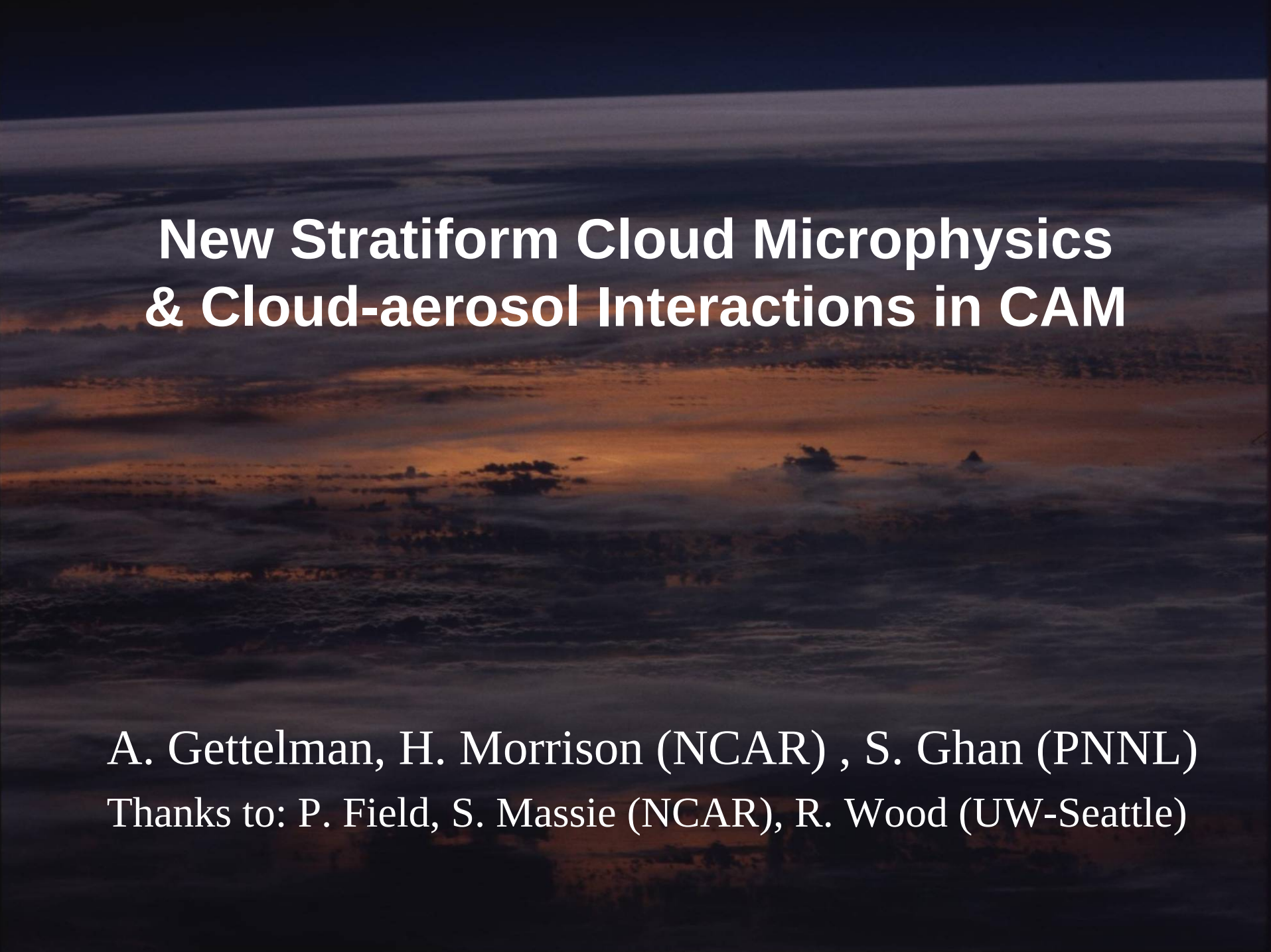


New Stratiform Cloud Microphysics & Cloud-aerosol Interactions in CAM

A. Gettelman, H. Morrison (NCAR) , S. Ghan (PNNL)

Thanks to: P. Field, S. Massie (NCAR), R. Wood (UW-Seattle)

Motivation

- Aerosol-cloud interactions
- Better treatment of ice
- Multi-scale modeling (unify treatments)

Method:

