



The Abdus Salam  
International Centre  
for Theoretical Physics



# The Madden-Julian Oscillation; Diagnosis and Modeling

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# Outline

- MJO introduction
- MJO Diagnosis
  - Temporal and time-space filtering
  - EOF analysis
- MJO Modeling
  - Role of cloud representation
  - Role of ocean variability
- Conclusions

Introduction

Diagnosis

Modeling

Conclusions

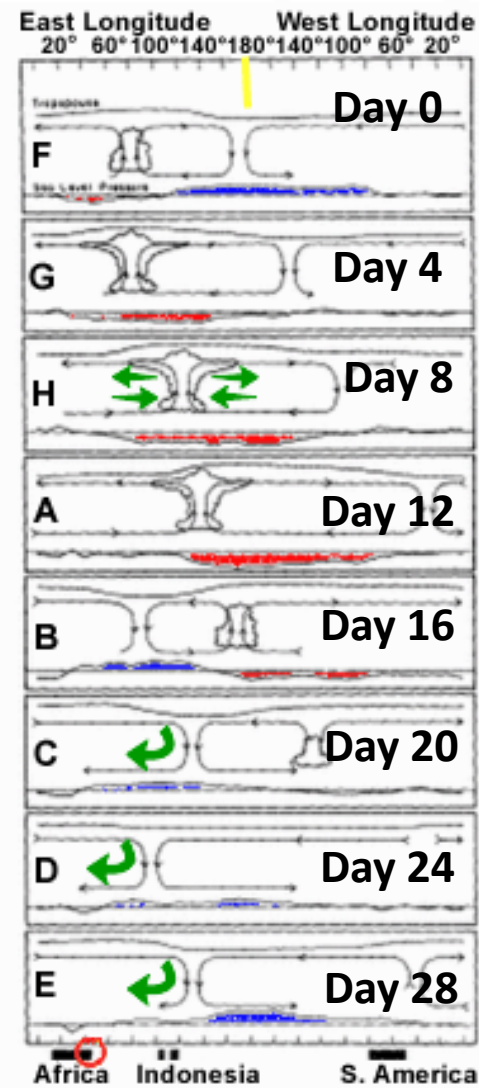
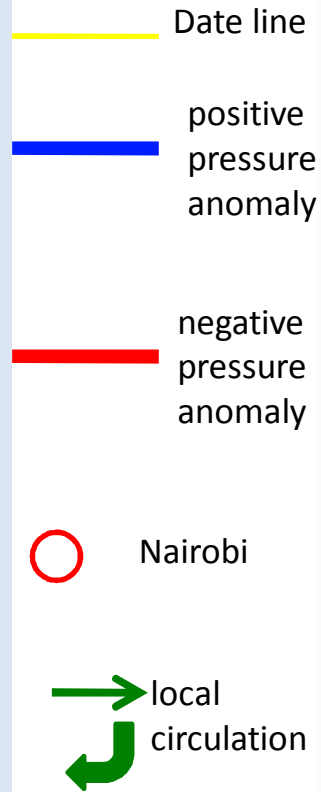
# MJO Overview



# MJO Overview

- A pattern of tropical convection in which a given location experiences enhanced precipitation about every 40-50 days
- Wavenumber 1, wavelength 12,000 – 20,000 km; Symmetric and circular in form
- Amplitude varies as waves travels around the globe
  - Has been observed to extend as much as  $20^{\circ}$ - $30^{\circ}$  away from the equator
- Can be identified by a maximum in the upper level divergence field
- Frequently accompanied by convection
- Average phase speed  $\sim 10\text{m/s}$
- Oceanic component
  - 60-75 days, evident in the SST, mixed layer depth, surface latent heat flux and surface wind stress

# MJO life-cycle

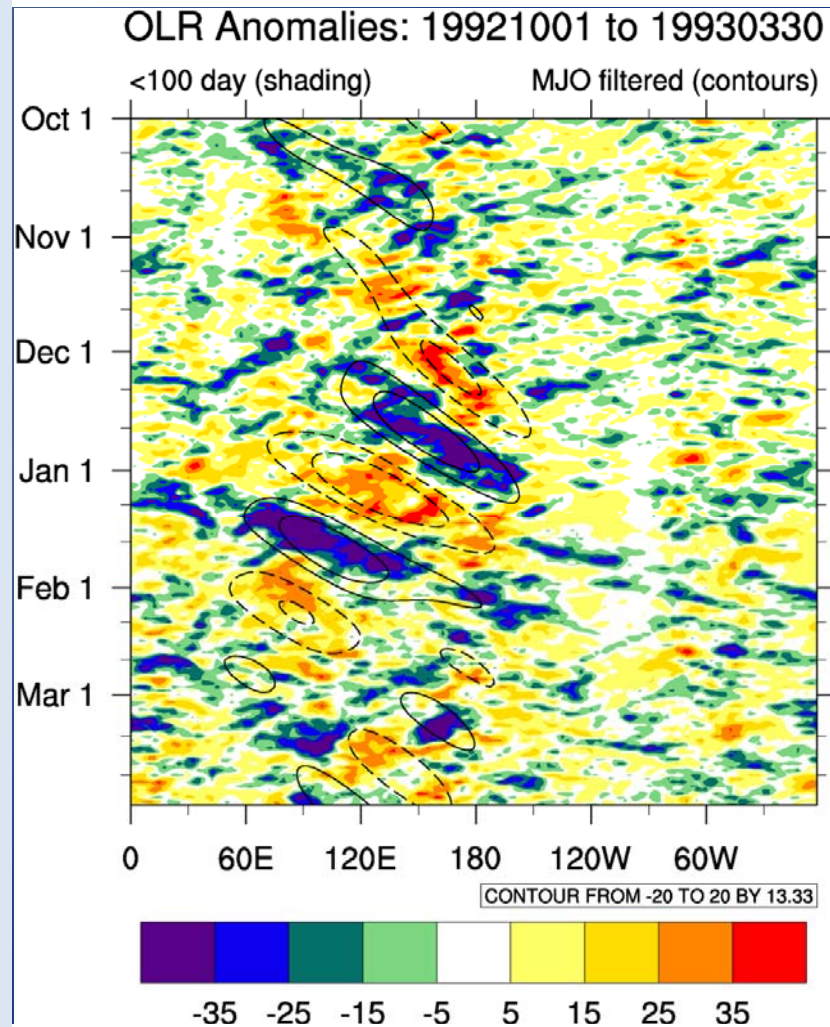


- Convection builds up in the Indian Ocean first, so this would be the initial time of an MJO
- Circulation cell east to the convection anomaly reaches only to the Date line
- Circulation cell to the west has strong upper tropospheric westerlies
- Low pressure anomaly in the Indian Ocean propagates rapidly eastward
- A: two symmetric circulations
- C: weak convection but not coupled to the circulation
- E: high pressure at Canton is maximum

# Methods of identifying the MJO

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

# Time filtering



## Pros

Captures the spatial and temporal scales of the oscillation

Does not constrain the spatial scale

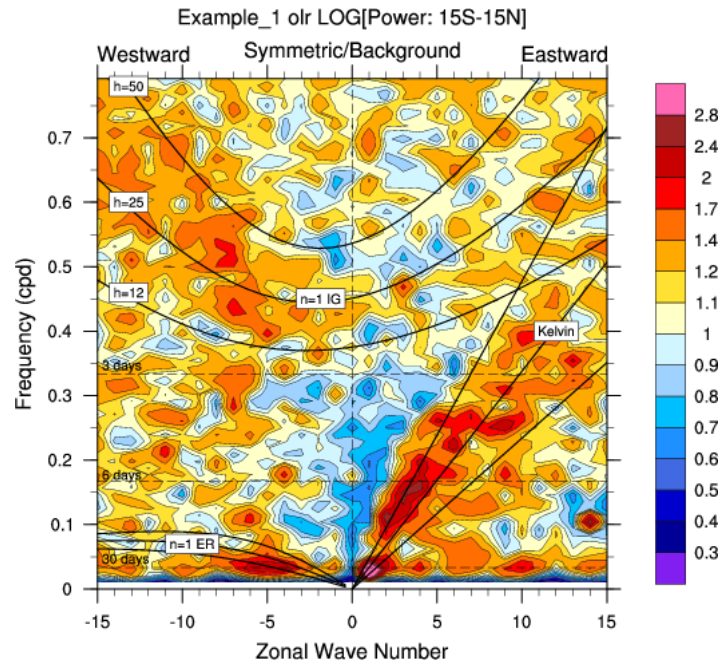
## Cons

Based on only one variable

Are the events linked?

When do events begin and end?

