# CAM standalone development simulations


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# Outline

- The evolution of CAM
- Status of the model at the last AWMG meeting
- Development since the last AWMG meeting
- AMIP simulations
- Conclusions

# CAM Evolution

| Release | 2004 | 2007 | April 2010 | June 2010 |
|---|---|---|---|---|
| **Model** | **CAM3 (L26)** | **CAM3.5 (L26)** | **CAM4/Track1 (L26)** | **CAM5/Track5 (L30)** |
| Boundary Layer | Holtslag and Boville (93) | Holtslag and Boville | Holtslag and Boville | UW *Diagnostic TKE*<br>Bretherton et al. (09) |
| Shallow Convection | Hack (94) | Hack | Hack | UW *TKE/CIN*<br>Park et al. (09) |
| Deep Convection | Zhang and McFarlane (95) | Zhang and McFarlane<br>Neale et al.(08), Richter and Rasch (08) mods. | Zhang and McFarlane<br>Neale et al., Richter and Rasch mods. | Zhang and McFarlane<br>Neale et al., Richter and Rasch mods. |
| Stratiform Cloud | Rasch and Kristjansson (98)<br>*Single Moment* | Rasch and K.<br>*Single Moment* | Rasch and K.<br>*Single Moment* | Morrison and Gettelman (08)<br>*Double Moment*<br>Park Macrophysics<br>Park et al. (10) |
| Radiation | CAMRT (01) | CAMRT | CAMRT | RRTMG Iacono et al. (2008) |
| Aerosols | Bulk Aerosol Model (BAM) | BAM | BAM | Modal Aerosol Model (MAM)<br>Ghan et al. (2010) |
| Dynamics | Spectral | Finite Volume (96,04) | Finite Volume | Finite Volume |

*Courtesy: Rich Neale*

# Development status at Breckenridge

- **CAM4 (Track 1) : Frozen model**

- **CAM5 (Track 5) : Still in development**

  **standalone simulation: competitive with CAM4 (Track 1)**

  **coupled simulation: worse than CAM4 (Track 1)**

  - **too low clear-sky OLR and LWCF**
  - **sea-ice too thin**
  - **excessive precipitation over tropical land**
    **=> affects river run-off**
  - **aerosol indirect effect: ~1.5 W/m2**
  - **no big volcanoes eruption**

# What happened since Breckenridge ?

**Since Breckenridge**

- **CAM5 (Track 5): 200 CAM standalone experiments**

**Some highlights of the accomplishments**

- **Improved parameterization of autoconversion**
- **Improved ice microphysics**
- **Turned on turbulent mountain stress parameterization**
- **Included the effect of big volcanoes**
- **Improved low cloud over the Arctic**
- **4th-order divergence damping**
  **+ Laplacian near model top**
- **New emission datasets for aerosols**

# Autoconversion parameterization

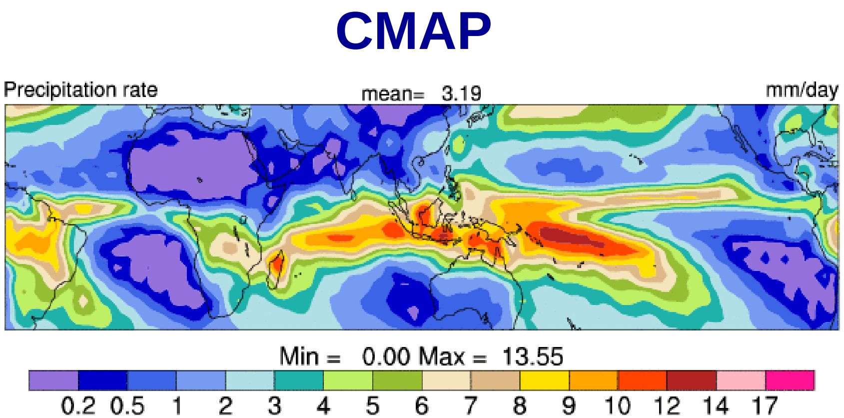
- **Convective precipitation is controlled by the autoconversion rate** *(~ process of coalescence that leads to the formation of new rain drops)*

- **Precipitation formation is easier over ocean than land (over land: more CCN => smaller droplet => less rain)**