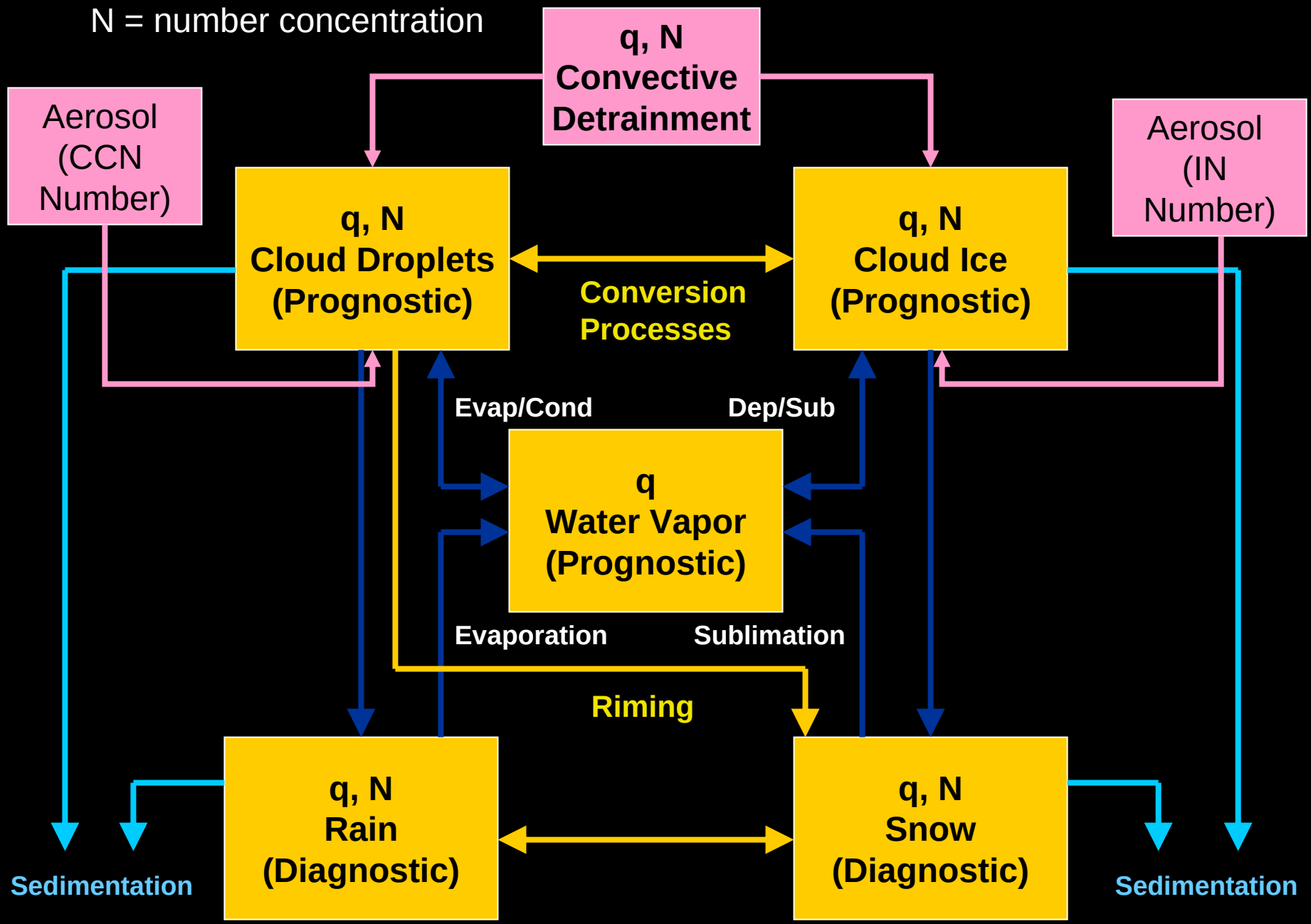
- Replace bulk microphysics
  - Current bulk scheme: Rasch & Kristjansson, (1998)
  - New Scheme based on Morrison et al (2005)
  - Currently same closure (Zhang et al, 2003)

History/Progress

- Microphysics Task Group (Nov 2005)
- Developments reported at AMWG, CCSM
- Progress:
  - Working in versions of CAM (uncoupled)
  - Coupled to prescribed aerosols
- Current status:
  - Reasonable uncoupled climate simulation
    - Slight bias improvements over control
    - Much better moist physics

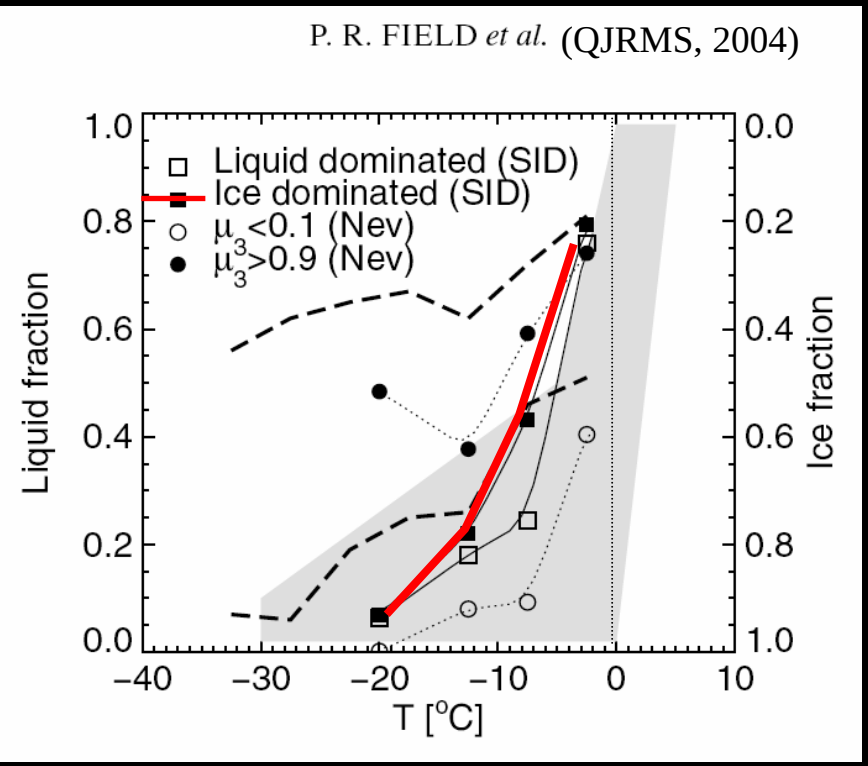
Key features of the new scheme

- Two-moment – predicts number concentrations and mixing ratios of cloud water and ice.
- Liquid/ice fraction determined by microphysical processes (Bergeron, heterogeneous freezing) instead of simple function of temperature.
- Coupled with aerosol by treating droplet nucleation (Abdul-Razzak and Ghan 1998) and ice nucleation (Cooper 1986).
- Mapping of Aerosol mass to number from Lohmann (1999)
- Diagnostic treatment of rain and snow mixing ratio and number concentration.
- Self-consistent treatment of sub-grid cloud water distribution for all relevant microphysics processes – straightforward to couple with diagnostic cloud scheme.
- Flexibility to allow independent column approach.

