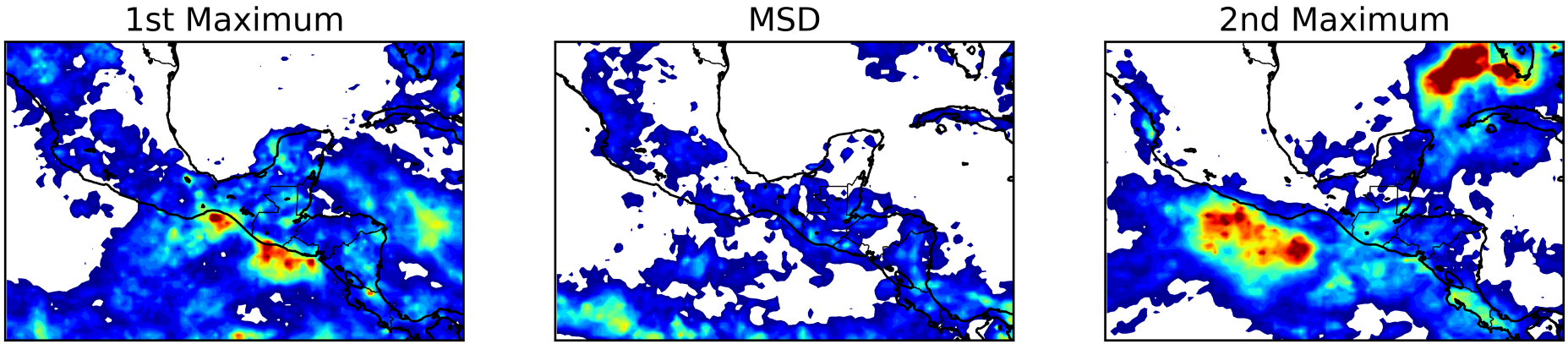

The patterns of meteorological fields to identify intraseasonal precipitation variability in Mesoamerica

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Jet Propulsion Laboratory
California Institute of Technology

Acknowledgement

- Special thanks of gratitude to Danielle Groenen at Florida State University.

- Groenen et al., ‘Atmospheric and Oceanic Features in Association with the Timing of the Onset and Demise of the Mesoamerican Monsoon’ will be submitted soon.

Outline

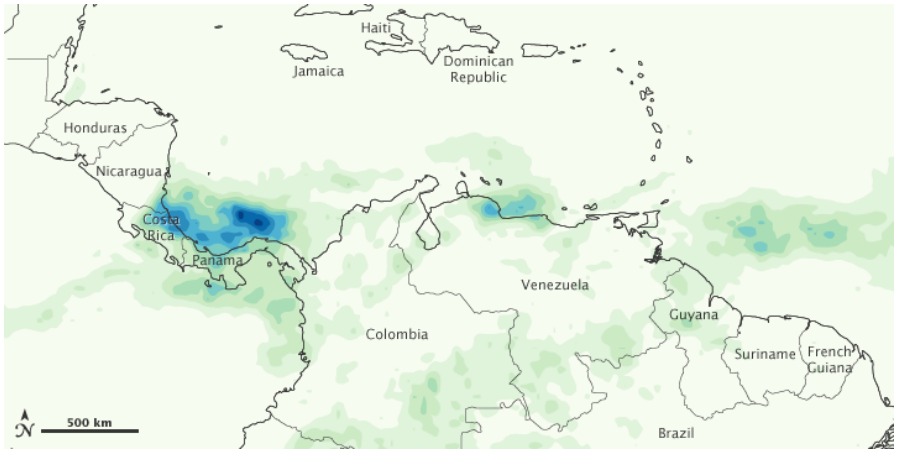
- Introduction
  - The rainy season and midsummer drought in Central America
- Data
  - Satellite observations and reanalysis data
- Methodology
  - Wavelet-based filtering and composite analysis
- Results
- Conclusions
  - The Madden-Julian oscillation from Maritime Continent modulates the intraseasonal variability in precipitation over Mesoamerica.

Mesoamerica

- Southern Mexico and Central America (Mesoamerica) have complex geography and harbors a wide range of unique and valuable ecosystems and resources.
- The economy of Mesoamerica is also rapidly developing and diversifying.
- It is therefore of great scientific, societal, and economic interest to better understand how climate is changing and will change over Mesoamerica.

The rainy season of Mesoamerica

- Mesoamerica has a distinct rainy season from May to October, (but not always).
- The mid-summer drought in the middle of the rainy season kills the coffee rust fungus which can destroy crops
- The timing and intensity of rainfall in Mesoamerica is a key component to the economies and agriculture of the region.

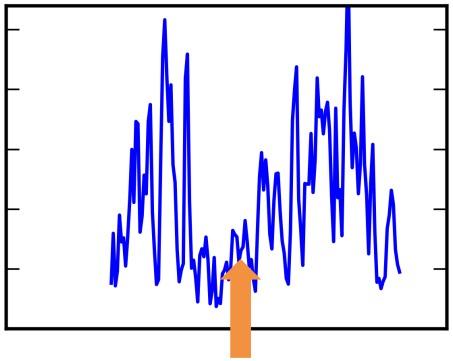


◀ Cumulative rainfall from November 25 to December 1, 2010

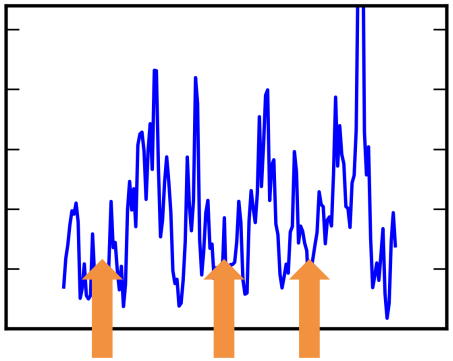
(from http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=47540)

The midsummer drought (MSD)

- Magaña et al. (1999): dynamical mechanisms explaining the MSD
- Maldonado et al. (2016): intraseasonal variability of the MSD
- In many rainy seasons, it is hard to define the MSD occurrence clearly.



vs.

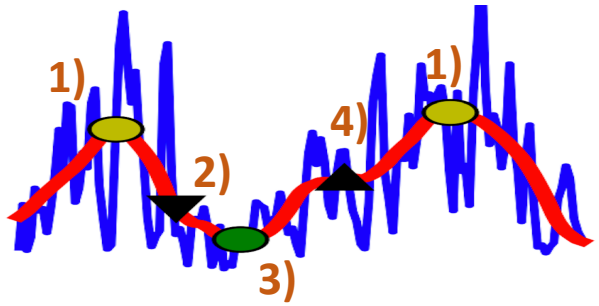


- When the precipitation cycle is not bimodal, how can we explain the multiple ups and downs in precipitation?
- We treat the multiple peaks same as the two peaks in the bimodal time series: all of the peaks may be explained by the same dynamical mechanism.

Objectives

- To investigate intraseasonal variability of the precipitation during the rainy season over the Southern Mexico and Central America.
  - ➢ differences in anomaly patterns of sea level pressure, zonal wind and moist static energy between the 1) maxima, 2) decrease, 3) minima, and 4) increase of rainfall.

daily precipitation ▸ time series



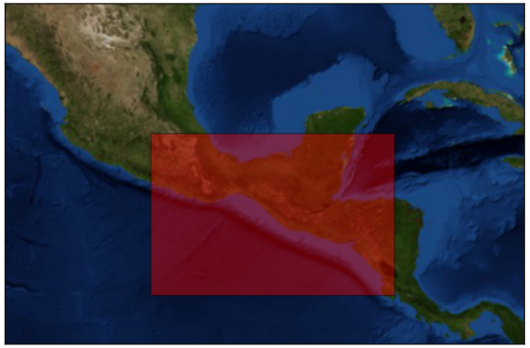
- To find large-scale meteorological fields related to frequency and period of the intraseasonal variability.

