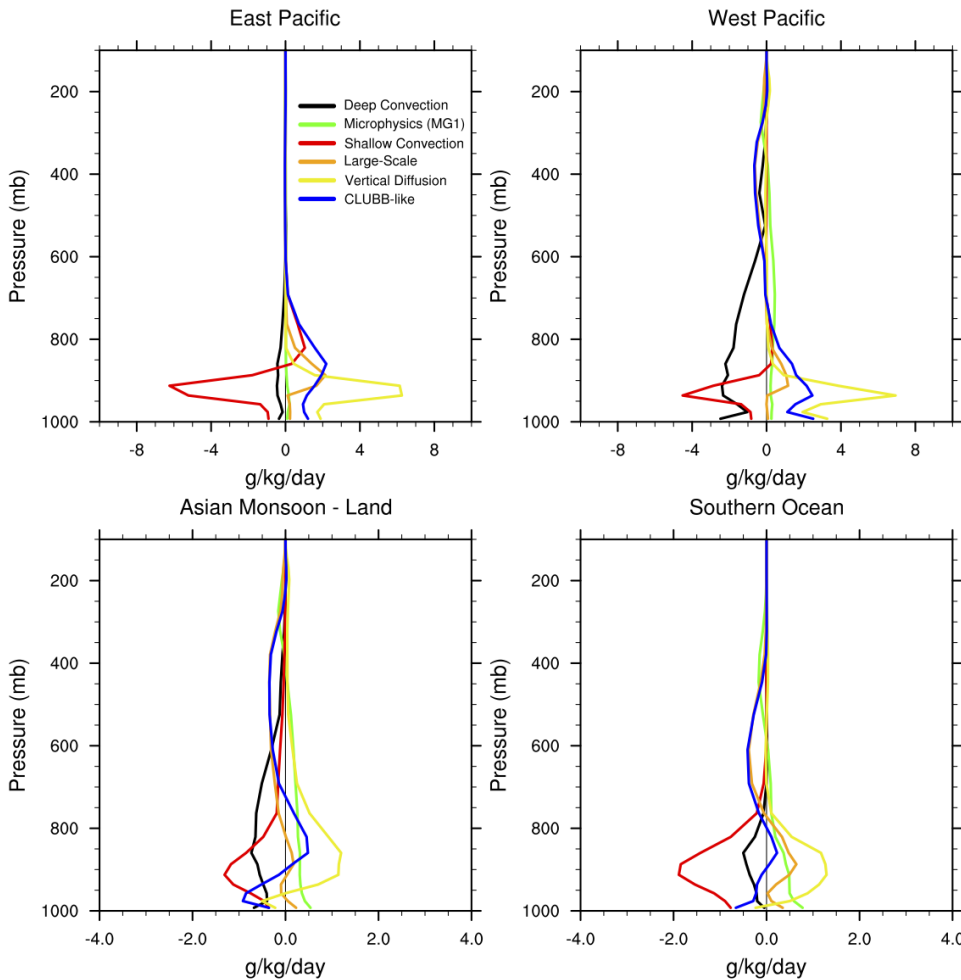


# A Comparison of Parameterization Tendencies Between CAM6 and CAM5



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AMWG February 21, 2019

Community Earth System Model **CESM**



# Tendency differences in CAM6

- CAM6 parameterization schemes changed significantly
- MG2 upgraded from MG1, deep ZM more sensitive
- CLUBB changes the paradigm
- CAM5: Shallow convection, vertical diffusion and large-scale/stratiform/resolved-scale cloud
- CAM6: All processes rolled into CLUBB
  
- *How do we interpret in similar detail the balance of these processes in CLUBB?*
- *Is CLUBB doing the same things as the 'familiar' processes in CAM5?*

# Initial CAM Tendency Study

- AMIP (1979-2005)
- Tendencies->increments to the model state by parameterized processes
- Depth averaged temperature and humidity tendencies. Climatological (ANN, DJF, JJA) values
  
- Global distributions, regional vertical profiles, PDFs
- CAM6 'revert' parameterization simulations

# Tendency differences ( $dT/dt$ , $dq/dt$ )

## CAM5

**“Total”**: Moist + vert. diffusion

Deep Convection

Microphysics (MG1)

LW Radiation

SW Radiation

Shallow Convection

Large-Scale Cloud

Vertical Diffusion

CLUBB-like

## CAM6

**“Total”**: Moist + vert. diffusion

Deep Convection

Microphysics (MG2)

LW Radiation

SW Radiation

CLUBB

\*Does not include surface fluxes or dynamical tendencies. But it will!

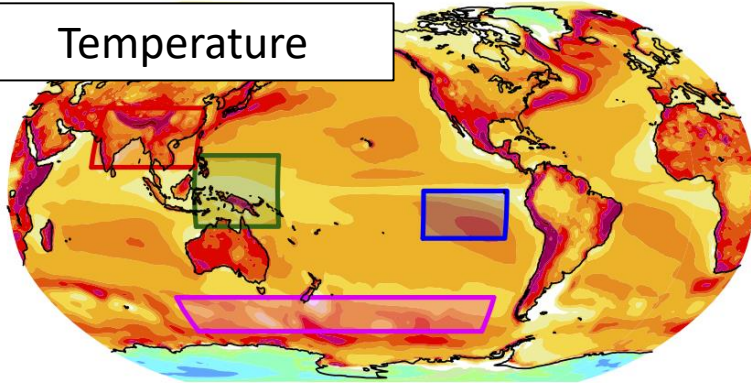
# Global Distributions

# Near Surface "Total" Tendencies (ANN)

## CAM6

Ave. = 1.88 Min. = -2.95 Max. = 15.42

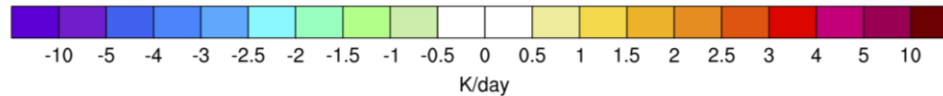
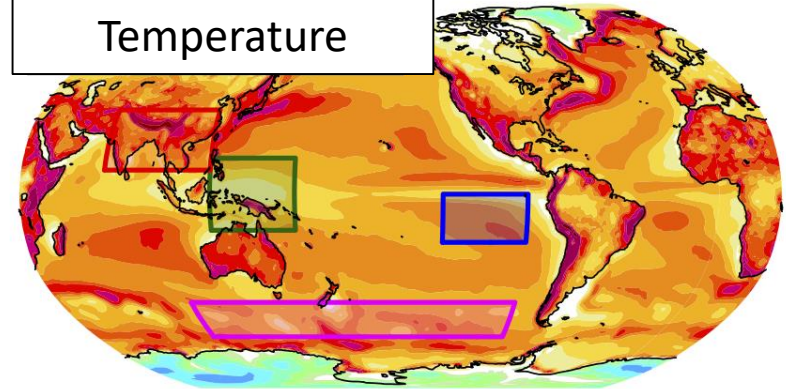
Temperature



## CAM5

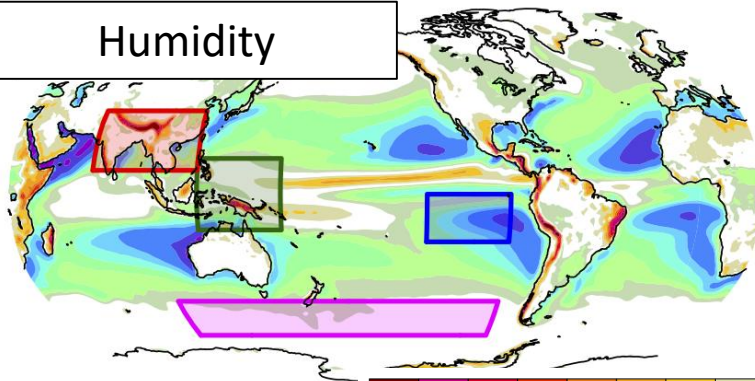
Ave. = 2.02 Min. = -3.01 Max. = 18.05

Temperature



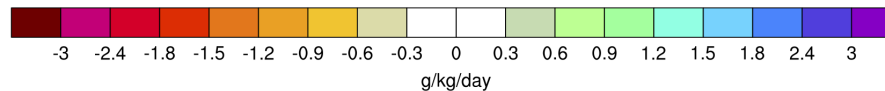
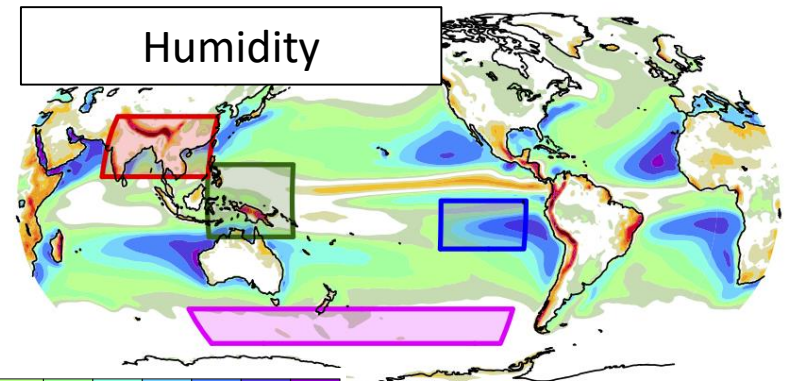
Ave. = 0.48 Min. = -7.41 Max. = 5.34