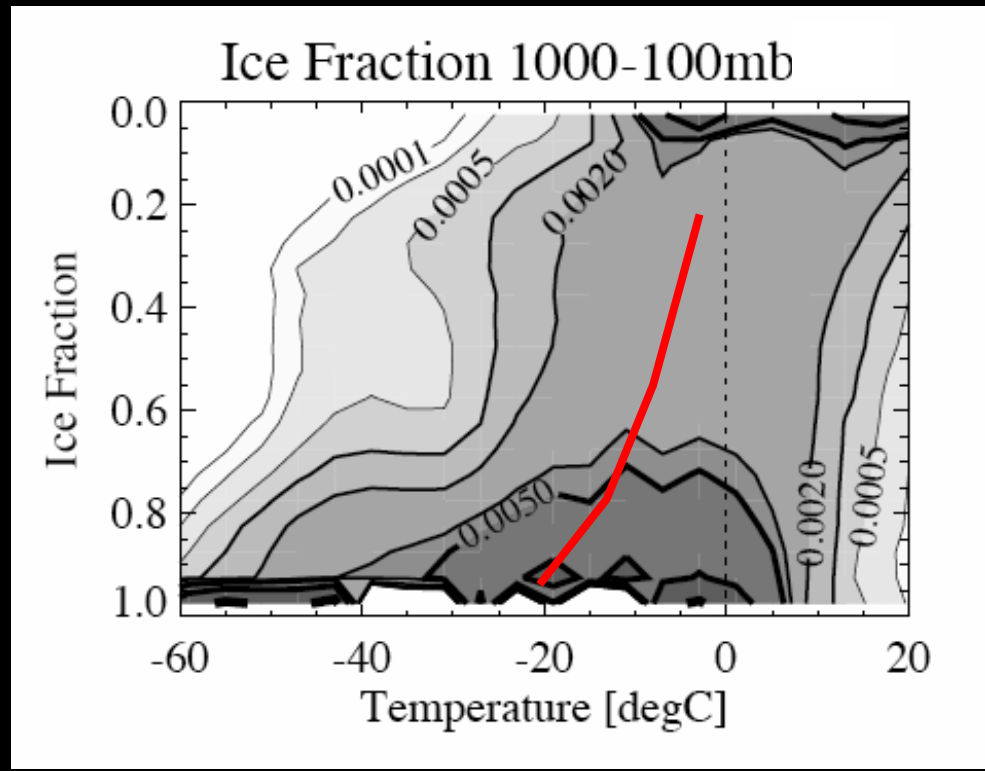

q = mixing ratio
N = number concentration
q, N
Convective
Detrainment
Aerosol
(CCN
Number)
Aerosol
(IN
Number)
q, N
Cloud Droplets
(Prognostic)
q, N
Cloud Ice
(Prognostic)
Conversion
Processes
Evap/Cond
Dep/Sub
q
Water Vapor
(Prognostic)
Evaporation
Sublimation
Riming
q, N
Rain
(Diagnostic)
q, N
Snow
(Diagnostic)
Sedimentation
Sedimentation

