# Monsoon Circulations and the Madden Julian Oscillation

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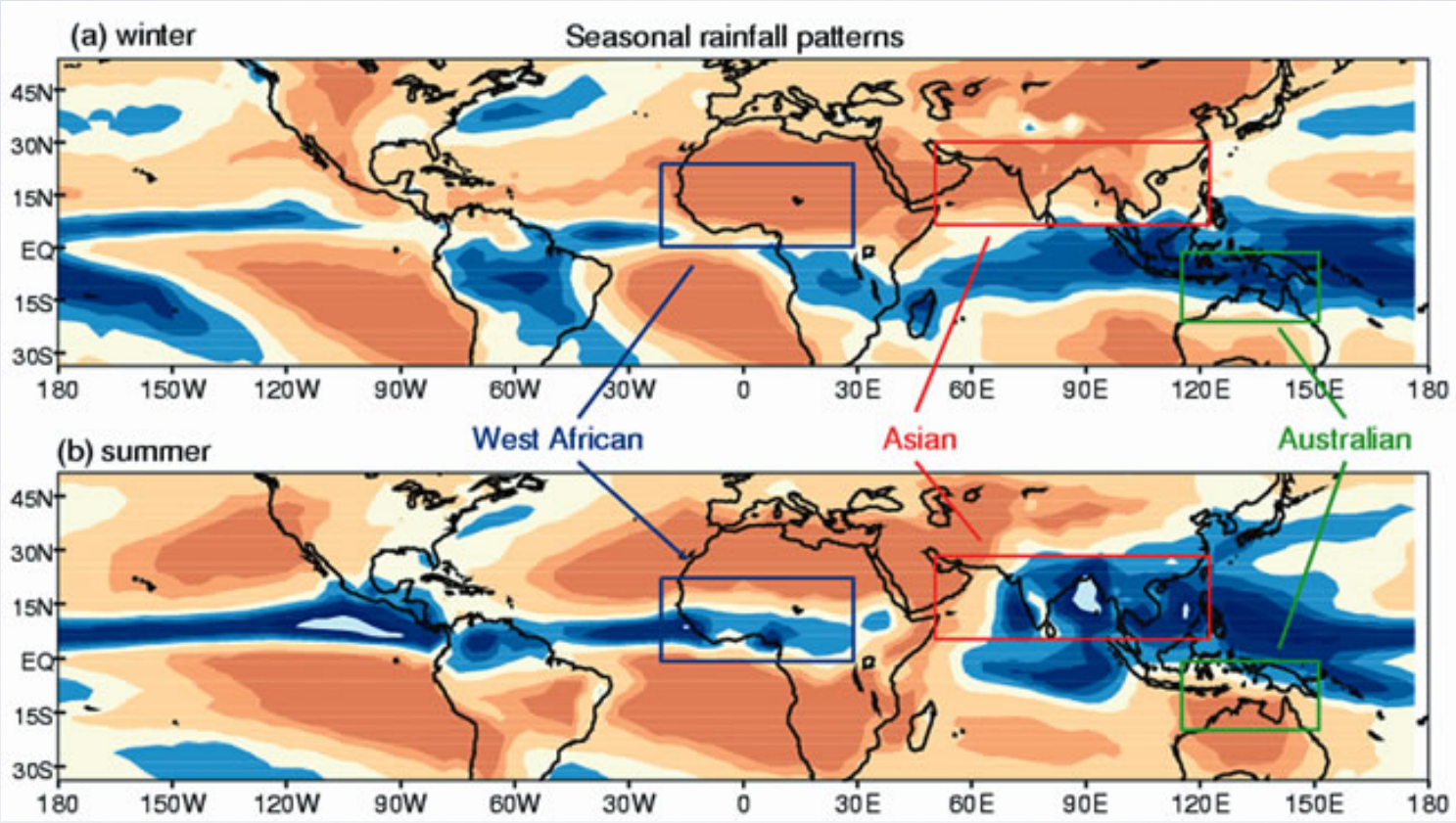
# Monsoon Circulations




http://planetearth.nerc.ac.uk/images/uploaded/custom/indian-monsoon.jpg

# Monsoon Circulations

## West African Monsoon

- affects western Africa
- it is fueled by the Atlantic Ocean to its south and produces clusters of storms that can become Atlantic hurricanes

## Asian Monsoon

- affects the Indian Ocean to the western Pacific Ocean
- in the summer the winds blow north from the Indian Ocean and dumps heavy rain on the area from April to October

## Australian Monsoon

- affects some of the Maritime Continent and Northern Australia
- it happens December through March since these regions are South of the equator and this is their summer

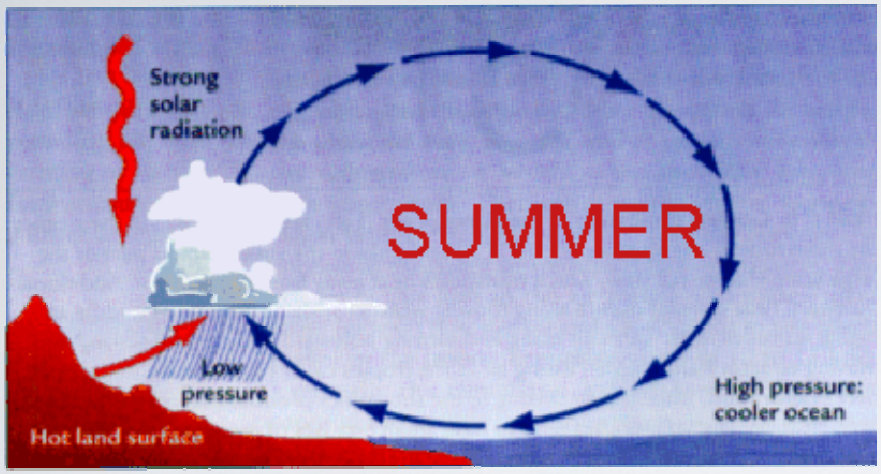
## North American Monsoon

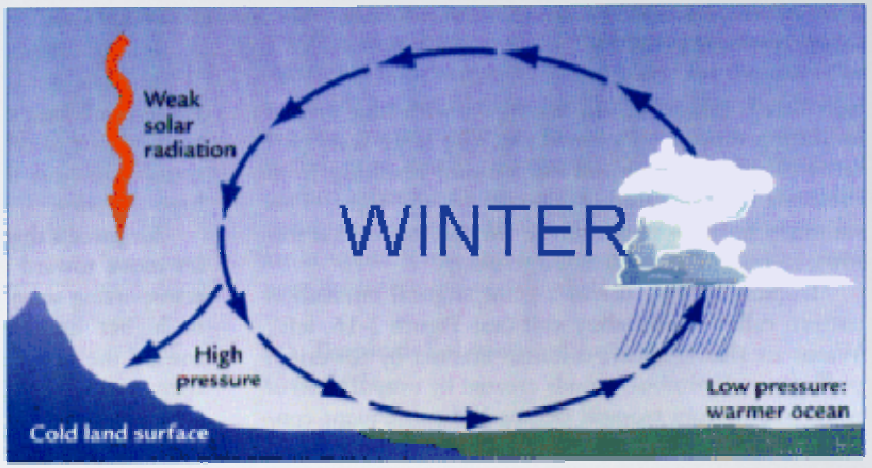
- affects the southwestern US
- does not really have a seasonally reversing wind; heavy rain and storms occur more frequently from July through September over southwest desert
- it is fueled by both the Gulf of Mexico and the Pacific Ocean

# Importance of Monsoon Circulation

- ✓ **65% of the world's population lives within monsoon regions**
- ✓ **Monsoon precipitation is directly related to food production in these regions**
- ✓ **Proper forecasting of location and quantity of precipitation is crucial to maintaining food supply.**
- ✓ **Year-to-year variation is quite dramatic - from the severe droughts to devastating floods.**

# Causes of Monsoon Circulation




http://hatteras.meas.ncsu.edu/secc_edu/images/monsoon.gif

✓ **Distribution of solar heating due to seasonal oscillation**

- **summer hemisphere net radiation is positive**

✓ **Distribution of land/sea**

- **heat capacity of land is much smaller than that of water, results in large temperature gradient between land and ocean surfaces**

