ISCCP simulator developments: Application in models and evaluation with ground-based data

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Outline

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Part I

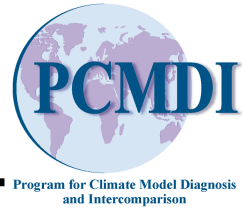
How do we know that the ISCCP simulator has been correctly implemented in models?

Part II

How do we know that the ISCCP simulator would reproduce the ISCCP observations if perfect cloud profile information were given the simulator?

Part I: Simulator misbehavior

ISCCP simulator post-facto tests



1. Does the sum of cloud fractions in the p_c-τ histogram equal the model's independently computed total cloud cover diagnostic?

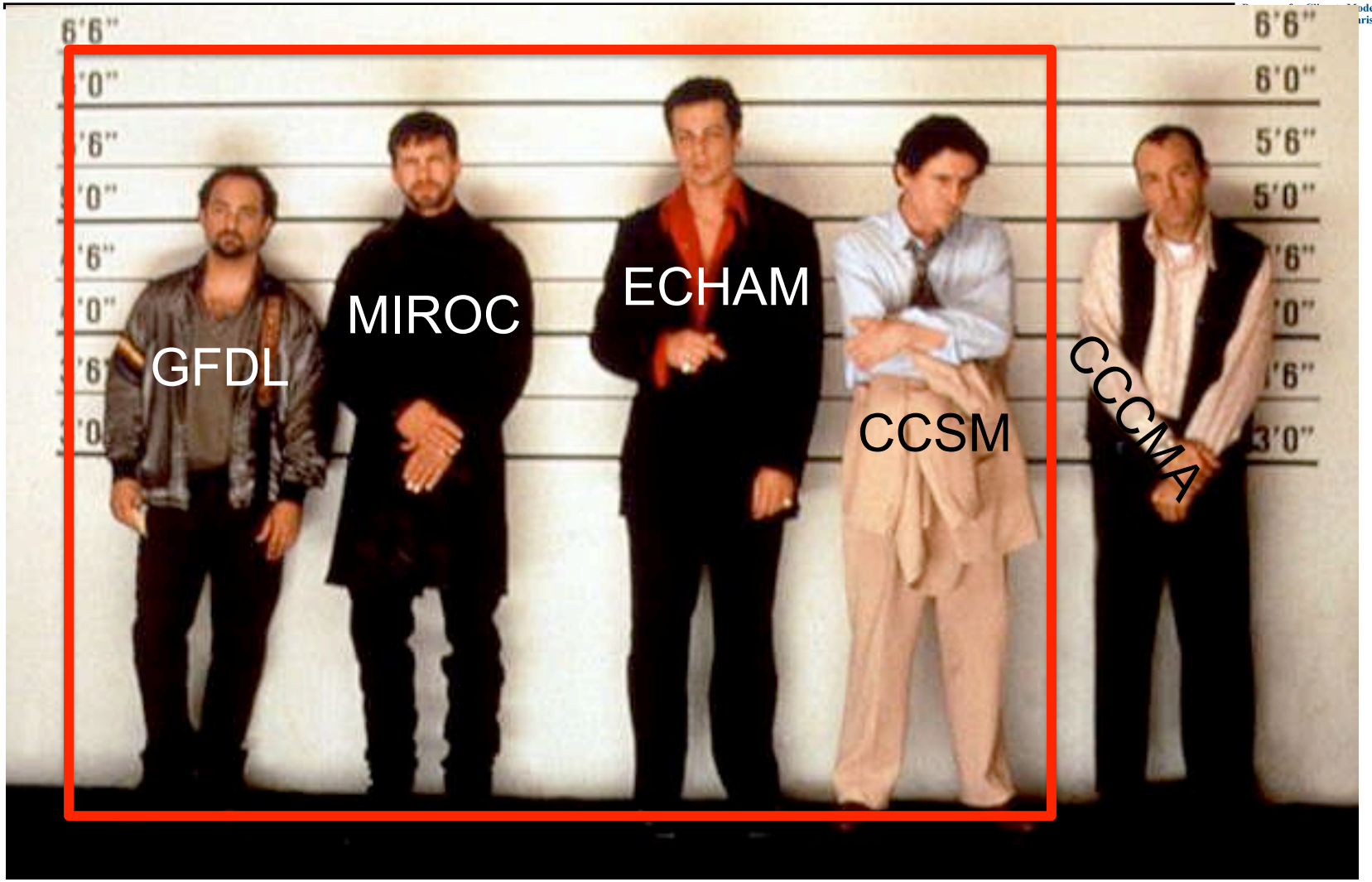
   It should if the ISCCP simulator was properly implemented (including cloud overlap assumption)*

2. Are cloud radiative effects calculated with ISCCP p_c-τ data consistent with the cloud radiative effects actually simulated by the model?

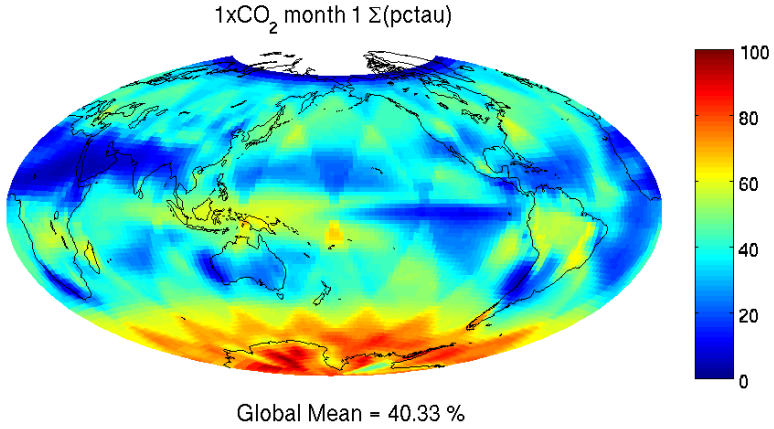
   Although not a requirement for implementation, consistency would facilitate multi-model analysis of cloud radiative effects

