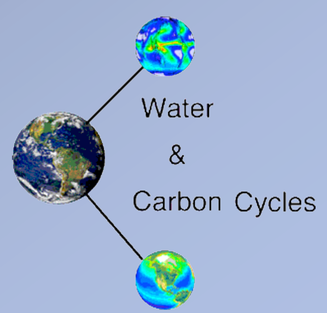
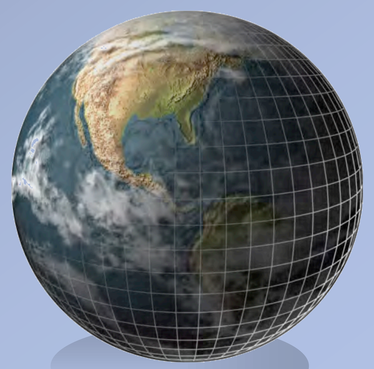
# Predictability and Forecast Issues Associated with the Madden-Julian Oscillation

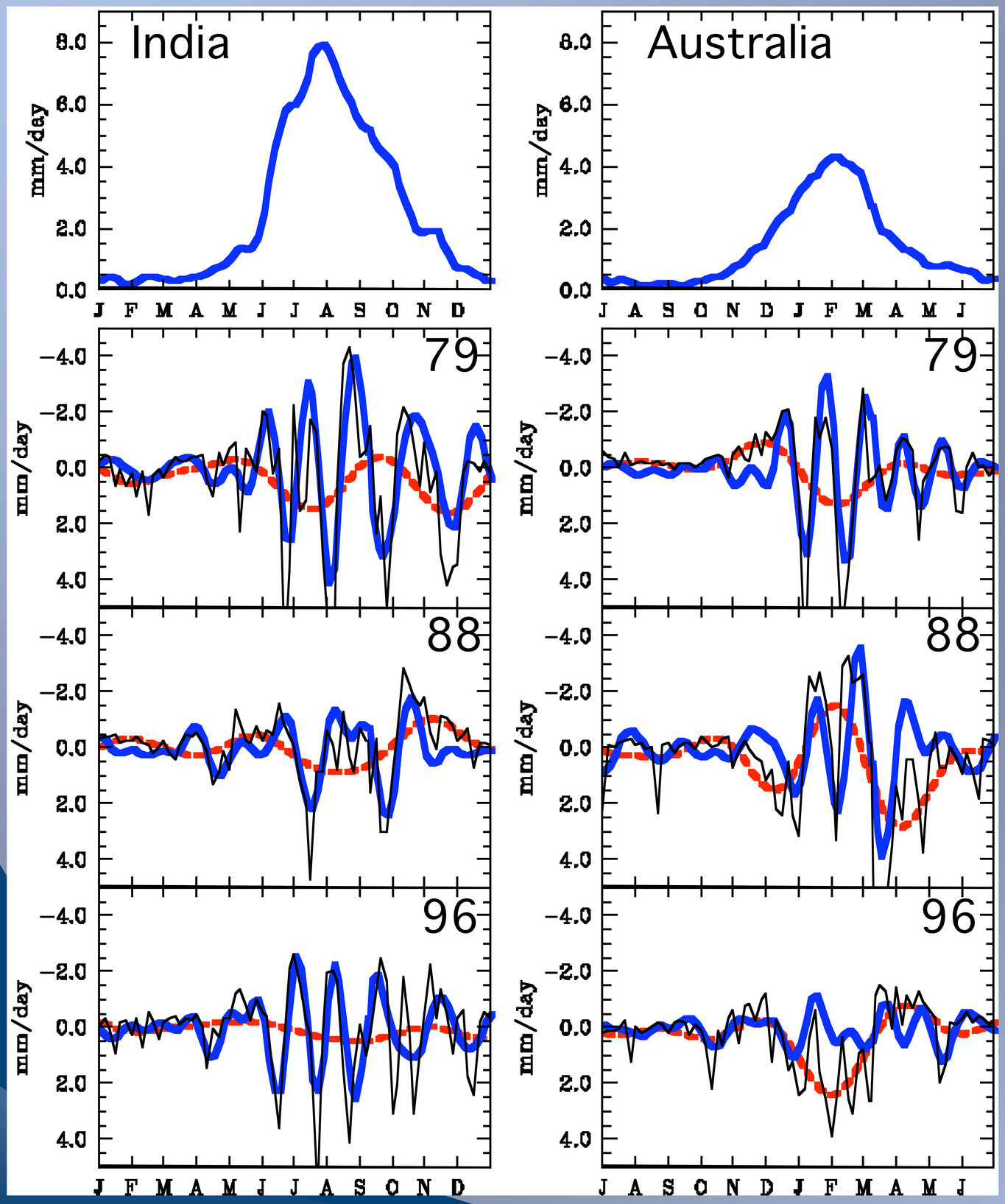
Workshop on the Organization and Maintenance of Tropical Convection and the Madden-Julian Oscillation, Trieste, Italy, 13-17 March, 2006


Duane Waliser
Water & Carbon Cycles
Sciences Division
JPL

# A Few Fundamentals



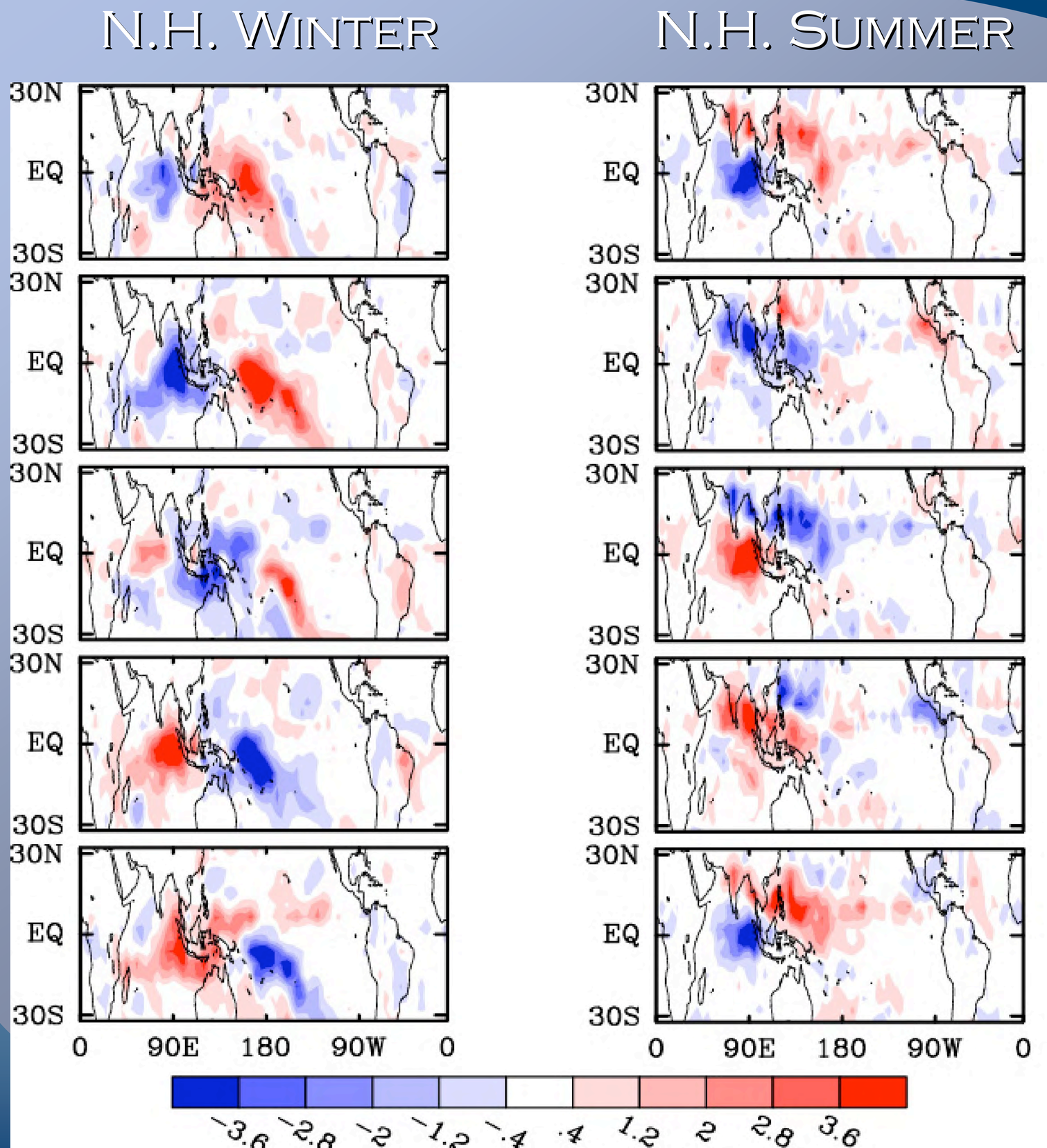



WALISER, 2004

# Annual, Interannual, & Intra-seasonal (Onsets & Breaks)

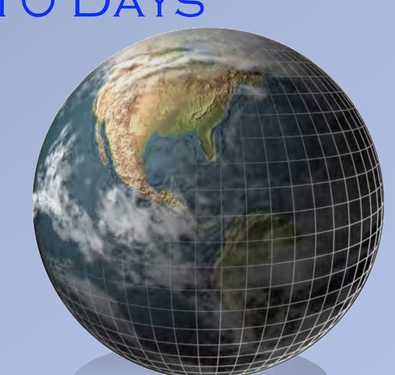
To date, most effort in monsoon prediction has been on S-I component with little success.

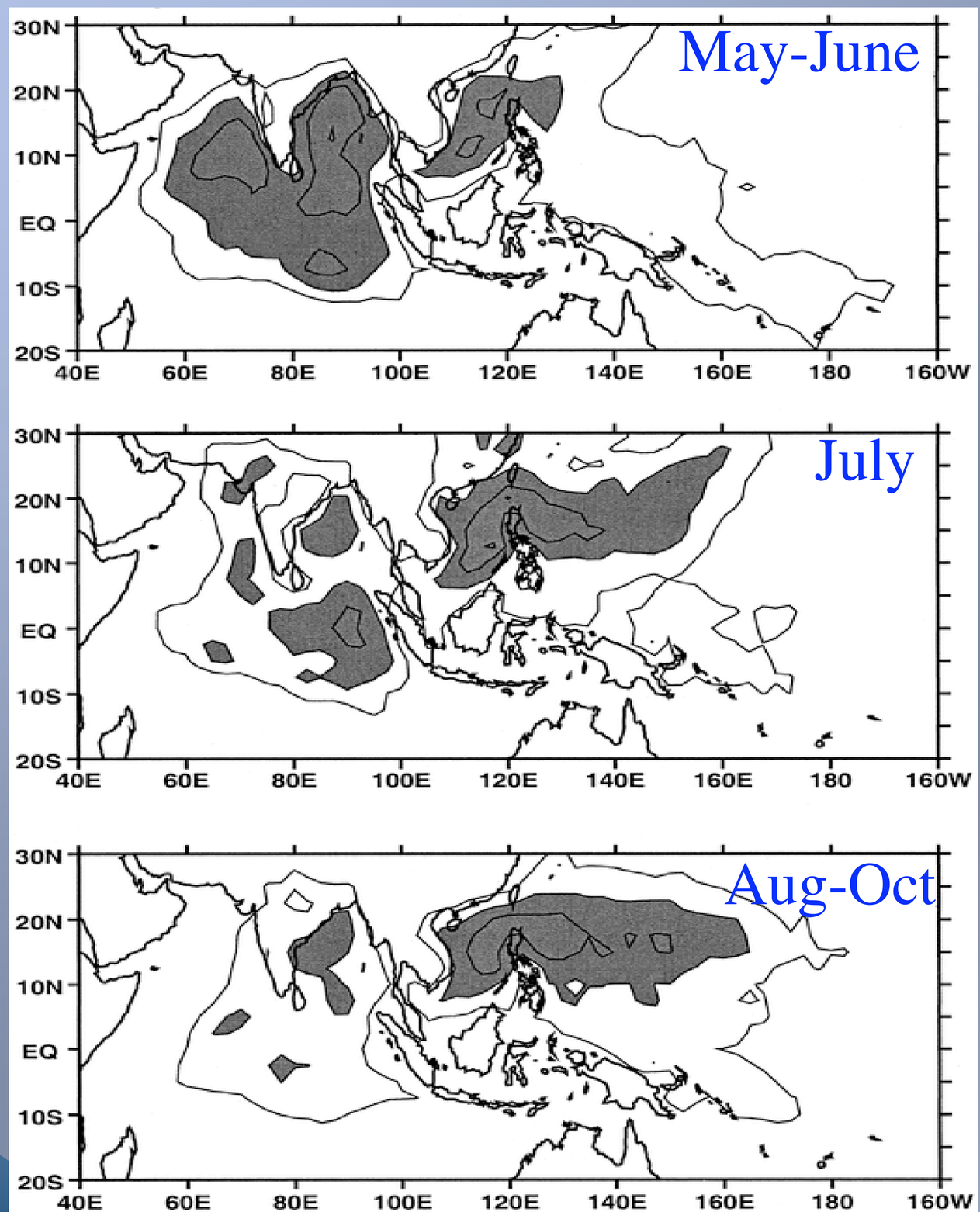
With this picture NOW in mind, it isn't obvious this should still be the case.




# Typical Rainfall Evolution & Annual Cycle Modulation of ISV

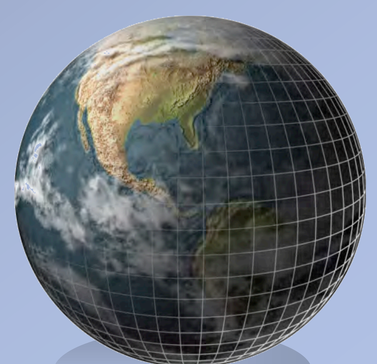
Panels Separated By 10 Days





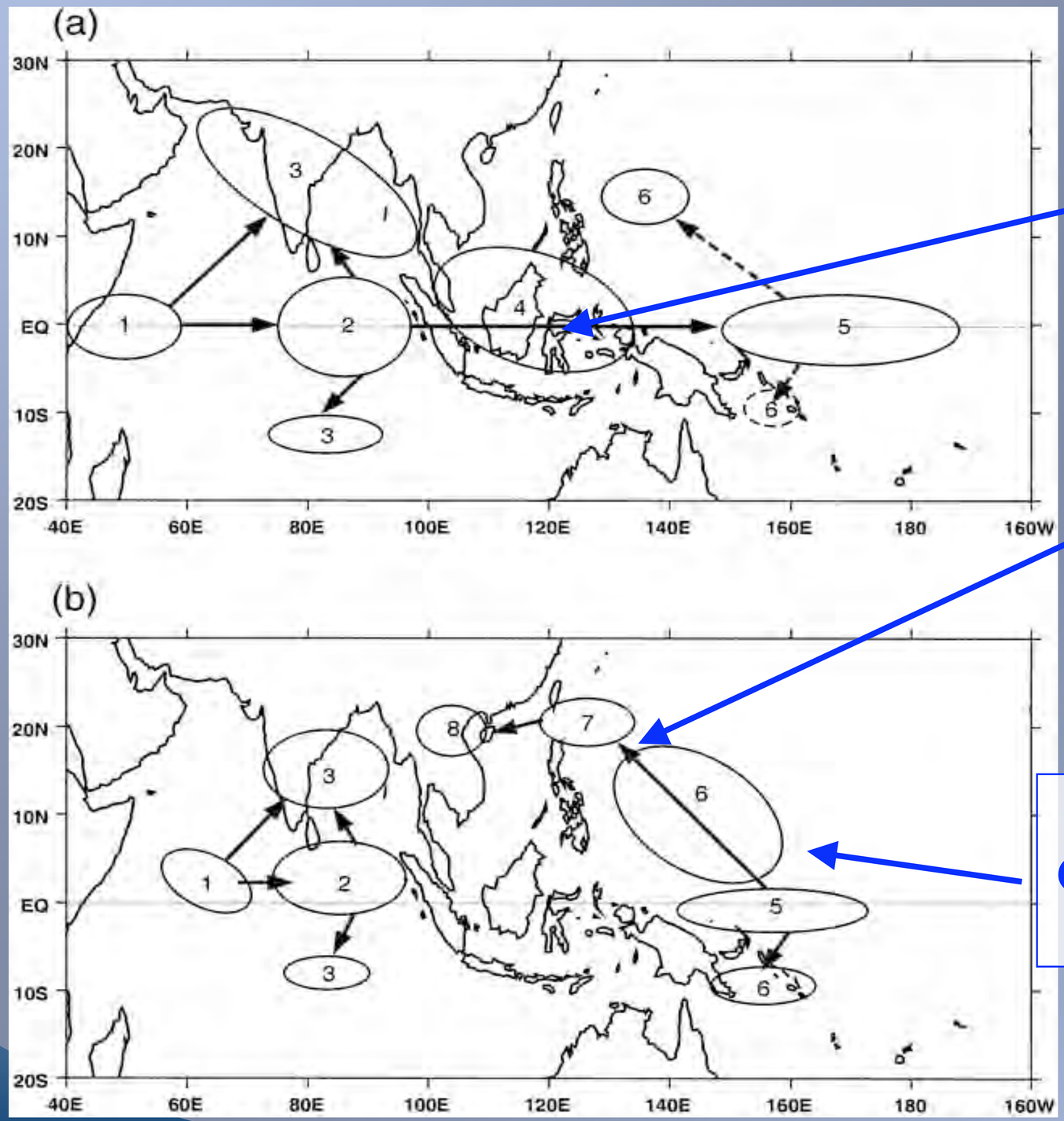

# Subseasonal Modulation of Intraseasonal OLR Variance

Pay Close Attention to the Time of Year



Kemball-Cook and Wang, 2000

# Complex Propagation & Multi-Scale Organization




**Eastward Propagating Convective Envelope ~40-50 days**

**Westward Propagating Rossby-Waves ~ 10-20 day; Modulated by 40-50day**

**Northward Propagation Of Rossby-Wave Convection (twisting, SST, moisture feedback)**

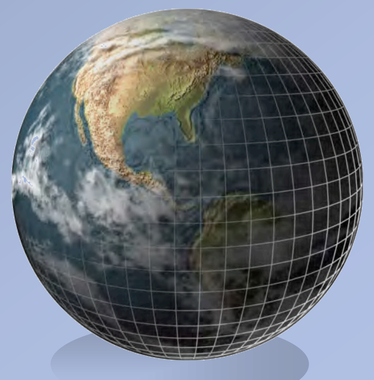
Kemball-Cook & Wang, 2001

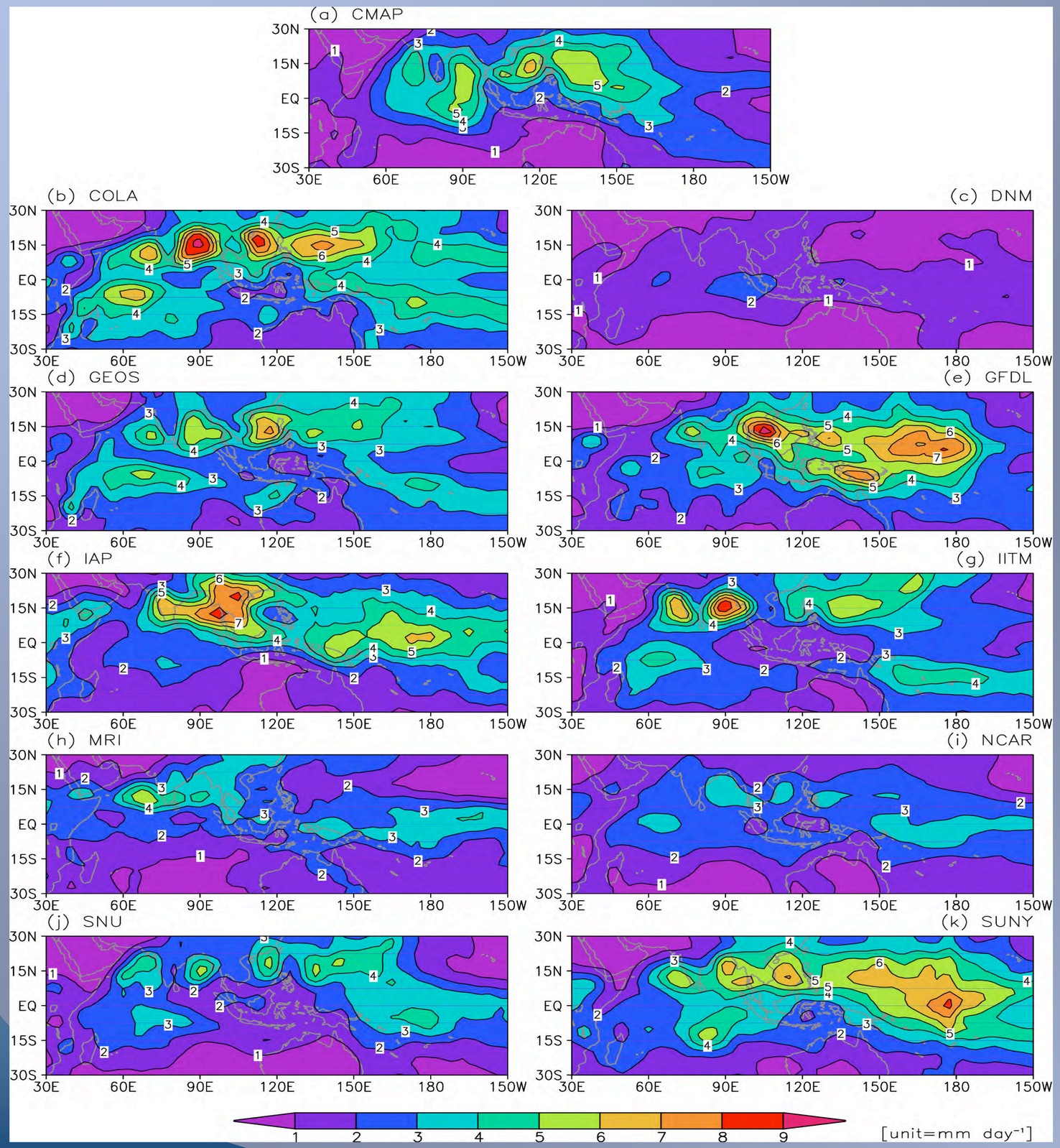
# Impacts/Interactions Are Far and Wide

- Clustering of Monsoon Tropical Depressions
- Tropical Storm/Hurricane Modulation
- Mid-Latitude Circulation Anomalies
  US West Coast Extreme Precipitation
- ENSO state "triggering"?
- Even Weather In Alaska!