Data

- TRMM and other satellites precipitation product (3B42, V7)
  - daily total precipitation [mm/day]
  - spatial resolution: 0.25°x0.25°
  - precipitation during the Central American rainy seasons for 16 years (1998-2013)
- MERRA2 reanalysis
  - daily mean sea level pressure (SLP), winds, and moist static energy (MSE)
  - spatial resolution: 0.625°x0.5°
- NOAA Interpolated Outgoing Longwave Radiation (OLR)
  - daily mean OLR averaged between 5° and 15°N at each longitude
  - spatial resolution: 2.5°x2.5°

Workflow

lat: 10-20°N
lon: 100-85°W



(i) spatially average TRMM data: daily time series

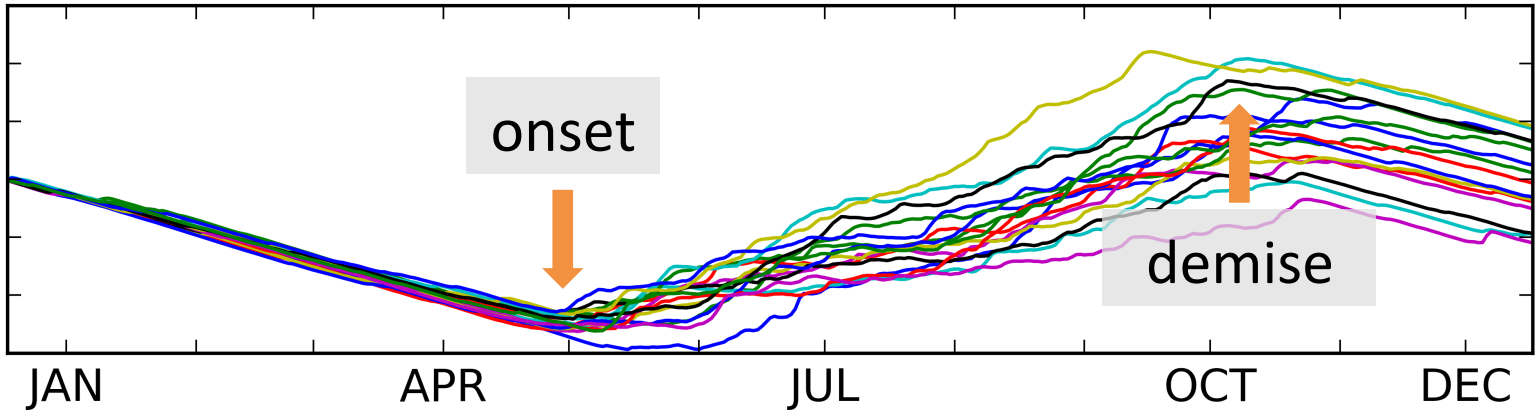
(ii) determine onset and demise of the rainy season

(iii) low-pass filtering using Daubechies 4 wavelet

(iv) identify maximum and minimum rainfall dates

(v) composite analysis of meteorological variables (SLP, U wind, MSE and OLR)

Mesoamerican Rainy Season Index (MARSI) [Groenen et al., 2016]

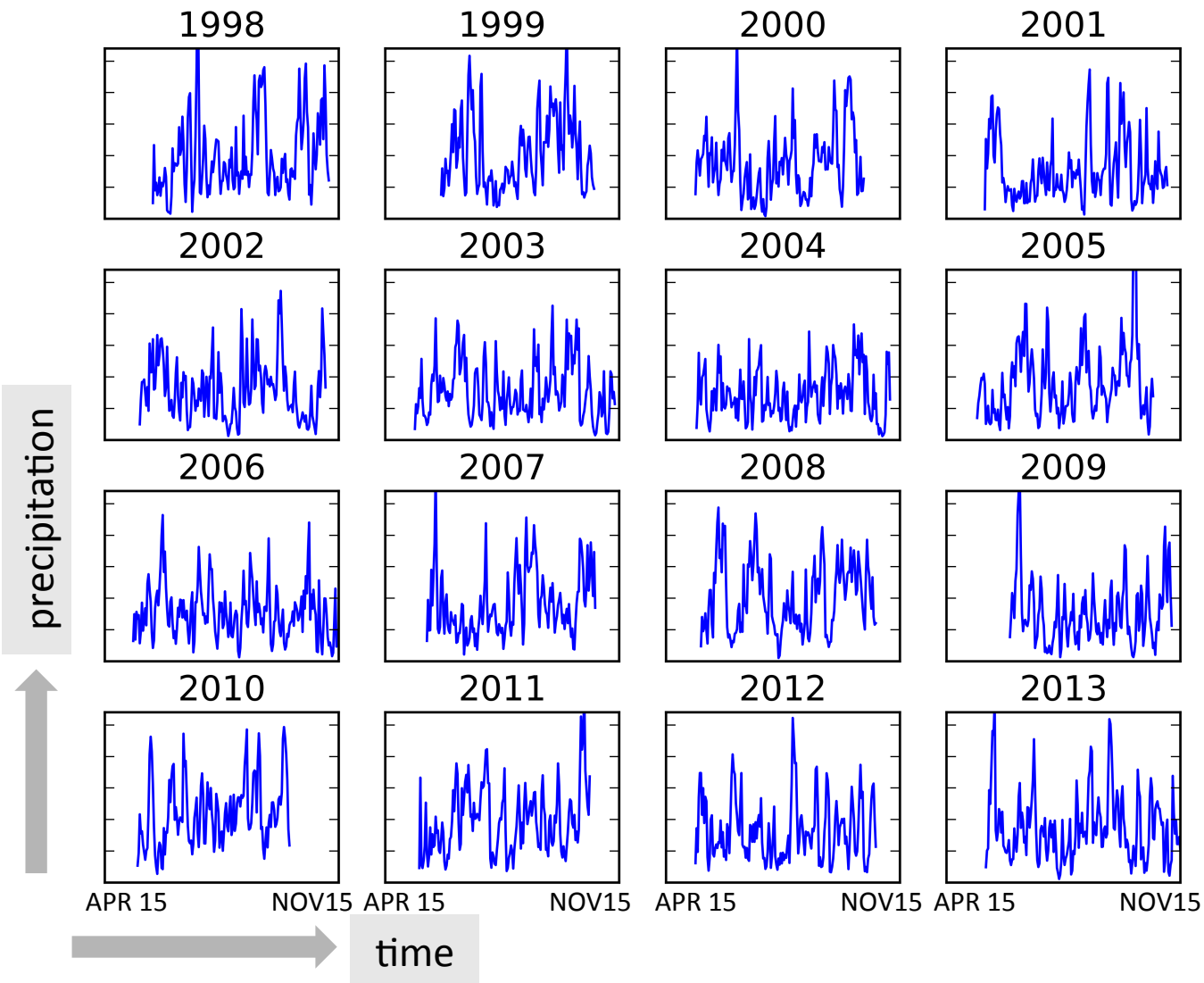


- Using the area-averaged precipitation (*P(i), i: Julian day*) over 10-20°N and 100-85°W,

$$C(n) = \sum_{i=1}^{n} [p(i) - \bar{P}] \quad \bar{P}\text{: climatological mean precipitation}$$

- Onset and demise dates of the rainy season in each year are defined as the minimum and maximum dates in the daily cumulative precipitation anomalies (*C(n)*).

Precipitation time series during the rainy season (from onset through demise dates)



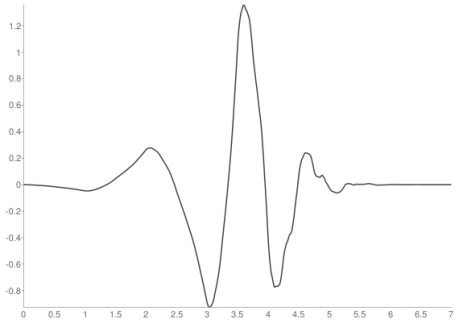
- Onset dates are more consistent.