# Wheeler-Kiladis Diagram



## Pros

Does not distinguish among the events

$$OLR(\phi) = OLRA(\phi) + OLRS(\phi)$$

$$OLRA(\phi) = \frac{OLR(\phi) - OLR(-\phi)}{2}$$

$$OLRS(\phi) = \frac{OLR(\phi) + OLR(-\phi)}{2}$$



# Multivariate EOF analysis

## Diagnosis

EOF analysis of 15D to 15N averaged OLR, u850, and u-200

## Modeling

Each variable is normalized by its standard deviation

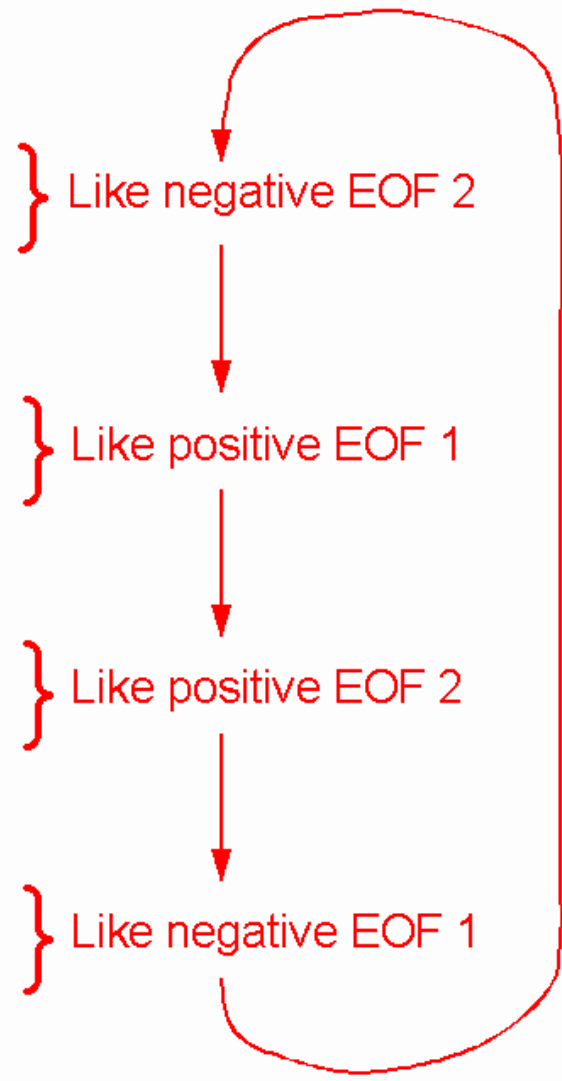
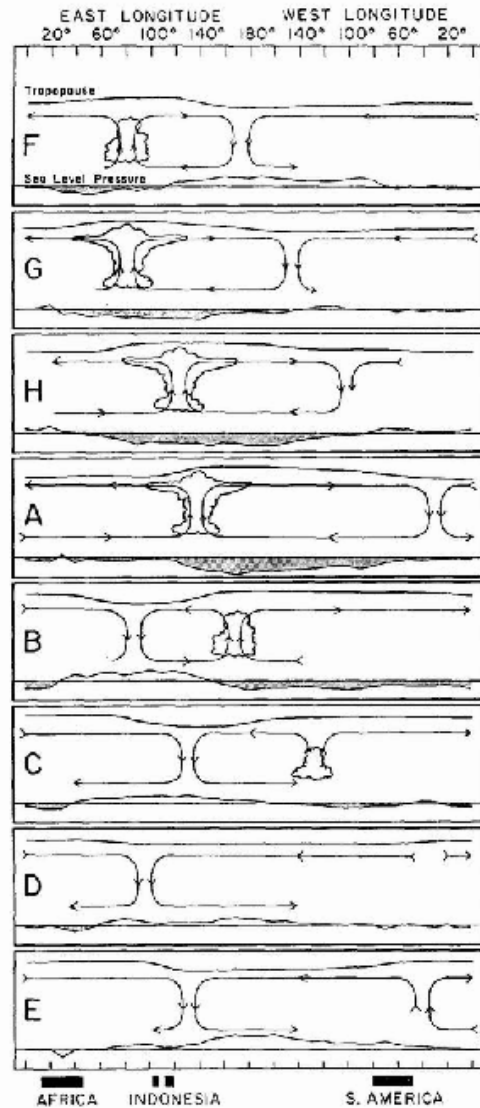
First two combined EOFs describe the propagating structure of the MJO

## Conclusions

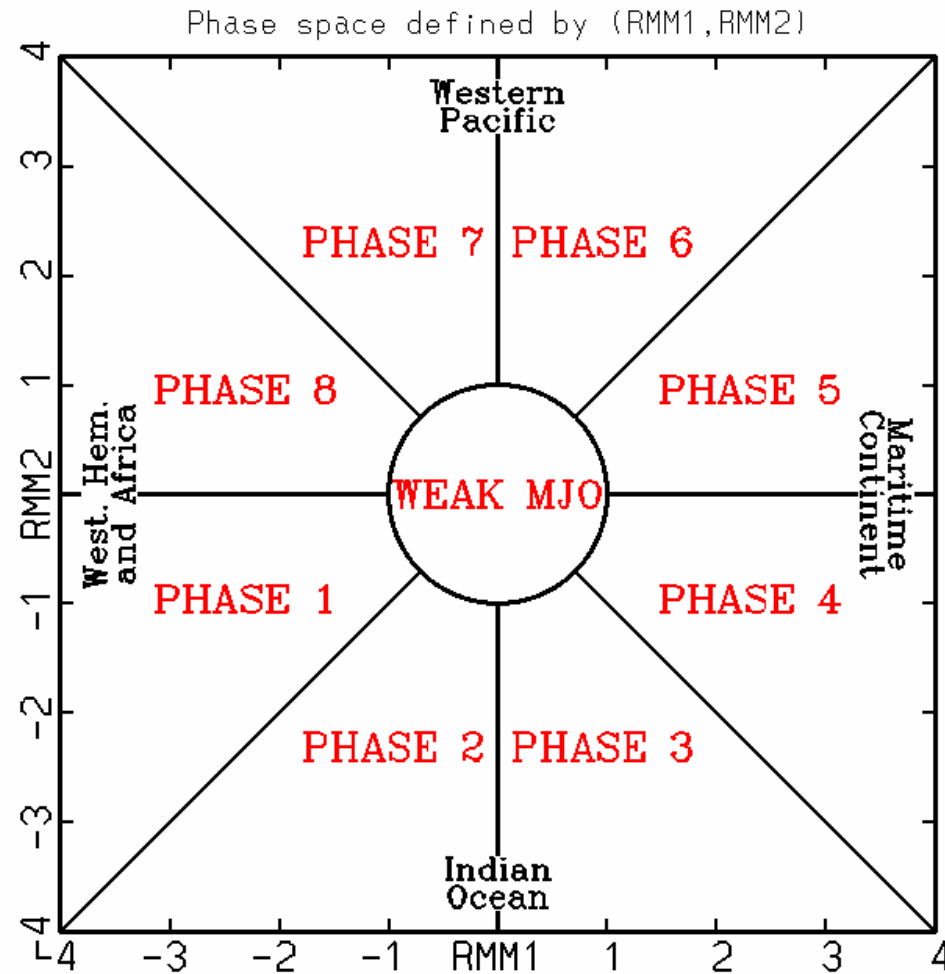
First two PCs combined into the Real Time Multivariate MJO (RMM) index

$$RMM = \sqrt{RMM_1^2 + RMM_2^2}$$

# Multivariate EOF analysis

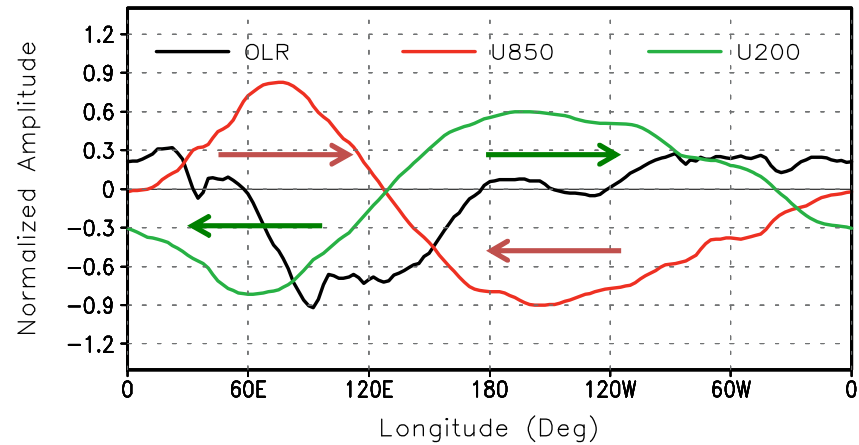


# Multivariate Analysis



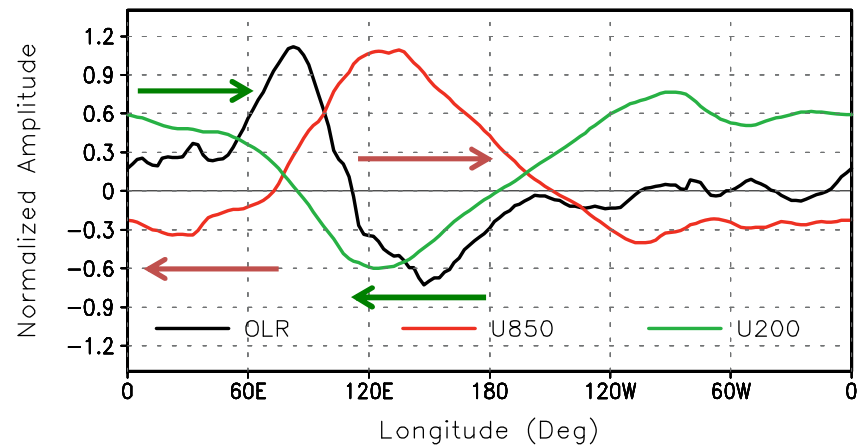
# Multivariate Analysis

a) 1st mode (22.20%)