ISV-Reach extends well beyond monsoon

# GCM Simulation Capabilities & Challenges





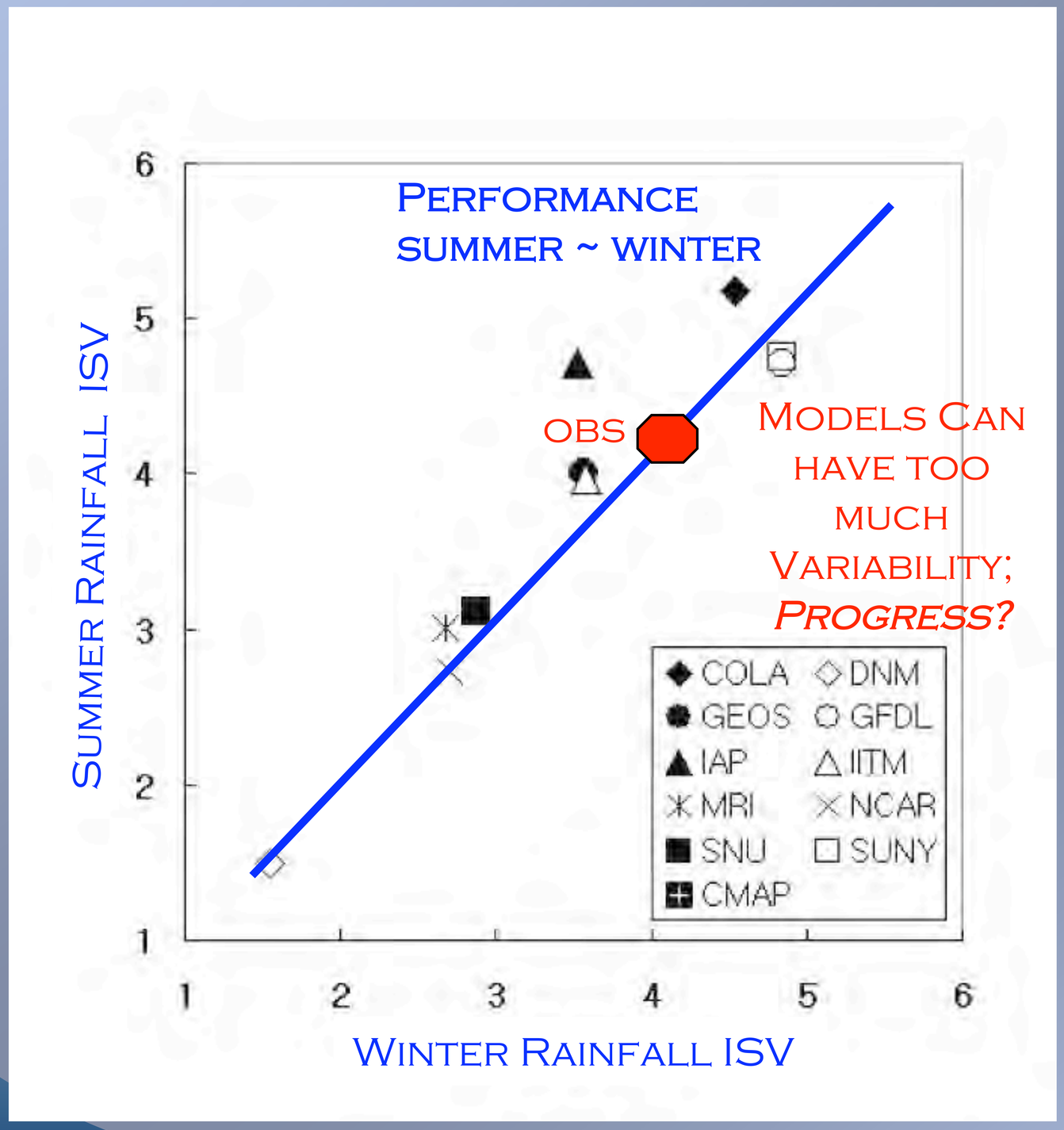

# CLIVAR/Monsoon GCM Intercomparison Project

## N.H. Summer MJO-related Rainfall Variability

- Variable Strength
- Too little C. IO variability
- N.H. peaks often okay
- Often split about equator
- Spurious S. IO peak

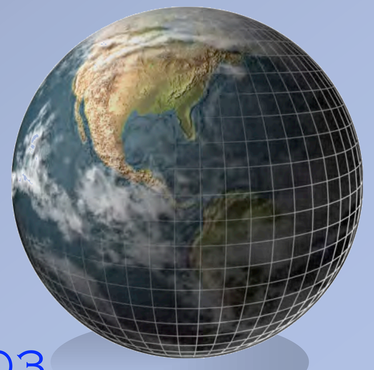
Waliser et al. 2003

# MJO MODELING



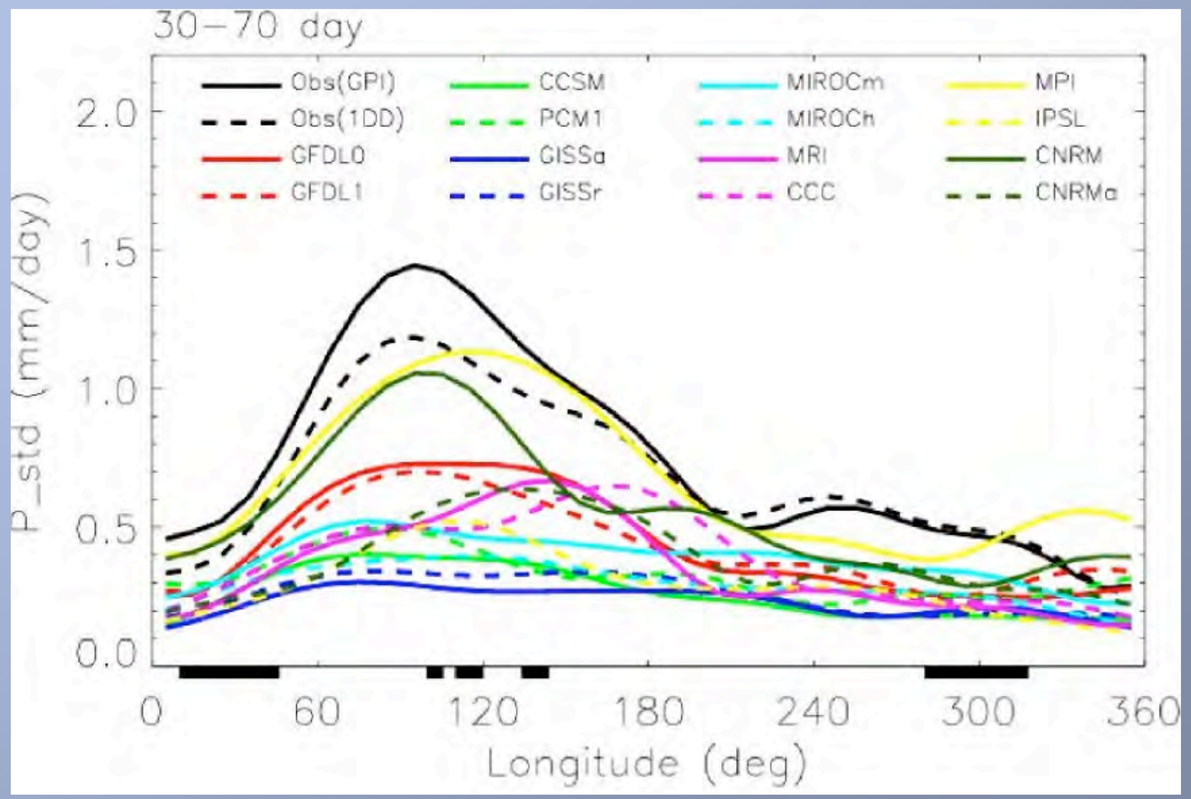

## N.H. Winter vs N.H. Summer

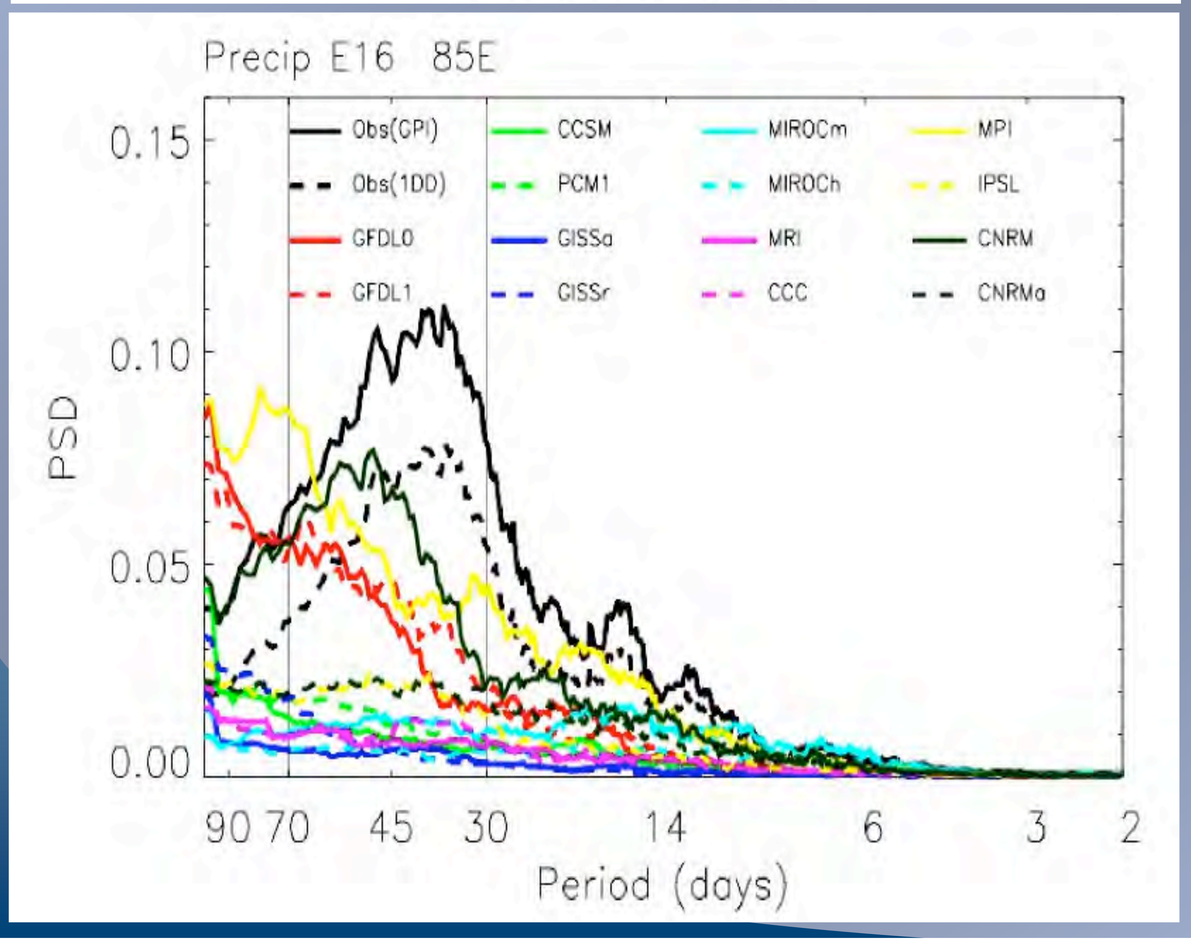
## Intraseasonal Rainfall Variance



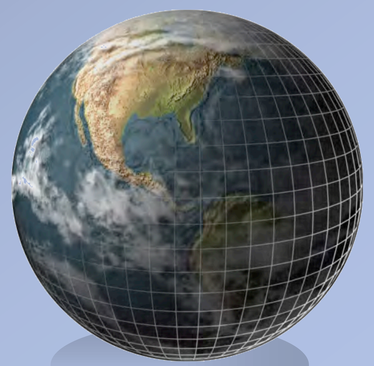
Waliser et al. 2003

# MJO MODELING IN IPCC MODELS

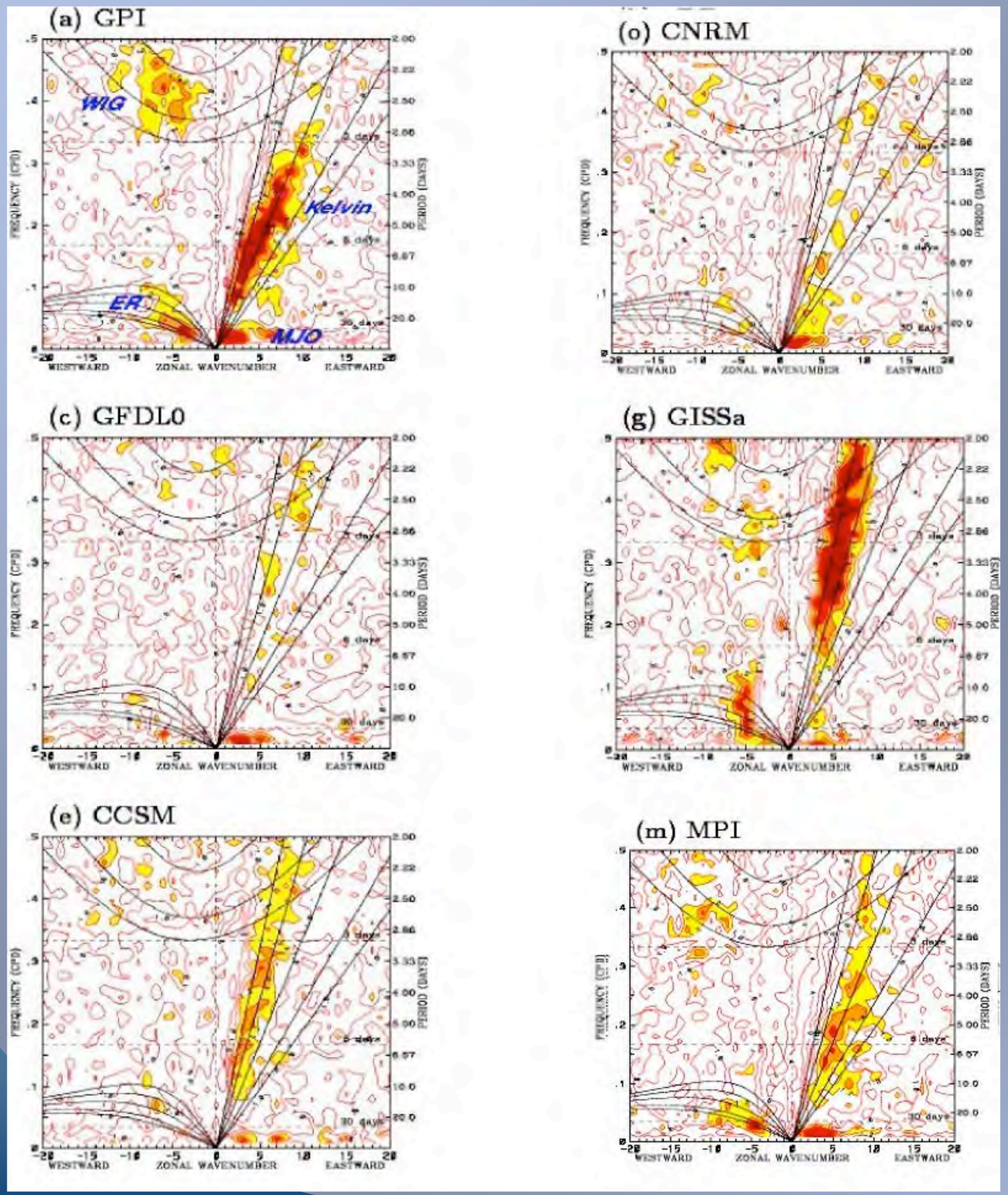



- **Almost all have weak variability in MJO.**
- **2-3 out of 14 some power at IS timescales ~ about same ratio as Slingo et al. 1996**

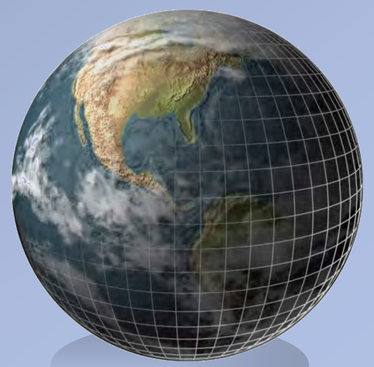


Lin et al., 2005

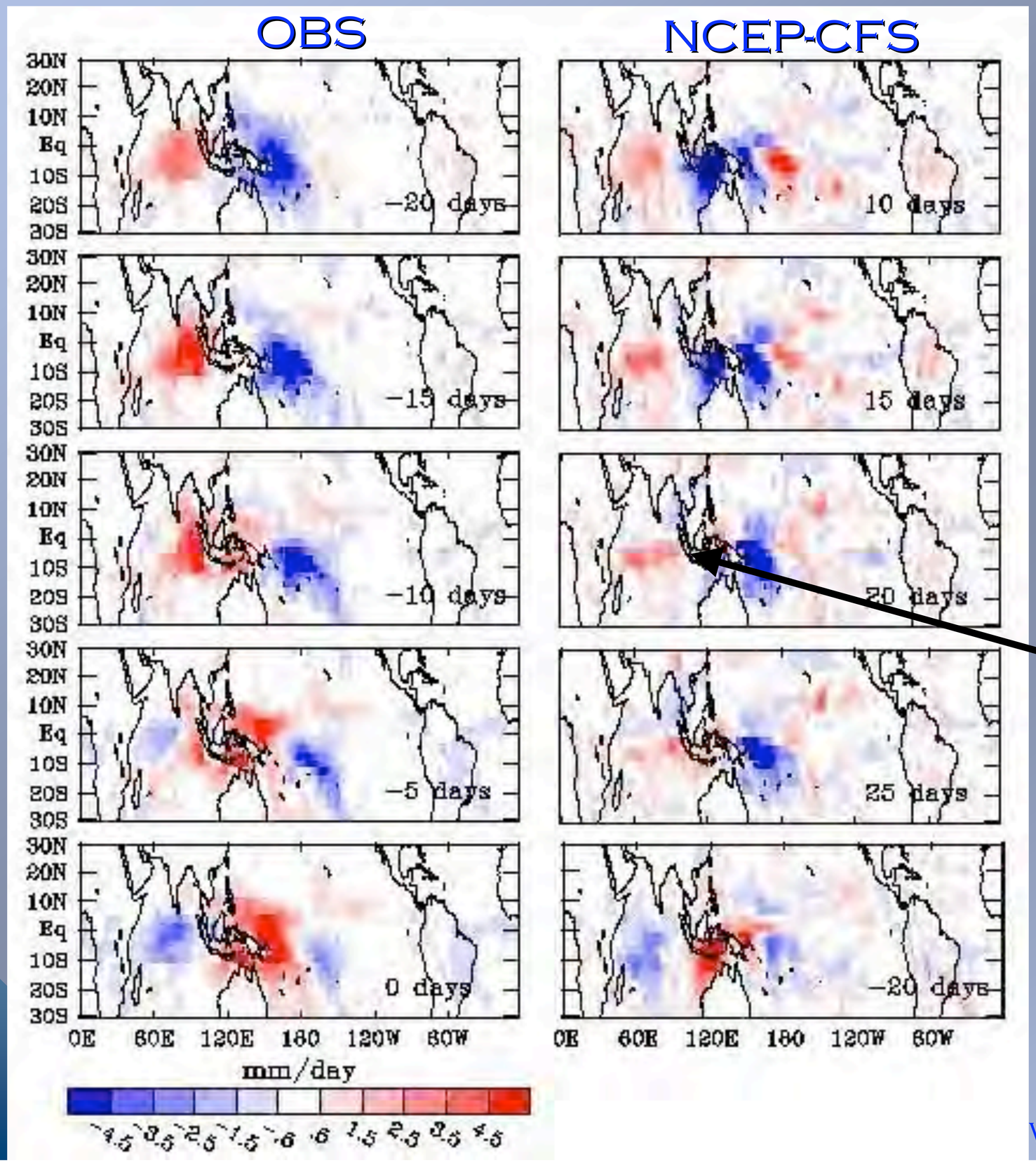



# MJO Modeling in IPCC Models

Difficult to get all Parts of the Variability Right



Lin et al., 2005



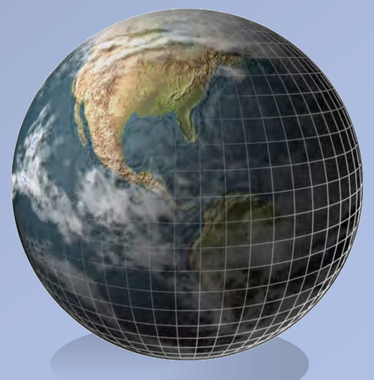

# How about Forecast Models?

## NCEP-CFS

Much Much Better, But Weak Growth In E. Indian Ocean - Revisit This

Waliser, Kirtman, Pan, Schubert

# Prediction & Predictability



# Prediction of the MJO

## Empirical Models

*von Storch and Xu 1990 - POP with VP200*
*Waliser et al. 1999 - SVD with OLR/U200*
*Lo and Hendon 2000 - EOF and Regression with OLR*
***Wheeler and Weickmann 2001** - Coherent OLR Modes/Eq. Waves*
*Mo 2001- SSA with OLR*
***Jones et al. 2003** - EOF and Regression with OLR, U200, U850*
*Goswami 2003- SSA with OLR*
***Wheeler and Hendon 2004** - All-Season Real-Time Multivariate MJO Index*
***Webster and Hoyas 2004**- Multi-variable Physically based Bayesian Model*
***Newman et al. 2003**- Linear Inverse Model (LIM)*

***BOLD** - real-time forecasts

Forecast Skill May Extend to at least 15 days, maybe 25 days or more.

Good enough that they could be considered a useful source of Information that could be assimilated into forecasts of some members

# Prediction of the MJO

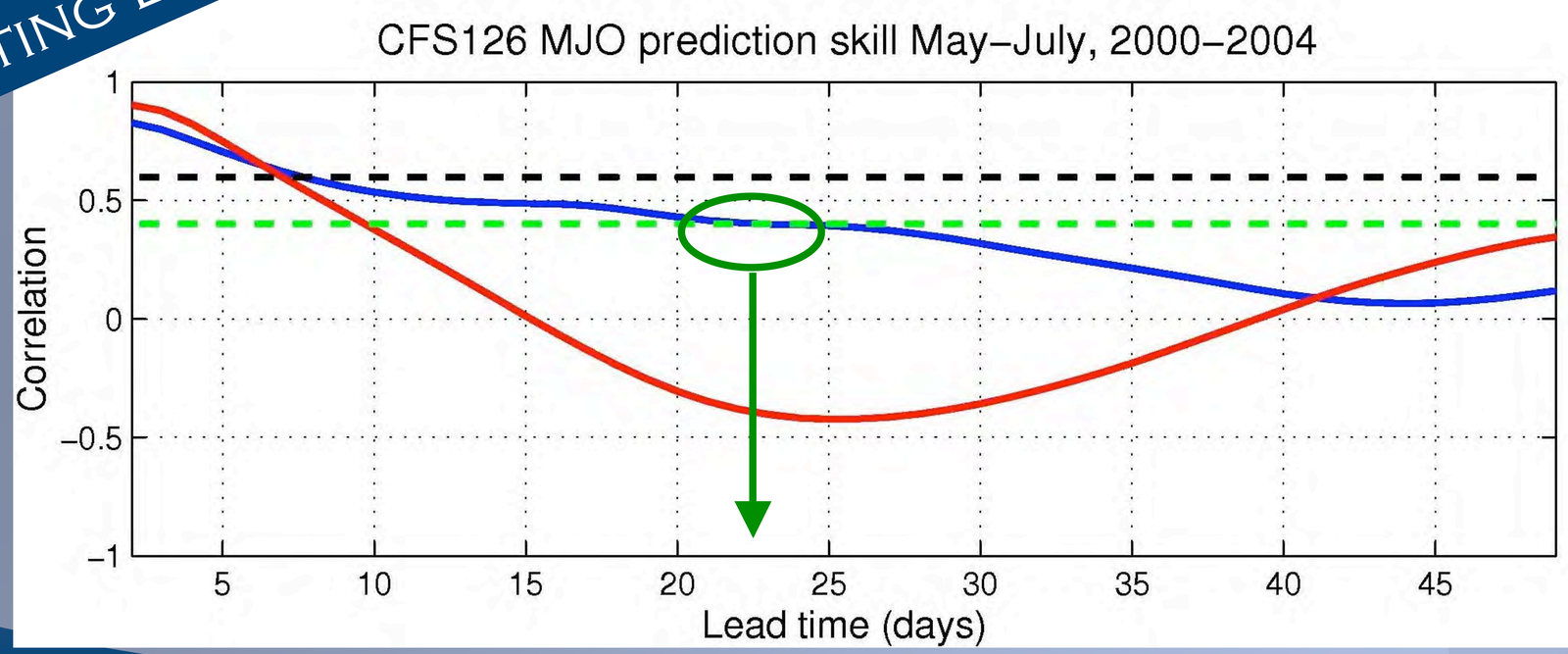
Dynamical Forecast Skill Studies

*Chen and Alpert, 1990*
*Lau and Chang, 1992*
*Hendon et al. 1999*
*Jones et al. 2003*

NMC/NCEP DERF-BASED
*POOR MJO/ISO - POOR SKILL*
*~7-10 days = corr ~ 0.3-0.4*

NWP/MRF is Getting Better

U200 Boreal Summer Pattern Corr.




