UCRL-PRES-207601

Using ARM Data to Evaluate and Improve Climate Model Parameterizations:

A Demonstration

(SCM → CAPT → GCM)

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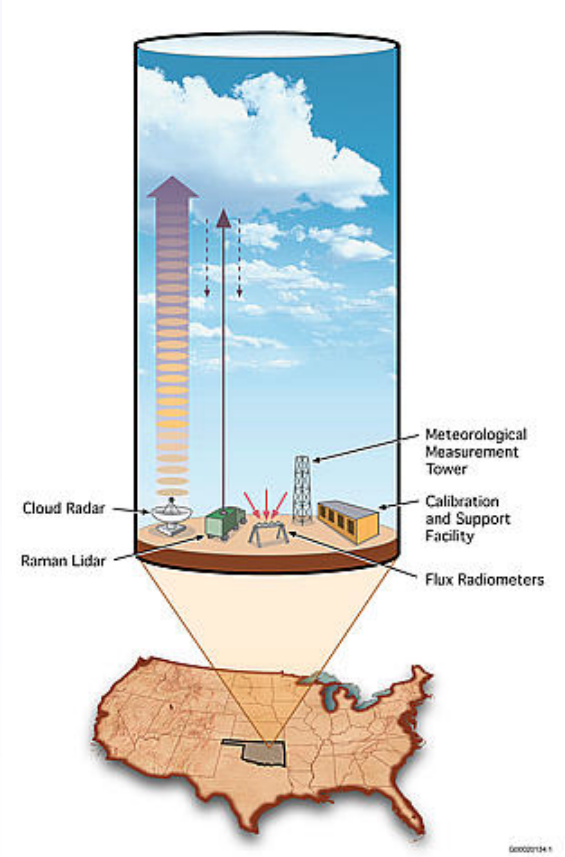
ARM CPMWG/CERES/GCSS WG 4 Joint Meeting, Williamsburg, VA, 1-4 November, 2004

ARM Atmospheric Radiation Measurement Program

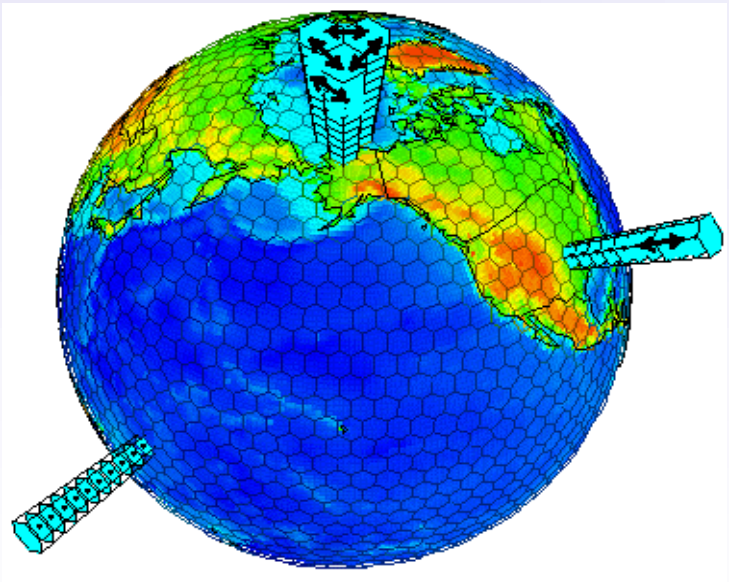
The DOE Largest Program for Climate Changes

- ✓ ***1990 ------***
- ✓ ***Collecting field data to validate and develop new parameterizations of clouds and radiation***

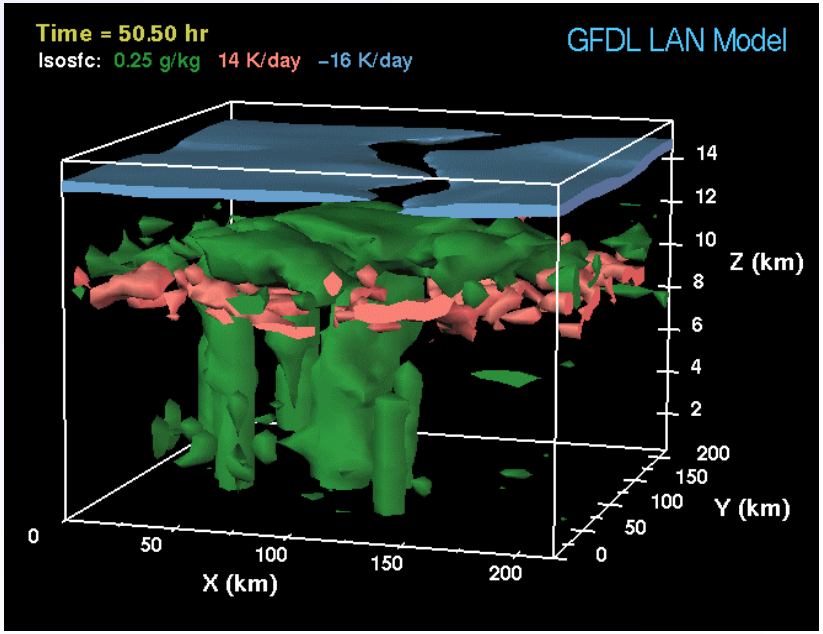


Modeling Approach: SCM + CRM

Single Column Model (SCM)



Cloud Resolving Model (CRM)



SCM directly links the field data to parameterization development

Randall et al. 1996 (J. Climate)

The SCM/CRM Forcing Approach

"Advective Forcing" computed from observations

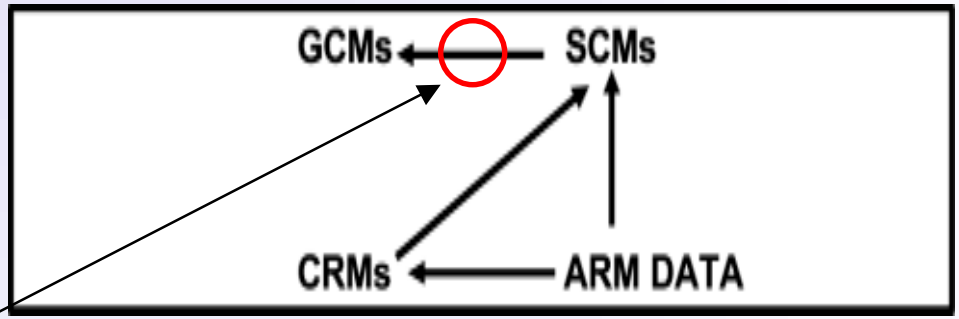
"Physics" computed from:

- **CRM explicitly**
- **SCM parameterizations**

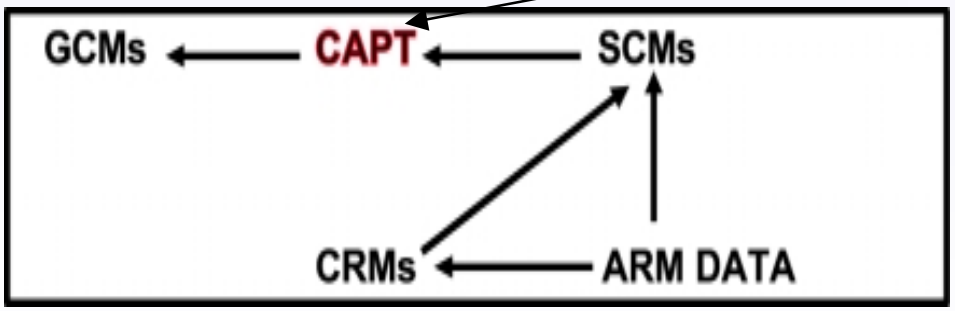
$$\frac{\partial s}{\partial t} = -V \bullet \nabla s - \omega \frac{\partial s}{\partial p} + L(c-e) - \frac{\partial \overline{\omega' s'}}{\partial p} + Q_{rad}$$

$$\frac{\partial q}{\partial t} = -V \bullet \nabla q - \omega \frac{\partial q}{\partial p} + (e-c) - \frac{\partial \overline{\omega' q'}}{\partial p}$$

Approach to Improve Model Parameterizations: Model + Data



A Gap exists?