\*Variance accounted for:  
 OLR=13.21%; u850=31.73%; u200=21.66%

b) 2nd mode (20.93%)

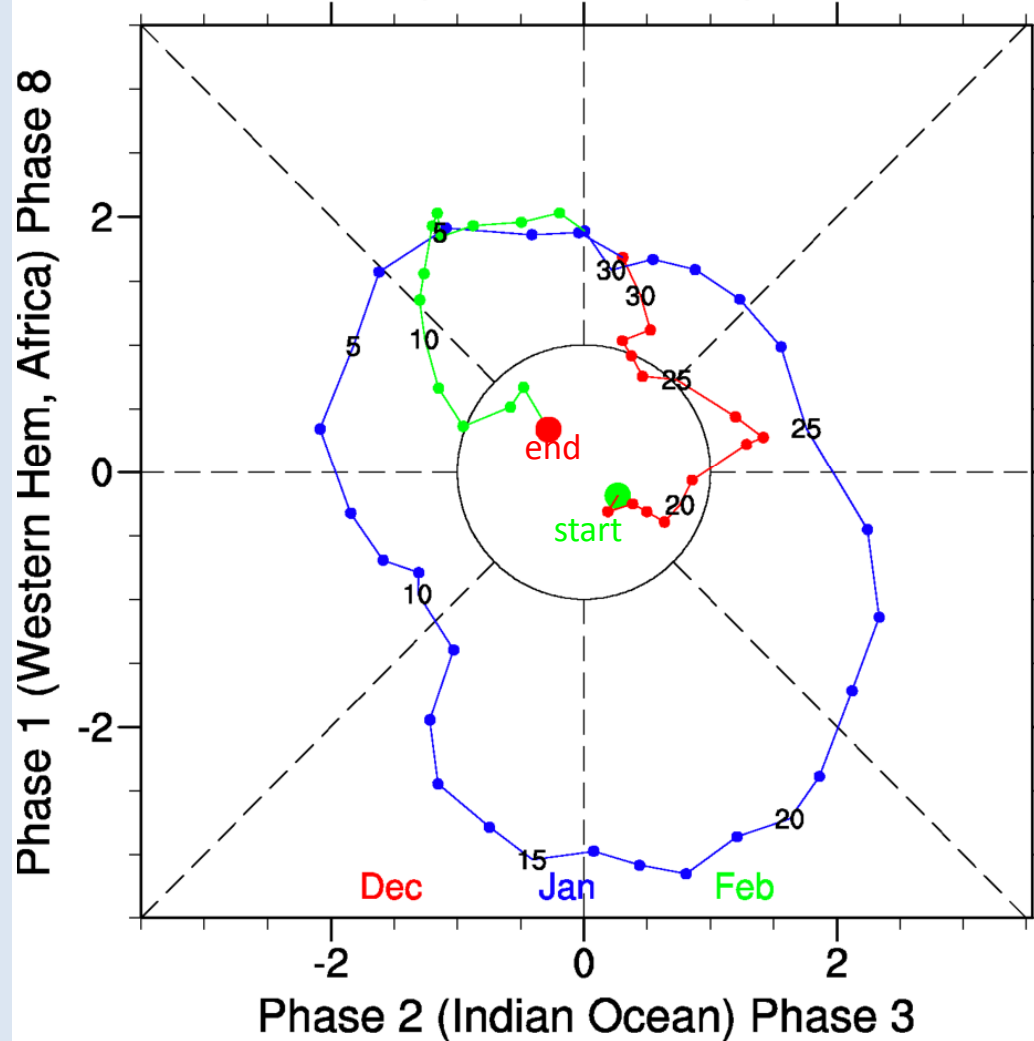


\*Variance accounted for:  
 OLR=15.91%; u850=23.11%; u200=23.78%

# Multivariate Analysis

RMM Index: 19921215-19930215

Phase 7 (Western Pacific) Phase 6



Pros

Shows the MJO initiation

Can distinguish between Events

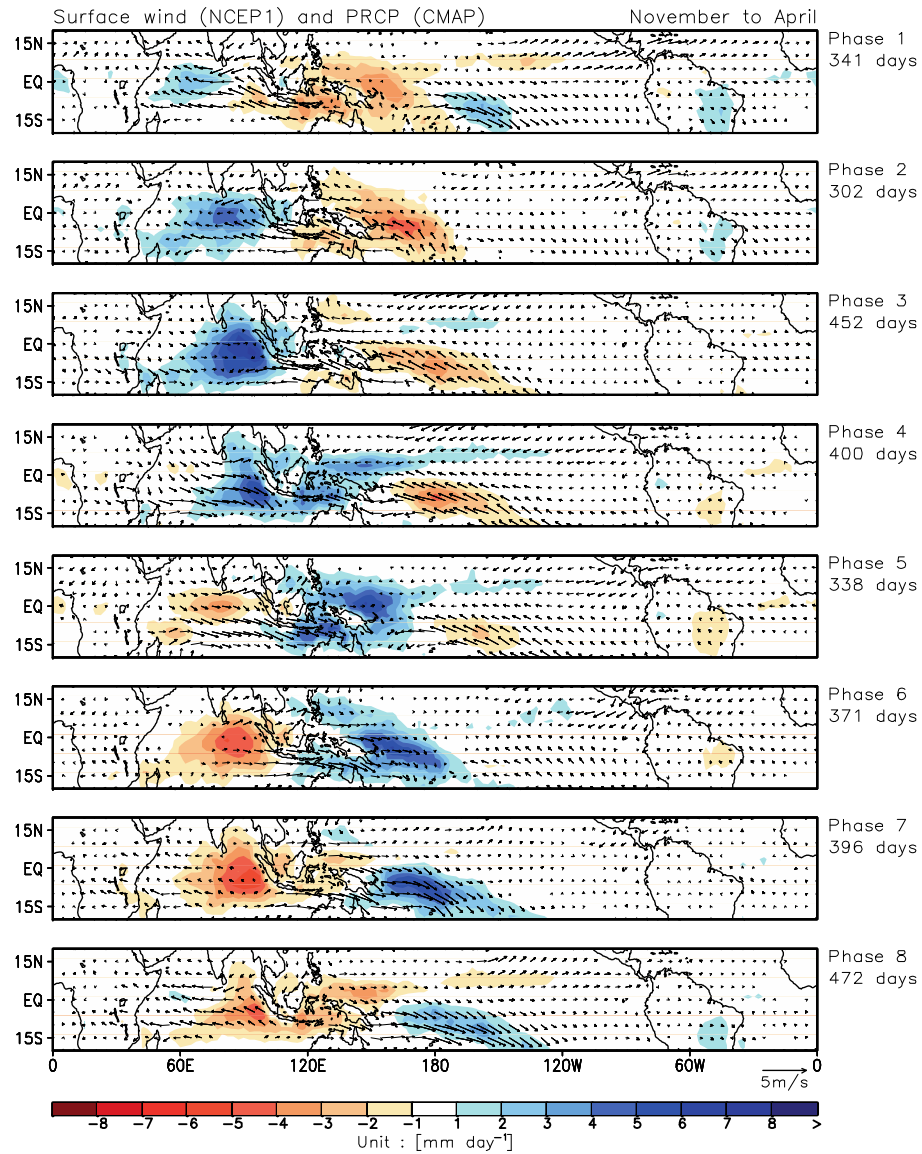
Based on multiple variables