*Small differences will occur due to differences between the nighttime and daytime average cloud fraction

CFMIP1 suspects for test 1



Suspect 1: GFDL



GFDL Slab-Ocean Model Σ p_c-τ bins; January climatology

- The histogram archived in the CFMIP1 database had not been divided by the fraction of radiation time steps with sunlit conditions
- Solution → Divide by the fraction of calls to the simulator in each month with sunlit conditions *(data field provided by R. Hemler (GFDL))*

Fix for suspect 1

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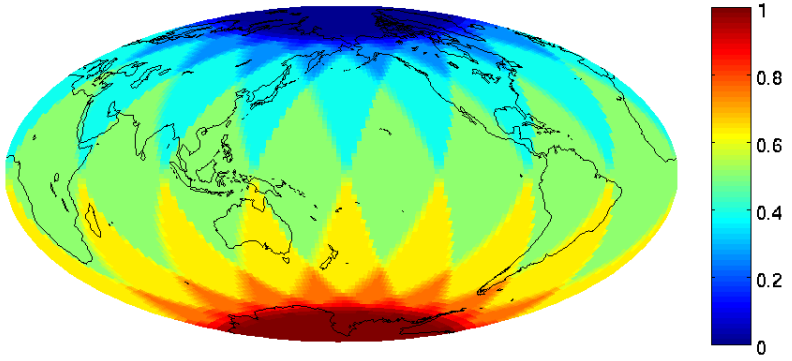
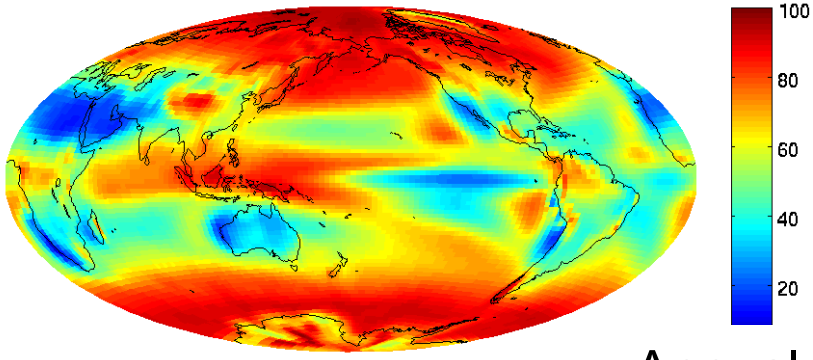
Sunlit Fraction



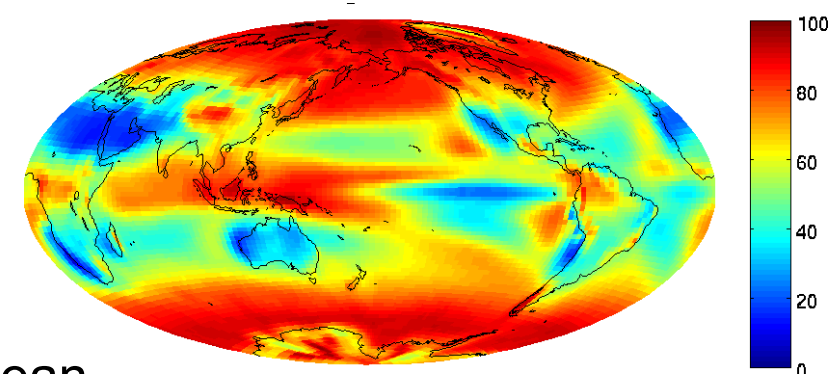
January fraction of 3-hourly radiation calls (performed at 00Z, 03Z, 06Z, etc.) under sunlit conditions

Total cloud cover (CLT) diagnostic



Global Mean = 63.09 %

Σ p_c-τ bins



Global Mean = 63.35 %

Annual mean

All studies with GFDL model had erroneous data!
(cloud fractions too low)

Suspects 2 – 3: MIROC & ECHAM

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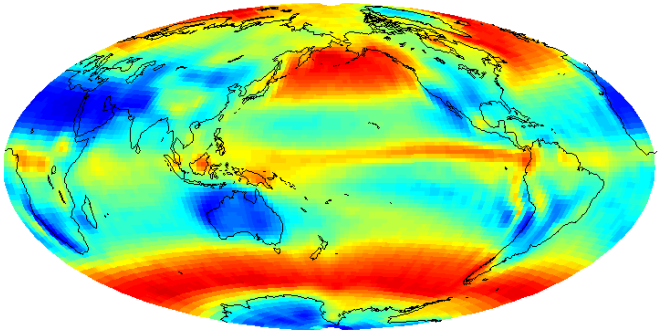
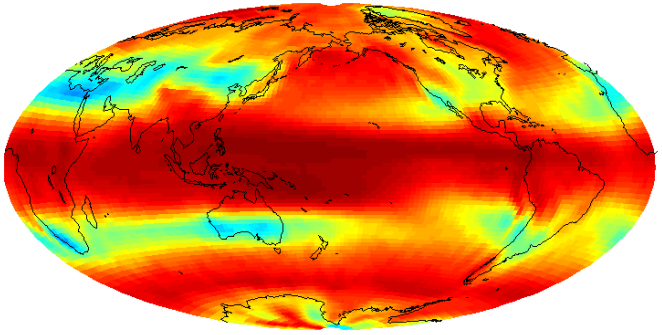
MIROC