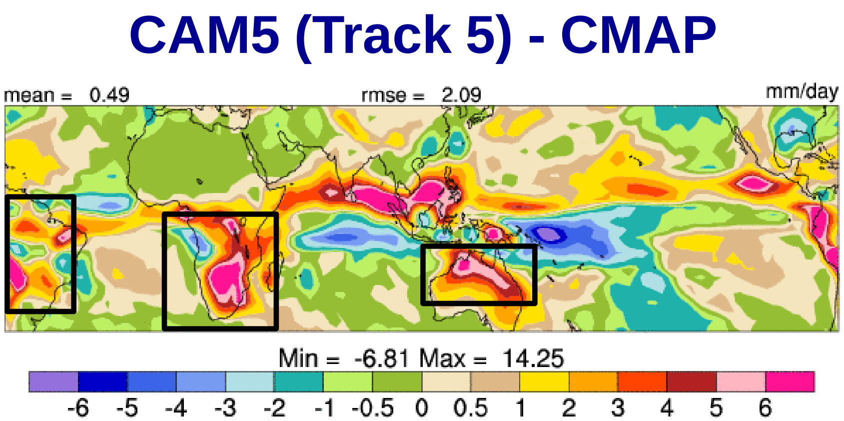
- **Improved parameterization**

  **Autoconversion efficiency: c0(ocn) > c0(lnd)**

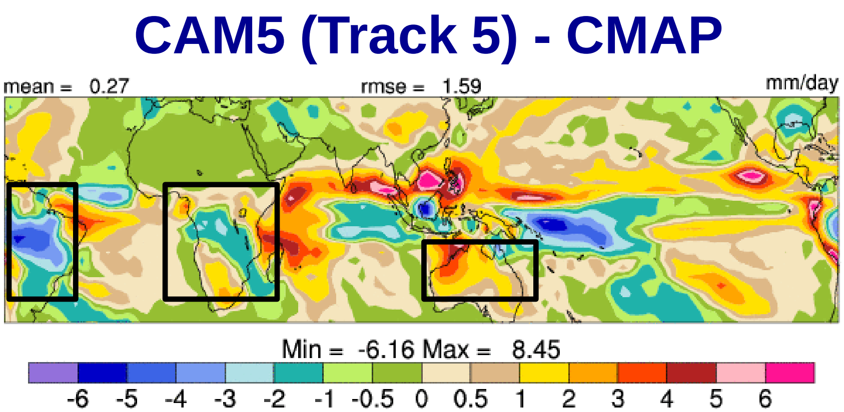
# Tropical precipitation, DJF




**New parameterization of autoconversion reduces the excessive land precipitation**




**Same autoconversion rate over land and ocean**




**Autoconversion rate weaker over land**

# Improvement of the ice microphysics

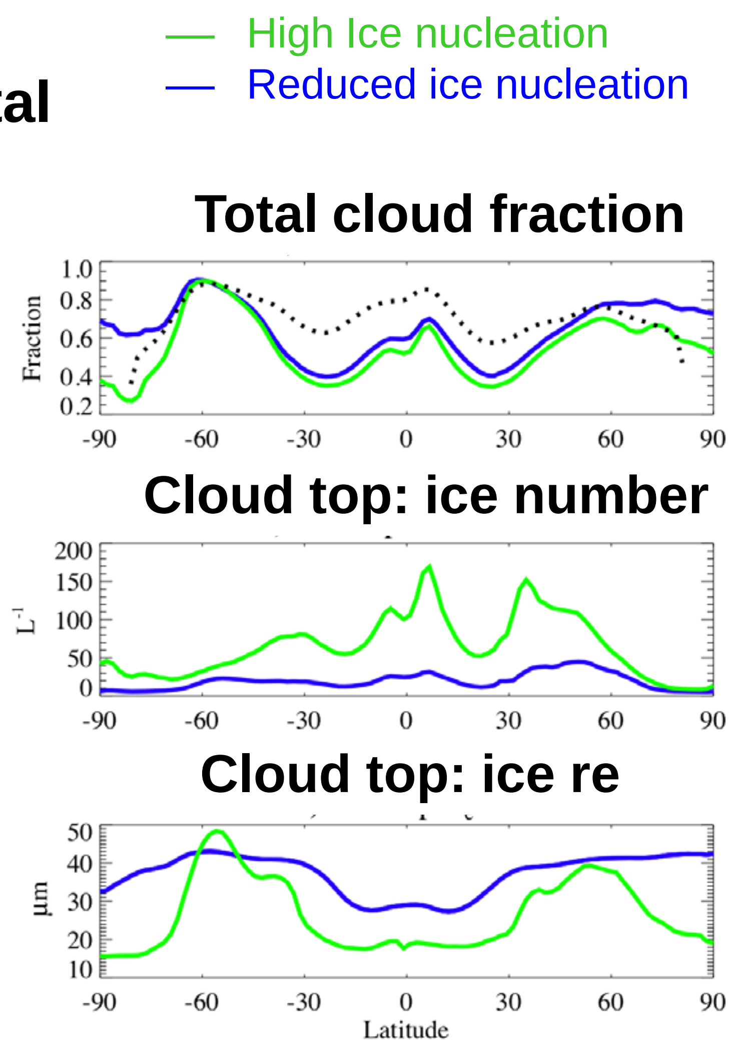
## Features

- **Reduces the nucleation of ice crystal**
- **Freezes supercooled rain at -5C**

## Impact

- **Better ice size and concentration**
- **Increases high cloud fraction**
- **Improve the spring sea-ice**