To complement the SCM test, a new DOE parameterization testbed CAPT has been recently built up in PCMDI/LLNL

Diagram From Randall et al. 1996 with modifications

DOE CAPT Project (*Led by PCMDI/LLNL)*

CAPT* == *CCPP-ARM Parameterization Testbed

CCPP+ARM ~ Model +Data

***CAPT* provides a flexible user environment for running climate models in NWP 'forecast' mode**

Comparing climate simulations and SCM tests:

- **More evaluation data**
- **Allows systematic errors to be identified before multiple errors compensated**
- **Be able to link deficiencies with atmospheric processes through case study**
- **Include all feedbacks**
- **Effectively transfers improvements from SCM tests into its parent GCM.**

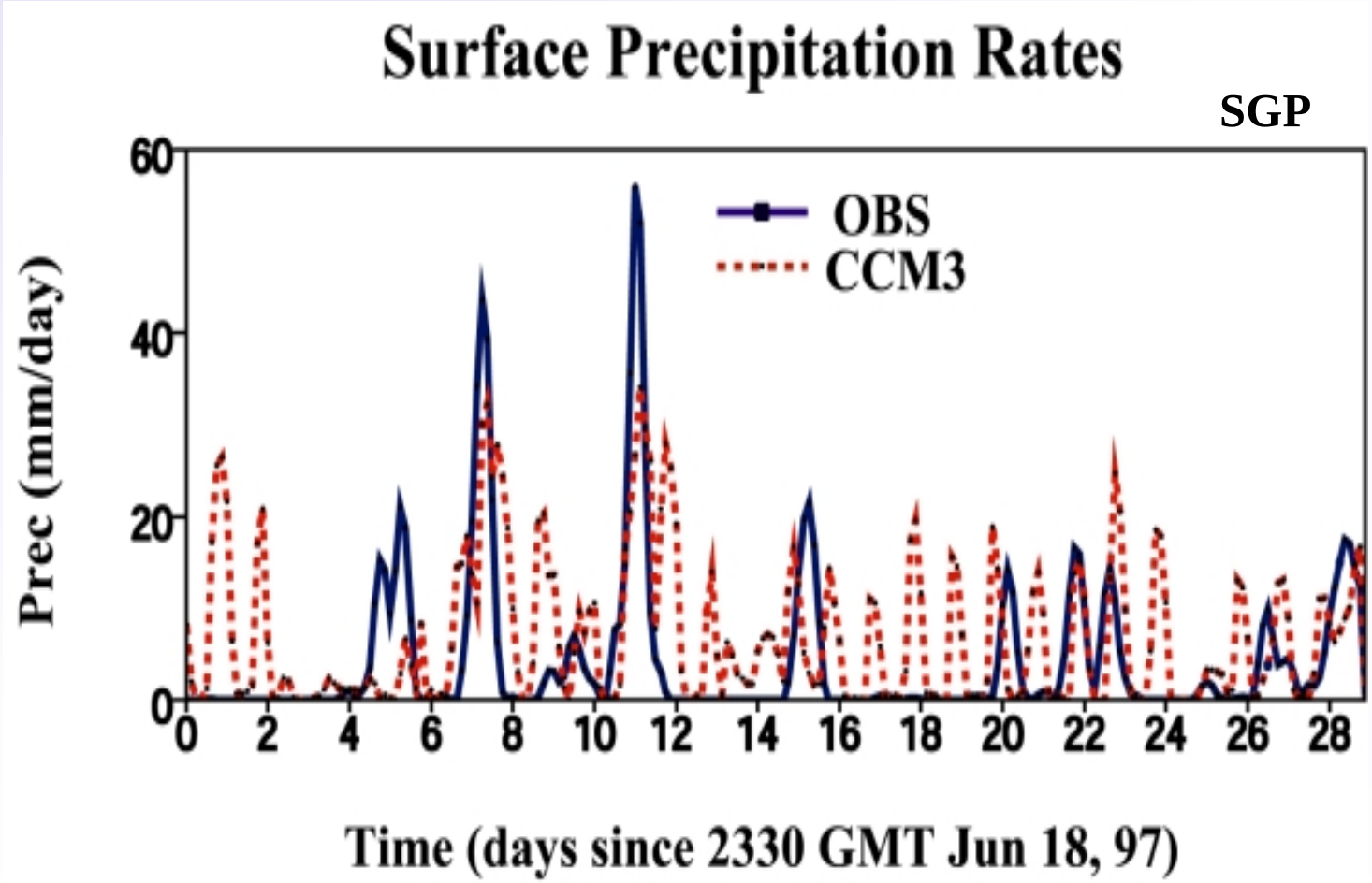
A DEMO

Using the approach "SCM→CAPT→GCM" to Improve Cumulus Parameterization in NCAR Climate Model

SCM Tests

Problem in CCM3-Produced Surface Precipitation

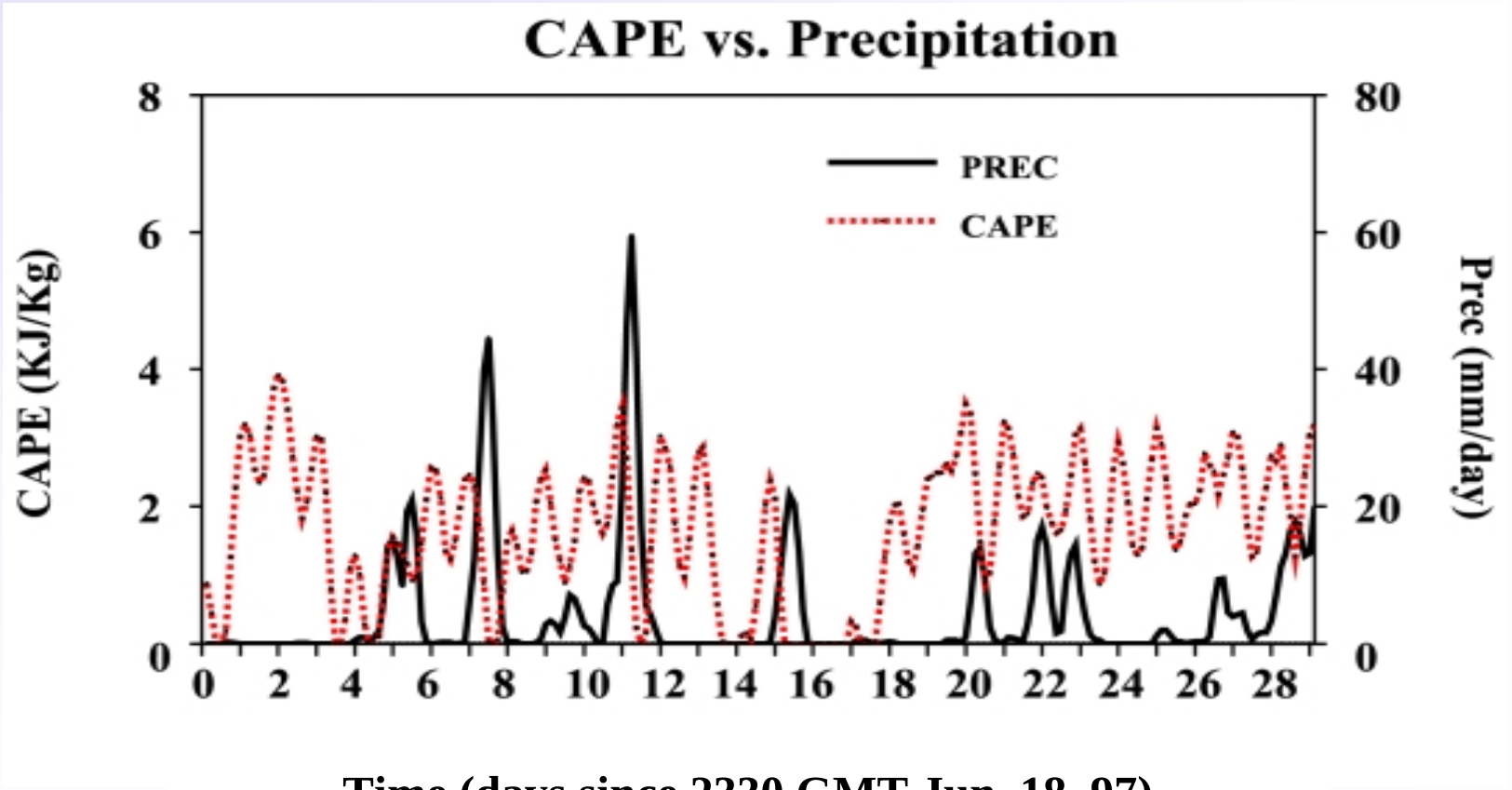
Convection over land is triggered too often during the day in warm season



