# Standalone simulations: CAM3, CAM4 and CAM5


## CAM5 Model Development Team

**Cécile Hannay, Rich Neale, Andrew Gettelman, Sungsu Park, Joe Tribbia, Peter Lauritzen, Andrew Conley, Hugh Morrison, Phil Rasch, Steve Ghan, Xiaohong Liu, and many others**



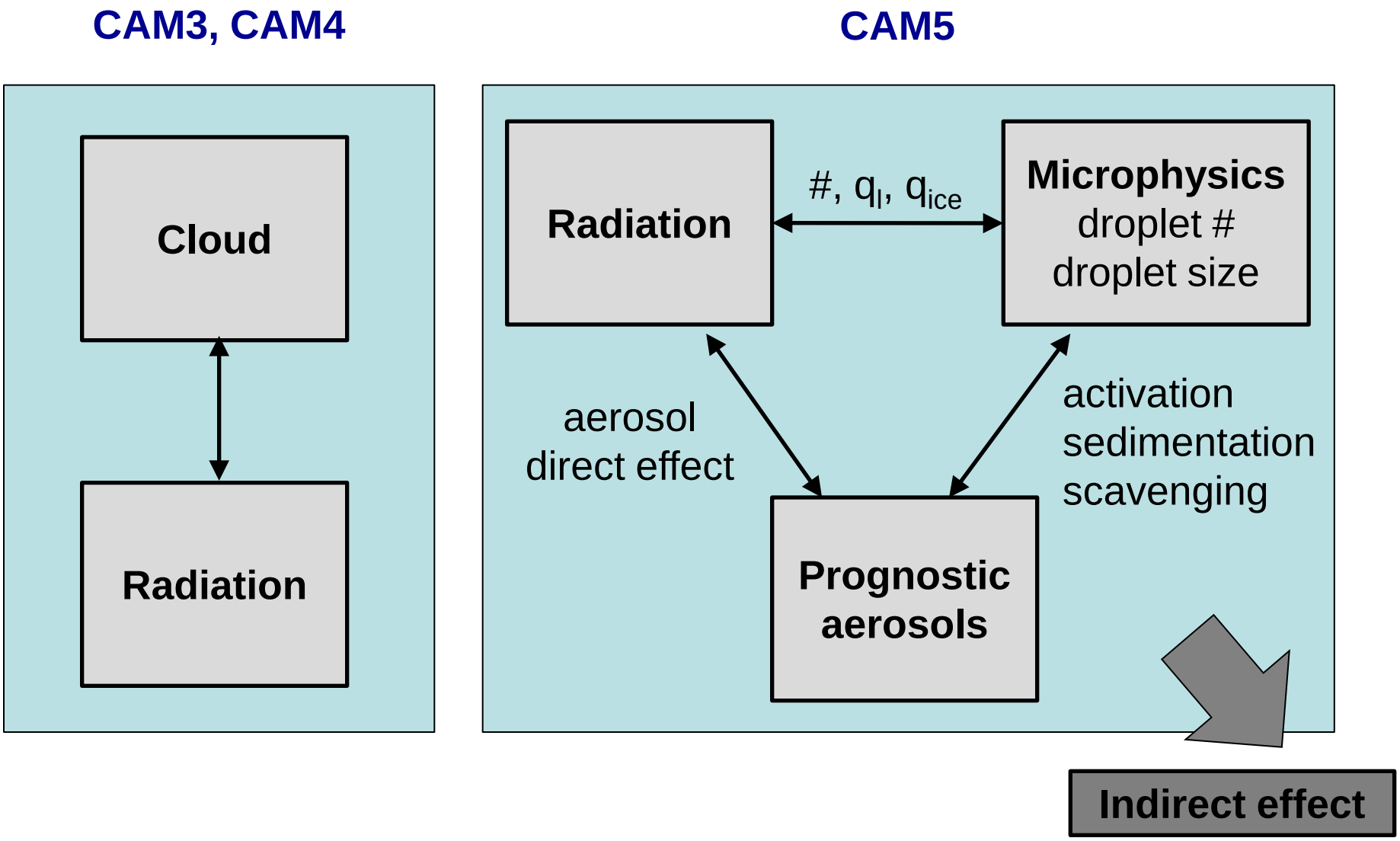
**15th Annual CCSM Workshop, Breckenridge, June 28 - July 1, 2010**

# CAM evolution

| Release | 2004 | April 1, 2010 | June 25, 2010 |
|---|---|---|---|
| **Model** | **CAM3 (L26)** | **CAM4 (L26)** | **CAM5 (L30)** |
| Boundary Layer | Holtslag and Boville (93) | Holtslag and Boville | UW *Diagnostic TKE*<br>Bretherton et al. (09) |
| Shallow Convection | Hack (94) | Hack | UW *TKE/CIN*<br>Park et al. (09) |
| Deep Convection | Zhang and McFarlane (95) | 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* | Morrison and Gettelman (08)<br>*Double Moment*<br>Park Macrophysics<br>Park et al. (10) |
| Radiation | CAMRT (01) | CAMRT | RRTMG Iacono et al. (2008) |
| Aerosols | Bulk Aerosol Model (BAM) | BAM | Modal Aerosol Model (MAM)<br>Ghan et al. (2010) |
| Dynamics | Spectral | Finite Volume | Finite Volume |

*Courtesy: Rich Neale*

# New challenges in CAM5



# Simulations

- **AMIP simulations with observed SSTs**

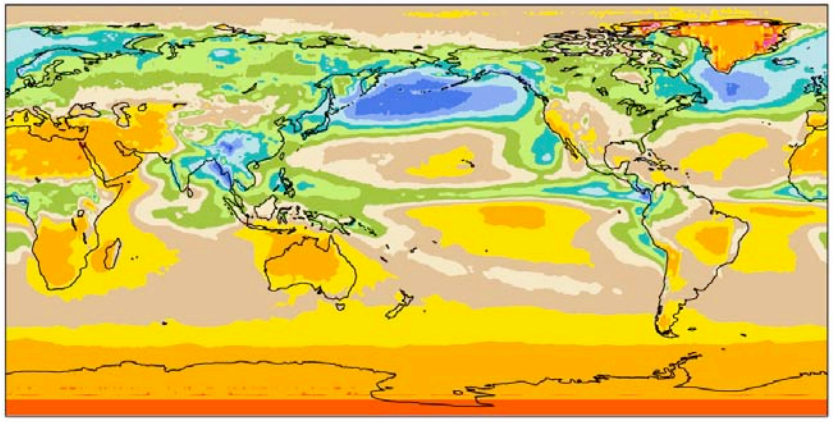
- **Dynamical core and resolution:**
  - **CAM3: Eulerian T42, 26 vertical levels**
  - **CAM4: finite volume 1.9x2.5 degrees, 26 levels**
  - **CAM5: finite volume 1.9x2.5 degrees, 30 levels**