Humidity

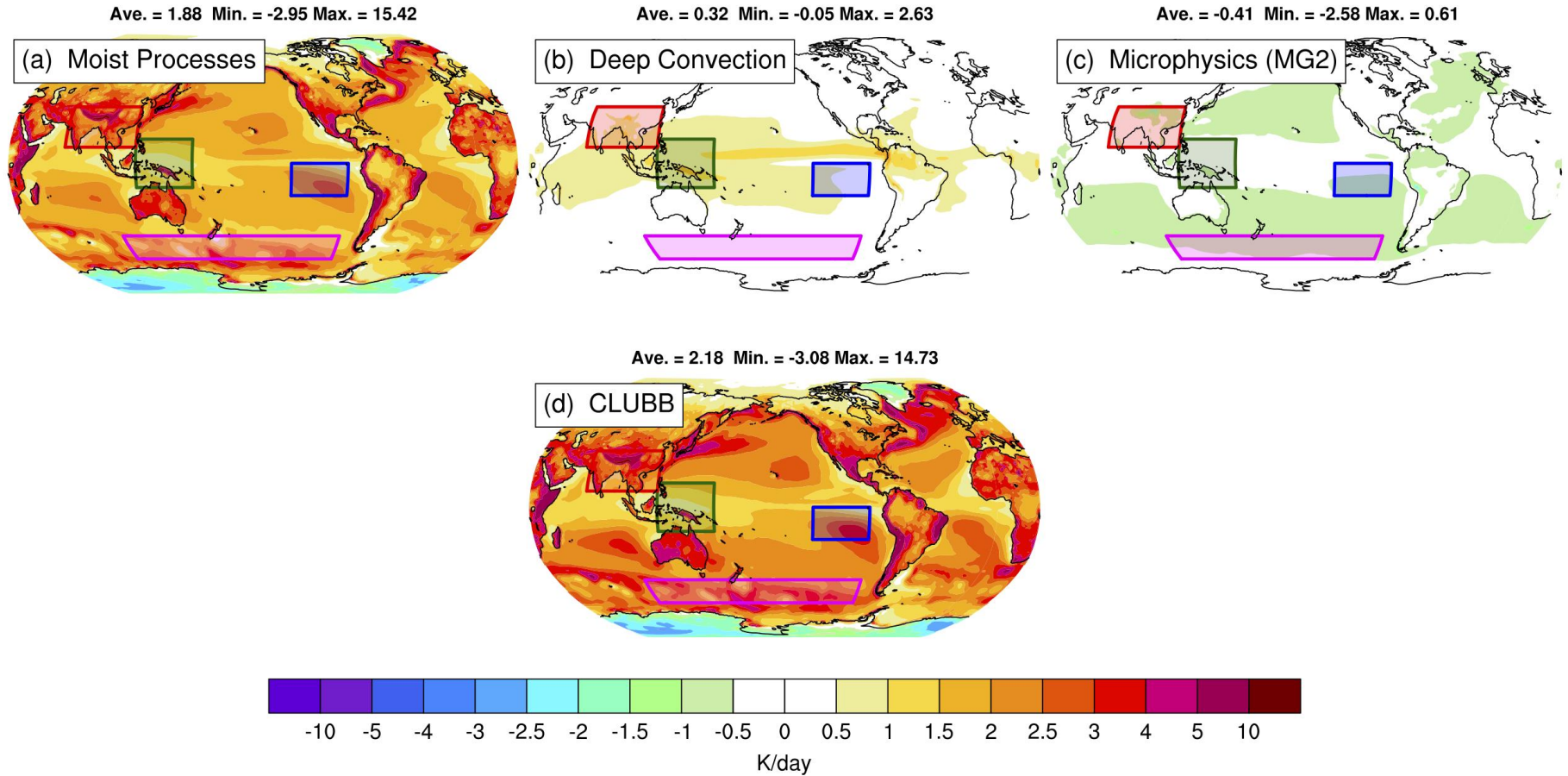


Ave. = 0.46 Min. = -8.12 Max. = 4.52

Humidity



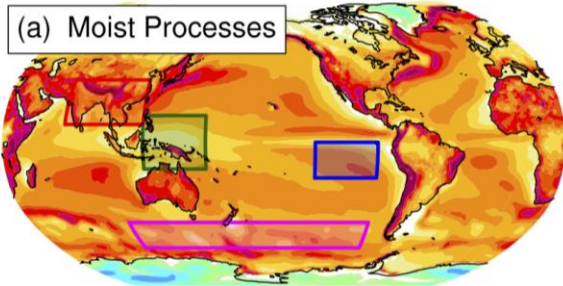
# PBL Temperature Tendencies (CAM6)



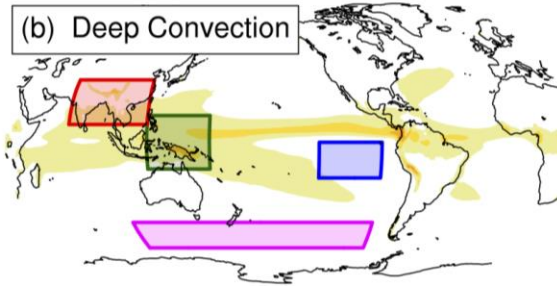
Most of PBL parameterization temperature tendency comes from CLUBB

# PBL Temperature Tendencies (CAM5)

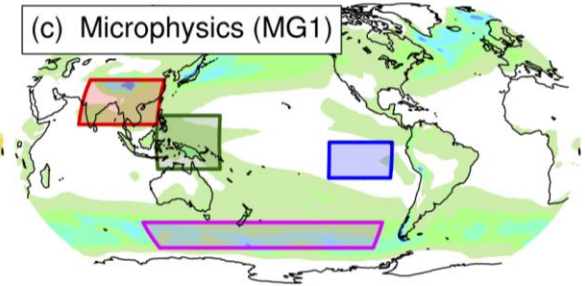
Ave. = 2.02 Min. = -3.01 Max. = 18.05



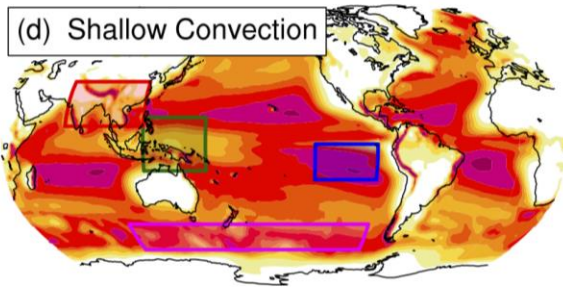
Ave. = 0.30 Min. = -0.10 Max. = 2.73



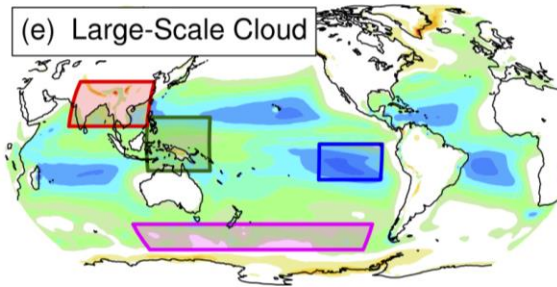
Ave. = -0.66 Min. = -3.44 Max. = 0.55



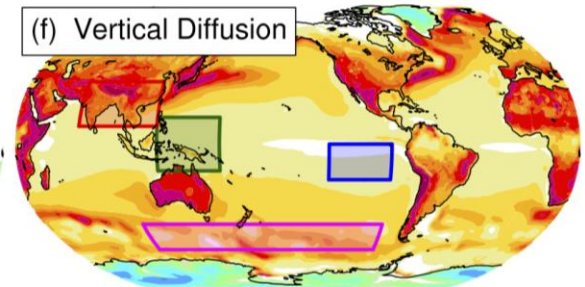
Ave. = 2.04 Min. = -0.02 Max. = 11.54



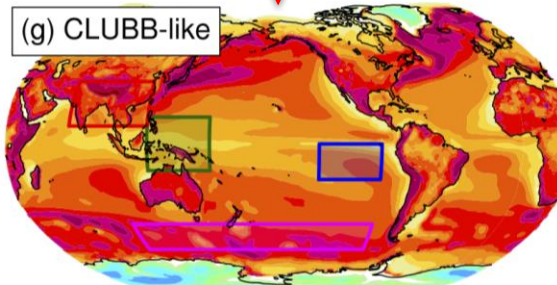
Ave. = -0.86 Min. = -6.01 Max. = 4.57



Ave. = 1.41 Min. = -3.10 Max. = 8.91

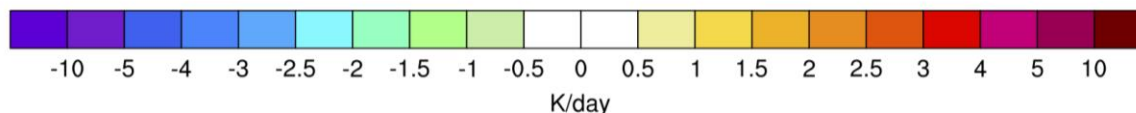


Ave. = 2.59 Min. = -3.09 Max. = 19.01



- CLUBB-like similar to CLUBB (a bit larger)
- But large compensation of ShCU and LS cloud over most of sub-tropical ocean

- Critical regions for cloud feedbacks

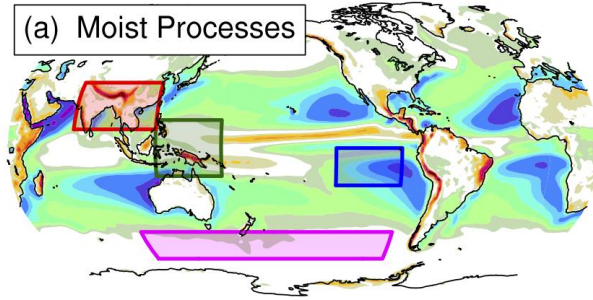




# PBL Humidity Tendencies (CAM6)

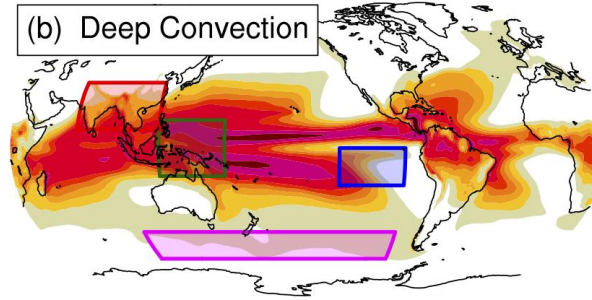
Ave. = 0.48 Min. = -7.41 Max. = 5.34

(a) Moist Processes



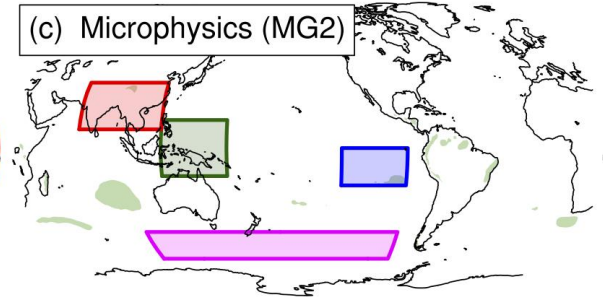
Ave. = -0.74 Min. = -4.40 Max. = 0.00

(b) Deep Convection



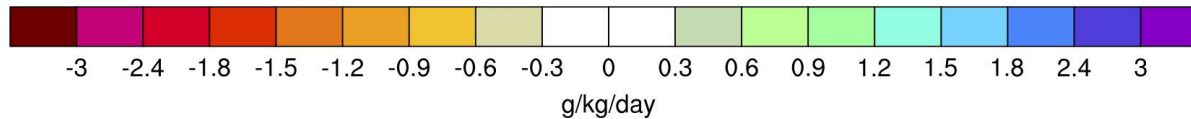
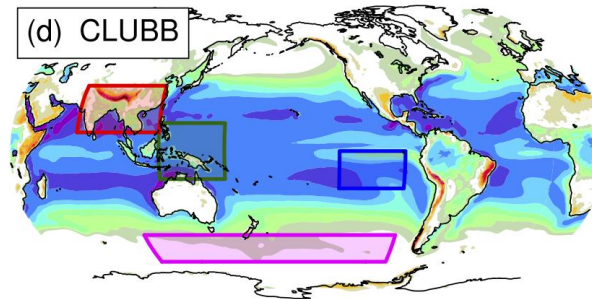
Ave. = 0.15 Min. = -0.14 Max. = 0.47

(c) Microphysics (MG2)