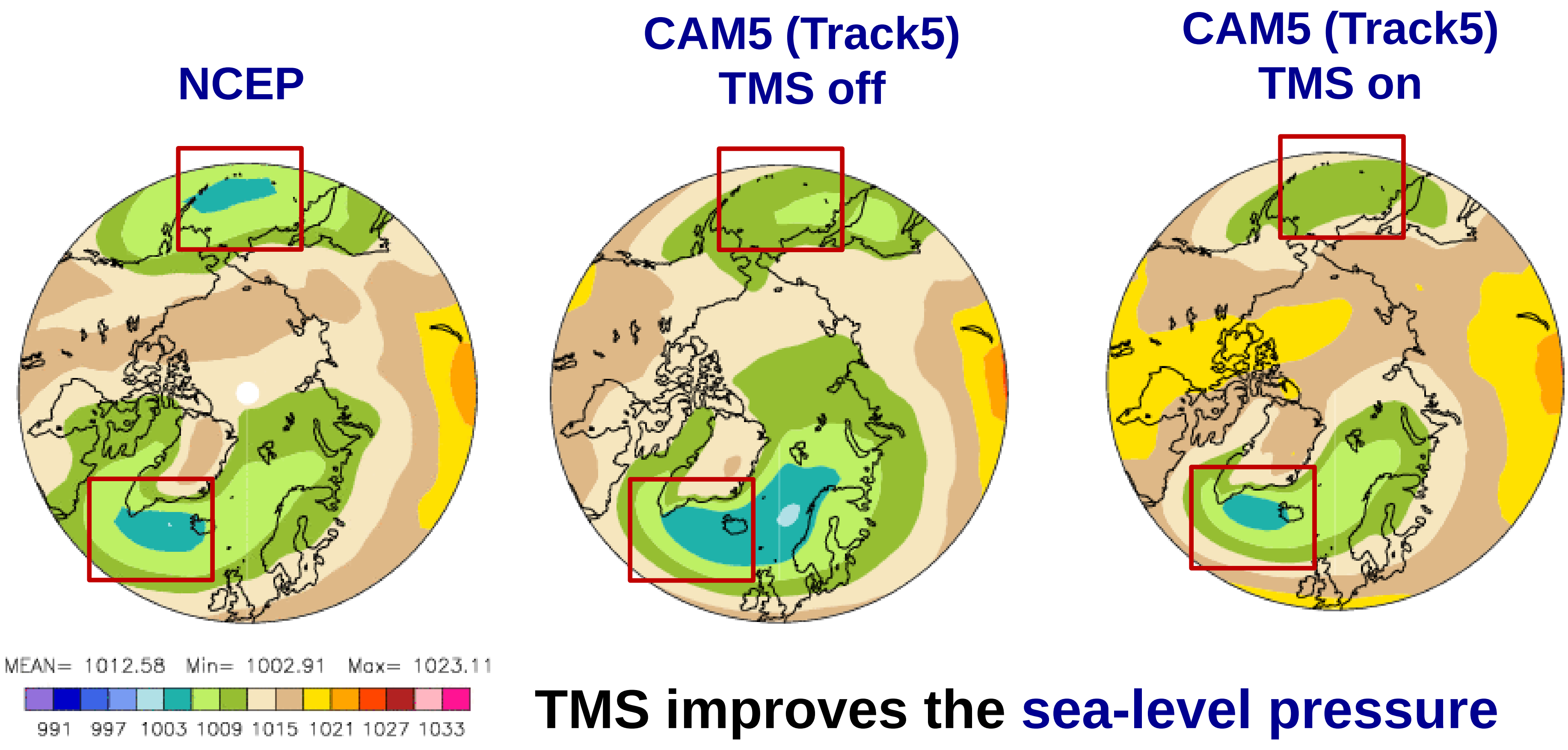
**See: Gettelman et al (2010)**




*Courtesy: Andrew Gettelman*

# Sea-level pressure, ANN

**Turned on the Turbulent Mountain Stress (TMS) parameterization *(~ take into account mountain roughness)***



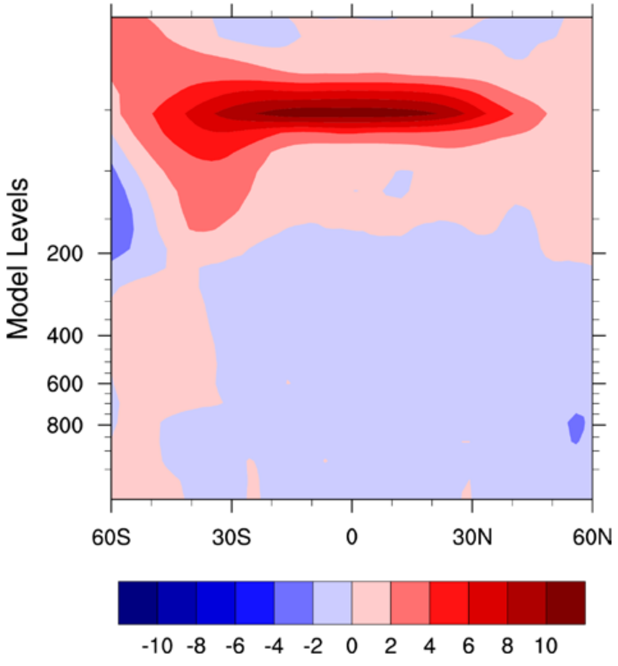

**TMS improves the sea-level pressure**

# Includes big volcanoes impact

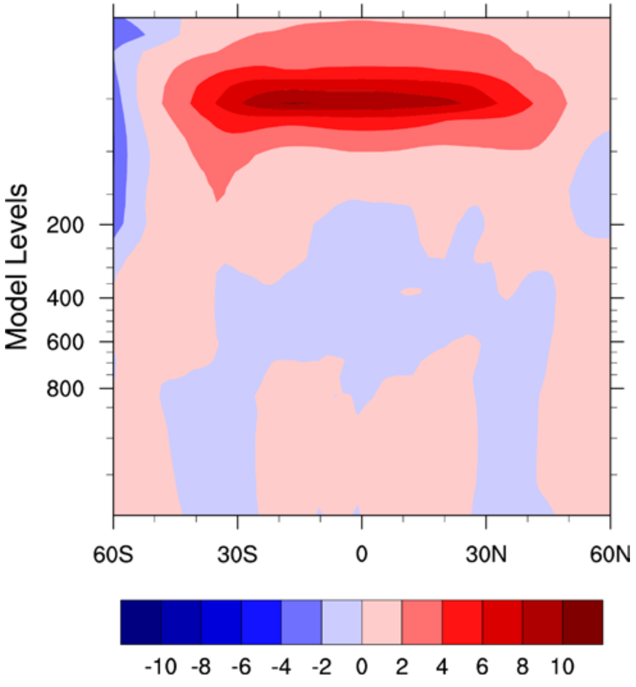
- Use prescribed volcanic aerosol mixing ratio

- June 1991 : Eruption of the volcano Pinatubo
  - warms stratosphere by 3 K (absorbs upwelling LW)
  - cools troposphere by a few 0.1 K (reflects SW)

CAM4 (Track 1)




CAM5 (Track 5)



# Simulations

## Model versions

- CAM4 (Track 1)
- CAM5 (Track 5)

## Run settings

- AMIP runs with observed SSTs
- Horizontal resolution: finite volume 1.9x2.5 degrees
- Vertical resolution: CAM4 (Track 1): 26 levels
  CAM5 (Track 5): 30 levels

## Comparison with observations

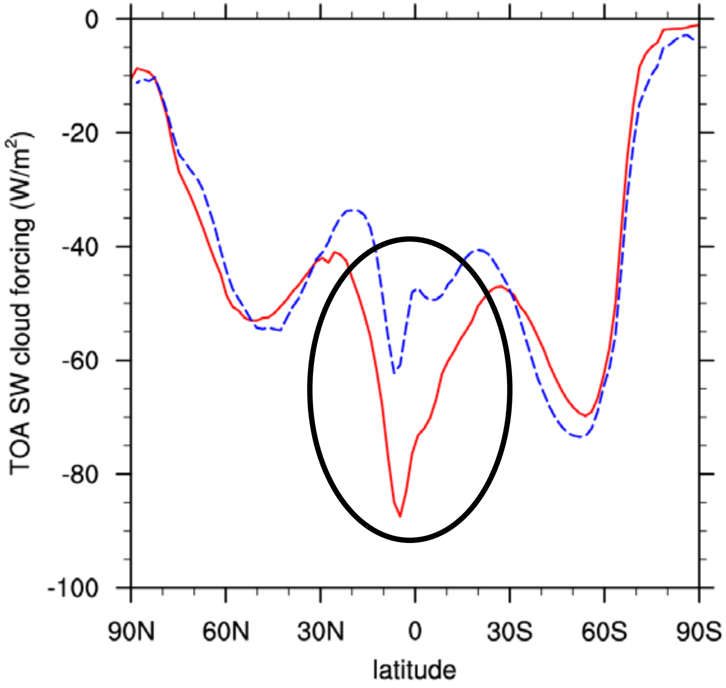
- 25-years climos (1978-2002)

# Shortwave cloud forcing (SWCF), ANN

**SWCF = Net SW$_{\text{all sky}}$ - Net SW$_{\text{clear sky}}$**

**Observations: CERES-EBAF** (Energy Balanced And Filled)

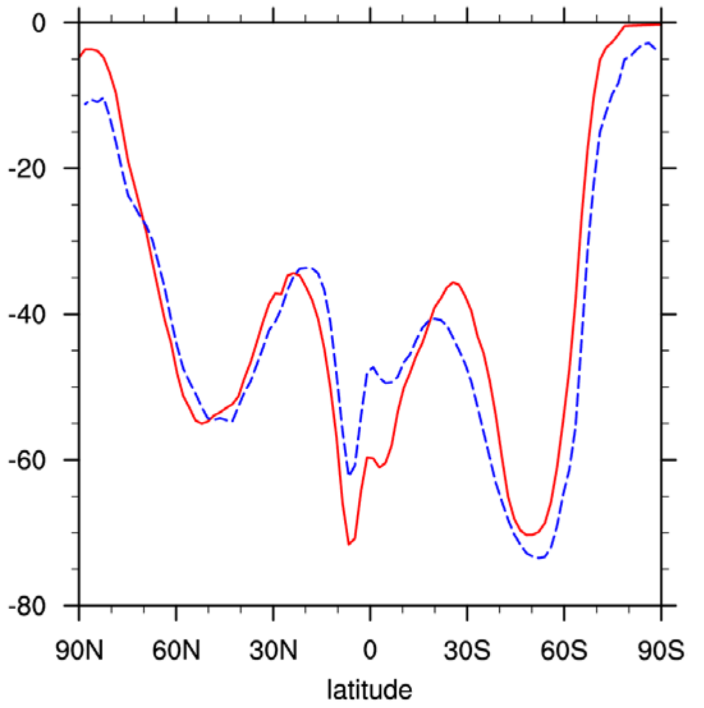
## CAM4 (Track 1)




