An updated variant of CAM with unified clouds and unified microphysics

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Outline

- Goal and background
  - Create a climate model with a unified parameterization of clouds and turbulence
  - CLUBB: cloud parameterization based on assumed PDF method
  - SILHS: Monte Carlo based interface to microphysics
- Recent developments
  - Tied SILHS to MG2 microphysics
  - Implemented new sampling method in SILHS
- Current results
  - Plots of cloud forcings and liquid water path from global simulation
  - Sample point sensitivity analysis

Climate models should use unified parameterizations

- A unified modeling approach means:
  - One cloud parameterization for all cloud types
  - One microphysics scheme for all cloud types
- Nature is “unified”
  - One set of governing principles for all cloud types
- Our unified parameterization is called CAM-CLUBB-SILHS

CLUBB: Cloud Layers Unified By Binormals

- CLUBB is a cloud parameterization.
- CLUBB predicts a PDF (probability density function) to represent subgrid variability
    - PDF includes cloud water, liquid water potential temperature, vertical velocity, ice, rain, and snow.
    - Rain and snow are new additions to the PDF.
- Equations are suitable to handle all cloud types

Monte Carlo sampling: an interface to microphysics

- Subgrid variability should not be ignored
  - Many microphysical processes are highly nonlinear
- Want consistent assumptions of subgrid variability between CLUBB and microphysics
  - MG2 assumes a gamma distribution for cloud water; CLUBB assumes a truncated bi-normal; these are inconsistent.
- Monte Carlo method is a general integration method
- Steps in Monte Carlo integration:
  - Generate subcolumns that represent points in the grid box
  - Evaluate microphysics on subcolumns as if they were uniform grid columns
  - Average back to grid columns
- Introduces statistical noise into simulations

SILHS: Subgrid Importance Latin Hypercube Sampler

- SILHS is a Monte Carlo sampler
    - Generates sample points from a PDF, such as CLUBB's PDF
- SILHS supports horizontal correlations between variates
- SILHS subcolumns represent vertical correlation of fields
    - In nature, clouds are vertically overlapped. This matters, e.g., for radiative transfer.
- Techniques employed to reduce sampling noise:
    - Latin hypercube sampling
    - Importance sampling