✓ **Earth’s rotation**

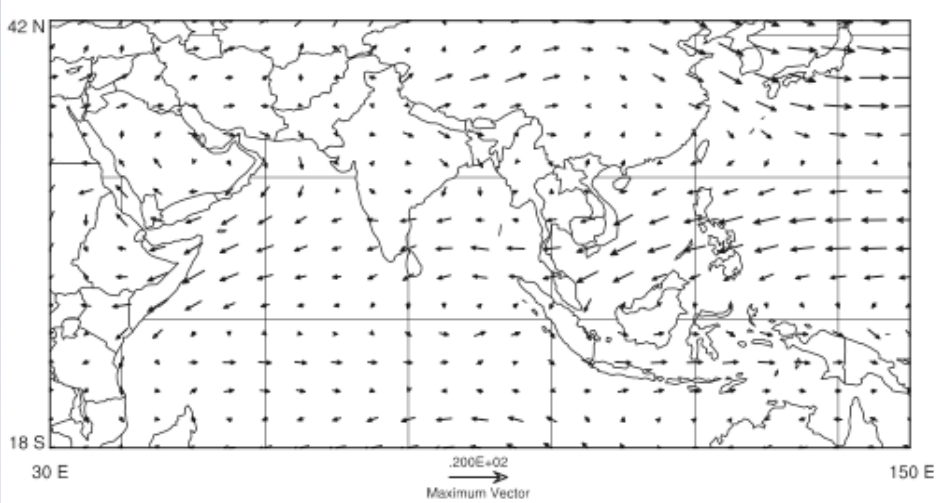
- **results in Coriolis force which affects location and intensity of winds and ocean currents**