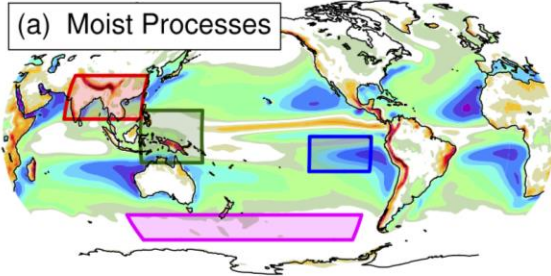
Ave. = 0.99 Min. = -6.00 Max. = 5.45

(d) CLUBB

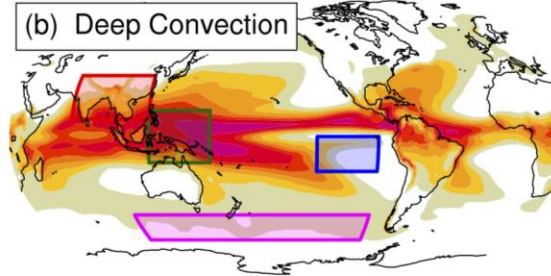


# PBL Humidity Tendencies (CAM5)

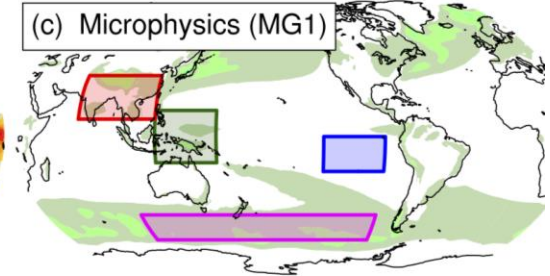
Ave. = 0.46 Min. = -8.12 Max. = 4.52



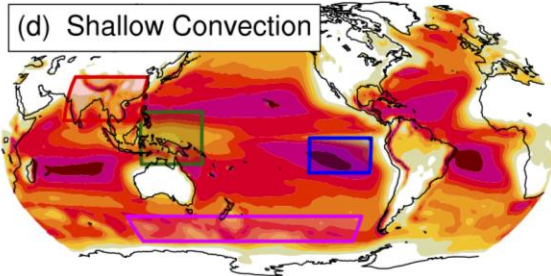
Ave. = -0.61 Min. = -2.99 Max. = 0.00



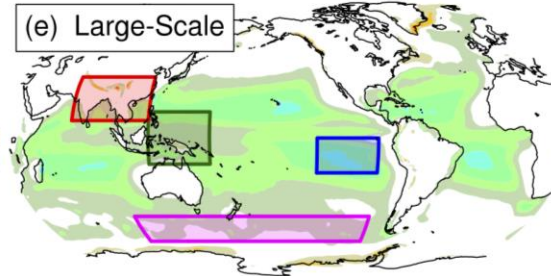
Ave. = 0.25 Min. = -0.19 Max. = 1.18



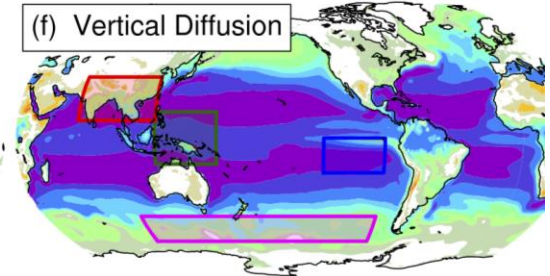
Ave. = -1.20 Min. = -7.00 Max. = 0.00



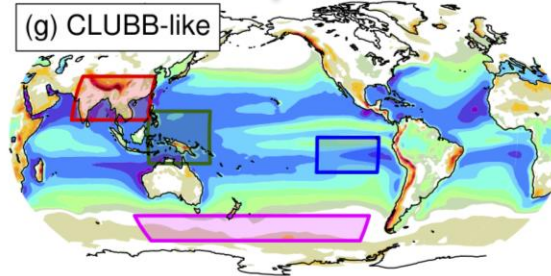
Ave. = 0.35 Min. = -1.83 Max. = 2.41



Ave. = 1.60 Min. = -1.90 Max. = 5.00

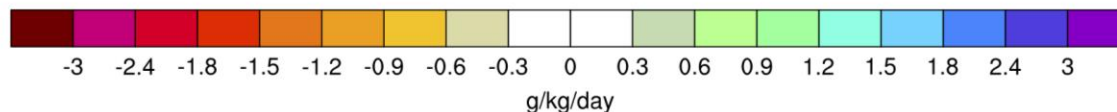


Ave. = 0.74 Min. = -7.41 Max. = 4.63



- CLUBB-like similar to CLUBB (a bit weaker)
- But large compensation of ShCu and vertical diffusion over most of tropical

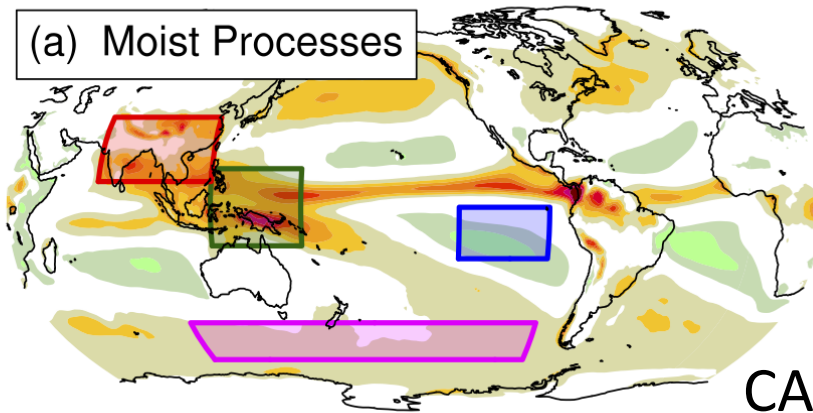
- MG2 has much larger influence than MG1 in mid-latitudes