- **Comparison with observations**
  - **20-years climos (1980-1990)**

# SWCF, JJA: CAM versus CERES-EBAF

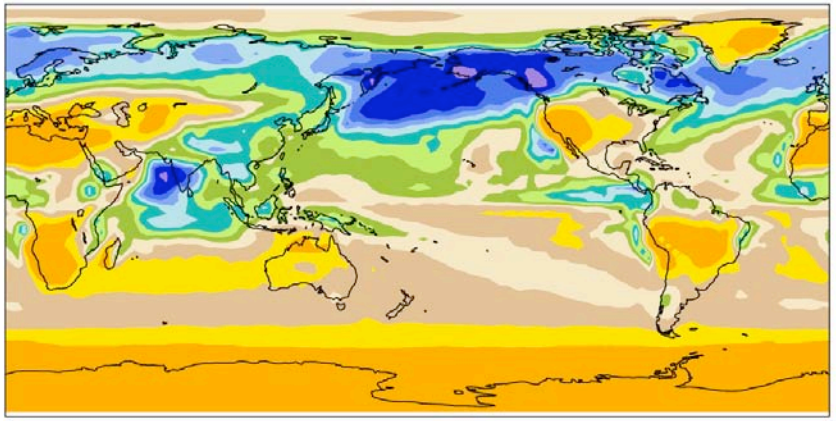
## CERES-EBAF

Mean: -45.0 W/m$^2$



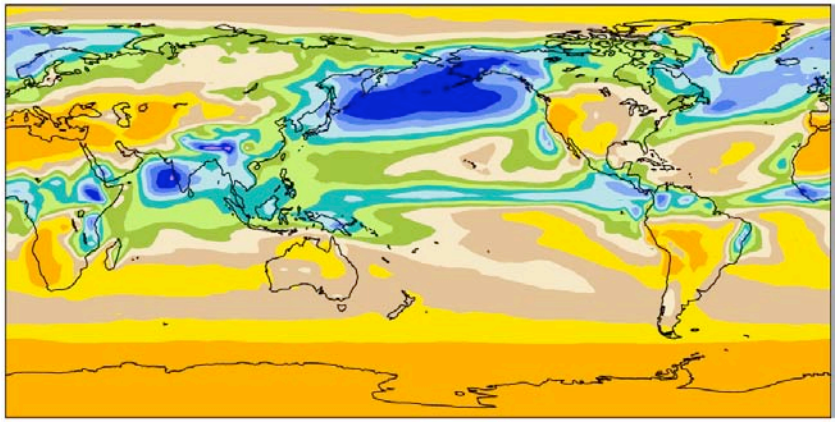
## CAM3

Mean: -54.4 W/m$^2$
RMSE: 23.4 W/m$^2$



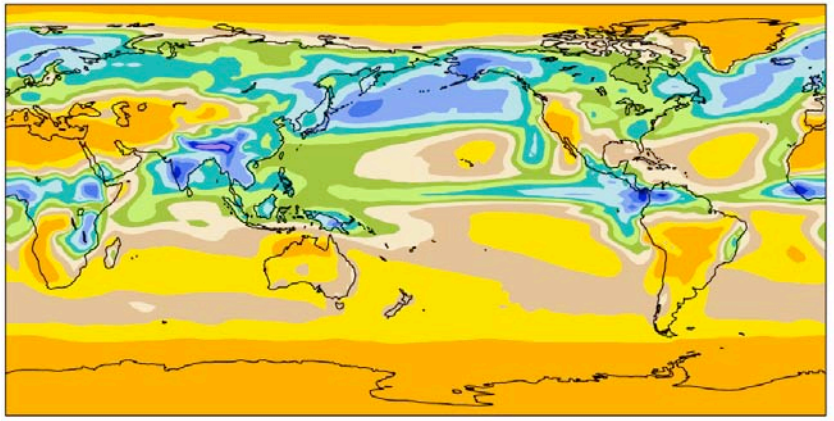
## CAM4

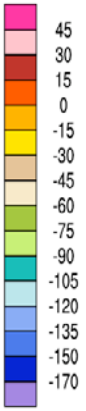
Mean: -54.7 W/m$^2$
RMSE: 23.0 W/m$^2$



## CAM5

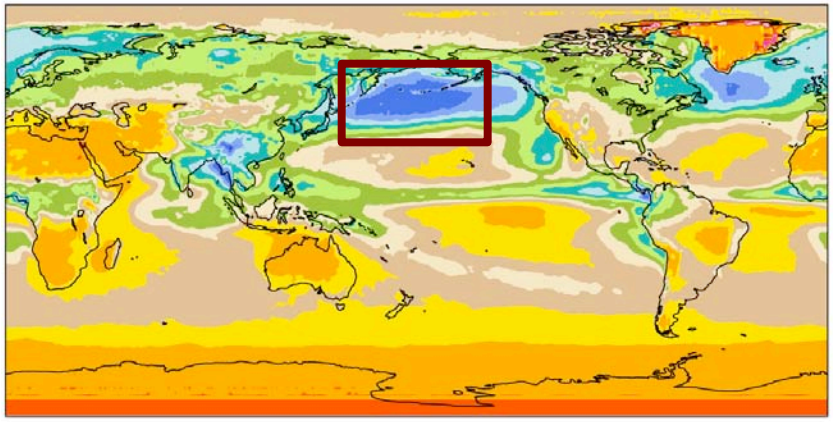
Mean: -50.4 W/m$^2$
RMSE: 19.2 W/m$^2$



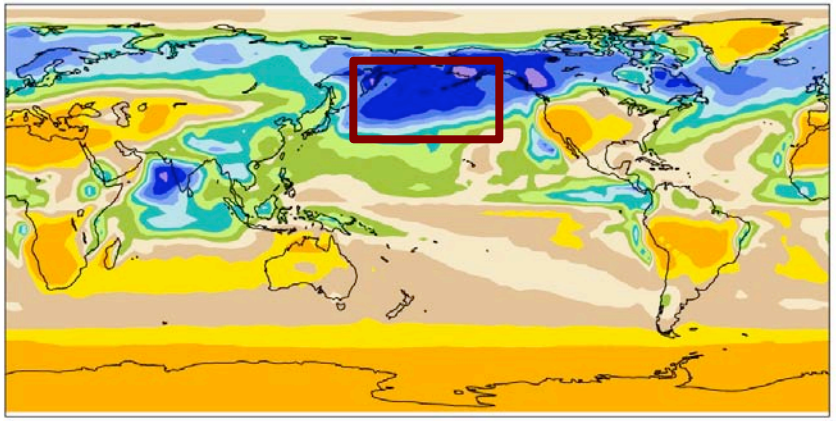


# SWCF, JJA: CAM versus CERES-EBAF

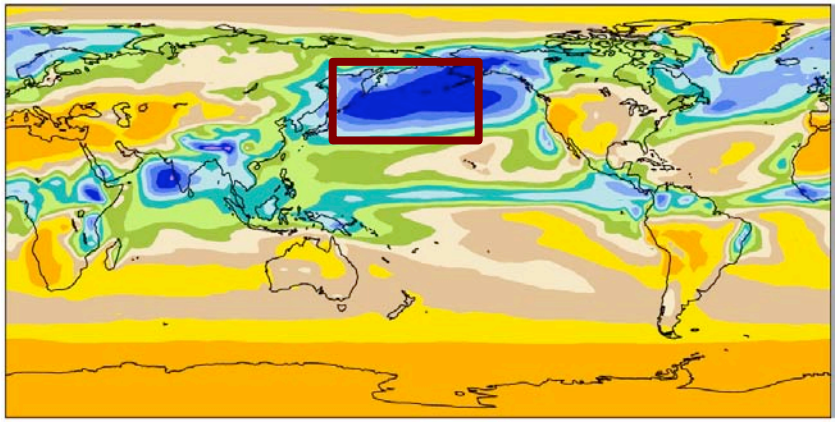
**CERES-EBAF** Mean: -45.0 W/m²



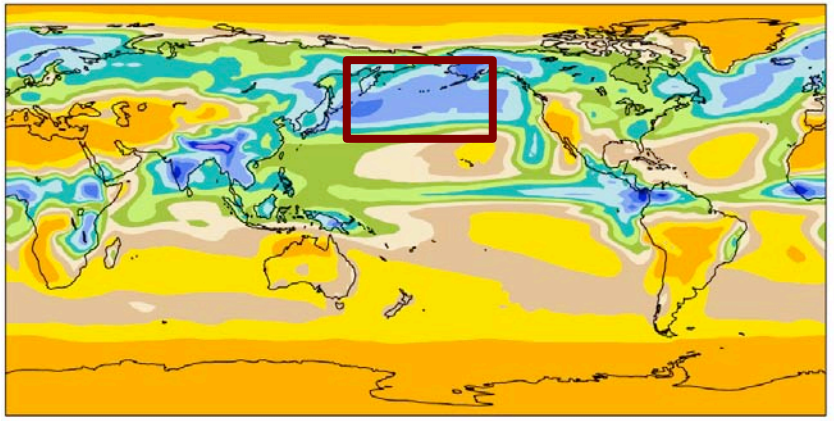
**CAM3** Mean: -54.4 W/m² RMSE: 23.4 W/m²

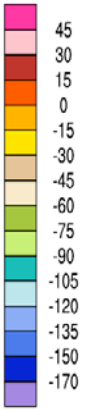


**CAM4** Mean: -54.7 W/m² RMSE: 23.0 W/m²



**CAM5** Mean: -50.4 W/m² RMSE: 19.2 W/m²

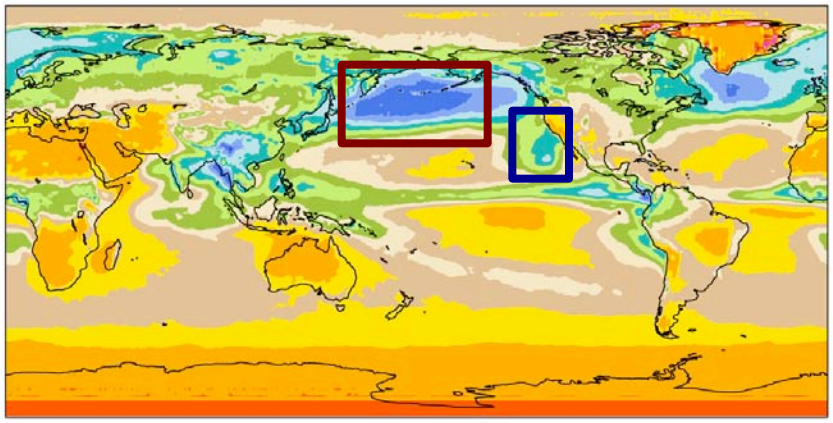




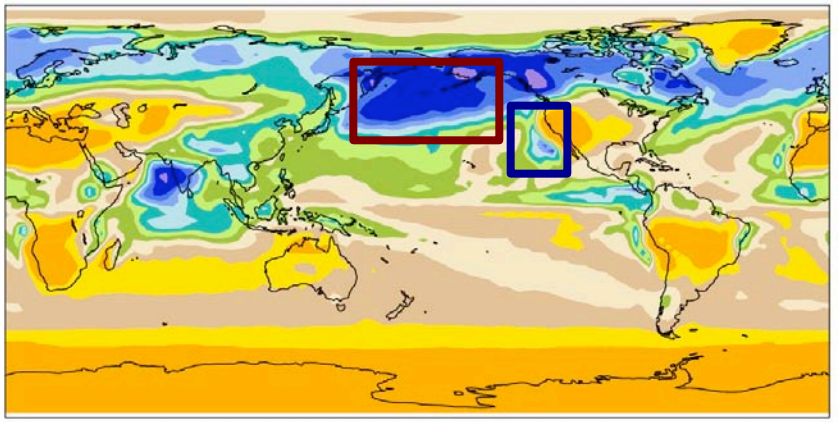

- Excessive SWCF in North Pacific (in CAM3 and CAM4) is reduced in CAM5.

# SWCF, JJA: CAM versus CERES-EBAF

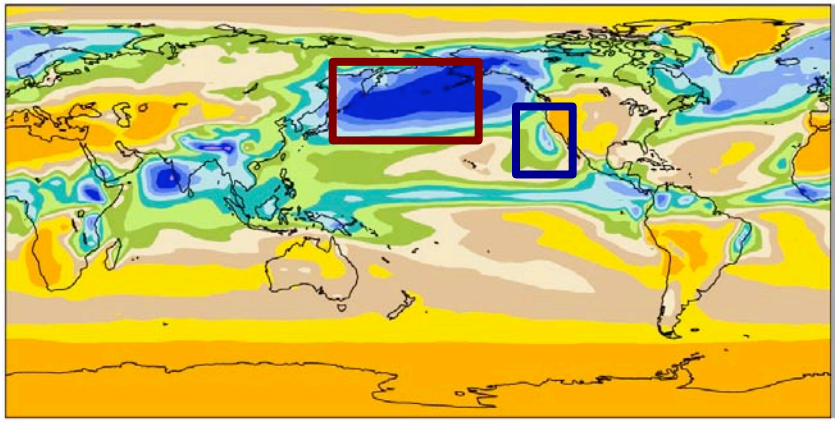
**CERES-EBAF** Mean: -45.0 W/m²



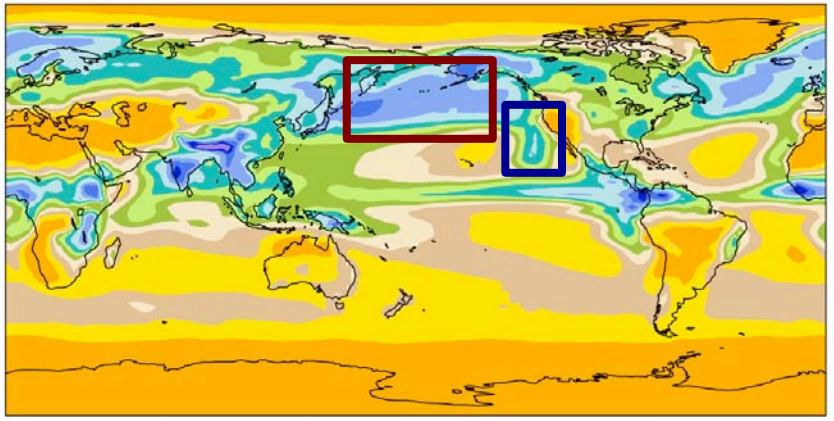
**CAM3** Mean: -54.4 W/m² RMSE: 23.4 W/m²