✓ **Moist processes**

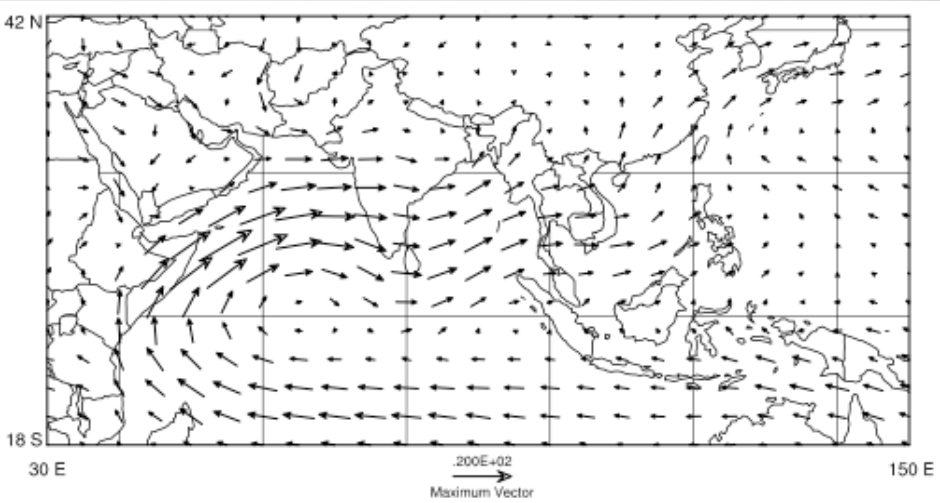
- **affect the water cycle**

# Description of Monsoon Circulation

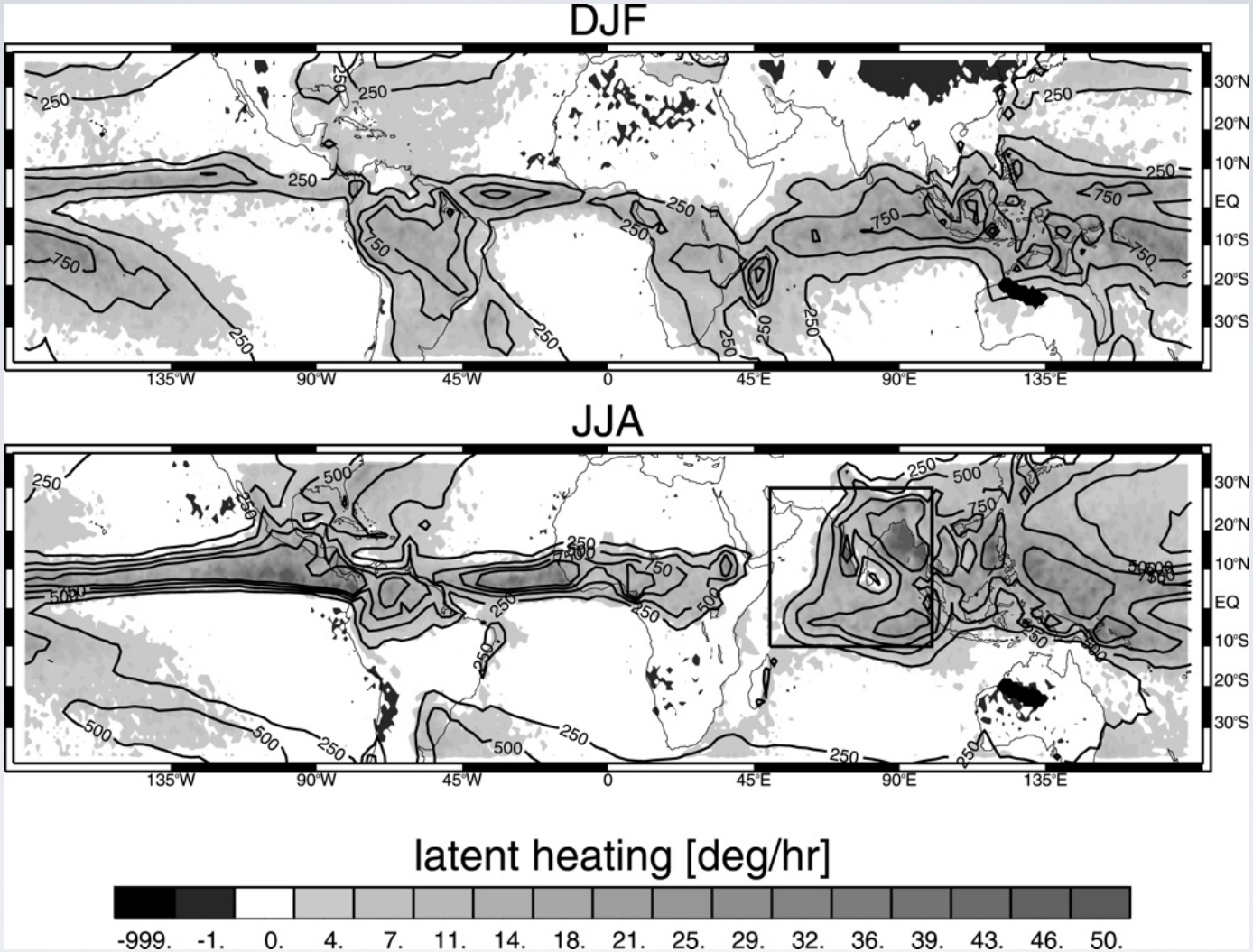
**January**




**July**



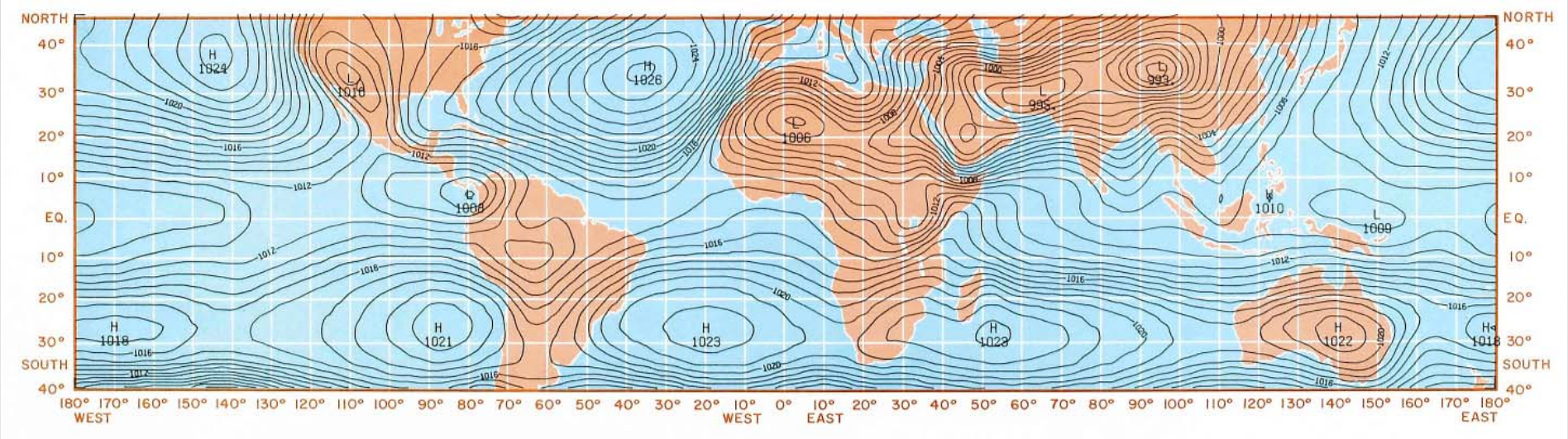

✓ **dramatic reversal of the low-level prevailing winds from the northeast in winter to the southwest in summer.**



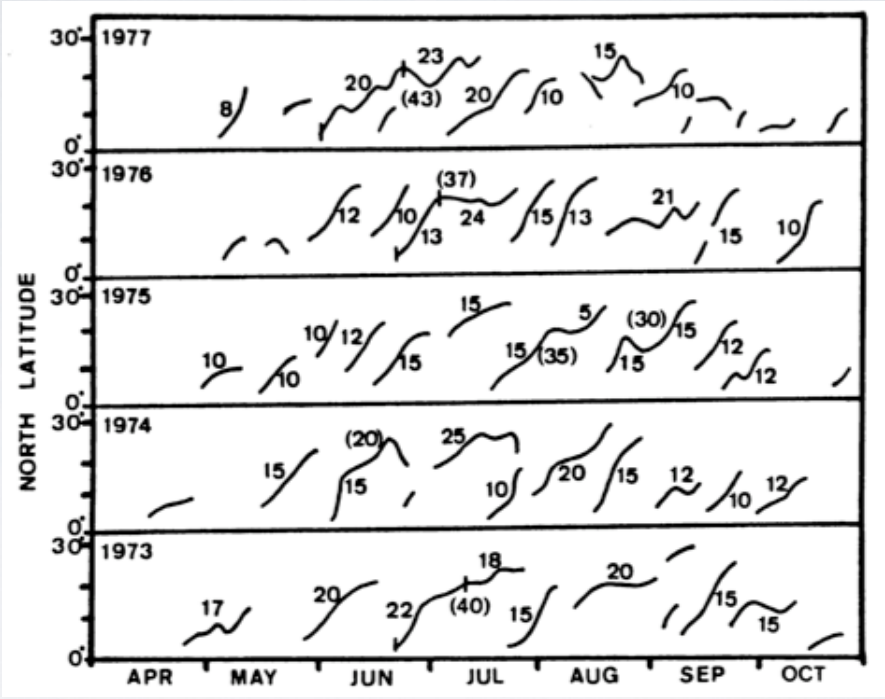

- ✓ **relatively low cooling in winter and low heat in summer implies a 3D ocean circulation**
- ✓ **monsoon moisture results from SH water cycle with divergence occurring in the SH and convergence in the NH**