# Free-troposphere (800-200 mb) Humidity Tendencies

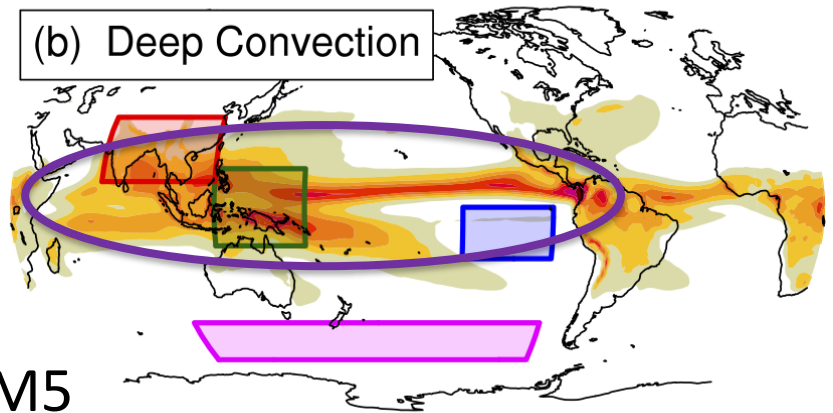
Ave. = -0.12 Min. = -3.40 Max. = 0.51

(a) Moist Processes



Ave. = -0.16 Min. = -2.48 Max. = 0.03

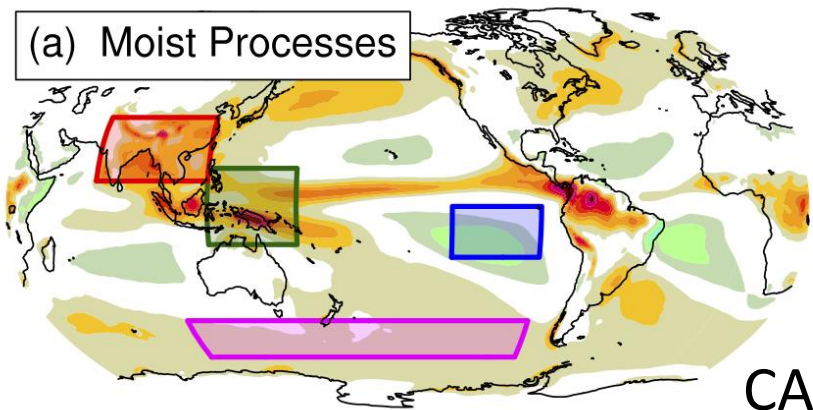
(b) Deep Convection



CAM5

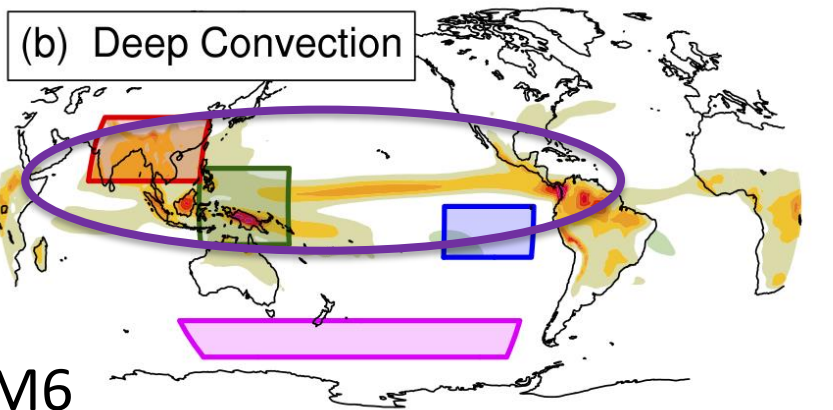
Ave. = -0.13 Min. = -2.71 Max. = 0.67

(a) Moist Processes

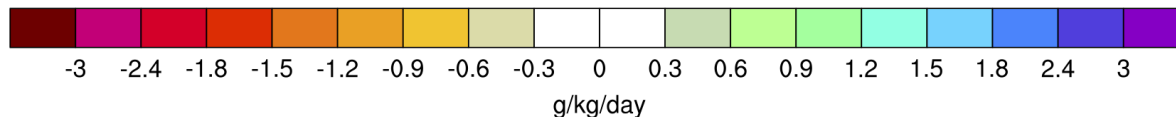


Ave. = -0.09 Min. = -1.83 Max. = 0.24

(b) Deep Convection

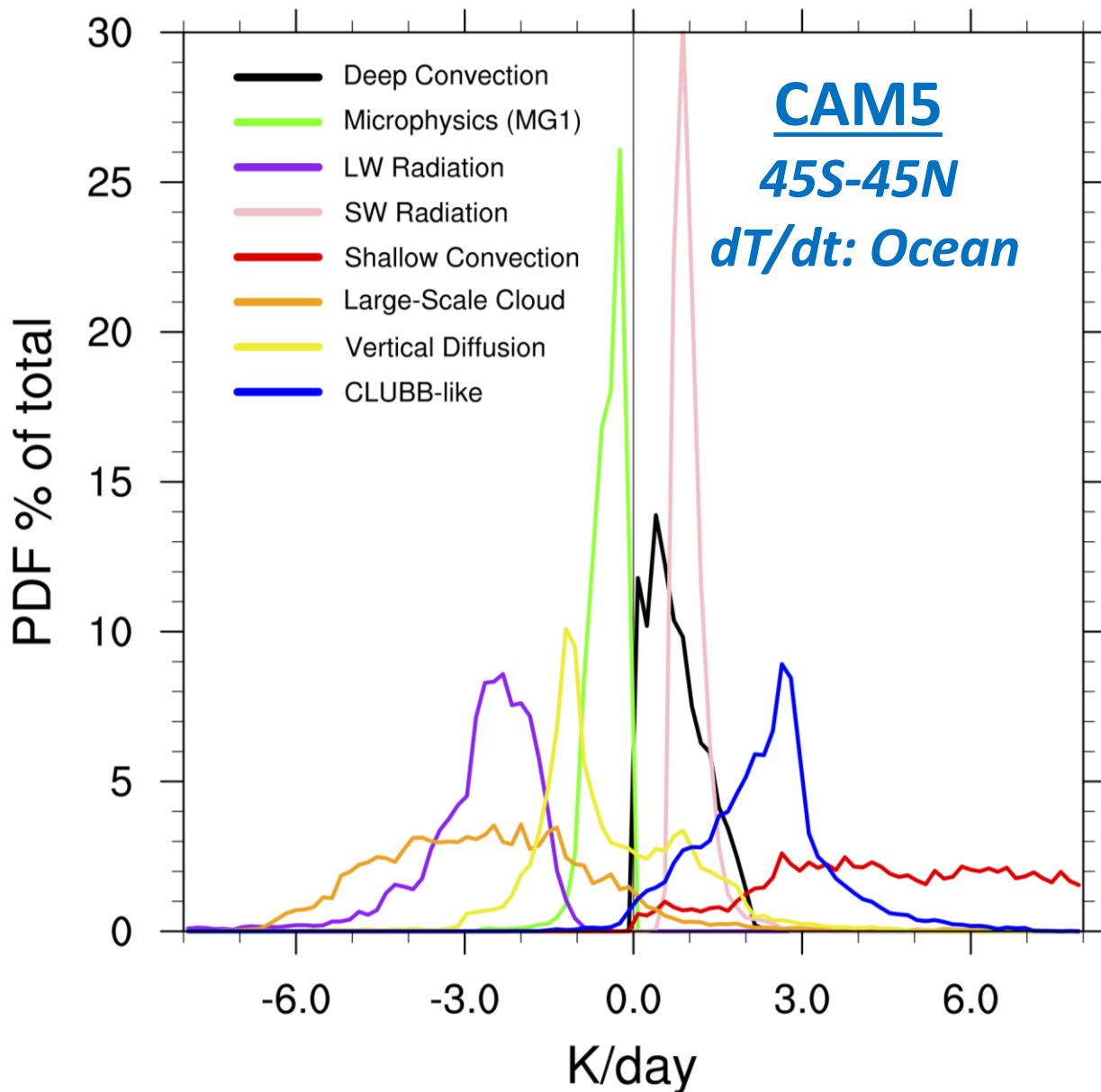


CAM6



PDFs

# Boundary layer (~900mb) PDF of tendencies



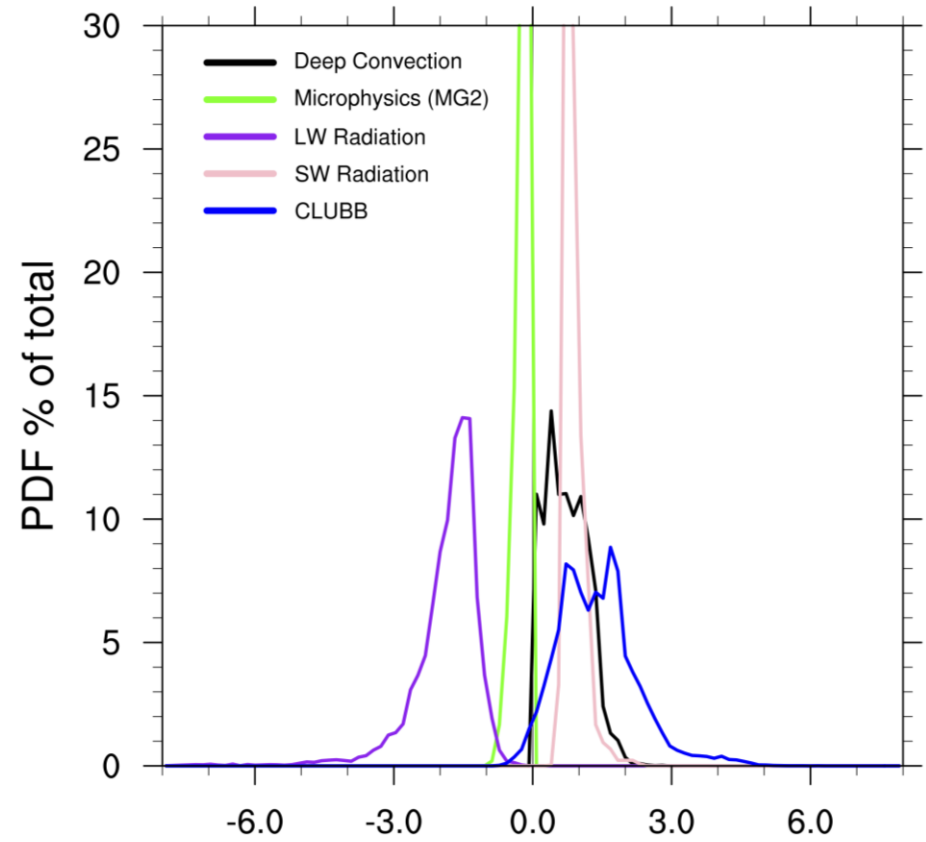
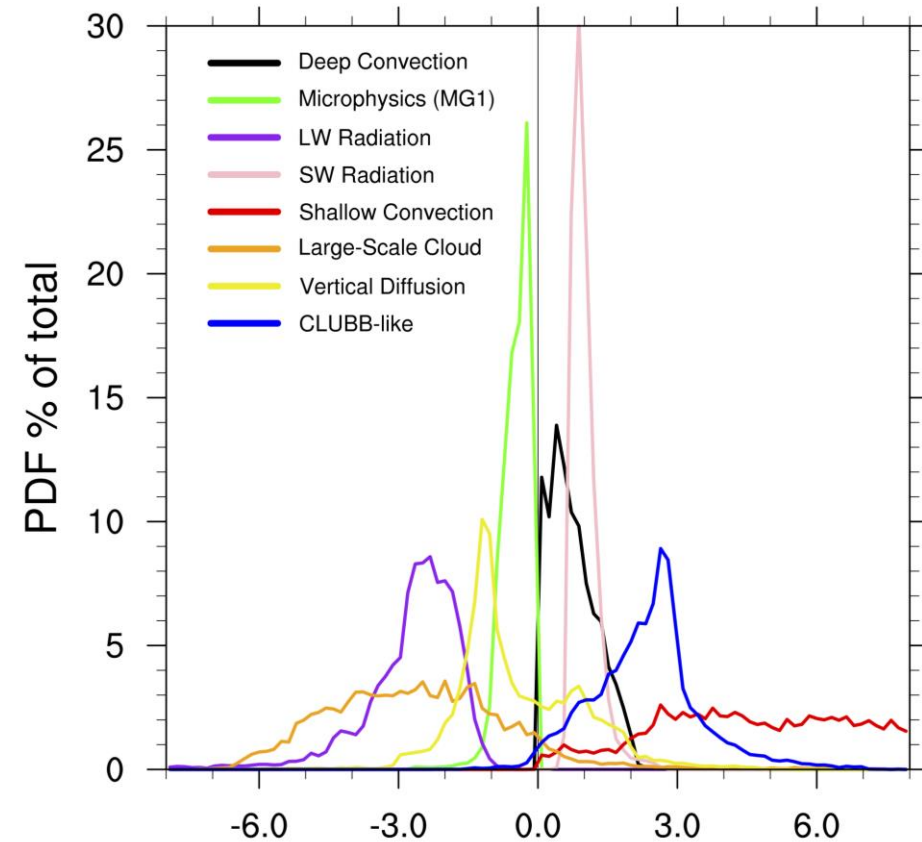
- CLUBB-like and LW radiation approx. balance
- Compensation of ShCu and LS cloud
- They can have very large magnitudes

# Boundary layer (~900mb) PDF of tendencies

## dT/dt: Ocean (45N-45S)

CAM5

CAM6



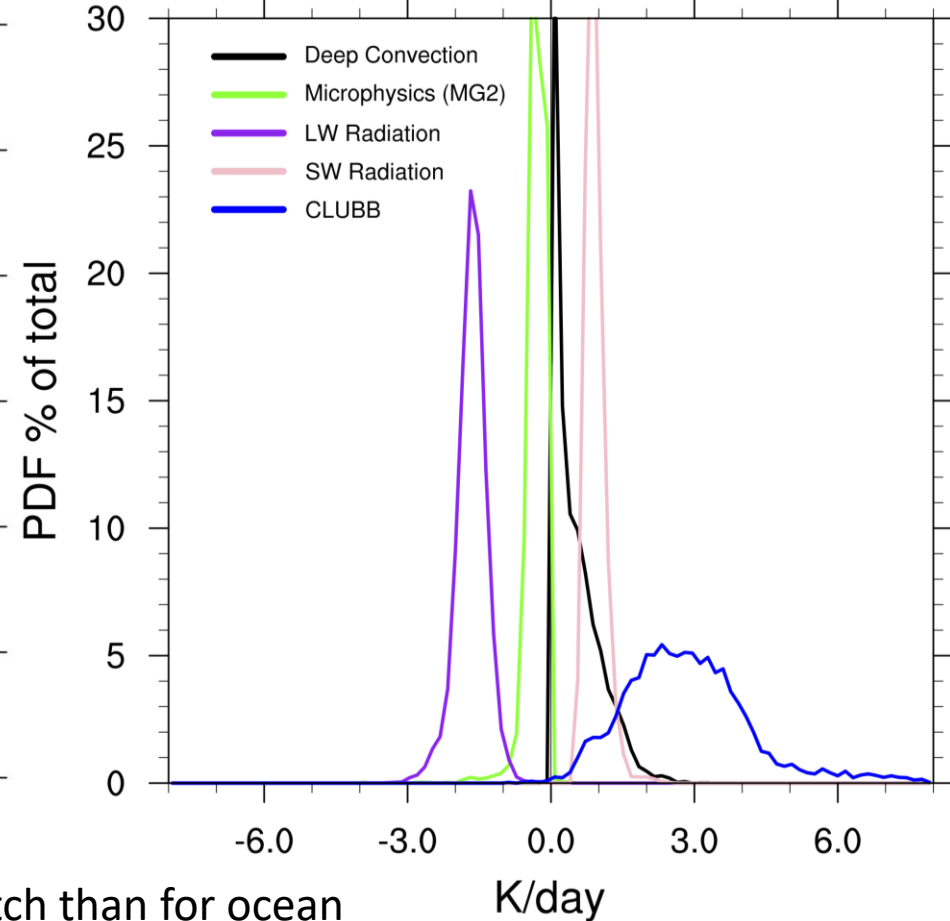
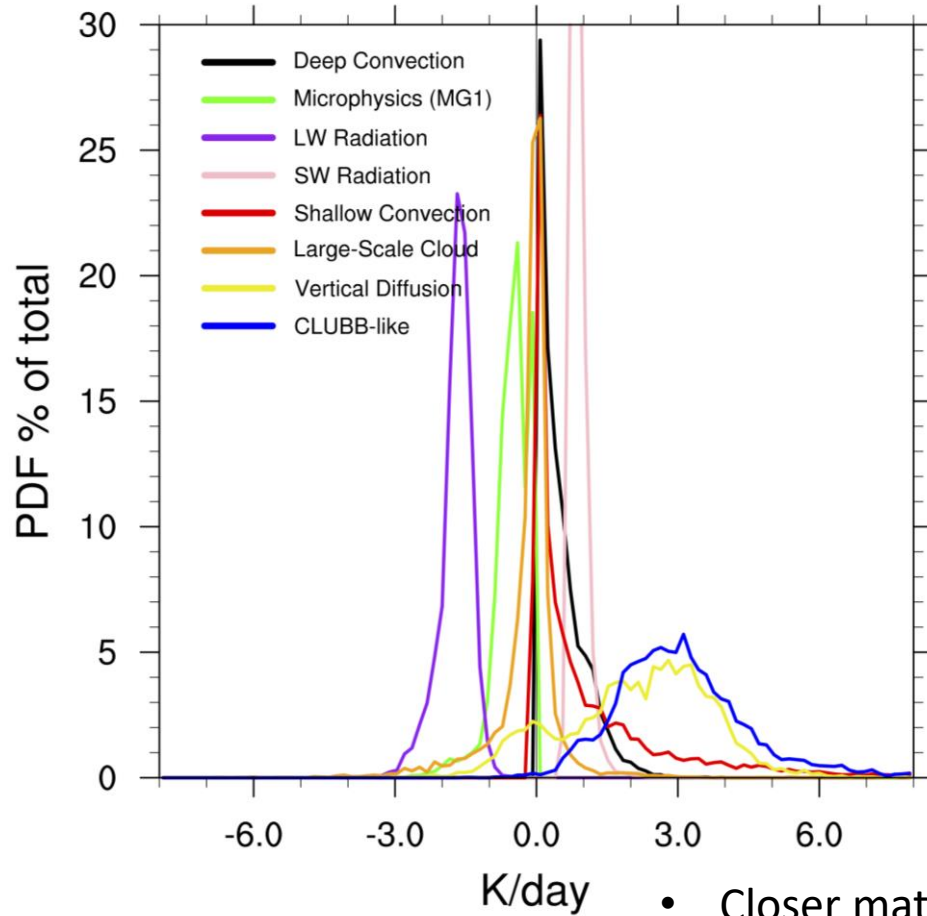
- CLUBB-like skews more +ve
- LW radiation skews more -ve
- Greater role for MG1 than MG2

