

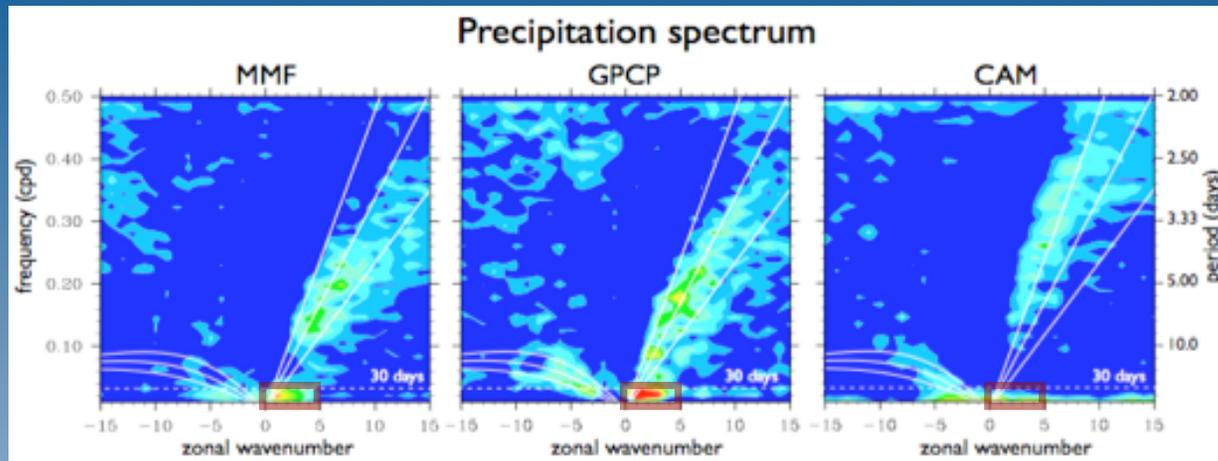
The MJO in the Super-Parameterized CAM

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29 September 2008



Overview



SPCAM

Observations

CAM3

- Tropical variability, of which the MJO is a leading contributor, is strongly linked to extratropical weather patterns and global climate
- MJO depiction in many GCMs is poor (e.g., Lin et al. 2006)... but improving
- Spectral character of MJO in SP-CAM is encouraging...
 - How does MJO time-height structure in SP-CAM compare to nature?
 - How does SP “give life” to the MJO in CAM3?



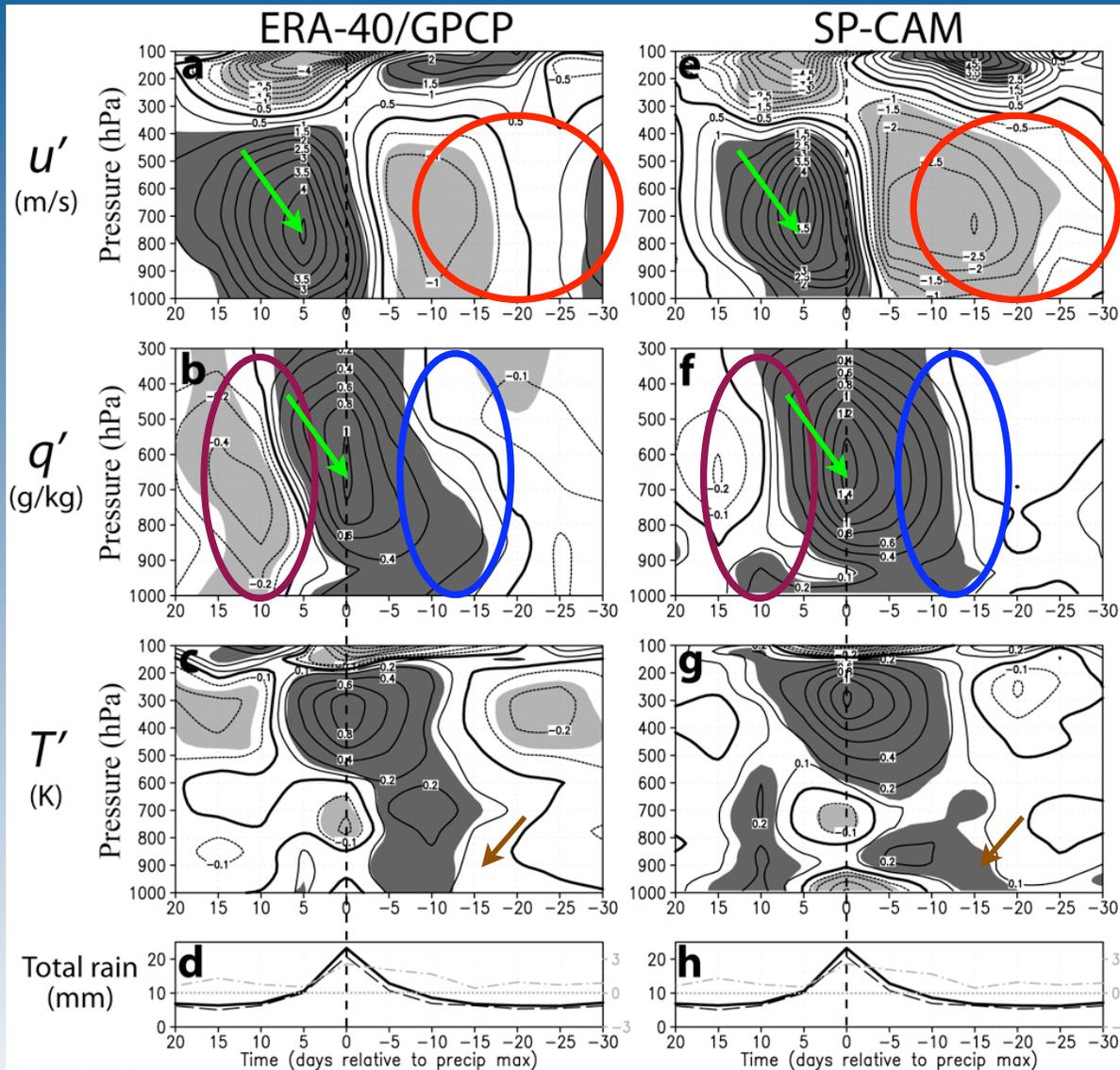
Model Configuration

	GCM (CAM3)	CRM (SAM)
Domain	3D	2D, periodic
Horizontal Resolution	T42 (~2.8°x2.8°)	4 km (N-S orientation)
Vertical levels	30 (3.6 hPa top)	28 (collocated w/CAM)
Time step	30 min	20 sec

- ▶ Integration: Sep 1985 - Sep 2004 (19yrs)
- ▶ Forcing: Prescribed (observed) SSTs

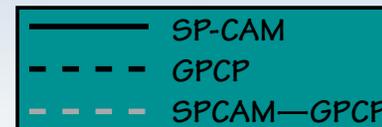


Results: Basic Variables



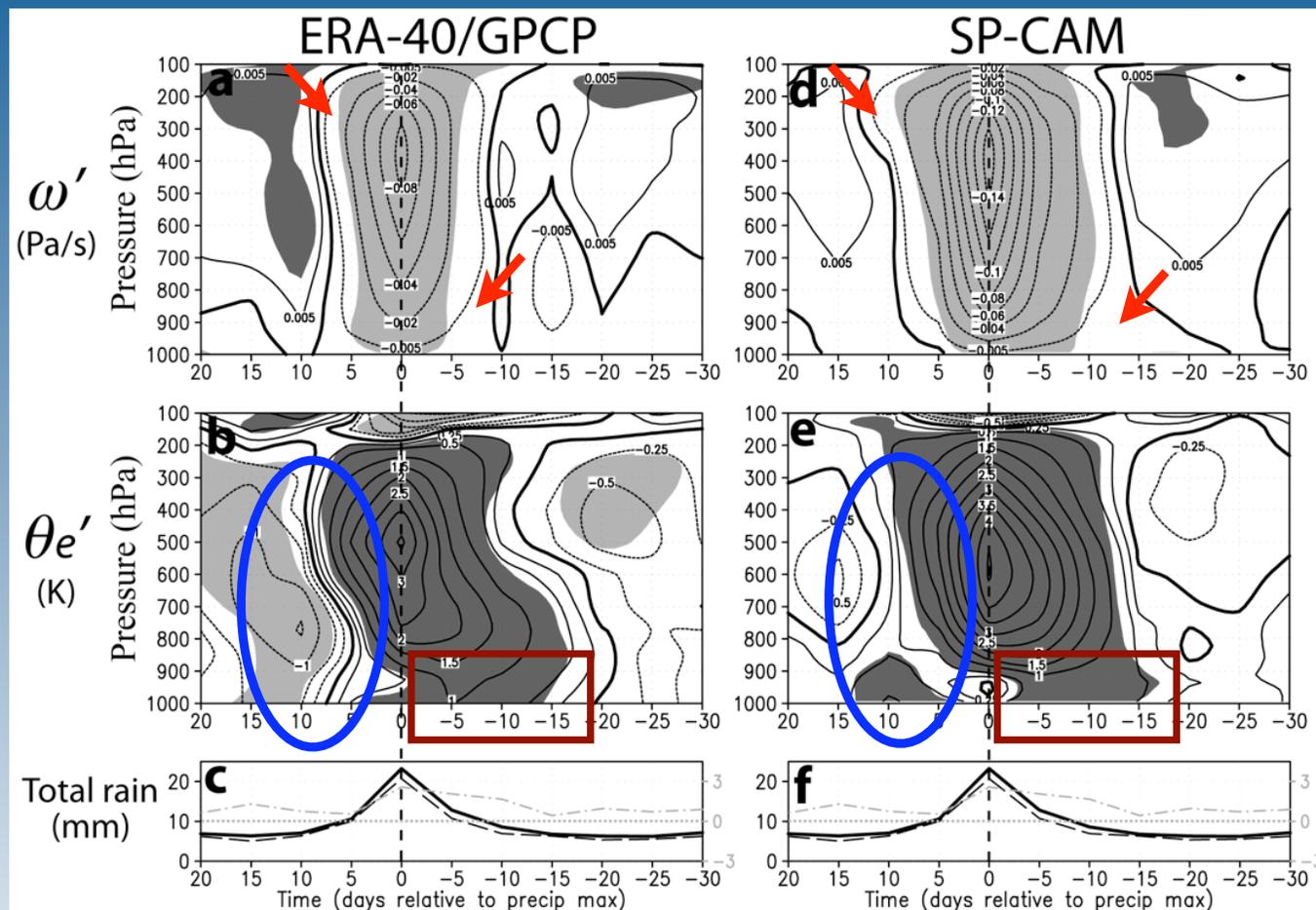
Compared to reanalysis, SP-CAM has...