CLT

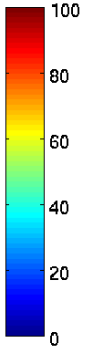


Global Mean = 52 %

Σ p_c-τ bins

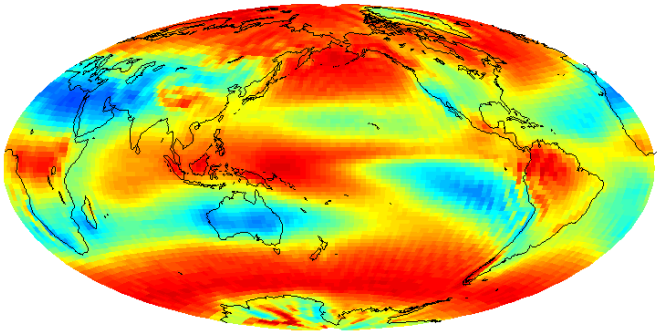


Global Mean = 76.21 %



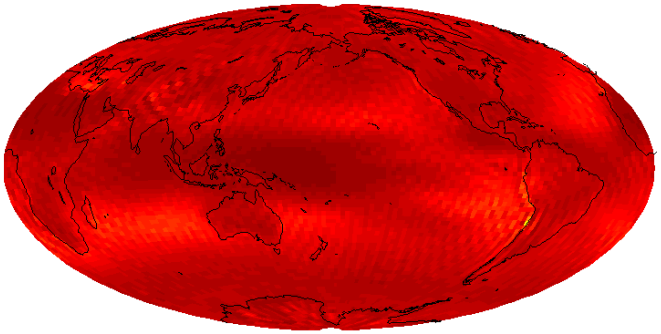
ECHAM

CLT

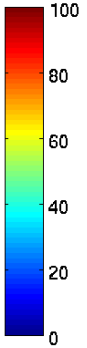


Global Mean = 63.51 %

Σ p_c-τ bins



Global Mean = 91.99 %

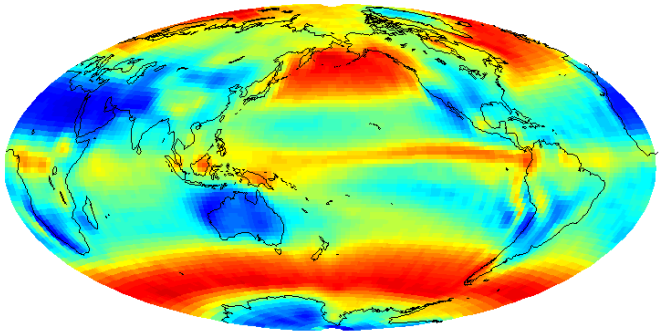


Fixes are not clear

- MIROC: If we remove the anomalously large amount of clouds in the highest-level p_c and lowest τ bin, we get agreement with the model's CLT diagnostic. But, is the simulator or CLT diagnostic in error?
- Doesn't work for ECHAM

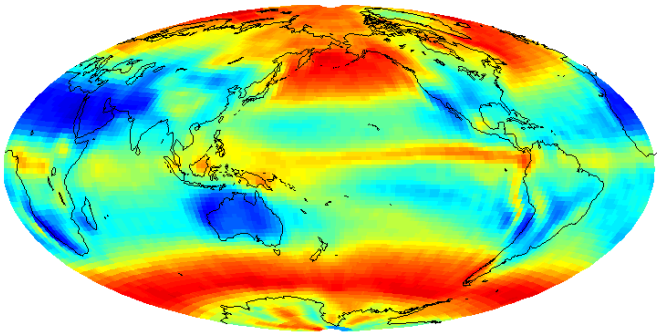
MIROC

CLT

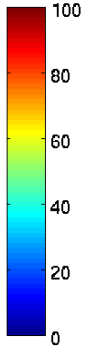


Global Mean = 52 %

Σ p_c-τ bins w/o highest/ thinnest cloud bin

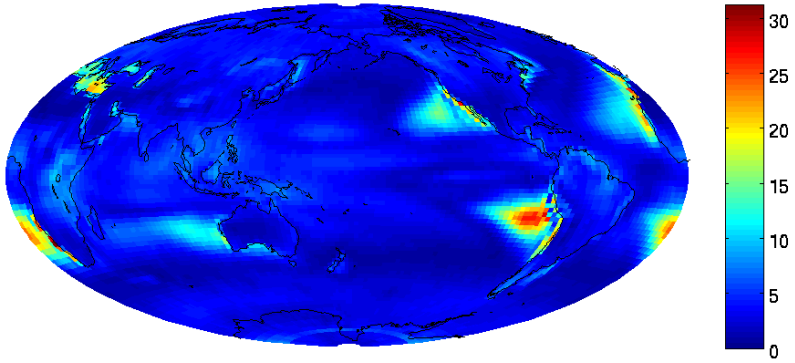


Global Mean = 52.84 %



Suspect 4: CCSM

RMSE(CLT – Σ p_c-τ)