Courtesy
A. Vintzileos
NCEP/EMC

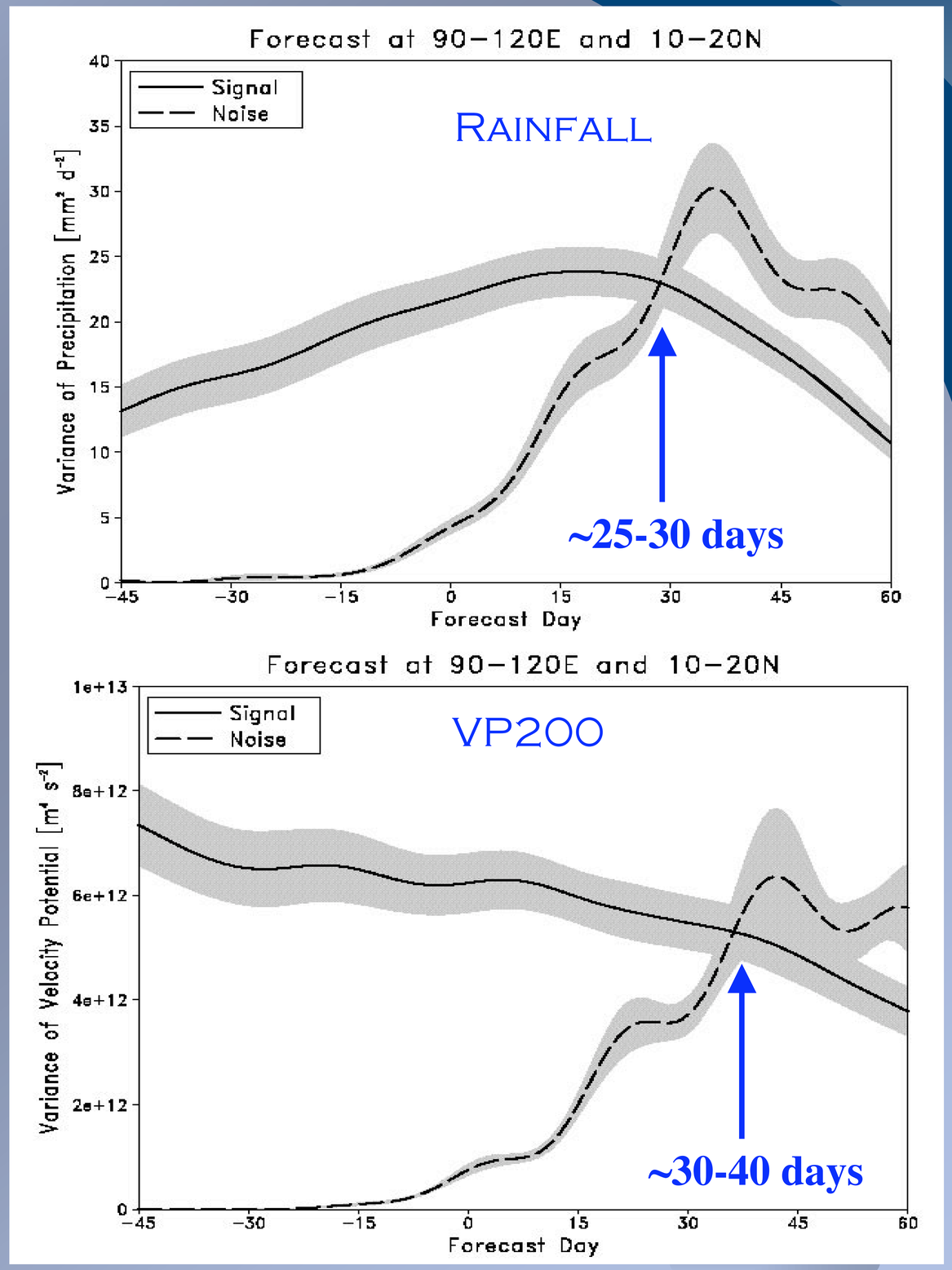
# Predictability of the MJO/ISO

Dynamic Predictability Studies
*Perfect Model Assumption*

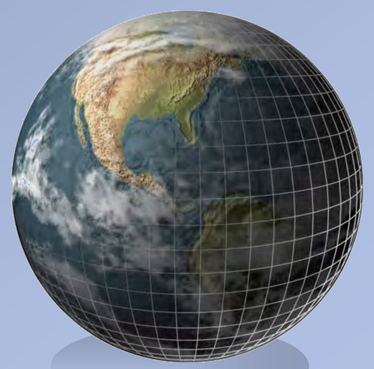
**Waliser et al., 2003a, 2004b**
*GLA, Climatological SSTs, Winter & Summer*

**Liess et al., 2004**
*ECHAM5, Climatological SSTs, Breeding ICs, Summer*

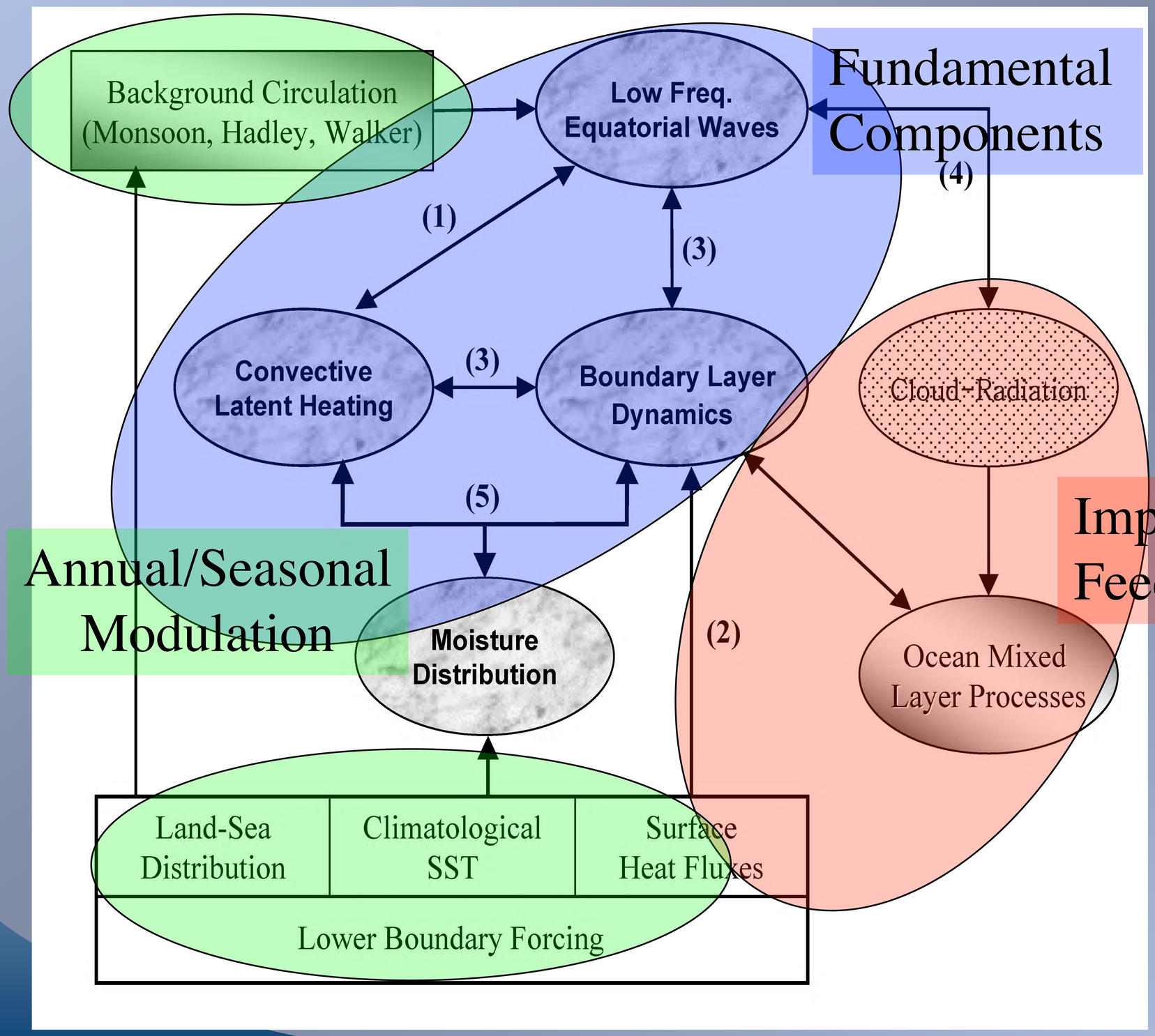
Strong Events Exhibit Considerable Predictability - No/Weak Events only Left with "weather" ~ 10 days.



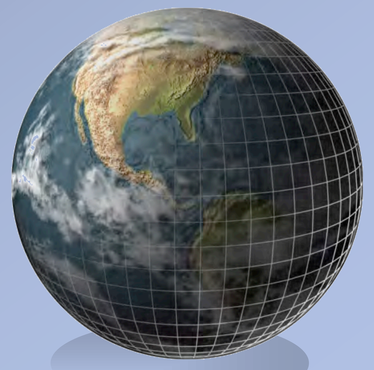
# Important Physical Processes



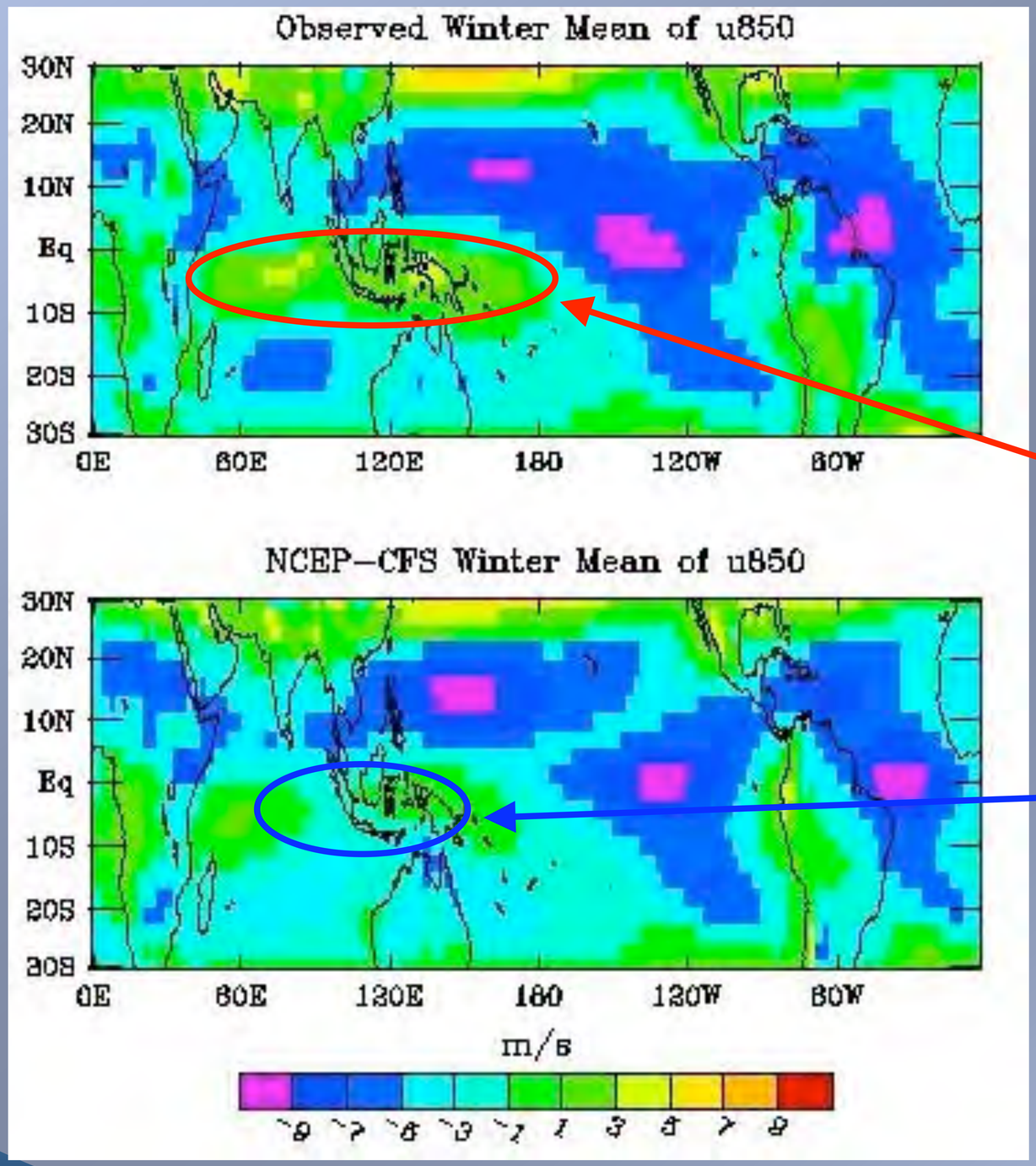
# Theory & Physical Processes




Wang, 2005



# Why Did the NCEP-CFS convection stall at 120E?



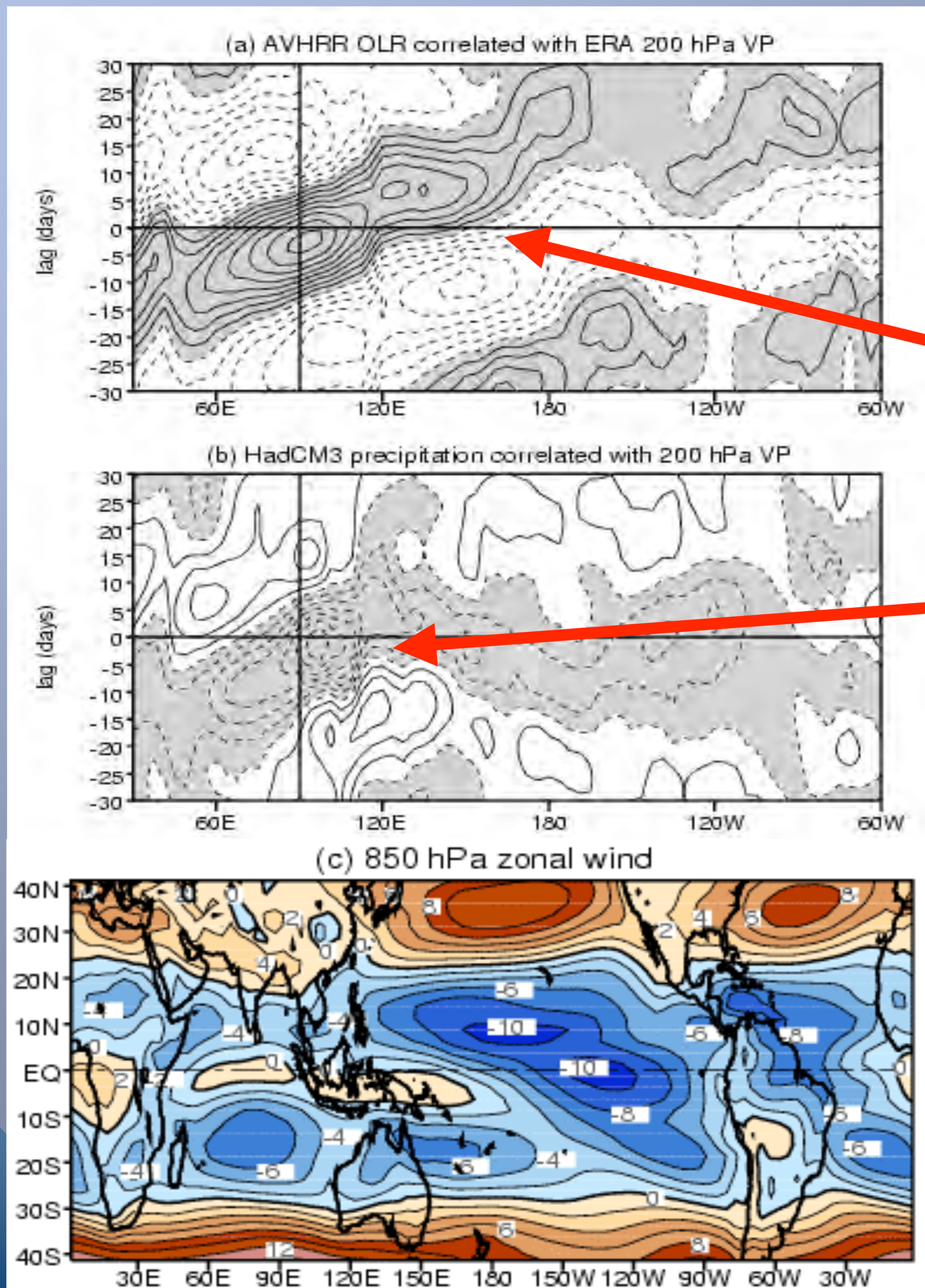

## Mean Low-Level Wind Bias

OBS WESTERLIES

NCEP-CFS EASTERLIES

Waliser, Kirtman, Pan, Schubert

# Westerly Duct & MJO Simulation




OBS - Extensive Westerlies
coherent and Extended Eastward Propagation

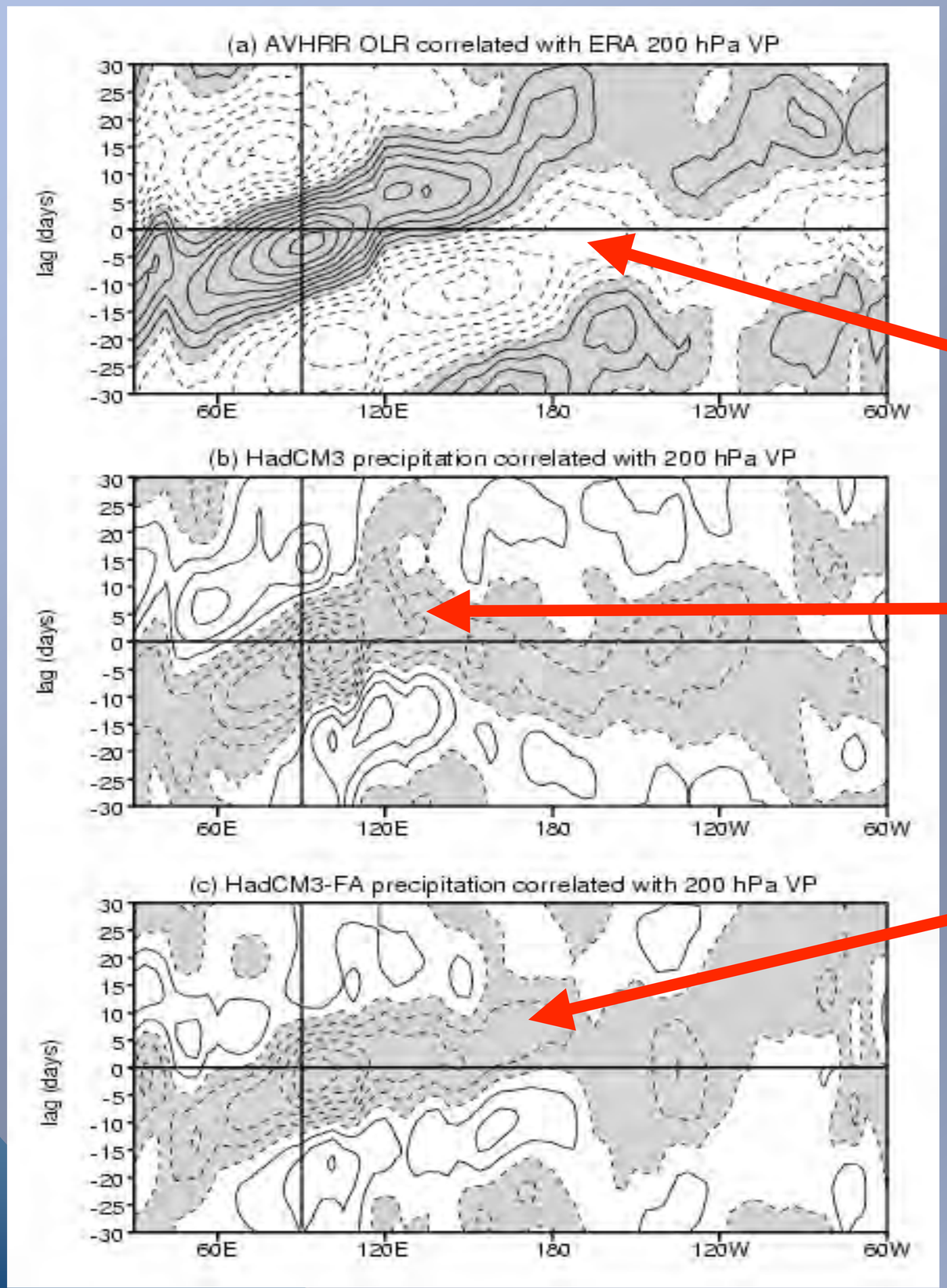
Coupled Model - Weak/Limited Westerlies - Limited Eastward Propagation

Flux-Adjusted Coupled Model - Improved Westerlies

Inness et al. 2003

Hendon et al., 1999
Sperber, 2004

# Westerly Duct & MJO Simulation




OBS - coherent and Extended Eastward Propagation

Coupled Model - Weak/Limited Westerlies - Limited Eastward Propagation

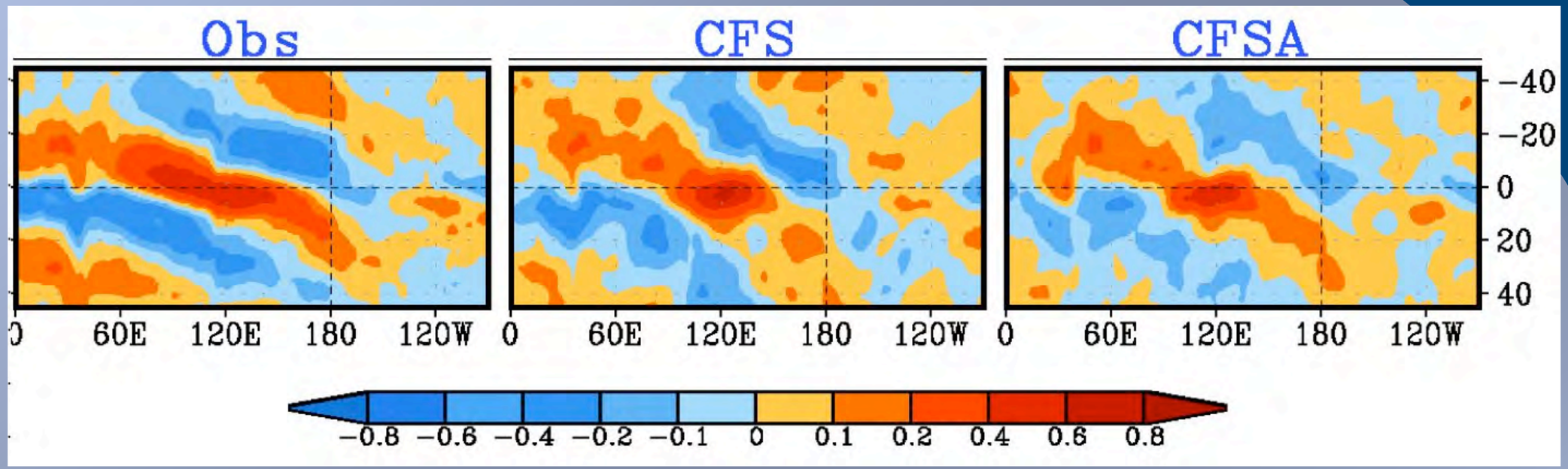
Flux-Adjusted Coupled Model - Improved Westerlies - Extended Eastward Propagation