# Boundary layer (~900mb) PDF of tendencies

**dT/dt: Land  
(45N-45S)**

CAM5

CAM6



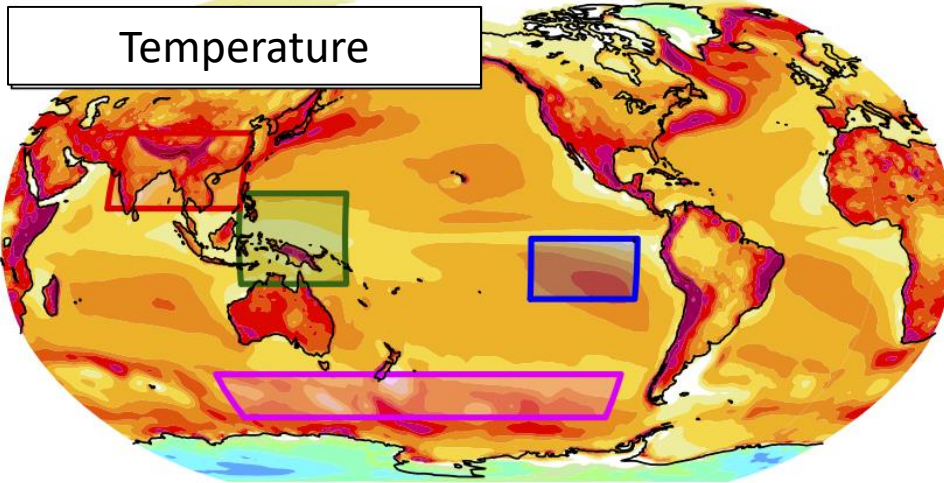
- Closer match than for ocean
- But, vertical diffusion dominates

# Regional Profiles

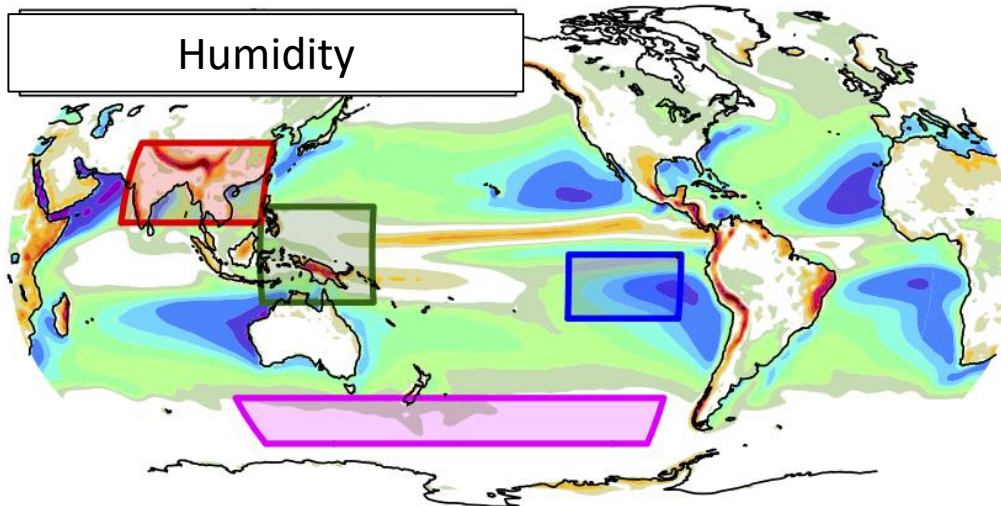


# East Pacific

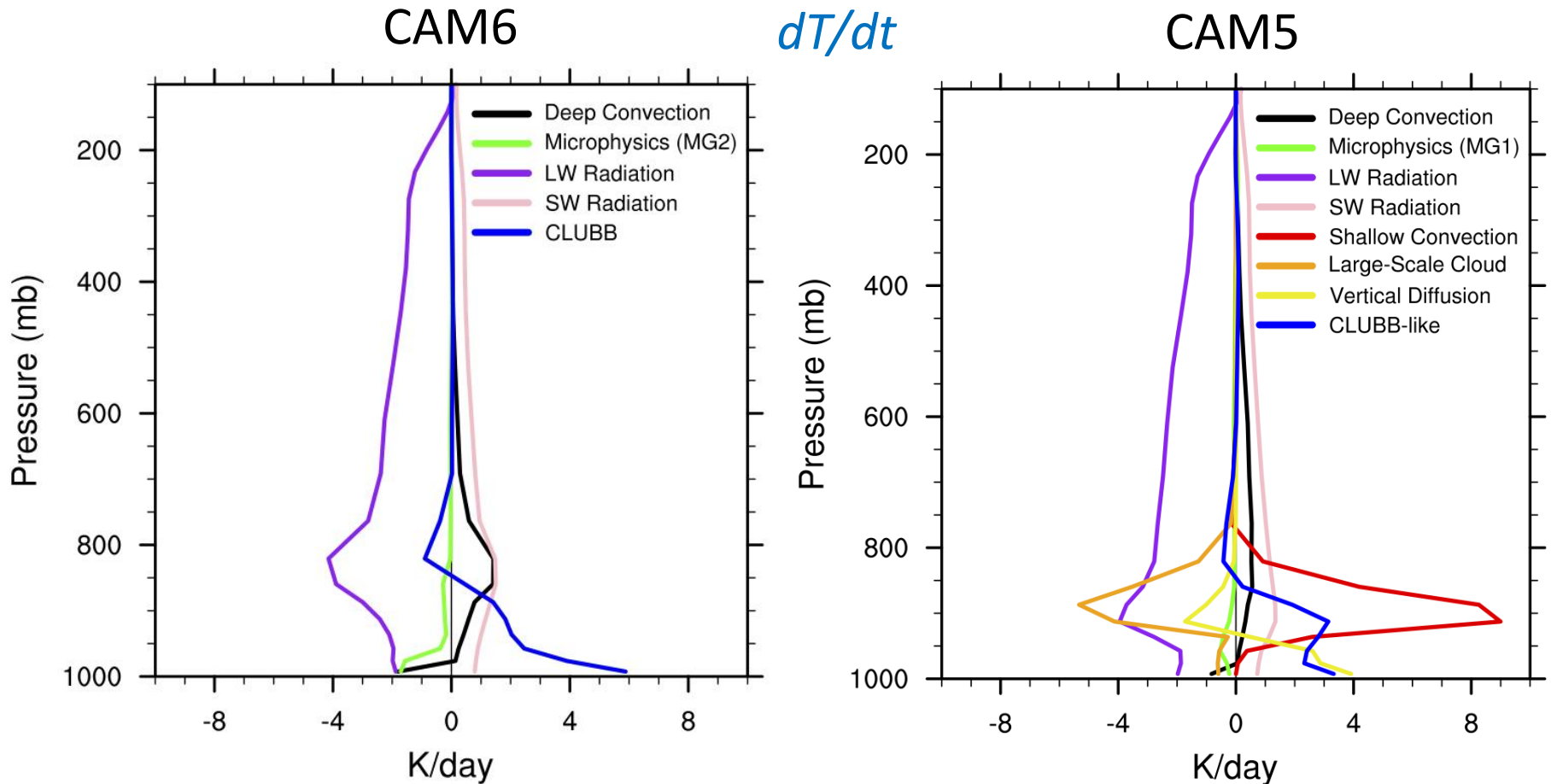
Ave. = 1.88 Min. = -2.95 Max. = 15.42



Ave. = 0.48 Min. = -7.41 Max. = 5.34



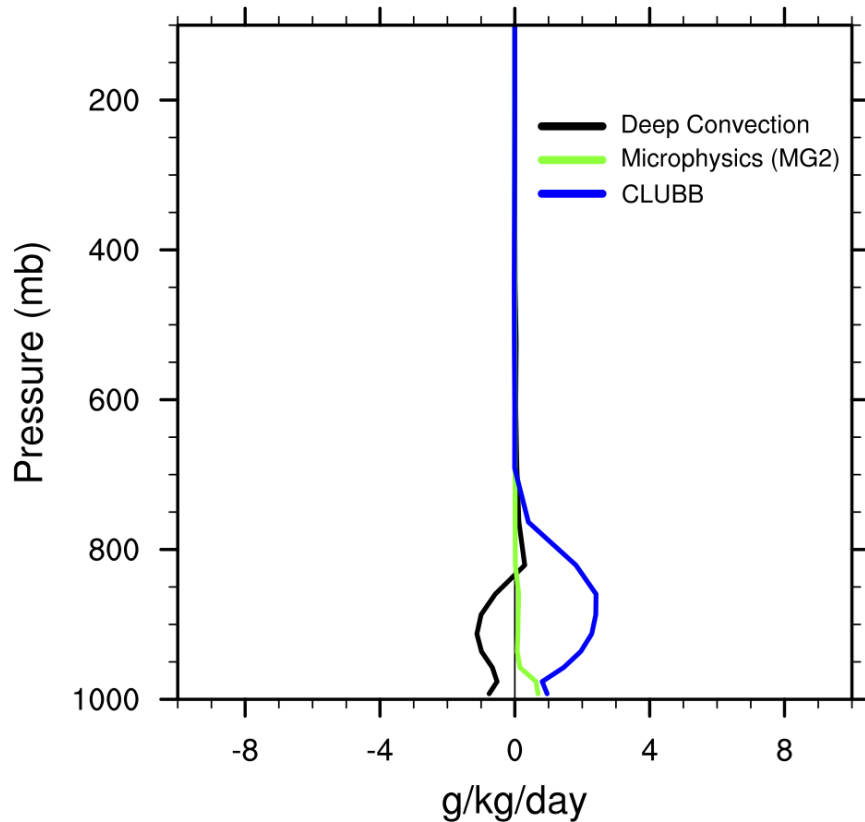
# Regional Budgets (Sub. Trop East Pacific)