Mixed Phase Processes

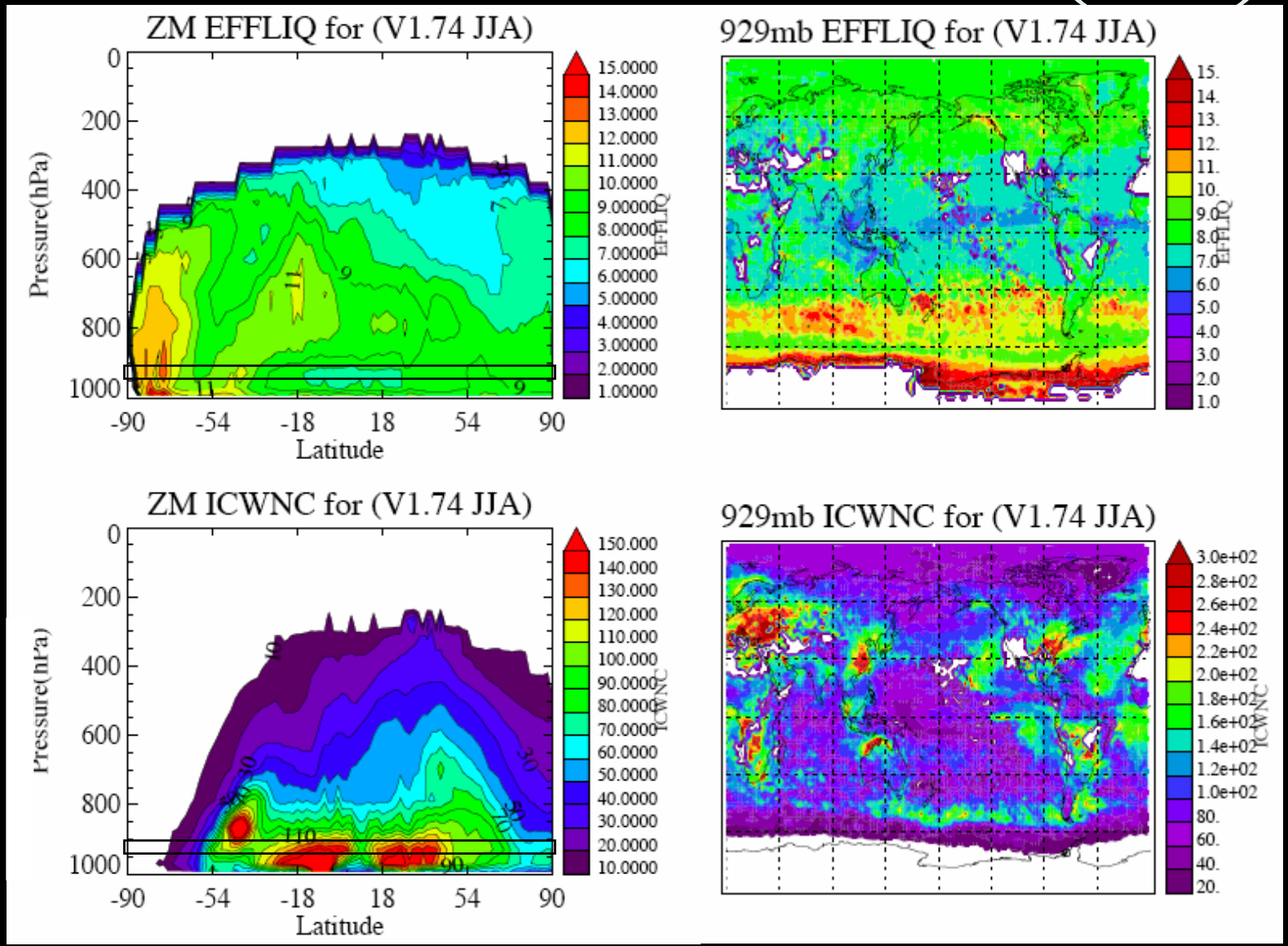
Observed



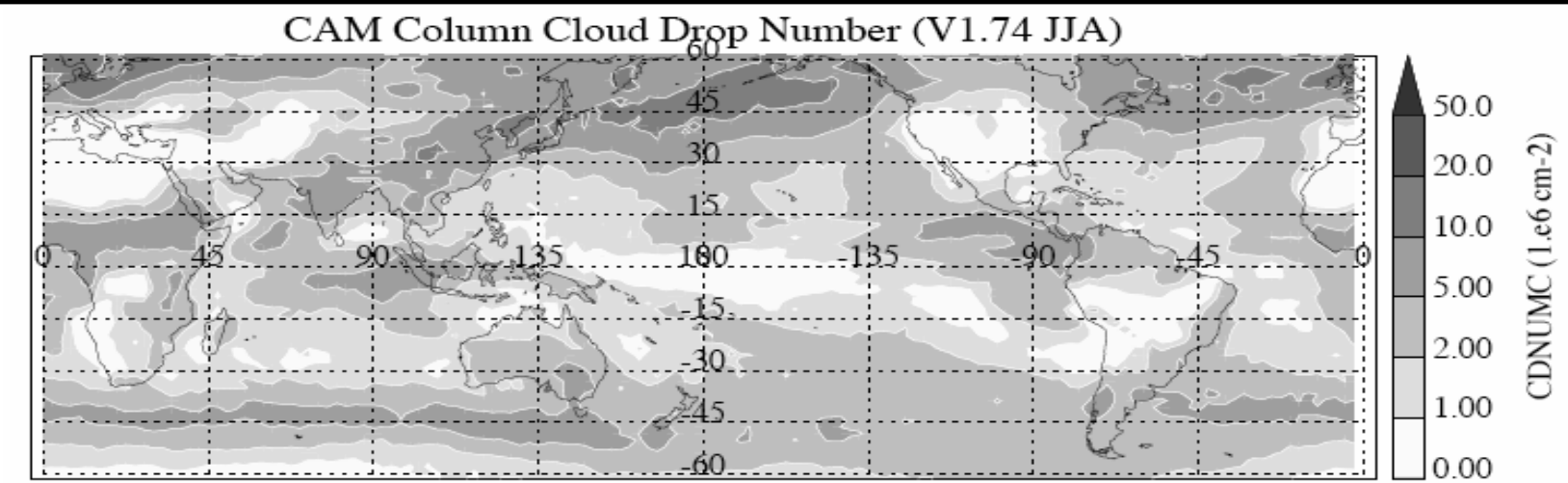
Simulated



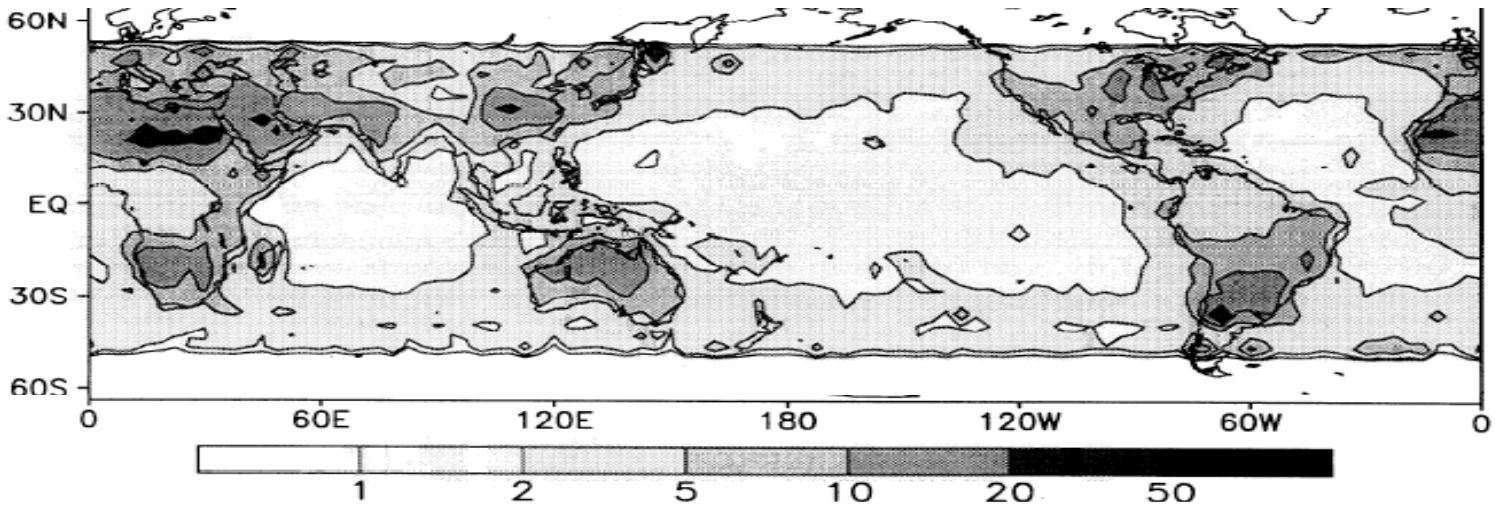
Particle Size and Number (JJA)