**Overestimates SWCF in the tropics**

**CERES-EBAF ----**
**Model ___**

## CAM5 (Track 5)

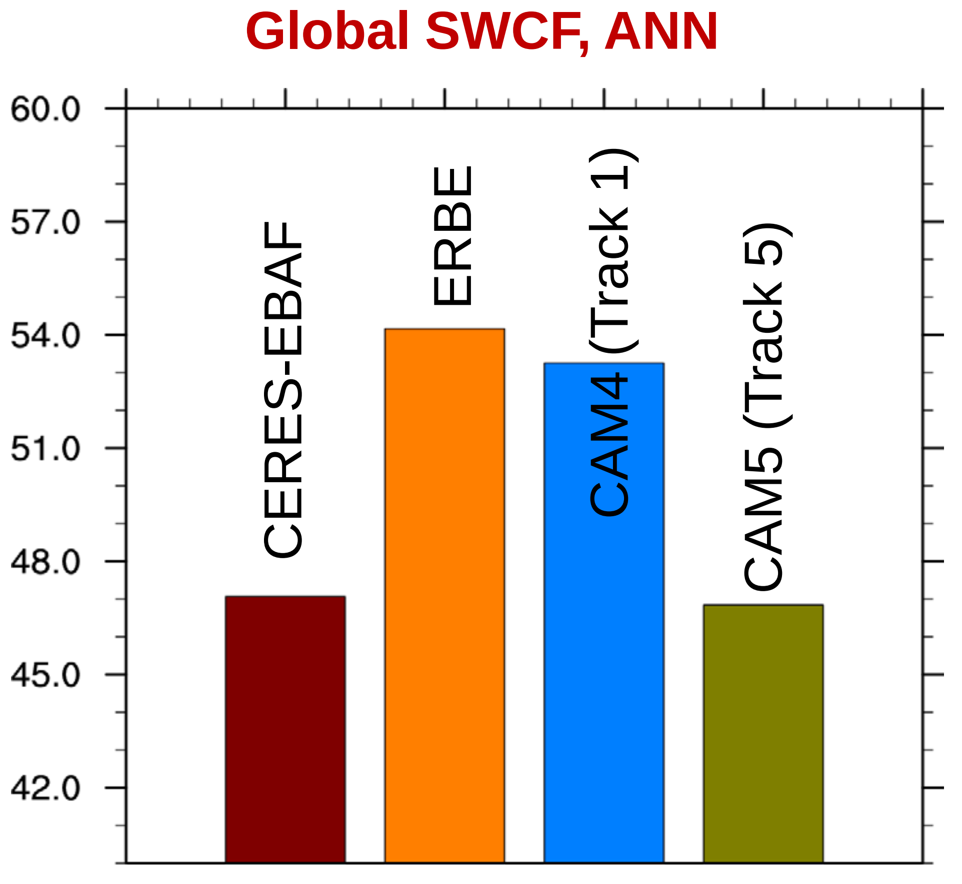



**More accurate SWCF**

# SWCF: CERES-EBAF versus ERBE

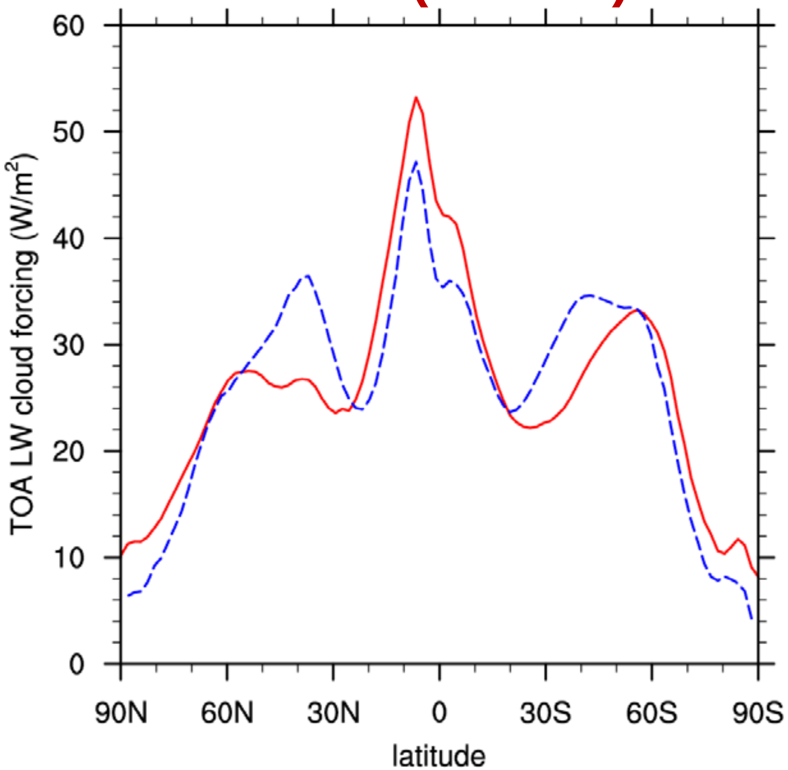
**Impact of the observation dataset**

- **CAM3 <=> ERBE**
- **CAM4 and beyond <=> CERES-EBAF**



# Longwave cloud forcing (LWCF), ANN

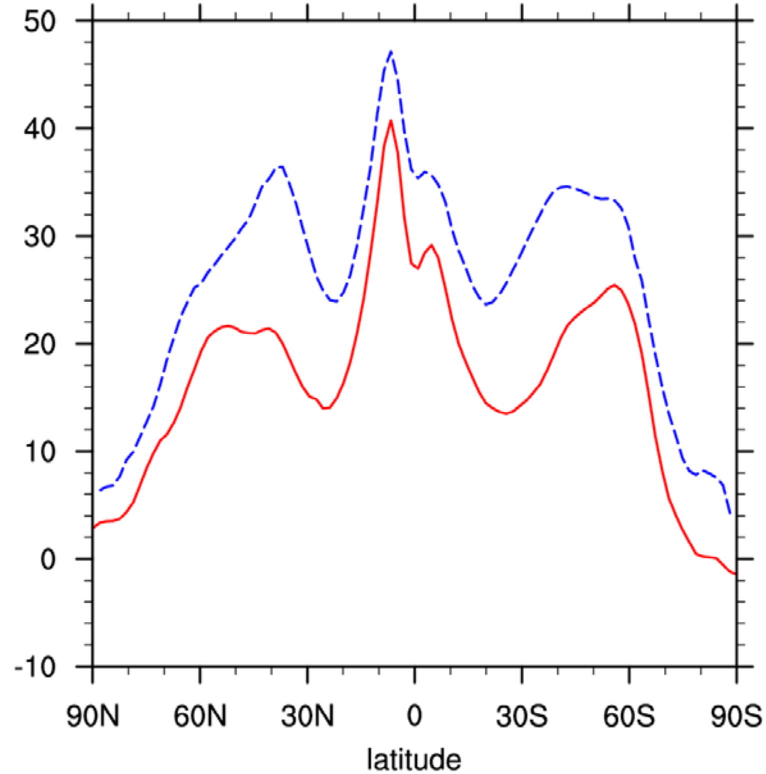
## CAM4 (Track 1)