***From Zuluaga et. al, 2010***

## SLP, July



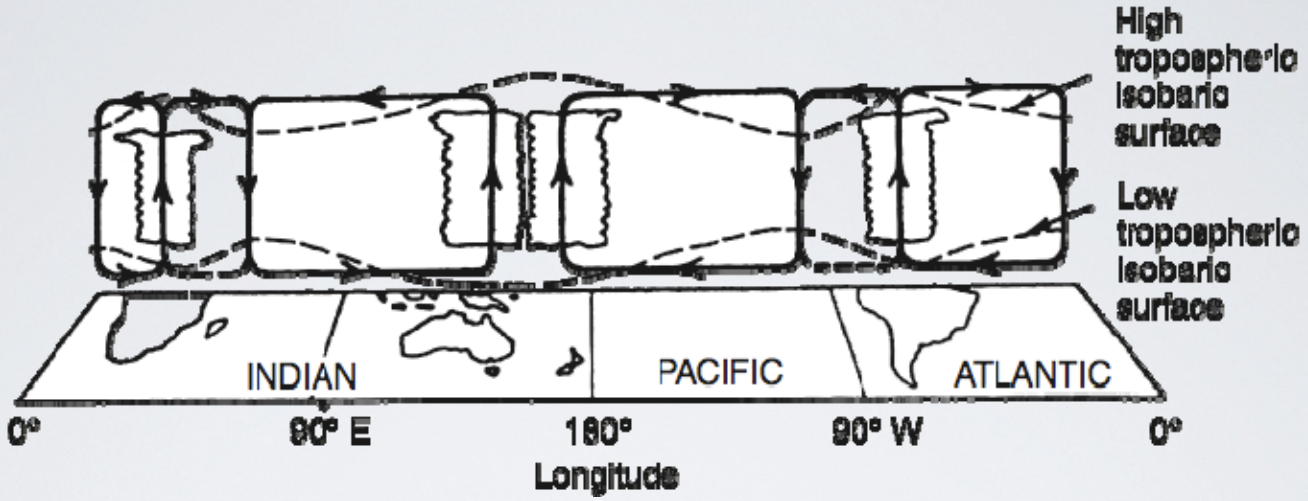

✓ **double trough pattern over southwest Pacific and Indian Oceans during Northern Hemisphere summer.**




**Mean latitudinal position of the monsoon trough in the Indian Ocean, as obtained from the maximum cloudiness zone.**

***From Webster 1987, Webster 1983, Sikka and Gadgil 1980.***

# Monsoon Interactions

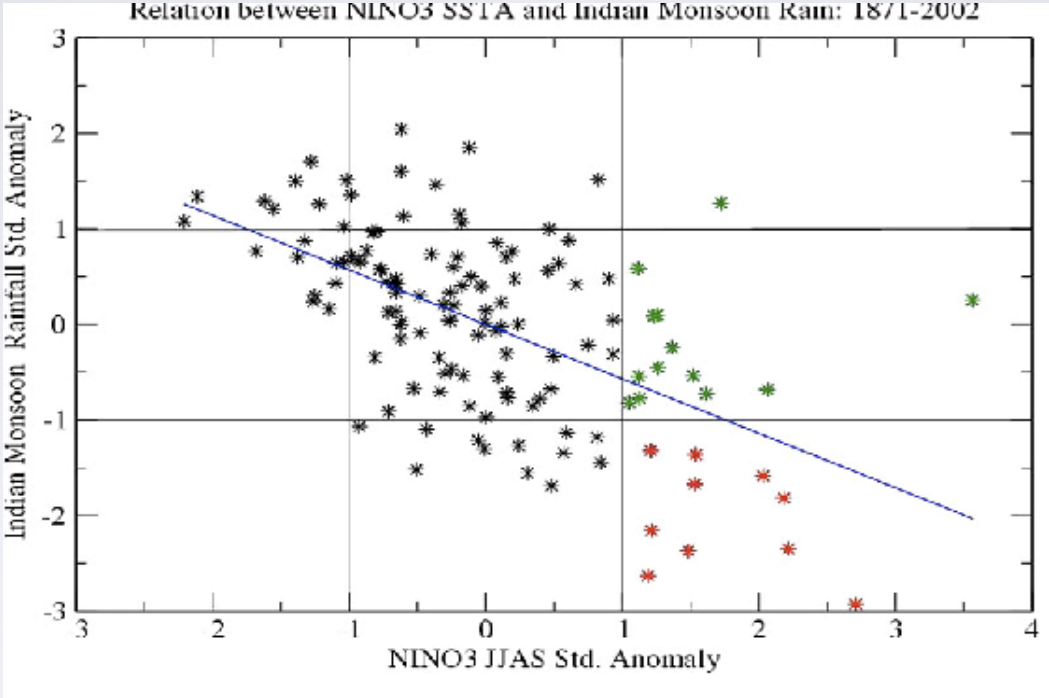



- ✓ **Walker Circulation**
- ✓ **Lateral Circulation: North-South between southern Indian Ocean and Indian region**
- ✓ **Transverse Circulation: East-West circulation between North Africa and Indian region**
- ✓ **ENSO**