Column Drop Number



AVHRR Column Drop Number

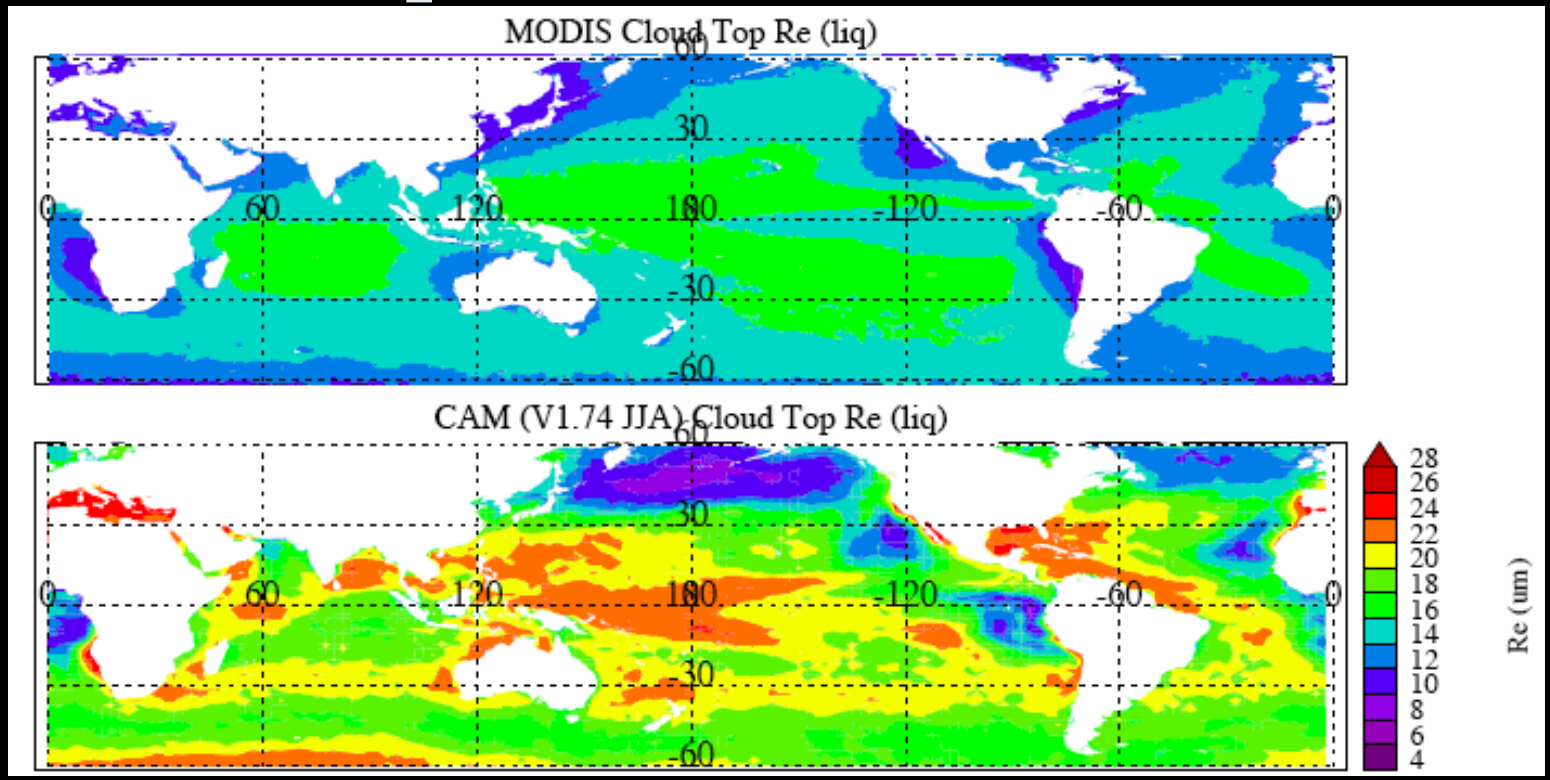


Lohmann et al, 1999 from Han et al 1998

Droplet Effective Radius

MODIS

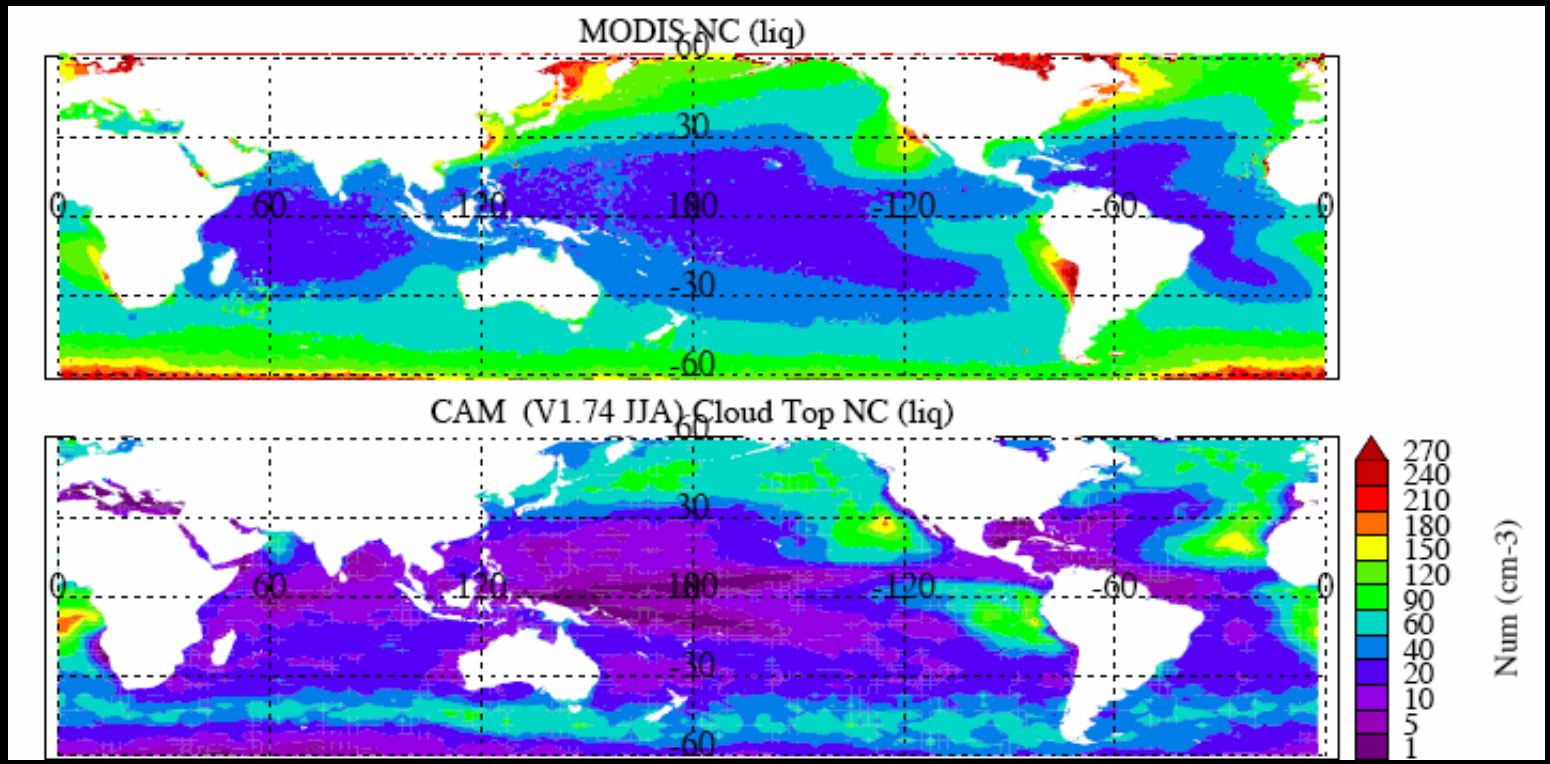
CAM ‘Cloud Top’