- Easterly wind anomalies that are too strong and extensive
- A favorable comparison of west wind structure
- Unrealistically rapid vertical moistening, insufficient drying
- 40% higher q' magnitude on Day 0
- An upper atmosphere that is too warm
- Pre-MJO PBL warming not seen in reanalysis
- ~20% more rainfall

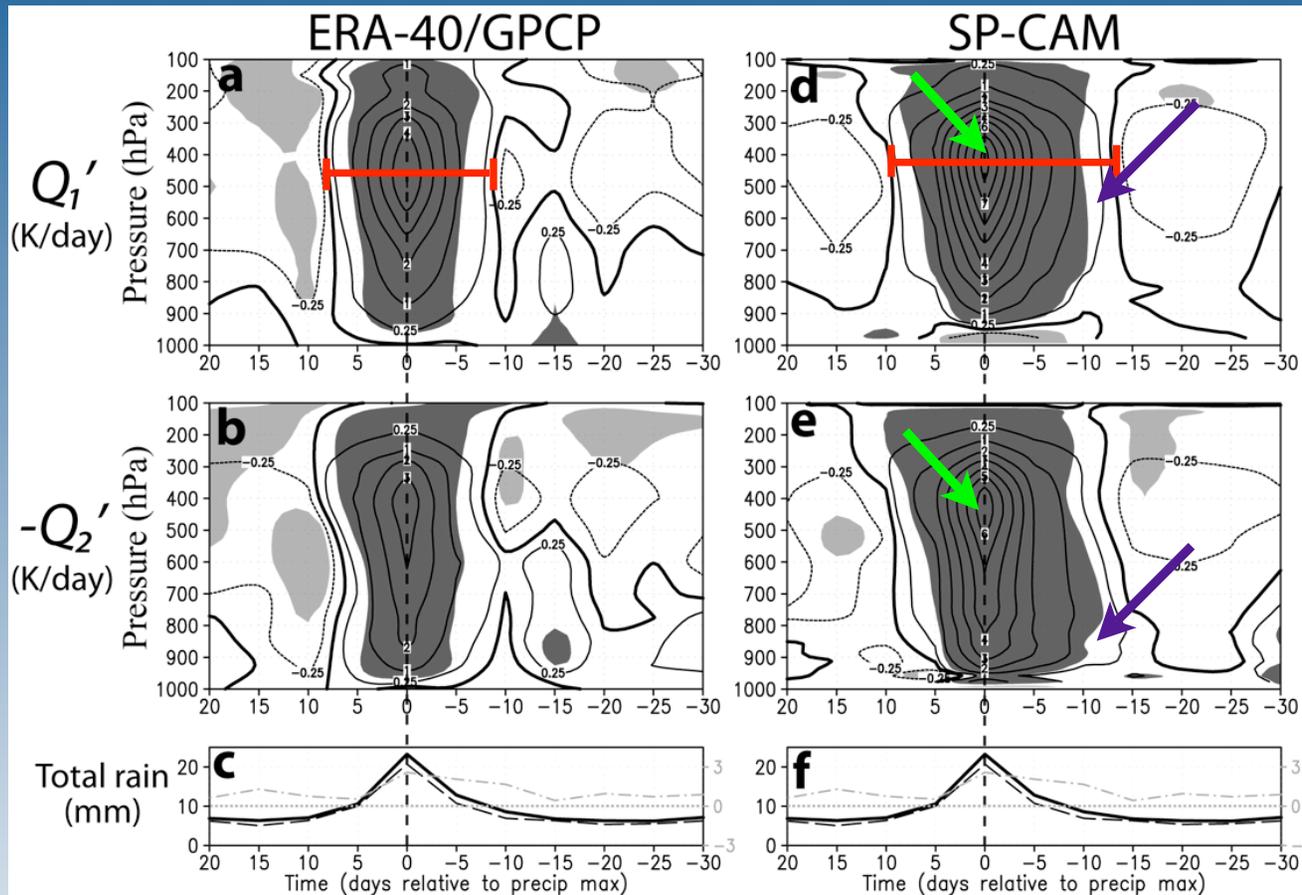


Results: Basic Variables

- Too strong rising motion, insufficient sinking motion
- Stronger evidence of **tilting** with height
- **Distribution** of θ_e' before heaviest rainfall
- **Insufficient decrease** of θ_e' following deep convection



Results: Convective Heating & Drying



- **Broader width** of anomalous convective heating in SP-CAM

- Simulated Q_1' and $(-Q_2')$ magnitudes during peak convection nearly **double** that in nature

- **Inferred intensity** of deep convection greater in SP-CAM near Day -10

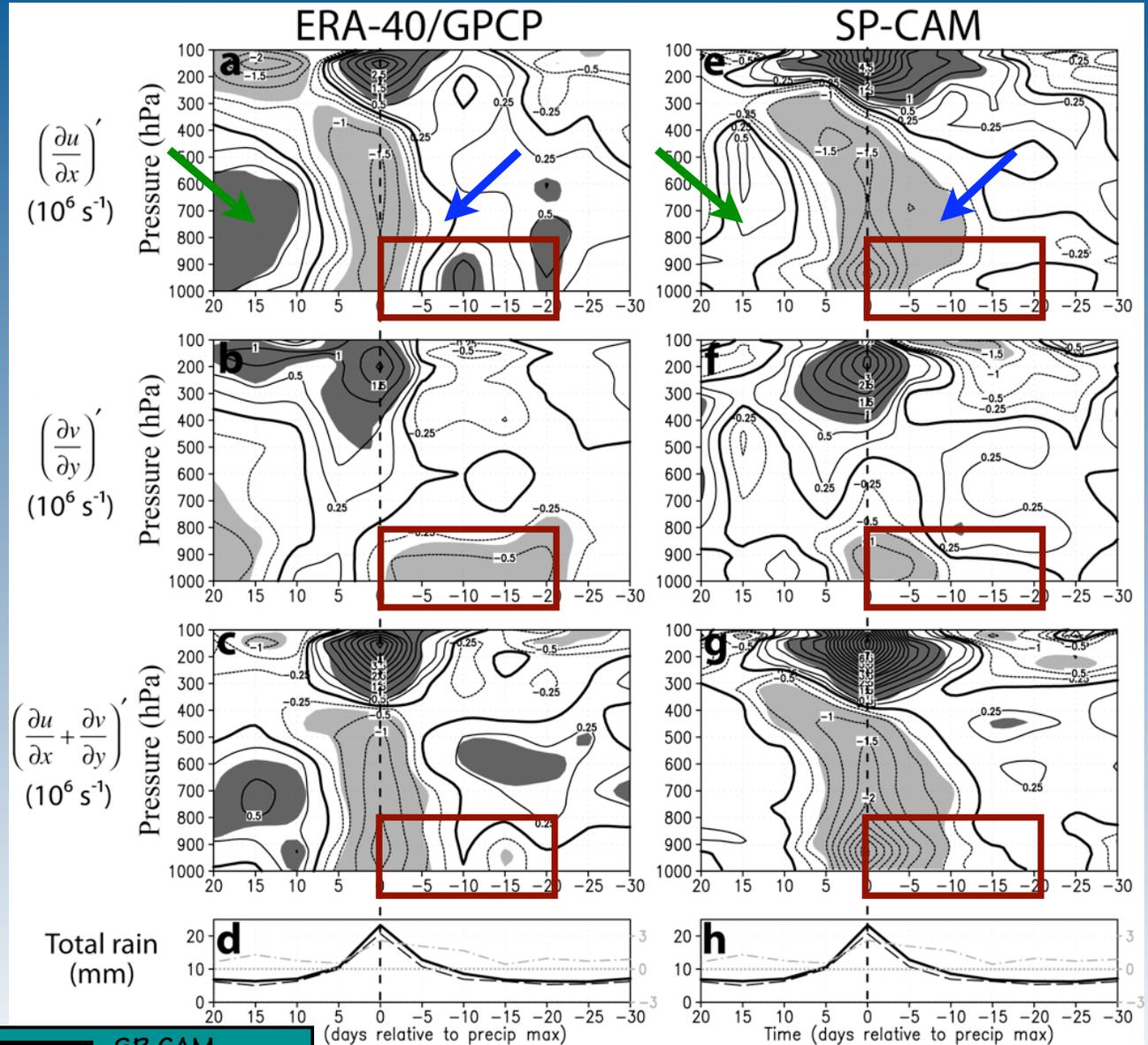


Results: Horizontal Divergence

- Overall, a qualitatively favorable comparison between model and nature

- Pre-deep-convective boundary layer convergence primarily accomplished by meridional component in model and nature

- Lower tropospheric zonal convergence unrealistically strong before Day 0, divergence too weak after Day 0