Cons

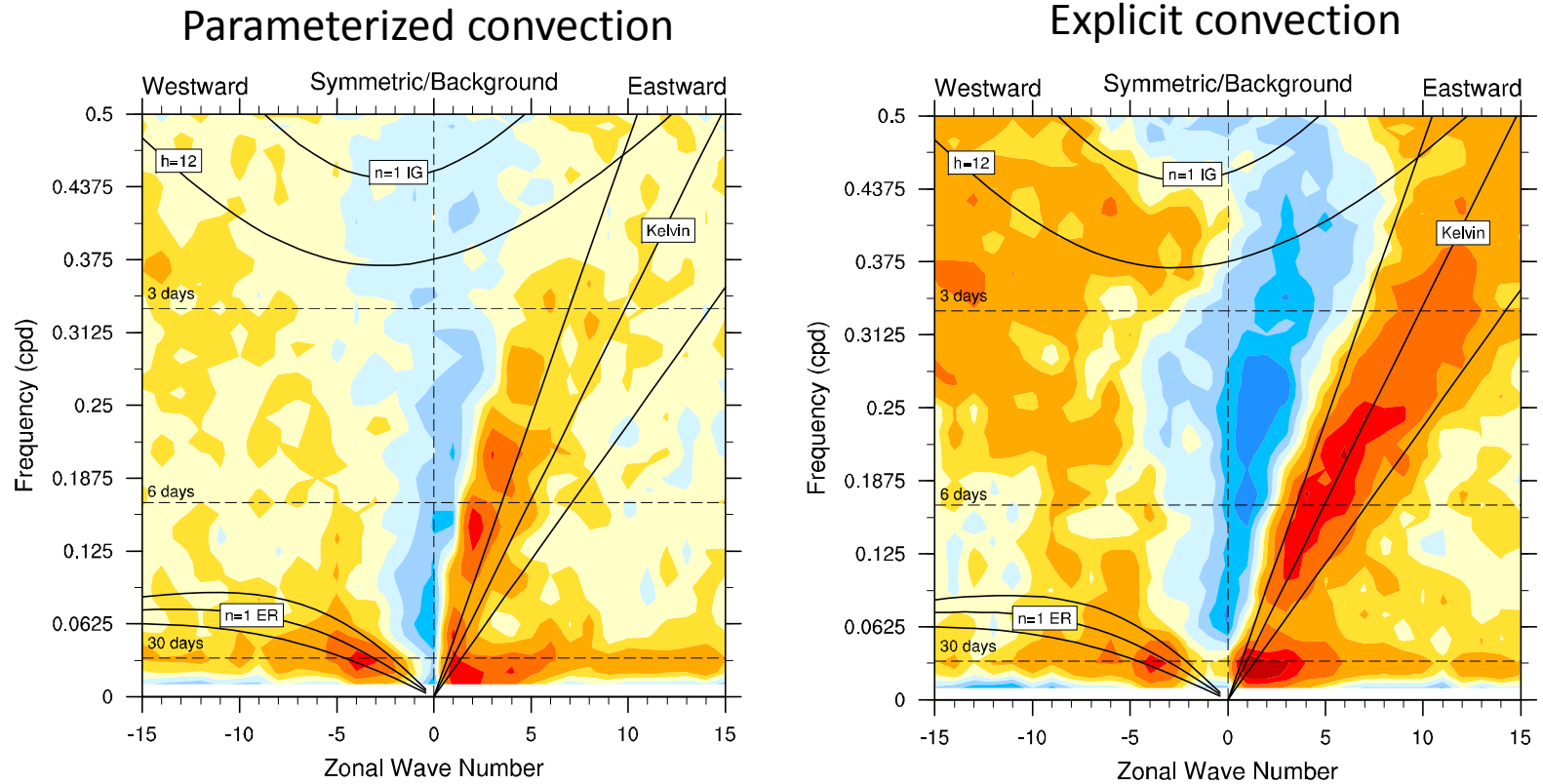
Wind dominates the signal

Gives false MJO events

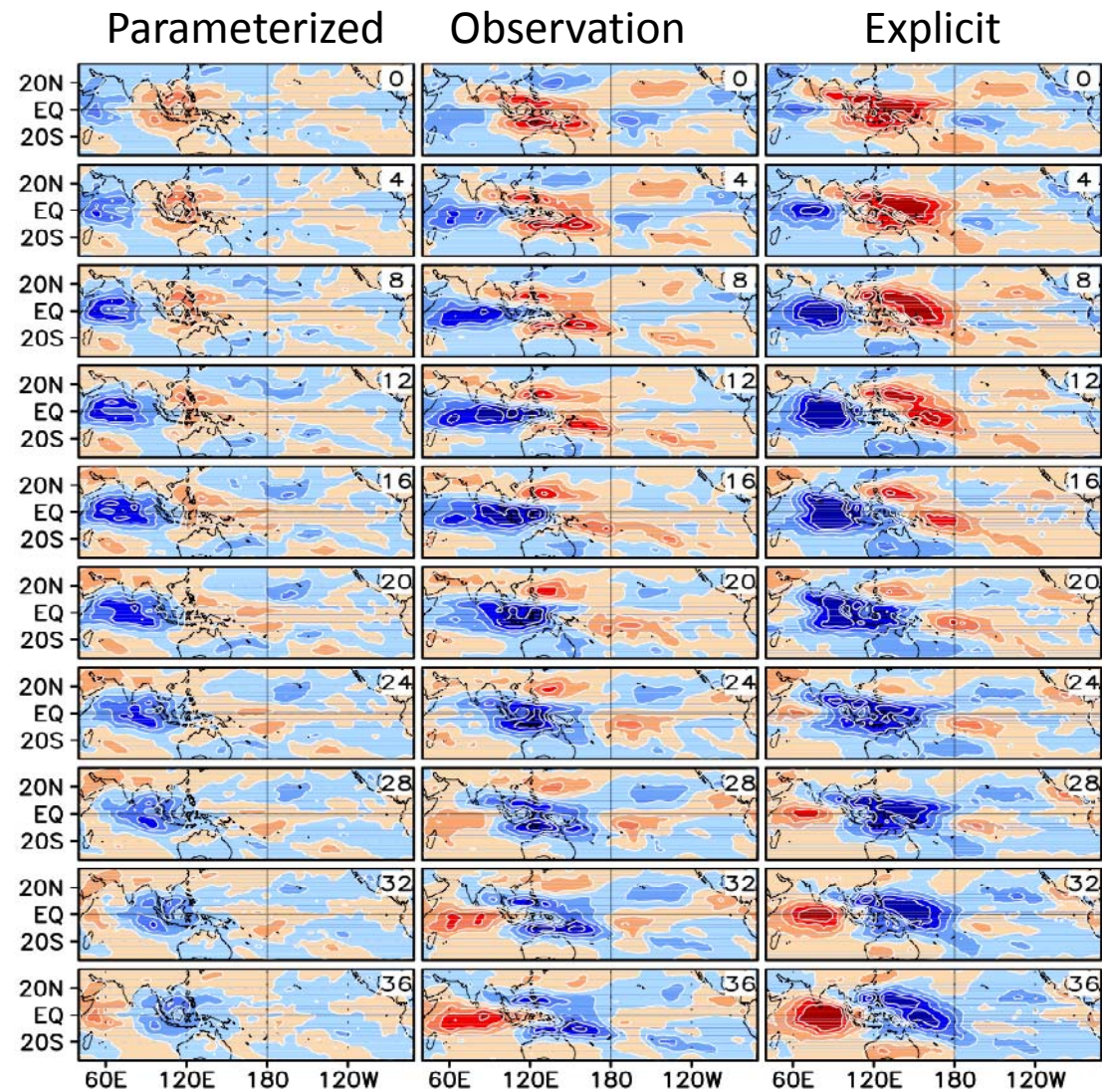
# MJO lifecycle



# Influence of convection representation



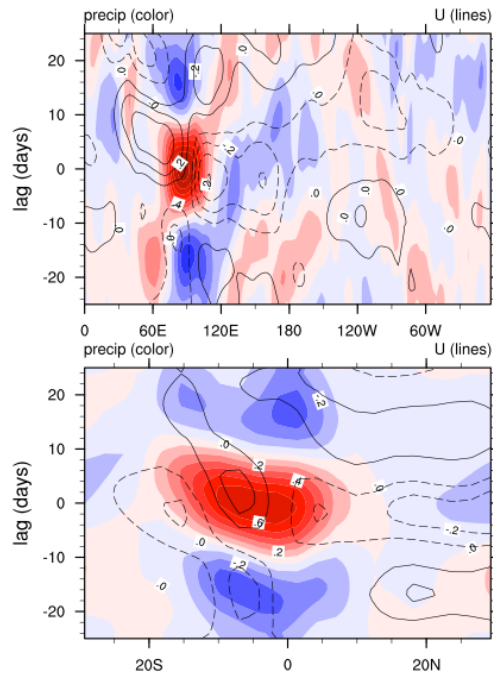
# MJO life cycle, OLR



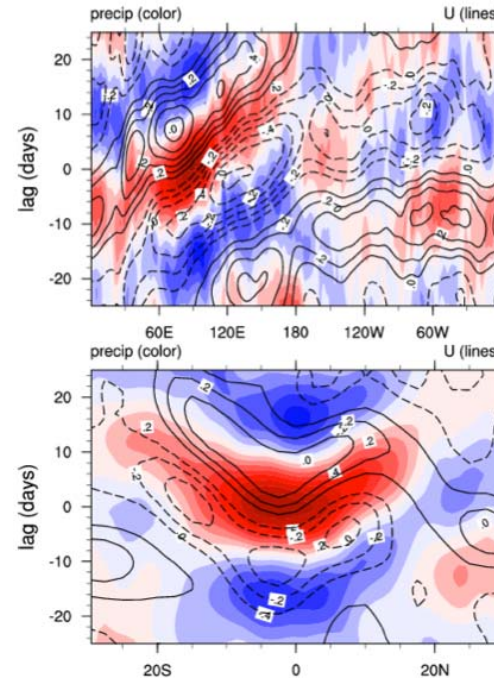


# MJO propagation

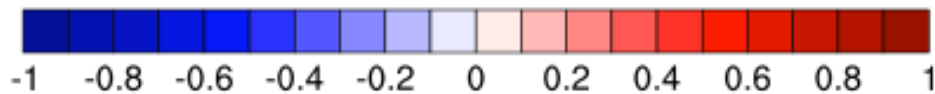
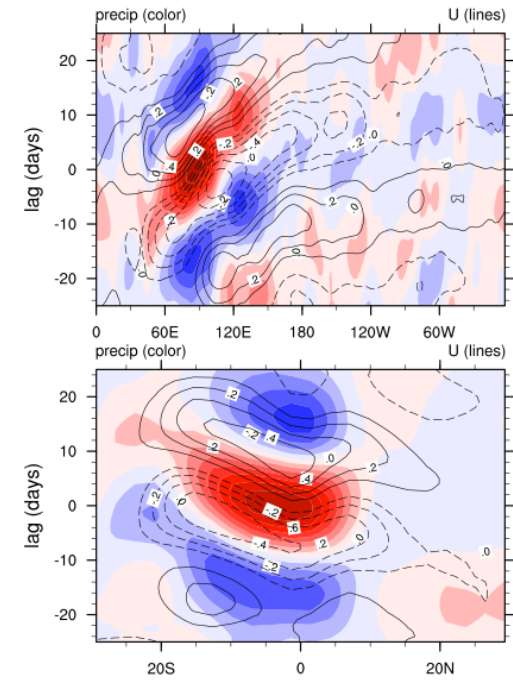
Parameterized