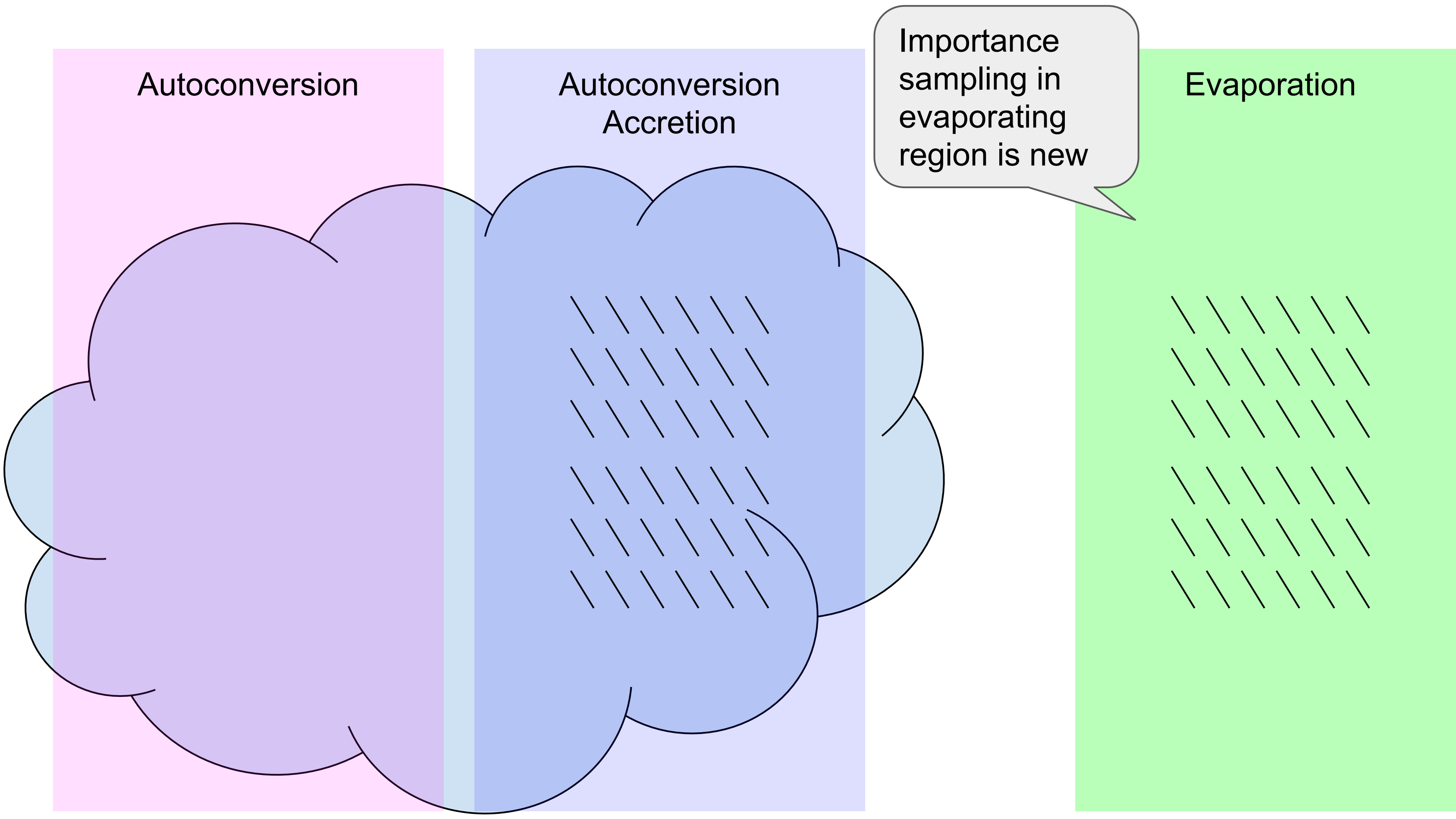
SILHS has been connected to MG2 microphysics

- MG2 prognoses rain and snow. This has advantages:
  - Allows for a better estimate of accretion
  - Allows SILHS to feed sample points of rain and snow into MG2. This gives greater control over the rain and snow distributions.

SILHS: new importance sampling method

- The goal is to make sure all important processes are well sampled
- Original importance sampling targeted cloudy region of grid box
  - Out of cloud process, evaporation of rain, was ignored
- New method divides grid box into “categories”
  - Categories based on cloud, precipitation, and PDF mixture component
  - Up to 8 categories can be used
- The sampling density can be adjusted individually for each category