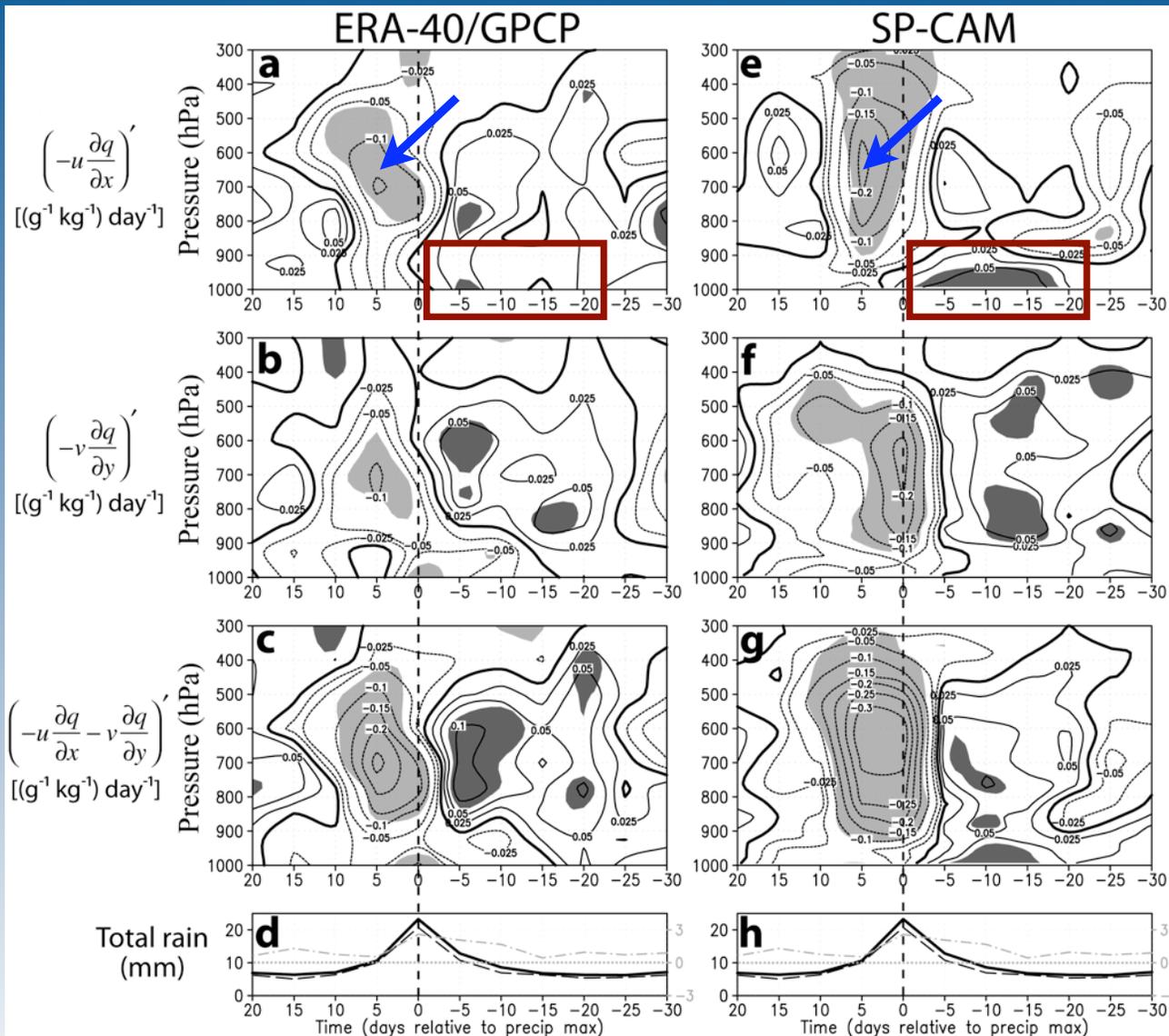


— SP-CAM
 - - - GPCP
 - · - · SP-CAM - GPCP

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Results: Horizontal Moisture Advection



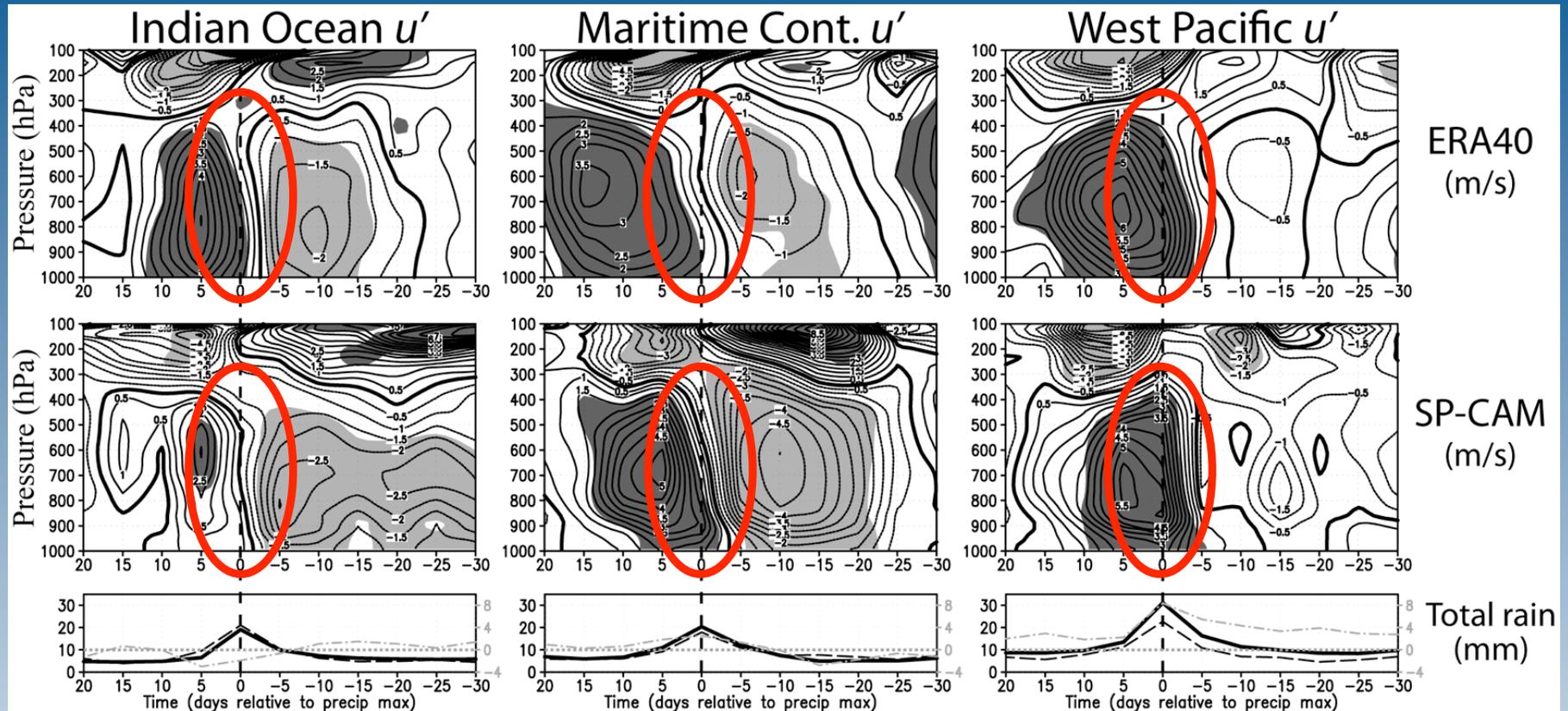
- Overall, SP-CAM replicates horizontal moisture advection well

- Strongest zonal advective drying 5 days after intense rain

- Gradual BL moistening via zonal wind in SP-CAM

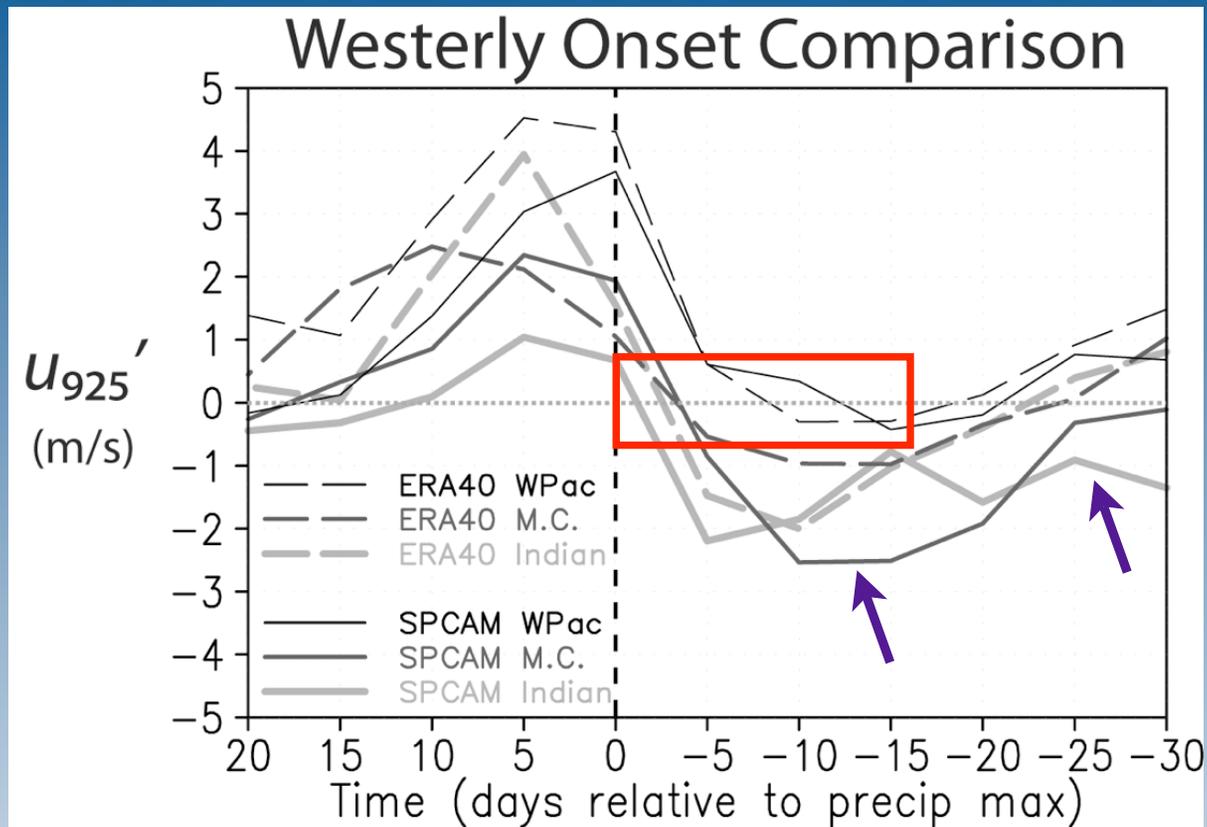


Results: Geographical Differences of u'