***From Webster 1983***

# Asian Summer Monsoon Variability

# Interannual Variability related to ENSO events

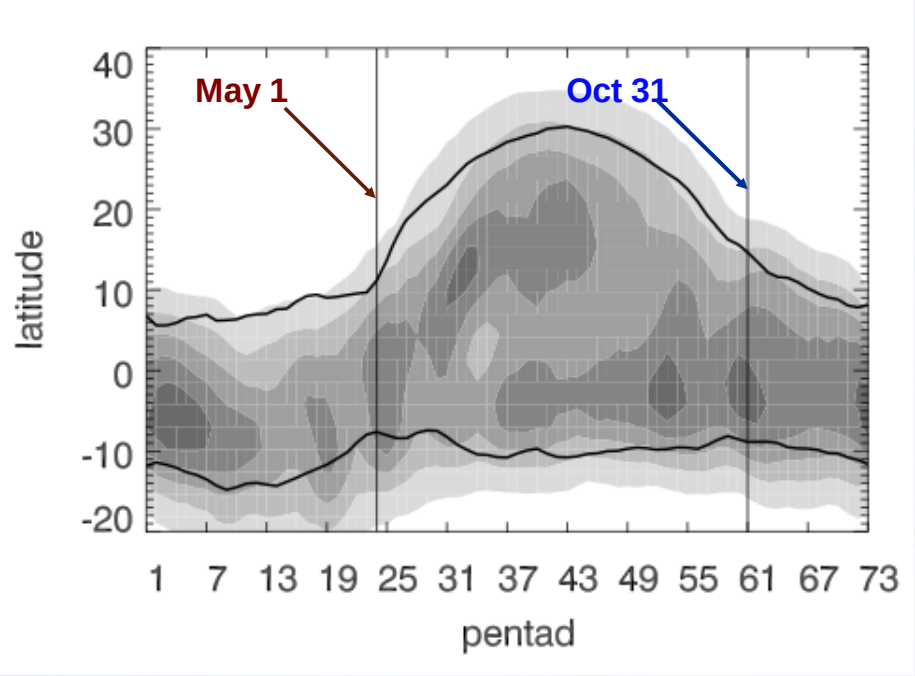



- **below average rainfall during El Nino, above average during La Nina**

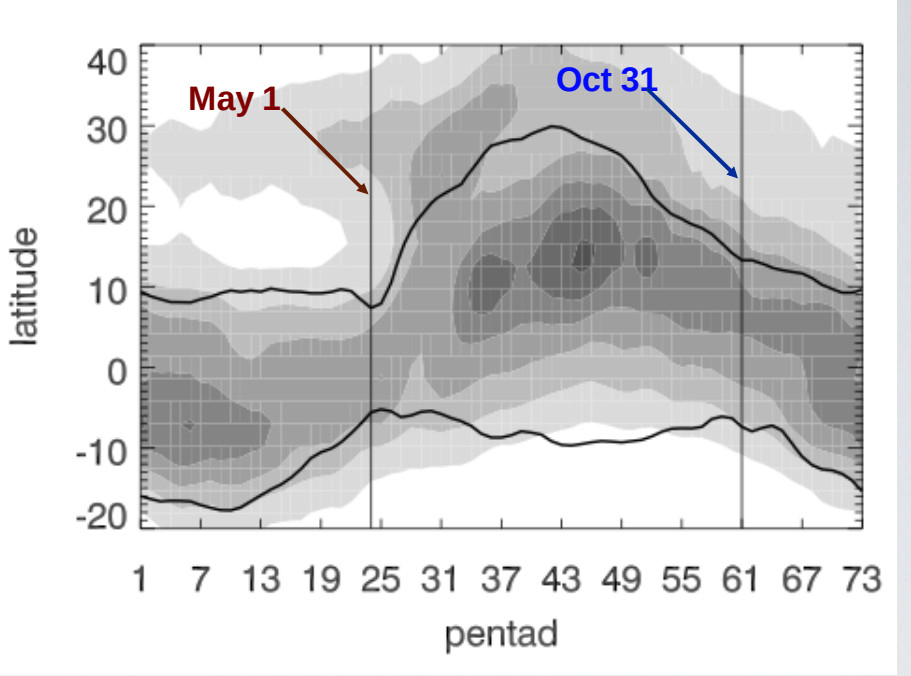
***From Kumar et al. 2006***

# Intraseasonal Variability associated with ISO

**Indian Ocean**



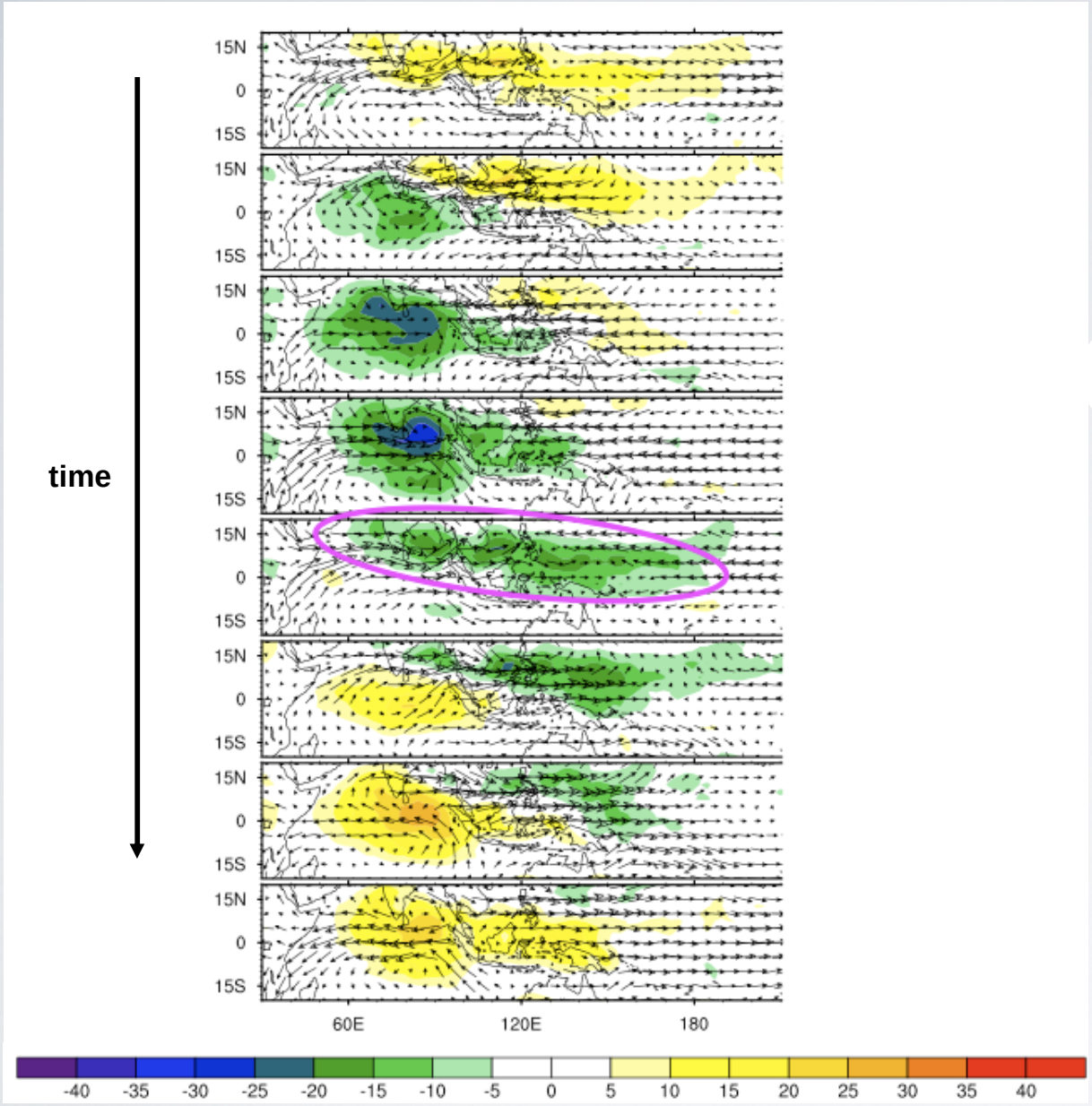

**Wester Pacific Ocean**

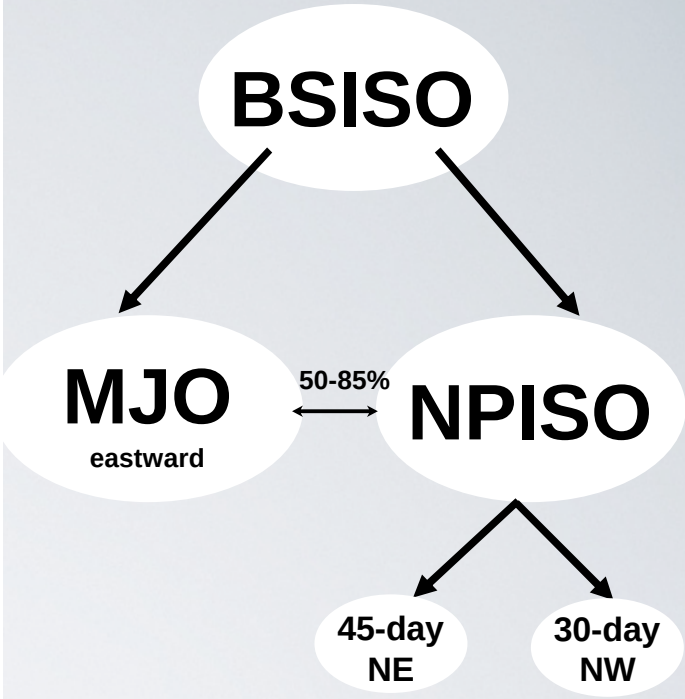



✓ **Active period: precipitation is high in the Bay of Bengal and over India, relatively dry over the equator**

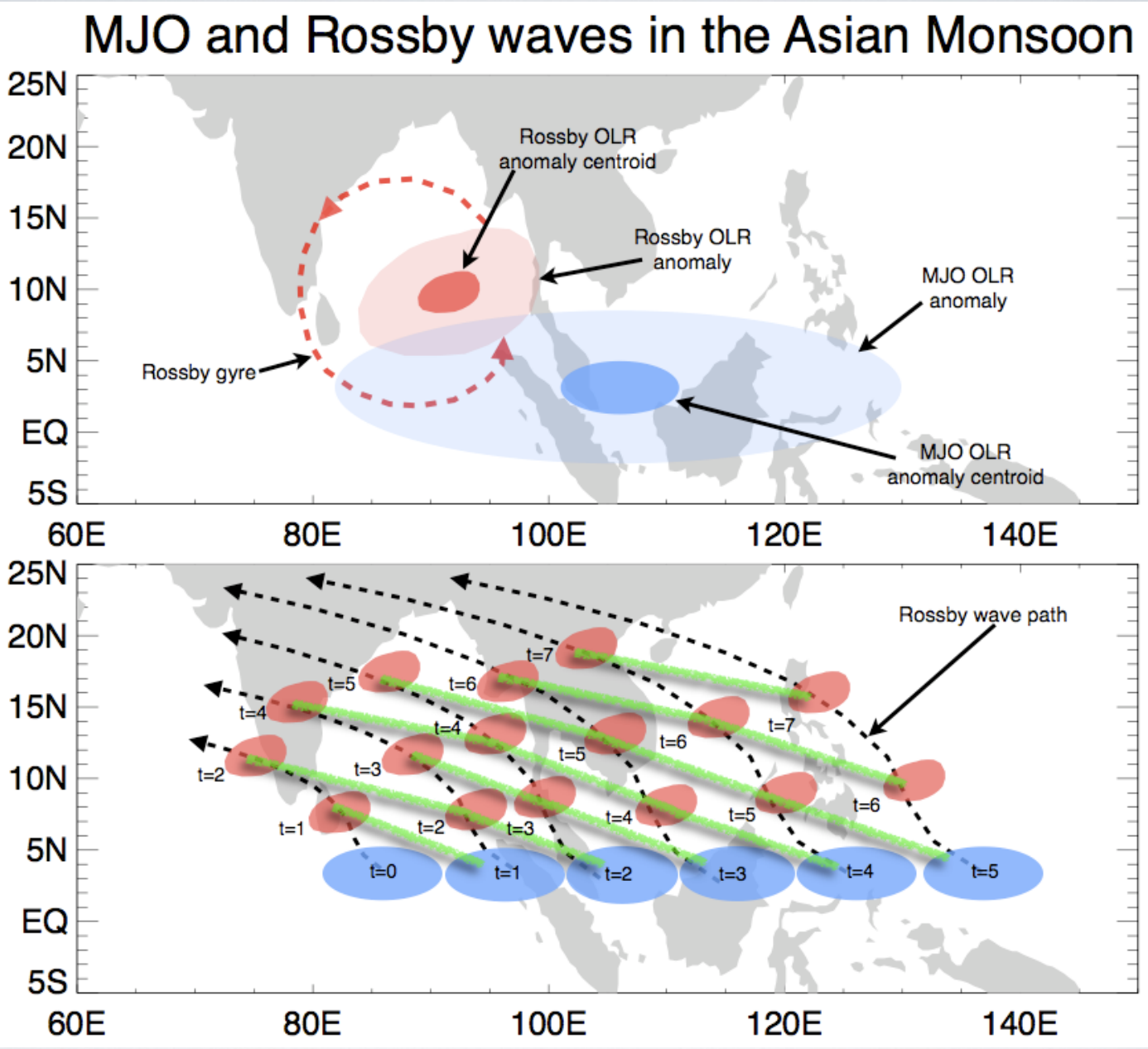
✓ **Break Period: precipitation is low in the Bay of Bengal and India, wet over the equator**

***From DeMott et al. 2011***


time
15N
0
15S
60E
120E
180
-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40