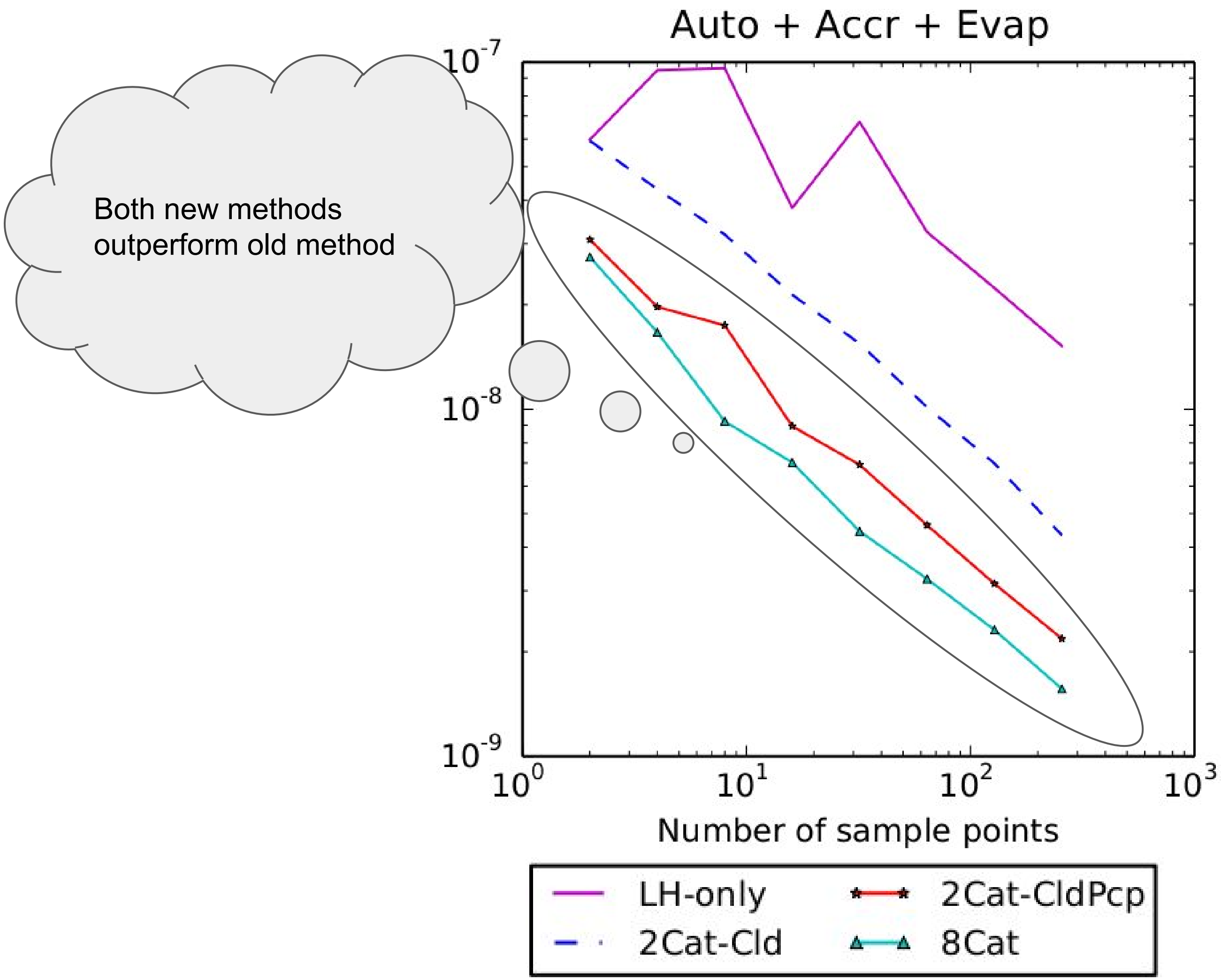
Different processes act in different regions



How should the sample points be distributed?

- 2Cat-Cld (original method)
  - Allocate 50% of sample points to cloudy regions, and 50% to clear air regions
- 2Cat-CldPcp (new default method)
  - Allocate points ("as many as we can") to regions containing either cloud or precipitation
  - Some points placed in the "boring" region with no precipitation and no cloud to avoid large weights
- 8Cat (new experimental method)
  - All eight category allocations set by user
  - Works well if "optimal" category allocations are similar for many cloud types