Improved wind-evaporation relationship

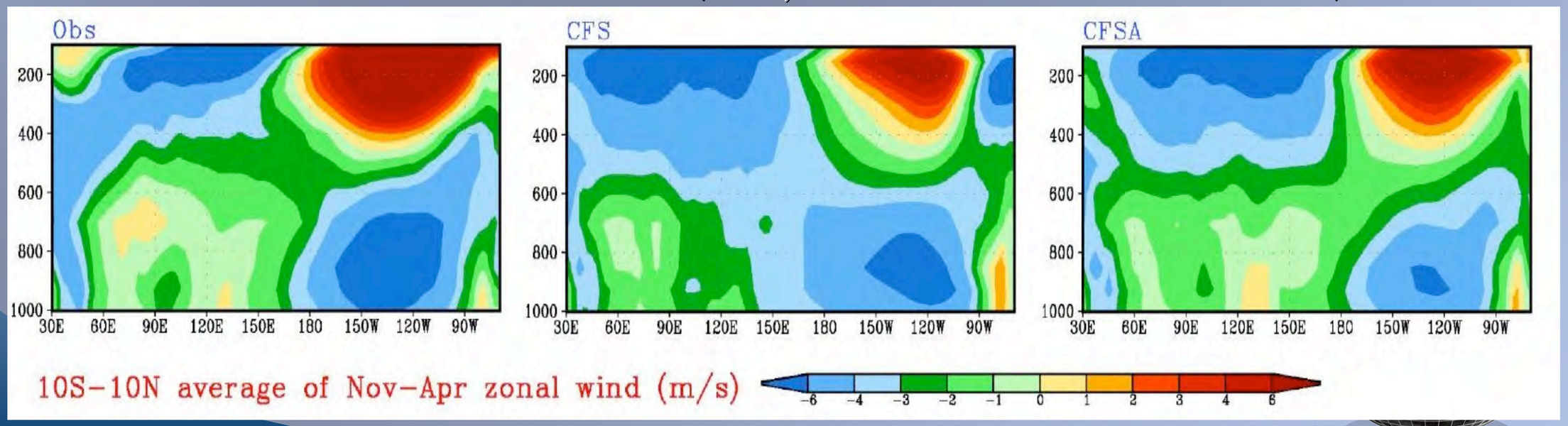
Inness et al. 2003;

# NCEP CFS & CFS Flux Adjusted

## Lag correlation OLR with Chi-850 @ 120E

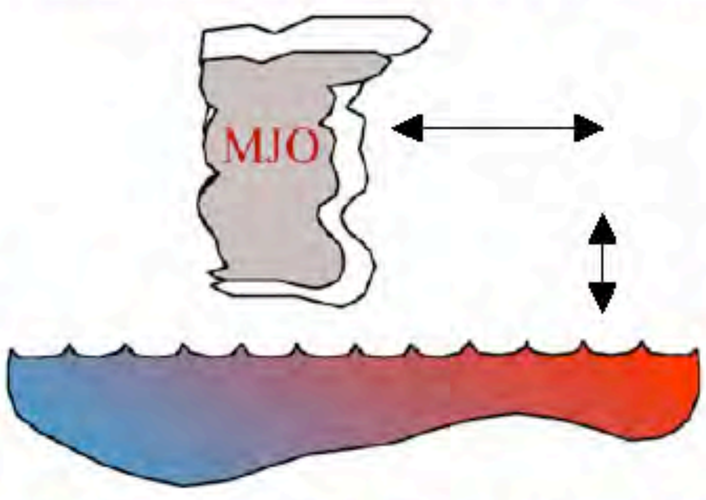



## easterly Vertical shear in the western Pacific favors eastward propagating waves (e.g., Zhang and Geller 1994)

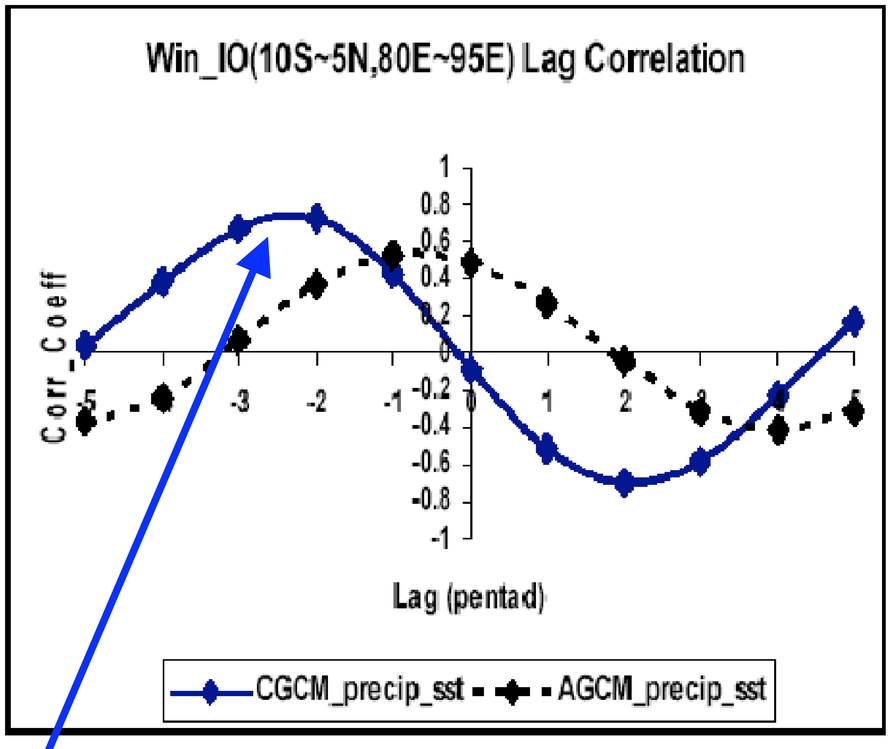



Courtesy Wanqiu Wang, NCEP

# Coupled SST Feedback



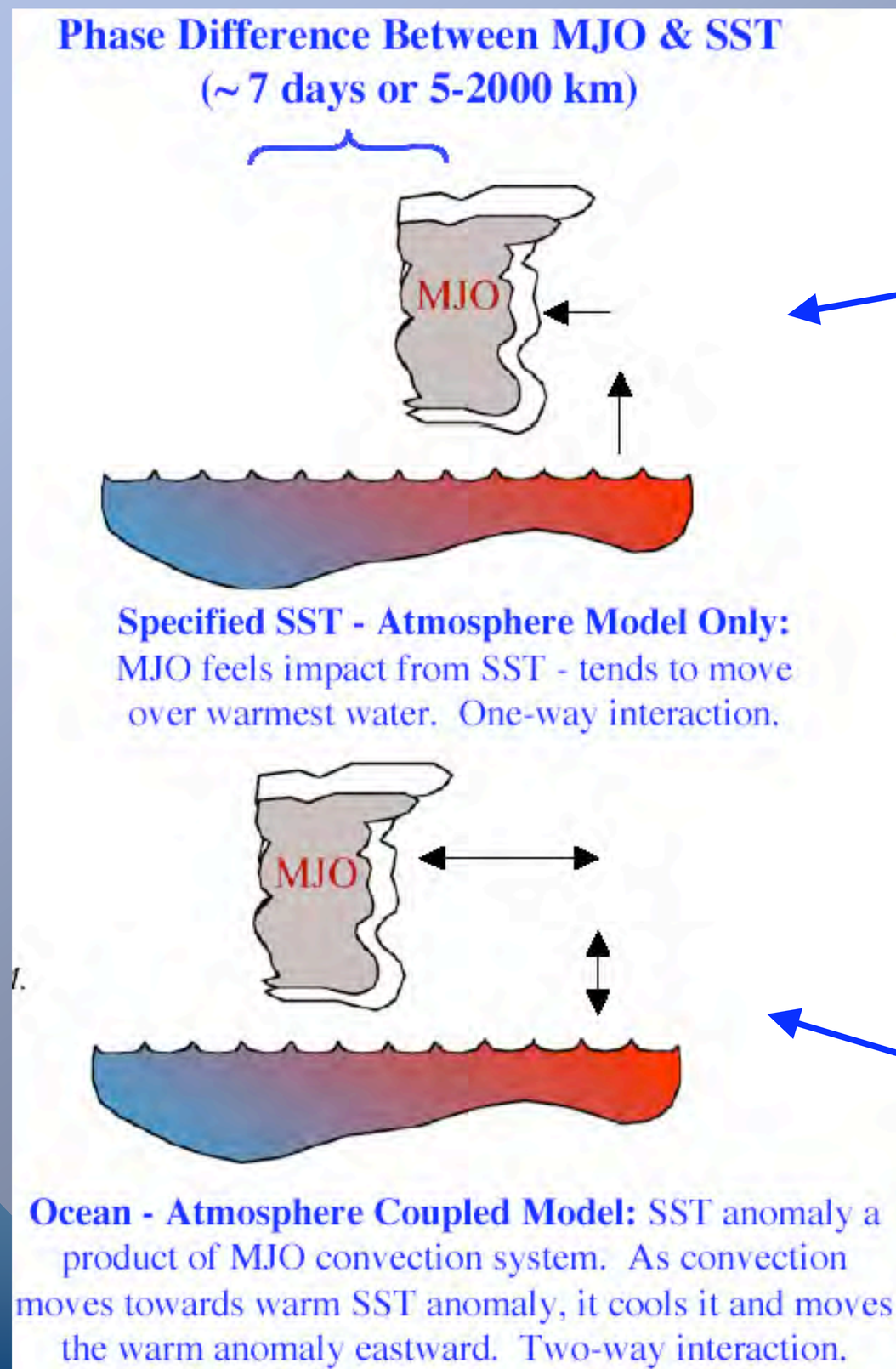

**Ocean - Atmosphere Coupled Model:** SST anomaly a product of MJO convection system. As convection moves towards warm SST anomaly, it cools it and moves the warm anomaly eastward. Two-way interaction.



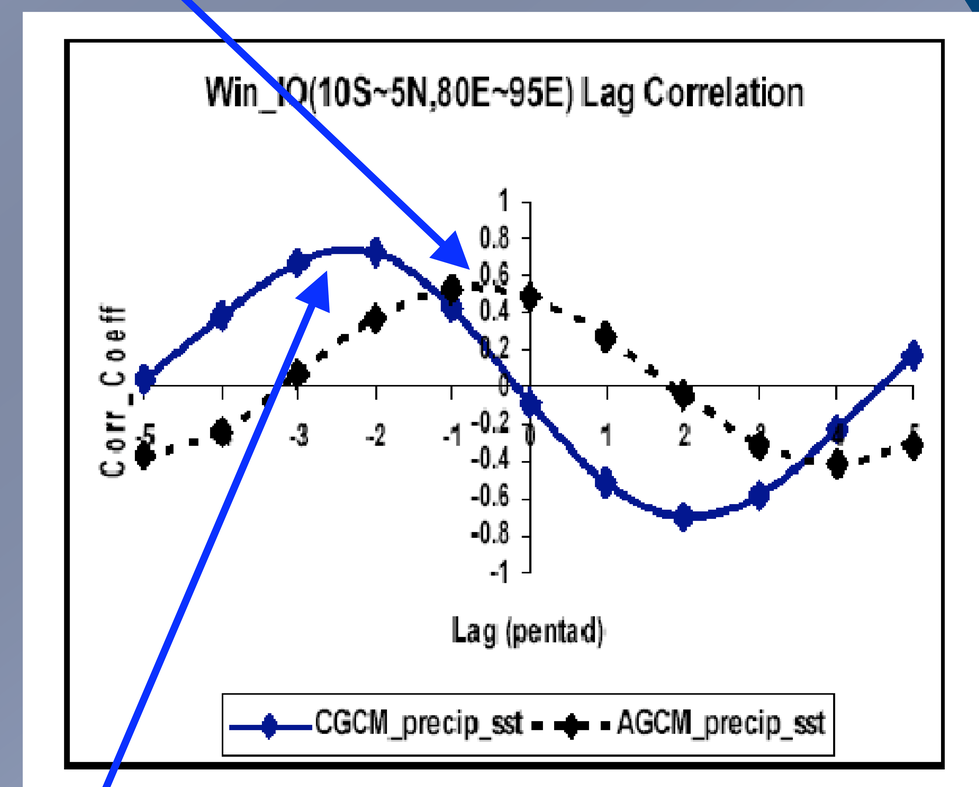

Coupled Atmos+Ocean Model
With Reasonable MJO : GFDL

Fu and Wang, 2004
Zheng, Waliser, Stern, Jones, 2004

# Coupled SST Feedback



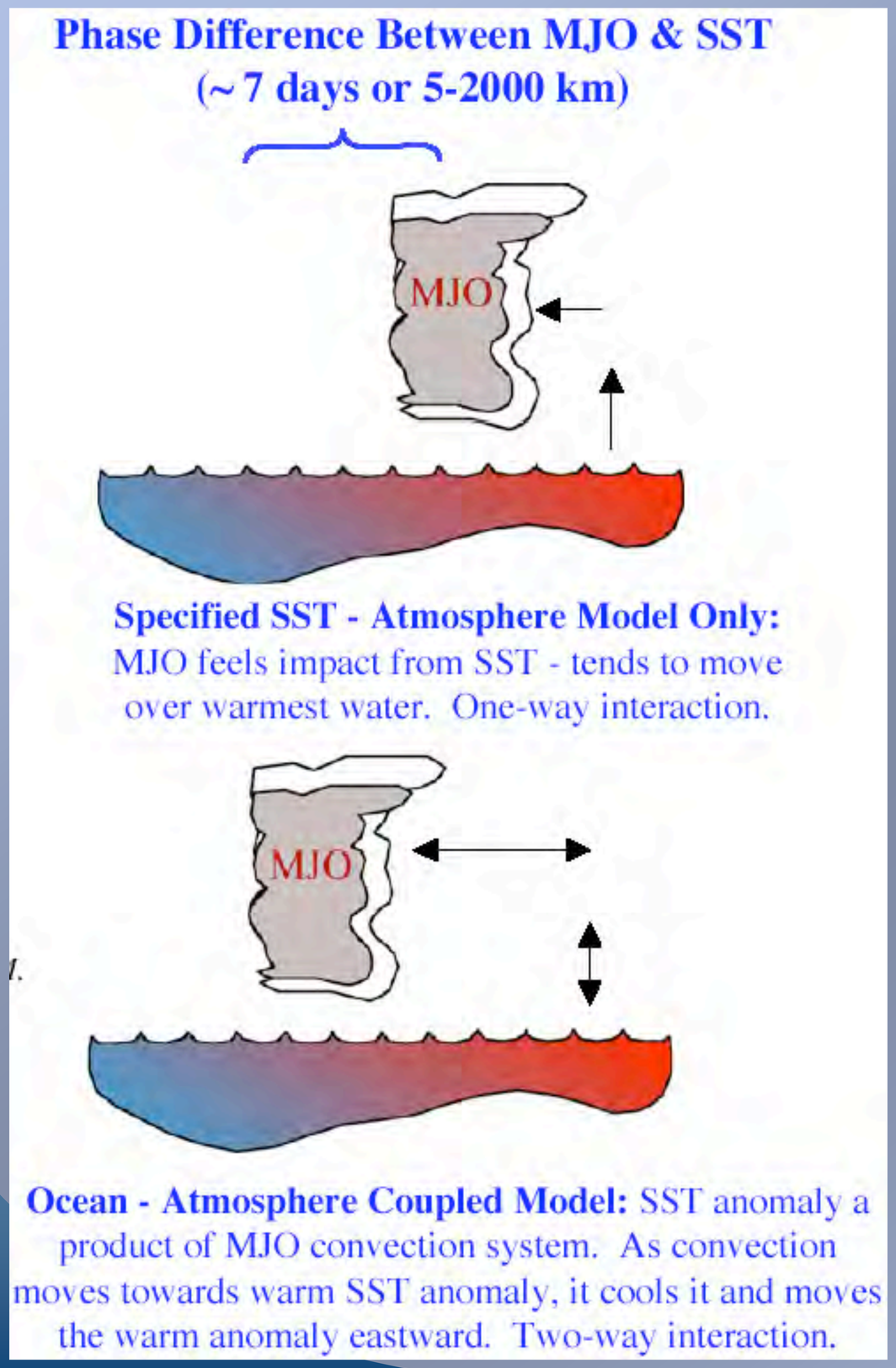

Atmos-Only Model with SSTs From Coupled Model




Coupled Atmos+Ocean Model With Reasonable MJO : GFDL

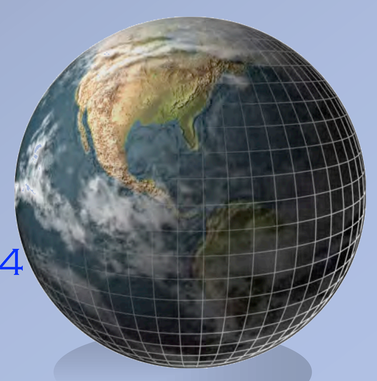
Zheng, Waliser, Stern, Jones, 2004
Fu and Wang, 2004

# Coupled SST Feedback




- Phase Errors in Tropical Heating ~ 7 days or ~2000km
- Subseasonal Predictions MUST Include SST Coupling
- Two-Tier Approach Inadequate For Subseasonal Problem

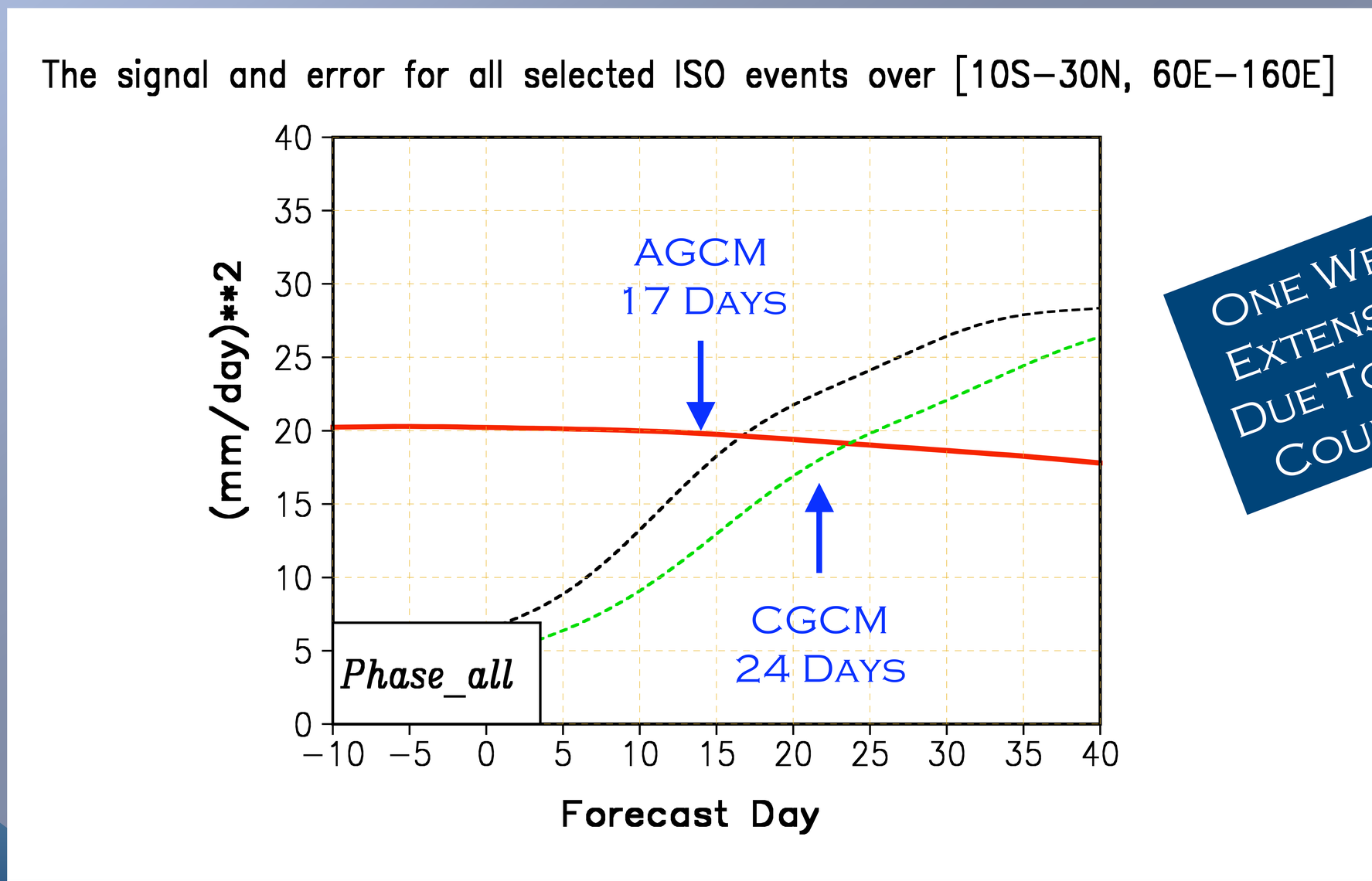
Zheng, Waliser, Stern, Jones, 2004
Fu and Wang, 2004



# MJO Predictability: Impact of Coupling

U. Hawaii CGCM
ECHAM4 + Intermediate Ocean Model

## Boreal Summer MJO Case - Tropical Indian/W.Pac




One Week Extension Due To SST Coupling

Fu, et al. 2005

# Other Notable Processes

## Easterly Vertical Shear / Basic State -> Northward ISOs

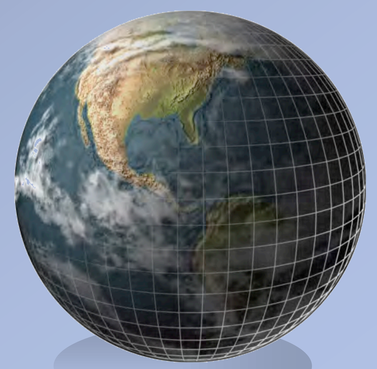
A combination of studies (e.g., Wang and Xie, 1997; Kemball-Cook et al. 2002, Jiang et al. 2004) have shown the importance of easterly vertical Shear to the development of Northward propagating Summer ISOs.

## Vertical Resolution

Inness et al. (2001) have shown MJO sensitivity to having adequate vertical resolution in the mid-troposphere in order to adequate resolve cumulus congestus - and thus to some extent delay the onset of deep convection.

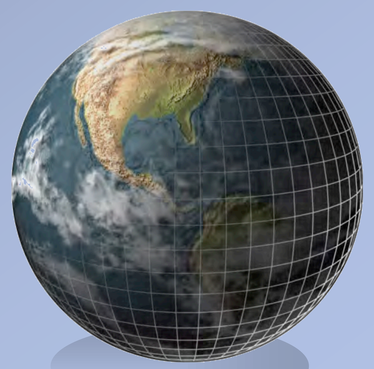
## Radiative Heating Feedback

Recent studies (Raymond 2001; Lee et al. 2001; Sobel and Gildor 2003) have found sensitivity in model MJO's to the size/sign of radiative feedbacks. Lin and Mapes (2004) have found net column radiative heating to enhance latent heating by about 10-15%.