- CLUBB has small tendencies where CAM5 has multiple (ShCu/LSC)
- Cloud depth lower in CAM5
- Near surface tendencies differ the most
- Some microp (MG2) compensation with large CLUBB warming

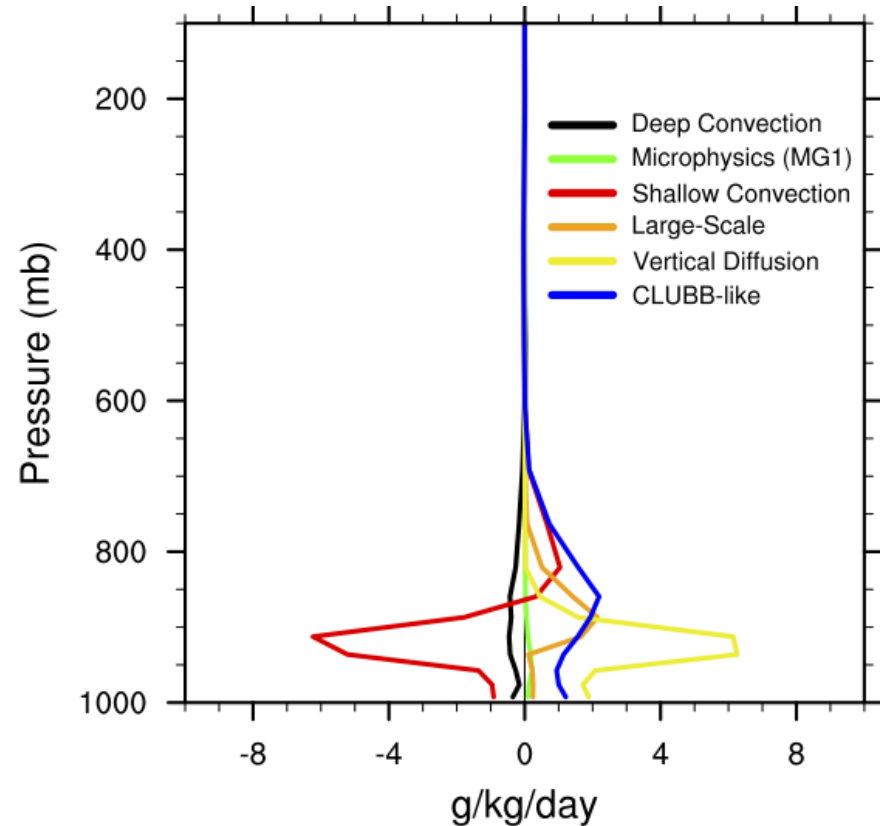
# Regional Budgets (Sub. Trop East Pacific)

CAM6



$dq/dt$

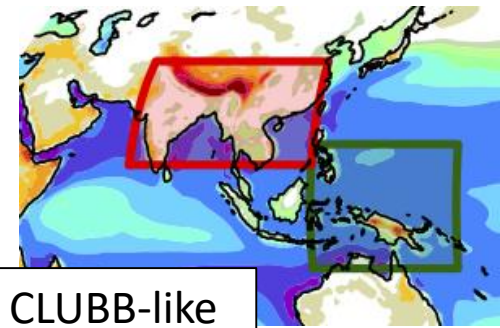
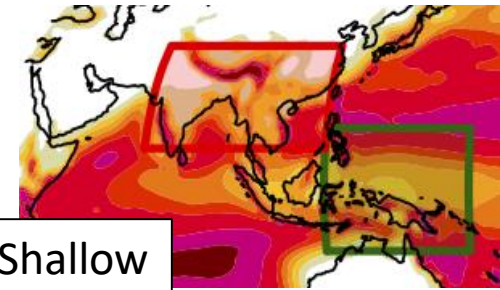
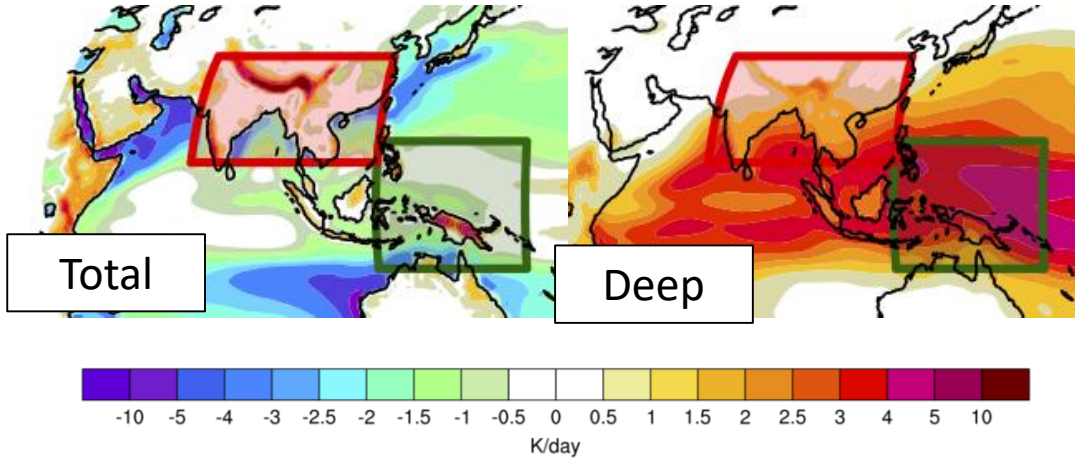
CAM5



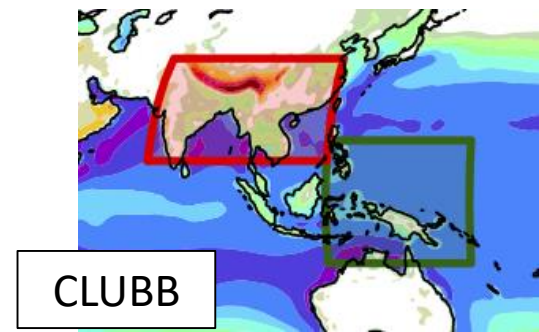
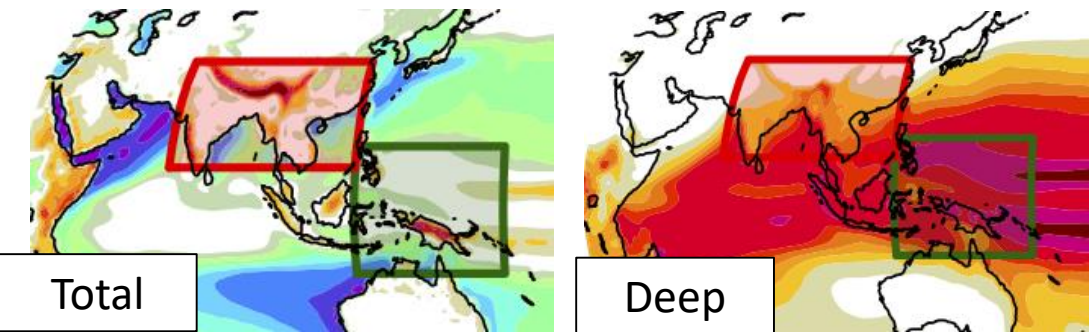
- CAM5 has different process balance to temperature (ShCu/Vdiff)
- Cloud depth lower in CAM5
- Deep convection largely balances CLUBB below 800 mb

# Tibetan Hot Spot

## CAM5



## CAM6



- MG2 and MG1: Largest cooling tendencies on planet in JJA!

# Tibetan Hot Spot (JJA)

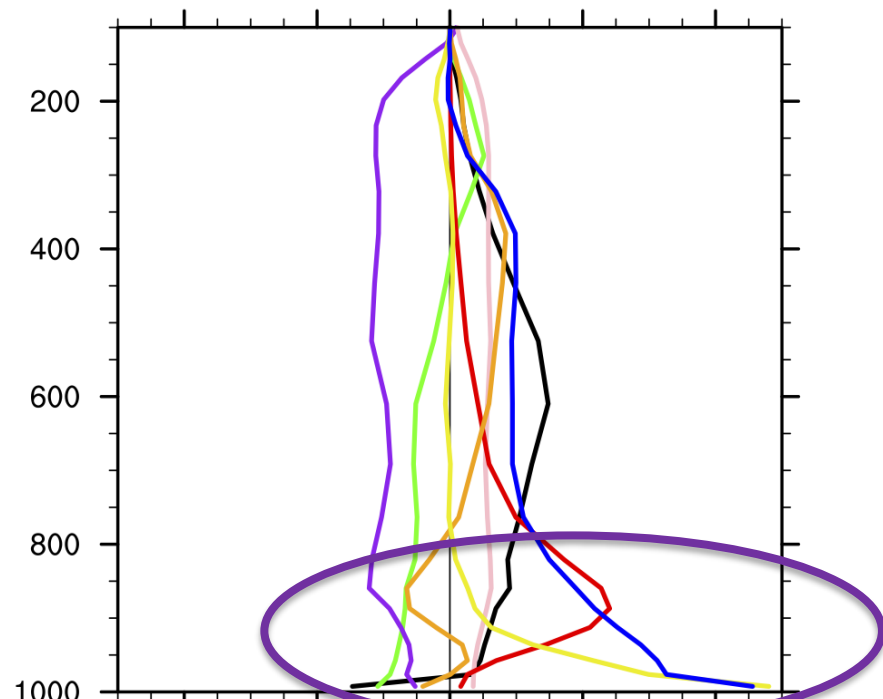
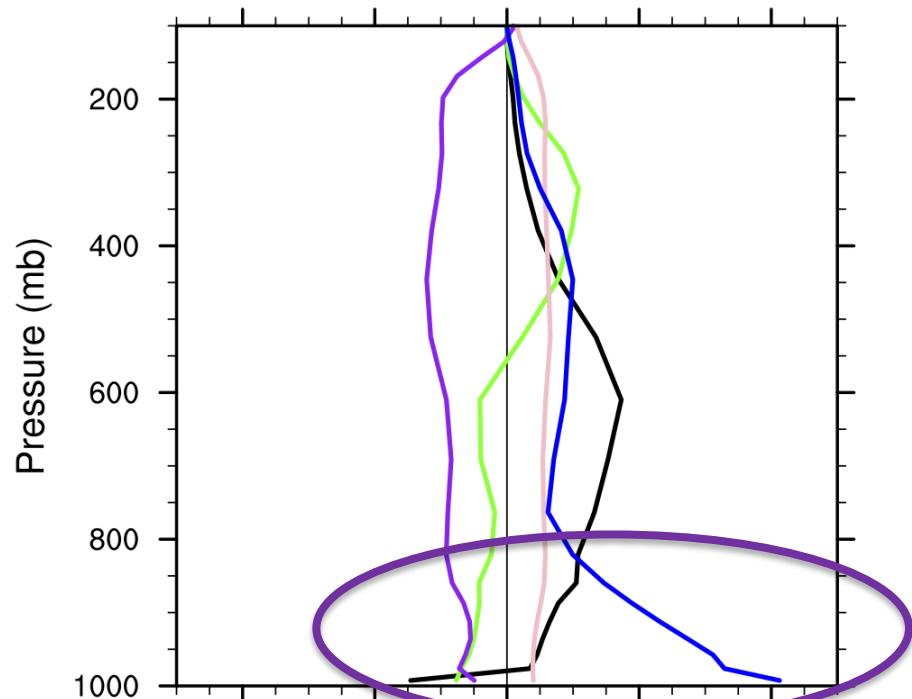
CAM6