5/11-5/20: 10 years
5/21-5/31: 4 years
6/01- : 2 years

- Demise dates

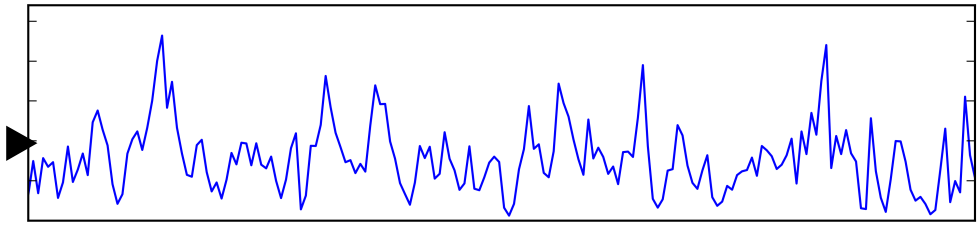
10/01-10/10: 1 year
10/11-10/20: 2 years
10/21-10/31: 5 years
11/01-11/10: 5 years
11/11-11/20: 3 years

Low-pass filtering using Daubechies 4 wavelet

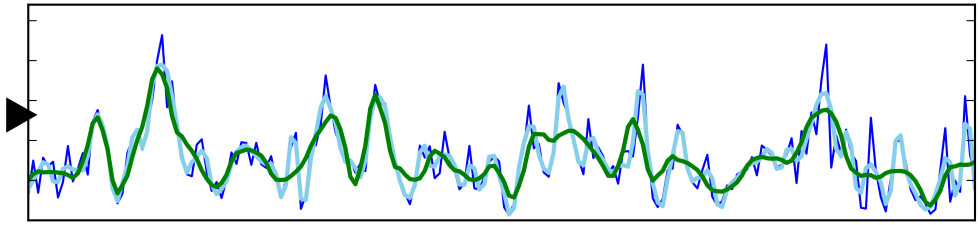


http://wavelets.pybytes.com/wavelet/db4/

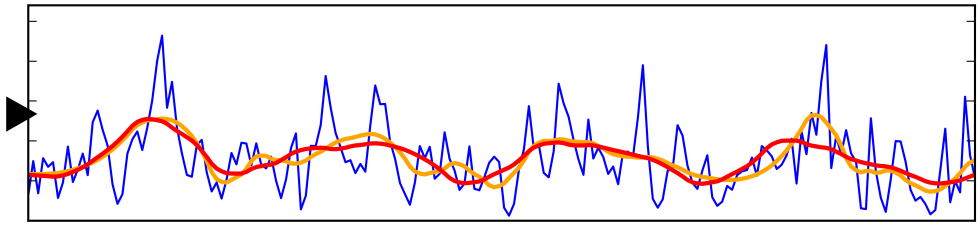
original time series



w/o period=2 days
period=4 days



w/o
period=8 days
period=16 days

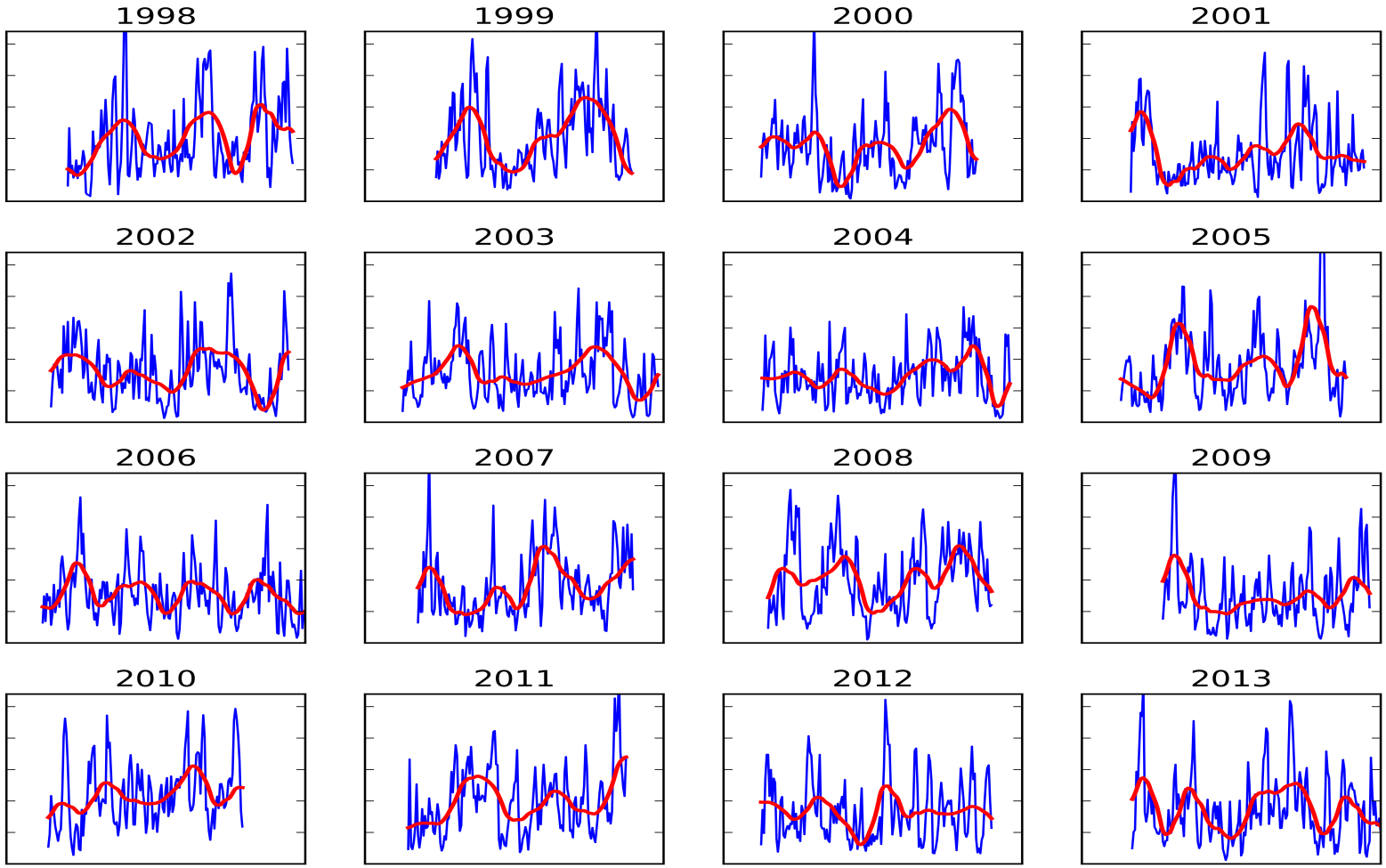


more filtering

- The goal of the low-pass filtering is to find stationary points related to the maximum and minimum rainfall during the rainy season.
- Daubechies 4 wavelet function can be replaced by another wavelet function to filter out high frequency variability.

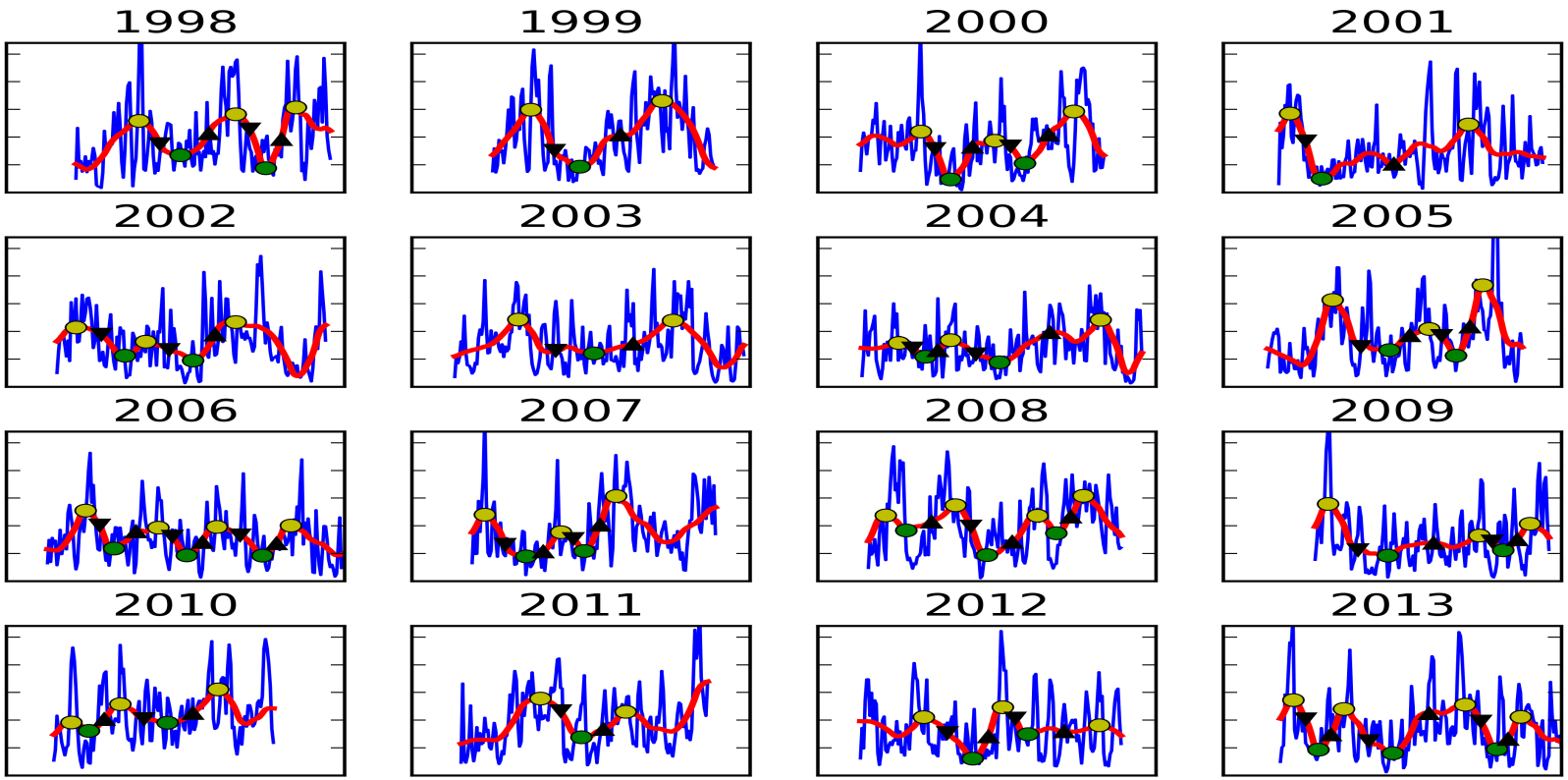
(iii) low-pass filtering using Daubechies 4 wavelet

Precipitation time series (filtered)



- Years with clear MSD: :1999 and 2003
- In most of the 16 years, the frequency of dominant intraseasonal variability is higher than that of MSD.