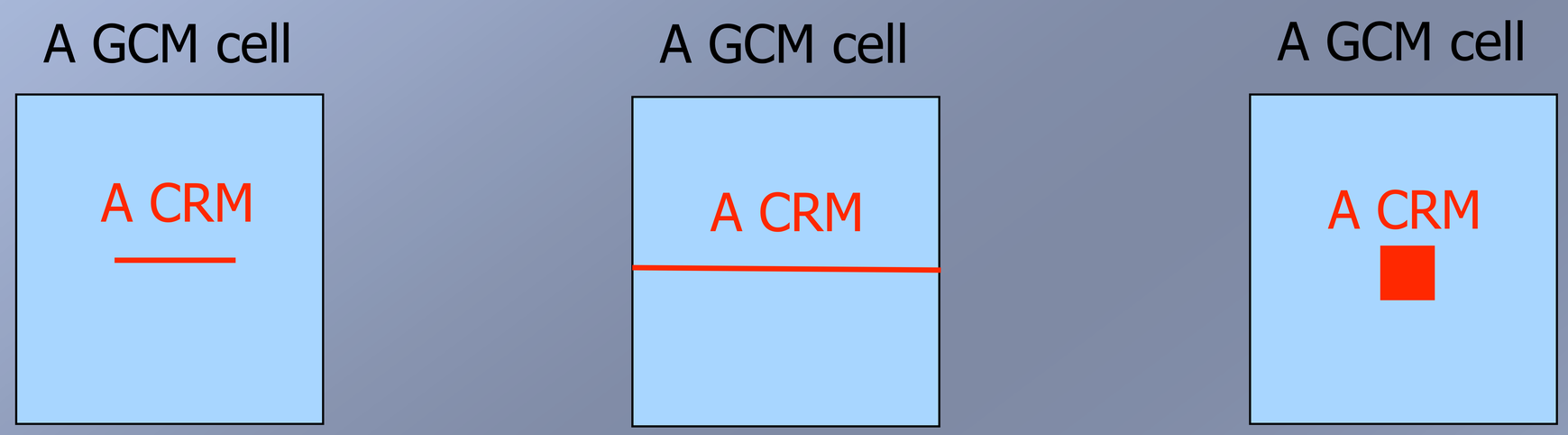
# New Horizons

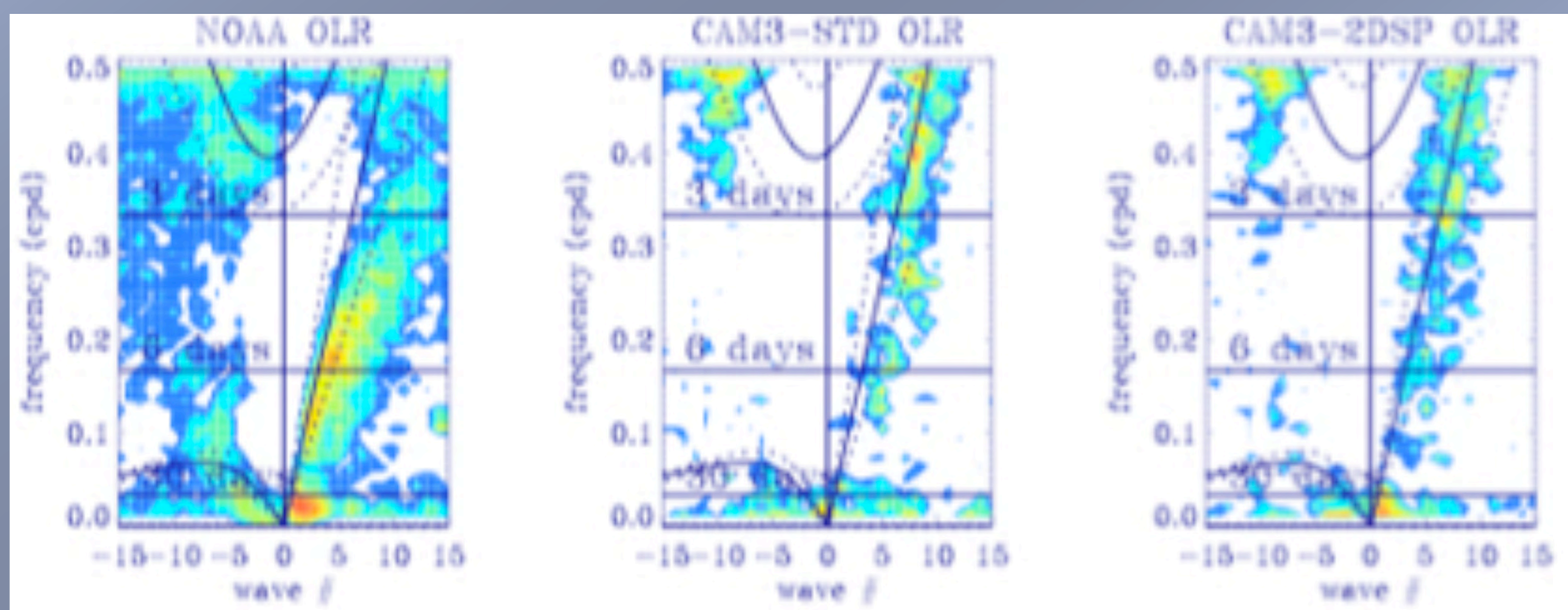
Infrastructure and Resources are Improving



# Proliferation and Advances In Super-Parameterization

NCAR->CSU->PNNL,LLNL,GSFC



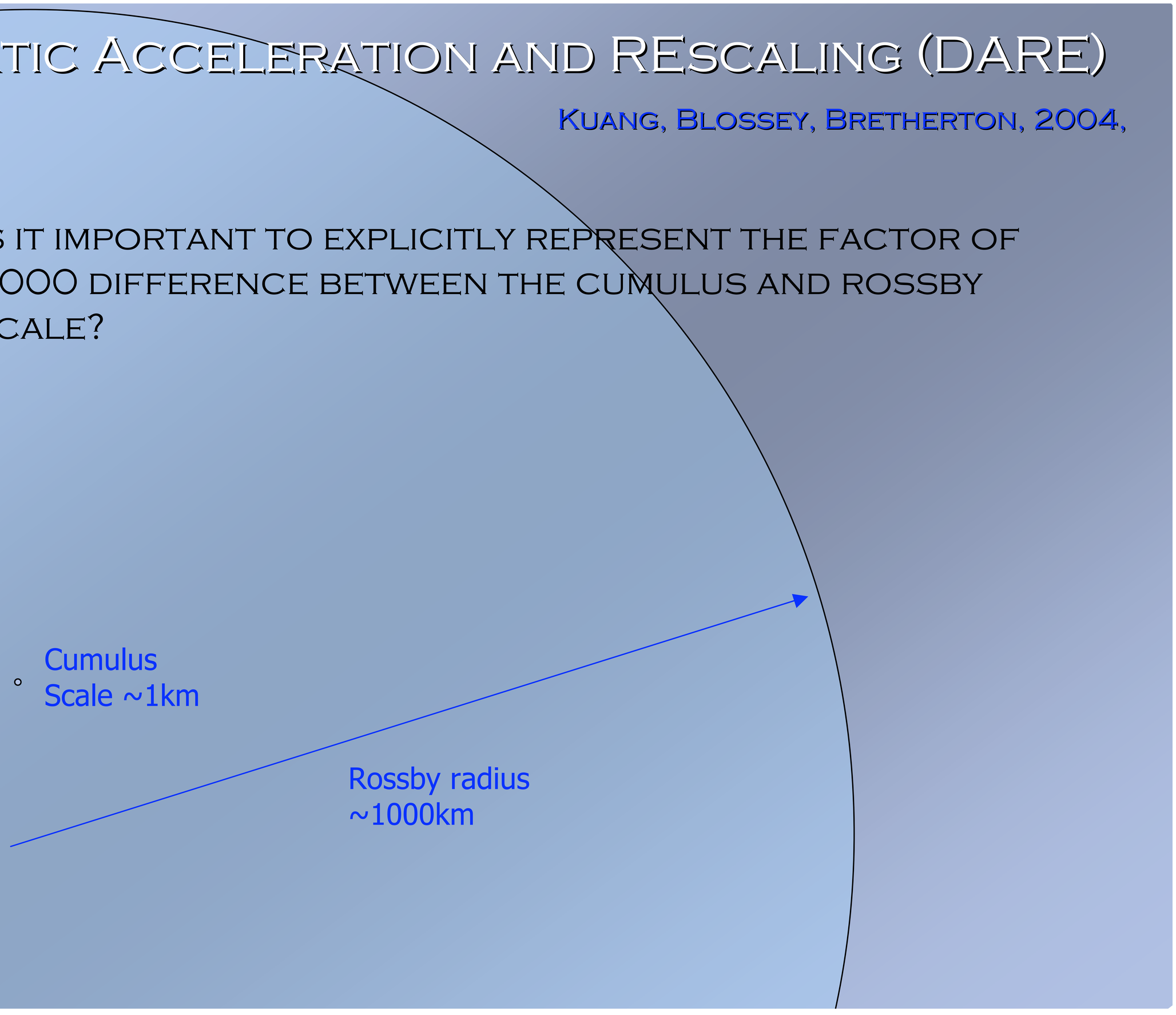




Courtesy of Khairoutdinov et al. 2005

# Diabatic Acceleration and REscaling (DARE)

Kuang, Blossey, Bretherton, 2004,

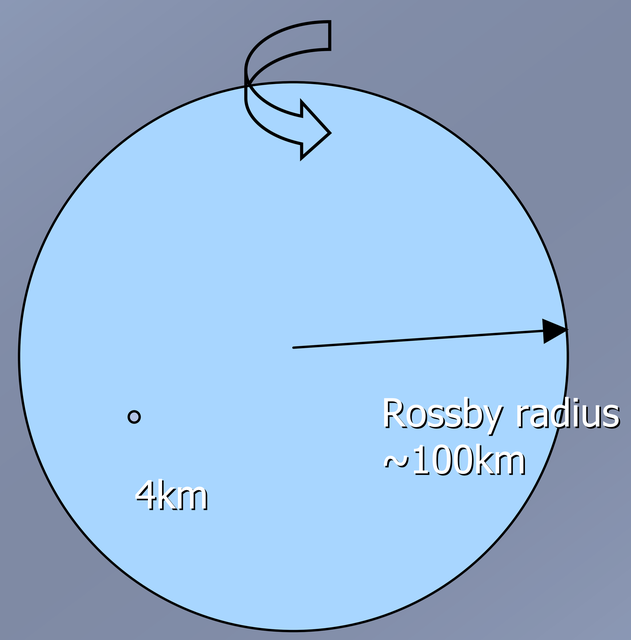
- Is it important to explicitly represent the factor of 1000 difference between the cumulus and rossby scale?



# Diabatic Acceleration and REscaling (DARE)

Approach

- Accelerate all diabatic processes, reduce Earth's size and increase its rotation by ~10.
- Rescaling does not alter the equations for the large scale circulation.
- Assumption is that scale interactions between the cumulus scale and the Rossby scale remain similar, so long as the two are well separated.



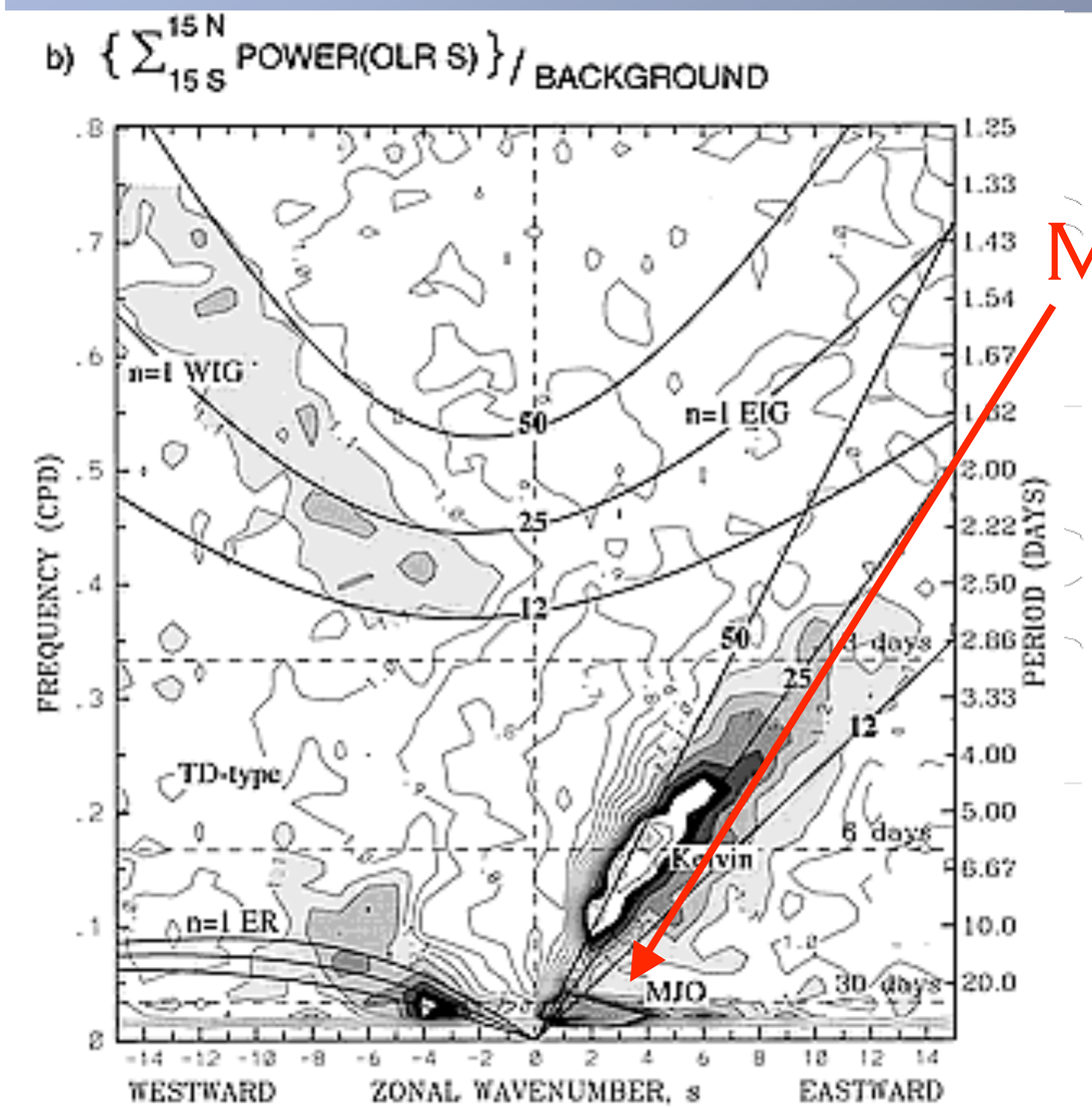

- Saves a factor of ~500 in computation.

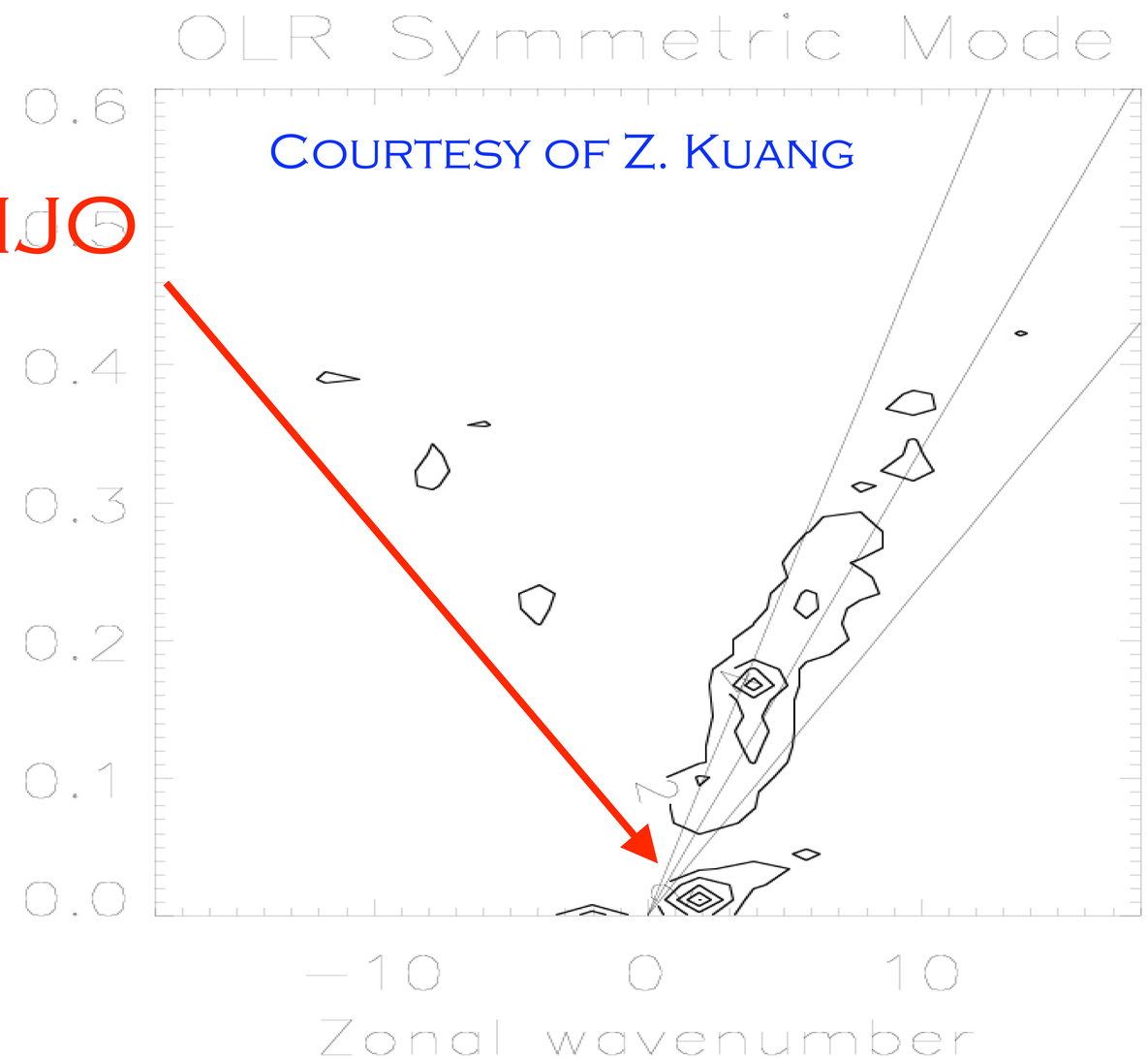
Kuang, Blossey, Bretherton, 2004

# Some Preliminary DARE Results

OBS

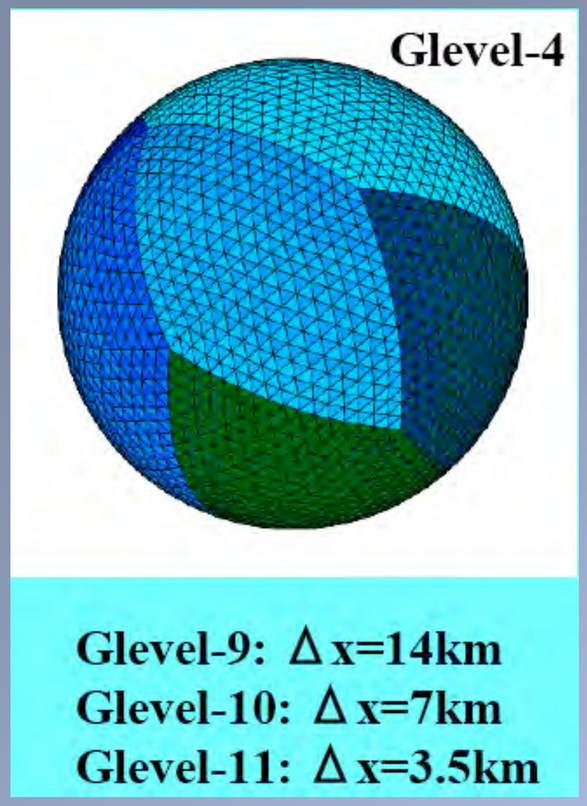
DARE

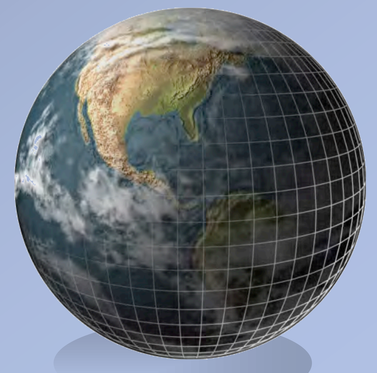


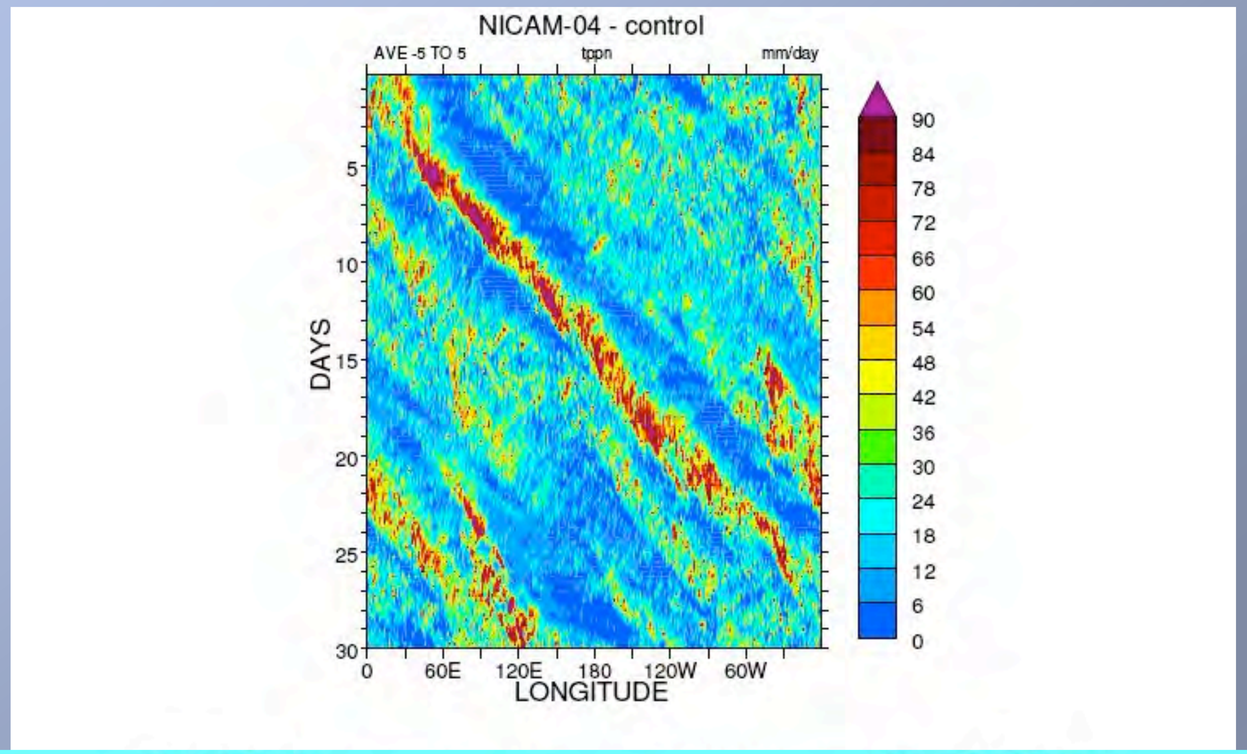
# Global Cloud Resolving Model

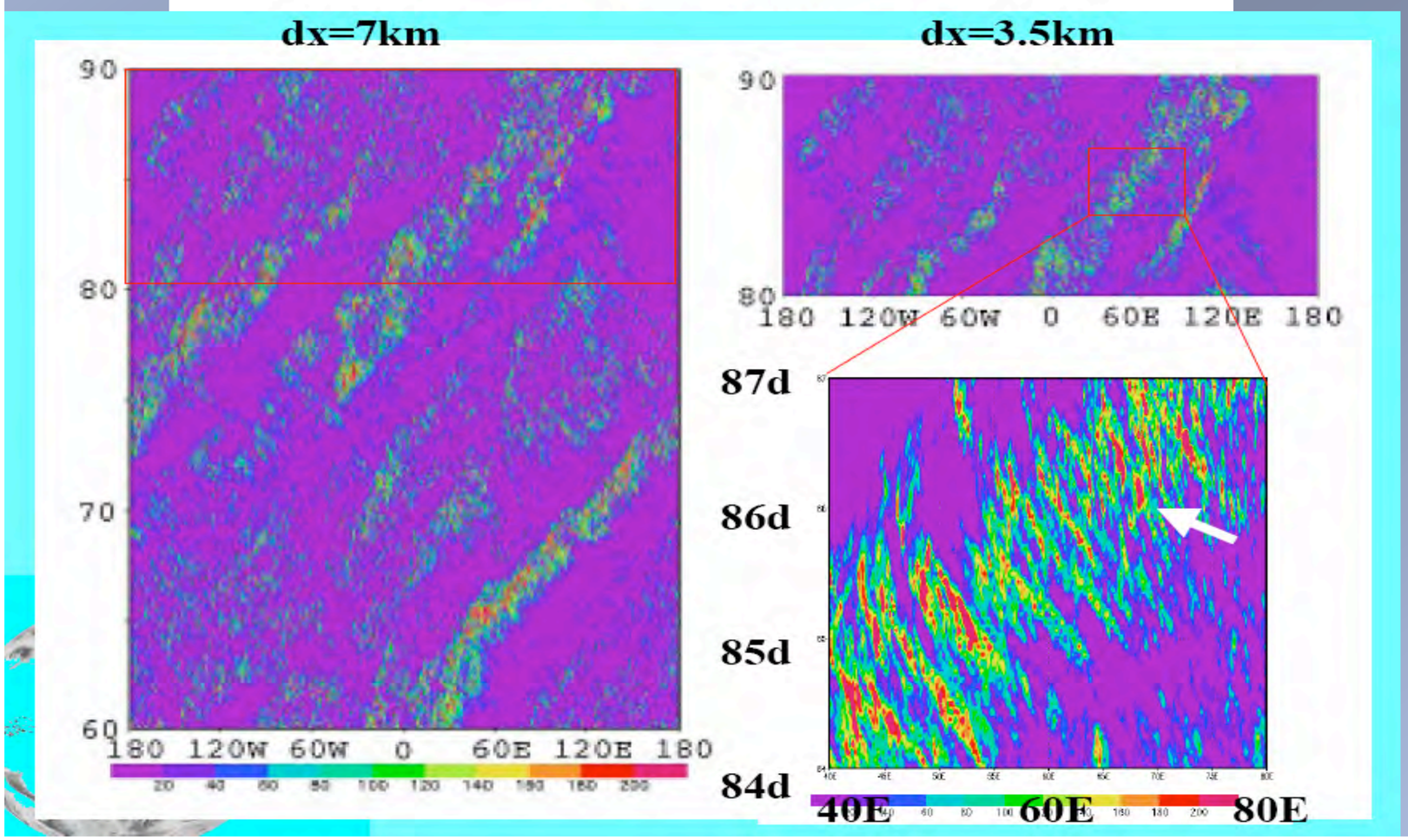
## *Earth Simulator Super-Duper Computer*