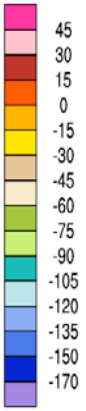


**CAM4** Mean: -54.7 W/m² RMSE: 23.0 W/m²



**CAM5** Mean: -50.4 W/m² RMSE: 19.2 W/m²

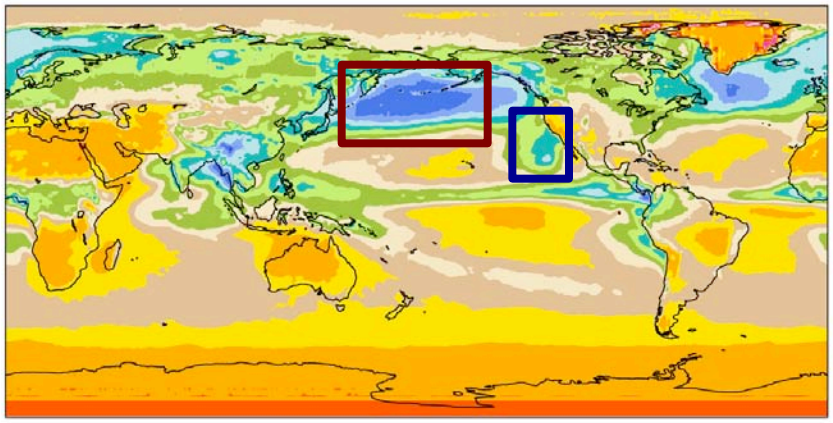




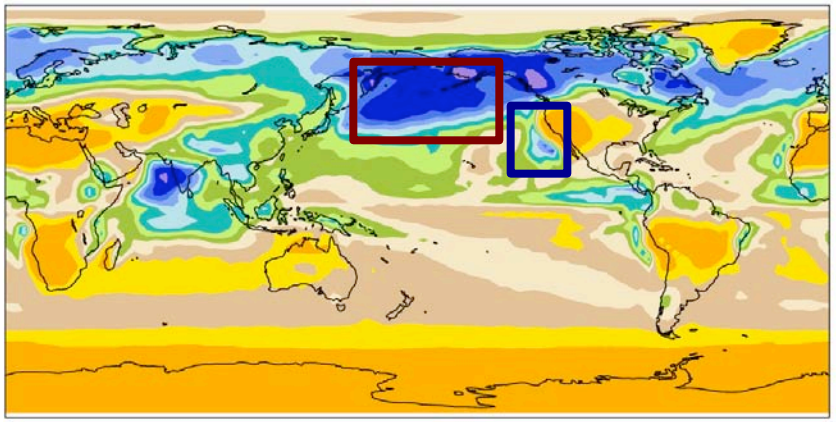

- Excessive SWCF in North Pacific (in CAM3 and CAM4) is reduced in CAM5.
- CAM5 improves stratocumulus

# SWCF, JJA: CAM versus CERES-EBAF

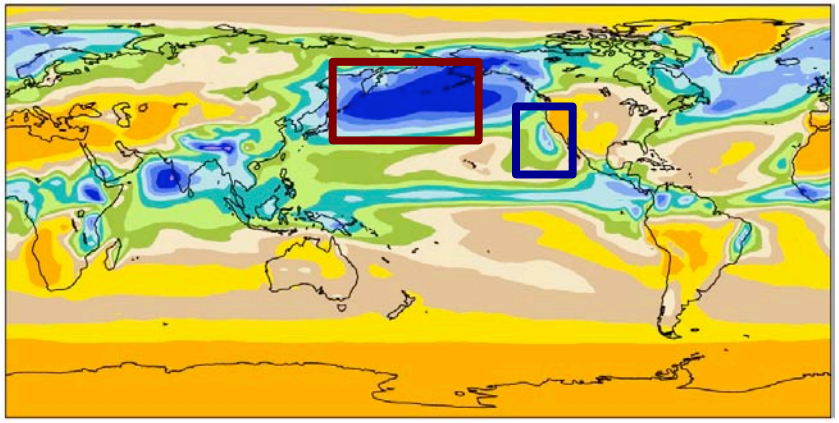
**CERES-EBAF** Mean: -45.0 W/m²



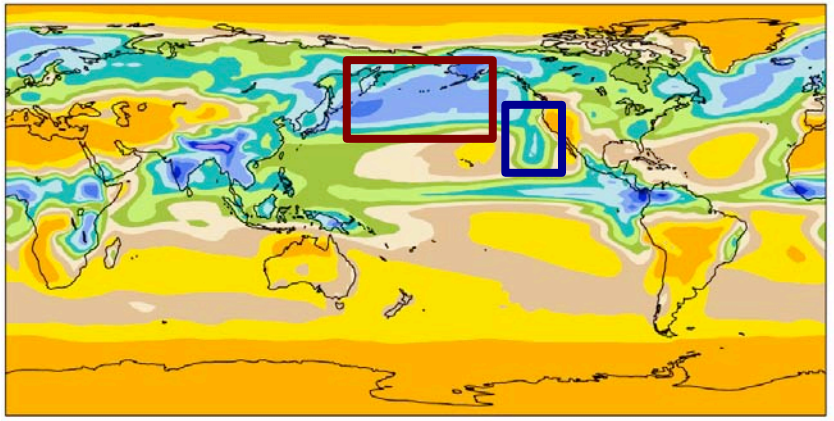
**CAM3** Mean: -54.4 W/m² RMSE: 23.4 W/m²

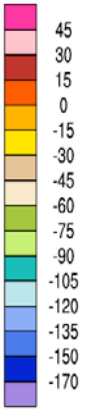


**CAM4** Mean: -54.7 W/m² RMSE: 23.0 W/m²



**CAM5** Mean: -50.4 W/m² RMSE: 19.2 W/m²



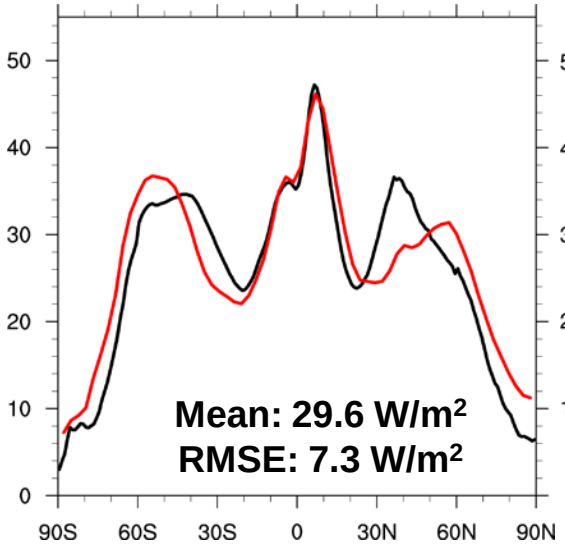



- Excessive SWCF in North Pacific (in CAM3 and CAM4) is reduced in CAM5.
- CAM5 improves stratocumulus
- CAM5 reduces RSME error (true even if compared to ERBE)

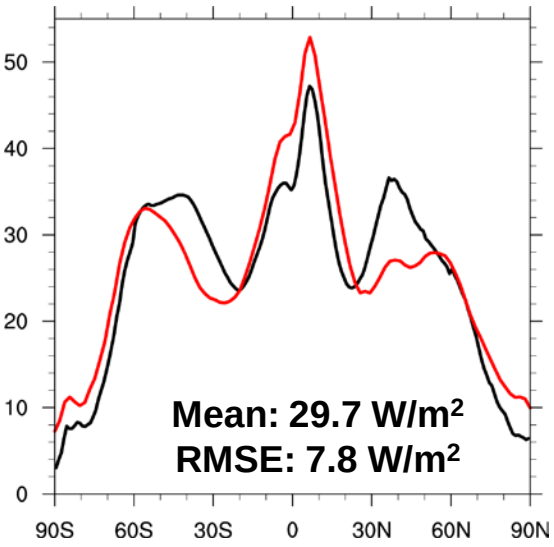
# Annual mean LWCF: CAM versus CERES-EBAF