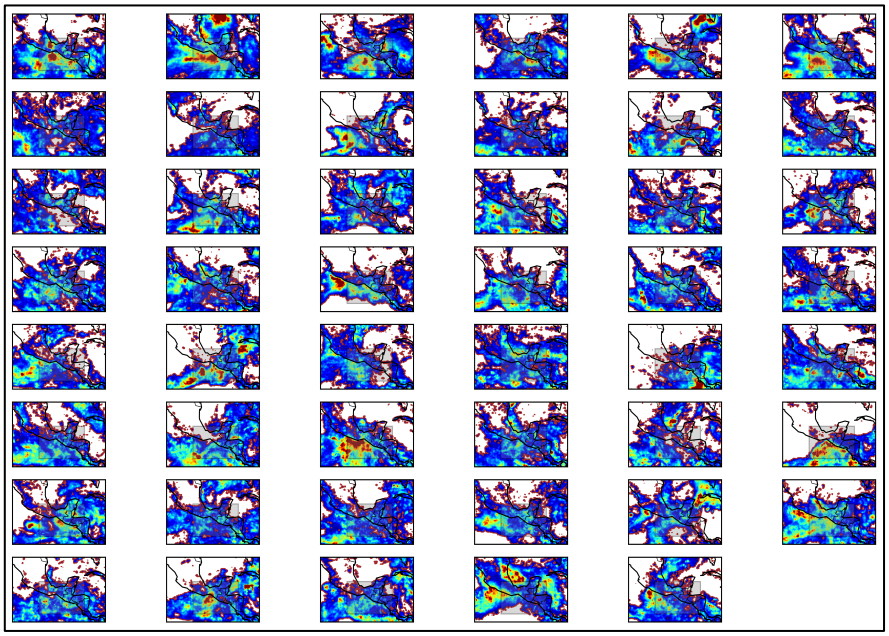
Identify the maximum and minimum precipitation dates



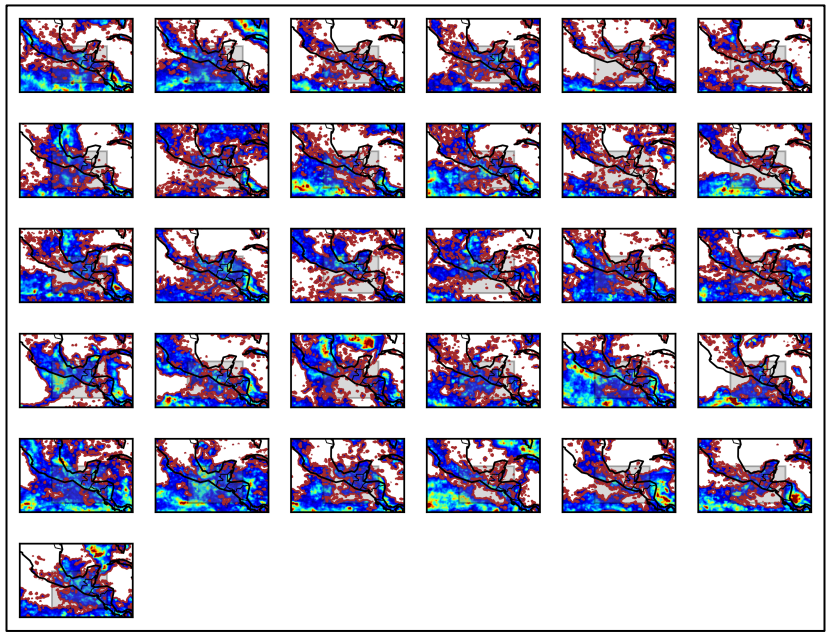
- Stationary points: dates of maximum or minimum precipitation
- date of decreasing precipitation = 0.5* [(MAX date) + (min date)]
- date of increasing precipitation = 0.5* [(min date) + (MAX date)]

Maximum and minimum precipitation days (5-day averages: ±2 days)

47 patterns for maximum precipitation



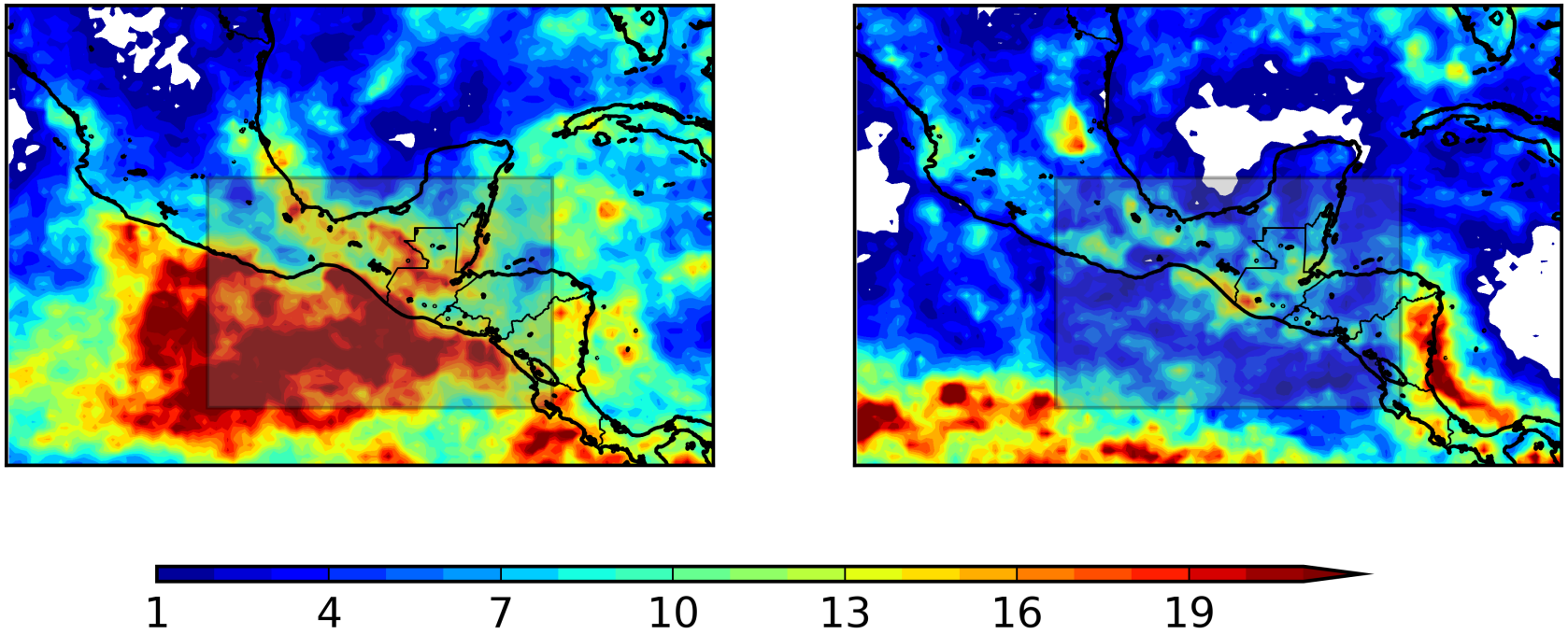
31 patterns for minimum precipitation



averaging the spatial patterns

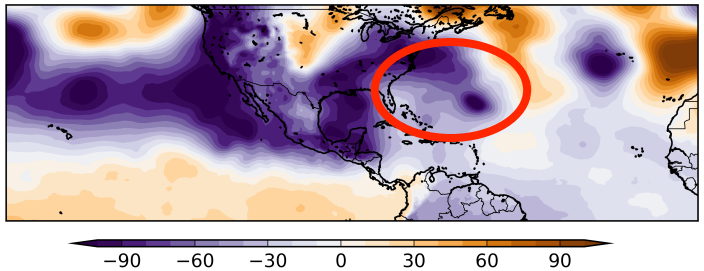
Averaged precipitation patterns

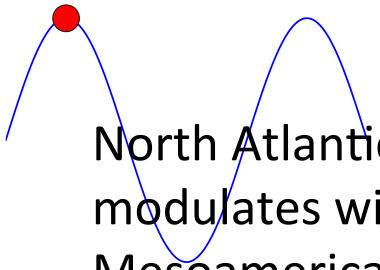
maximum precipitation days **minimum precipitation days**