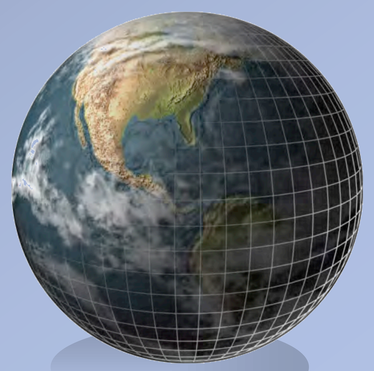



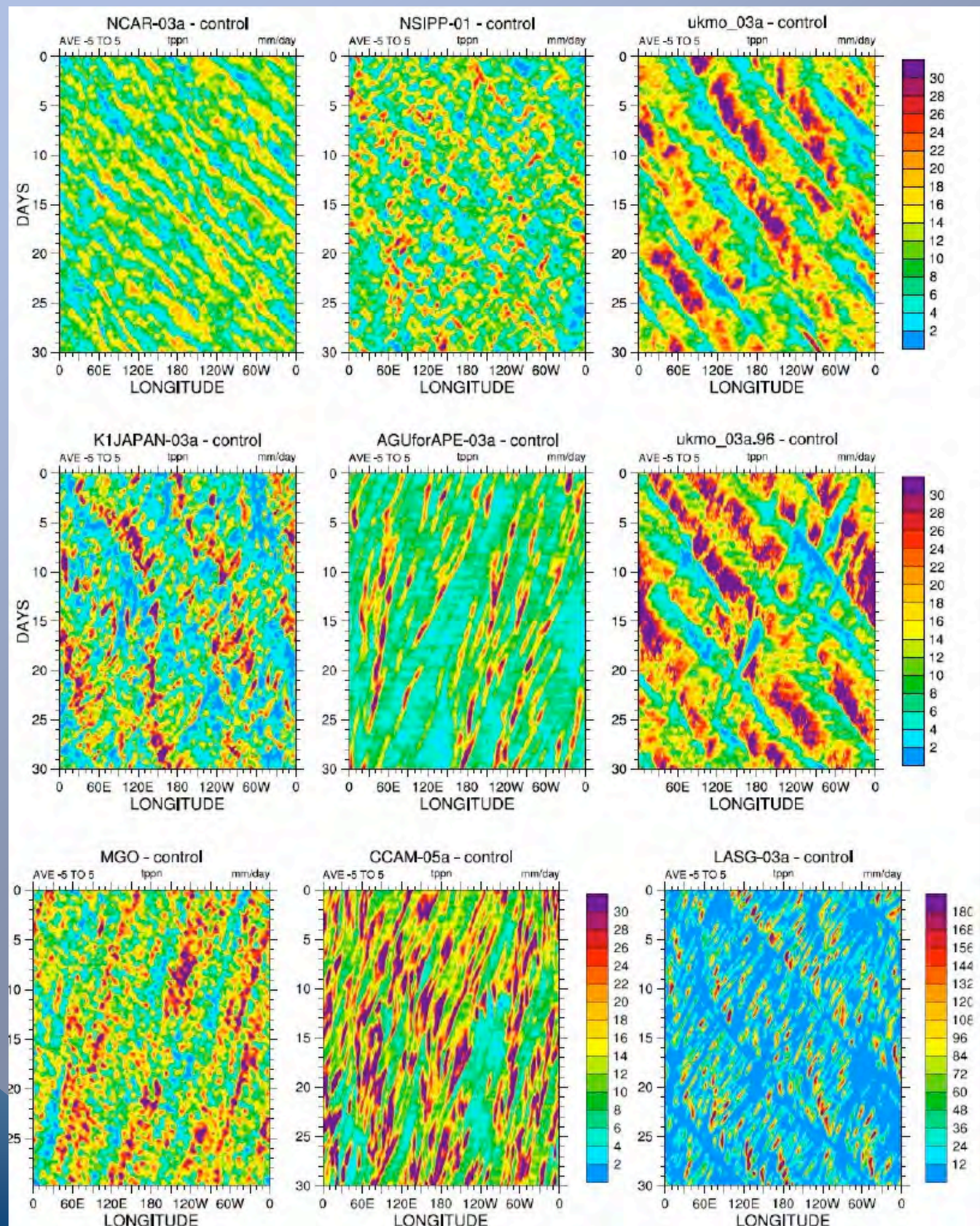
# Global Cloud-Resolving NICAM - 3.5 km



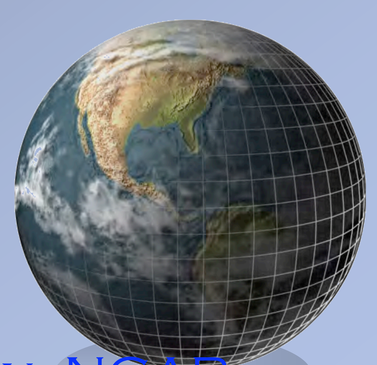

Variability Closely resembles MJO with Super-cluster westward-moving substructures (e.g., Nakazawa, 1988)






# Results from the Aqua-Planet Experiment (APE)

No Model seems to have An "MJO"

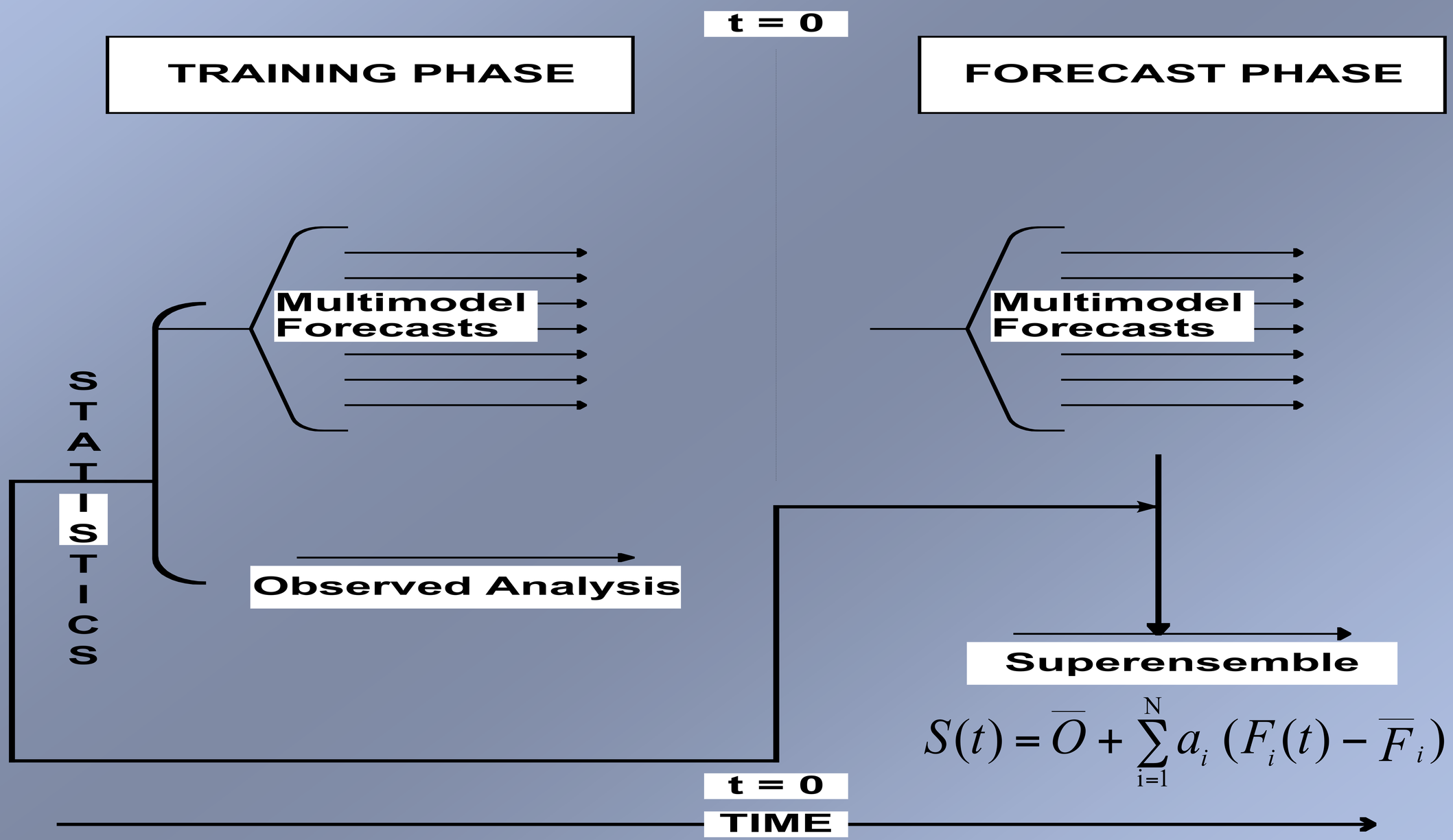


Courtesy,
Dave Williamson, NCAR

# Prediction:Coupled-Multi-Model Superensemble

## 4 Physical Members: 2 Rad x 2 Conv

1987-2002; Cross-Validation; 90-day Forecasts



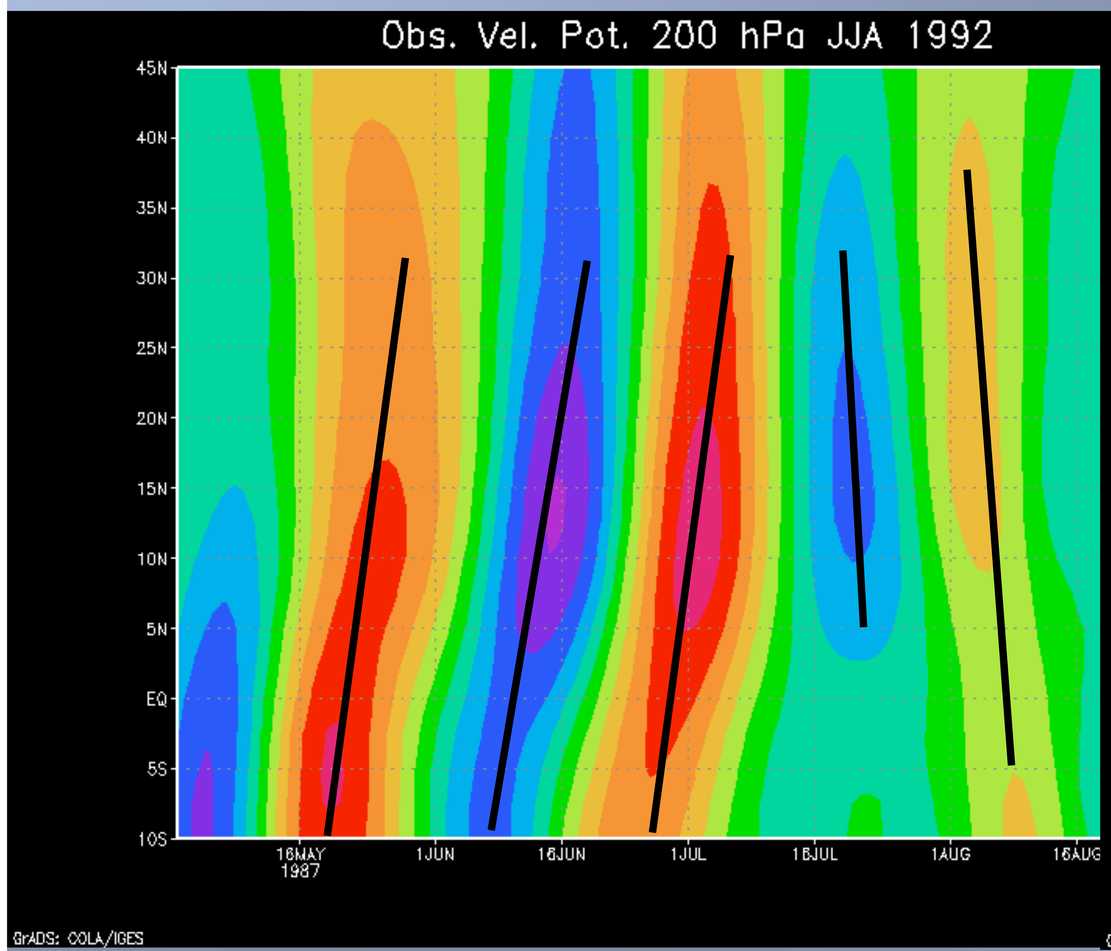

$$S(t) = \overline{O} + \sum_{i=1}^{N} a_i \left(F_i(t) - \overline{F}_i\right)$$