- General SP-CAM zonal wind structure compares favorably to ERA-40 wind structure
- **Onset of west winds** based on geography is well simulated

Results: Timing of Westerly Onset



Solid lines: Model

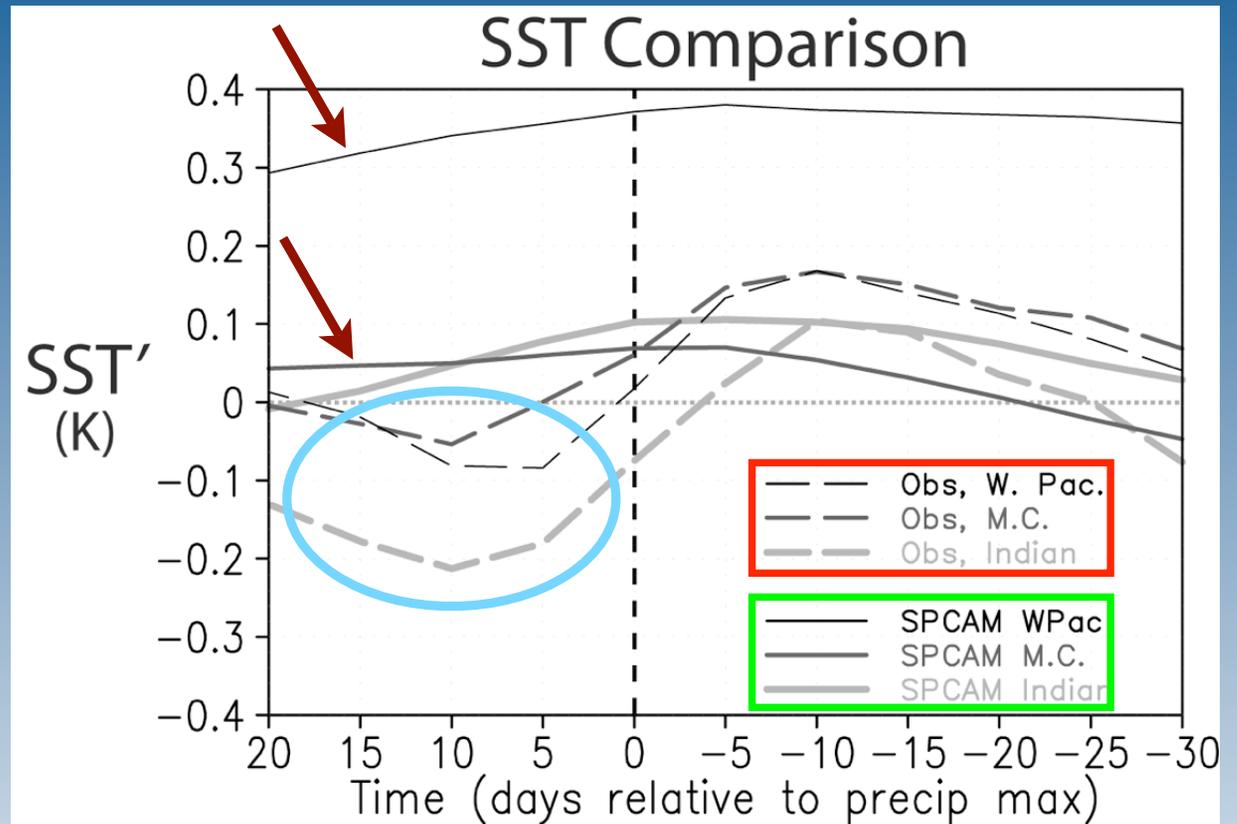
Dashed lines: ERA-40

- Both SP-CAM and ERA-40 have earlier **onset of westerly wind** anomalies as MJO-related convection propagates eastward
- **Unrealistic pre-MJO easterlies** noted in Indian and Maritime Continent regions



SST: Model vs. Nature

- In **nature**, SSTs are warm as an MJO disturbance approaches, then **rapidly cool** afterward...
- In the **SP-CAM**, SSTs are warm before MJO-related deep convection but **do not cool significantly** afterward...
- SSTs are prescribed in SP-CAM, and lack of coupling could play a role in its overestimation of convective intensity (e.g., surface fluxes)



Summary: MJO in SP-CAM & nature

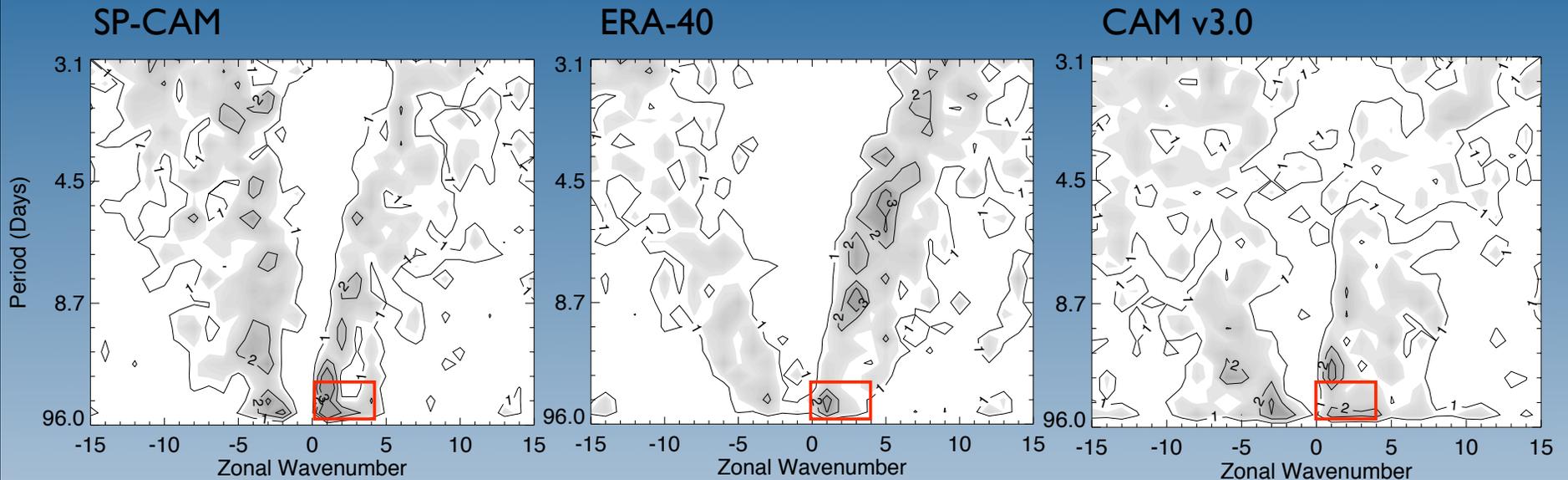


- Overall, the SP-CAM compares very favorably with nature regarding the MJO time-height structure of dynamic and thermodynamic variables
- The model overestimates MJO-related convective intensity, particularly concerning deep convective heating

- The SP-CAM exhibits insufficient suppressed-phase subsidence and drying, particularly in the boundary layer
- Several important mechanisms, including the timing of westerly onset and advective drying tendencies, are captured well by the SP-CAM



SP-CAM => Good MJO



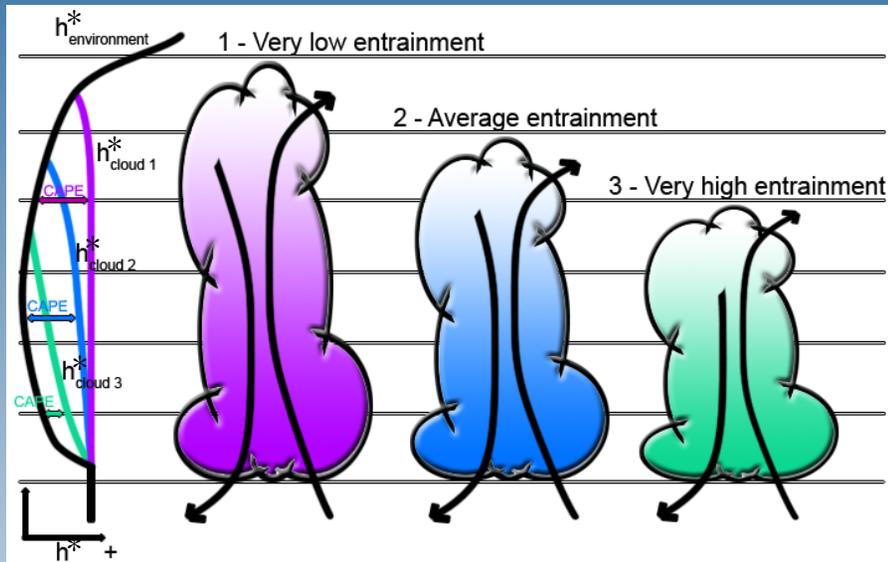
- CAM => Not So Good MJO
- Why? What basic processes of the MJO did we get right in the SP-CAM, but are missing in the traditional CAM?