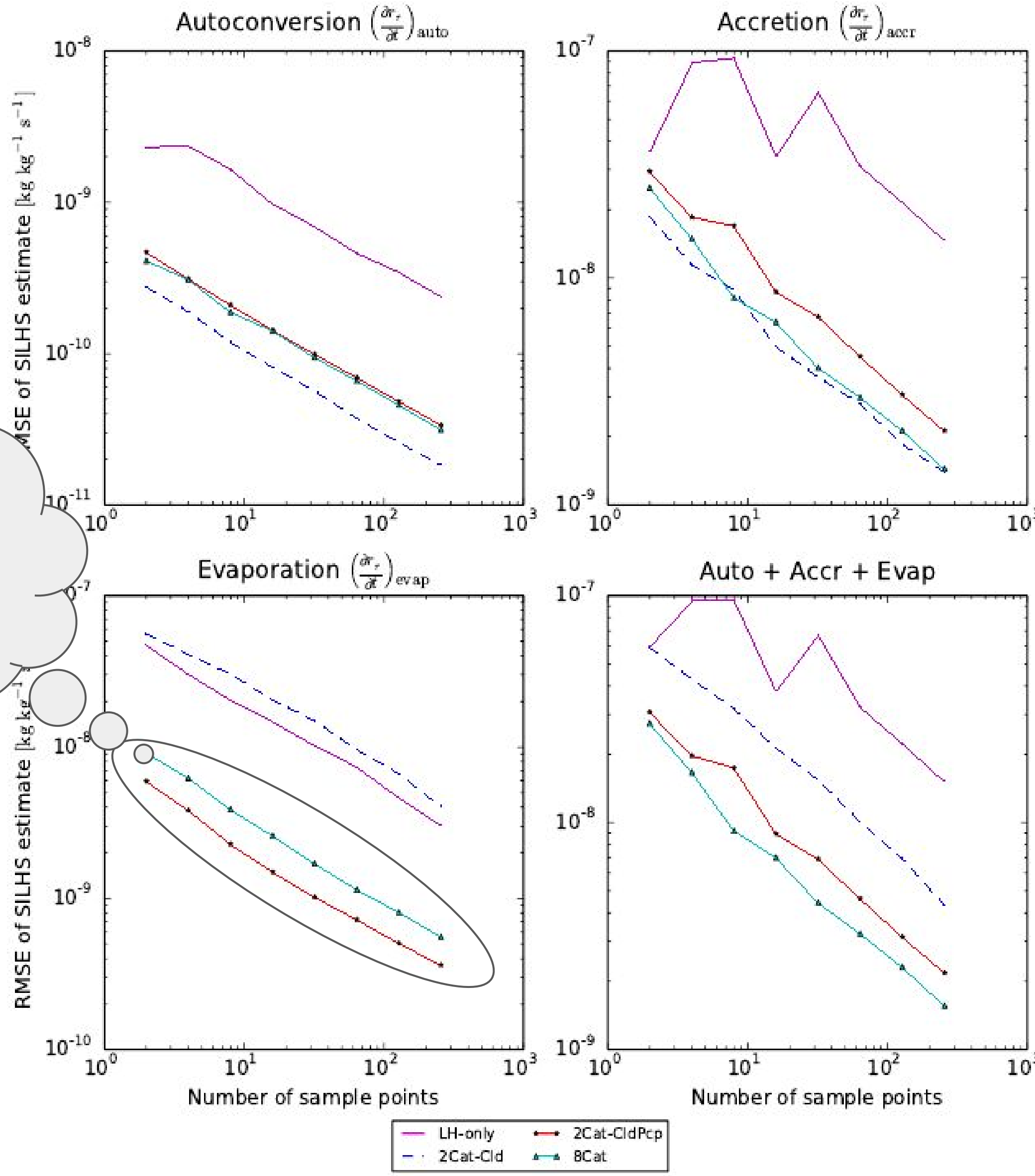
Single column result (RICO Cu): the new methods improve the rain tendency estimate