V. Kumar and T.N. Krishnamurti

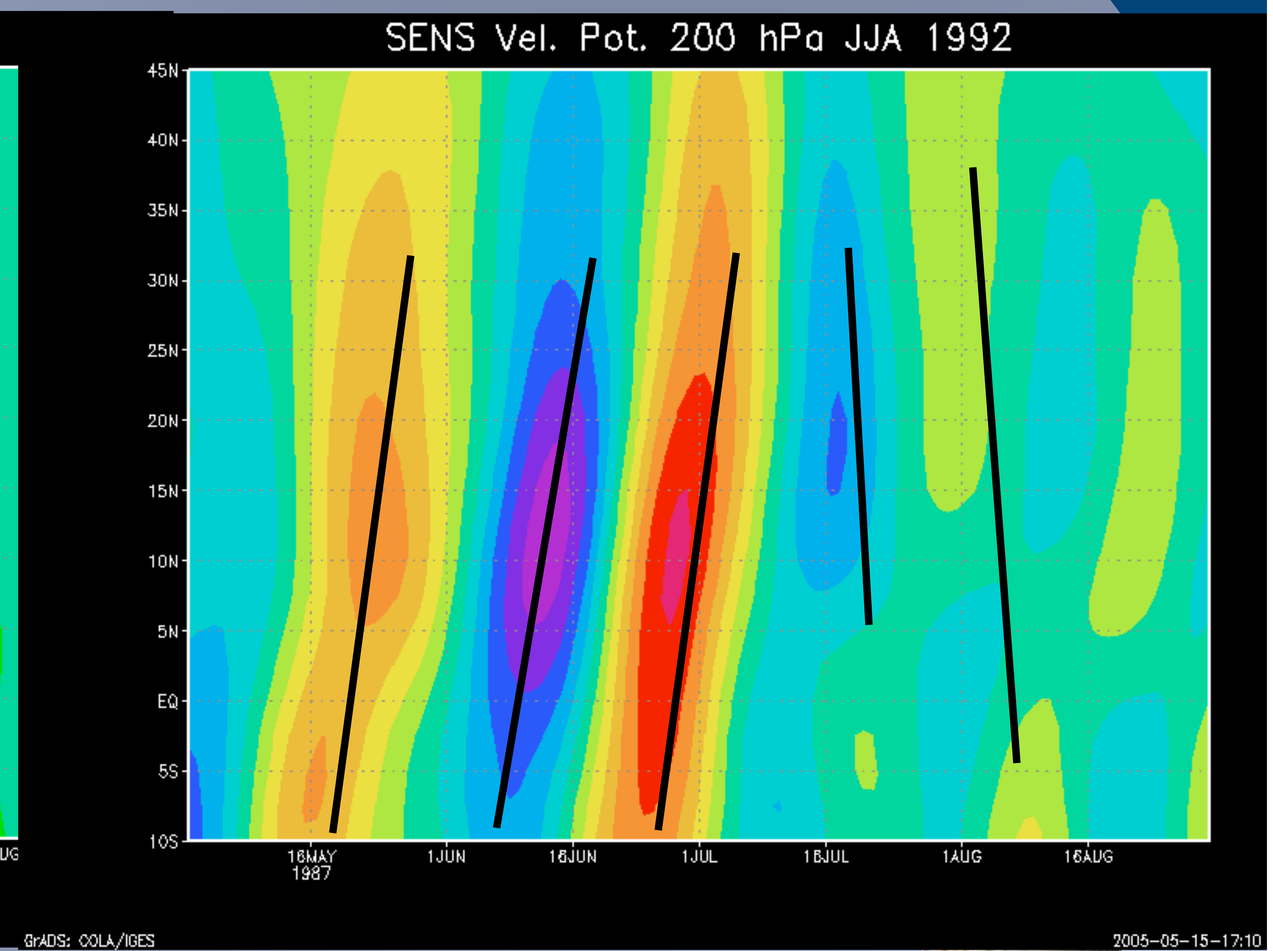
# Results for Case Study 1992

## Northward Propagation of VP200

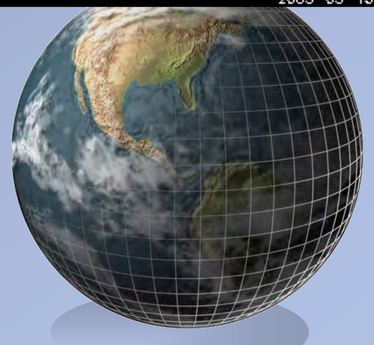
OBS



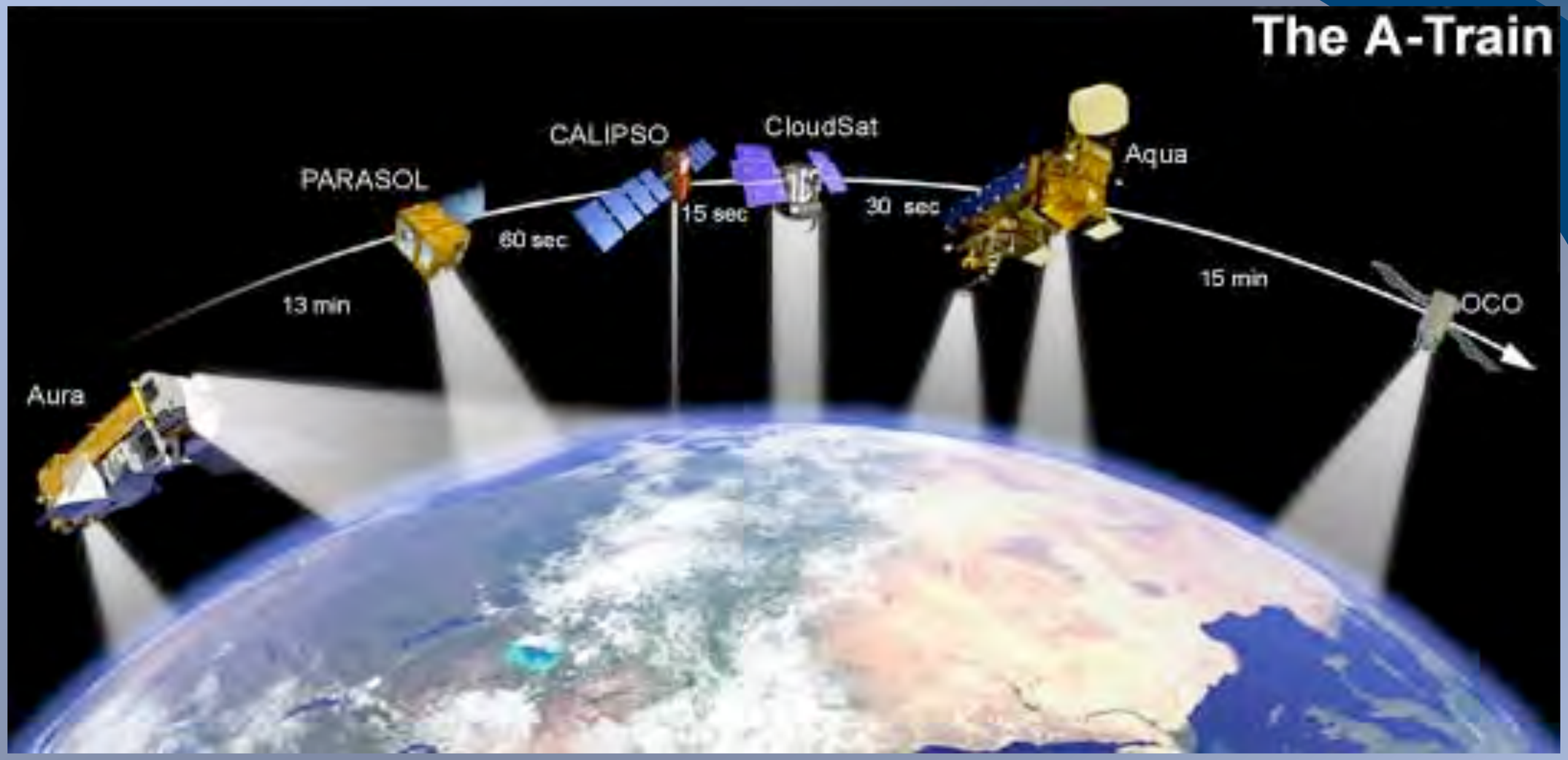

Super-Ensemble




2 months

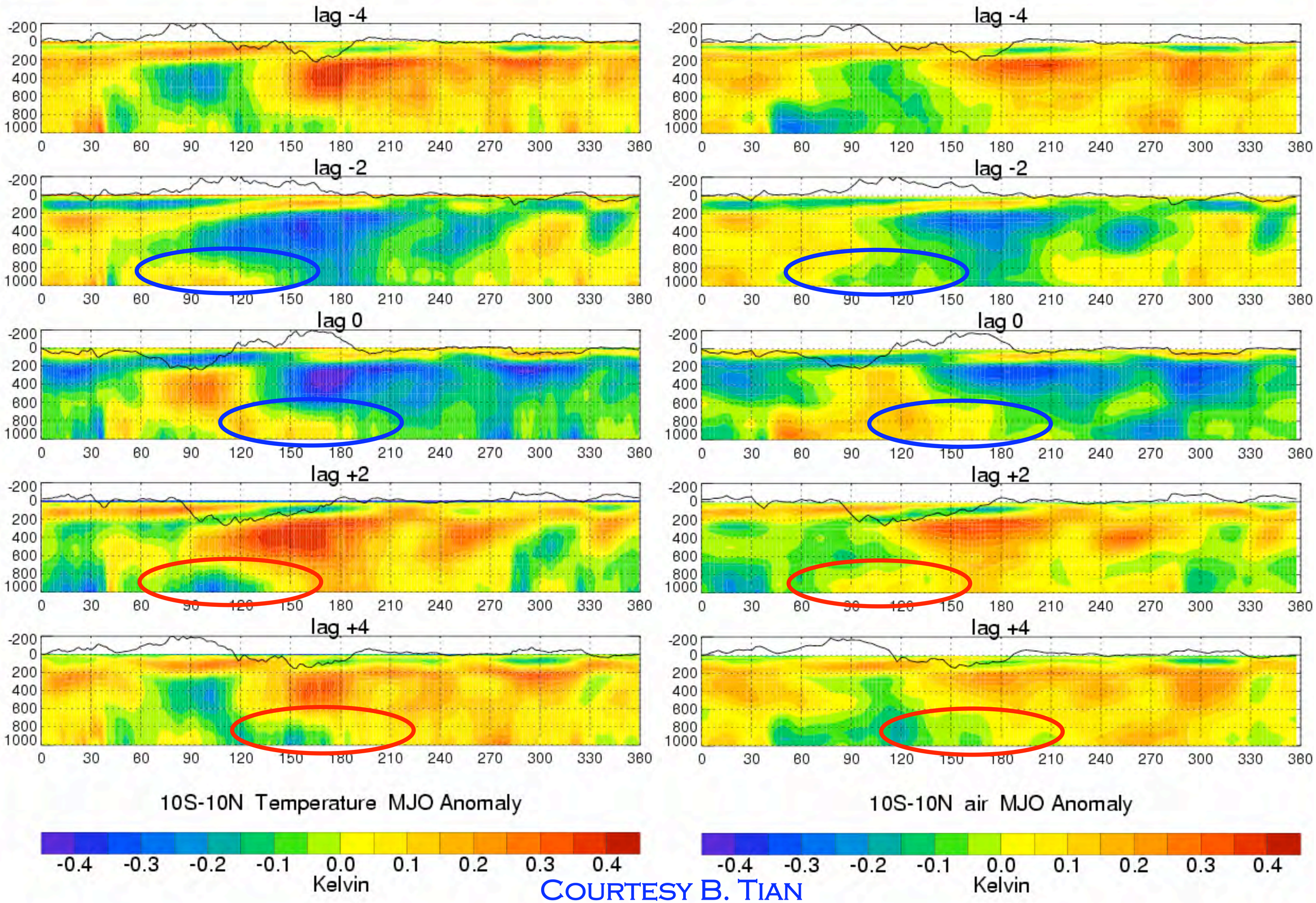


# EOS A-Train



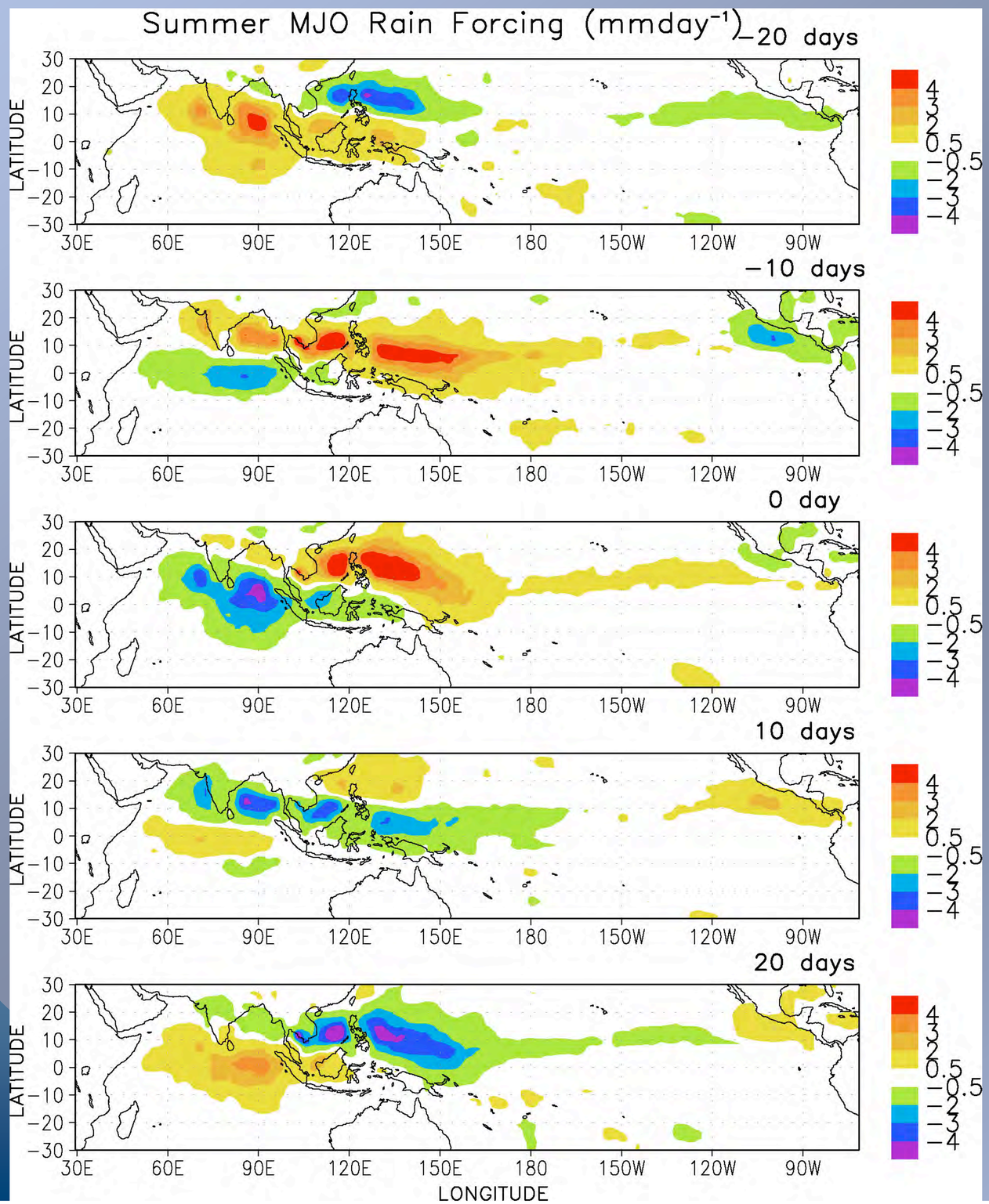

- Ideal for multi-scale interactions ~diurnal, synoptic, ISO
- Ideal for NWP Perspective/CAPT Effort (e.g., Potter)

# "OBS" MJO



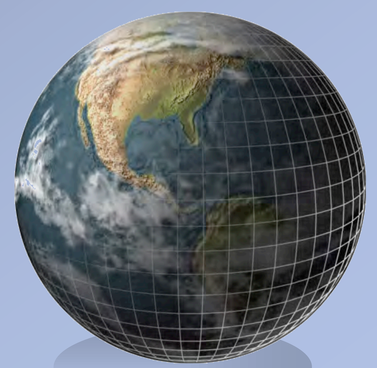

Courtesy B. Tian

# MJO & Ocean Biology?

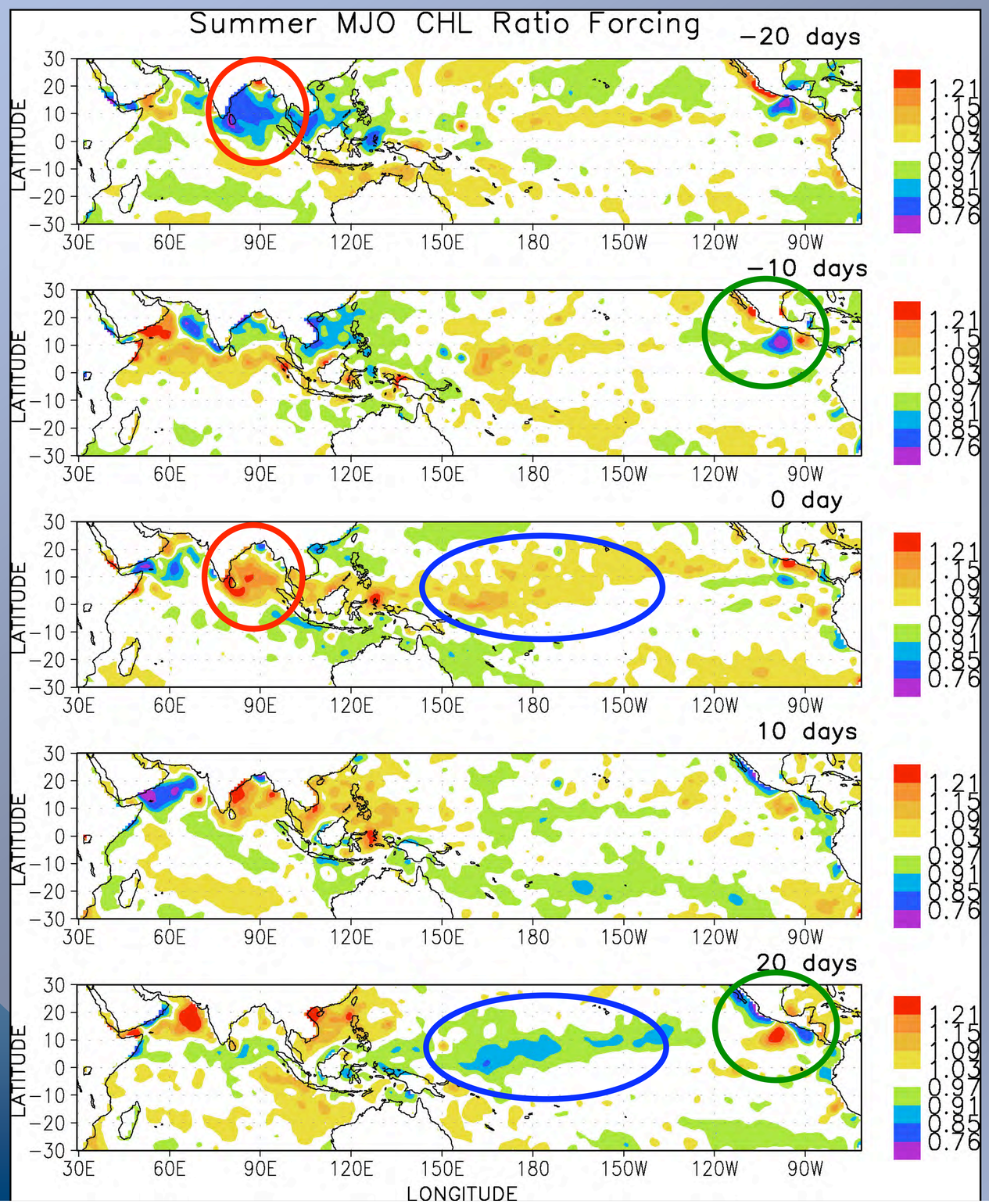



## Boreal Summer MJO Rainfall Evolution

## Predictable with 2-3 Week Lead Times?

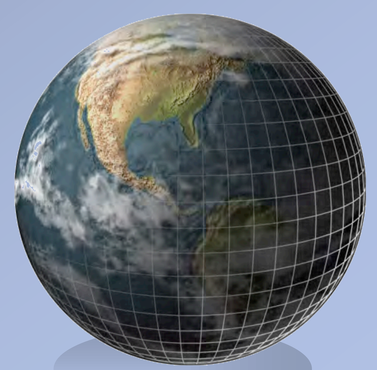


# MJO Modulation of Ocean CHL




Boreal Summer Corresponding CHL from SeaWiFs

Could Then CHL and thus Potential Fish Catch Be Predictable with Similar Lead Times?



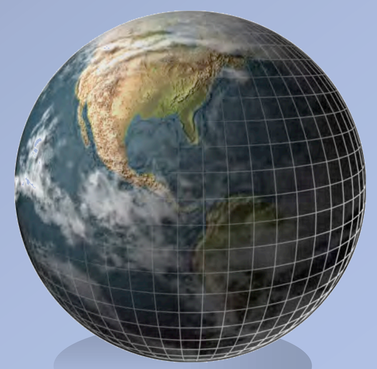
# SUMMARY

- ISV is of Paramount importance to monsoon understanding, modeling, prediction

## Remaining challenges & opportunities

- Multi-scale interactions (cumulus<-> planetary, 10-20 day, synoptic; interannual/decadal).
- Mean state Simulation (IO, double ITCZ, westerly duct).
- Data - enough to know models are bad but lack info on hydrological cycle (e.g., microphysics, latent heating profiles), vertical structure, boundary layer processes & cloud-radiative interactions

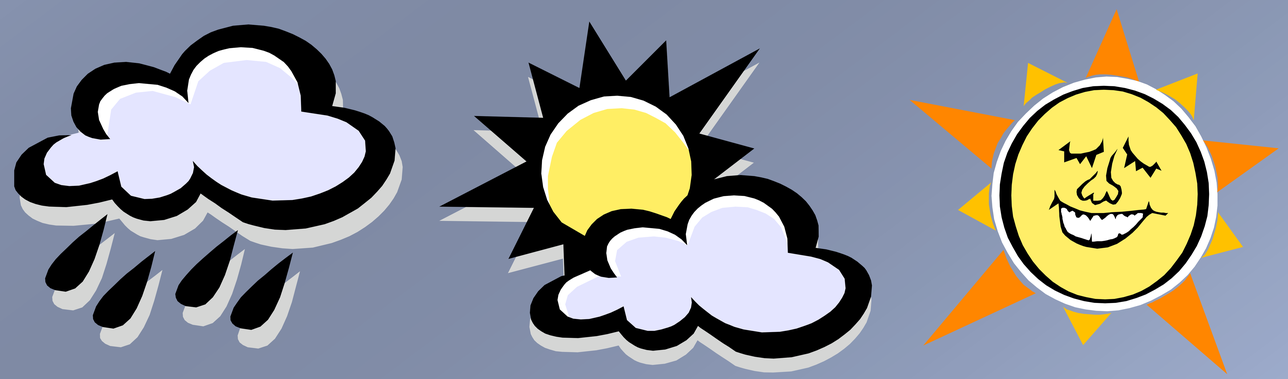
- In 1979 we had FGGE;
  - BOBMEX, JASMINE , GAME-GEWEX, SCSMEX , CEOP, the CLIVAR/AGCM Intercomparison Project,
  - Indian Ocean moored array and drifter program, TRMM, AIRS, MODIS, CloudSat.
- Subseasonal Prediction methodology - e.g., Init. Cond.; bound. Cond.



