scale features of the Madden-Julian Oscillation (MJO) through its life cycle (from top to bottom).
Time is downwards at roughly 5 day intervals. Enhanced large-scale convection is symbolized by cumulus and cumulonimbus; the relative tropopause height is shown at the top of each panel. Mean pressure anomalies are plotted at the bottom of each image. (From Madden and Julian 1972, © American Meteorological Society. Used with permission)

Schematic depiction of the 3D structure of the MJO



Schematic depiction of the large-scale wind structure of the MJO. "A" and "C" mark the anticyclonic and cyclonic circulation centers, respectively. (From Rui and Wang 1990, © American Meteorological Society. Used with permission)

The tropical large-scale circulation associated with the MJO has a baroclinic structure. It can be described in terms of convectively coupled equatorial waves.

- East of the convective center, the low-level easterlies and upper level westerlies resemble the equatorial Kelvin wave.
- To the west, low-level westerlies (upper level easterlies) and the associated pair of cyclonic (anticyclonic) circulation or gyres straddling the equator are the characteristics of the equatorial Rossby wave.

Summary

- A quasi periodic oscillation of the upper- and lower-level wind and convection fields. The period varies between 30 and 90 days (a rough period range); local wavelength is roughly 12,000-20,000 km.
- The MJO propagates eastward with a phase speed of about 5-8 m s^{-1}, much slower than the Kelvin wave.
- The atmospheric circulation associated with the MJO has a baroclinic structure
- Seasonal variations: strongest in boreal winter
- MJO signals in convection are normally confined to the Indian and western Pacific oceans (the "warm pool"). MJO signals in some circulation fields can be detected across the entire tropics.

References

- Kim, D., Sperber, K., Stern, W., Waliser, D., Kang, I.-S., Maloney, E., Wang, W., Weickmann, K., Benedict, J., Khairoutdinov, M., Lee, M.-I., Neale, R., Suarez, M., Thayer-Calder, K., & Zhang, G. (2009). Application of MJO Simulation Diagnostics to Climate Models, *Journal of Climate*, *22*(23), 6413-6436.
- Madden, R. A., and P. R. Julian (1972), Description of global-scale circulation cells in the tropics with a 40 – 50 day period, J. Atmos. Sci., 29, 1109–1123.
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- Xu, W., Rutledge, S. A., Schumacher, C., & Katsumata, M. (2015). Evolution, Properties, and Spatial Variability of MJO Convection near and off the Equator during DYNAMO, Journal of the Atmospheric Sciences, 72(11), 4126-4147
- NOAA CPC MJO website: https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/mjo.shtml