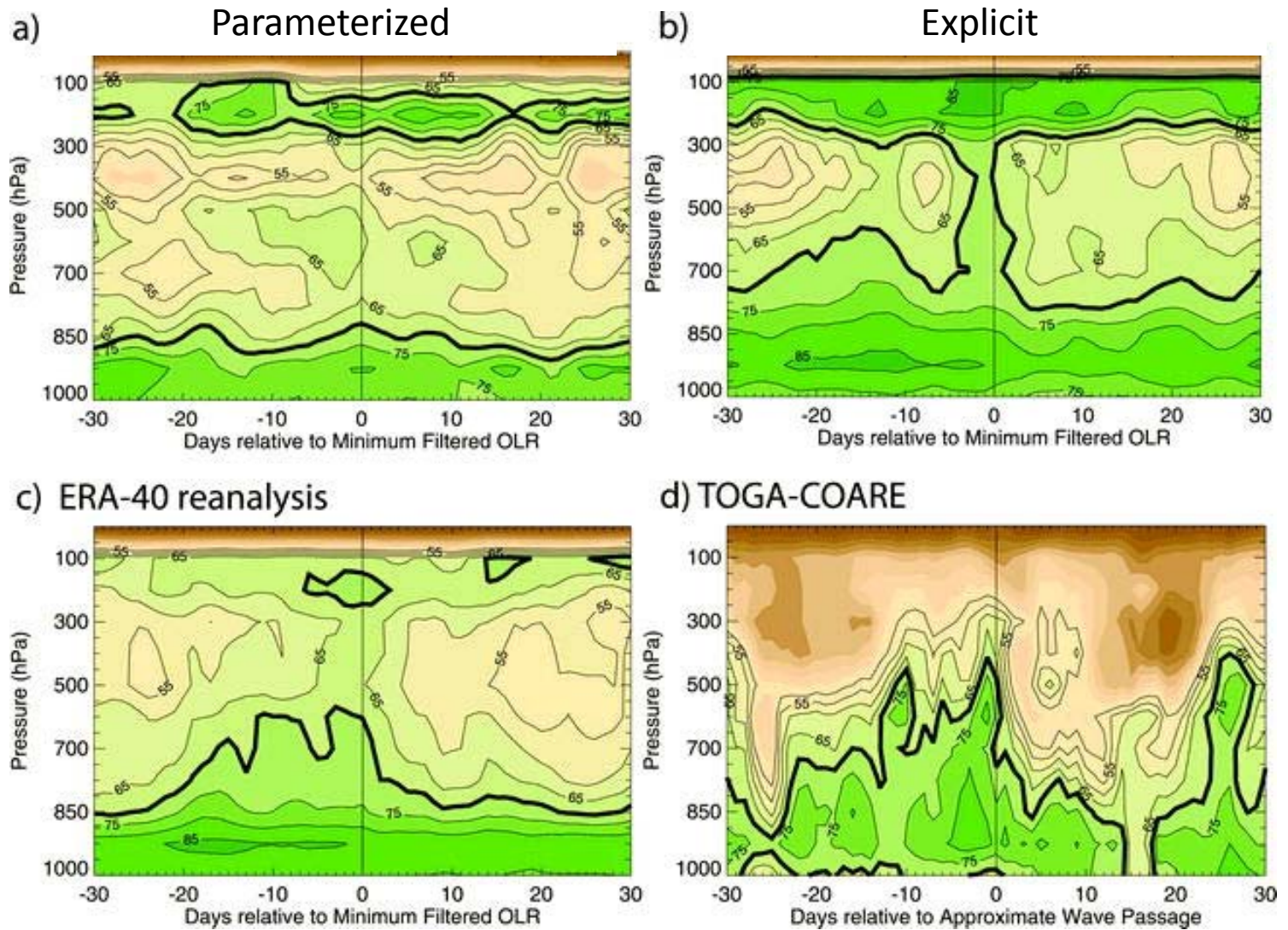
Observation



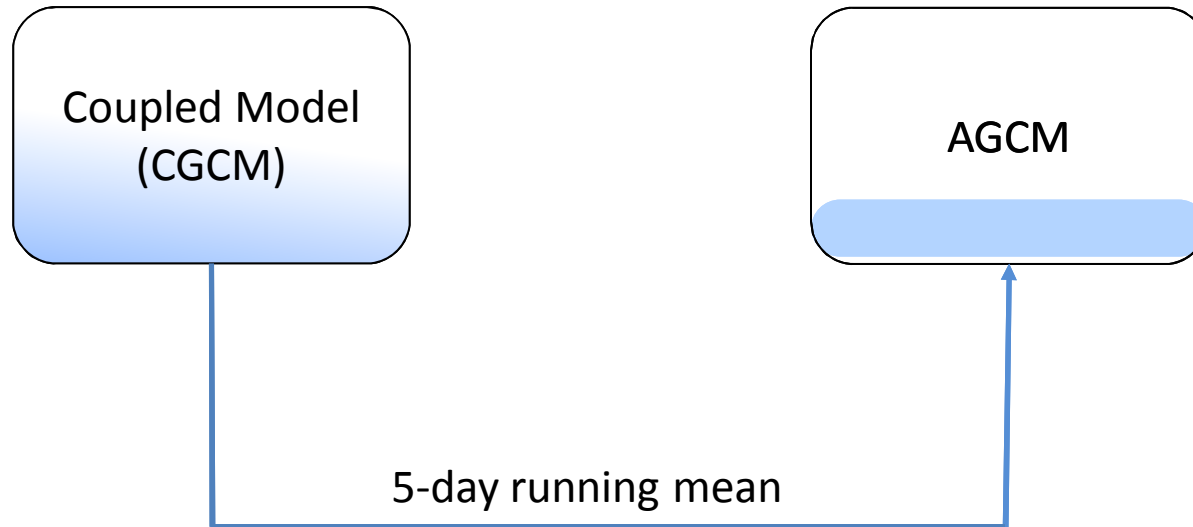
Explicit convection



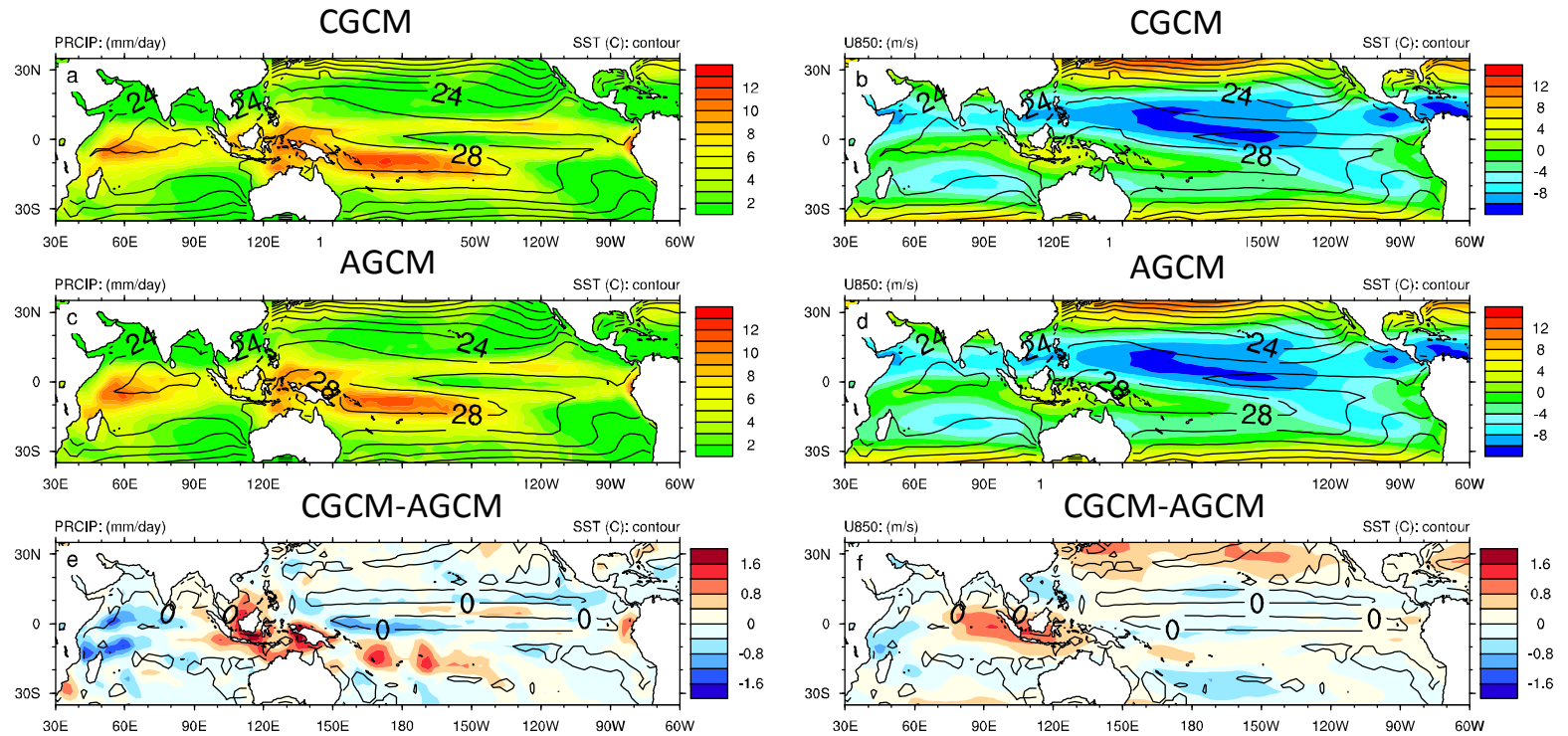
# Boundary-layer effects



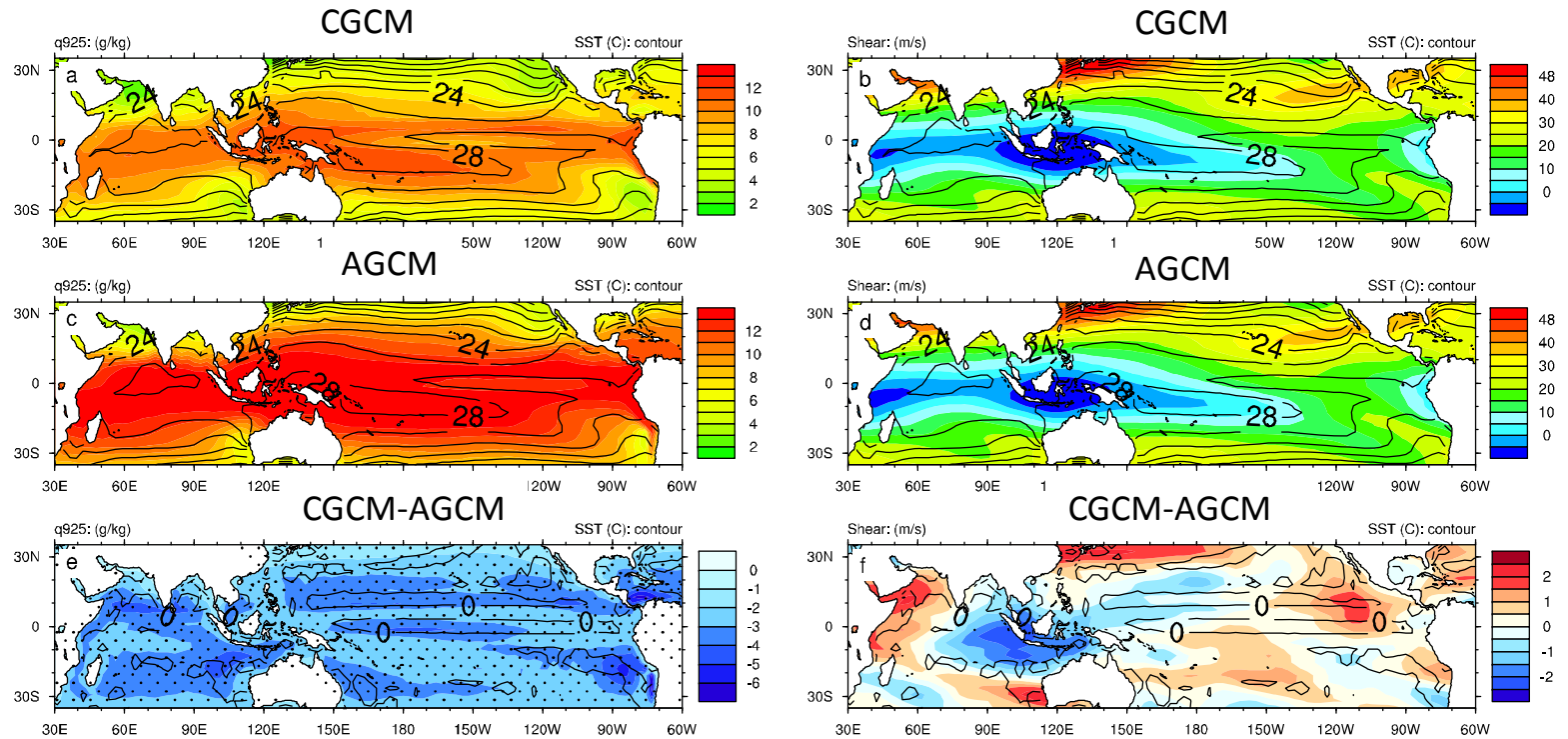