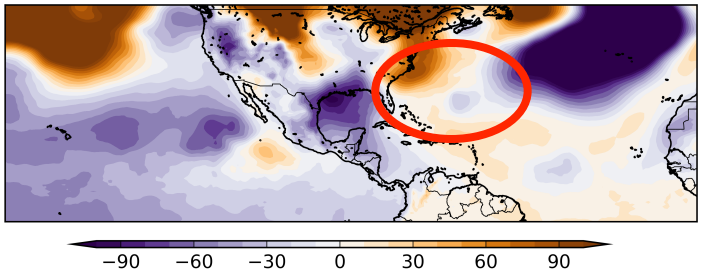
- The precipitation difference is prominent over the Pacific Ocean.
- MSD involves the orographic precipitation in the eastern Nicaragua and Costa Rica.

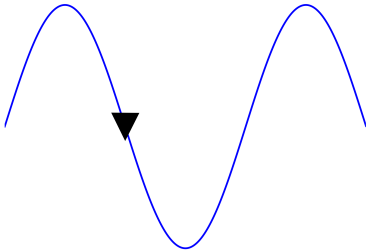
Sea level pressure anomalies (deseasonalized)

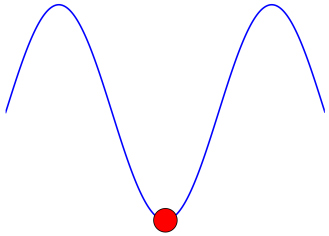


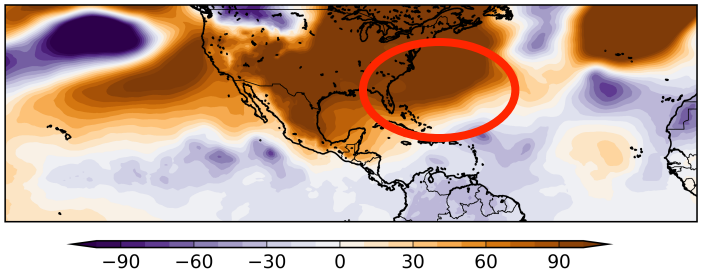


North Atlantic Subtropical High (NASH) modulates winds important for Mesoamerica.

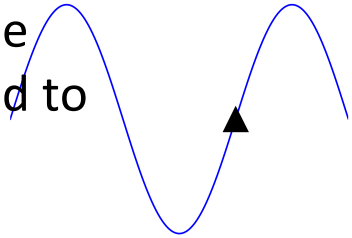


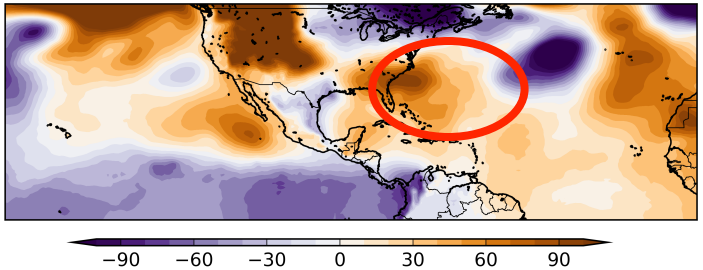






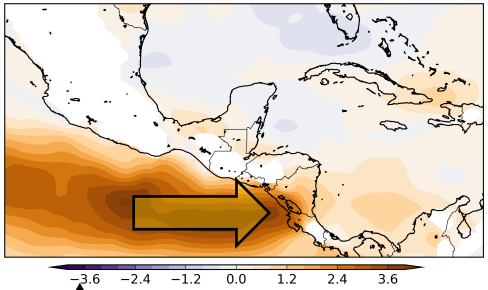
The anomalies and position of the North Pacific High are also related to the intraseasonal variability of precipitation over Mesoamerica.

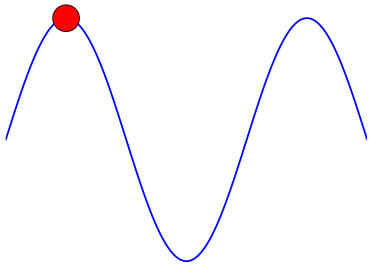


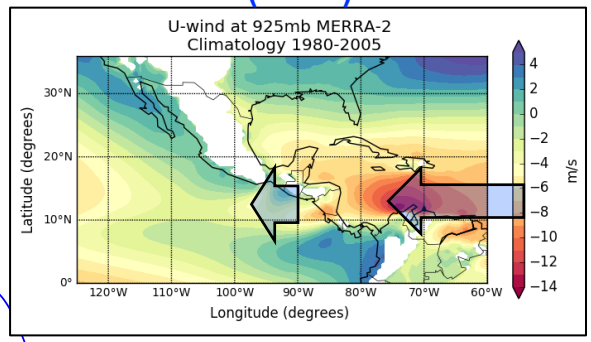


Zonal wind anomalies at 925 hPa (deseasonalized)

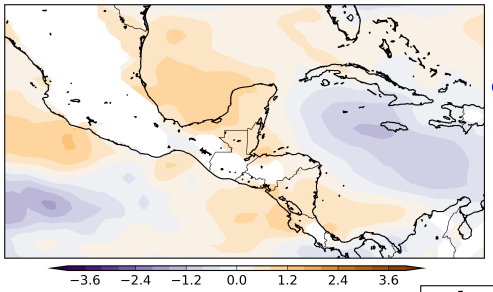
Caribbean Low Level Jet (CLLJ)

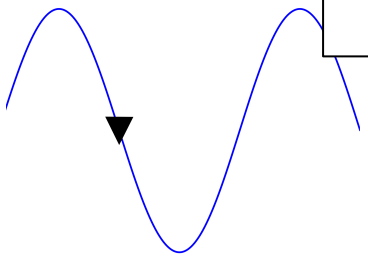


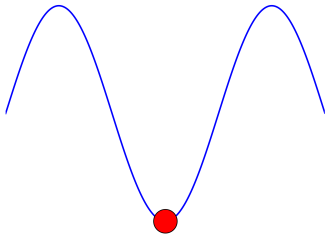


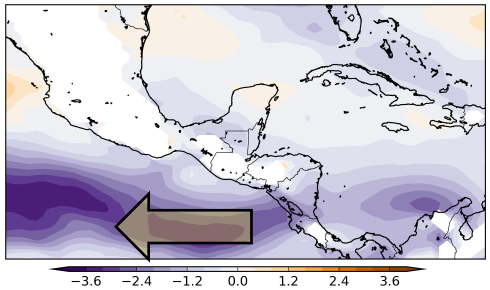


The strong convergence zone is developed over the eastern Pacific Ocean.