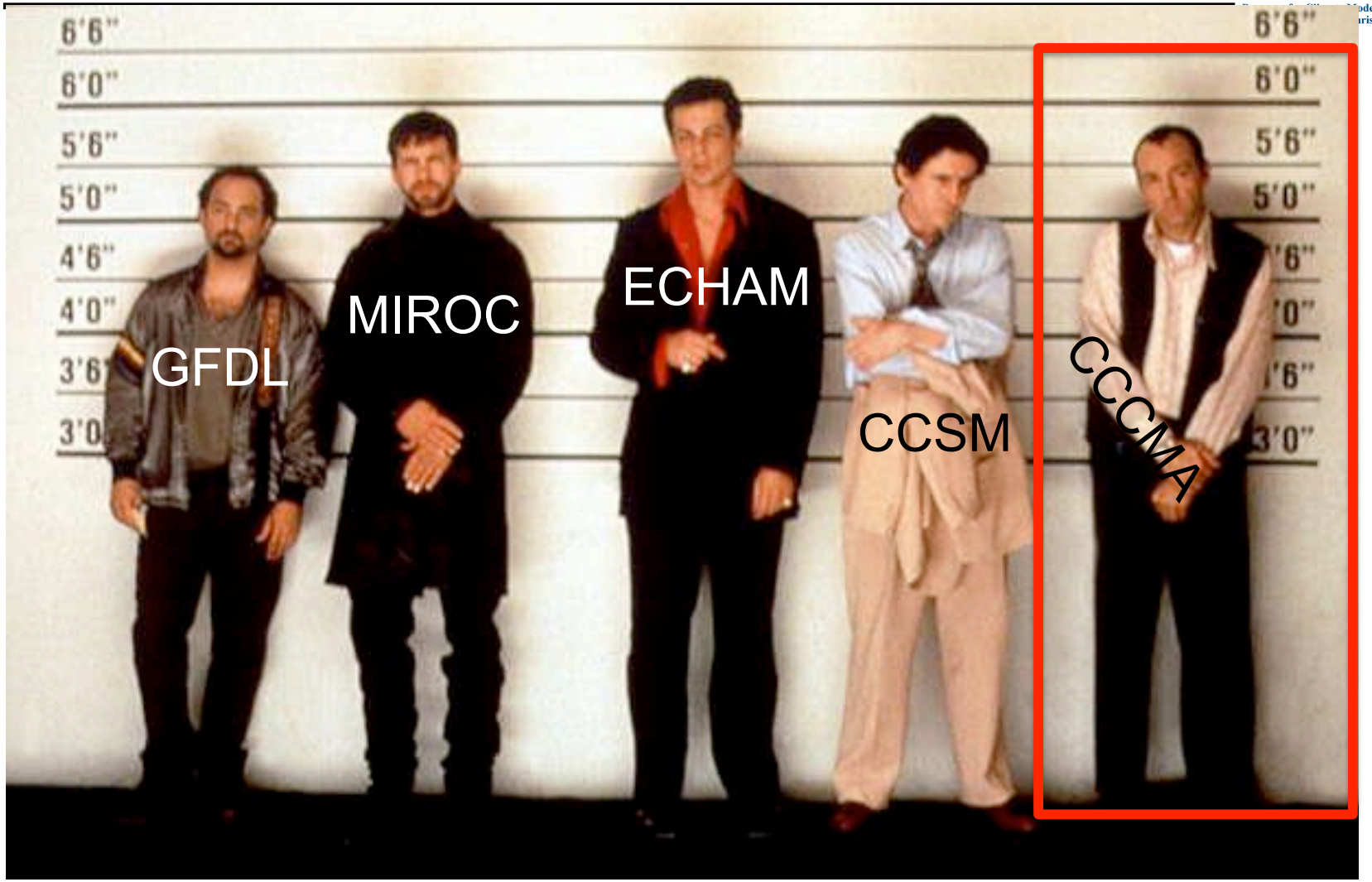


Global Mean = 4.01 %

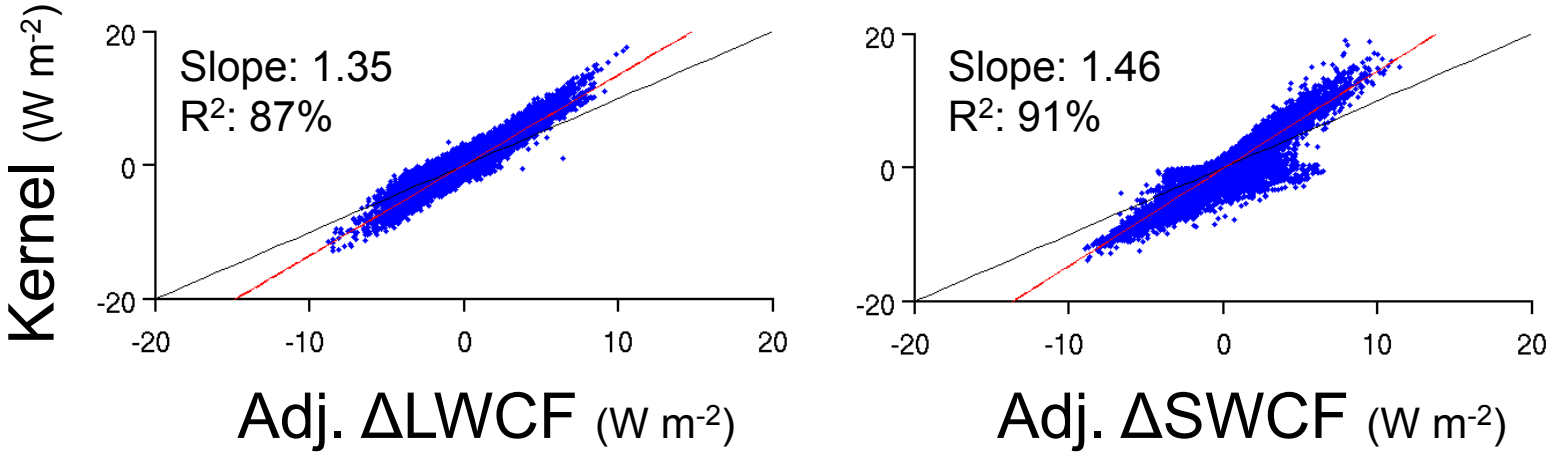
CCSM

- B. Medeiros & C. Hannay (NCAR) indicate that CLT includes “empty” clouds (clouds with zero τ) which preferentially occur in marine stratocumulus regions where the differences are largest
- Apparently, the ISCCP simulator excludes “empty” clouds whereas the CLT diagnostic includes them
- ISCCP simulator gives radiatively relevant clouds

CFMIP1 suspect for test 2



Radiative consistency in CCCMA



- Cloud feedbacks calculated from the CCCMA p_c-τ histogram *(Zelinka et al. 2011, submitted)* overestimate the cloud feedbacks estimated from the adjusted cloud radiative forcing diagnostic *(Soden et al. 2008 method)*. Why?

Why radiative inconsistency?