# Influence of ocean variability



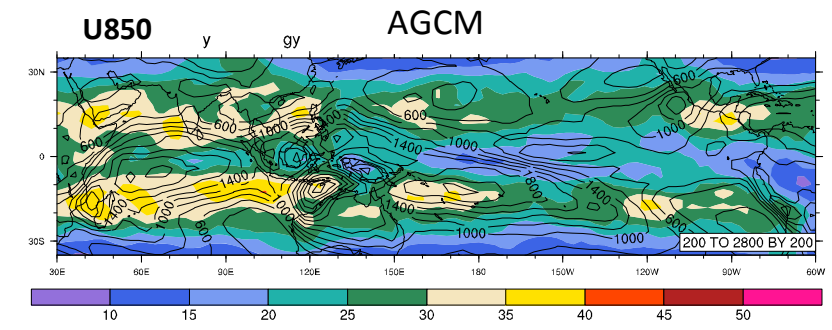
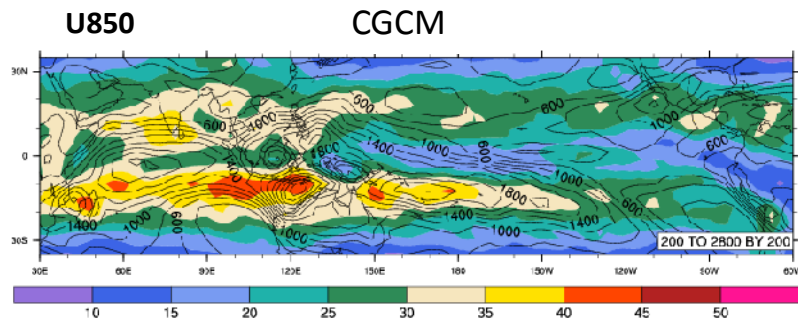
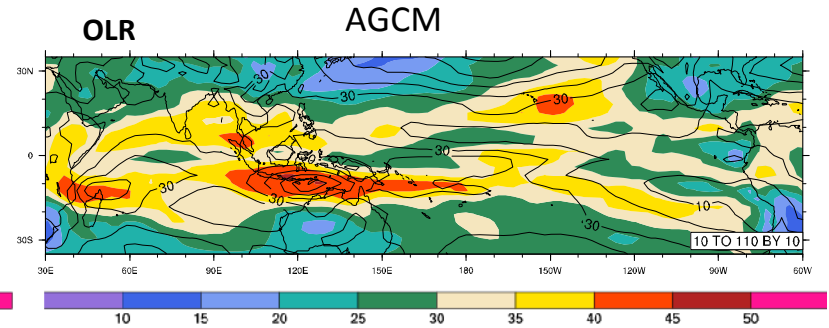
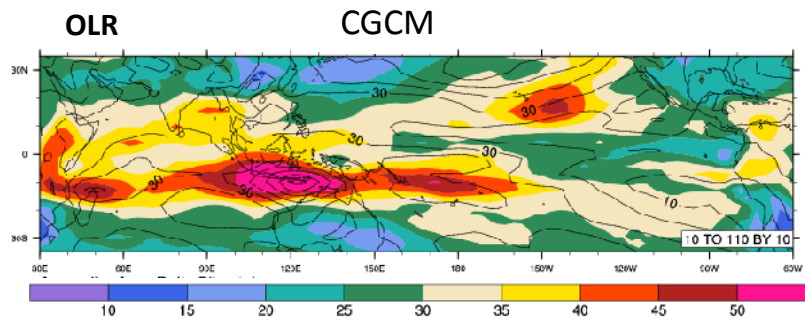
# Models Mean State