**CERES-EBAF: annual LWCF = 29.6 W/m$^2$**

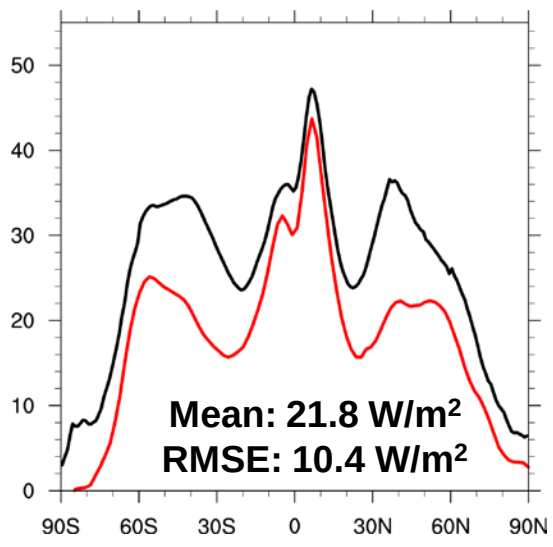
**CAM3**




**CAM4**



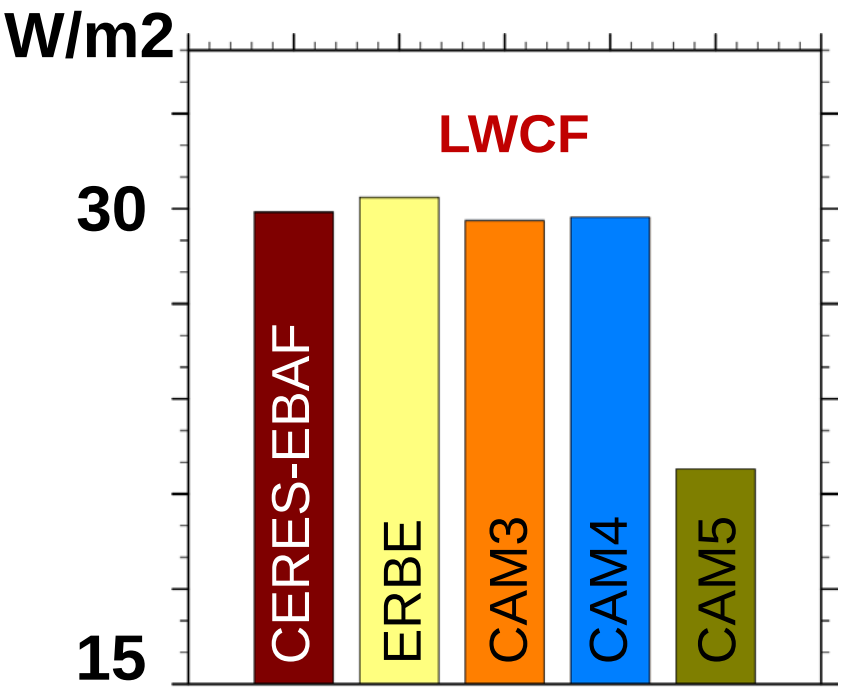

**CAM5**




**Underestimates LWCF in the mid-latitudes**

**Underestimates LWCF everywhere !**

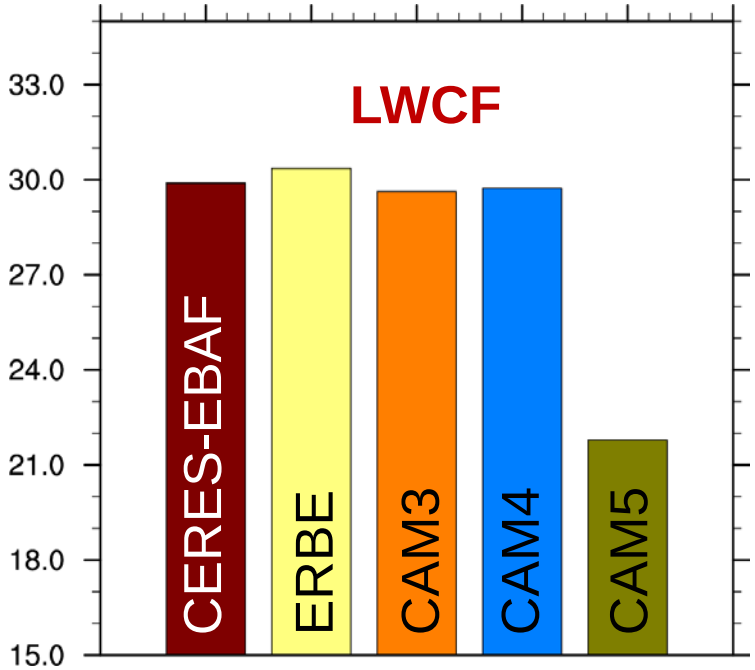
# Global LWCF and OLR (W/m2)

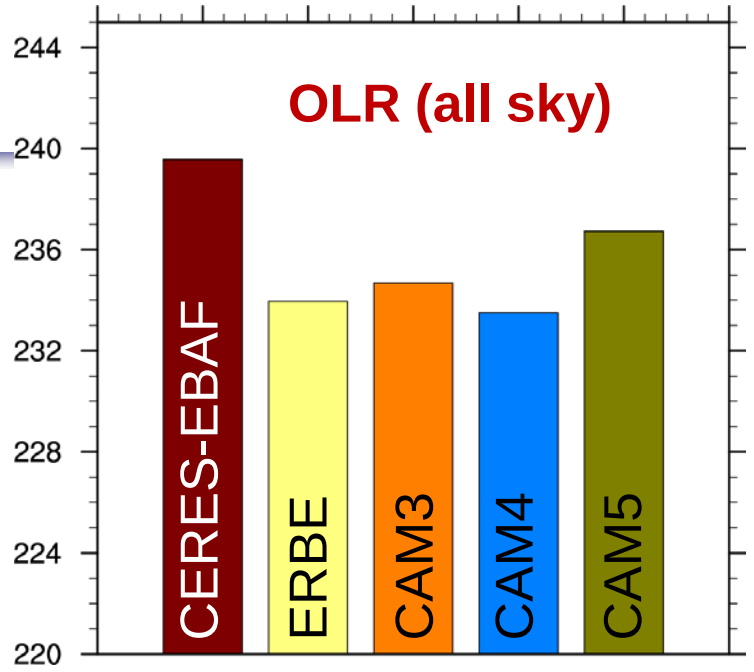


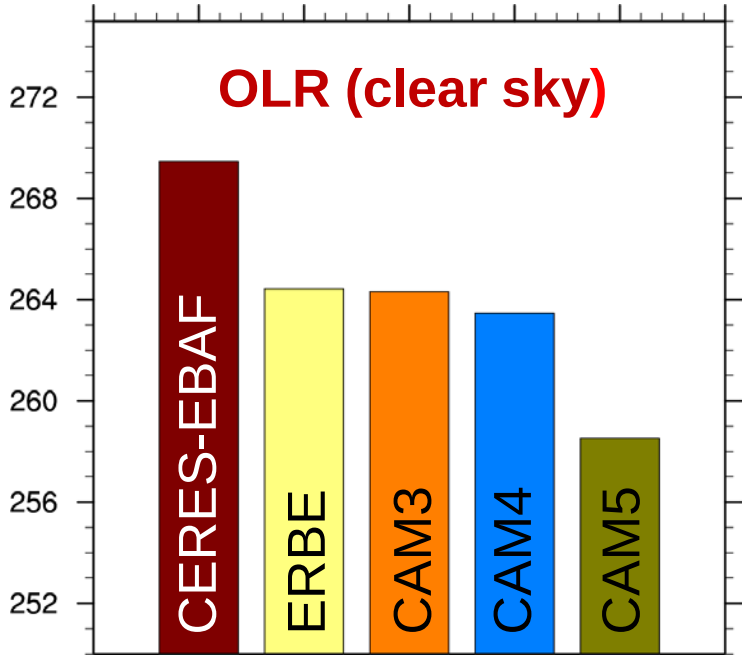

**CAM5 underestimates global LWCF by 8 W/m2 !**

# Global LWCF and OLR (W/m2)

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



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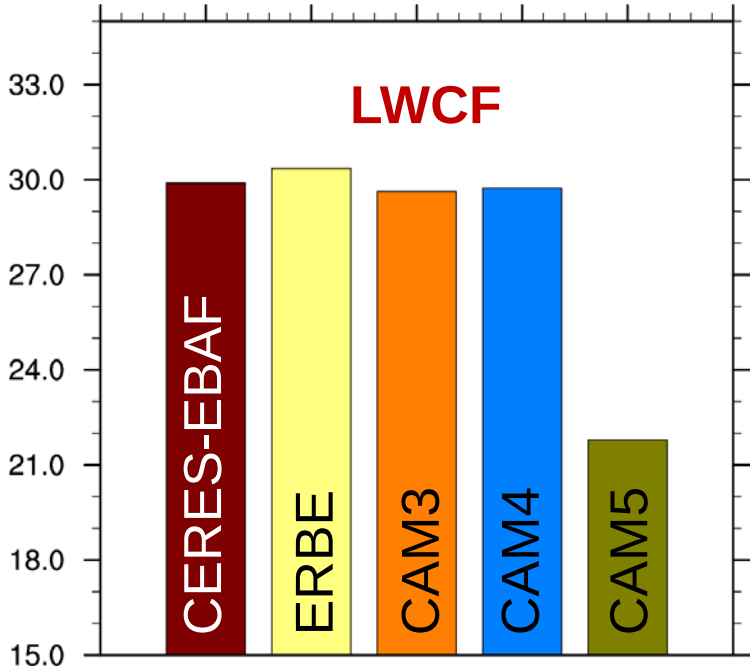
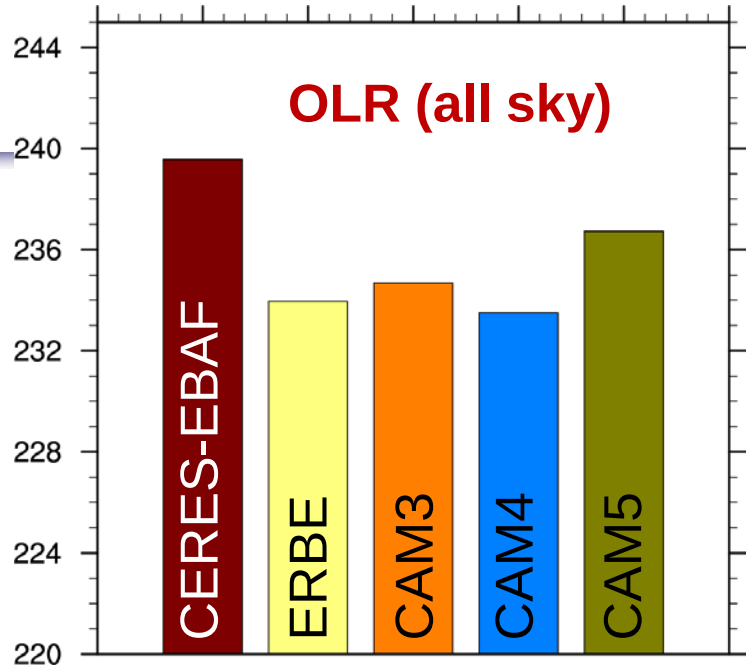
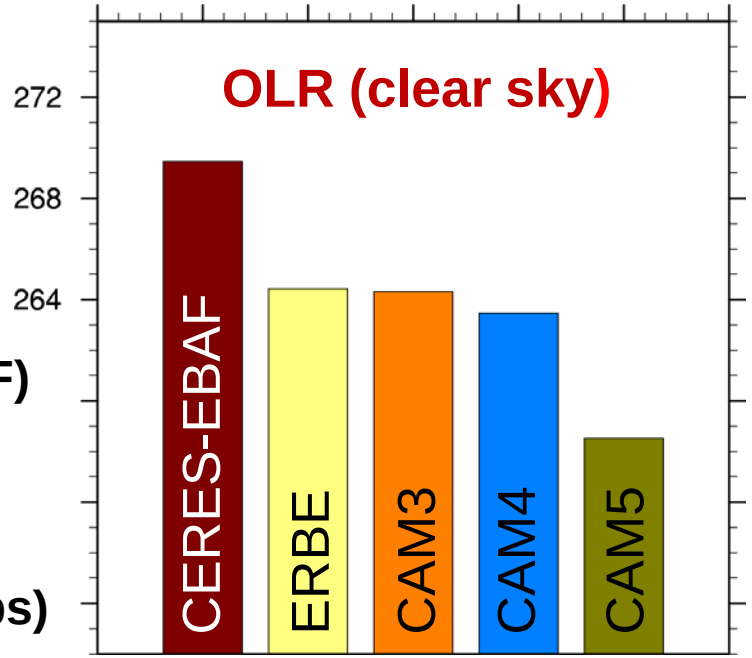
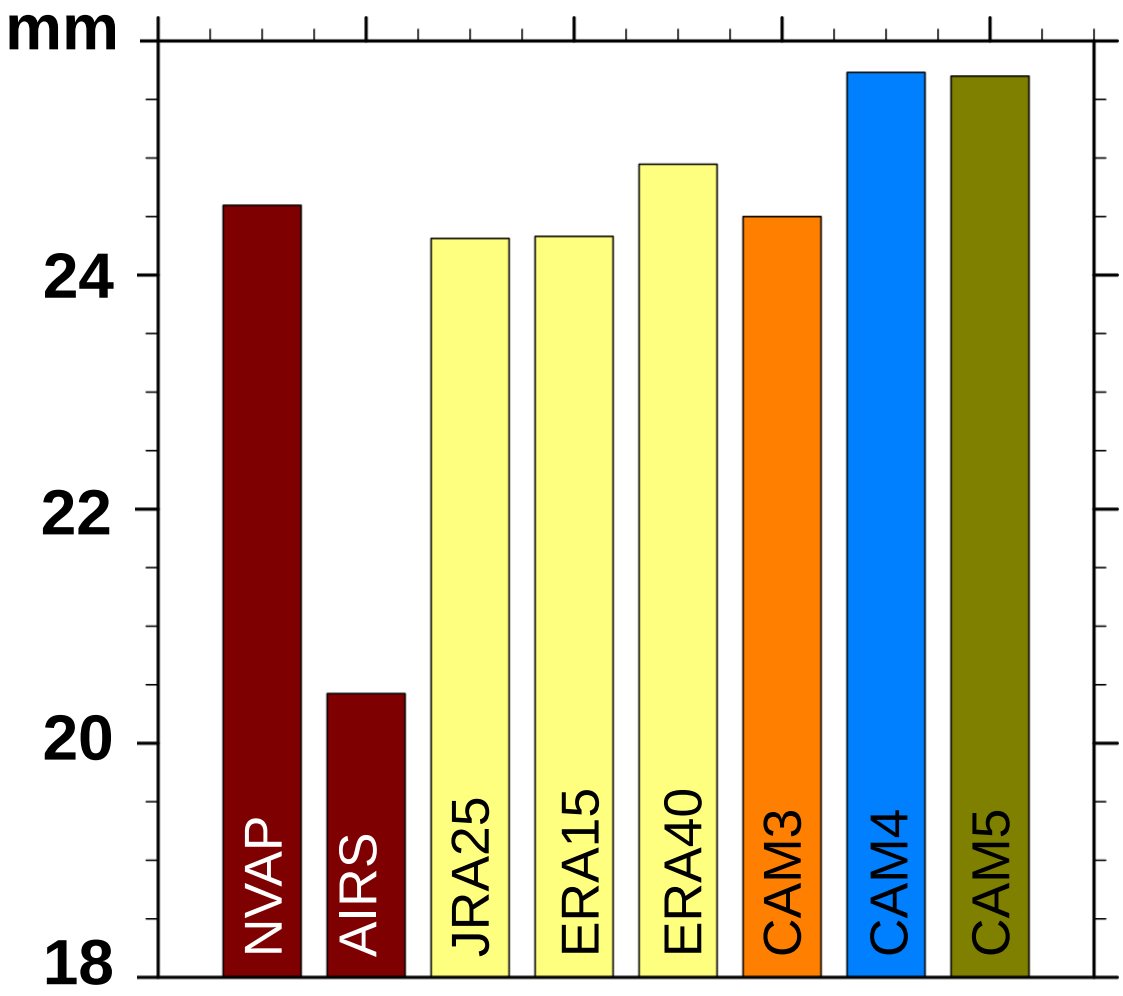