- In CCCMA, cloud τ is scaled down for radiation calculations to account for subgrid-scale inhomogeneity (plane-parallel albedo bias) *(Li and Barker 2002)*
- Because the ISCCP simulator is called prior to this scaling, the cloud fields reported in the histogram do not represent the clouds seen by radiation code
- Solution → Log-linearly interpolate the cloud radiative kernels from the original τ of the ISCCP simulator to a scaled-down τ *(Eq. 12 of Li et al. 2005)*

Radiative consistency fixed

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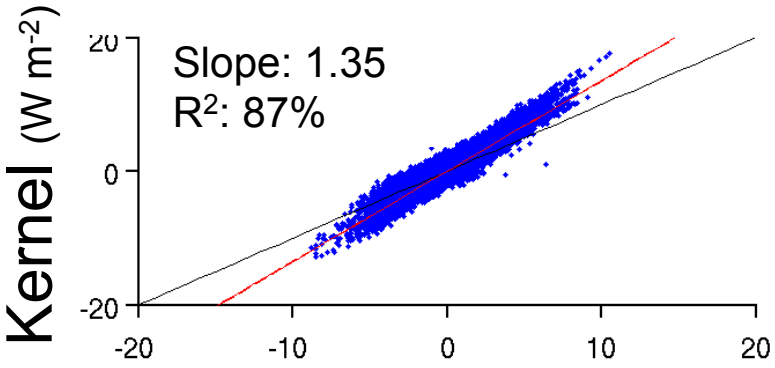
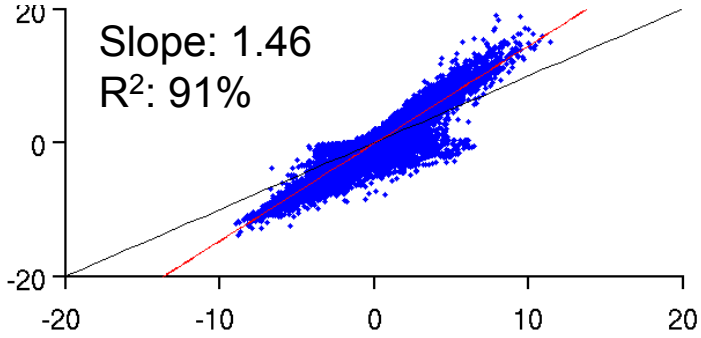
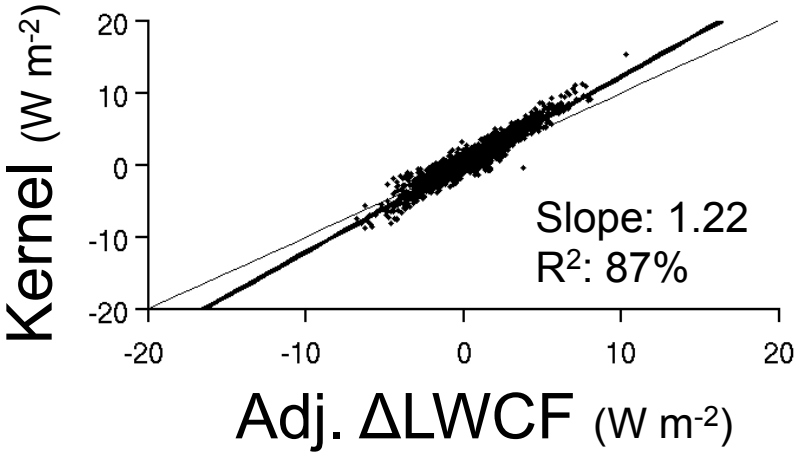
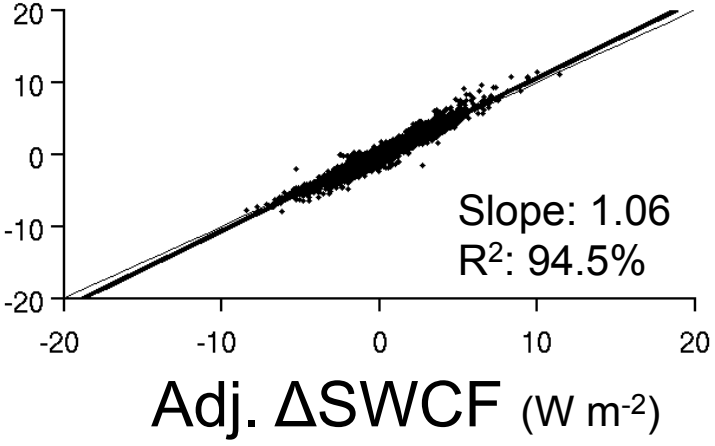
Before re-scaling the kernels …





After re-scaling the kernels …





Part I: Lessons

- Please check consistency of ISCCP simulator output as archived with the model's total cloud cover diagnostic
- Please give the simulator package the cloud radiative properties that are directly used in the model's radiative transfer calculations

Please check simulator output before (and after) submission to CFMIP2/CMIP5 archive!