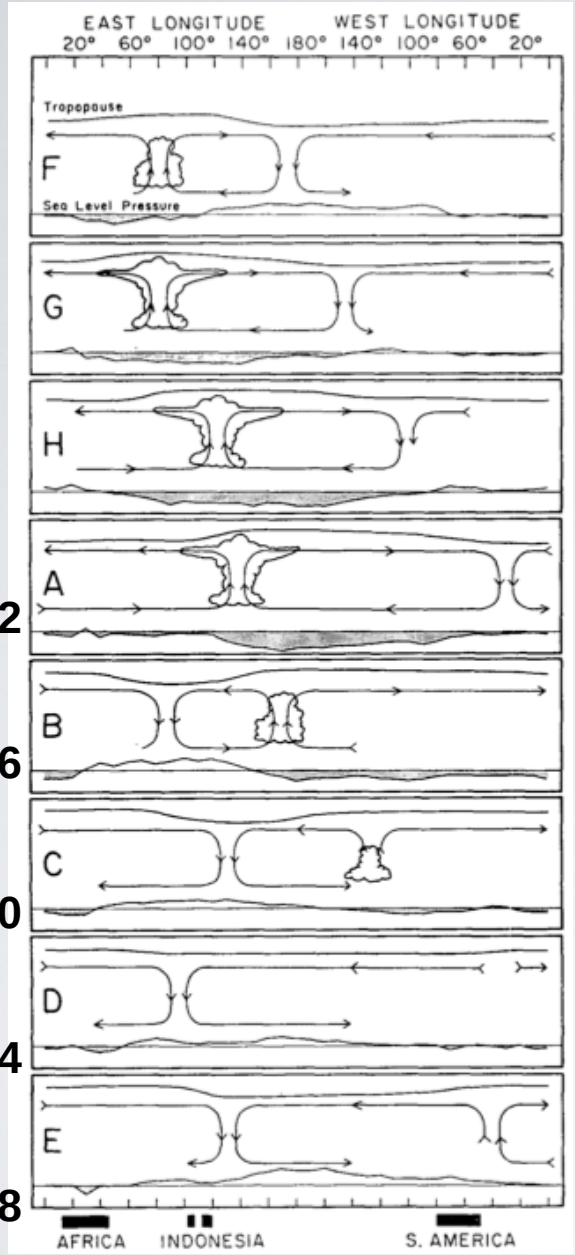

BSISO
MJO
eastward
50-85%
NPISO
45-day
NE
30-day
NW

# MJO and Rossby waves in the Asian Monsoon




*From DeMott et al. 2011*

# The Madden Julian Oscillation




Day 0
Day 4
Day 8
Day 12
Day 16
Day 20
Day 24
Day 28

- ✓ **Oscillation of that the tropical troposphere undergoes with a period of 30-60 days**
- ✓ **The first baroclinic mode, equatorially trapped, convectively-coupled disturbance propagating at a phase speed of about 5m/s as it travels from the Indian Ocean eastward to the dateline, where the convective coupling diminishes and propagates at about 12m/s**
- ✓ **Involves eastward moving of rainy and dry weather in the Indian and West Pacific Oceans**
- ✓ **A region can expect on average 20 days of above normal rainfall followed by 20 days of below normal rainfall**
- ✓ **In the convectively active phase is characterized by strong surface westerlies and high surface latent fluxes**
- ✓ **In the convectively inactive phase is characterized by weak surface easterlies and high downward radiative fluxes**

***Madden and Julian , 1972***

# Theories explaining the MJO

- ✓ **wave-CISK theories (e.g., Hayashi, 1970; Lindzen, 1974; Hayasi and Sumi, 1986; Lau and Peng, 1987; Salby et al, 1994)**
  - **large-scale dynamical and thermodynamical structure and the cumulus heating sustain each other and propagate eastward via their mutual interaction and feedback**
  - **cannot explain the observed phase speeds and vertical structure of waves**

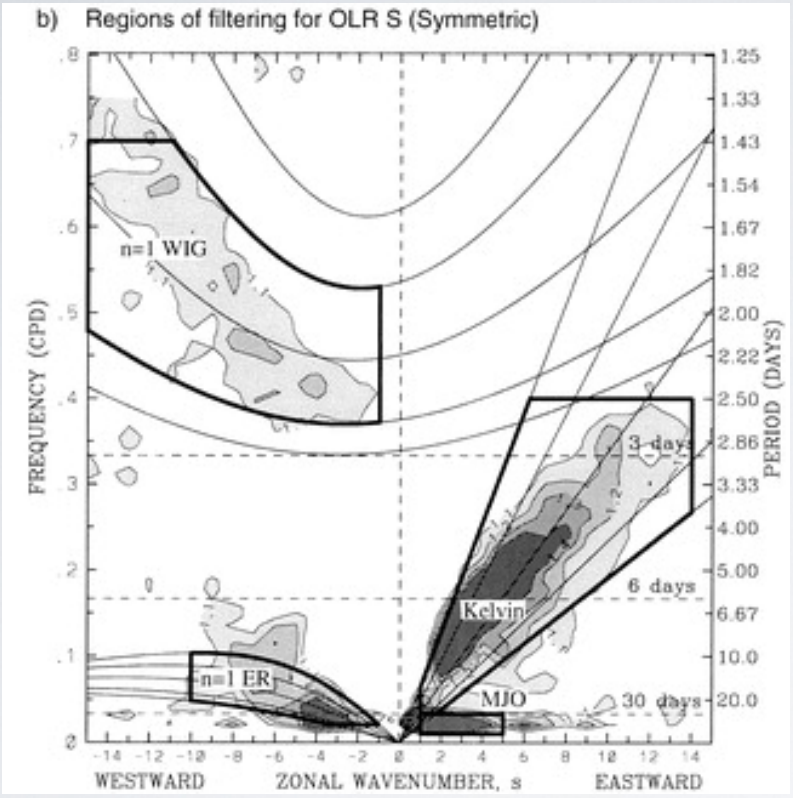
- ✓ **WISHE (Wind-Induced Surface Heat Evaporation; Emanuel, 1987; Neelin and Yu, 1994)**
  - **the heat source is maintained by the interaction between the waves with the low-level flow.**
  - **requires existence of mean easterly flow in the Indian and western Pacific Oceans**

- ✓ **Discharge-recharge theories (Blade and Hartmann, 1993; Hu and Randall, 1994; Salby and Garcia, 1997; Flatau et al, 1997)**
  - **a low-frequency tropical heat source excites waves that propagate slowly eastward and dry out the mid-troposphere; in time the base of this very dry layer rises and the atmosphere moistens from below, restoring conditions for the next MJO convective disturbance**

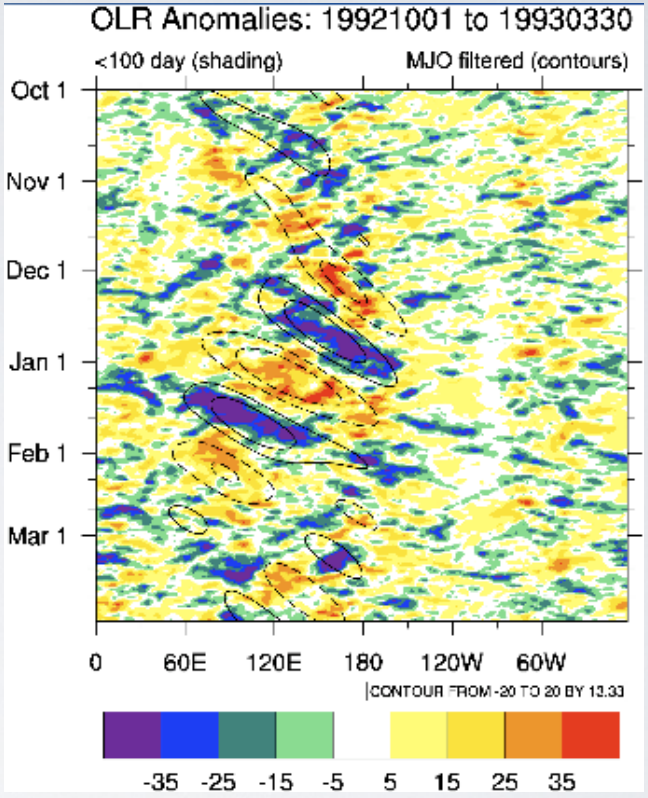
# Methods of identifying the MJO

- ✓ **Temporal filtering (e.g., 20-100 days)**
- ✓ **Space-time filtering (e.g, 20-100 days, eastward wavenumber 0-6)**
- ✓ **EOF analysis of a single variable**
- ✓ **Multivariate EOF analysis**

# Space-time filtering




*Wheeler et al, 2000*




**captures spatial and temporal scales of interest**
**does not constrain horizontal structures**

- **takes only one variable into account**
- **does not distinguish between events**