ARM 97 Summer IOP

Problems with the Original Trigger (CAPE>0)

Strong diurnal variations in CAPE over land in warm season



Time (days since 2330 GMT Jun. 18, 97)

ARM 97 Summer IOP

Convective Triggering Mechanisms

An air parcel is energetic enough to penetrate the layer of convection inhibition == > Convection Occurs

- ***Large-scale upward motion***
- ***Lifting associated with fronts and orography***
- ***Pre-existing convection***
- ***Subgrid-scale dynamic instability***
- ***Surface heterogeneity***
- ***Growth of the boundary layer***

A Revised Trigger (*DCAPE >0*) for CAM2

Xie and Zhang (2000) introduced a positive dynamic CAPE generation rate (DCAPE) that describes a combined measurement of lifting and inhibition effects to control the onset of deep convection.

$$DCAPE = \{CAPE^*(T^*, q^*) - CAPE(T,q)\}/\Delta t$$

Where

$$T^* = T + (\partial T/\partial t)_{adv} * \Delta t$$

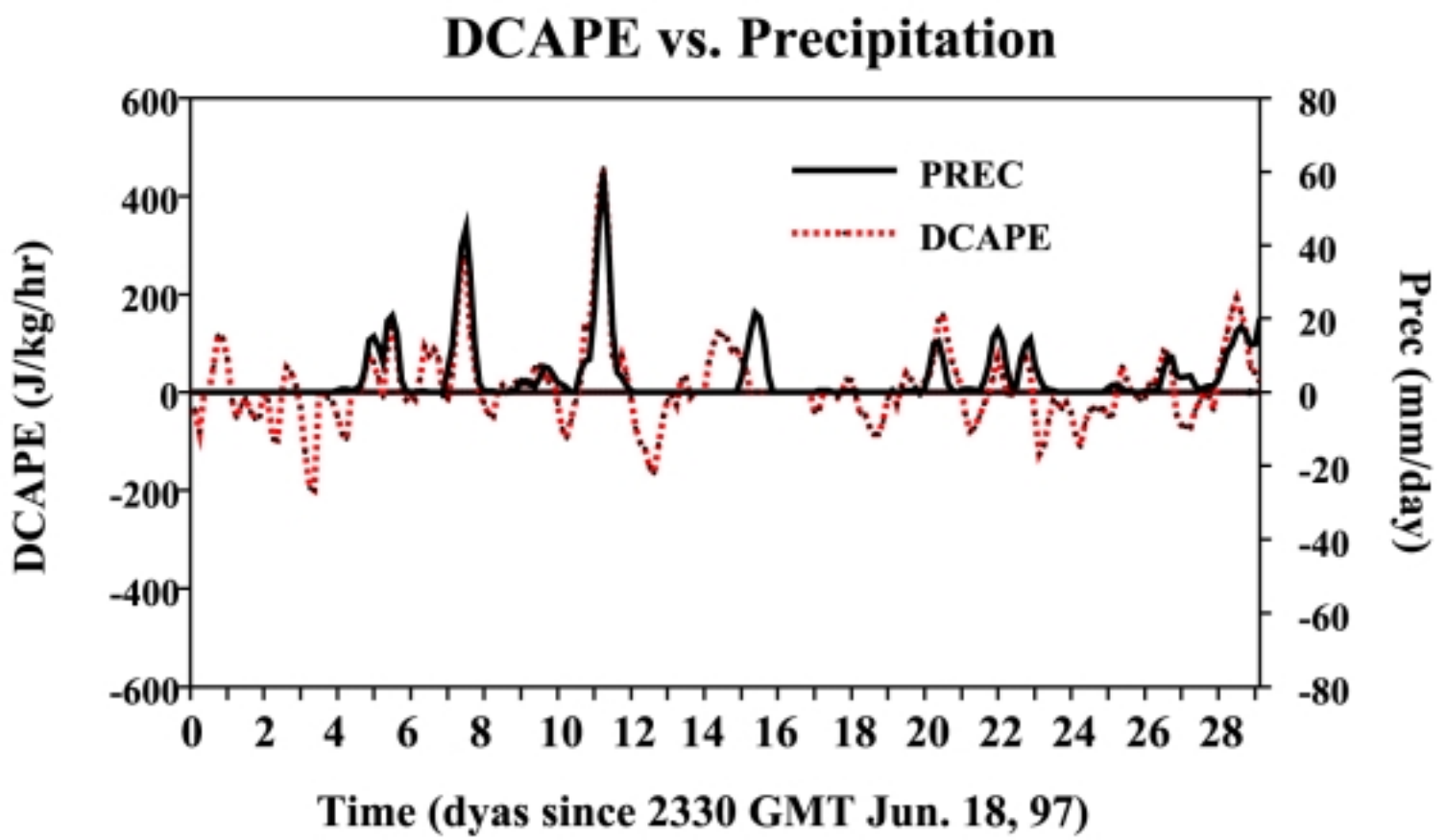
$$q^* = q + (\partial q/\partial t)_{adv} * \Delta t$$

New Trigger: CAPE>0 & DCAPE>0

The new triggering function links cumulus convection directly to the large-scale dynamic forcing, such as lower level convergence.

A Revised Trigger (*DCAPE >0*)