**Underestimates LWCF in the mid-latitudes**

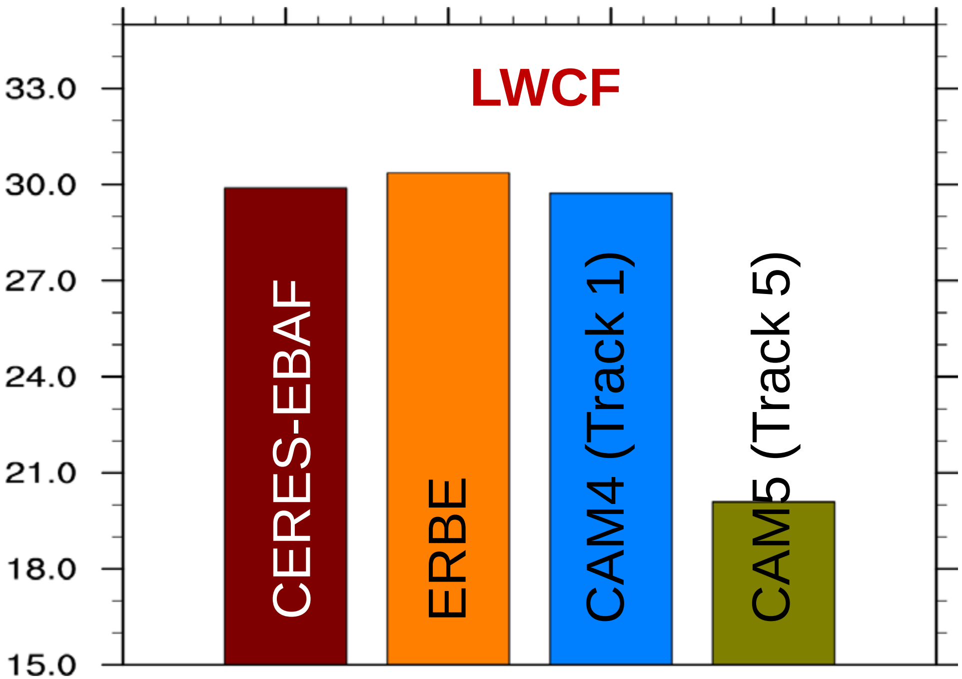
**CERES-EBAF ----**
**Model __**

## CAM5 (Track 5)




**Underestimates LWCF everywhere !**

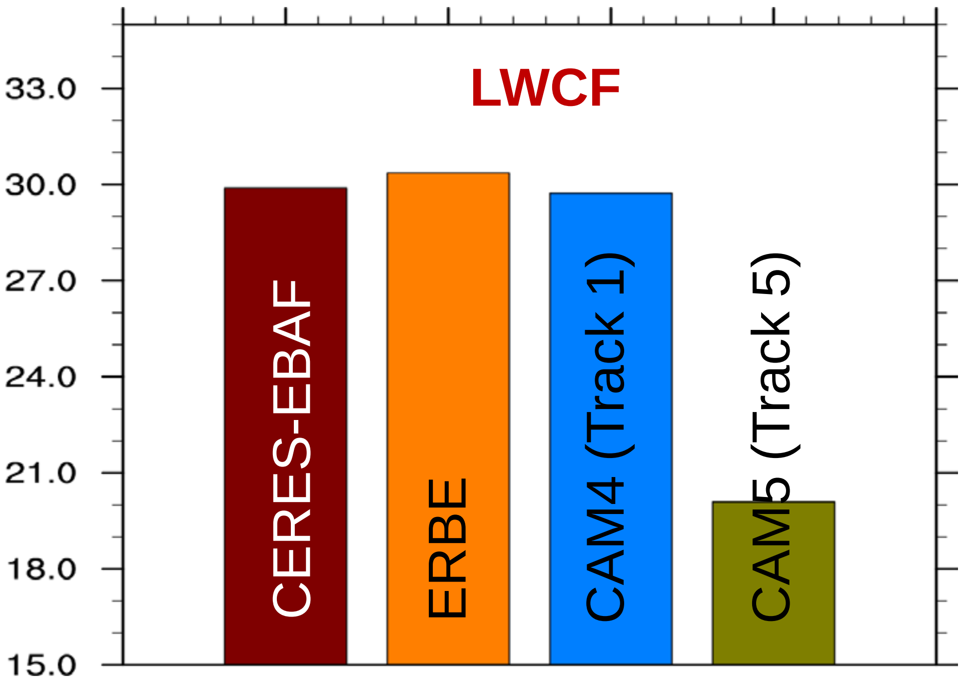
# Global LWCF and OLR (W/m2)