About the Models

- NCAR CAM v3.0
 - 4 years of 3 hourly data between June 1998 and June 2002
 - $2.0^{\circ} \times 2.5^{\circ}$ grid with 26 layers
 - Finite Volume Dynamical Core
 - 4 different parameterizations used to represent cloud effects
 - AMIP Style boundary conditions
- SP-CAM
 - Same temporal and large scale grid properties as the CAM
 - 2D CRM embedded in each gridcell to simulate clouds
 - CRM has 64 columns 4 km wide oriented East-West with 24 layers



CAM Deep Convection



Zhang and McFarlane (1995)

- Triggered by instability, clouds persist until CAPE is mostly depleted
- All detrainment occurs at cloud top, which must be above minimum of saturated MSE
- All downdrafts exit below cloud base, and all clouds in the ensemble have the same base

Some Observational Data

- **TRMM Rainfall**

- Combined passive microwave and visible/infrared sensors
- Use the gridded 3B42 product: calibrated IR with TRMM and other satellite data

- **ERA-40**

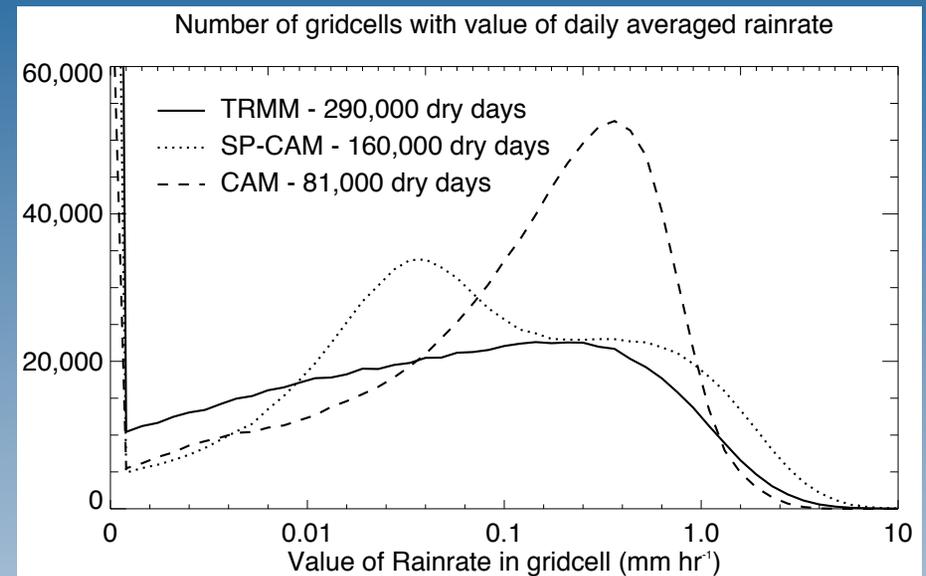
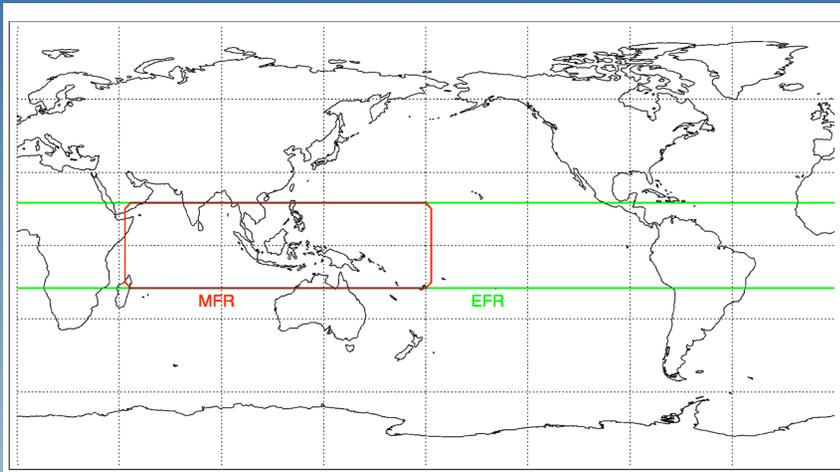
- 2.5°x2.5°, 12 pressure levels 1000 hPa-50hPa
- Replace reanalysis precipitation with TRMM

- **TOGA-COARE**

- IOP: Nov 1, 1992 - Feb 28, 1993
- Six sounding sites between 1°N-4°S and 147°E-167°E
- Tipping buck rain gauge data recorded per minute, summed to daily rain



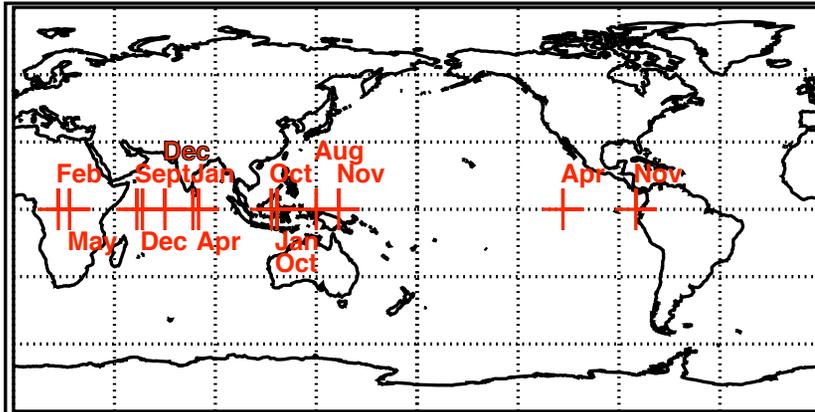
Composite Views of the MFR



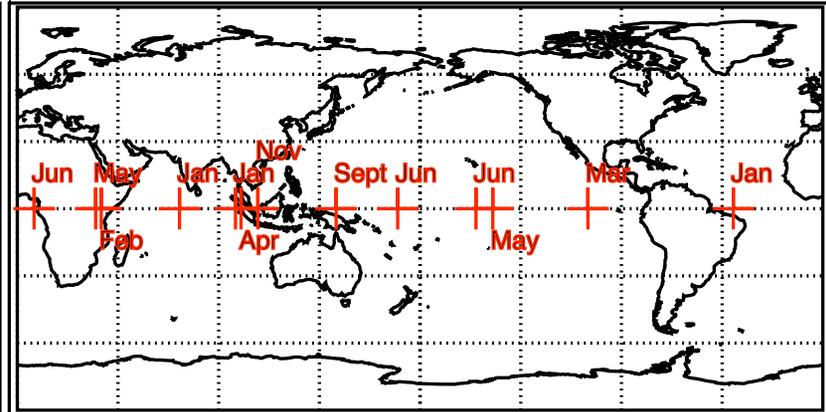
- All data is averaged to a $2.5^{\circ} \times 2.5^{\circ}$ grid and daily timescale
- Each gridcell is identified and binned by the daily average rainrate
- Profiles above the gridcells are averaged with others in the bin to create a composite profile per rainrate