Droplet Number

MODIS

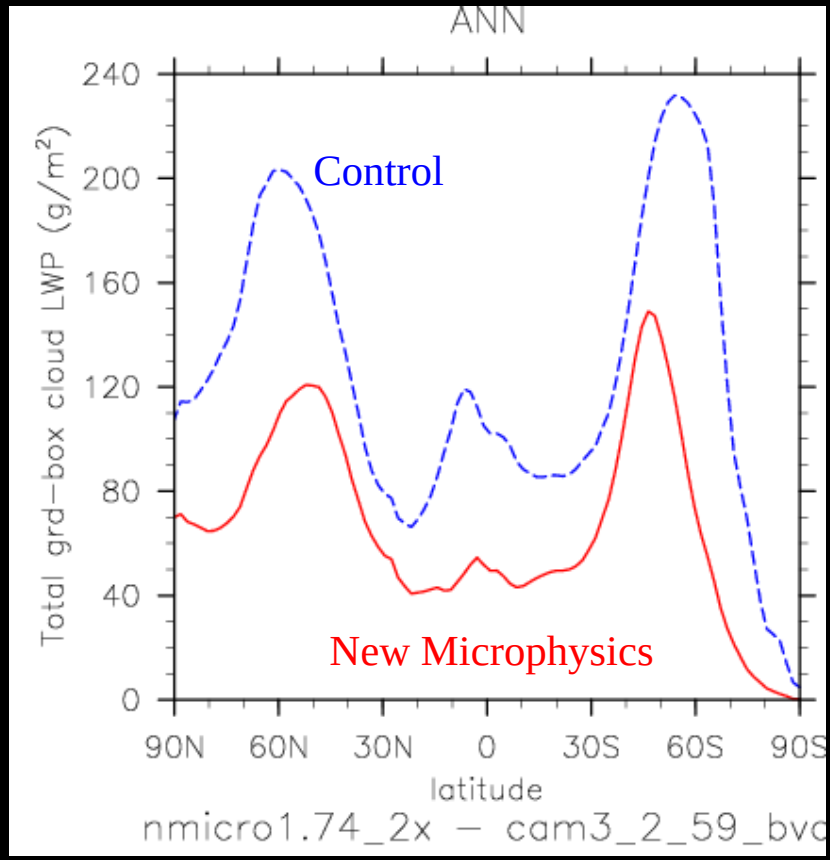
CAM ‘Cloud Top’



Performance Relative to Control

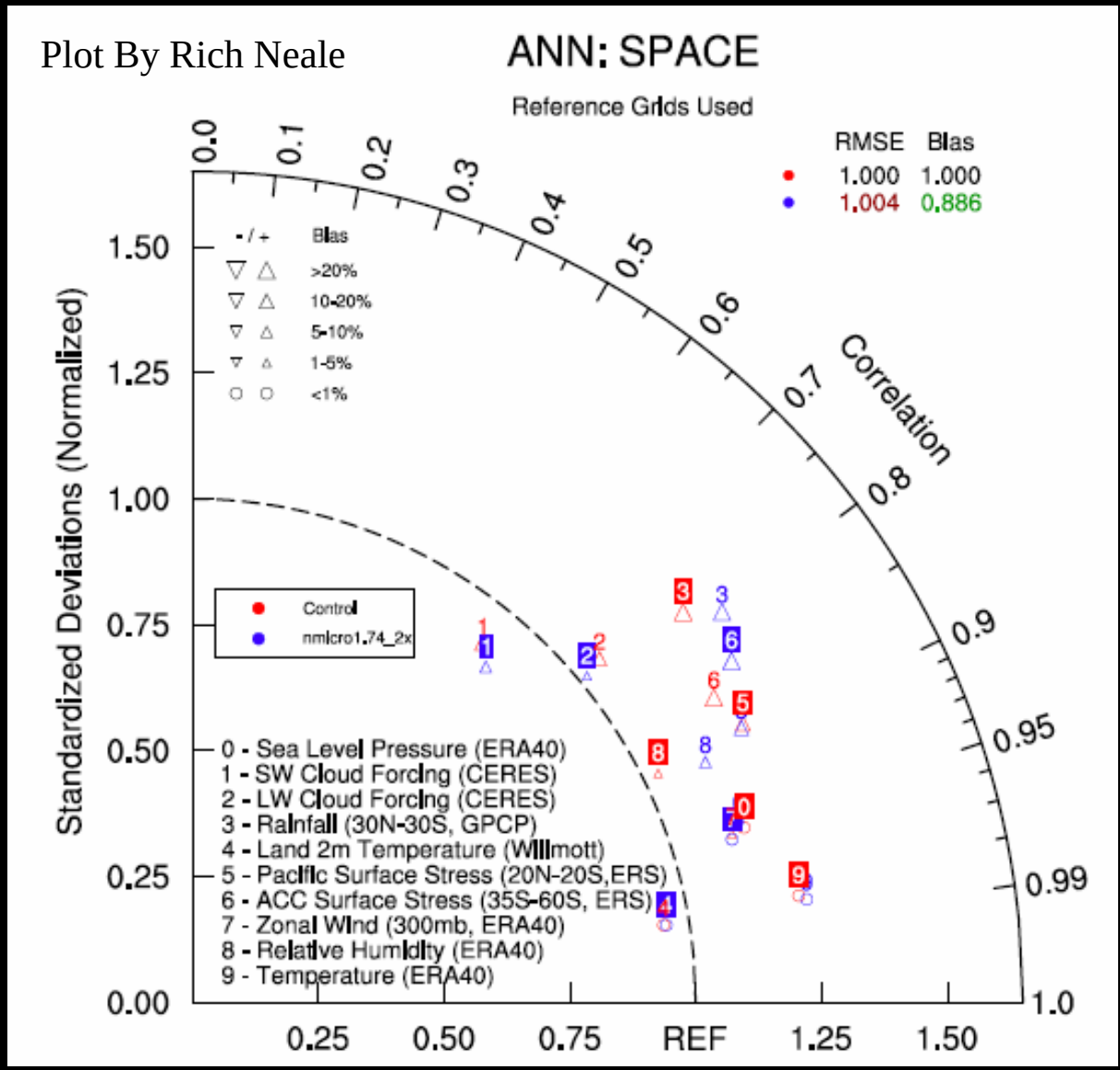
- TOA balance within 1W/m2
- SW & LW cloud forcing ‘reasonable’
- Little change in precip patterns
- 50% reduction in LWP v. Control
- Diagnostics available (URL at end)
- Taylor metrics: 10% reduction in bias