- CAM5 underestimates clear-sky OLR (and LWCF)
- New radiation code: RRTMG ⇔ CAMRT
- Problem in clear sky longwave is likely due to the vertical distribution of T and q
- Difference in "clear-sky" definition (model ⇔ obs)

# Precipitable Water



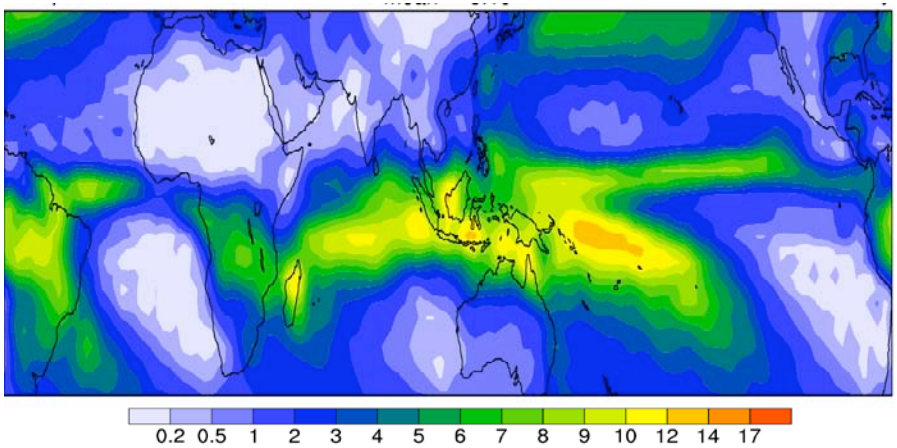

**CAM3: overall good agreement with observations and reanalysis (with some error cancellations)**

**CAM4 and CAM5 are too moist**

# Precipitation, DJF: CAM versus CMAP (Xie-Arkin)

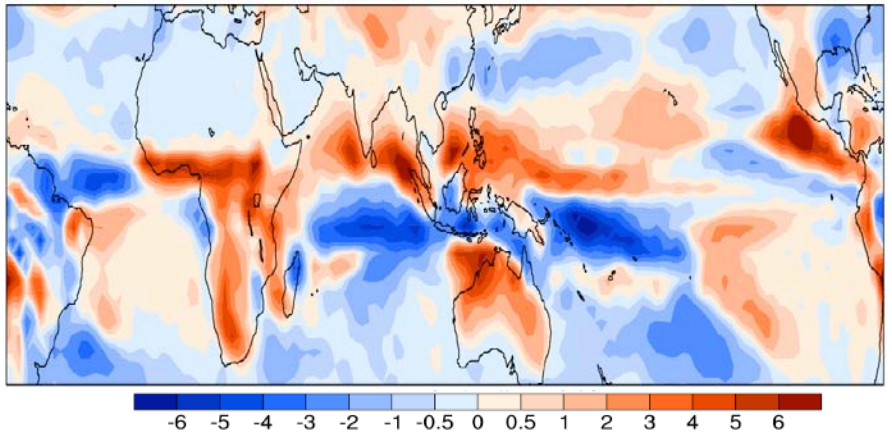
## CMAP

**Mean: 3.19 mm/day**



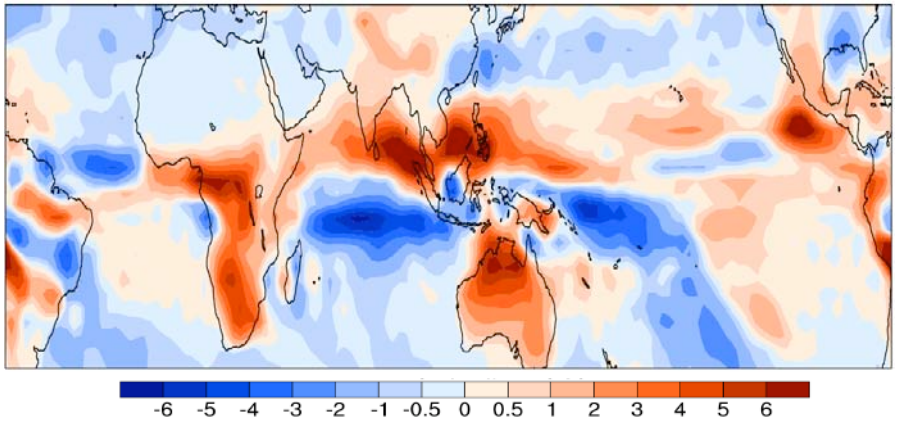

## CAM3-CMAP

**Mean: 3.28 mm/day**
**RMSE: 1.80 mm/day**



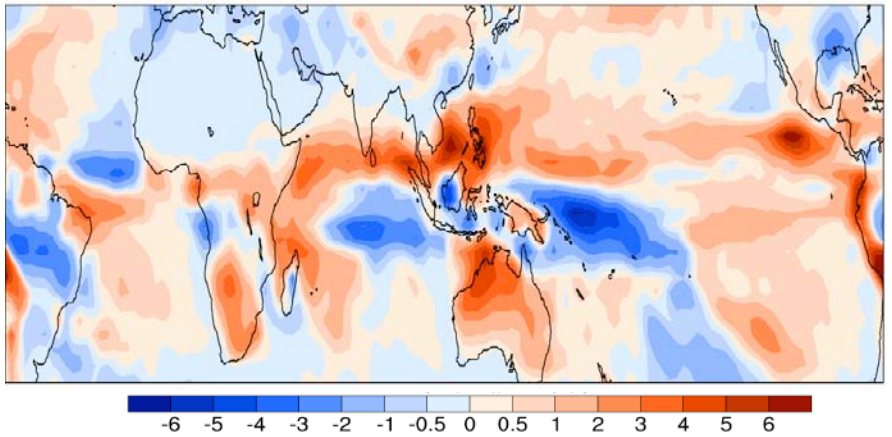

## CAM4-CMAP

**Mean: 3.45 mm/day**
**RMSE: 1.80 mm/day**




## CAM5-CMAP

**Mean: 3.57 mm/day**
**RMSE: 1.46 mm/day**




- **CAM3: performs fairly well in the mean but error cancellations**
- **Improved RMSE in CAM5**

# Precipitation, DJF: CAM versus CMAP (Xie-Arkin)

## CMAP

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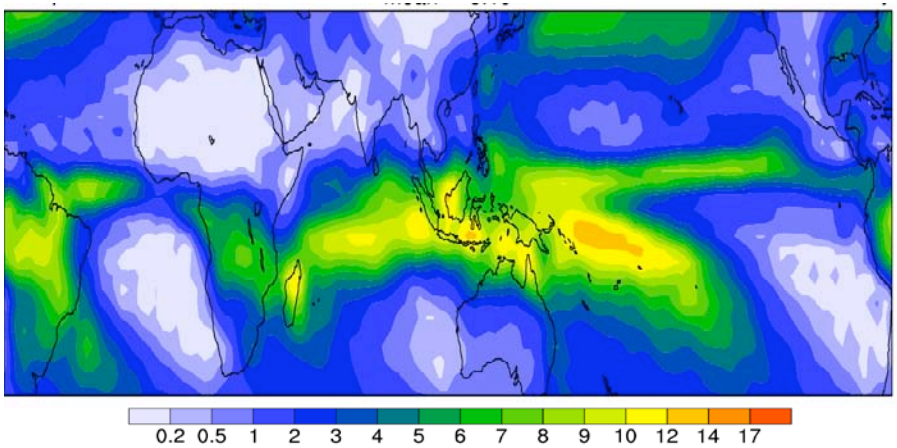