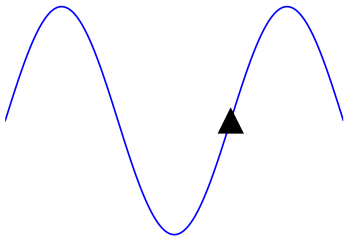


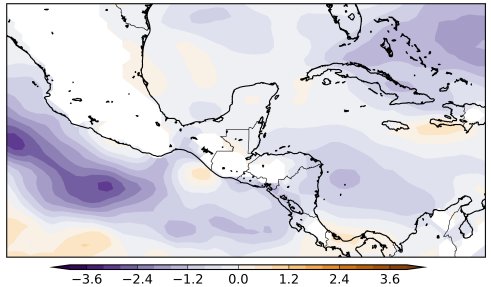




Strengthening of CLLJ

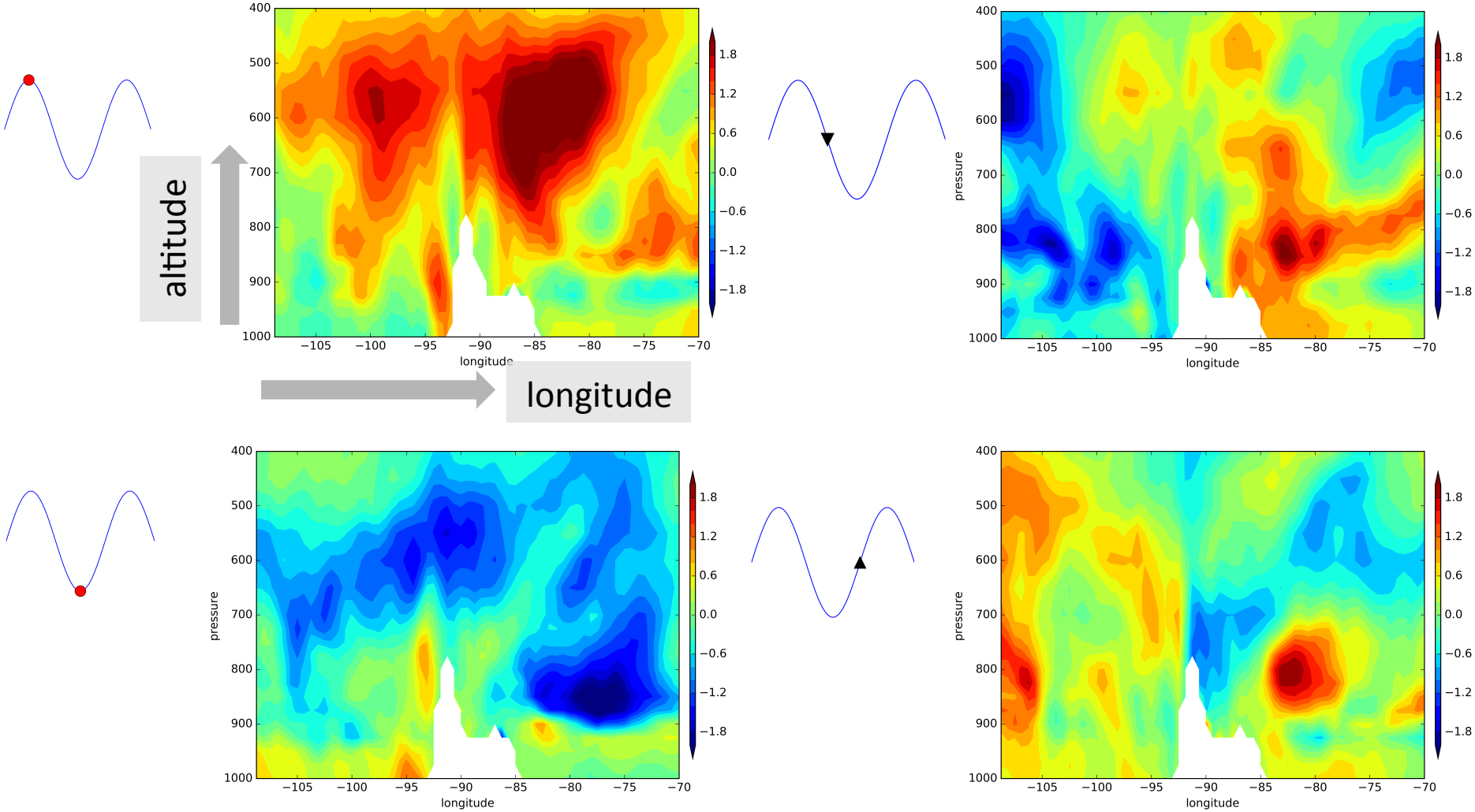
The U wind anomalies are larger over the eastern Pacific Ocean than those of CLLJ.





Moist static energy anomalies at 15°N (deseasonalized)

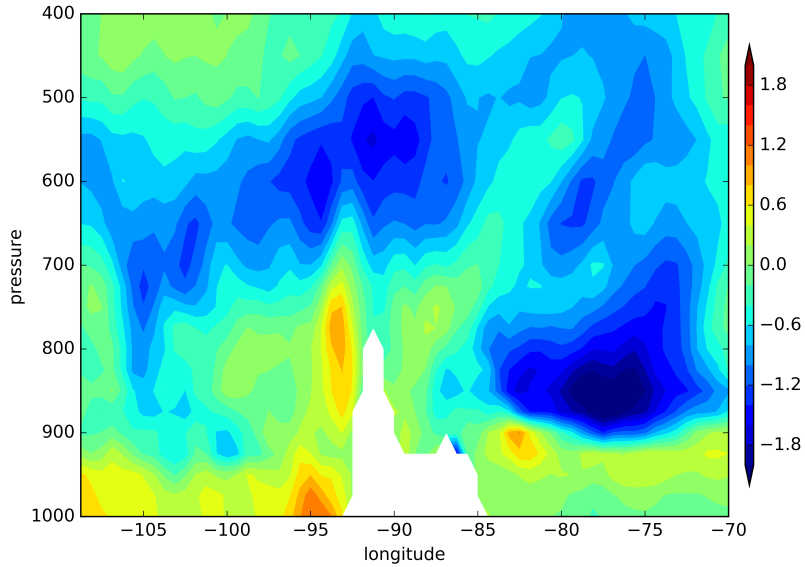
$$MSE = C_p \times T + L_v \times q + g \times z$$



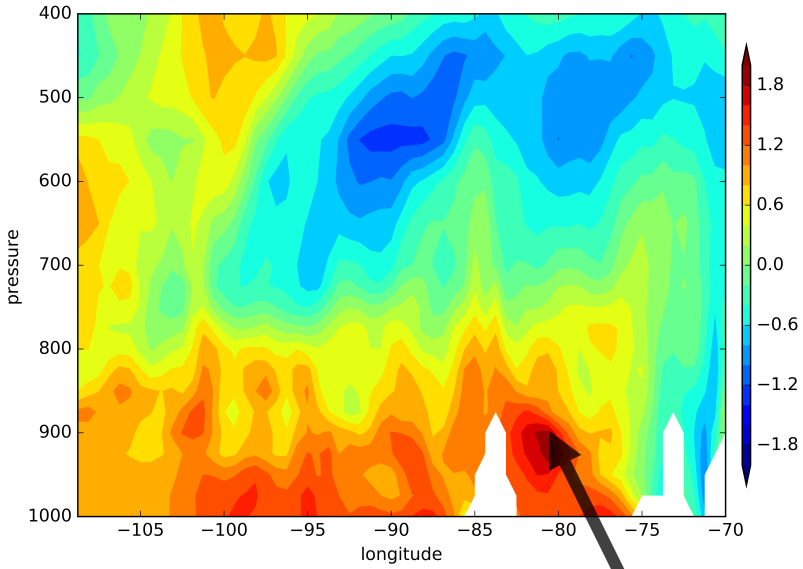
- The anomalies of precipitation and MSE in the mid-troposphere are approximately in phase.

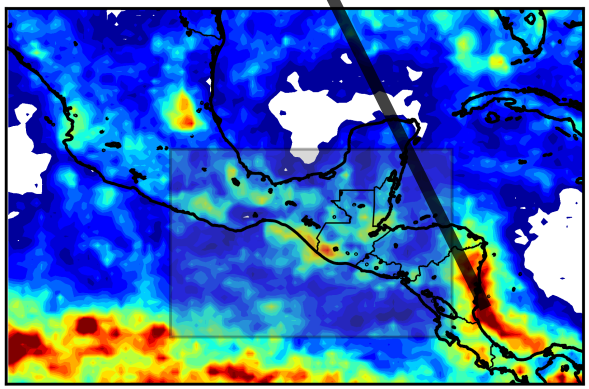
MSE anomalies on the minimum precipitation days

Latitude: 15°



Latitude: 10°



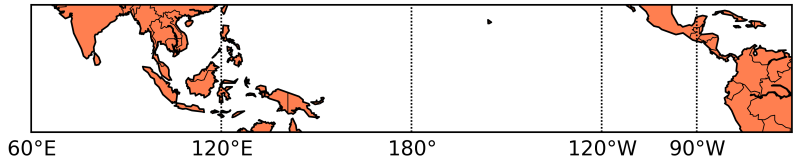


- The large MSE anomalies in the lower troposphere are related to the precipitation anomaly in the eastern Nicaragua and Costa Rica.