Reduced LWP

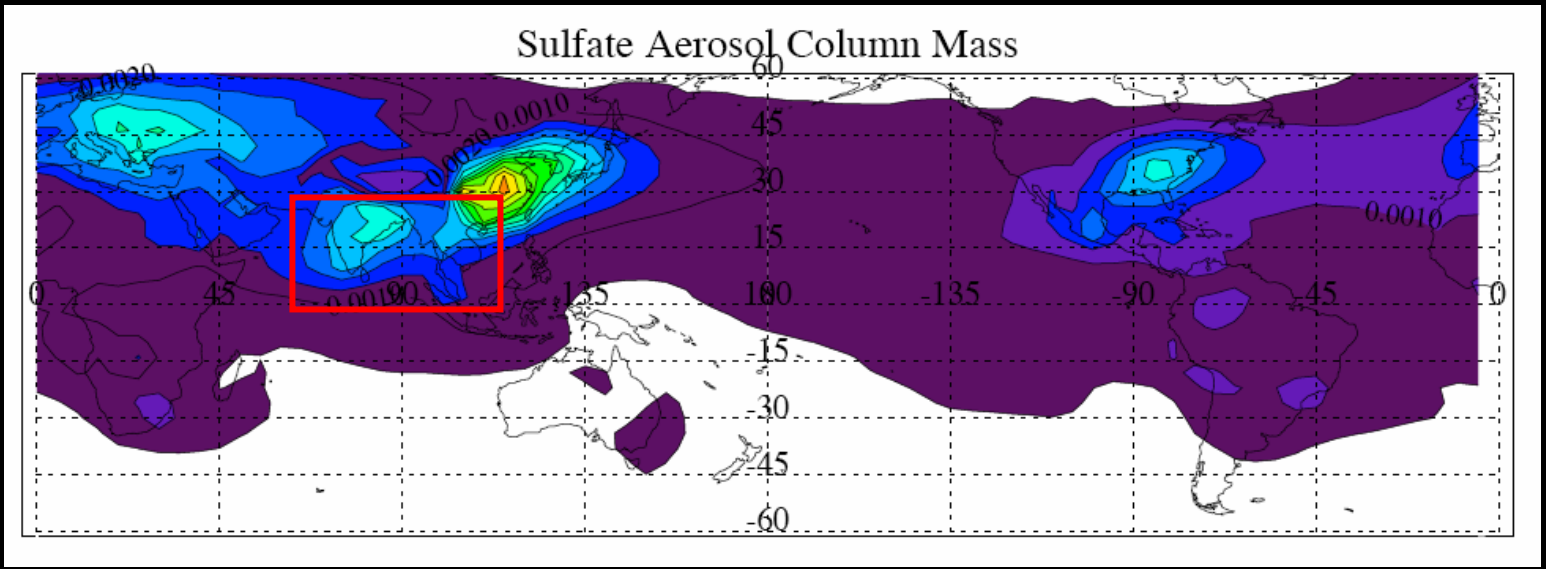


- Reduction in LWP
  - Improvement v. control
- How?
  - Smaller Particles
  - Larger Cloud Fraction
  - Closer to CERES rad balance (3Wm^{-2} less)