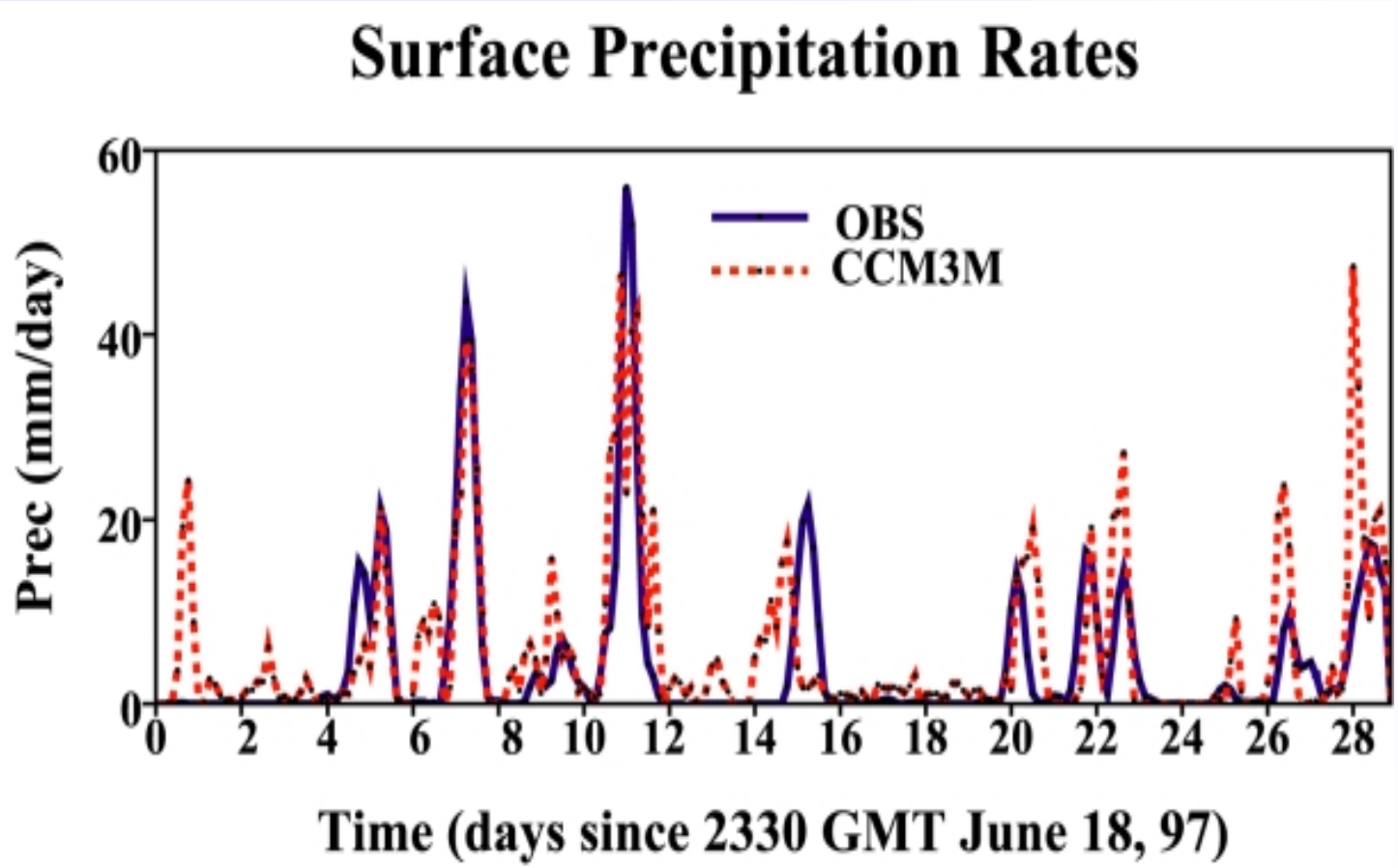
Observations show a strong correlation between positive DCAPE and convection (and associated precipitation).



ARM 97 Summer IOP

CCM3 SCM Tests

The new trigger largely reduces the effect of the strong diurnal variations in the surface isolation on the initiation of convection.

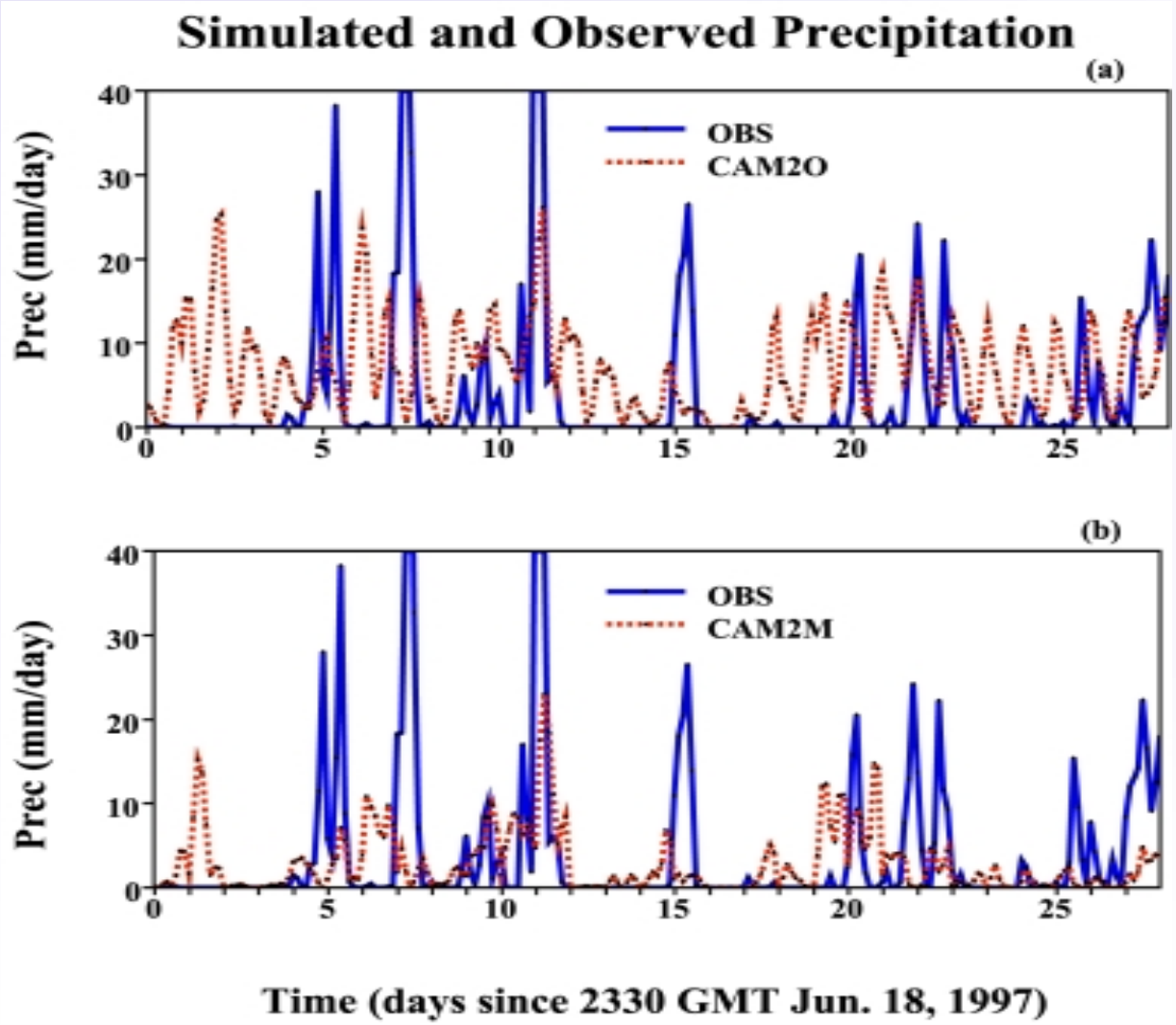


ARM 97 Summer IOP

CAPT Tests

CAM2 initialized with ERA40 reanalyses

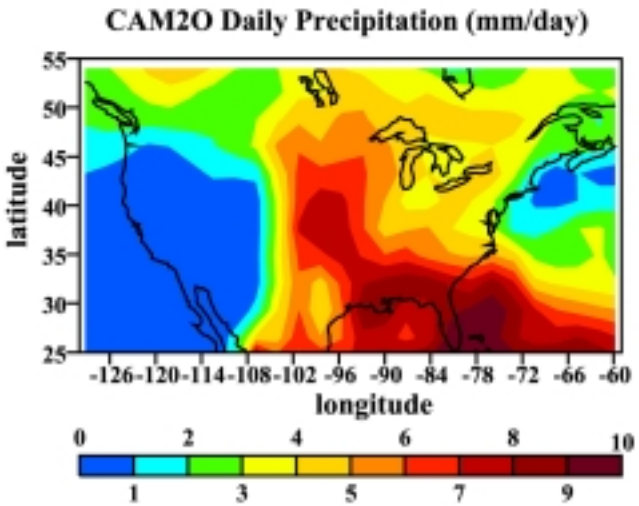
CAM2 CAPT Tests (SGP Site)