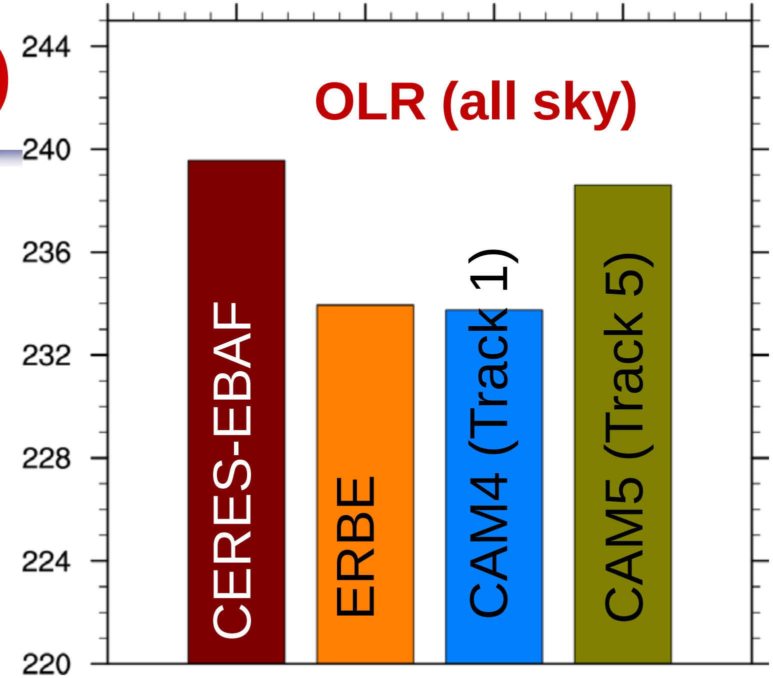


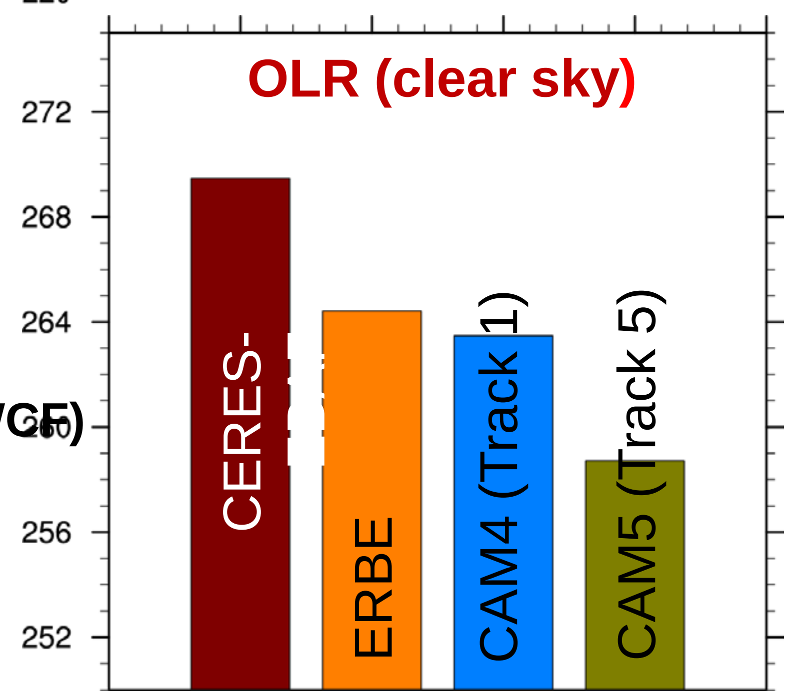

**Track5 underestimates global LWCF by 10 W/m2 !**

# Global LWCF and OLR (W/m2)

**LWCF = $OLR_{all\ sky} - OLR_{clear\ sky}$**

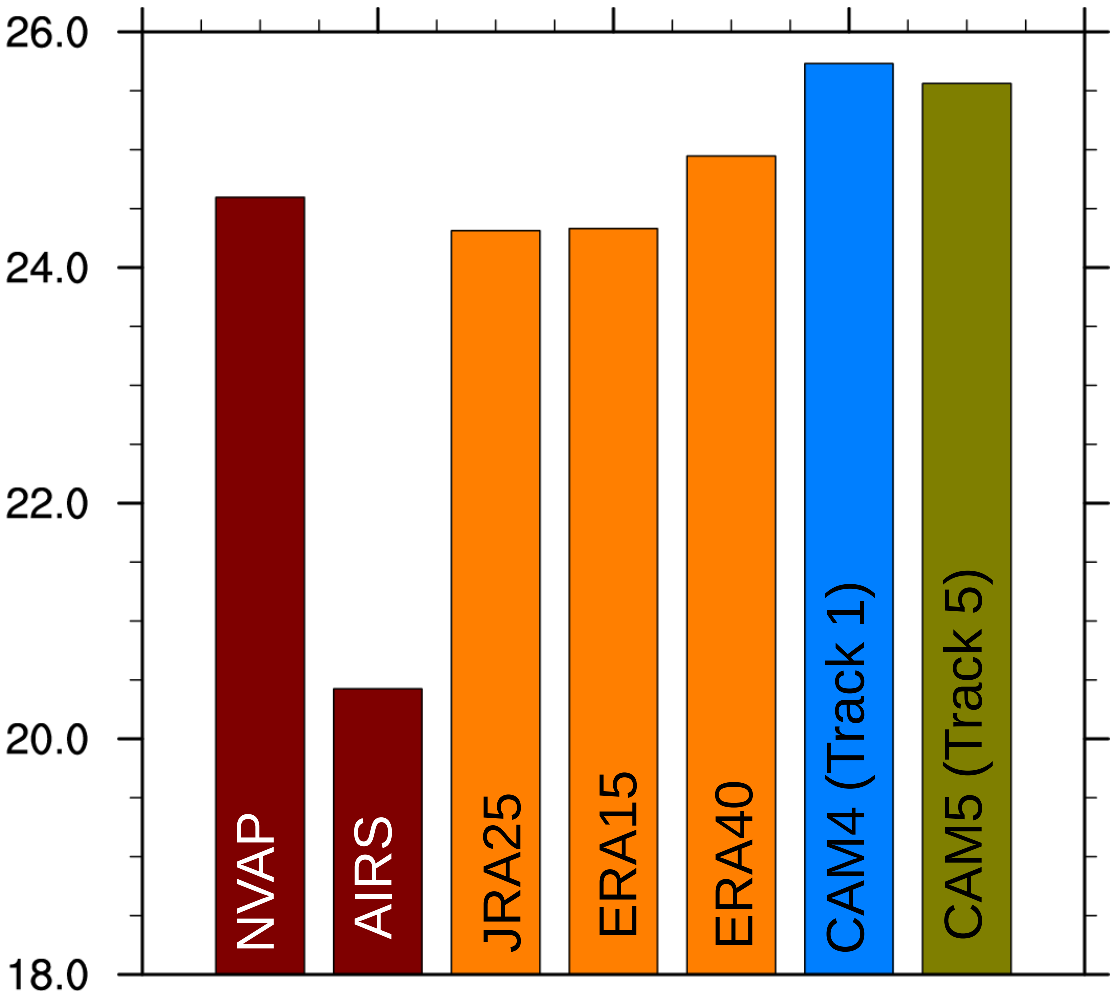



- **Track 5 underestimates clear-sky OLR (and LWCF)**
- **New radiation code: RRTMG ⇔ CAMRT**
- **Problem in clear sky longwave is likely due to the vertical distribution of T and q**
- **Difference in “clear-sky” definition**

# Precipitable water: global annual means

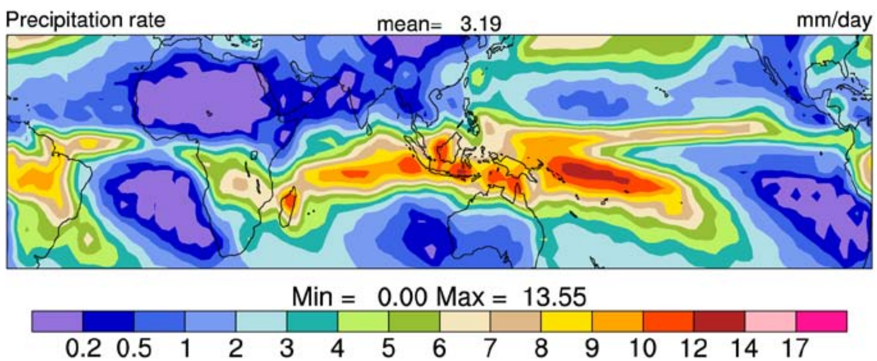



**Both versions of CAM are too moist compared to observations and reanalysis**

**CAM5 (Track5): improvement since Breckenridge**

# Tropical precipitation: DJF

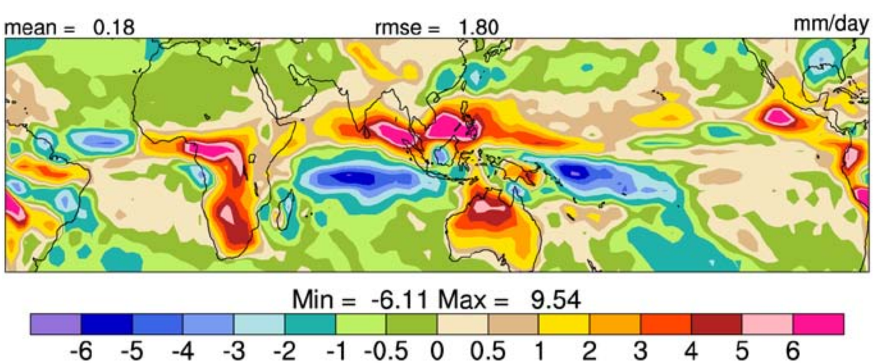
## CMAP




**Over ocean:**

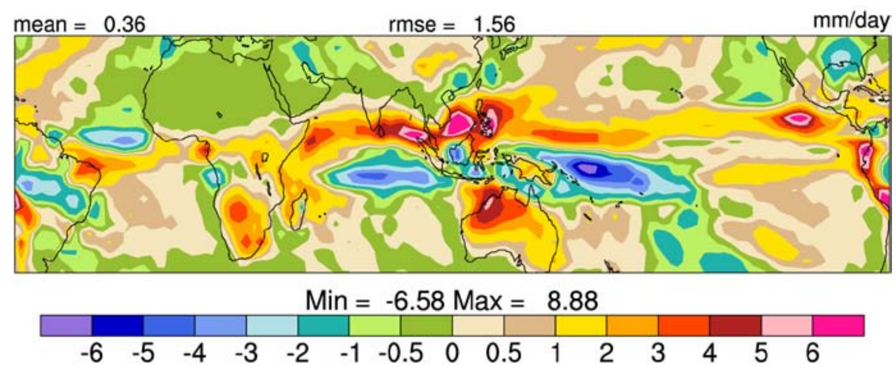
- **same precipitation pattern in CAM4 (Track 1) and CAM5 (Track 5)**
- **same deep convection scheme**