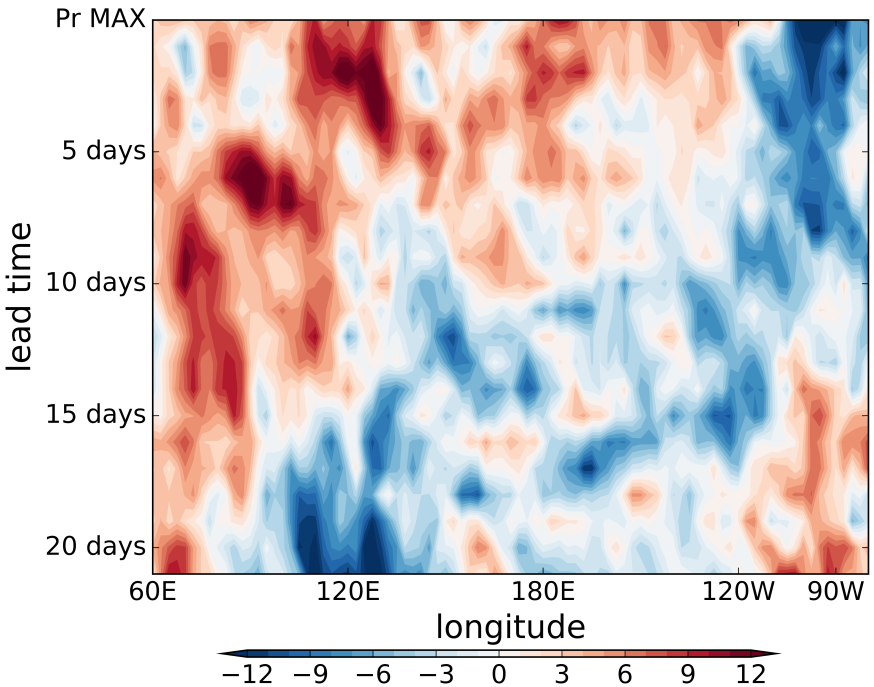
What determines the period/frequency of the intraseasonal variability in precipitation?

- The interaction between high-frequency and low-frequency modes: in-phase of the two modes can amplify the zonal wind variability
- Tropical cyclones and their landfall
- The eastward propagation of the Madden Julian Oscillation from the Indian Ocean

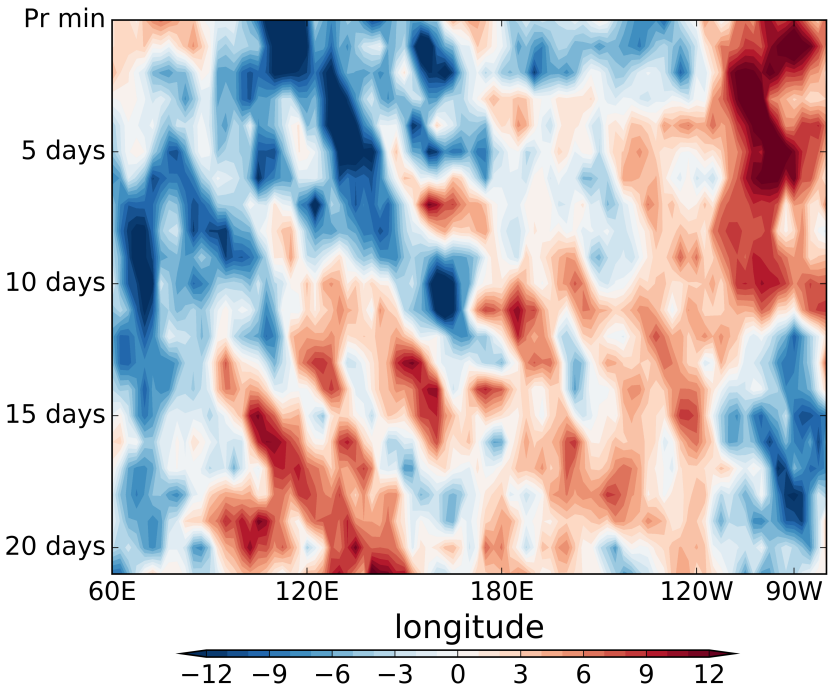
Meridionally averaged (5°-15°N) OLR anomalies (deseasonalized)



Before the maximum precipitation days



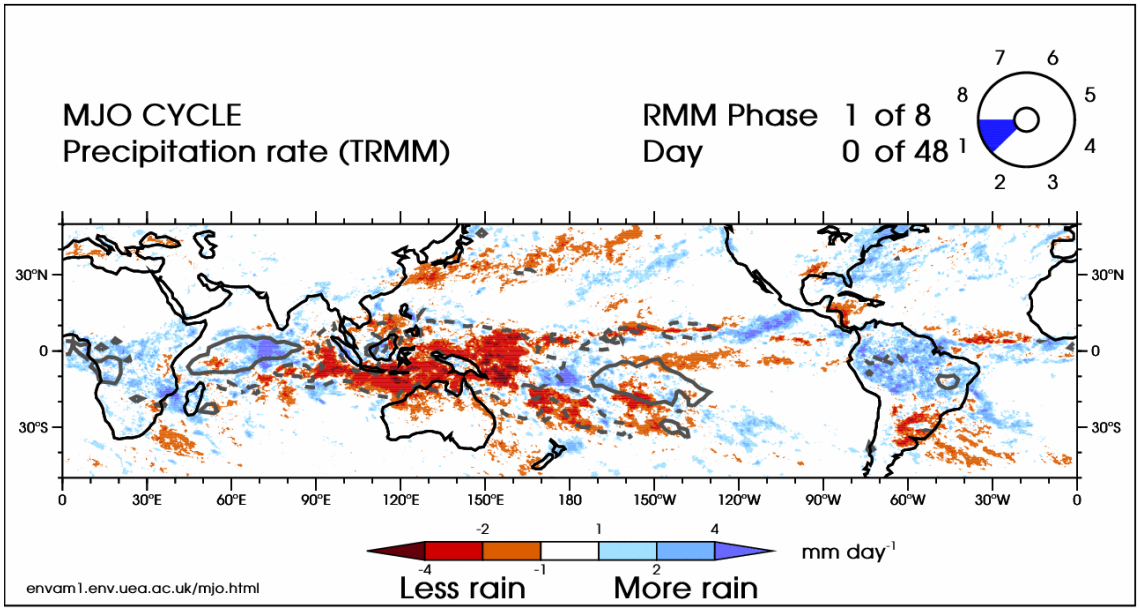
Before the minimum precipitation days



- There is a leading anomaly pattern of OLR over the Indian Ocean about three weeks before the maximum and minimum precipitation occur over Mesoamerica.

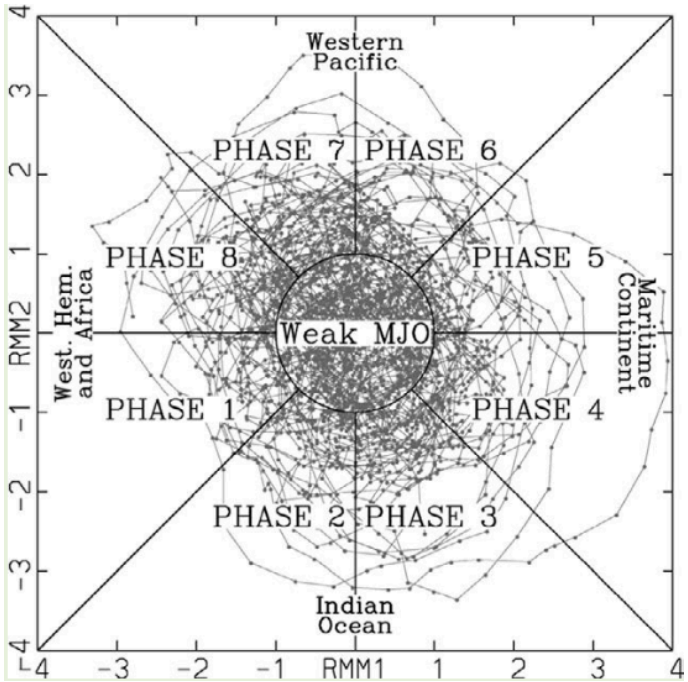
Madden-Julian oscillation

- The Madden-Julian oscillation (MJO) dominates the intraseasonal (20- to 100-day) variability in the tropical atmosphere.
- An eastward progression of large regions of enhanced and suppressed tropical rainfall.
- The MJO phase (1-8) is defined by Wheeler and Henson [2004].