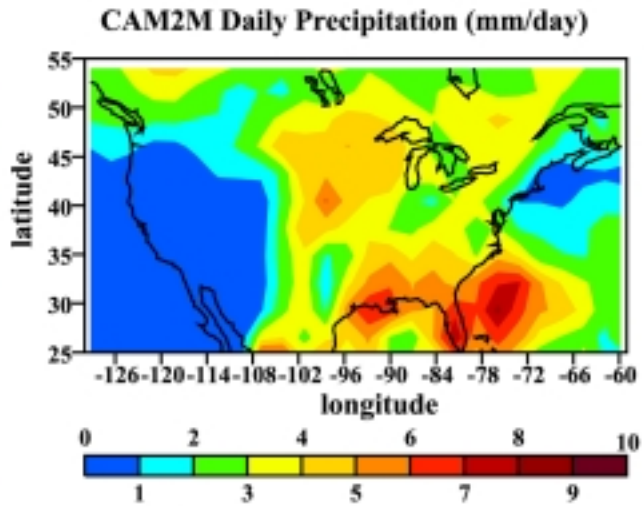


ARM 97 Summer IOP

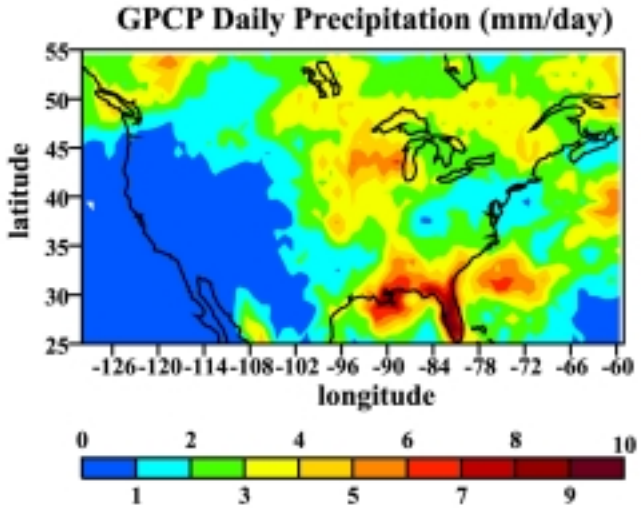
The new trigger produces less frequent precipitation.

CAM2 CAPT Tests (United States)





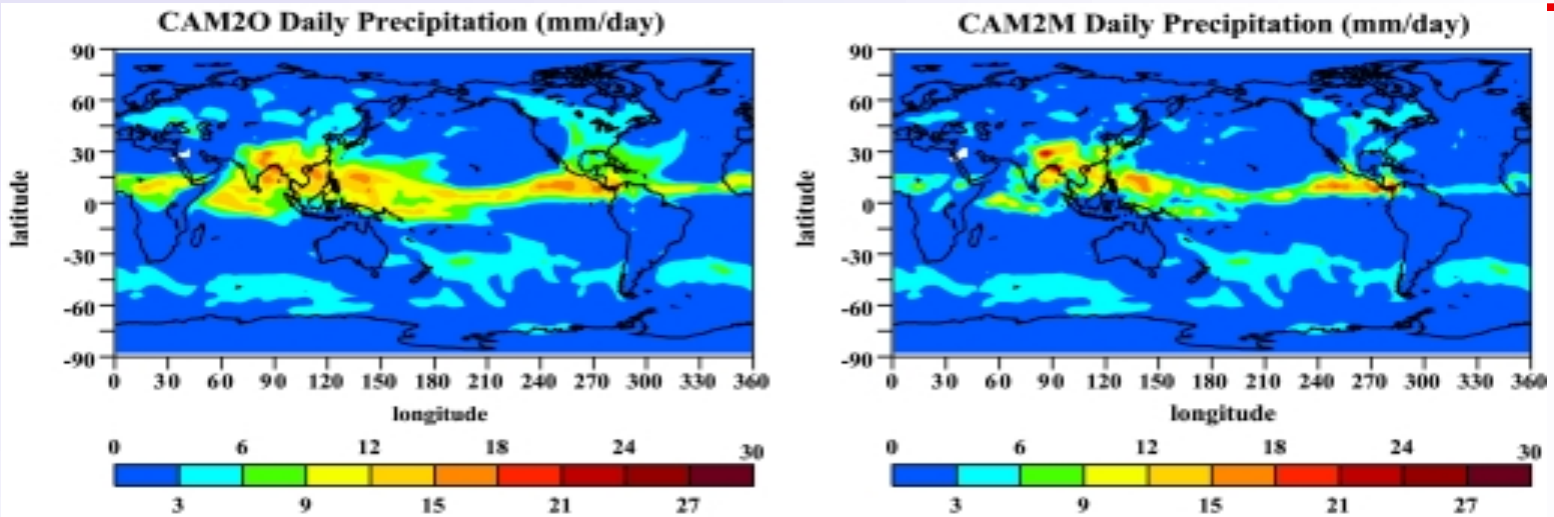
Daily Precipitation Rates (mm/day)

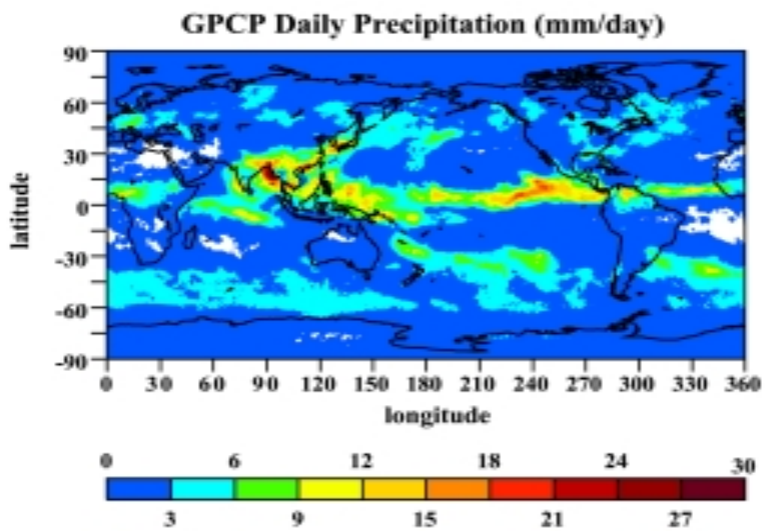


The original model overestimates the observed precipitation in most parts of the United States while the excessive precipitation is clearly reduced using the new trigger

30-day ensemble mean of 0-24 hour forecasts (June 18 – July 17, 1997)

CAM2 CAPT Tests (the Globe)