Identification of Events

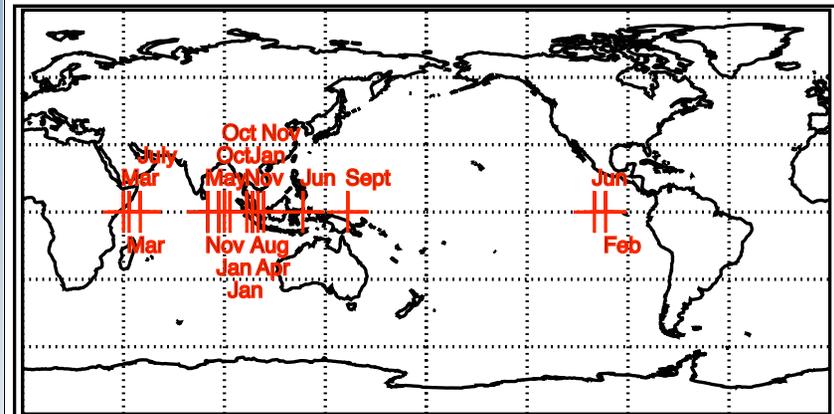
Locations of SP-CAM Filtered OLR Minima



Locations of CAM Filtered OLR Minima



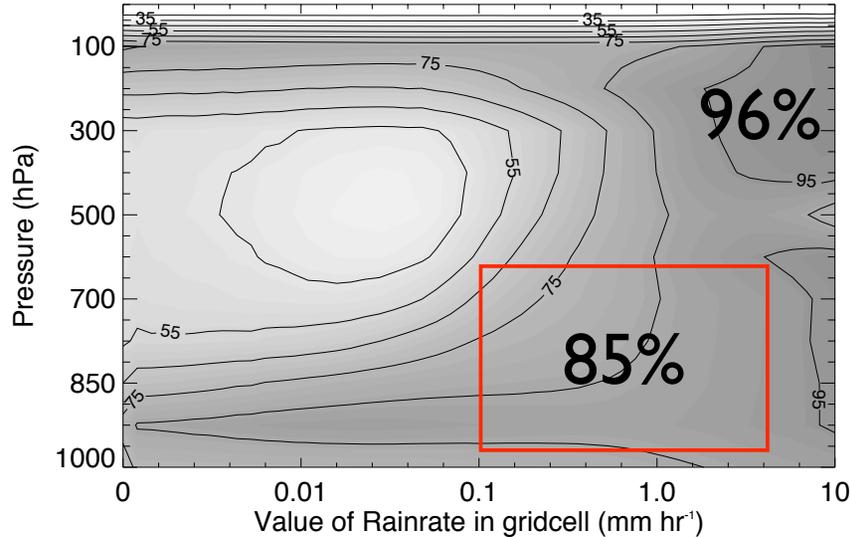
Locations of ERA-40 Filtered OLR Minima



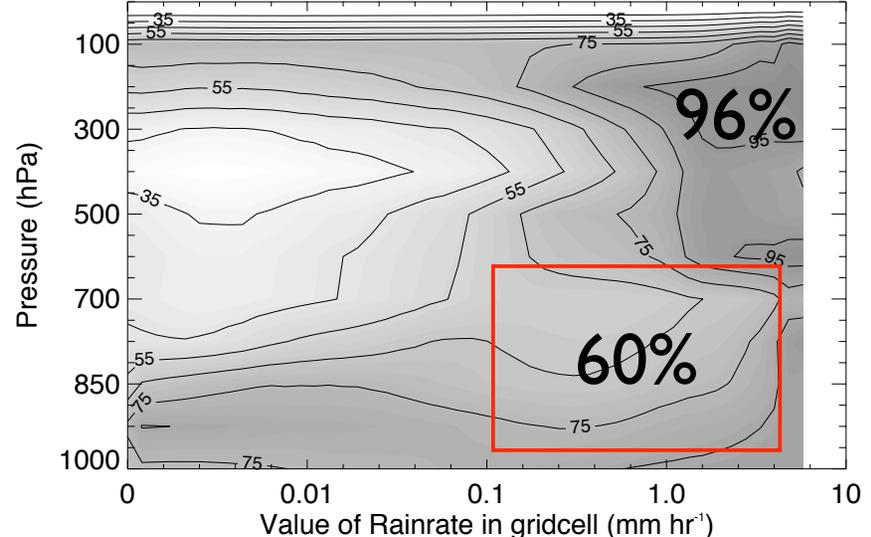
- Similar to Jim's approach, except using filtered OLR
- Any OLR anomaly less than 1σ is selected
- Only events in the Eastern Hemisphere are composited

Moisture and Rainrates

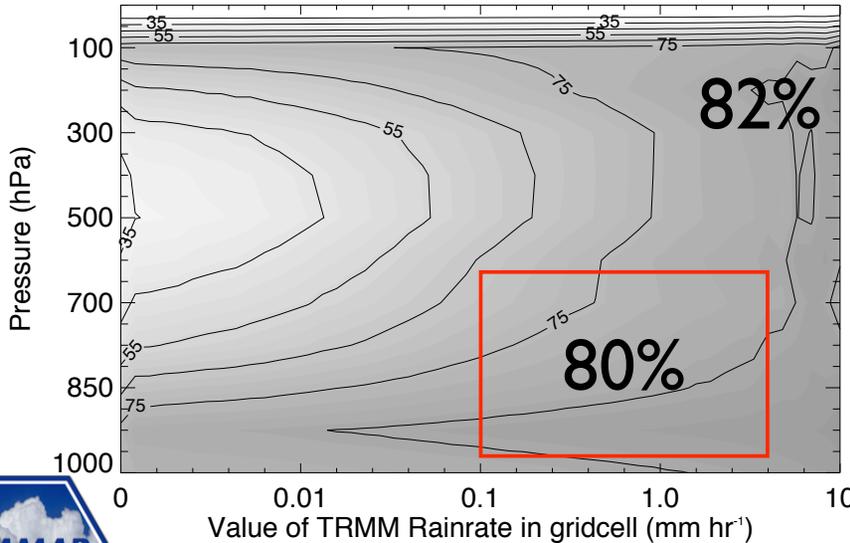
SP-CAM Relative Humidity (%) per Value of Rainrate



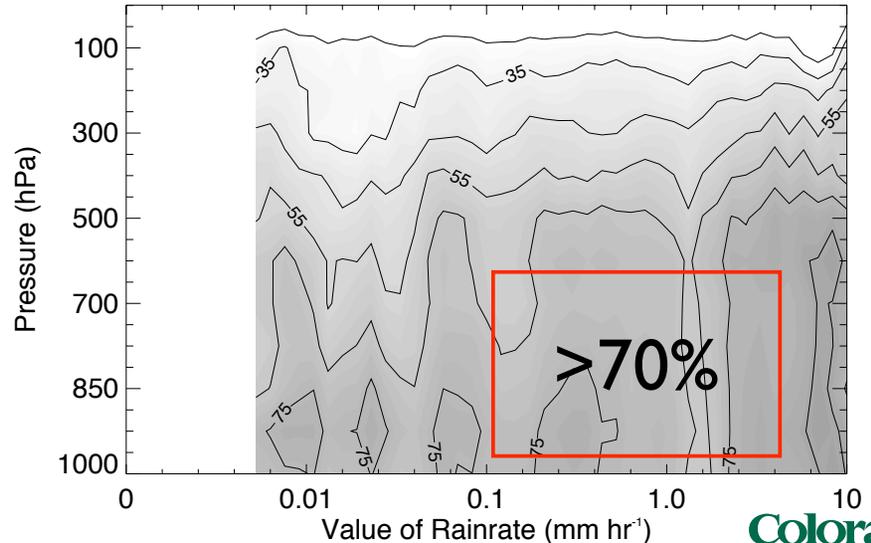
CAM Relative Humidity (%) per Value of Rainrate



ERA-40 Relative Humidity (%) per Value of Rainrate

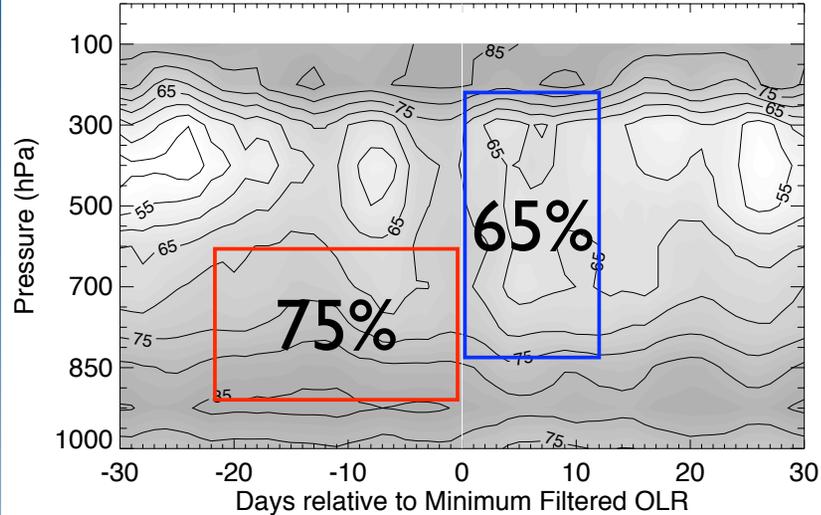


TOGA-COARE Relative Humidity (%) per Value Rainrate

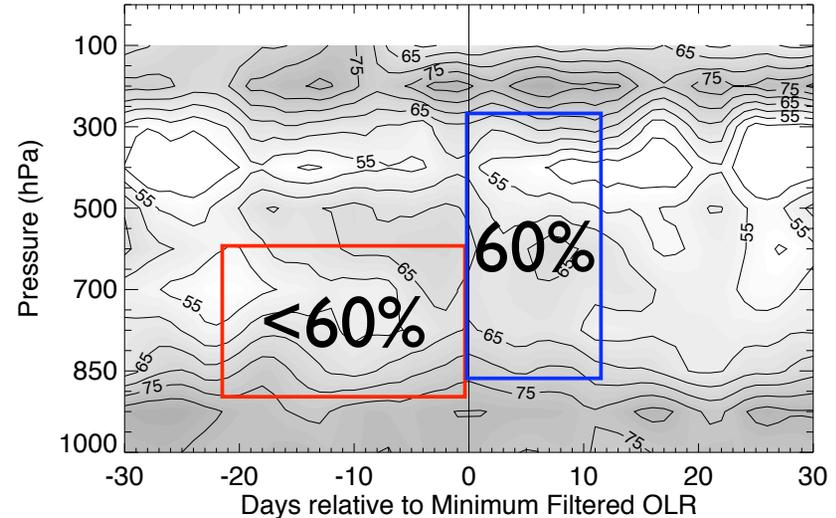


Moisture and the MJO

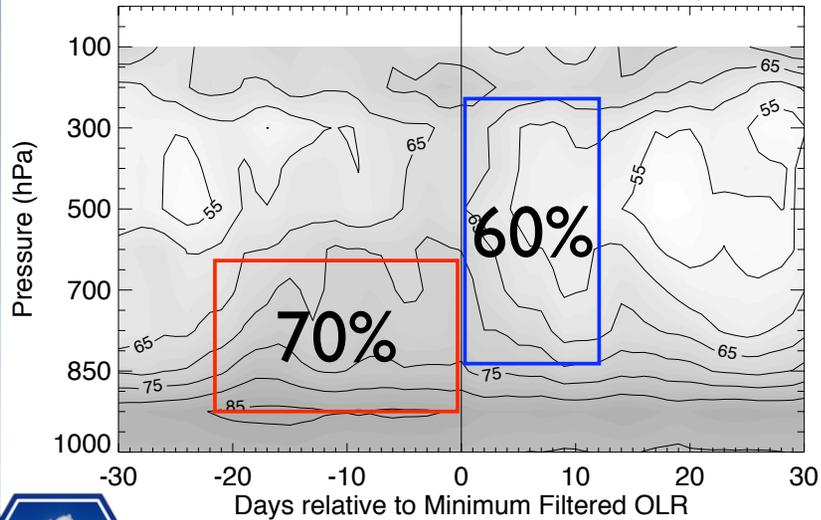
Relative Humidity Profile during MJO Passage (SP-CAM)