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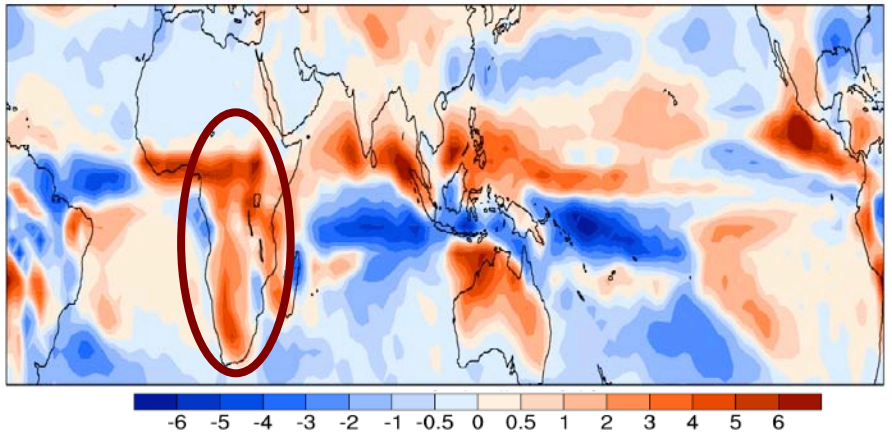
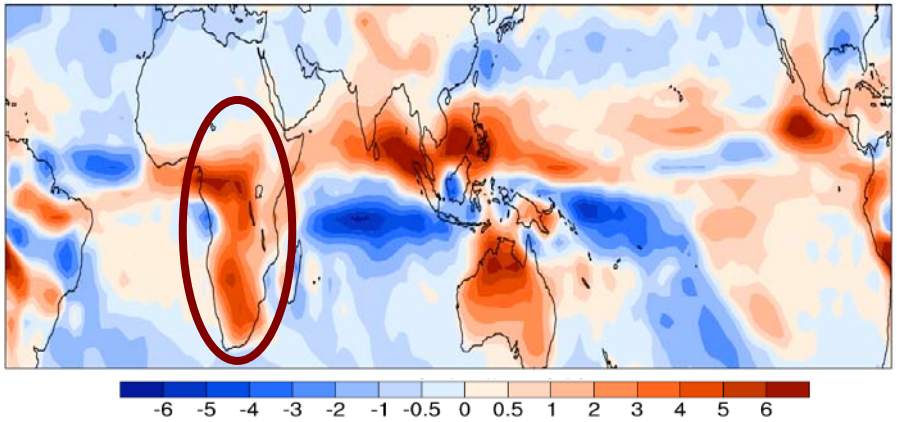



## CAM4-CMAP

Mean: 3.45 mm/day
RMSE: 1.80 mm/day




## CAM5-CMAP

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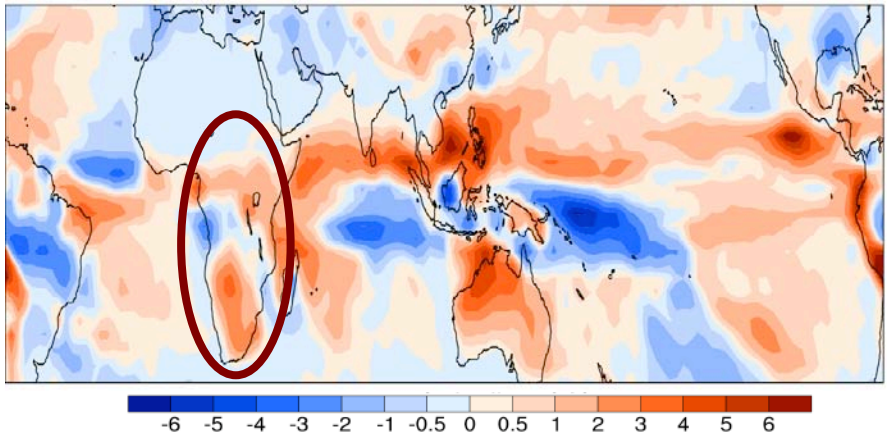
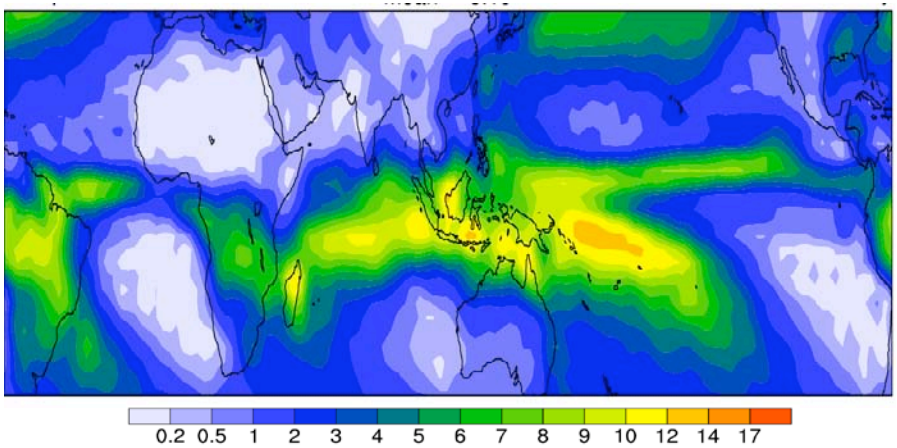



- **CAM3: performs fairly well in the mean but error cancellations**
- **Improved RMSE in CAM5 (land)**

# Precipitation, DJF: CAM versus CMAP (Xie-Arkin)

## CMAP

Mean: 3.19 mm/day

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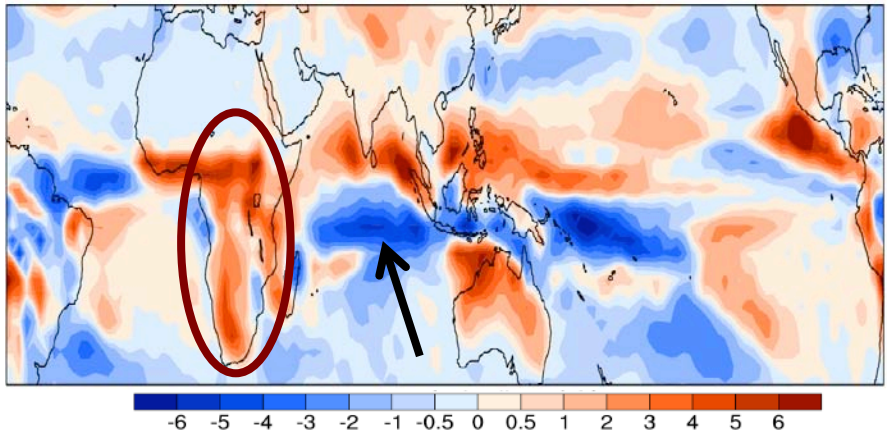
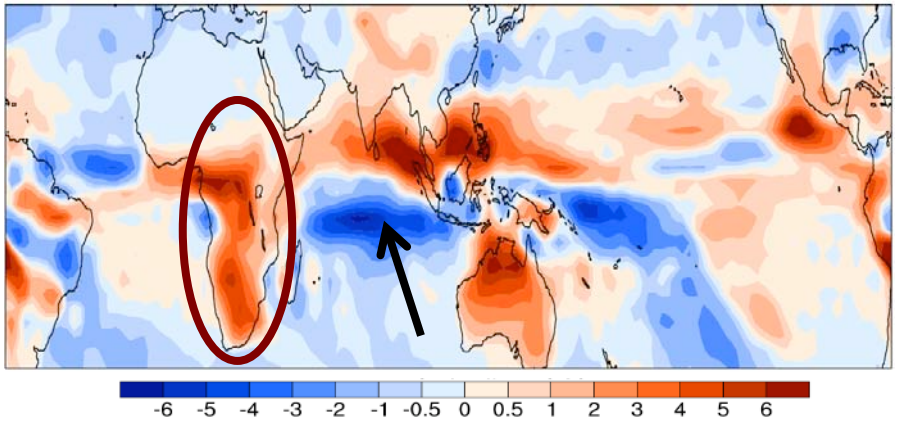


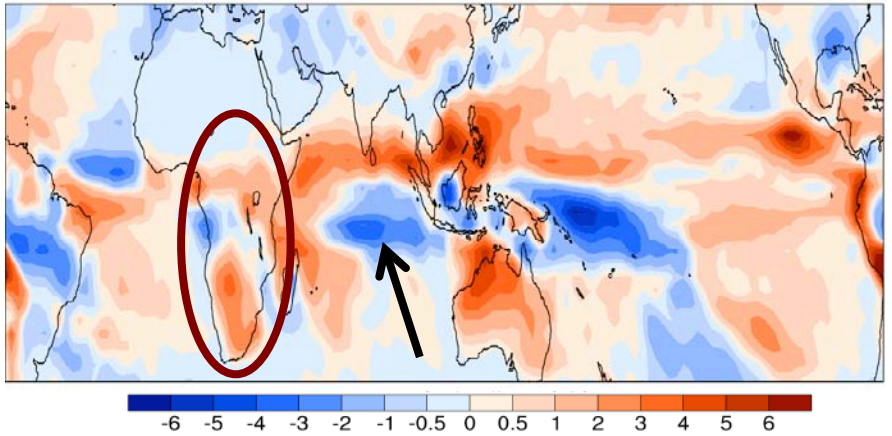

## CAM4-CMAP

Mean: 3.45 mm/day
RMSE: 1.80 mm/day




## CAM5-CMAP

Mean: 3.57 mm/day
RMSE: 1.46 mm/day




- CAM3: performs fairly well in the mean but error cancellations
- Improved RMSE in CAM5 (land, Indian Ocean)

# Precipitation, DJF: CAM versus CMAP (Xie-Arkin)

## CMAP

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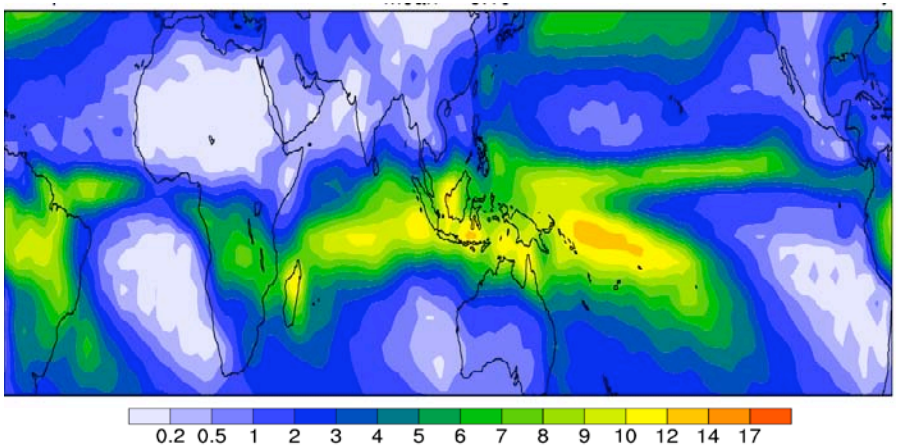