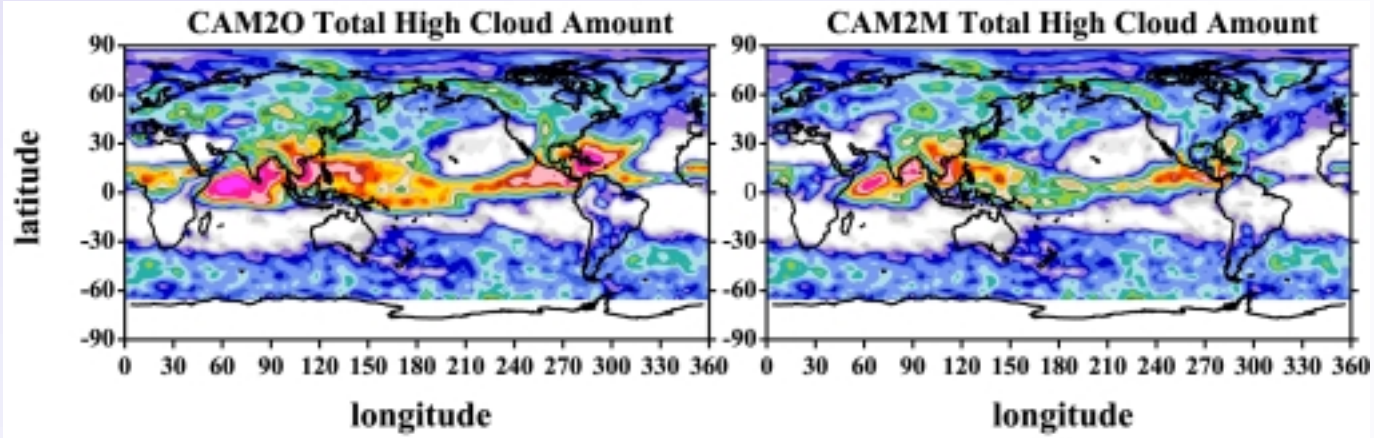


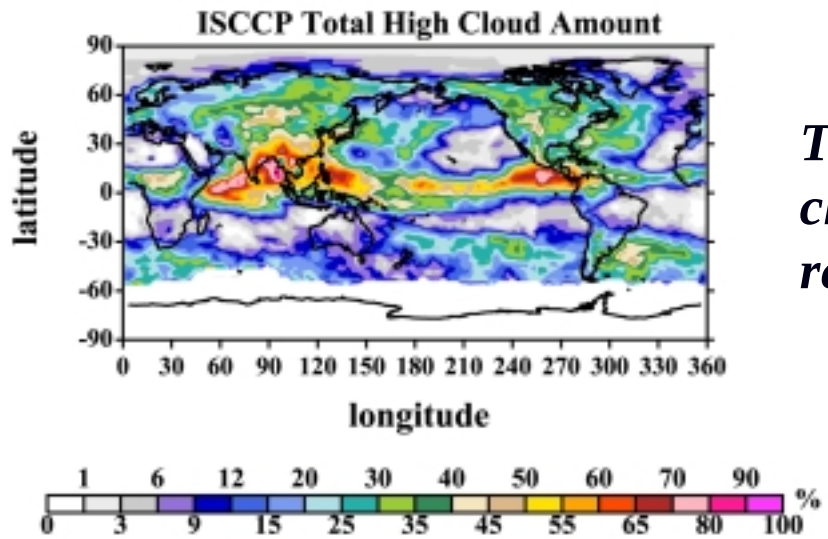


The new trigger gives a more realistic spatial pattern of precipitation in the tropics

30-day ensemble mean of 0-24 hour forecasts (June 18 – July 17, 1997)

CAM2 CAPT Tests (the Globe)





The overestimation of high clouds has been noticeably reduced in CAM2M

30-day ensemble mean of 0-24 hour forecasts (June 18 – July 17, 1997)

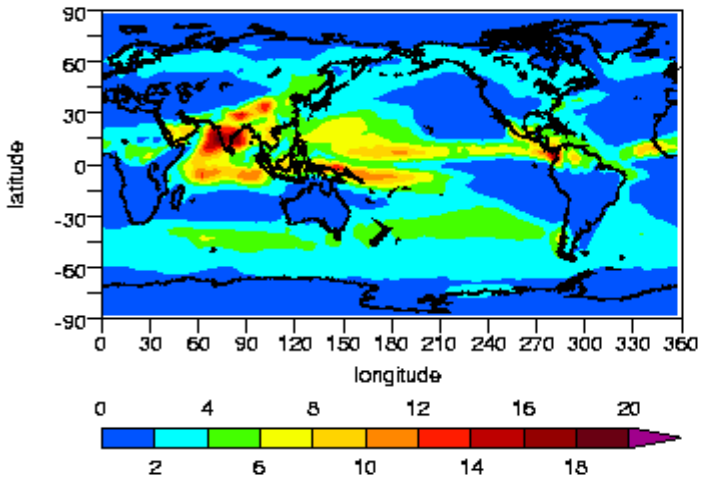
Climate Simulations (AMIP run)

CAM2 Climate Simulations (10 yr AMIP run)

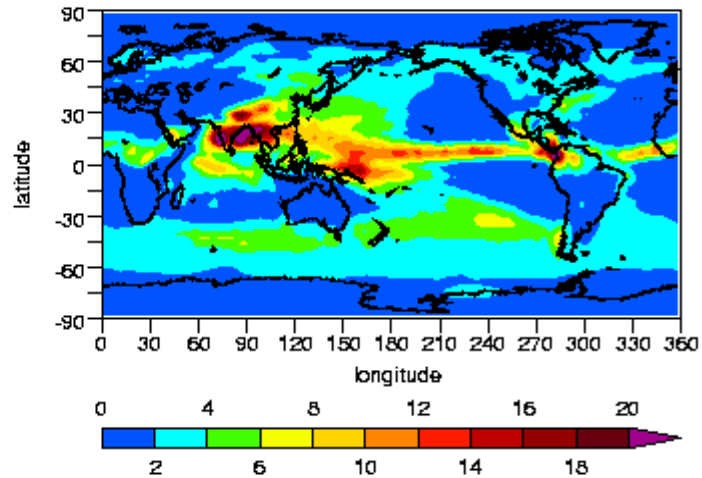
Precipitation Rates (mm/day)

JJA

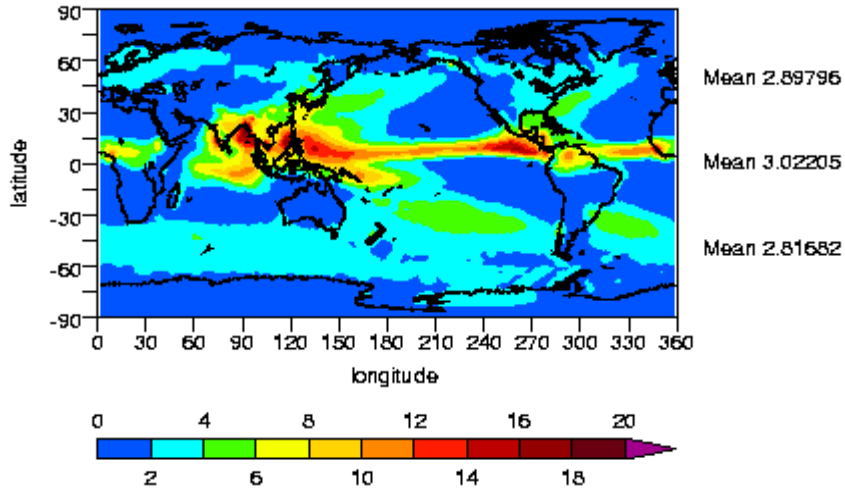
CAM2O



CAM2M



Xie-Arkin

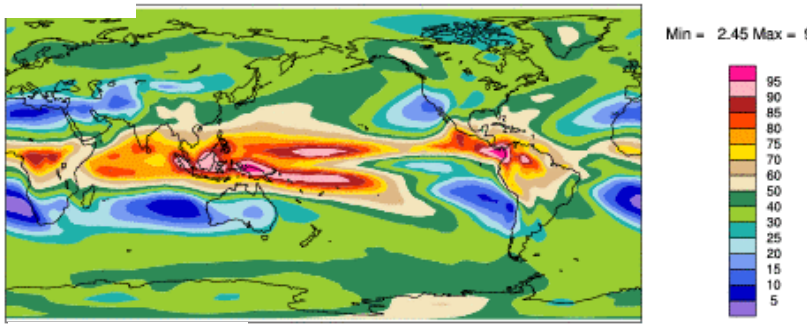


Double ITCZ has been noticeably reduced

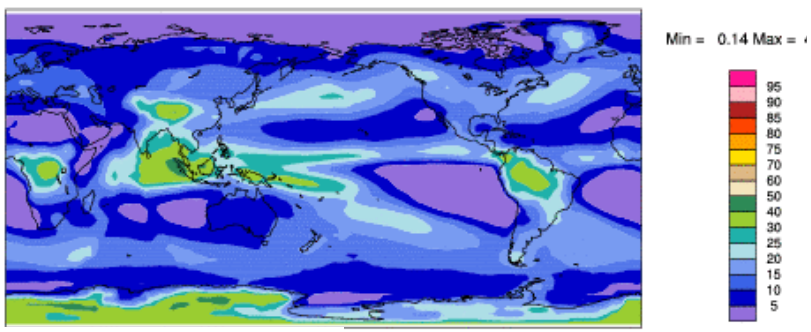
High Clouds (ANN)