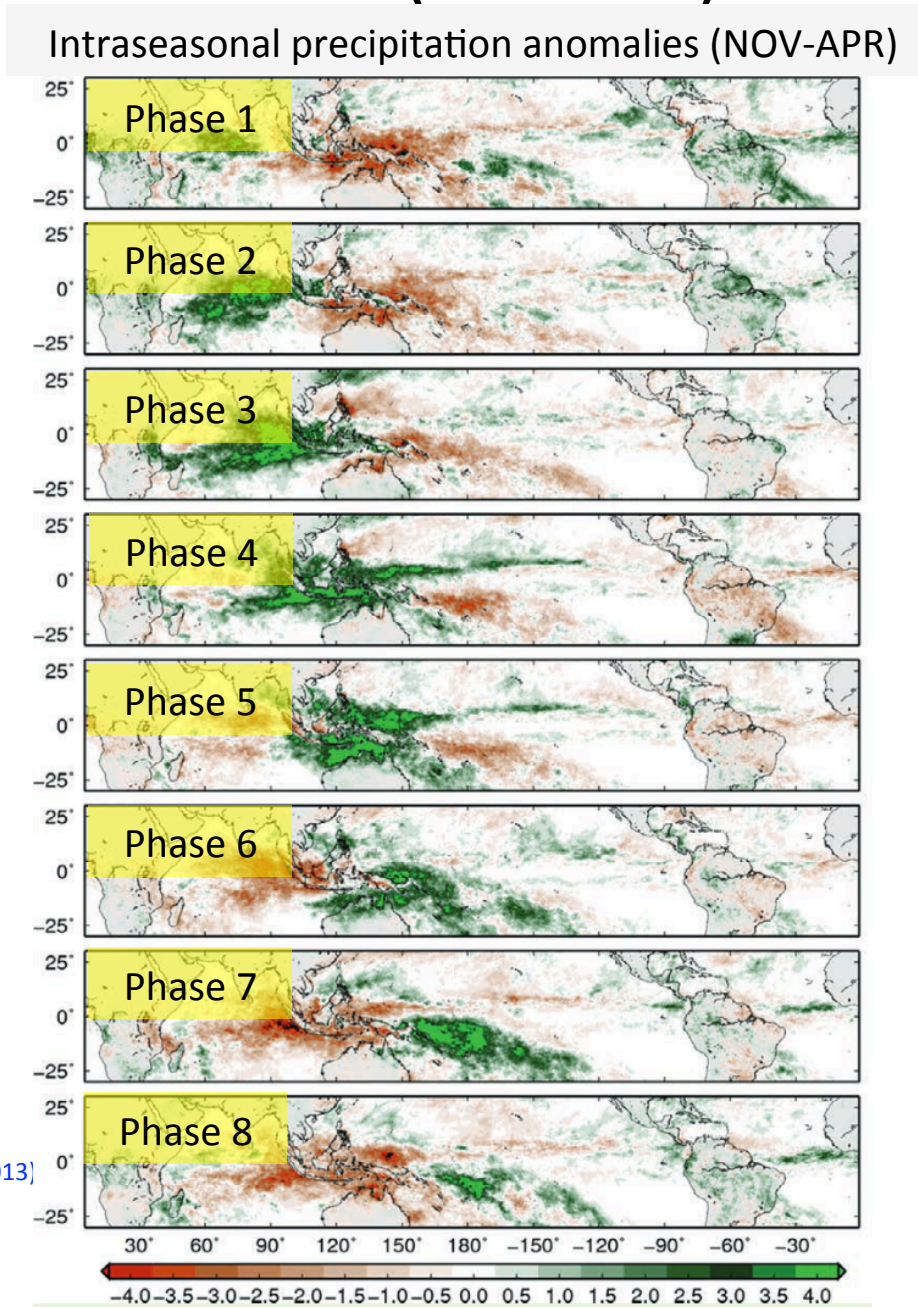


The real-time multivariate (RMM) index for MJO

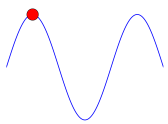
- The RMM index (Wheeler and Hendon [2004]) is derived from the two leading modes of combined EOF of zonal wind at upper and lower troposphere and OLR.
- Each dot represents each day's MJO phase.

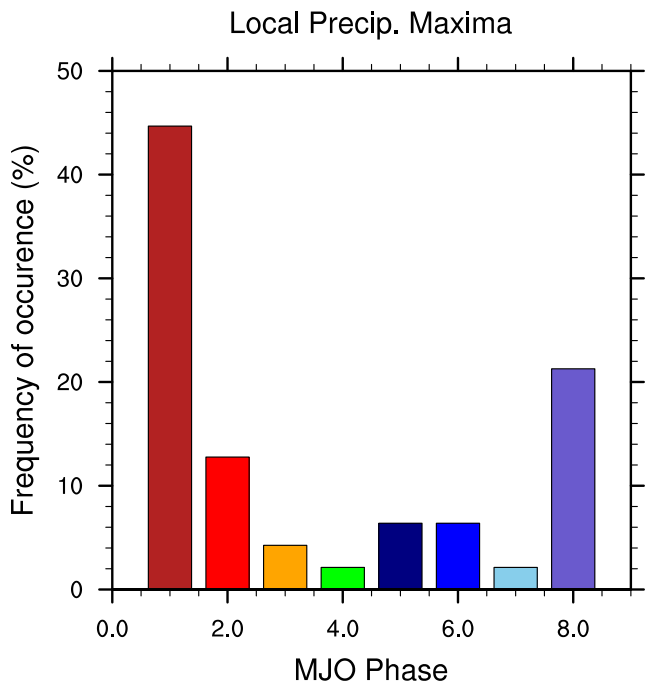


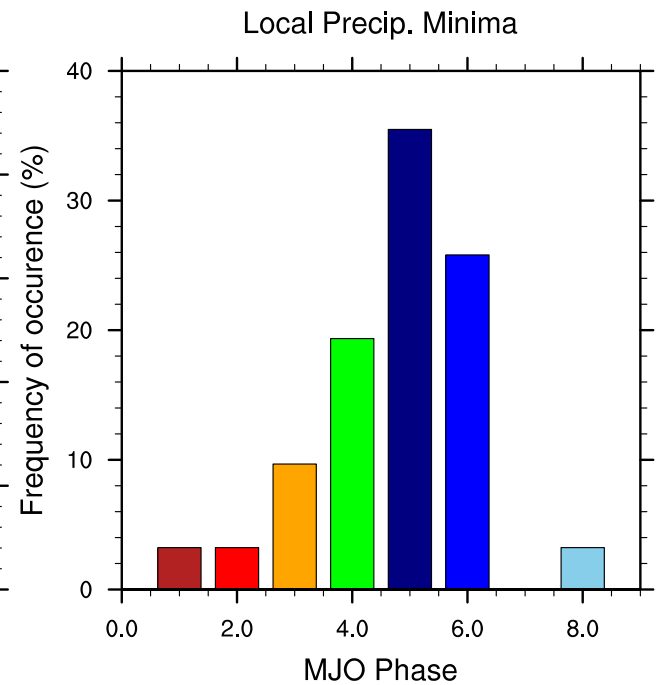
from Zhang (2013)

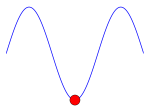


MJO phases and the precipitation cycle over Mesoamerica









- A large fraction of the precipitation maximum (minimum) occur when the MJO is over eastern Pacific and Atlantic with phase 8 and 1 (over the western Pacific warm pool region with phase 4-6).
- MJO phase 8 or 1 develops more convective clouds over eastern Pacific and Atlantic, whereas active convection over the warm pool region with MJO phase 4-6 produce descending branch over the Mesoamerica.

Conclusions

- Onset and demise of the Mesoamerican Rainy Season can be defined using the cumulative precipitation anomalies.
- Demise of the rainy season shows considerable interannual variability.
- Even when the annual precipitation cycle is not bimodal, the dynamical mechanism for precipitation maximum and minimum is along the same lines as the midsummer drought: strengthening of North Atlantic Subtropical High, strong easterly wind at low troposphere, negative anomalies of moist static energy and strong precipitation anomaly in the eastern Nicaragua and Costa Rica.
- The anomalies of outgoing longwave radiation indicates strong relationship between Madden-Julian oscillation and the intraseasonal variability over Mesoamerica.
- Accurate simulations of Madden-Julian oscillation over the Indian Ocean and Maritime Continent and its propagation may improve predictability of the intraseasonal variability over Mesoamerica including the midsummer drought.