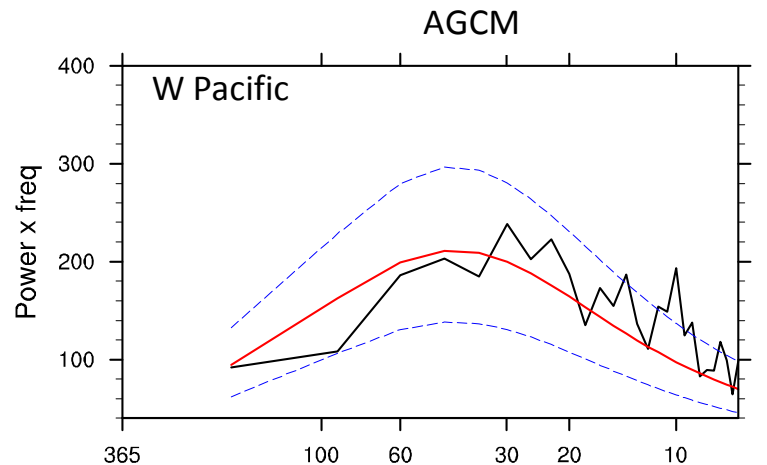
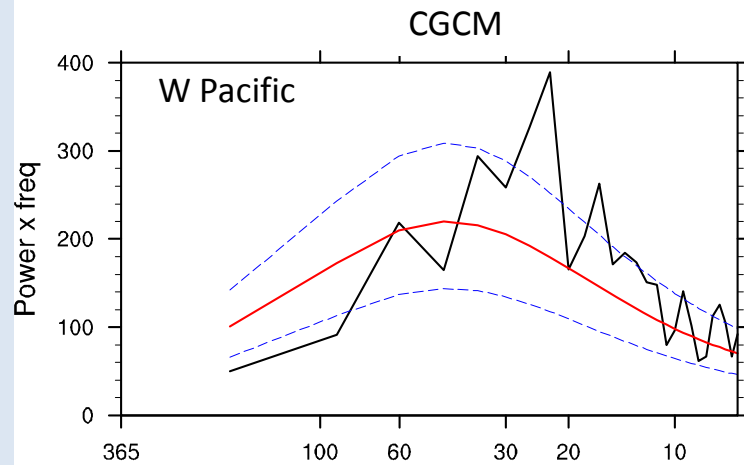
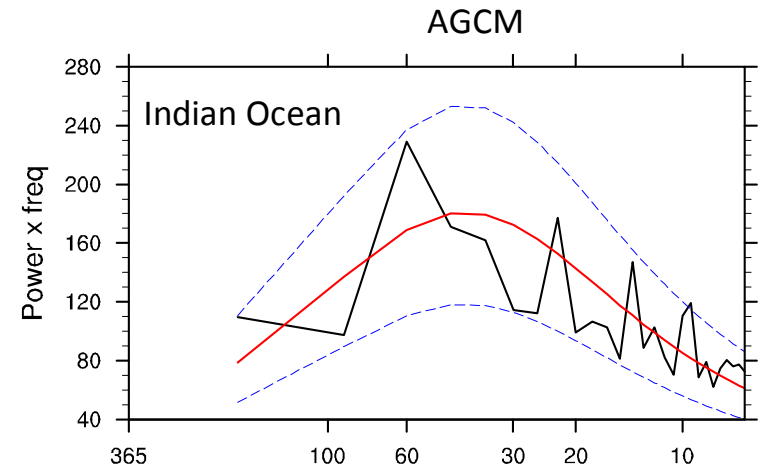
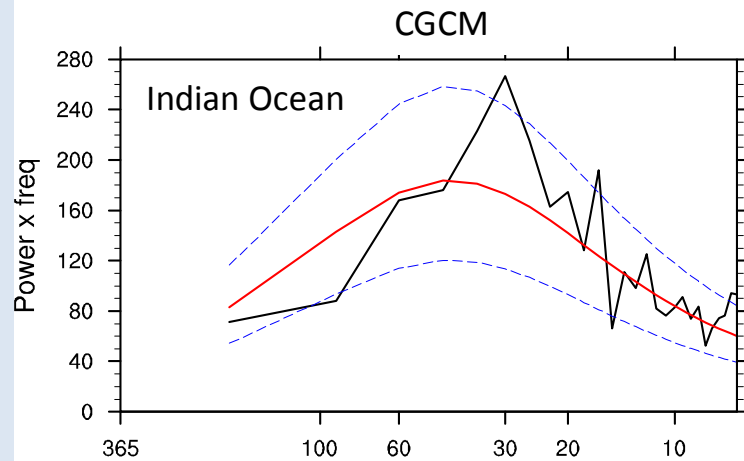
# Models Mean State