newsstamip06

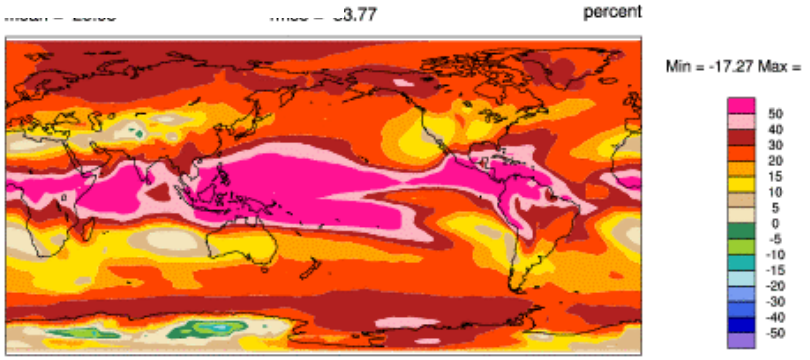
CAM2



ISCCP



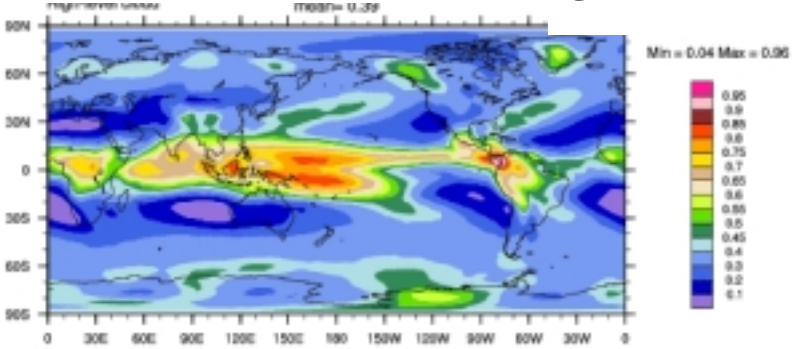
CAM2 –ISCCP



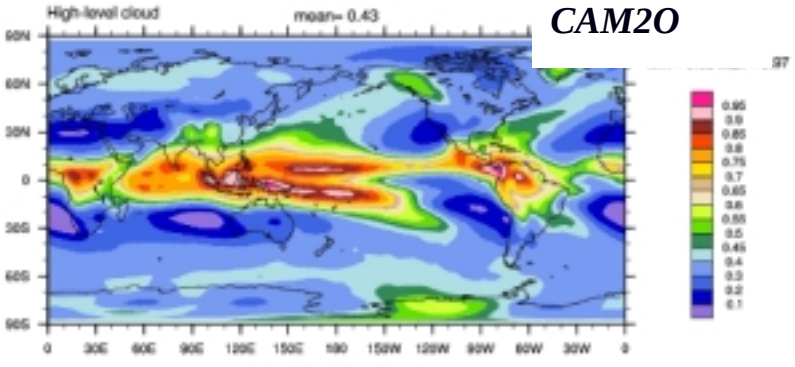
Created: Mon May 20 12:38:35 MDT 2002

DIAG Ver

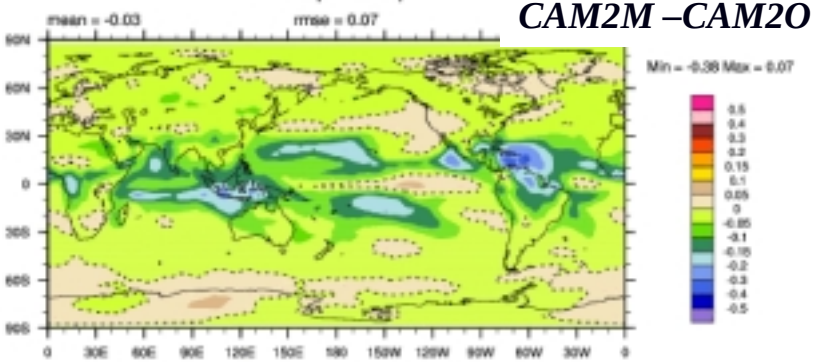
CAM2M



CAM2O



CAM2M –CAM2O

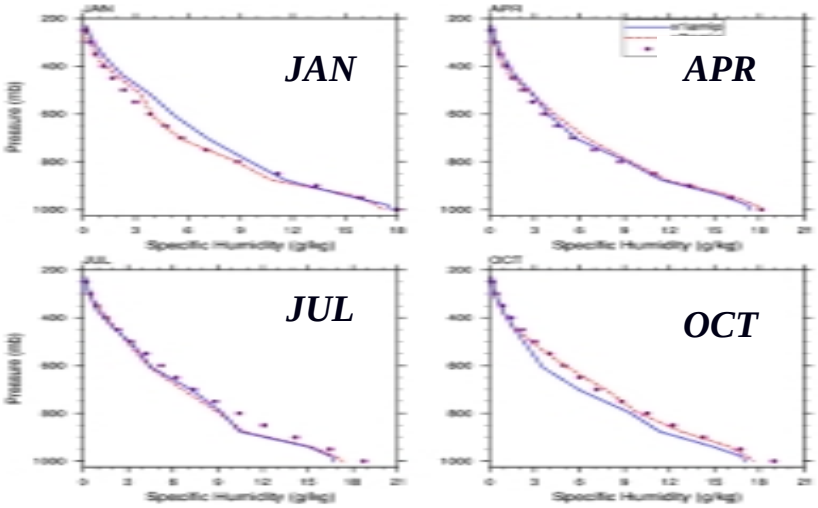


High Clouds are considerably reduced, especially in the tropical and sub-tropical regions.