# Multivariate EOF analysis

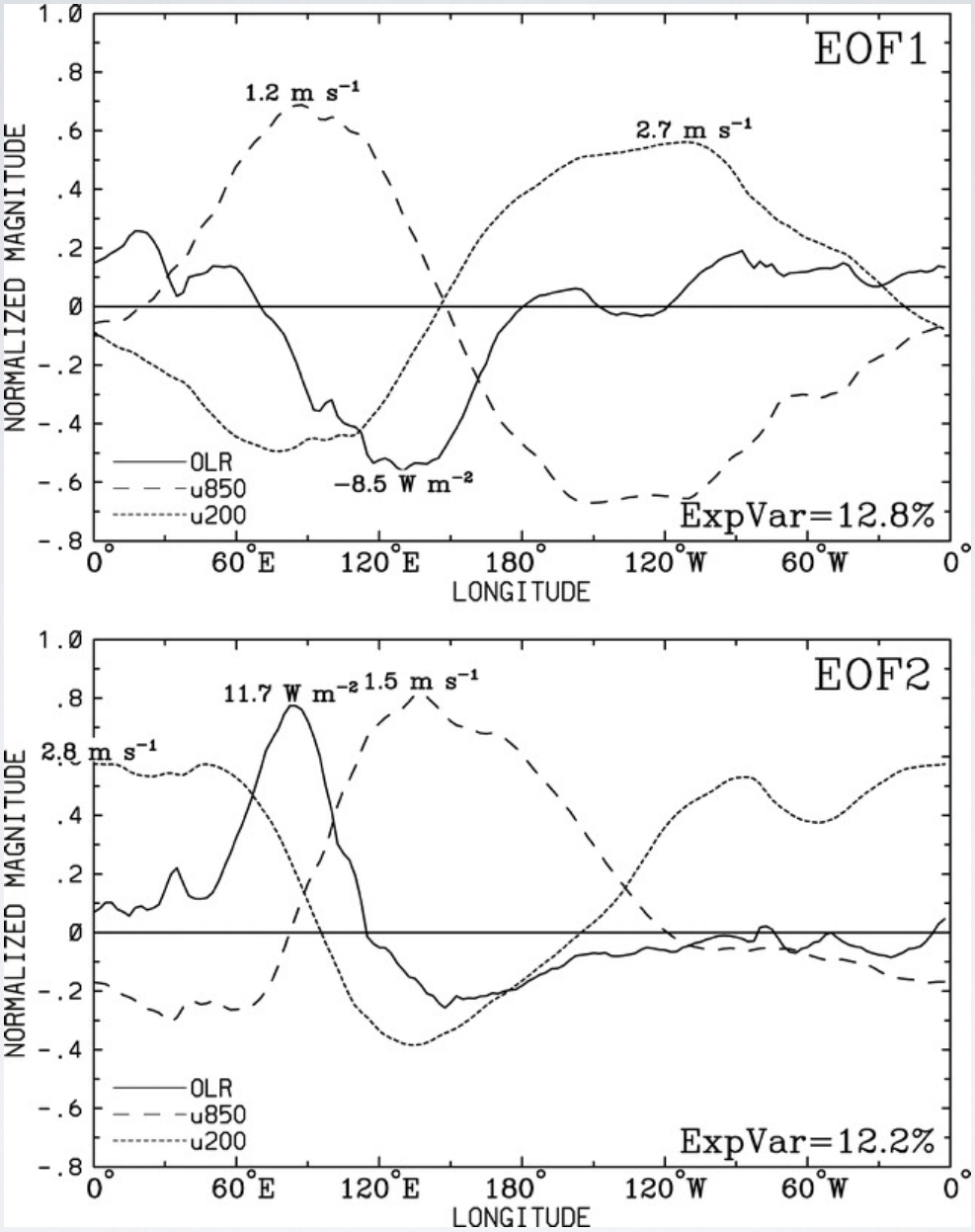
**EOF analysis of 15S to 15N averaged OLR, u850 and u200**

- **each variable is normalized by its standard deviation**
- **first two combined EOF describe propagating MJO structure**
- **RMM = Realtime Multivariate MJO index: project OLR, u850, and u200 onto the first 2 combined EOFs**