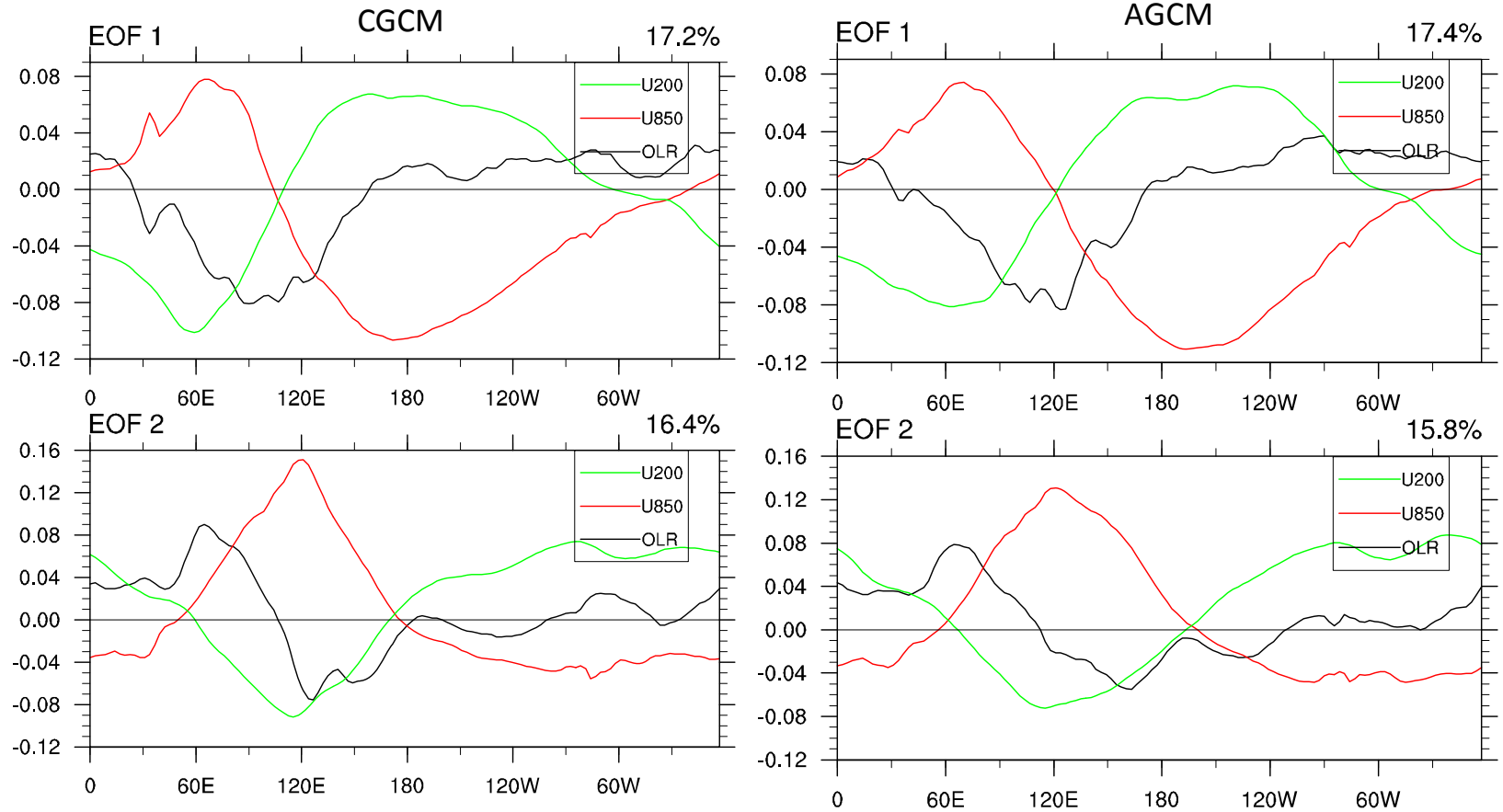
# Intraseasonal Variability



# Power Spectrum

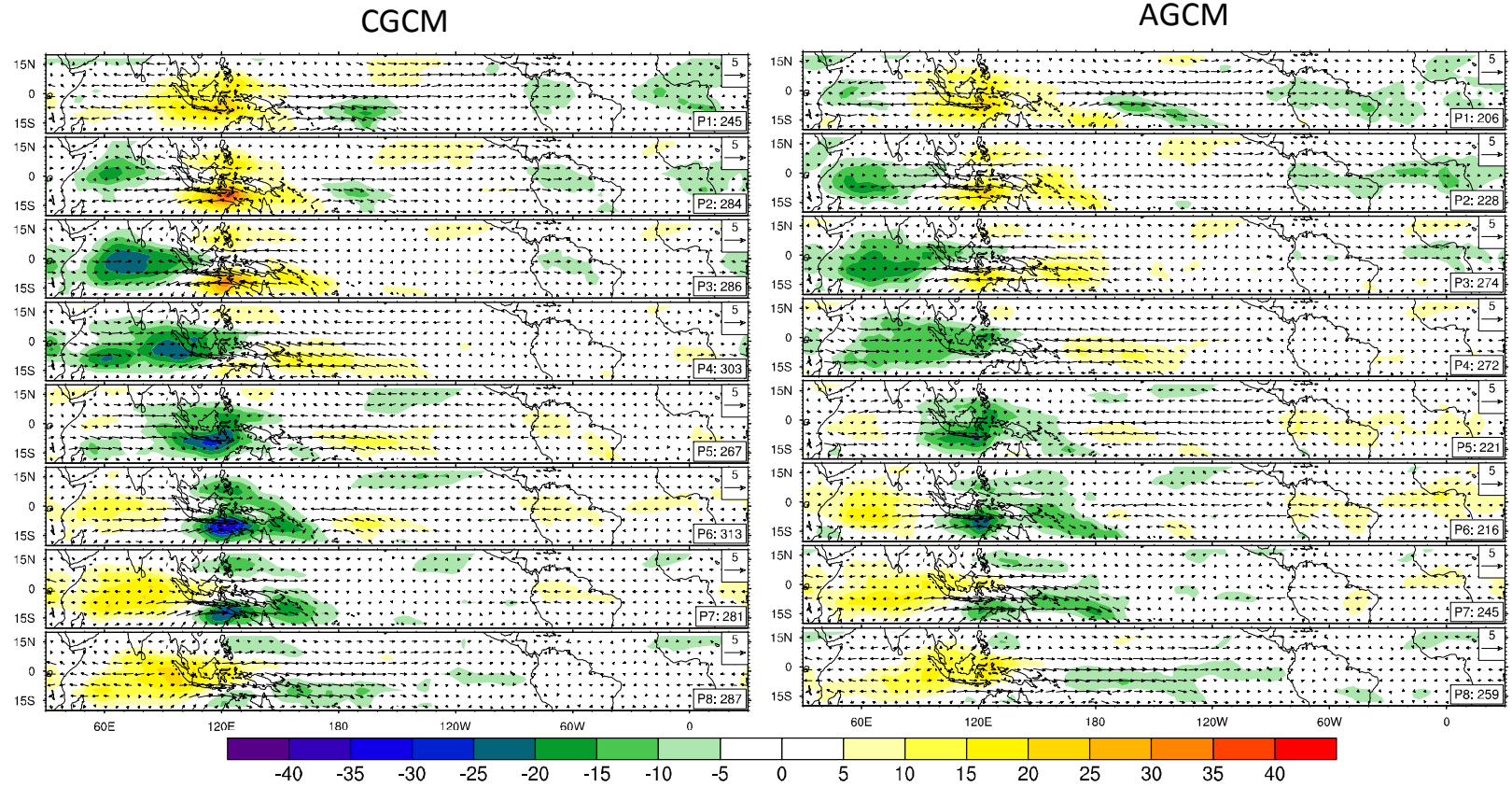


# Multivariate EOF analysis

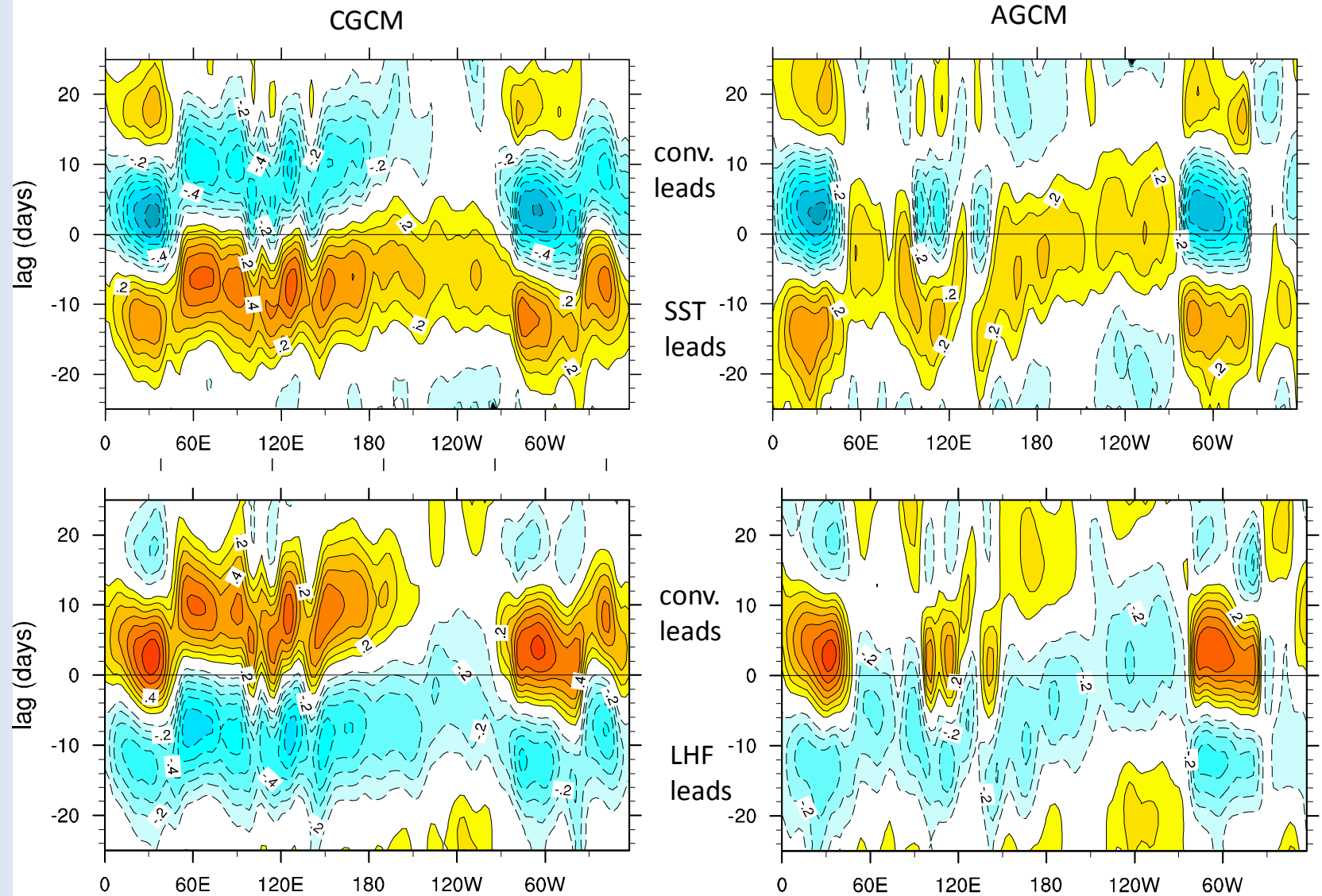




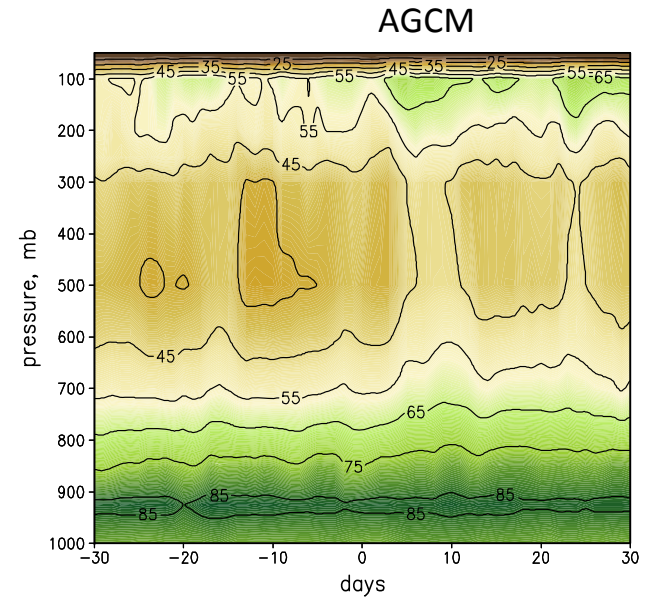
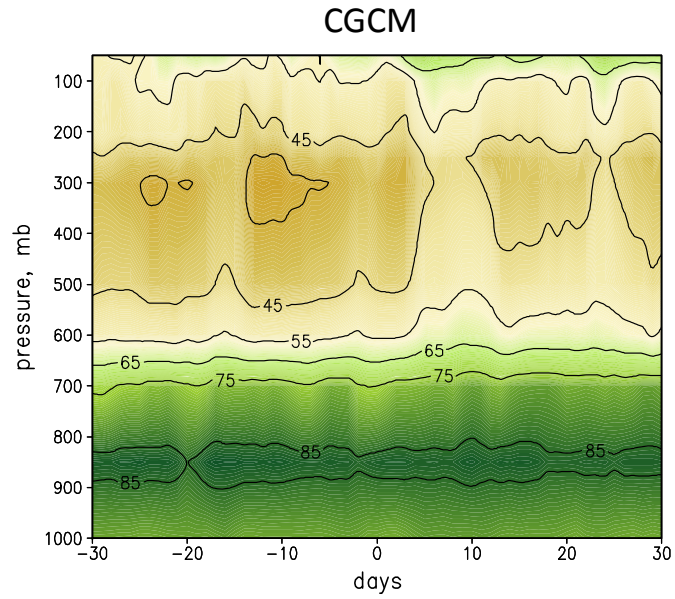
# MJO lifecycle



# Lag Correlation



# Boundary layer moisture



# Conclusions

- The representation of cloud processes is the key element in simulating the observed characteristics of the MJO; convection preconditions the boundary layer
- The high-frequency variability of the SST enhances the intraseasonal variability controls the coupling between the dynamics and convection affects the distribution of moisture in the boundary layer.