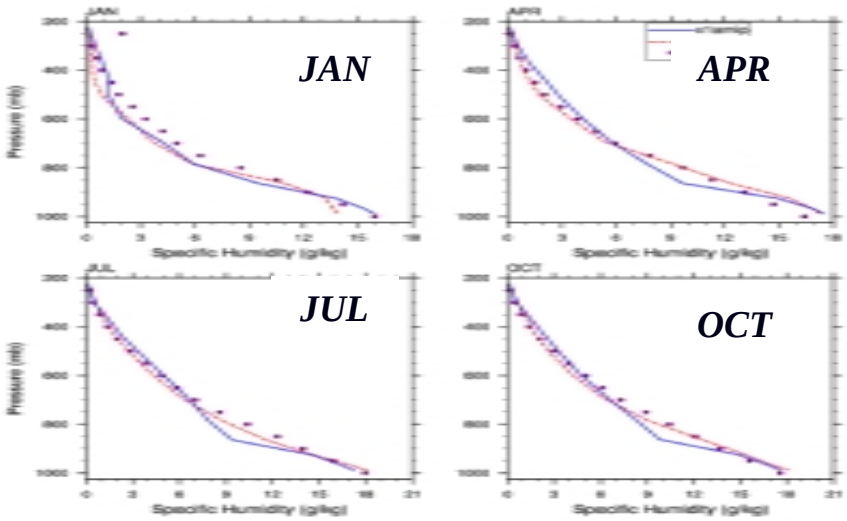
Specific Humidity

CAM2O
CAM2M

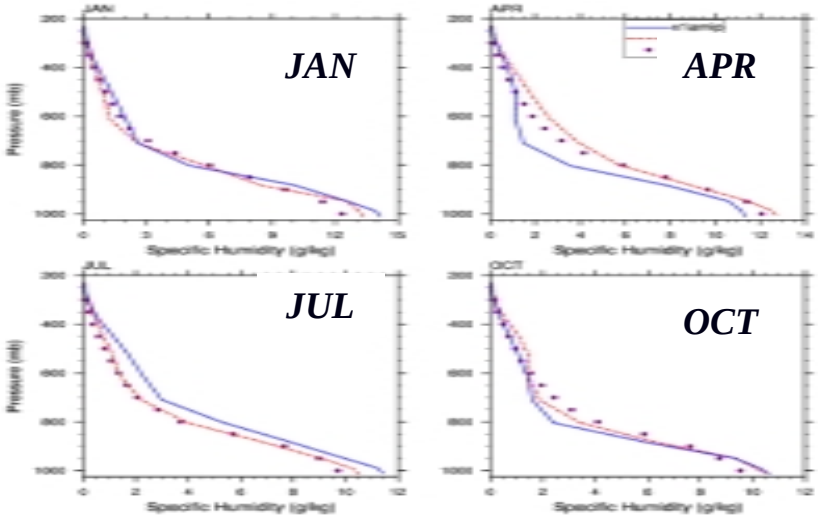
Yap (9.4N, 138.1 E)



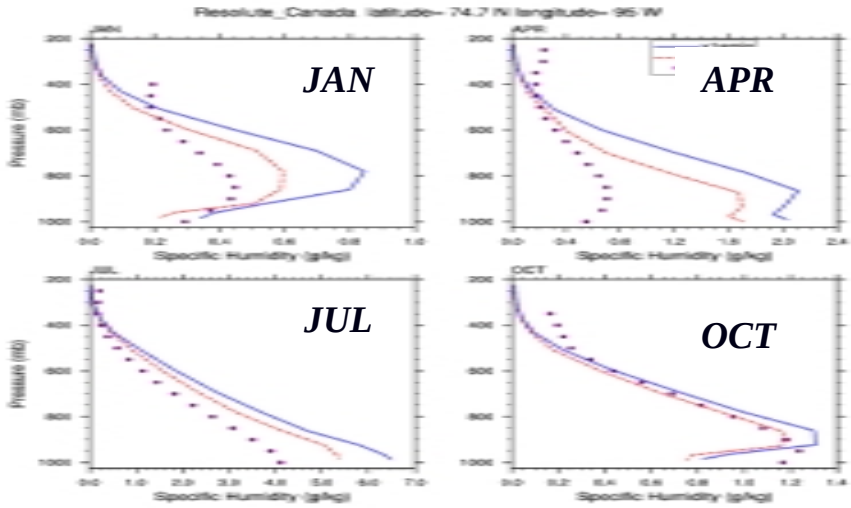
Panama (9N, 79W)



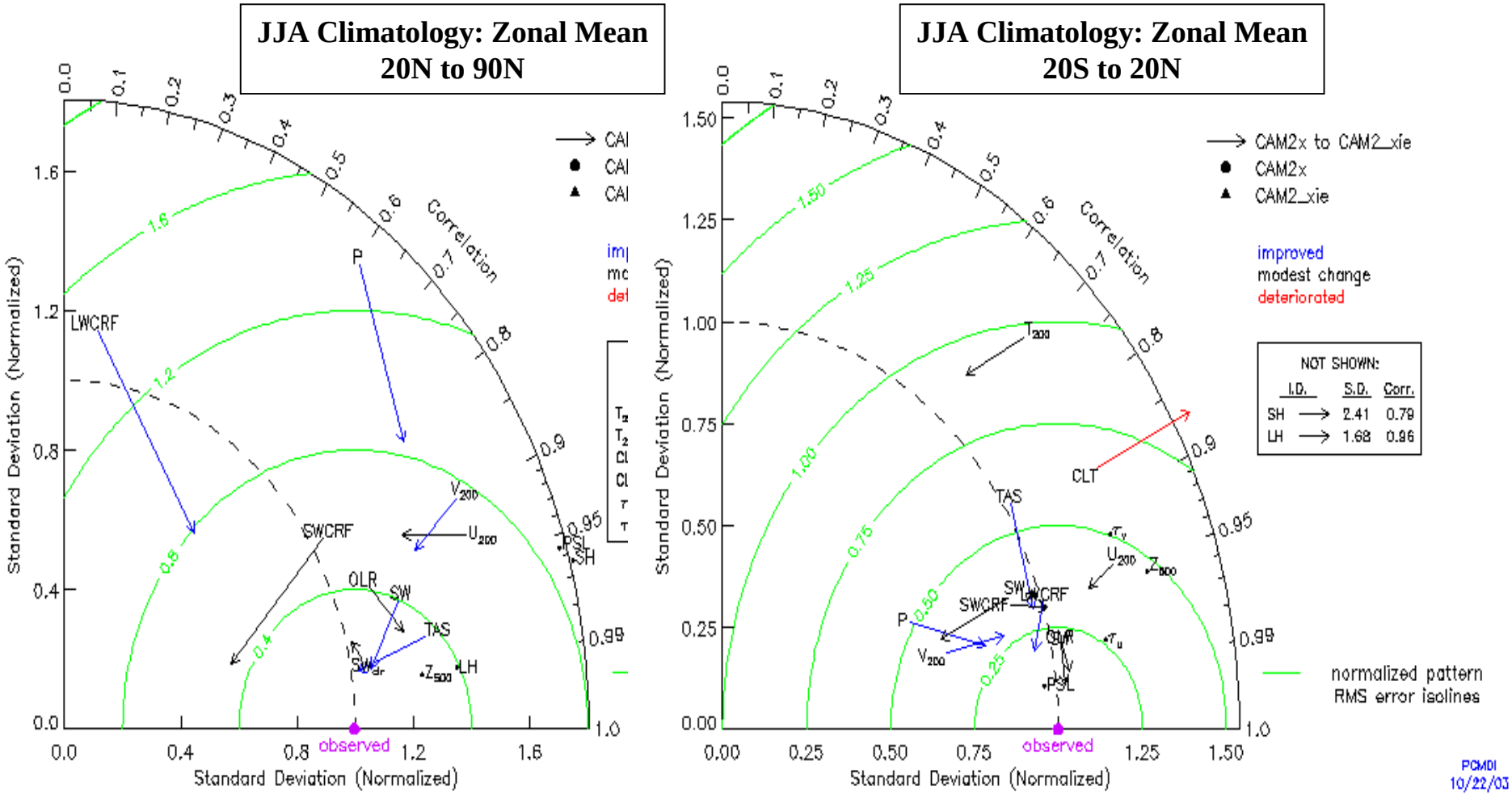
Easter Island (27S, 110W)



Resolute_Canada (74.7N, 95W)



Taylor Diagram (10 yr AMIP run)



Summary

- **SCM/CRM**
  - Effectively link the field data to GCM,
  - Isolate the tested scheme from the rest of the model
  - Inexpensive

  However:
  - Results are highly dependent on quality of large-scale forcing
  - No internal feedback from dynamic processes
  - Improvements are not guaranteed to be transferable to its parent GCM

- **CAPT**
  - Complement the SCM test
  - All feedbacks included
  - More evaluation data
  - Allows systematic errors to be identified before multiple errors compensated
  - Be able to link deficiencies with atmospheric processes through case study
  - Effectively transfers improvements from SCM tests into its parent GCM

SCM+CAPT: a more complete test

The End