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Part II

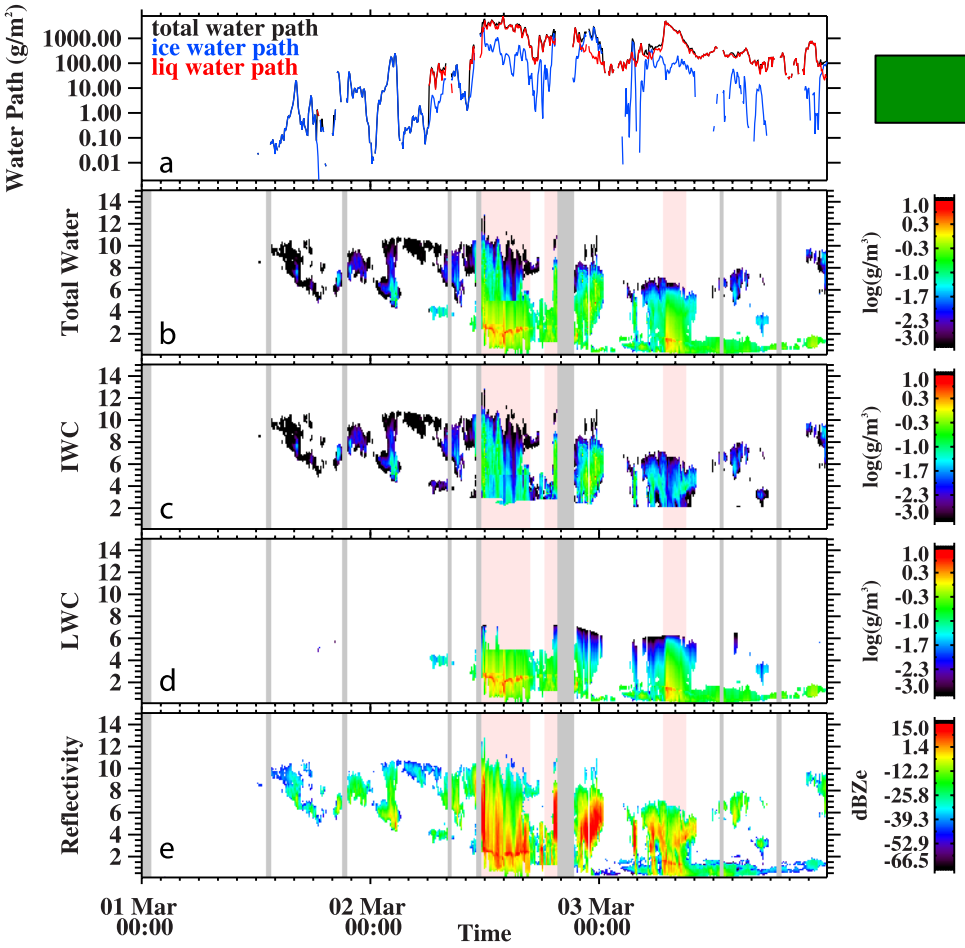
Does the ISCCP simulator behave as intended?

Mace, Gerald G., Stephanie Houser, Sally Benson, Stephen A. Klein, Qilong Min, 2011: Critical Evaluation of the ISCCP Simulator Using Ground-Based Remote Sensing Data. *J. Climate*, **24**, 1598–1612.

Premise

- If the inputs to the ISCCP simulator were perfect, would the simulator produce p_c-τ values that match the ISCCP satellite observation?
  - Inputs are vertical profiles of cloud quantities (primarily)
- These inputs are available from the cloud retrievals performed with long-term ARM cloud radar and lidar data *(Mace et al. 2006)*
- Radiation calculations performed with these cloud retrievals well reproduce both the observed surface and top-of-atmosphere radiative fluxes

Comparison flowchart



Sample of Mace ARM Retrievals

ICARUS

p_c-τ ? p_c-τ

Actual ISCCP observations

Pseudo-ISCCP observations derived from ARM data

Details

What is a fair test?

- Only compare overcast scenes at SGP in which the satellite observed cloud deck is fairly homogeneous

What are we testing?

- We are testing the ICARUS part of the simulator which computes an infrared brightness temperature T_b and applies (simplified) ISCCP single-layer cloud retrieval algorithms to derive values of p_c-τ that ISCCP would see
- ICARUS primarily adjusts p_c; in nearly all cases, τ is unchanged from its input value

Results: Good news

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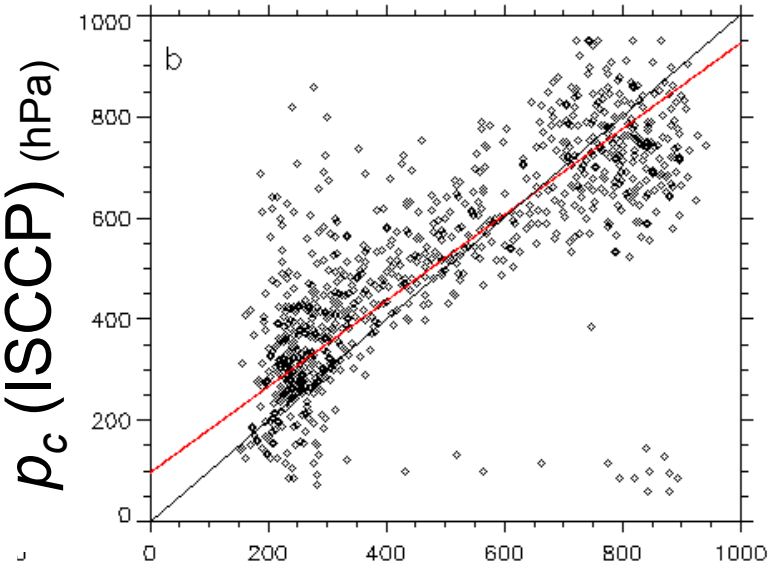
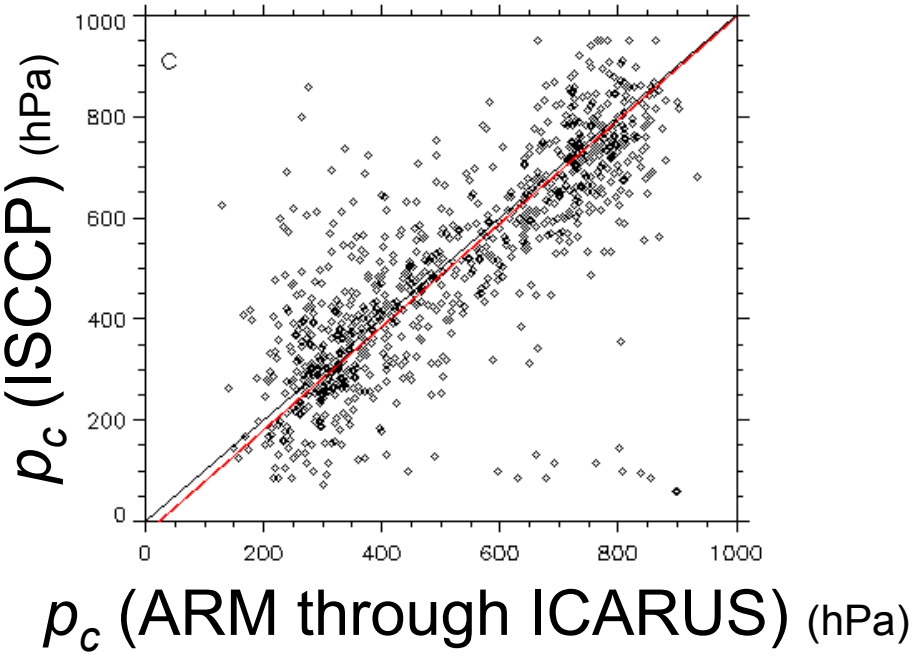
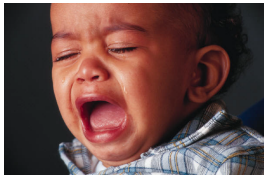
- ICARUS improves agreement of p_c