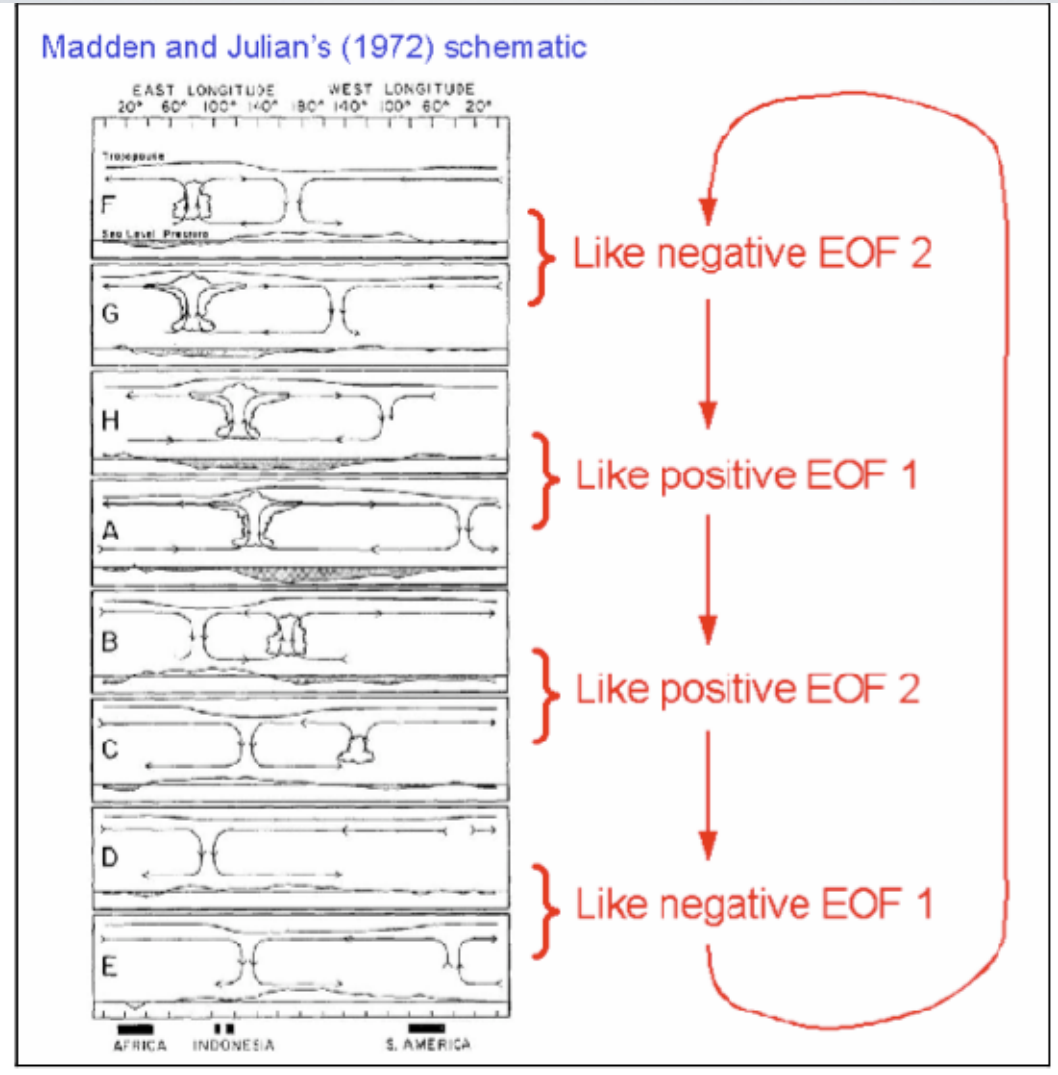
**Includes both  OLR and wind**

**Distinguish between the MJO events**

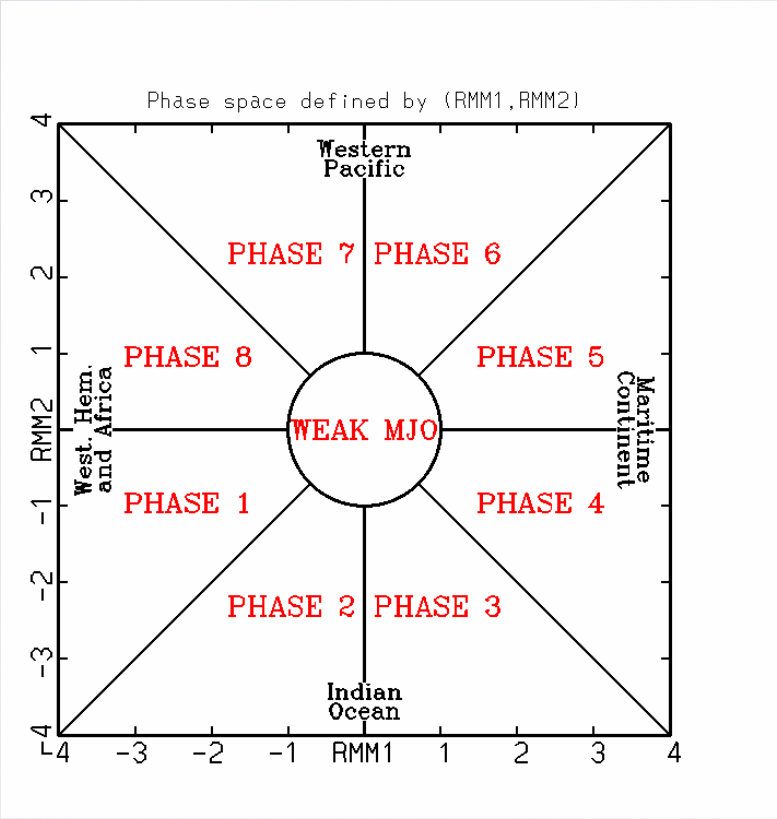
- **Winds dominates the signal**
- **False MJO signals**

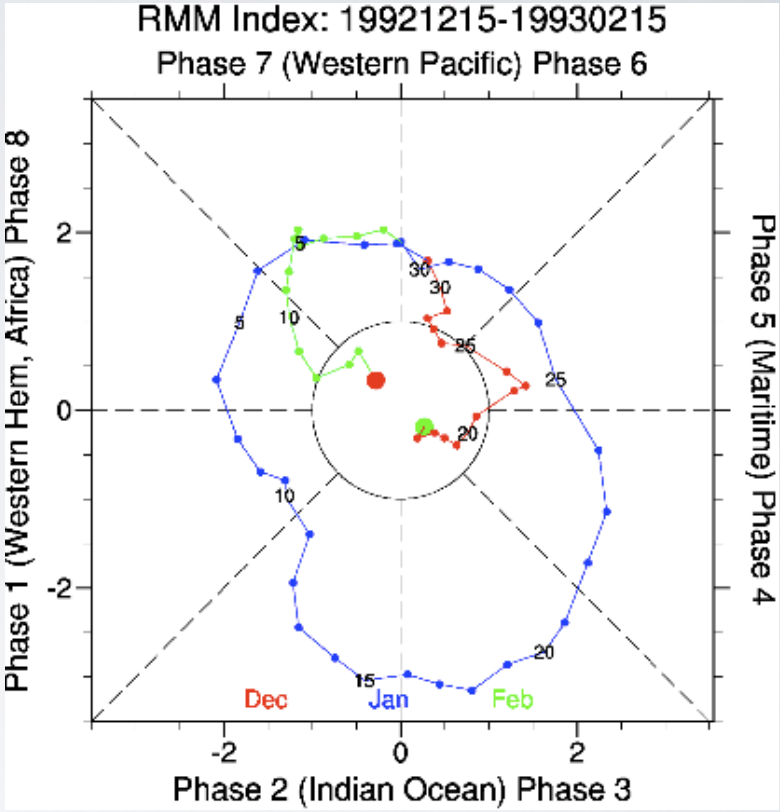


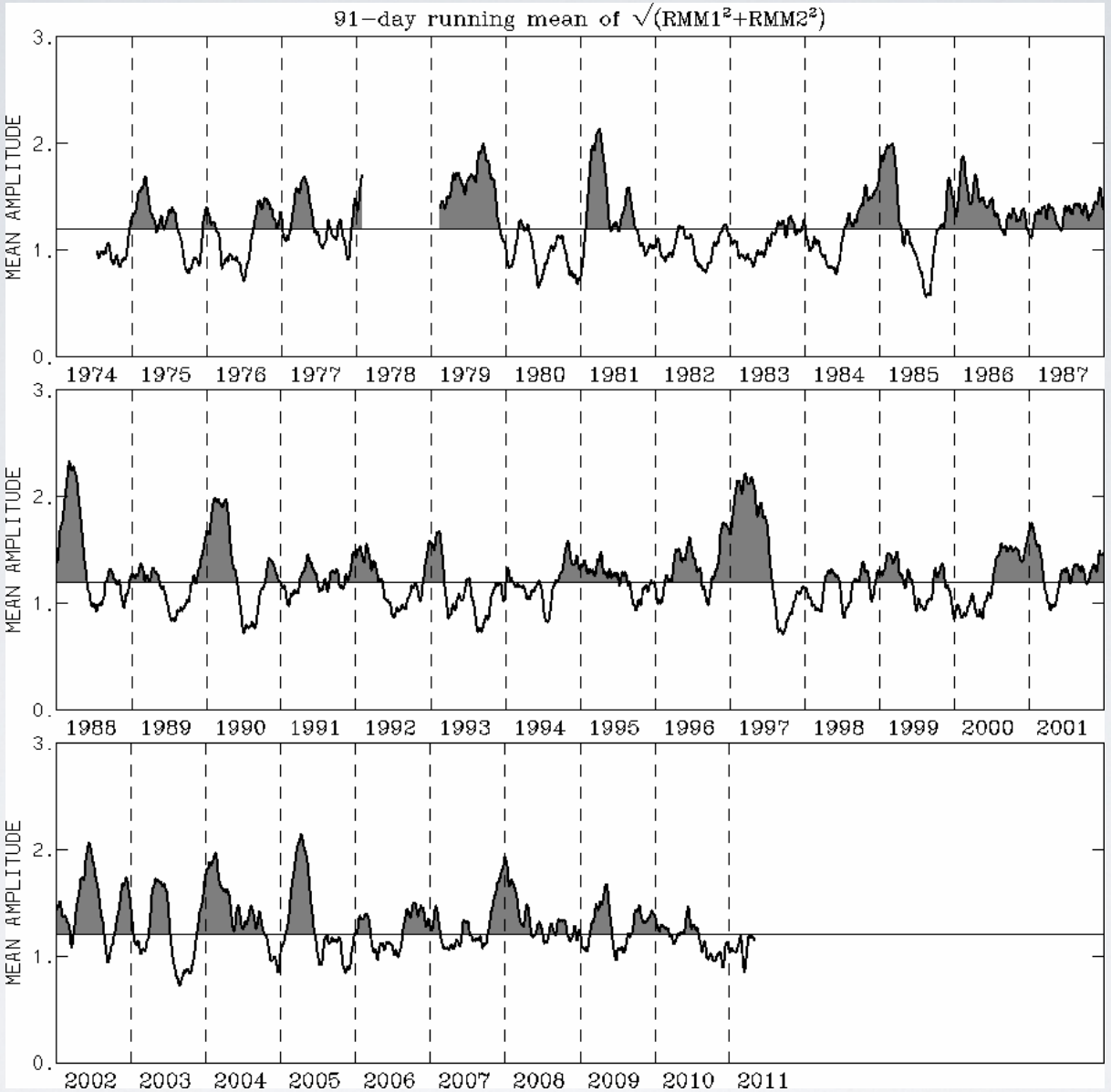

***From Wheeler and Hendon, 2004***




*From http://cawcr.gov.au/staff/mwheeler/maproom/RMM/eof1and2.htm*


Phase space defined by (RMM1,RMM2)
Western Pacific
PHASE 7
PHASE 6
PHASE 8
PHASE 5
West. Hem. and Africa
Maritime Continent
WEAK MJO
PHASE 1
PHASE 4
PHASE 2
PHASE 3
Indian Ocean
RMM1
RMM2


RMM Index: 19921215-19930215
Phase 7 (Western Pacific) Phase 6
Phase 1 (Western Hem, Africa) Phase 8
Phase 5 (Maritime) Phase 4
Phase 2 (Indian Ocean) Phase 3
Dec
Jan
Feb




http://cawcr.gov.au/staff/mwheeler/maproom/RMM/ts.PCamp91drm.gif