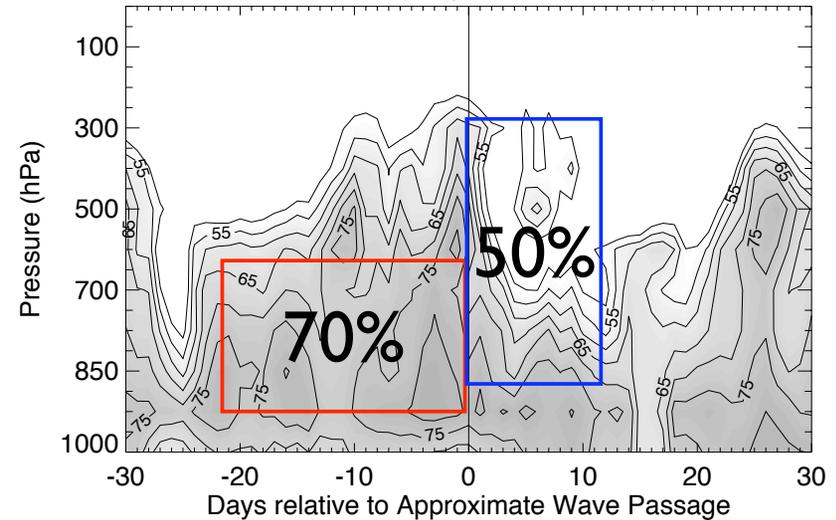
Relative Humidity Profile during MJO Passage (CAM)



Relative Humidity Profile during MJO Passage (ERA-40)

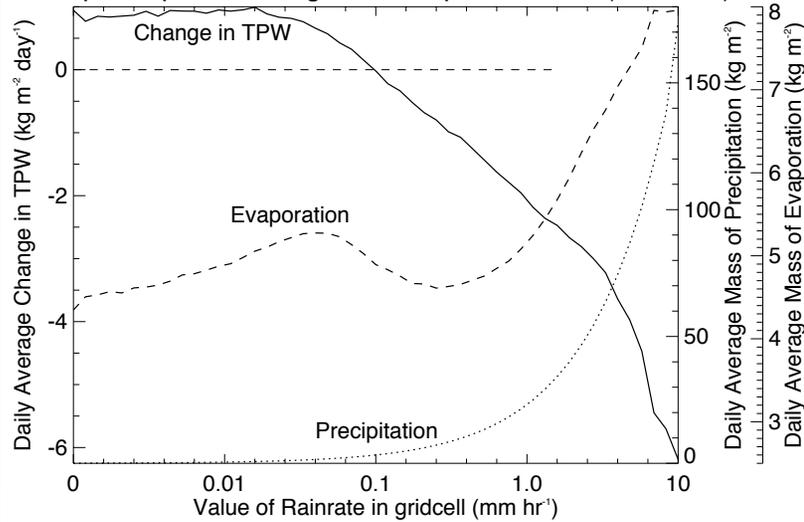


Relative Humidity Profile during MJO Passage (TOGA-COAR)

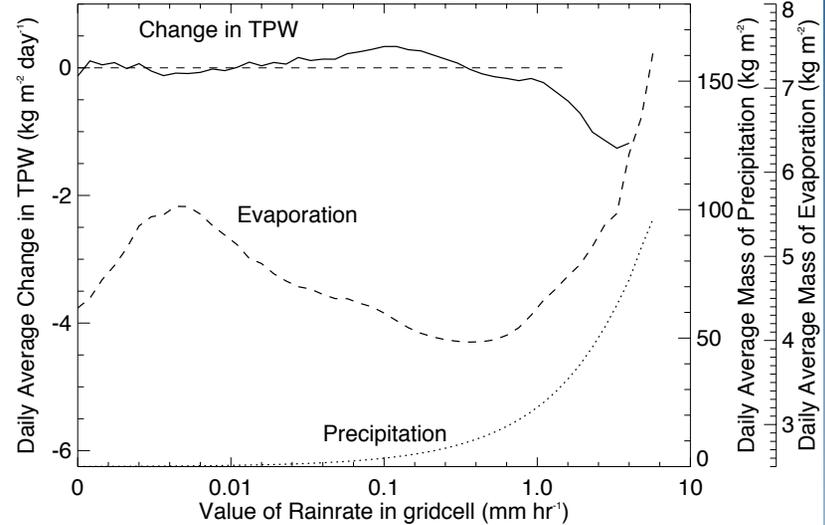


Moisture Budgets

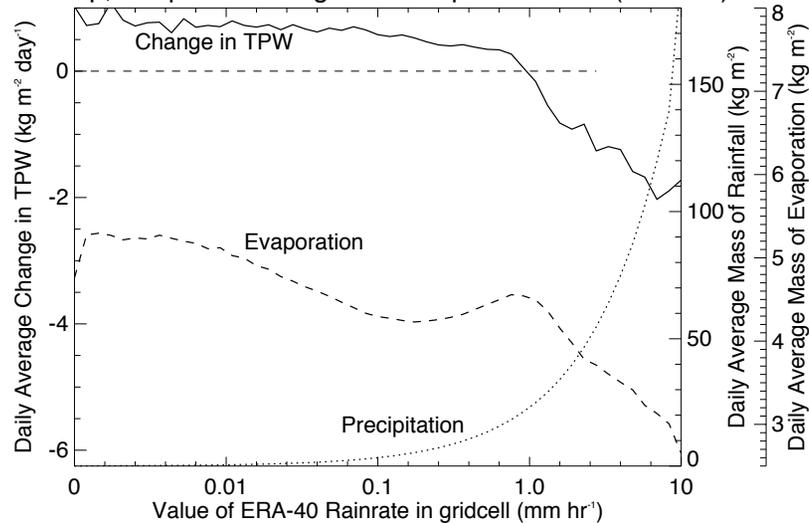
Precip, Evap and Change in TPW per Rainrate (SP-CAM)



Precip, Evap and Change in TPW per Rainrate (CAM)

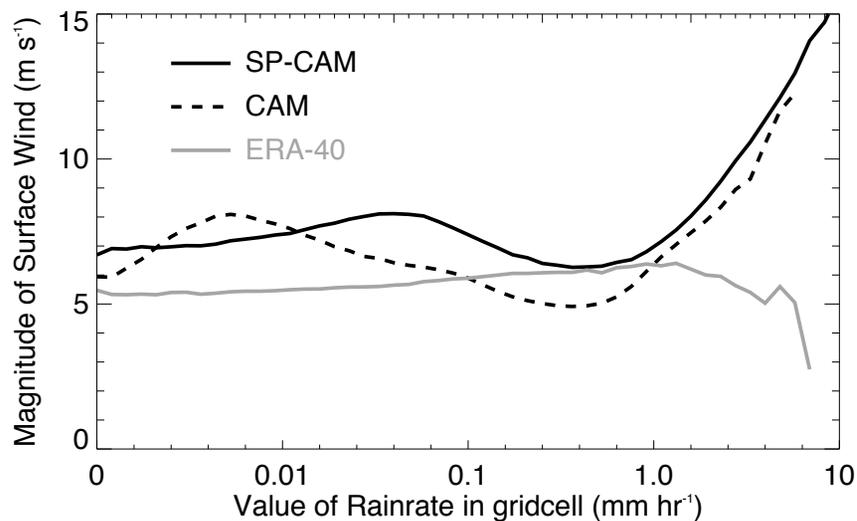


Precip, Evap and Change in TPW per Rainrate (ERA-40)