$dT/dt$

CAM5

Asian Monsoon - Land

Asian Monsoon - Land



- Deep Convection
- Microphysics (MG1)
- LW Radiation
- SW Radiation
- Shallow Convection
- Large-Scale Cloud
- Vertical Diffusion
- CLUBB-like

K/day

K/day

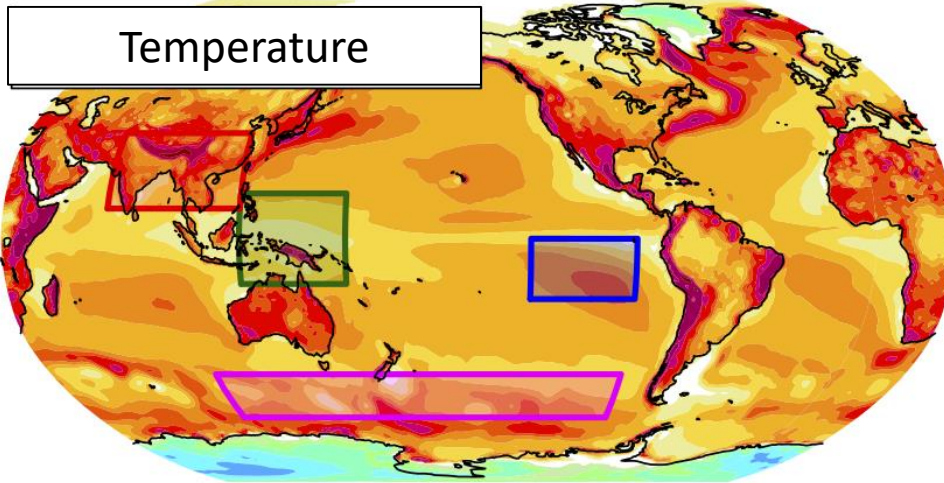
- CLUBB/CLUBB-like tendencies are very similar
- CAM5 has strong contributions from ShCu and Vertical Diffusion
- Can we diagnose whether CLUBB is doing the 'same', given the response is the same?

- Deep Convection
- Microphysics (MG2)
- LW Radiation
- SW Radiation
- CLUBB

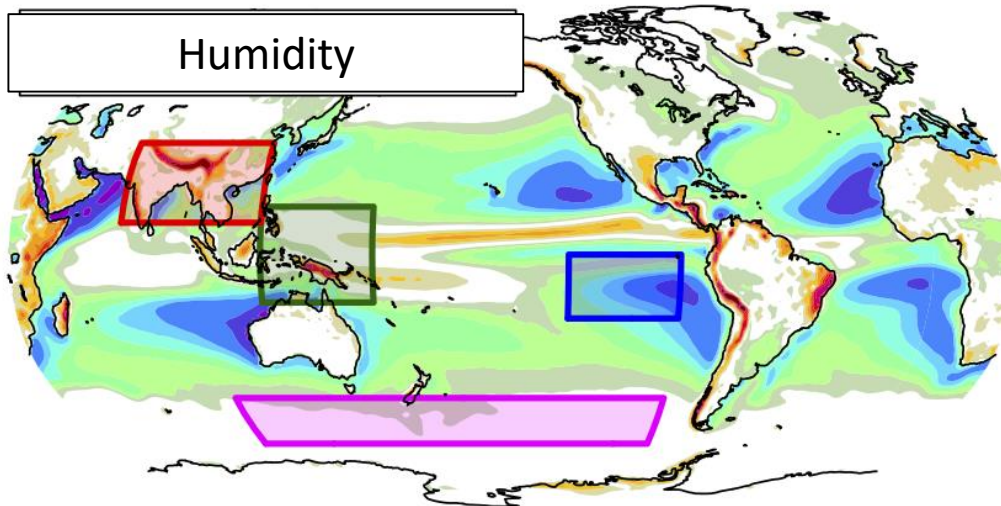
# AMIP 'Revert' Experiments (Cecile)

# Southern Ocean (JJA)

Ave. = 1.88 Min. = -2.95 Max. = 15.42



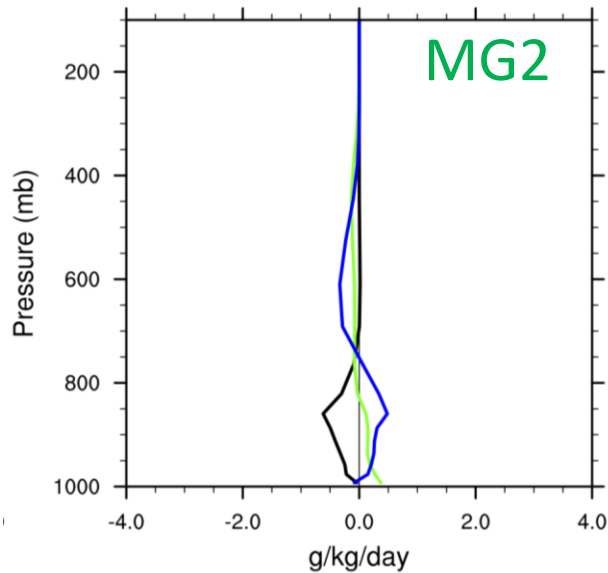
Ave. = 0.48 Min. = -7.41 Max. = 5.34



# Humidity Sensitivity: CLUBB->UW/park

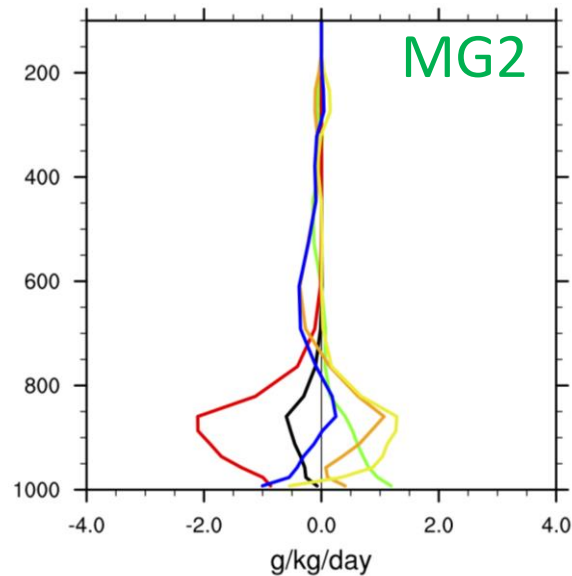
CAM6

Southern Ocean



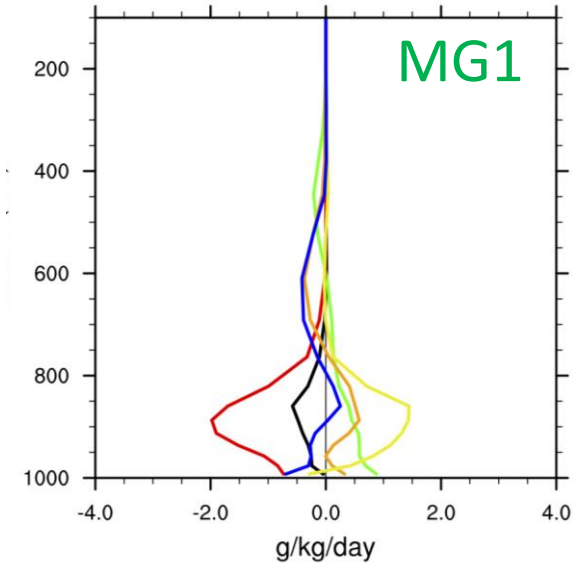
CAM6->UW/park

Southern Ocean



CAM5

Southern Ocean



- Deep Convection
- Microphysics (MG2)
- CLUBB

**Southern Ocean (JJA)**  
***Humidity tendencies***

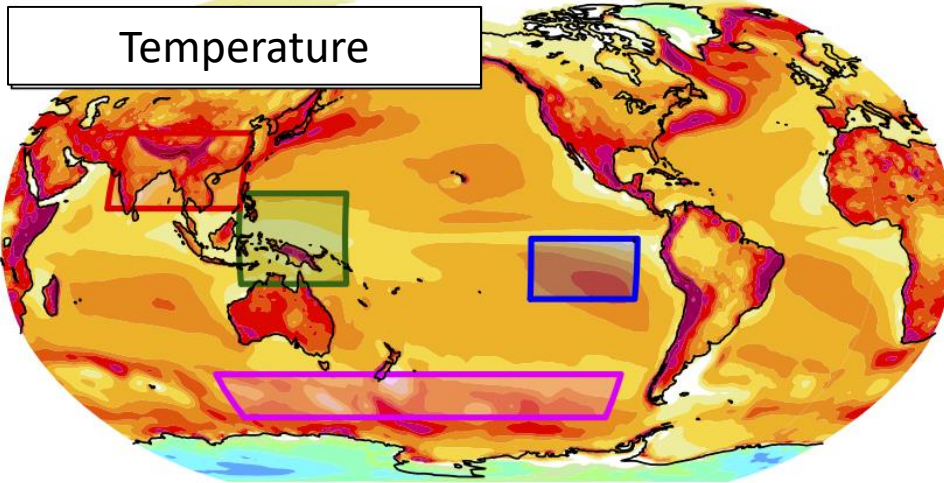
- Deep Convection
- Microphysics (MG1)
- Shallow Convection
- Large-Scale
- Vertical Diffusion
- CLUBB-like