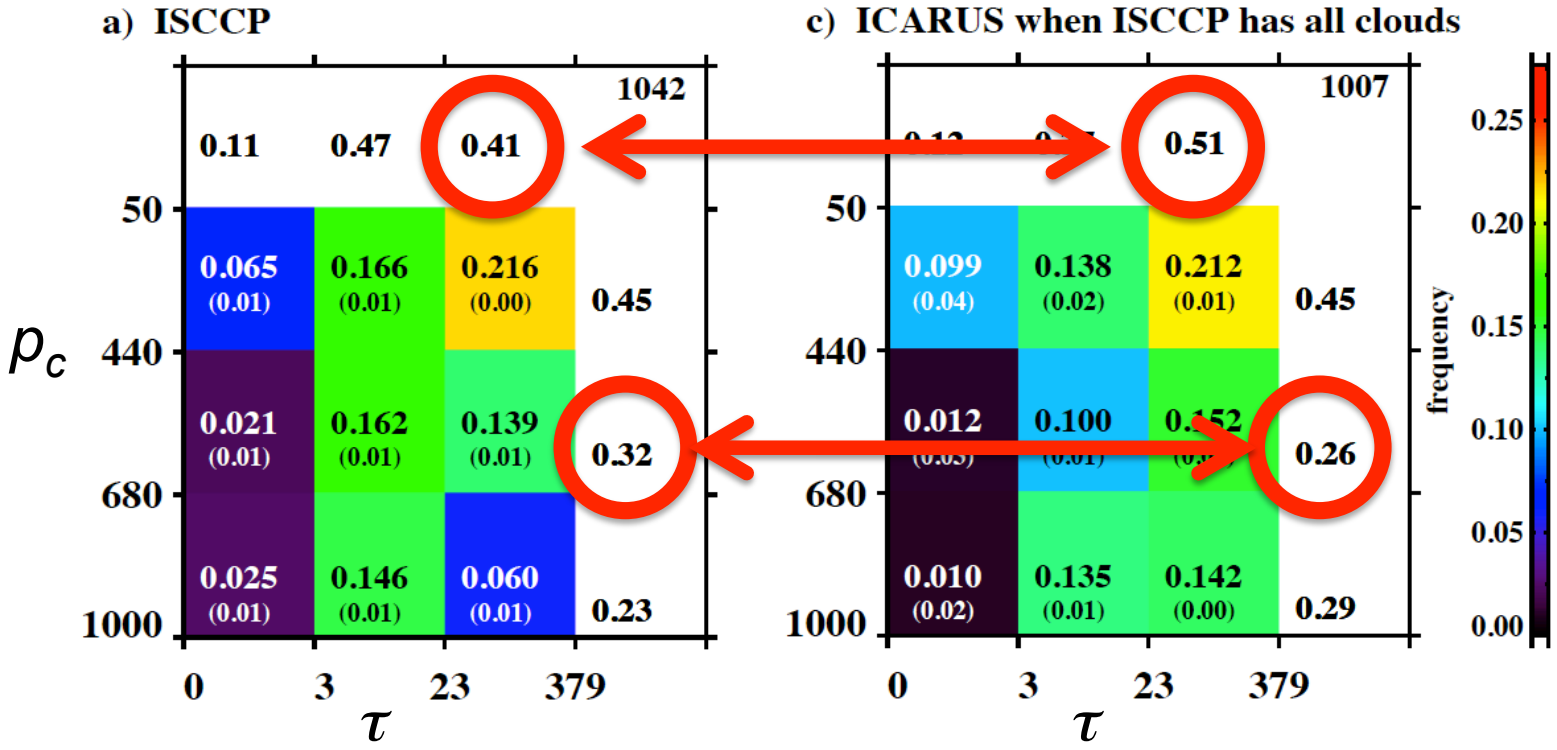




- ICARUS T_b agrees with that computed with a more complete radiative transfer code

Results: Not so good news





- Like GCMs *(Zhang et al. 2005)*, ARM observations passed through ICARUS have
  - More thick cloud than ISCCP
  - Less mid level cloud than ISCCP