## CAM4 (Track 1) - CMAP




**excessive land precipitation**

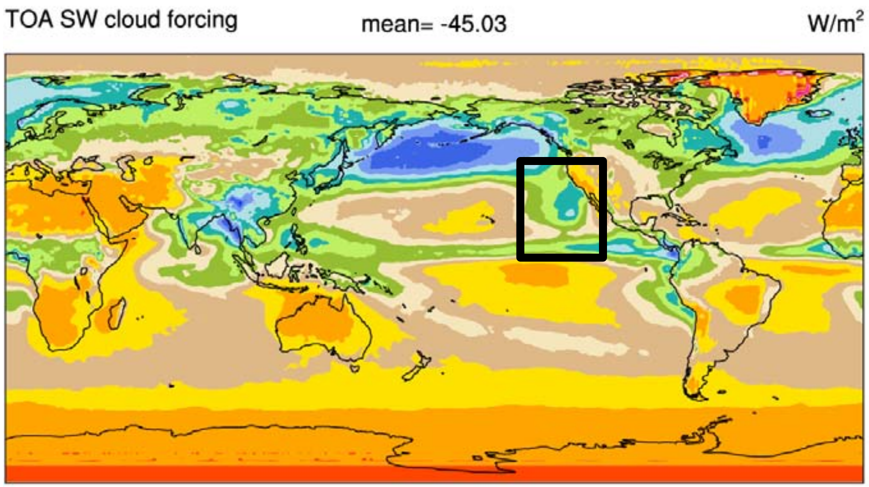
## CAM5 (Track 5) - CMAP




**improved land precipitation (land autoconversion efficiency)**

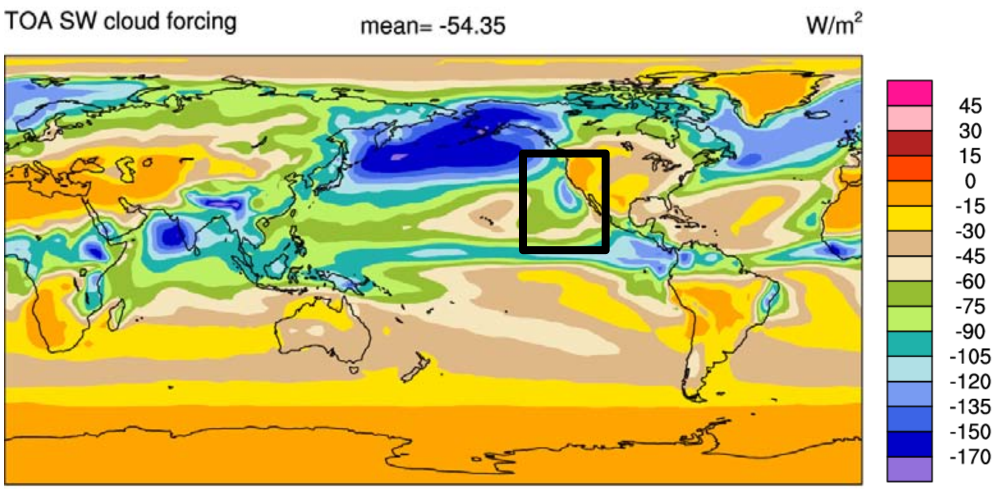
# SWCF in stratocumulus decks: JJA

## CERES-EBAF

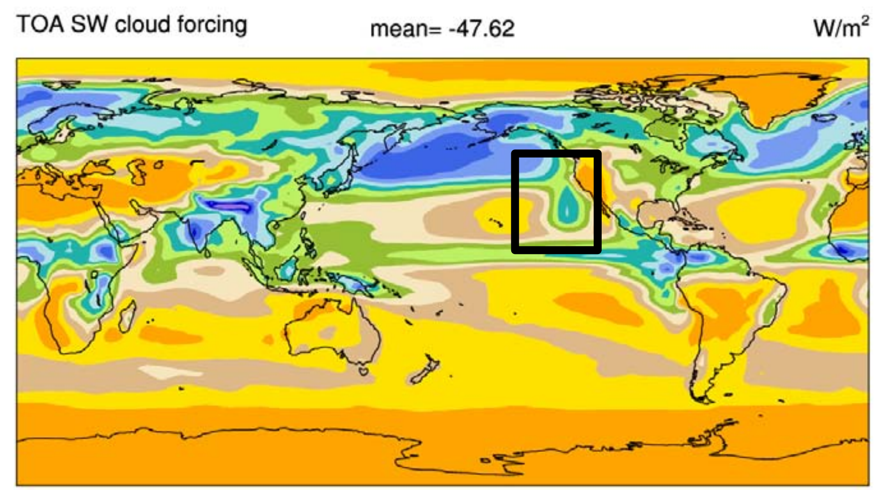



- Improved SWCF in **stratocumulus** regions
- Due to the new PBL scheme

## CAM4 (Track 1)

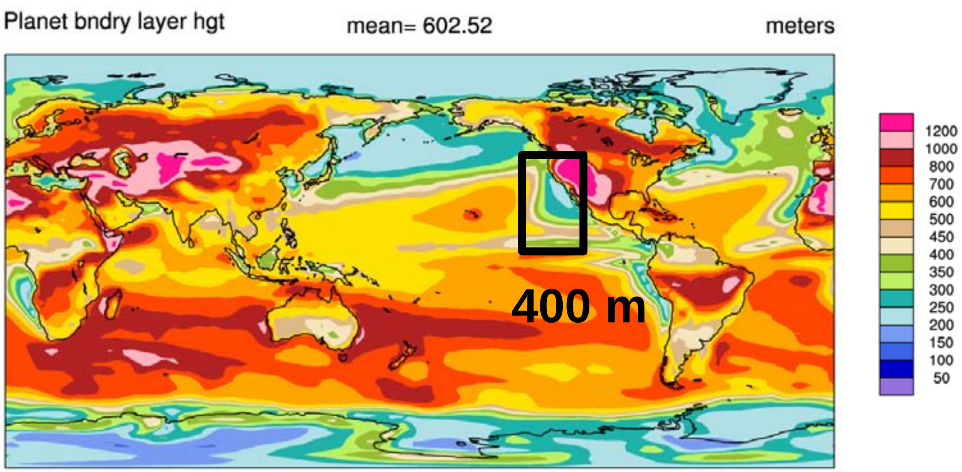



## CAM5 (Track 5)

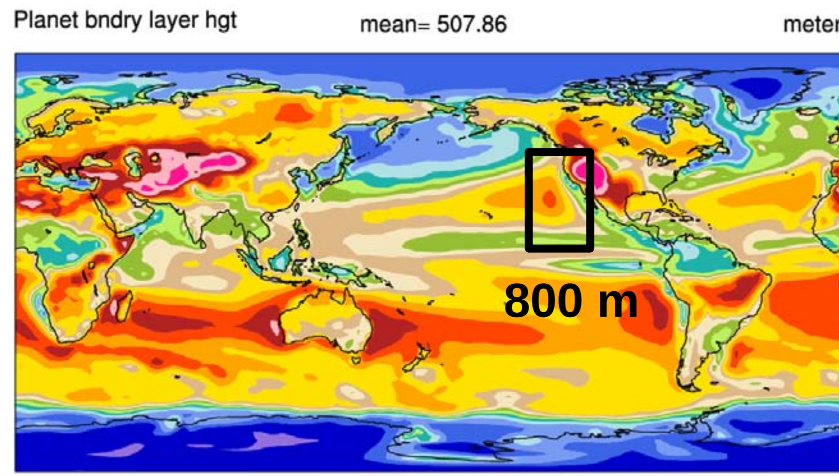


# PBL height: JJA

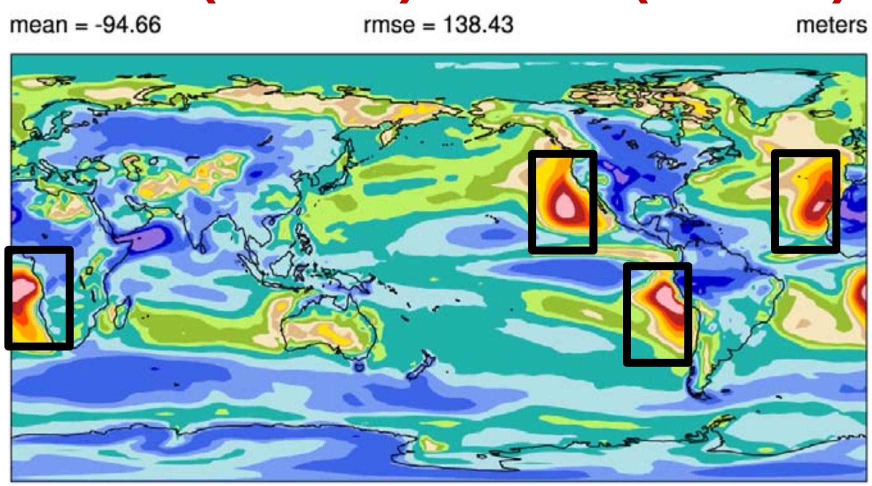
## CAM4 (Track 1)