# While Challenges Remain……
# Based on growing awareness, interest, resources & capabilities

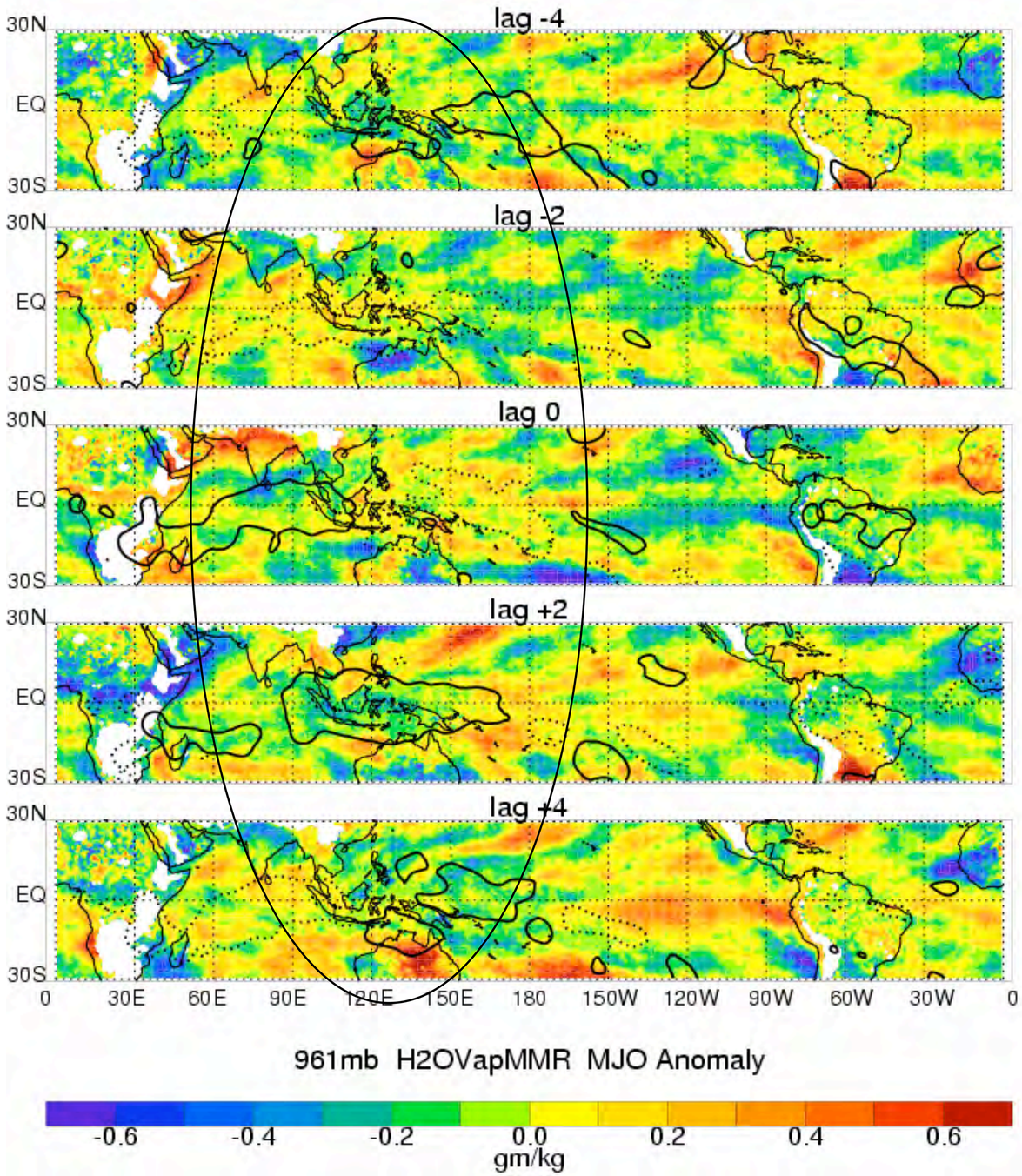
## Subseasonal Monsoon Outlook

| Day 1-10 | Day 11-20 | Day 21-30 |
|---|---|---|

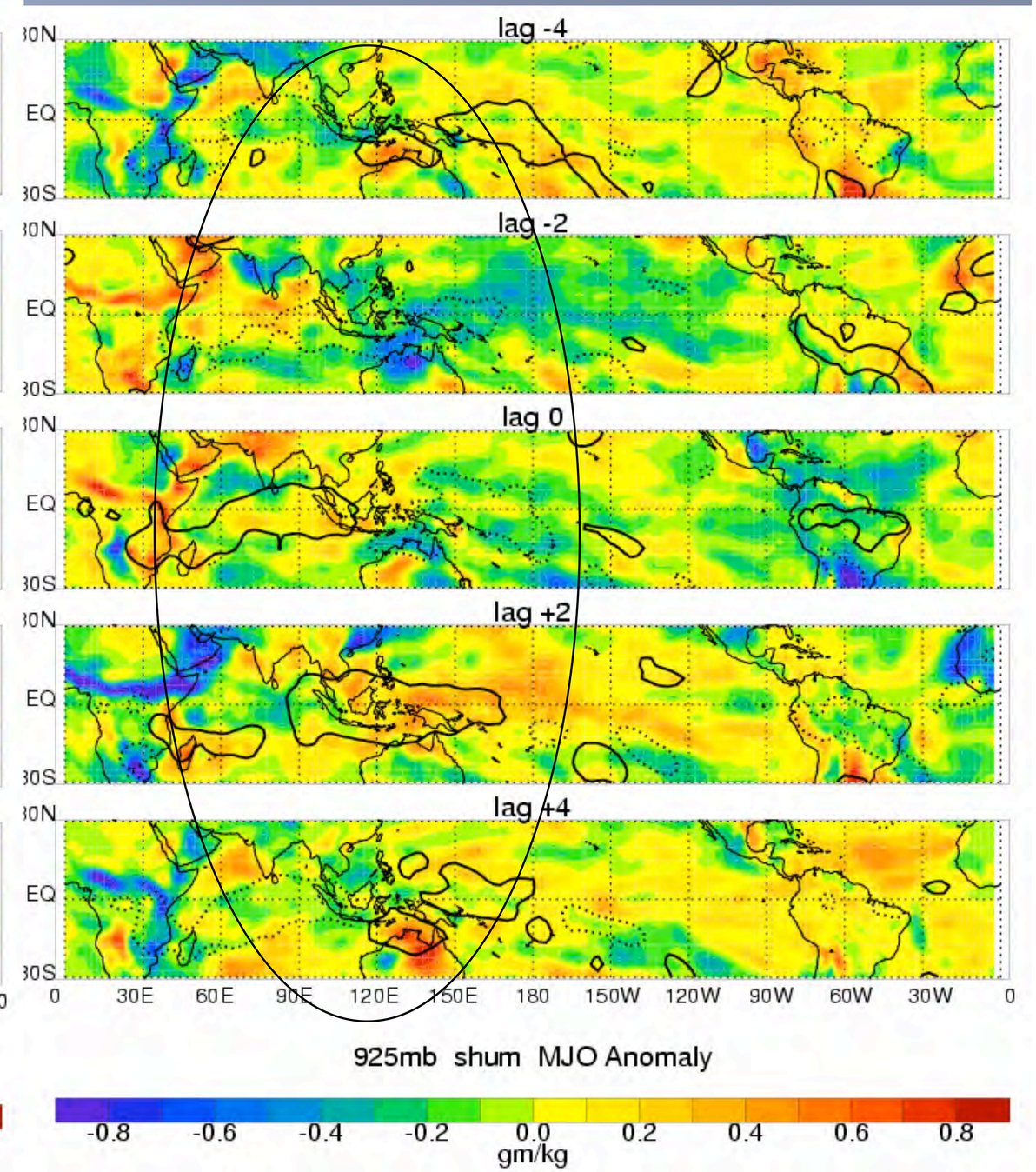


THE END

## AIRS L3




## NCEP

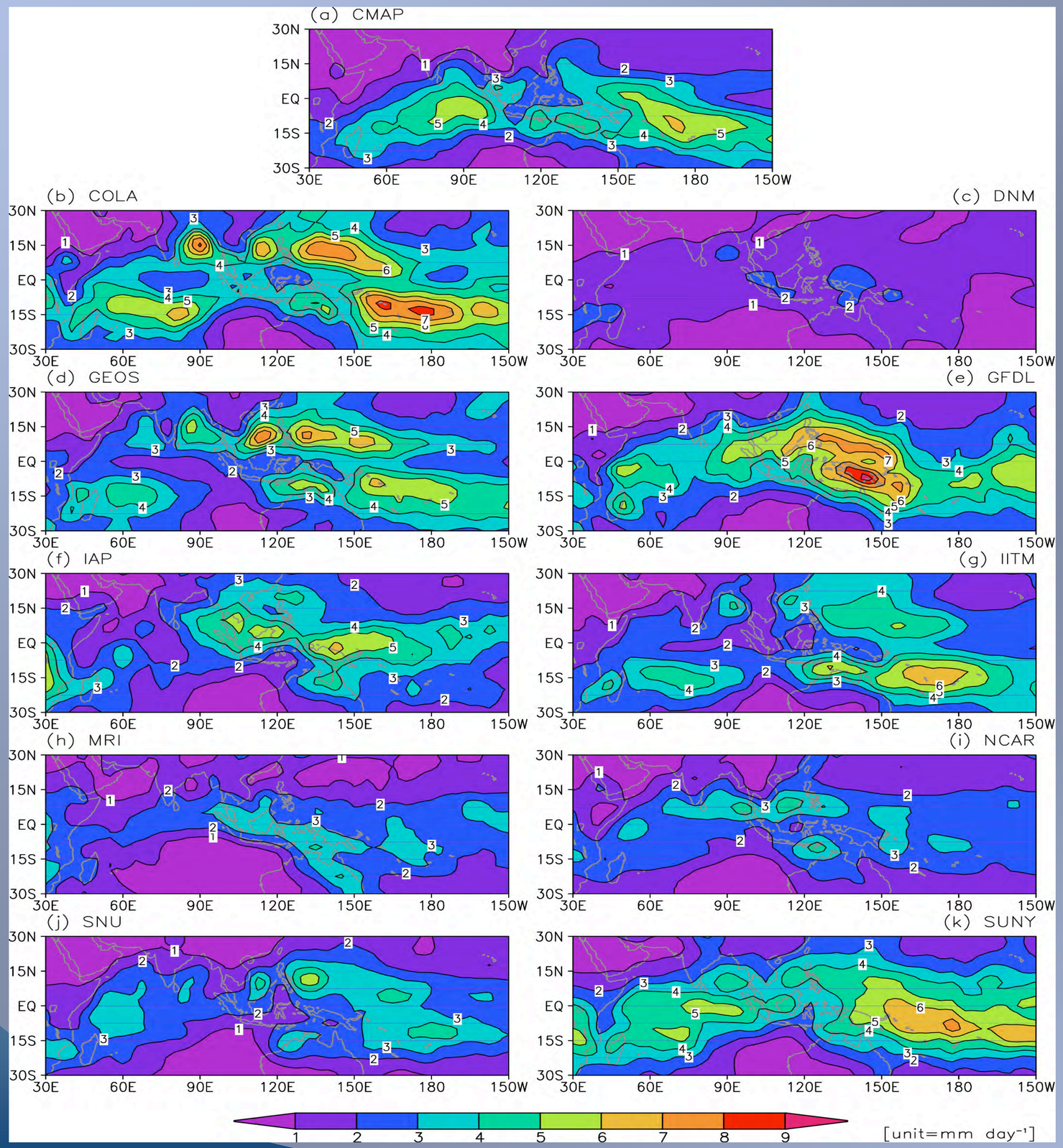



**IN AIRS, moistening (drying) is found under suppressed (enhanced) convection**

**IN NCEP, moistening (drying) is found under enhanced (suppressed) convection**

# MJO MODELING

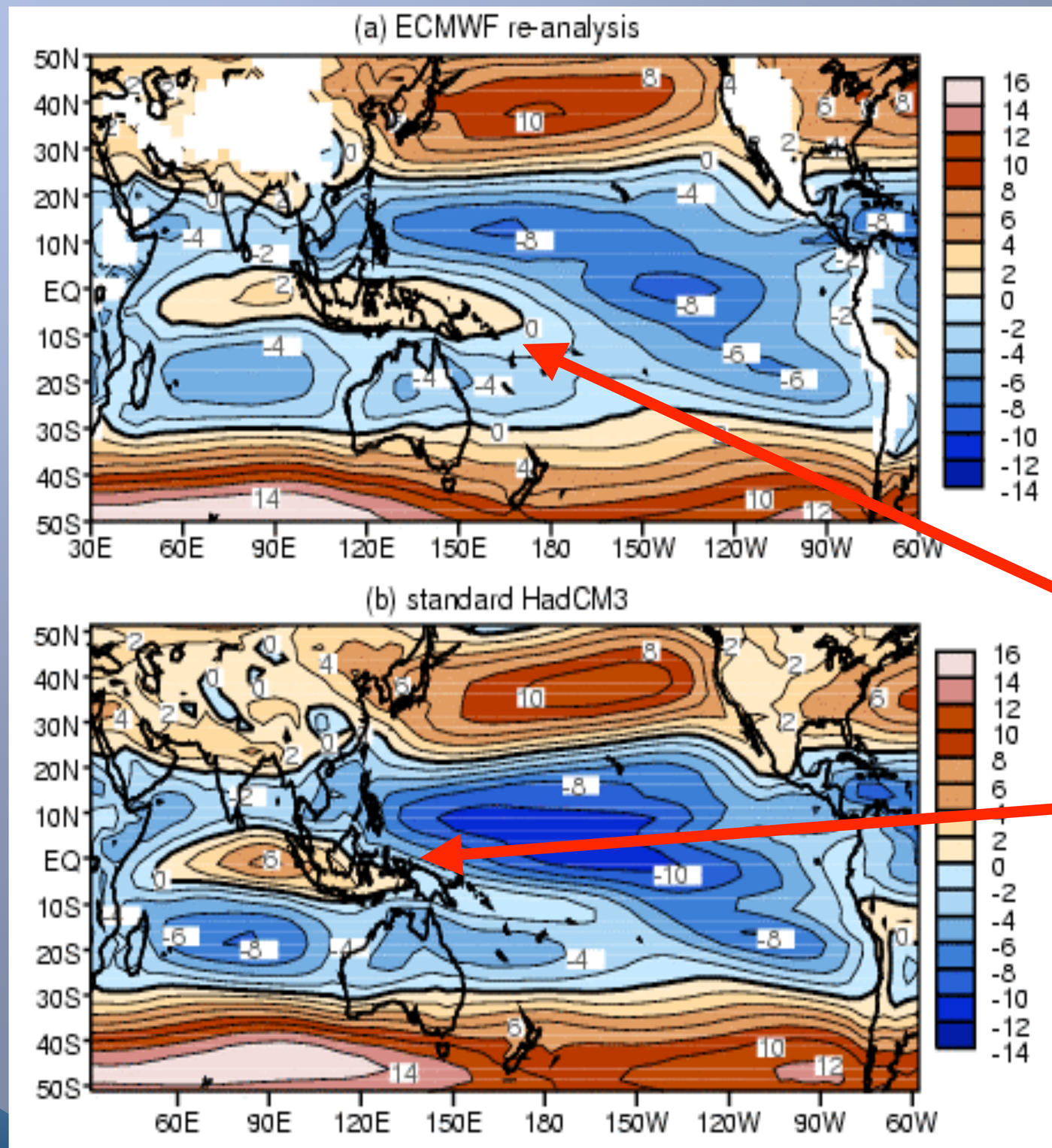
## N.H. Winter MJO-related Rainfall Variability




- Variable Strength
- Too little C. IO variability
- S.H. peaks often okay
- Often split about equator
- Spurious N.H. peaks

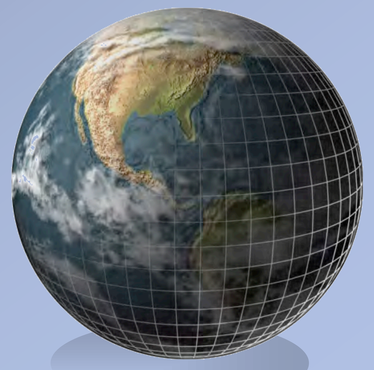
Waliser et al. 2003

# Importance Of Westerly Duct to MJO Eastward Propagation

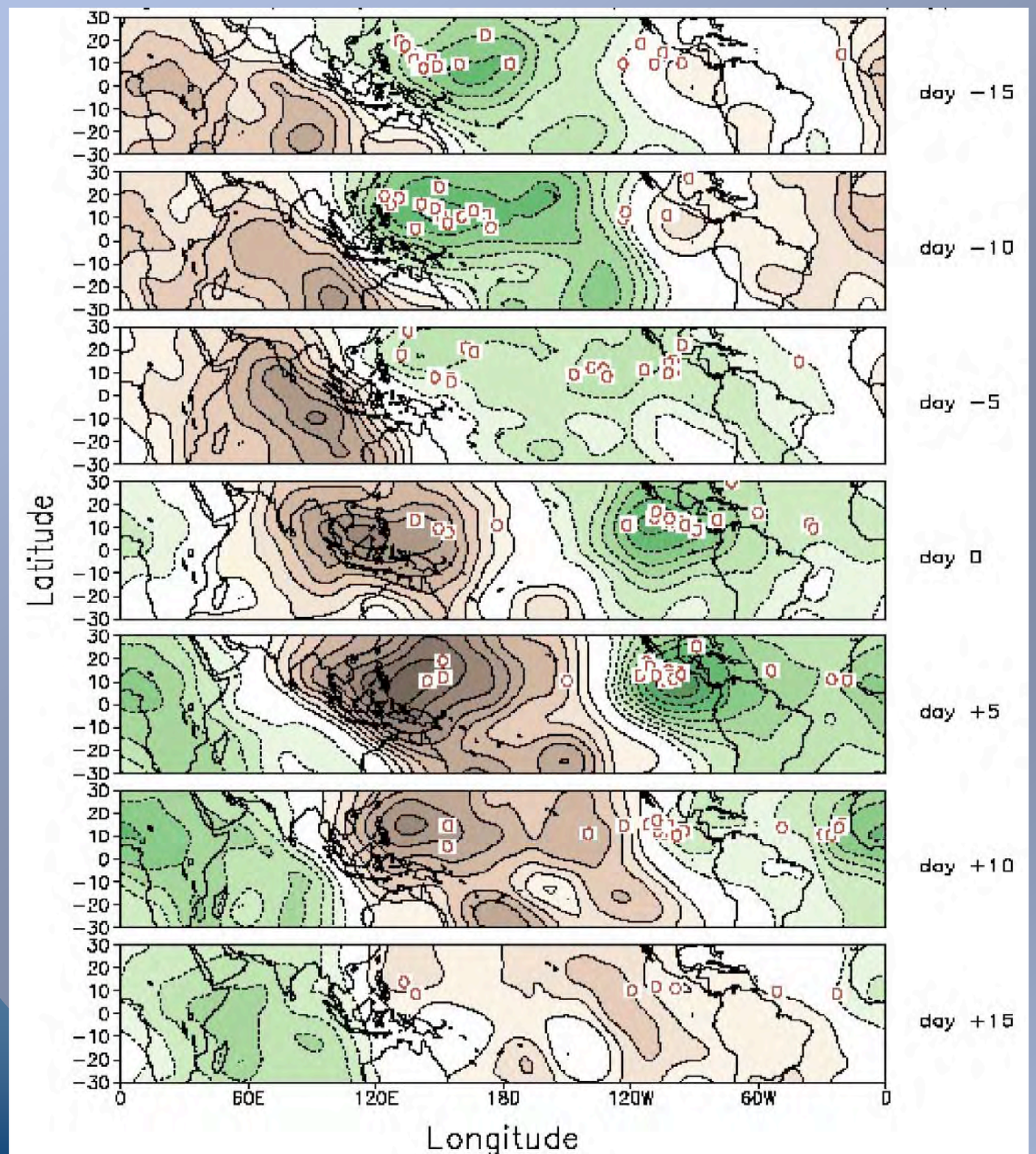



Robust

Weak/Limited

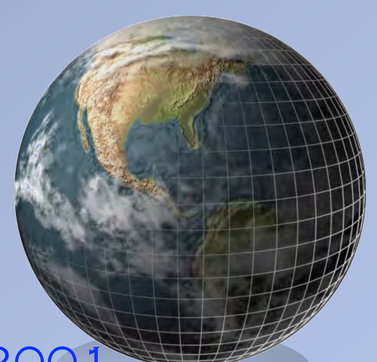


Innes et al. 2003; Hendon et al., 1999; Sperber, 2004




# Remote Synoptic Organization By ISO

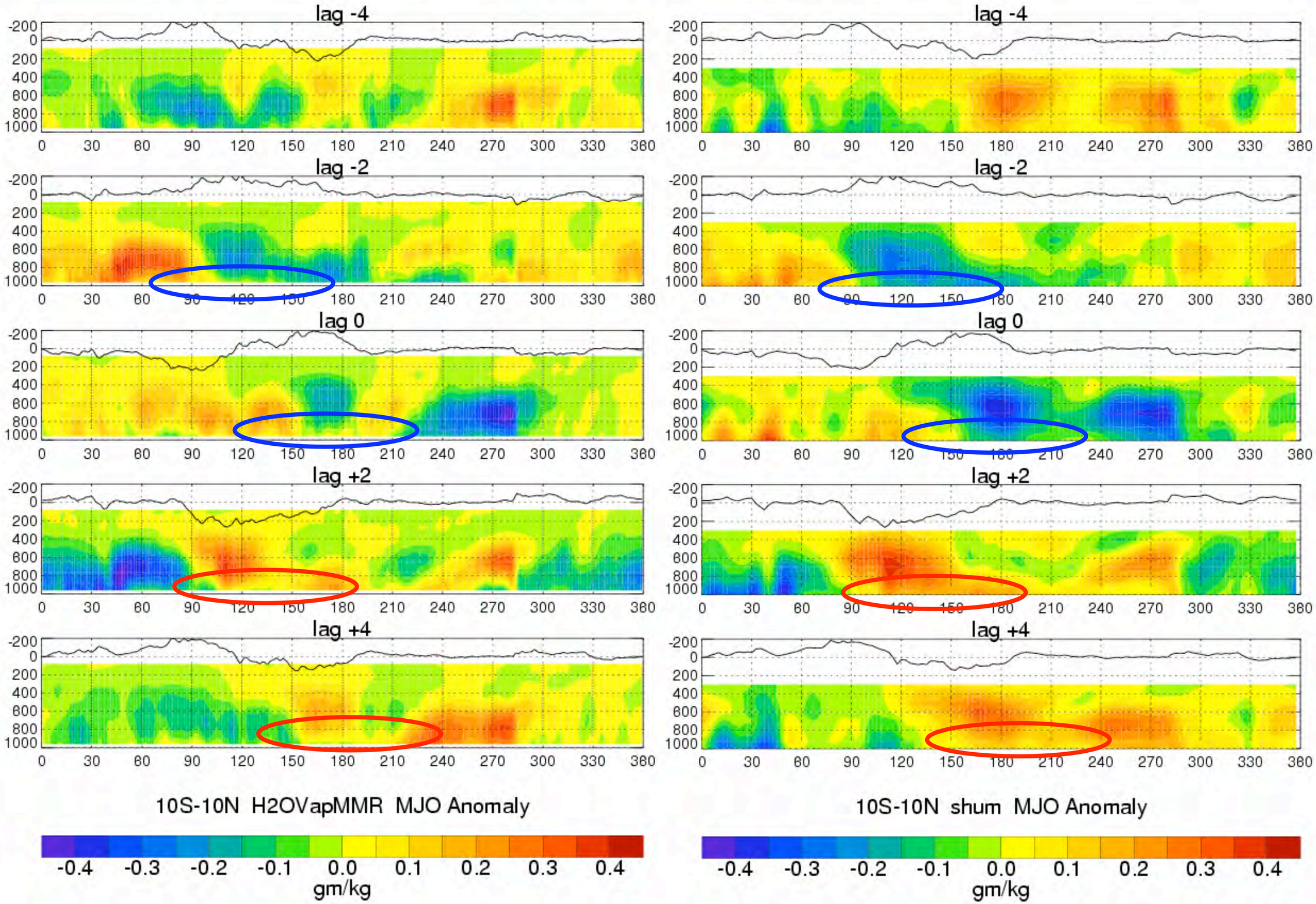
Wavenumber 1 Circulation Modulates Tropical Hurricane Development

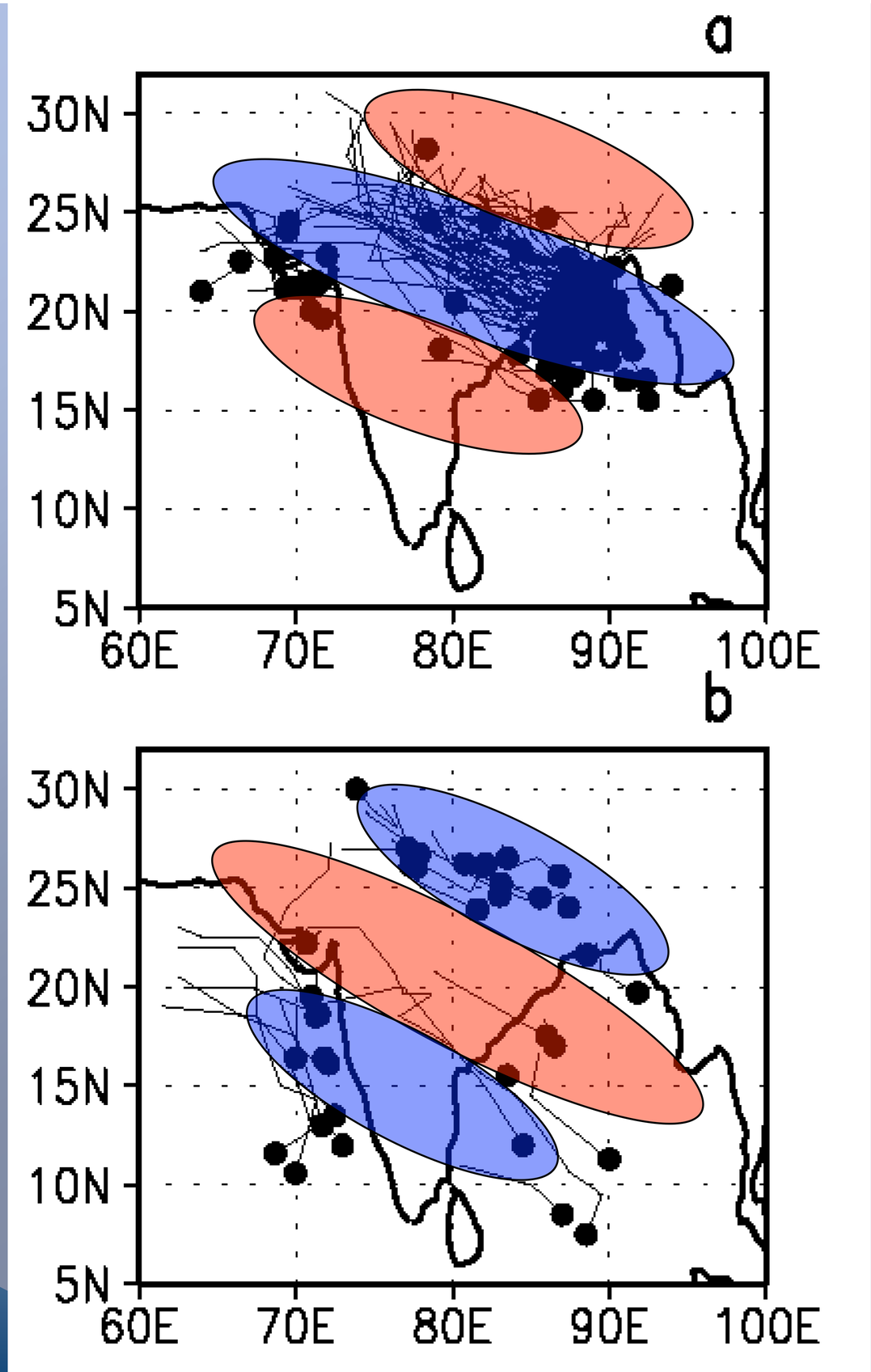


Higgins and Shi 2001

## AIRS L3

## NCEP

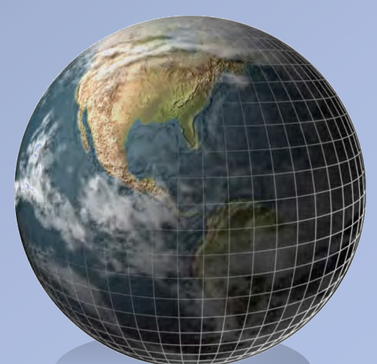

lag -4
lag -2
lag 0
lag +2
lag +4
-200
0
200
400
600
800
1000
0 30 60 90 120 150 180 210 240 270 300 330 360
10S-10N H2OVapMMR MJO Anomaly
10S-10N shum MJO Anomaly
-0.4 -0.3 -0.2 -0.1 0.0 0.1 0.2 0.3 0.4
gm/kg




# Local Synoptic Organization By ISO

Low Pressure Systems And Their Tracks

Goswami et al. 2003



# Barrow, Alaska

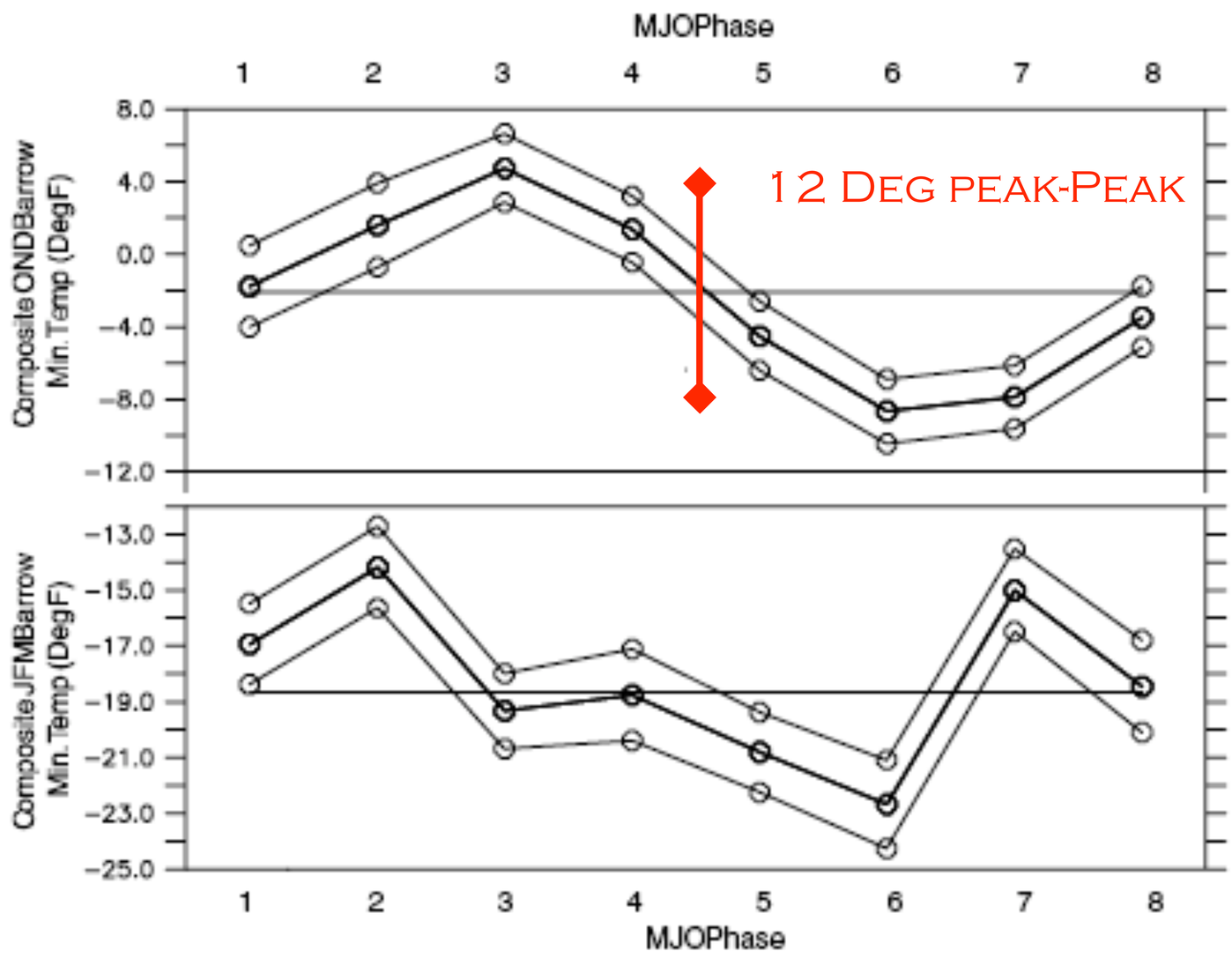
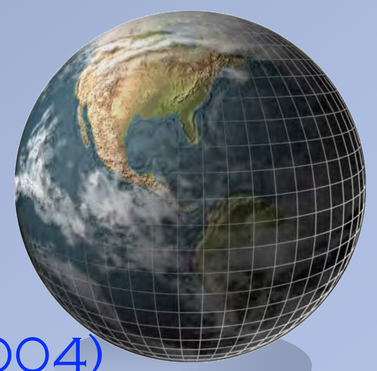



Figure 1. Minimum temperatures (°F) as a function of MJO phase at Barrow, Alaska during October through December (top) and January through March (bottom).

# High-Latitude Circulation Influences By the MJO

Analysis suggests that both radiative and advective effects are important in driving surface air temperature anomalies



Vecchi G. A., N. A. Bond (2004)