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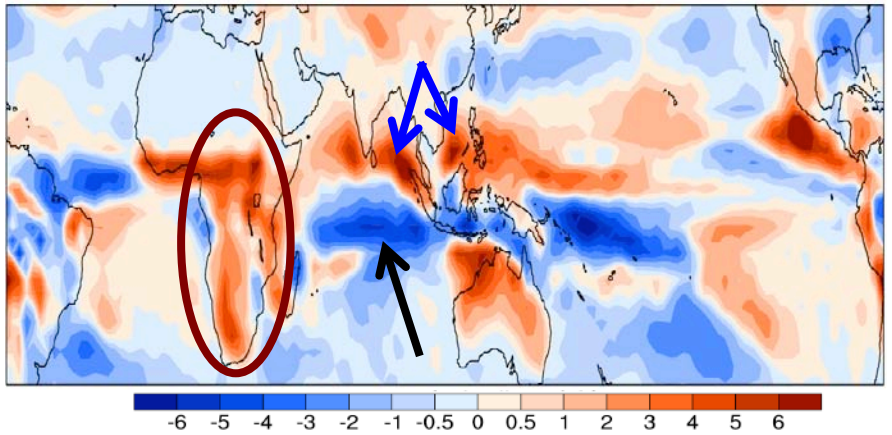


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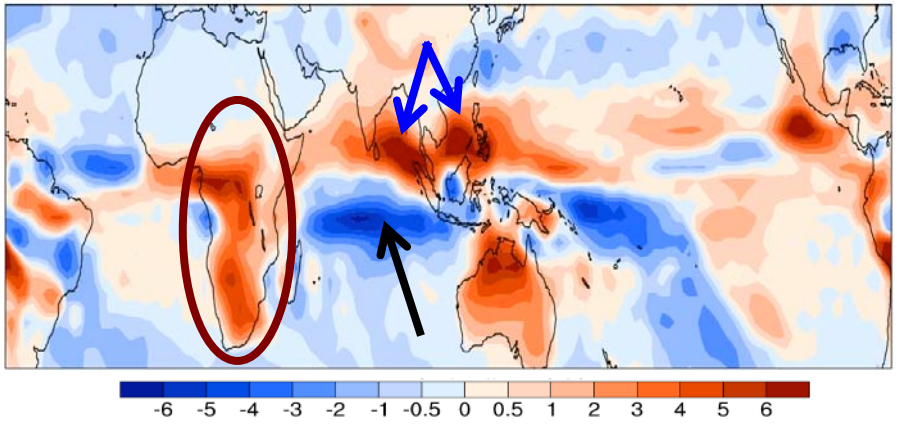
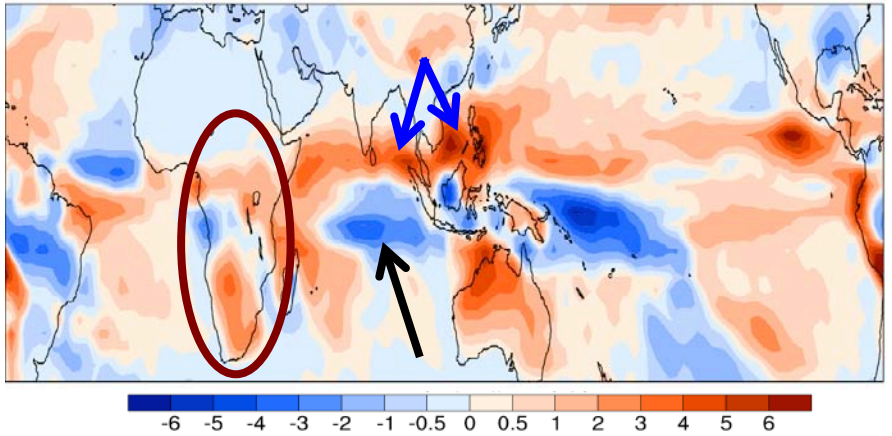
RMSE: 1.80 mm/day



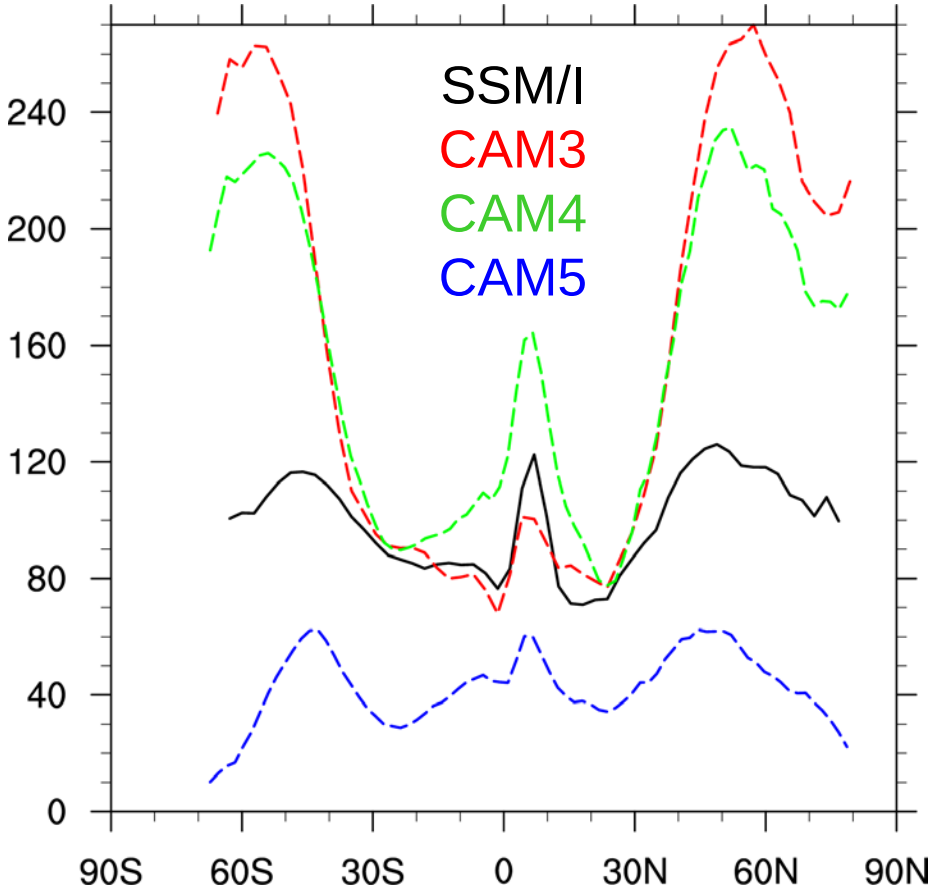

## CAM5-CMAP

Mean: 3.57 mm/day
RMSE: 1.46 mm/day




- CAM3: performs fairly well in the mean but error cancellations
- Improved RMSE in CAM5 (land, Indian Ocean and Bay of Bengal/China Sea…)

# Zonal LWP: CAM versus SSM/I




**CAM3 and CAM4: overestimate LWP at mid-latitudes**

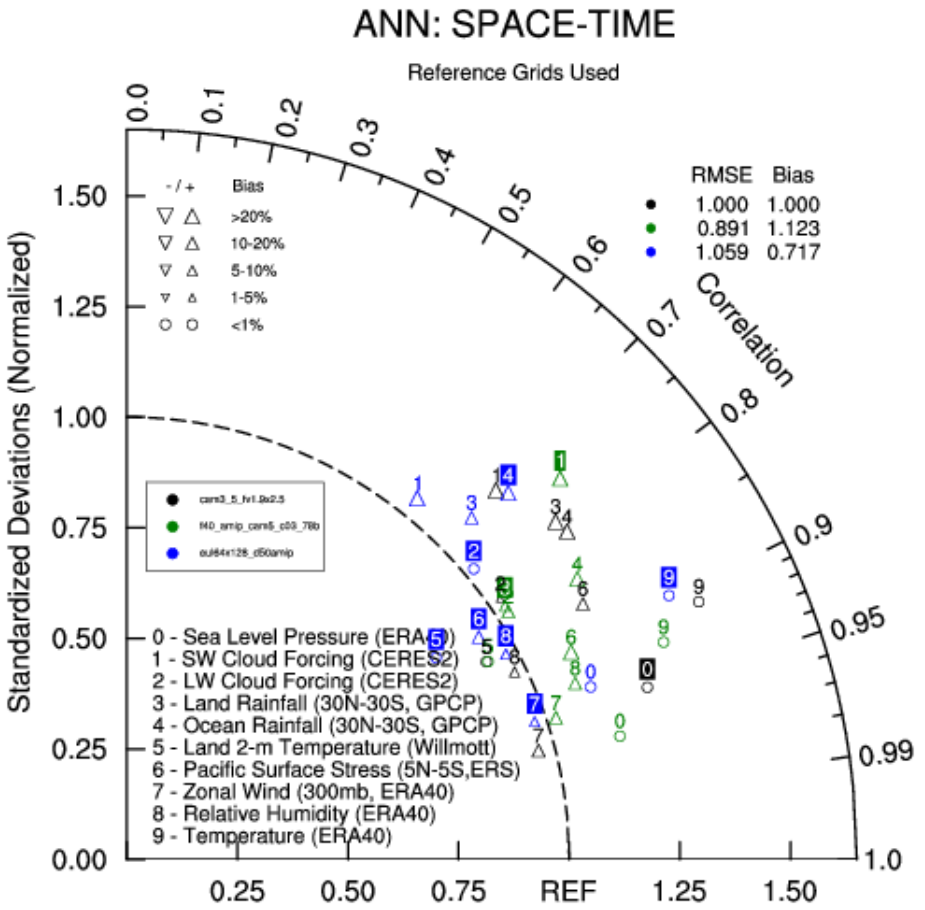
**CAM5 underestimates LWP because of increased autoconversion of rain.**

**This illustrates trade-offs in CAM5: to reduce SWCF in deep convection area, we increased autoconversion of rain and snow with the drawback that it decreased LWP**