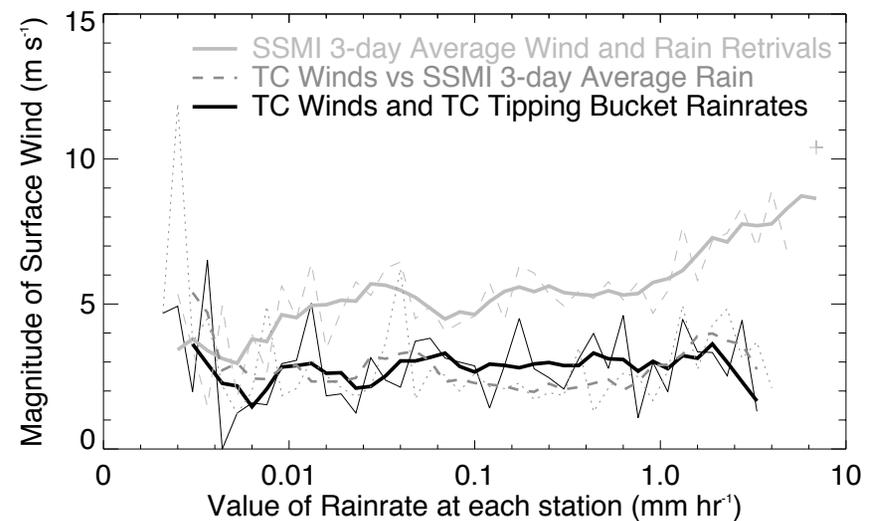


Mean Low-Level Winds

Composite Near-Surface Winds per Value of Rainrate

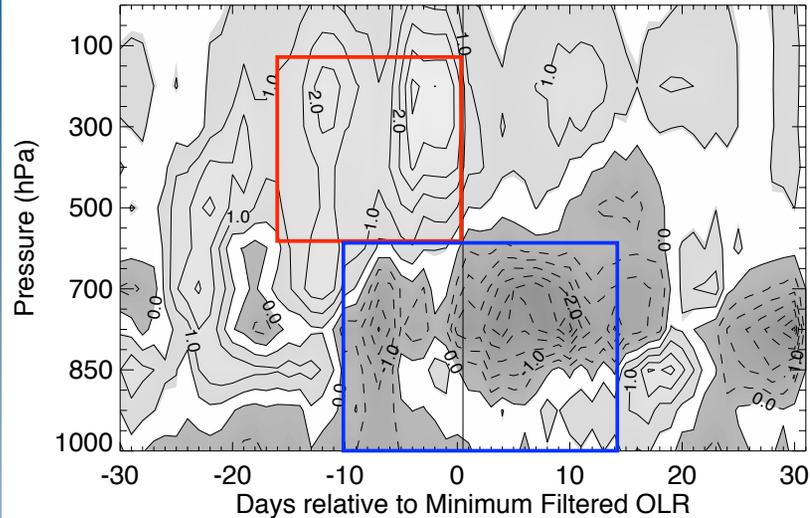


TOGA-COARE IOP Near-Surface Winds per Value of Rainrate

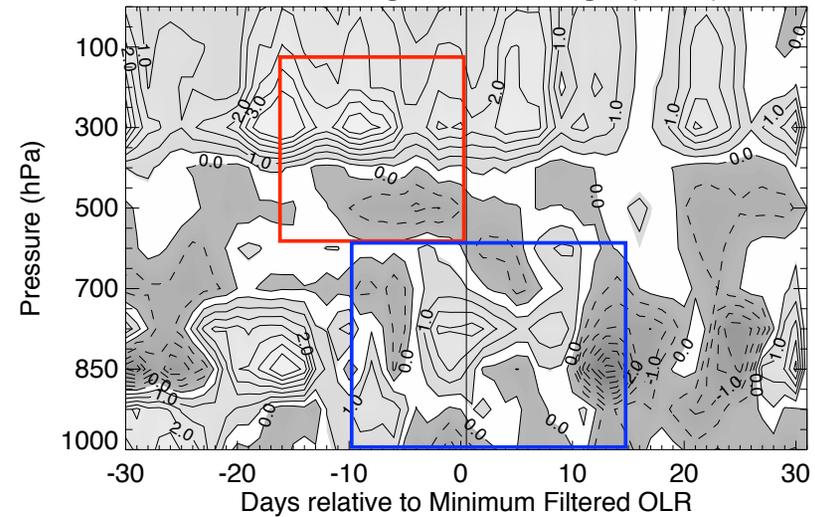


Convective Drying

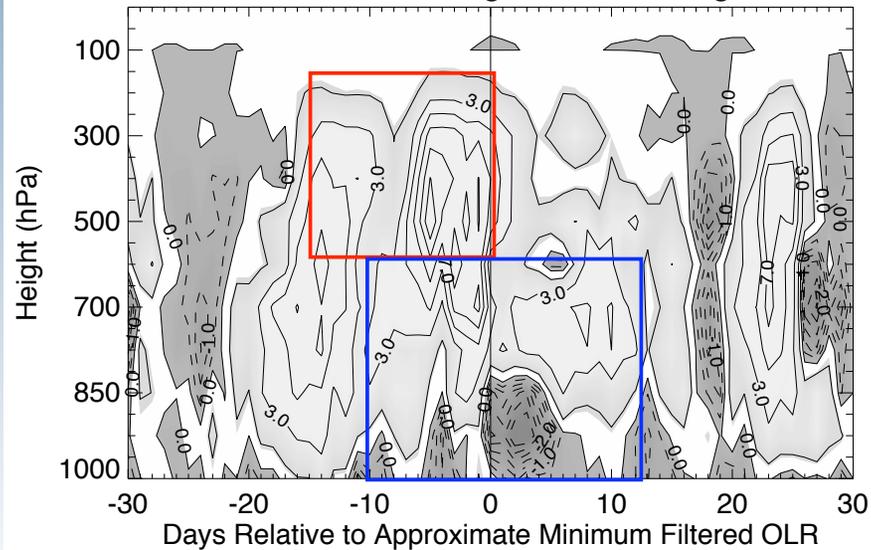
Q2 Profile during MJO Passage (SP-CAM)



Q2 Profile during MJO Passage (CAM)



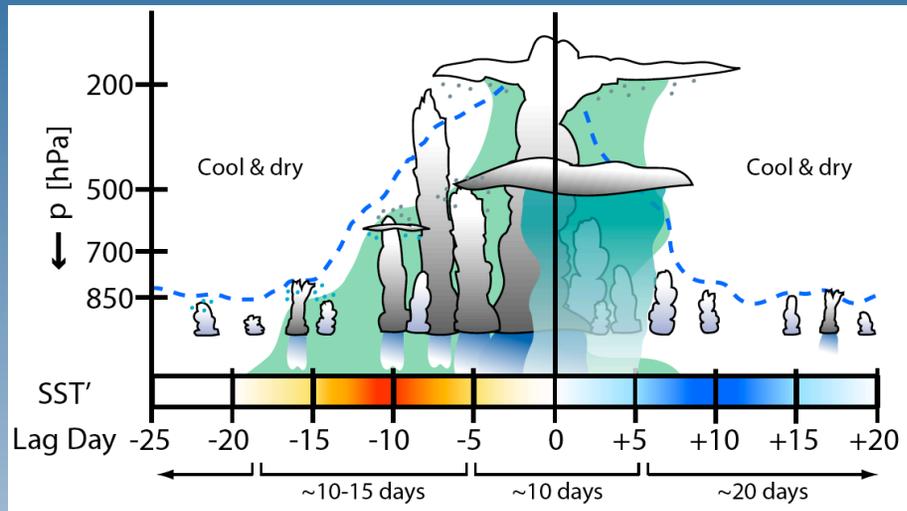
TOGA-COARE Q2 Heating Profile Average Over IFA



Discharge-Recharge Cycle

From Bladé and Hartman 1993

Figure from Benedict and Randall 2007

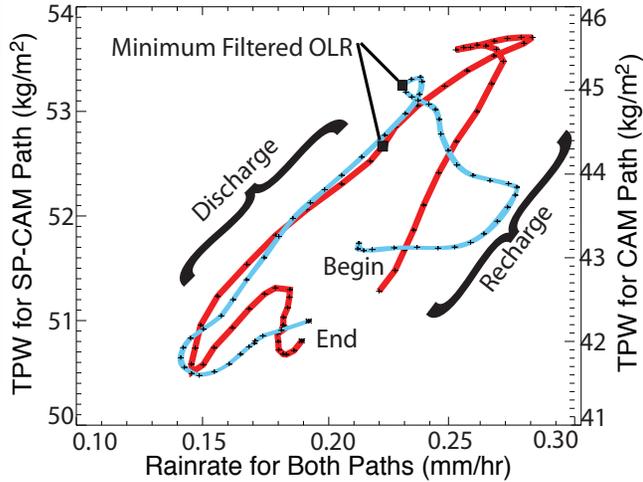


- Proposes MJO is an intrinsic oscillatory state of the tropics
- During suppressed convection regimes, convection moistens and destabilizes the area
- Extra-tropical stochastic forcing sets off deep convection
- Huge convective system travels through the tropics restabilizing the area and suppressing convection after passage

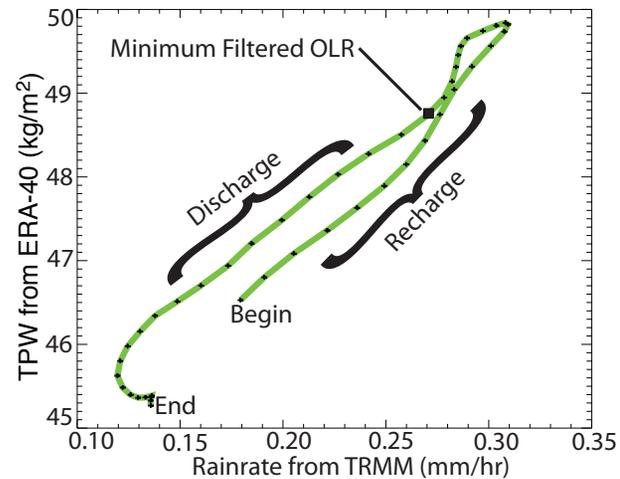


Discharge-Recharge

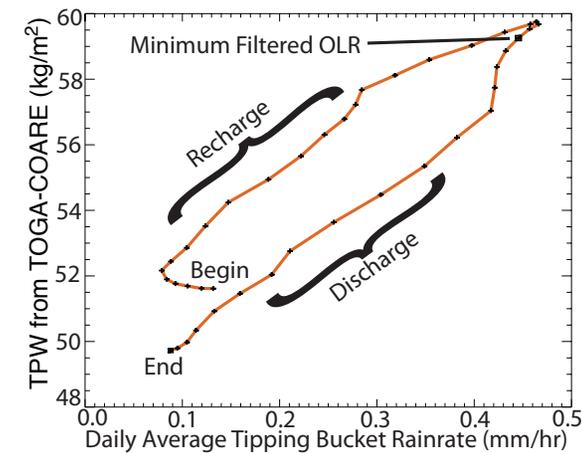
CAM v3.0 and SP-CAM



ERA-40 / TRMM



TOGA-COARE



Tropical Convection, Moisture, and the MJO

- In the tropics, deep convection usually occurs in a very moist environment (Bretherton, Peters and Back 2004)
 - Convection increases the environmental relative humidity
 - Increased environmental humidity decreases dilution by entrainment
 - Increased environmental humidity decreases the evaporation of downdraft air
- The Discharge-Recharge Cycle
 - The MJO occurs on a semi-regular interval dictated by the time required for convection to moisten the atmosphere (Recharge) to the point where deep convection is not effective at restabilization and a large-scale circulation is induced (Discharge).



Summary

- The SP-CAM does a better job of producing convection in a moist column than the CAM, most likely because of better coupling of multi-scale convective processes.
- There is evidence of convection-wind-evaporation feedback which causes the SP-CAM to be overly humid, and have stronger convection.
- The MJO appears in the SP-CAM because the representation of convection does a better job of moistening the tropics and creating a Discharge-Recharge Cycle.



Questions?



CMMAP EAP Meeting, Fort Collins, September 2008