Raut and Larson, 2015

Key improvement is in estimate of evaporation

RMSE of evaporation estimate is greatly improved (reduced) in new methods

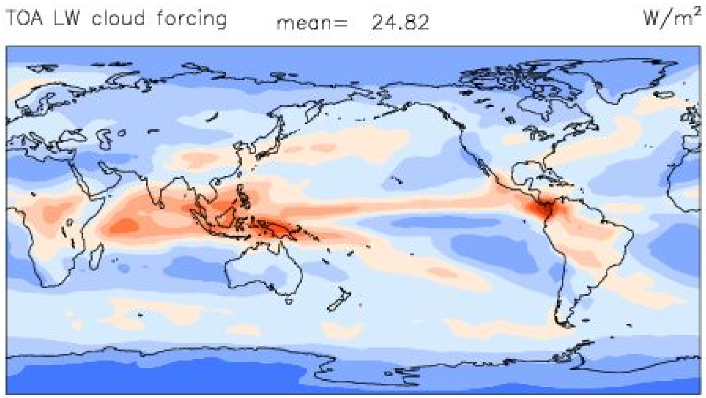


The new method has several advantages

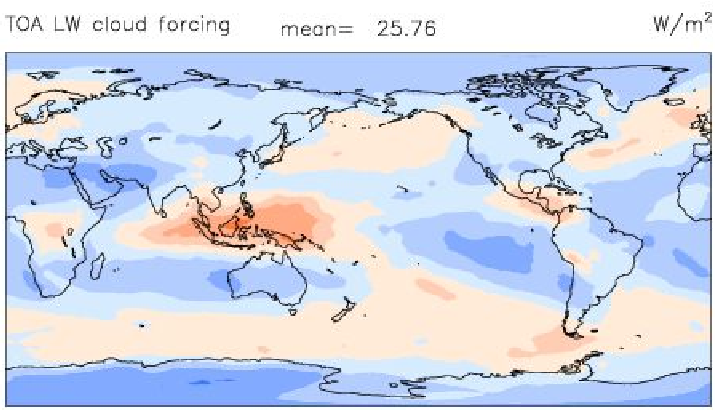
- Flexibility in distributing sample points
  - E.g., the ability to sample out-of-cloud processes preferentially is important for evaporation
  - Provides a framework for research in importance sampling
- Decreased computational cost
  - Reduced noise: need less points to achieve a desired accuracy in estimation
  - The method itself does not significantly affect computational cost as compared to the old method.