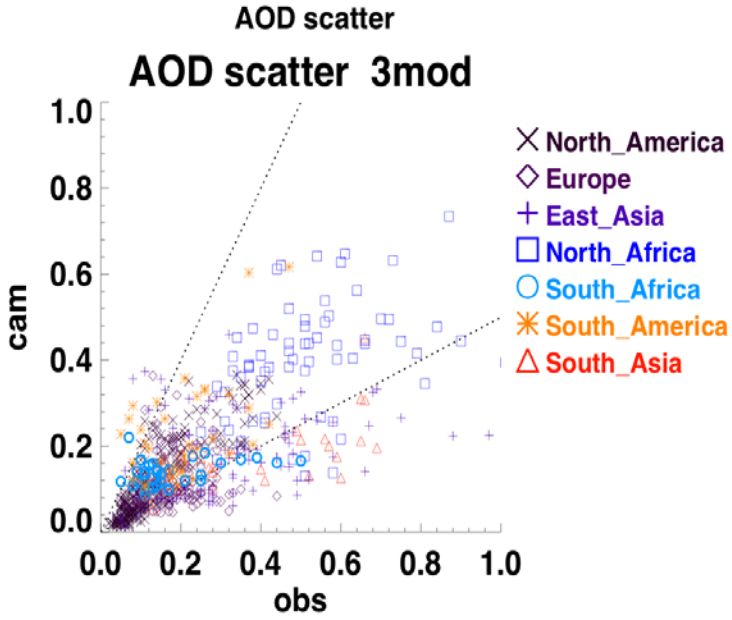
# Taylor Diagrams

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

| | RMSE | Bias |
|---|---|---|
| CAM3.5 | 1.00 | 1.00 |
| CAM3 | 1.06 | 0.72 |
| CAM4 | 1.02 | 1.17 |
| CAM5 | 0.89 | 1.12 |



# Aerosol Optical Depth (AOD): CAM5 vs AERONET




*Courtesy: Xiaohong Liu*

**AOD is an important parameter for aerosol radiative forcing.**

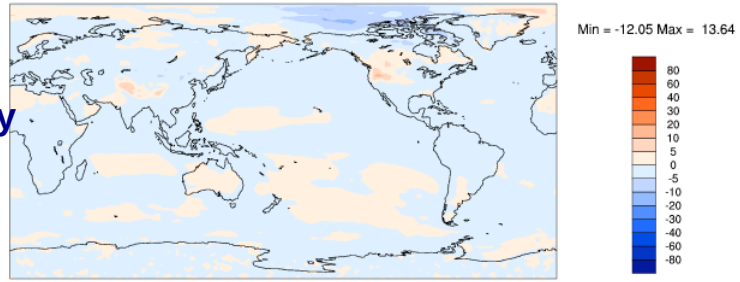
**The model agree with AERONET data within a factor of 2.**

- **North America: very good agreement**
- **Asia: underestimates AOD (due to emission)**

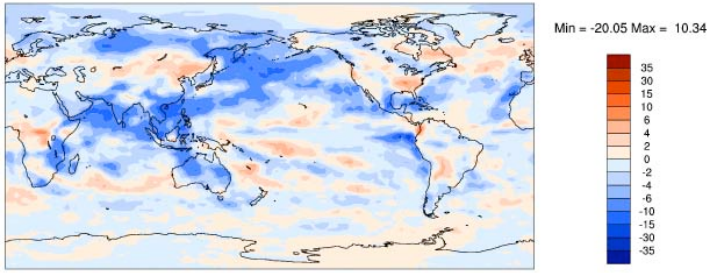
# Aerosol direct and indirect effect

## Present day - pre-industrial

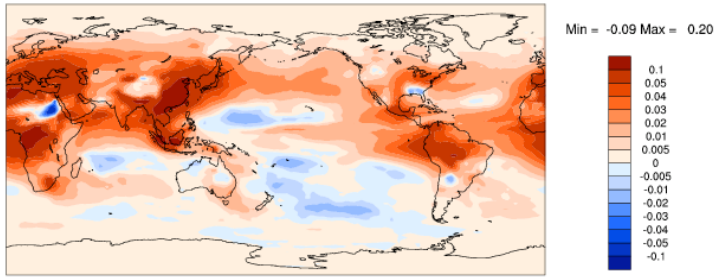
**FSNTC clear-sky SW at sfc**




**SWCF**




**AOD**




## Changes due to aerosol only between 1850 and 2000

**Direct effect**

- aerosols scatter and absorb solar and infrared radiation

**Indirect effect**

- If aerosols increase => number of cloud droplets increase => droplet size decrease => for same LWP, clouds are brighter

| | Direct effect W/m2 | Indirect effect W/m2 |
|---|---|---|
| CAM5 | -0.48 | -1.6 |
| IPPC | -0.5 [-0.9 to -0.1] | -0.7 [-1.8 to -0.3] |

# Conclusions

**This is our first release of CAM5. There will be future improvements.**

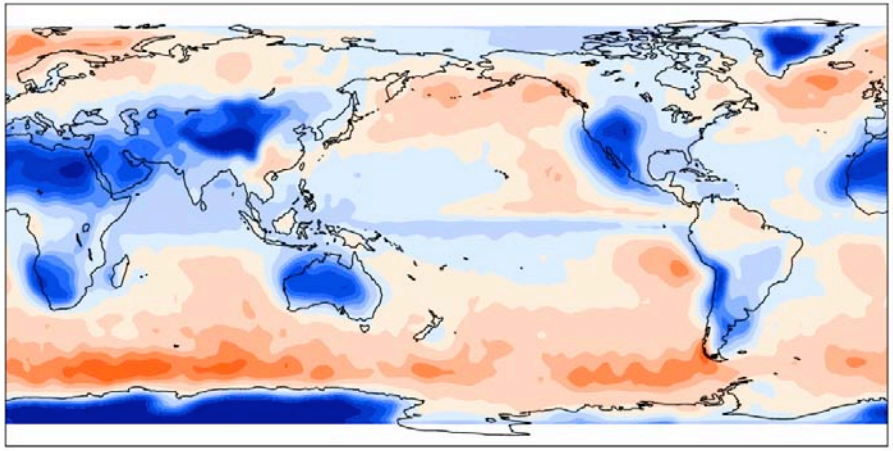
## CAM5 versus CAM3/CAM4

- better overall score
- better SWCF in the tropics
- better tropical precipitation (land, …)
- improved stratocumulus deck (and PBL height)
- aerosol indirect effect ~ 1.6 W/m$^2$

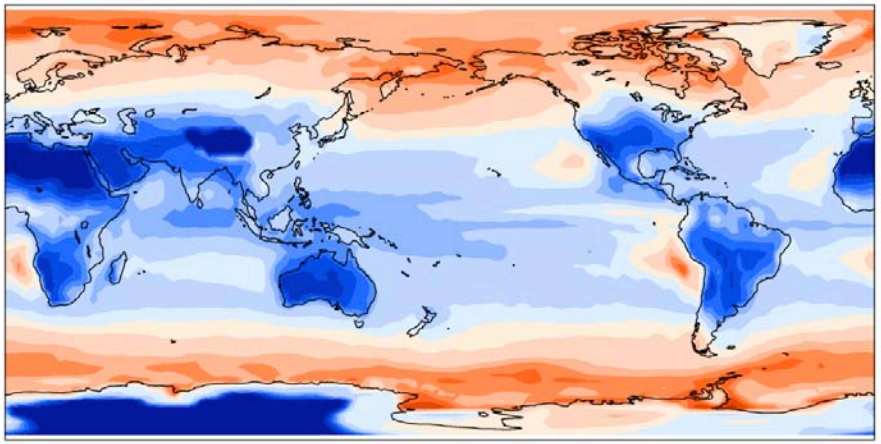
- worse clear sky OLR and LWCF
- model is too moist
- LWP is too low

# Cloud fraction, ANN: CAM versus CloudSat

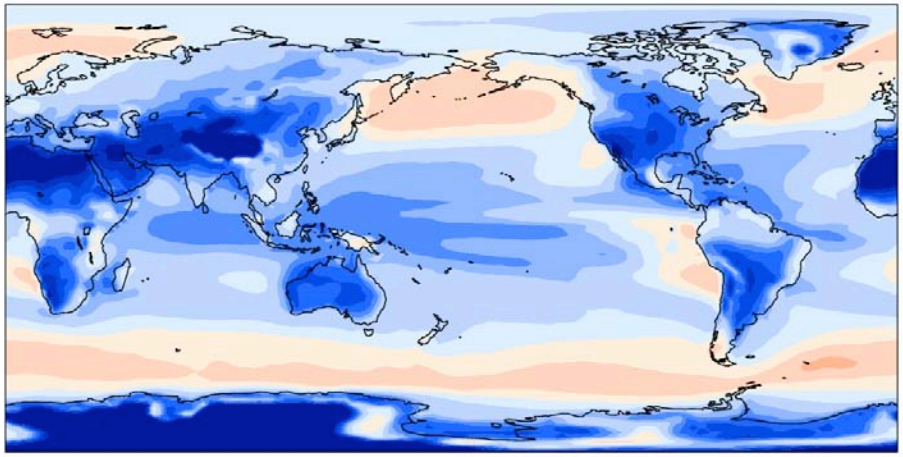
**CloudSat** Mean: 48.1



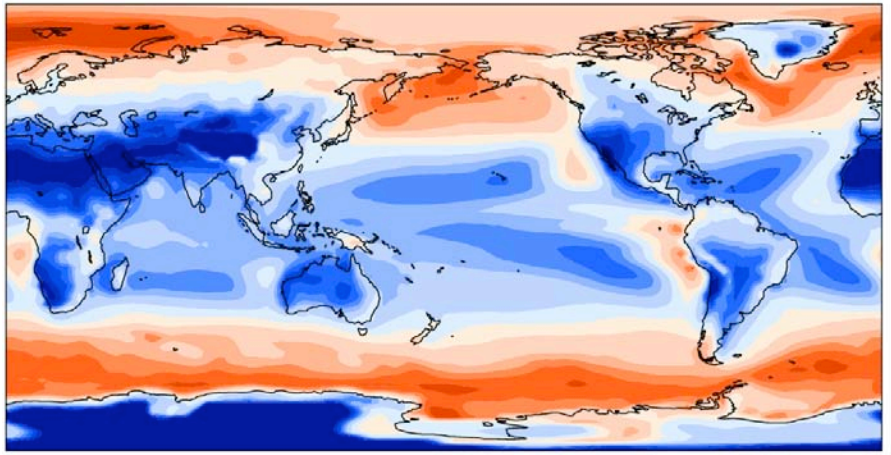
**CAM3** Mean: 42.0; RMSE: 15.3

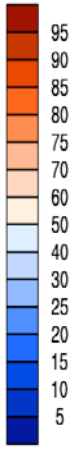


**CAM4** Mean: 35.2; RMSE: 16.5



**CAM5** Mean: 41.4; RMSE: 16.1






- Datasets: Warren (Mean = 39.9) ⇔ CloudSat
- Differences reflect parameterization changes: Klein-Hartman, Freeze-dry