What does ISCCP observe when ARM through ICARUS observes…

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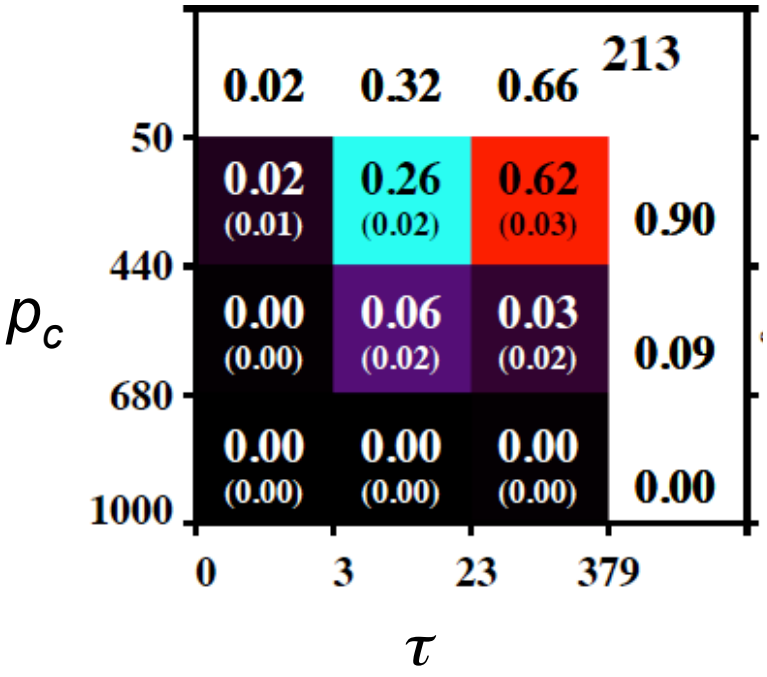
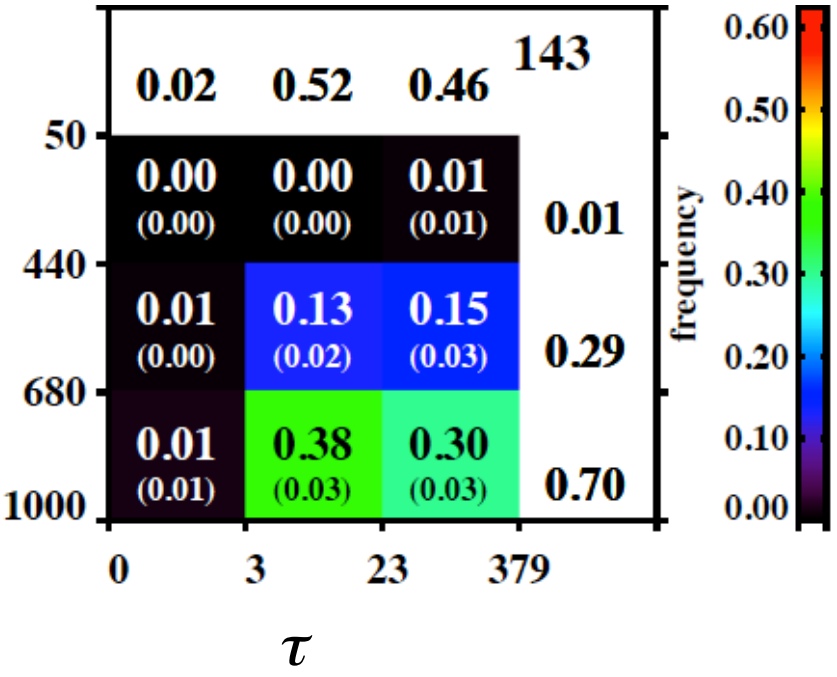
Deep (p_c <440, τ > 23)

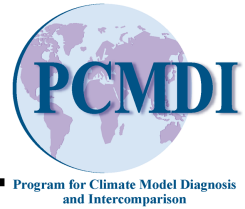


Stratus (p_c >680, τ > 23)



- Between 30 to 60% of clouds diagnosed by ARM as optically thick are diagnosed by ISCCP as optically intermediate

Are there τ retrieval biases not yet accounted for the simulator?



- Jay (and others) have found that τ retrievals from ground-based sensors are larger than those retrieved from satellites
- To what degree is this difference due to sub-satellite pixel variability (at scales < 1 km) biasing low the satellite-retrieved τ? (plane-parallel albedo bias, again)
- From Jay's data $\sigma(\tau) / \tau \sim 30\%$ for a satellite pixel. This would translate to a 7% underestimate for $\tau \sim 23$
- Preliminary result: Accounting for sub-pixel variability improves agreement moderately

Part II: Conclusions

- ICARUS p_c retrieval works well
- To the extent we better trust ground-based τ retrievals, it appears incorrect to assume that satellite-retrieved τ is directly comparable to model predicted τ as the ISCCP simulator does
- Jay recommends that the ISCCP simulator be modified to include a means of simulating the τ that would be diagnosed from pixel-mean radiances
- Where possible, simultaneous use of ground-based and satellite retrievals in the evaluation of model clouds is encouraged

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That's all folks!

Extra slides

How do ground-based and space-based optical depths compare?

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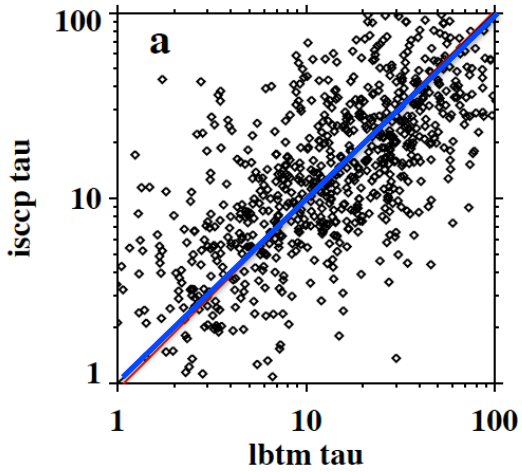
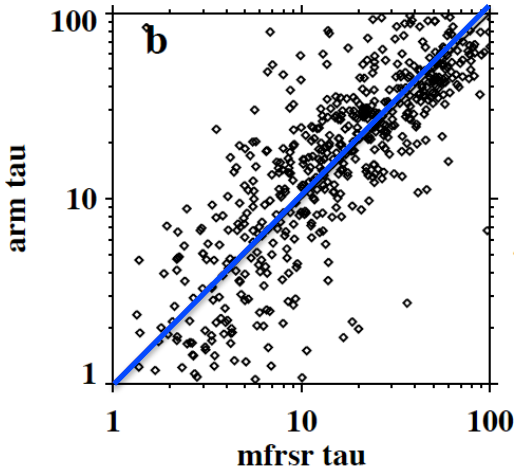
Comparing two Satellite τ



Comparing two ground based T



Comparing ground based & Satellite τ