LWCF: weak ITCZ but global mean is comparable to observations

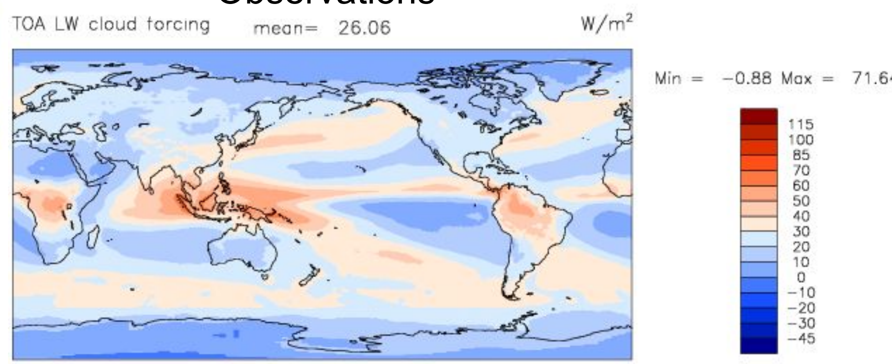
CAM5



CAM-CLUBB-SILHS

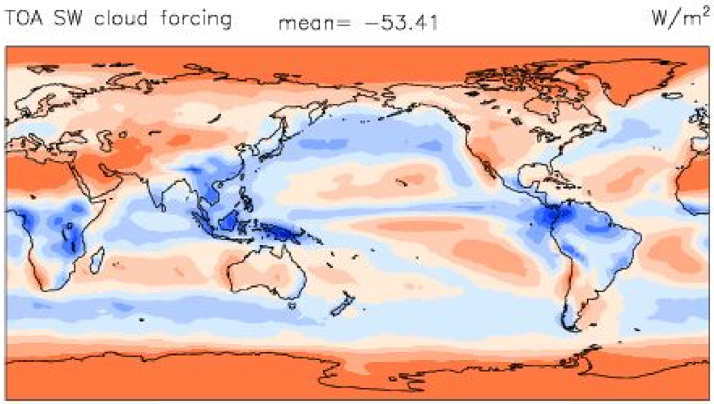


Observations

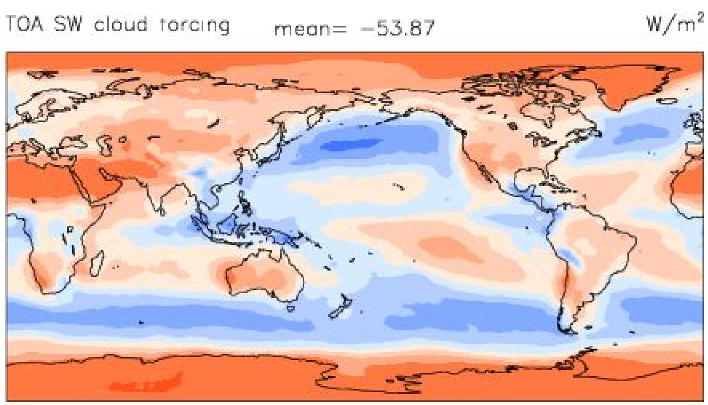


SWCF: weak ITCZ but reduced bias over tropical lands

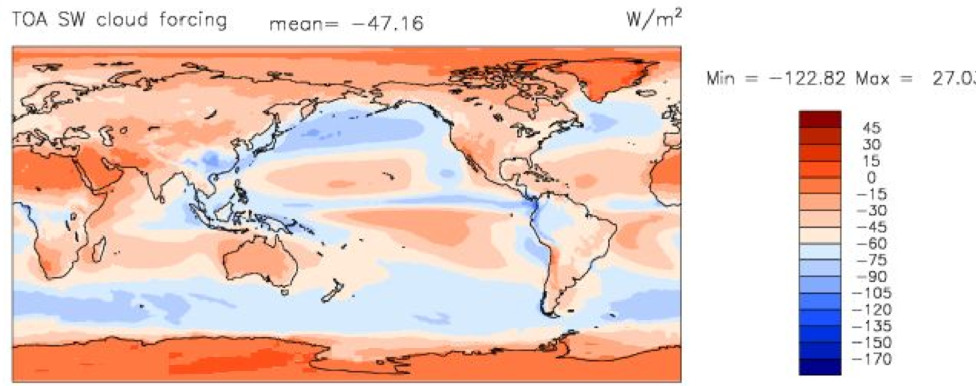
CAM5



CAM-CLUBB-SILHS

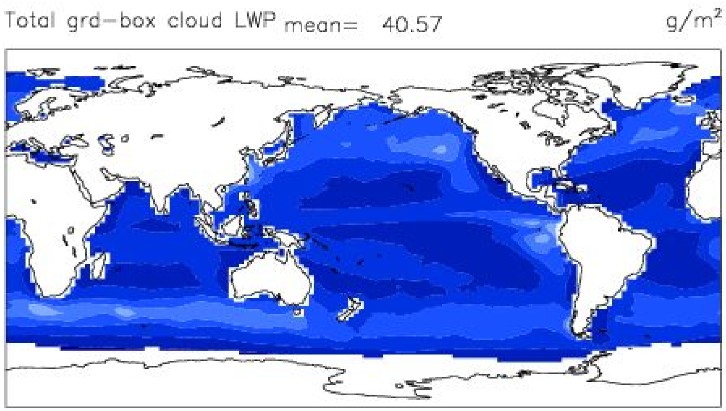


Observations

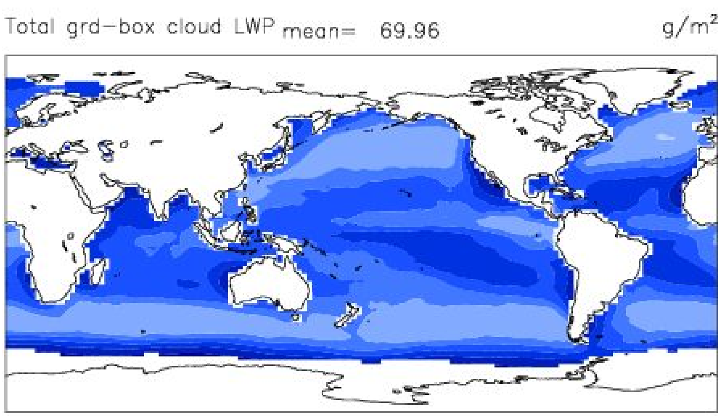