- CAM5 process ordering recovered
- Cloud fraction tuning only sig. difference

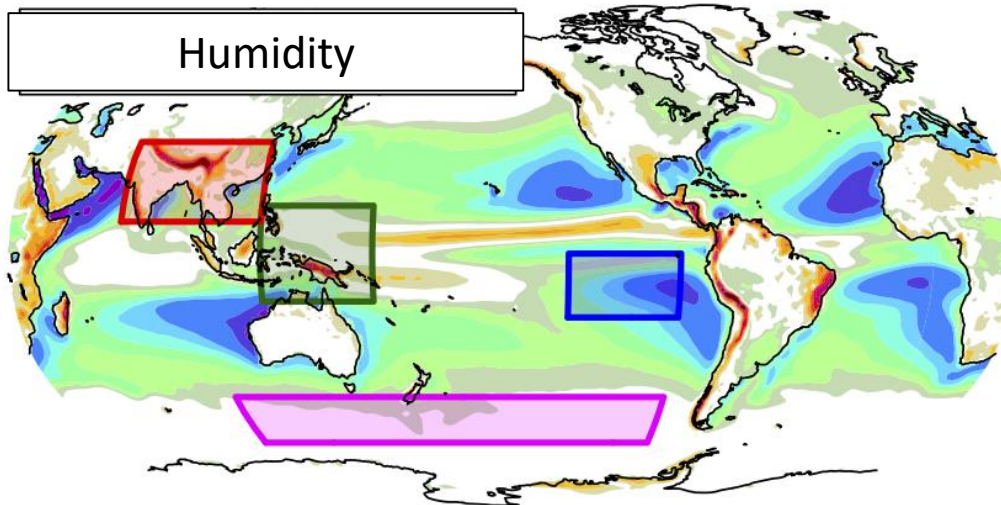


# West Pacific (Ocean, DJF)

Ave. = 1.88 Min. = -2.95 Max. = 15.42



Ave. = 0.48 Min. = -7.41 Max. = 5.34

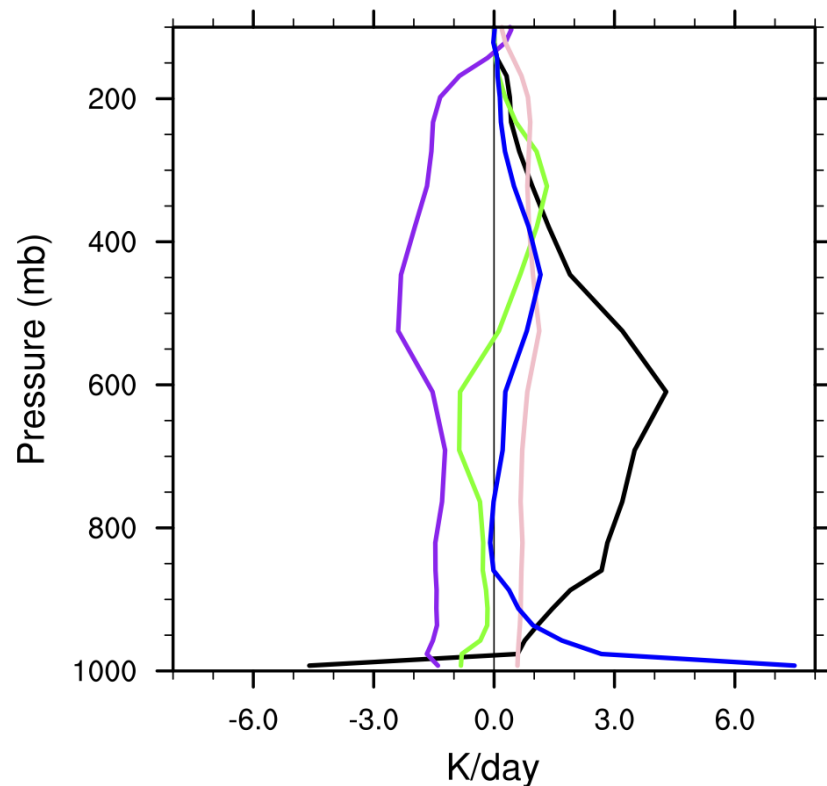
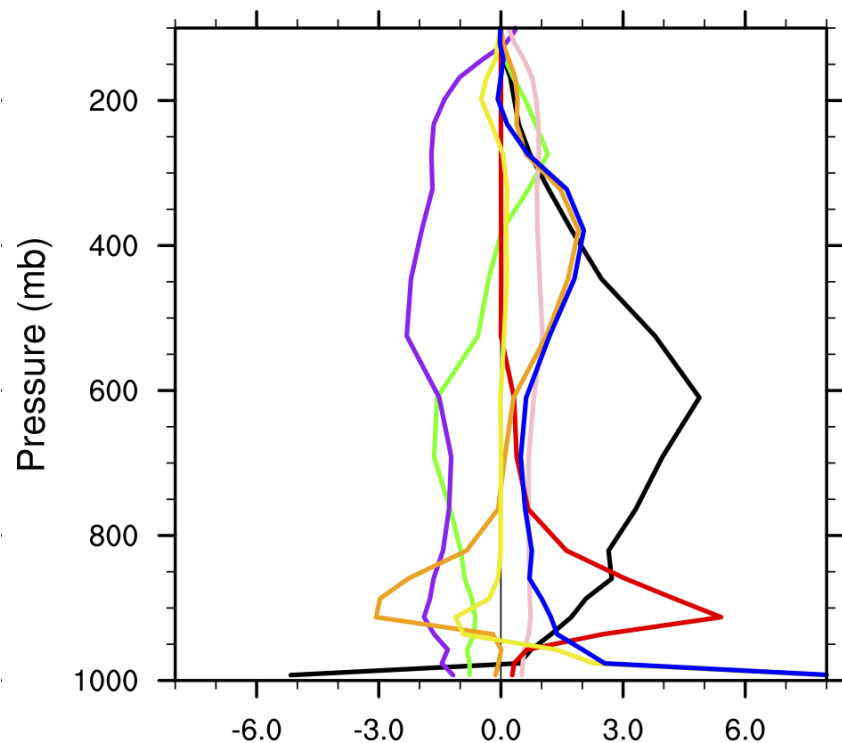


# Deep Convection Sensitivity: capeten

CAM5  
West Pacific

$dT/dt$ :  
DJF

CAM6 revert capeten  
West Pacific



- Deep Convection
- Microphysics (MG1)
- LW Radiation
- SW Radiation
- Shallow Convection
- Large-Scale Cloud
- Vertical Diffusion
- CLUBB-like

- Revert to CAM5 deepens deep convection
- CLUBB compensates in CAM6

- Deep Convection
- Microphysics (MG2)
- LW Radiation
- SW Radiation
- CLUBB

# Summary and Next

- Initial parameterization tendency analysis (T,q)
- CLUBB combines shallow convection, diffusion, LS cloud
- CLUBB-like and CLUBB are often similar
- CAM5: Process are often strongly opposed
- Greater differences over the ocean
- Near-surface differences are largest
- MG2 more active than MG1; deep less active
- Revert experiments can tease out role of CAM5/6 changes
  
- *Condensed species, momentum tendencies, dynamics*
- *Exploit CLUBB higher order information to infer, “shallow convection”, “large-scale” and “diffusion” contributions*
- *Climate change response through tendencies*

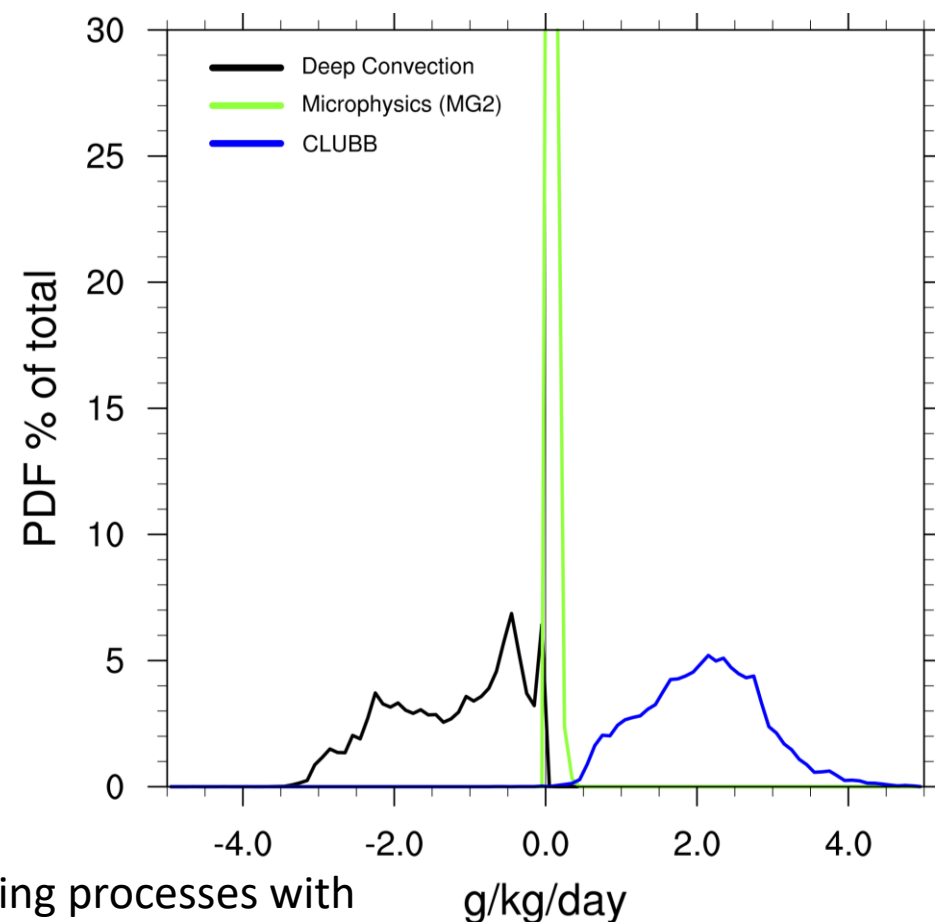
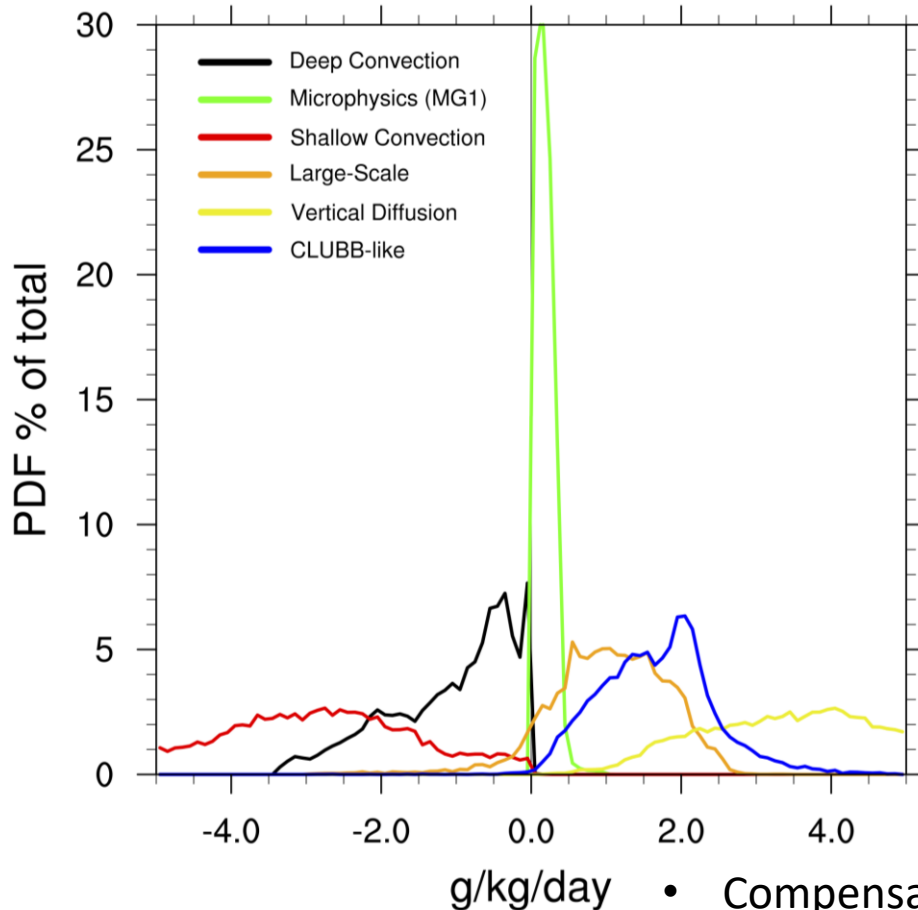


# Boundary layer (~900 mb) PDF of tendencies

$dq/dt$ : Ocean  
(45N-45S)

CAM5

CAM6



- Compensating processes with large tendencies
- Balanced by convective drying