## CAM5 (Track 5)




## CAM5 (Track 5) - CAM4 (Track 1)



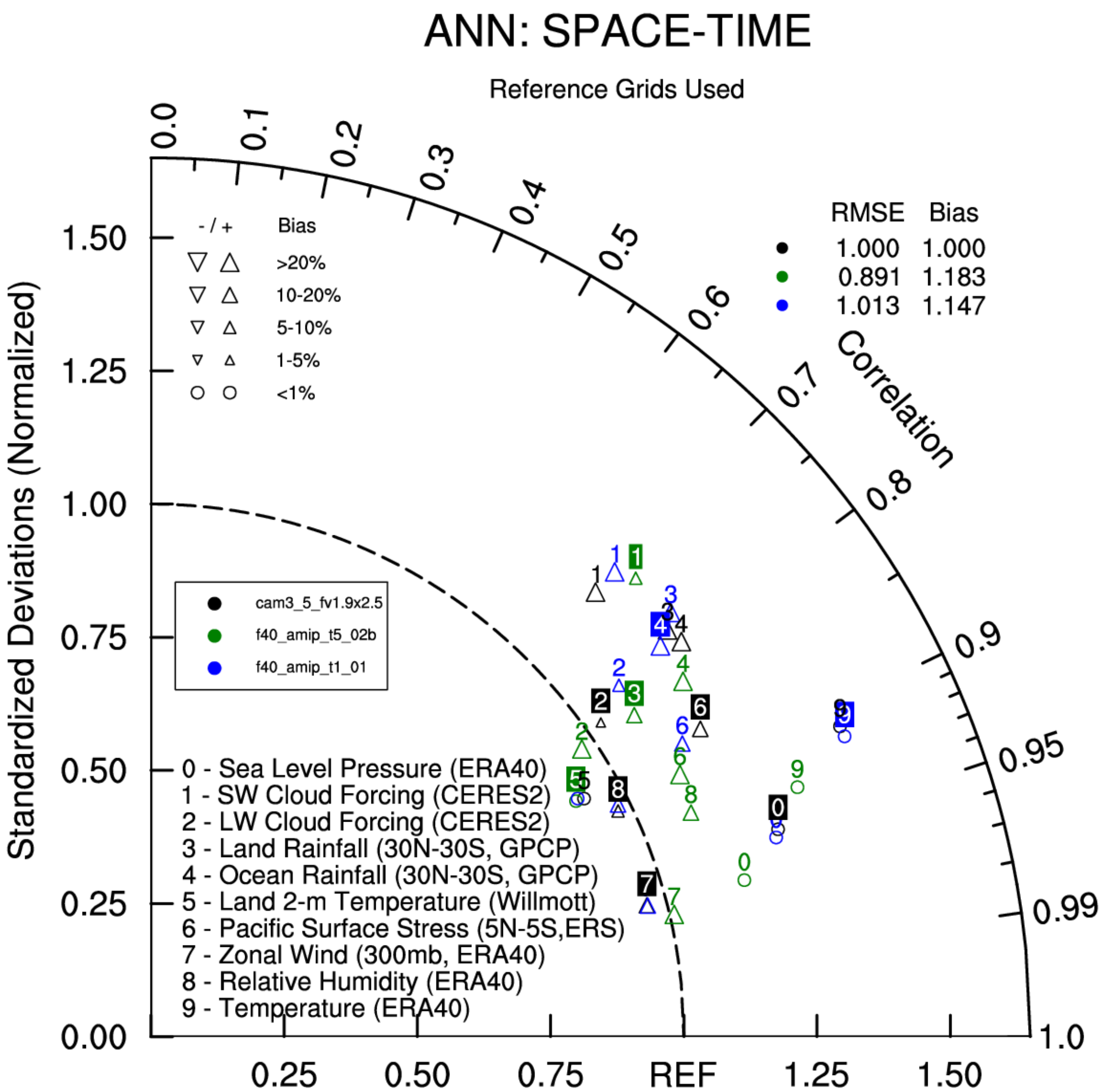

- **Improved PBL height in stratocumulus regions**

- **Entrainment of dry air at the top of the cloud => increase PBL height**

# Taylor diagrams

**condense information about variance and RMSE of a particular model run when compared with observations**

| | RMSE | Bias |
|---|---|---|
| CAM3.5 | 1.00 | 1.00 |
| CAM4 (Track1) | 1.01 | 1.15 |
| CAM5 (Track5) | 0.89 | 1.18 |



# Correlation: Space-Time

| | CAM3.5 | CAM5 (Track 5) | CAM4 (Track 1) |
|---|---|---|---|
| cor coef: Space-Time | cam3_5_fv1.9x2.5 | f40_amip_t5_02b | f40_amip_t1_01 |
| | ANN | ANN | ANN |
| Sea Level Pressure (ERA40) | 0.949 | 0.967 | 0.953 |
| SW Cloud Forcing (CERES2) | 0.707 | 0.726 | 0.706 |
| LW Cloud Forcing (CERES2) | 0.820 | 0.832 | 0.799 |
| Land Rainfall (30N-30S, GPCP) | 0.785 | 0.832 | 0.775 |
| Ocean Rainfall (30N-30S, GPCP) | 0.802 | 0.831 | 0.793 |
| Land 2-m Temperature (Willmott) | 0.876 | 0.874 | 0.873 |
| Pacific Surface Stress (5N-5S,ERS) | 0.872 | 0.896 | 0.875 |
| Zonal Wind (300mb, ERA40) | 0.967 | 0.974 | 0.967 |
| Relative Humidity (ERA40) | 0.900 | 0.924 | 0.895 |
| Temperature (ERA40) | 0.912 | 0.933 | 0.918 |

**Green means better**

**Red means worse**

# Conclusions (1): CAM development since Breckenridge

**CAM4 (Track 1): Frozen model**

**CAM5 (Track 5): Improvements include**

- **Improved ice microphysics => better ice # and Re**
- **autoconversion = f(lnd, ocn) => better land precip**
- **Turned on turbulent mountain stress => better SLP**
- **Included the effect of big volcanoes**

# Conclusions (2): 25-year AMIP simulations

## CAM4 (Track 1)

- overestimates SWCF in the tropics
- underestimates LWCF in mid-latitude
- excessive precipitation over land
- poor representation of stratocumulus deck

## CAM5 (Track 5)

- better overall score than CAM4 (Track 1)
- better SWCF in the tropics
- worse clear sky OLR and LWCF
- better tropical land precipitation
- improved stratocumulus deck (and PBL height)

# Conclusions (3): what's next ?

## In CAM5 (Track 5)

- improve precipitation
- clear sky OLR and LWCF
- indirect effect