LWP: improved compared to CAM5

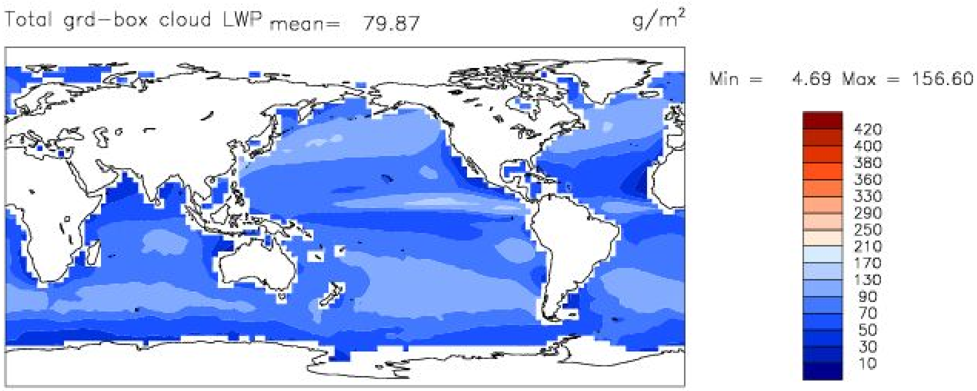
CAM5



CAM-CLUBB-SILHS



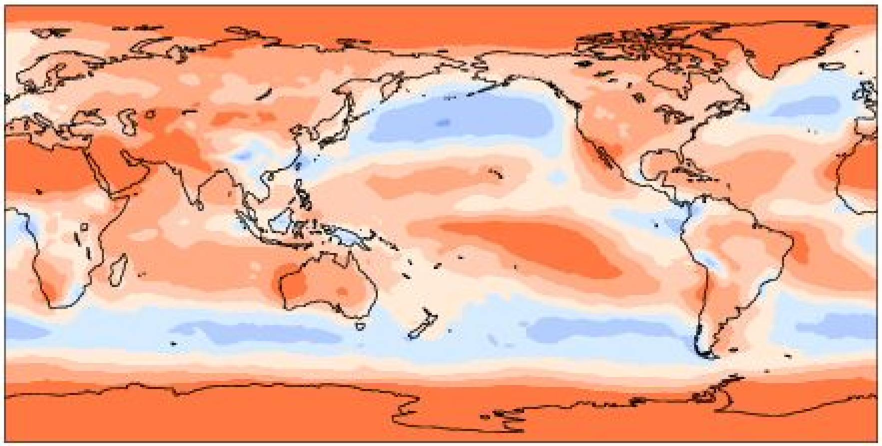
Observations



Simulation is sensitive to the number of sample points used

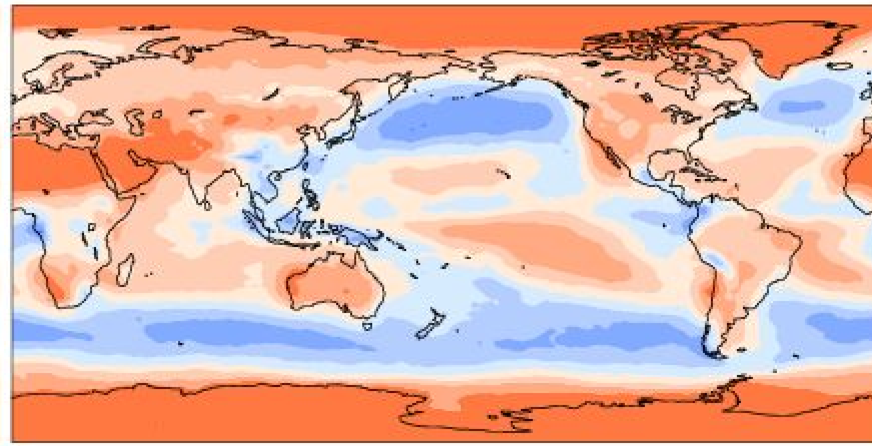
1 subcolumn

TOA SW cloud forcing mean= −38.25 W/m^2



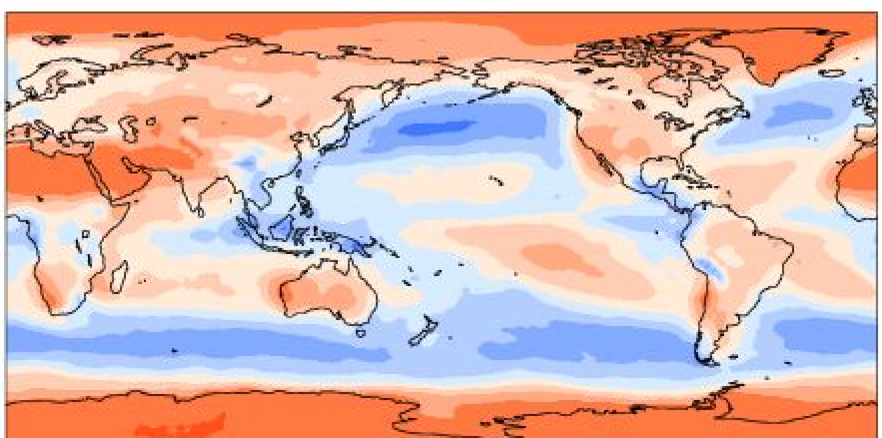
2 subcolumns

TOA SW cloud forcing mean= −48.99 W/m^2



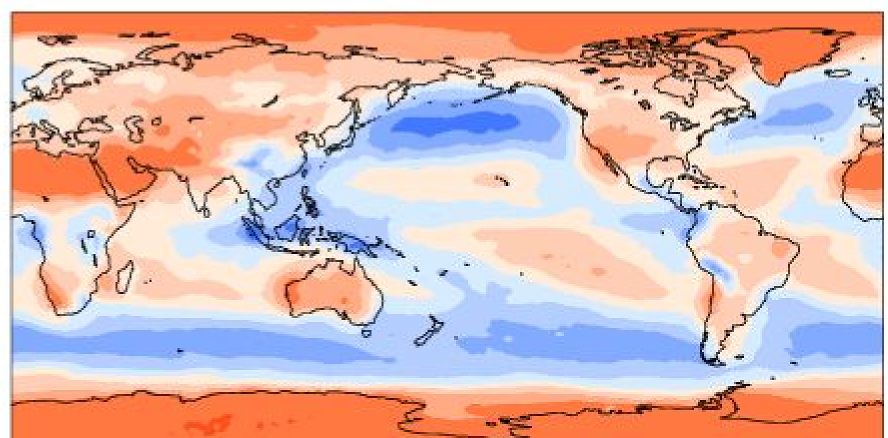
4 subcolumns

TOA SW cloud forcing mean= −53.87 W/m^2



8 subcolumns

TOA SW cloud forcing mean= −54.91 W/m^2



Conclusions

- A new sampling method has been implemented in SILHS
  - More flexible
  - Can improve estimates of, e.g., evaporating rain
- CAM-CLUBB-SILHS has been updated to support MG2
- ITCZ clouds are too weak; storm tracks are too bright
- LWP is improved as compared to CAM5

Questions?

Thank you for your time!