Bias Reduction: Taylor Diagram



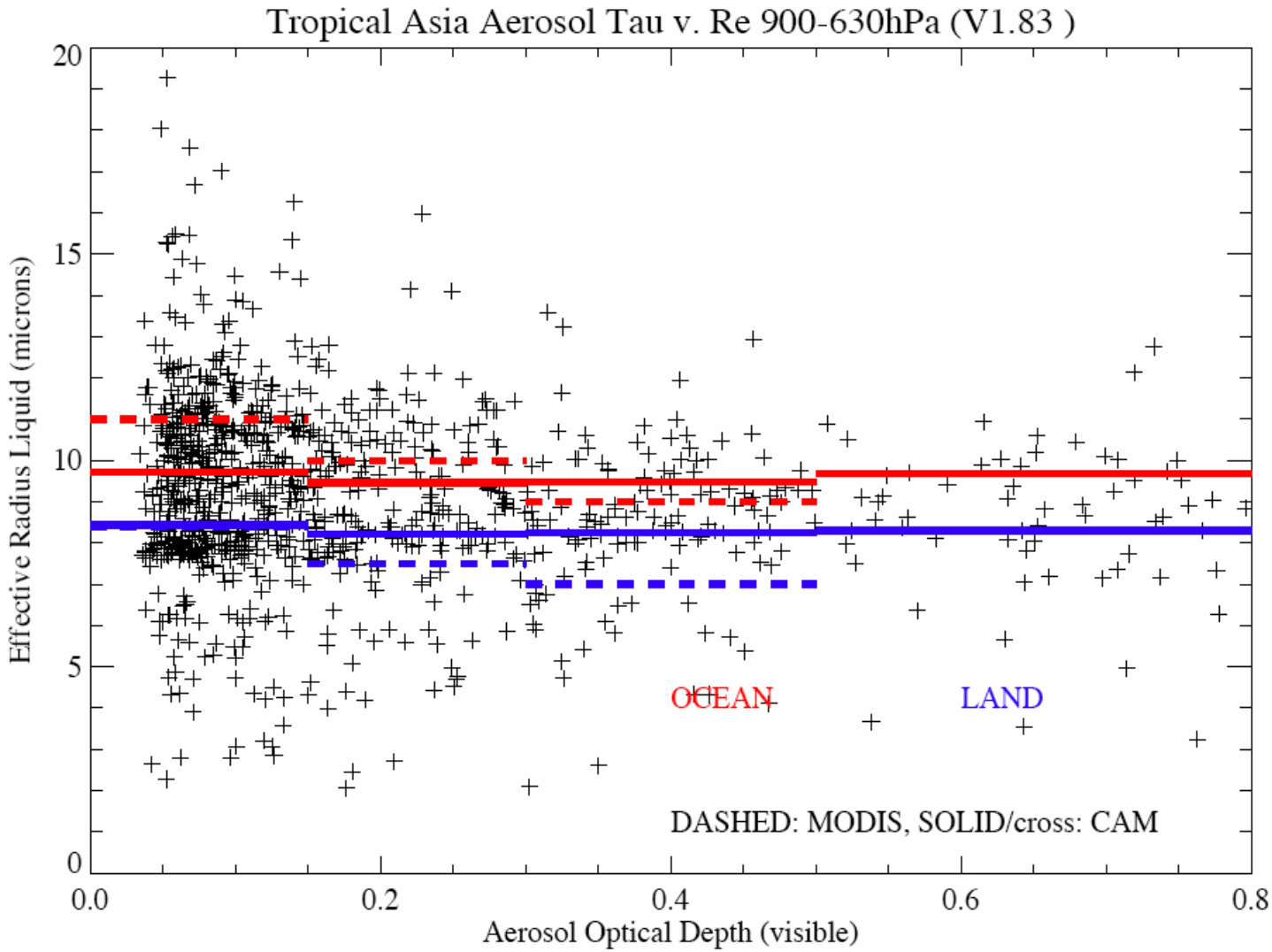
Tests of Aerosol effects



1. Test with MODIS observations:
   - Massie et al (2006): Indian ocean case
2. Also: Test with sulfur scaled to 30% present
   - Approx value for pre-industrial

Note: MODIFY Abdul Razzak and Ghan with scaling from mass -> nucleated number of Lohmann 99. Change is from linear to square root (exponent 0.58) scaling.

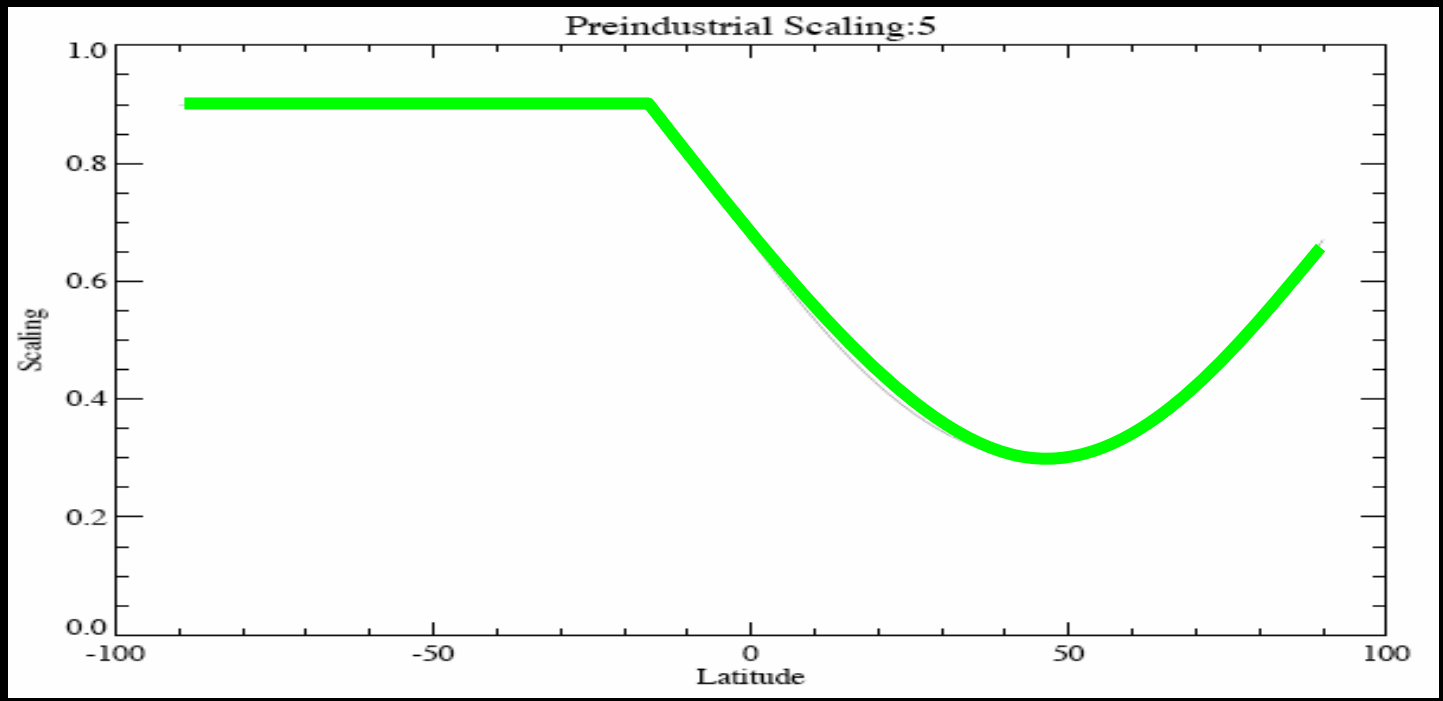
Observed Aerosol effects



MODIS data: S. Massie, 2006

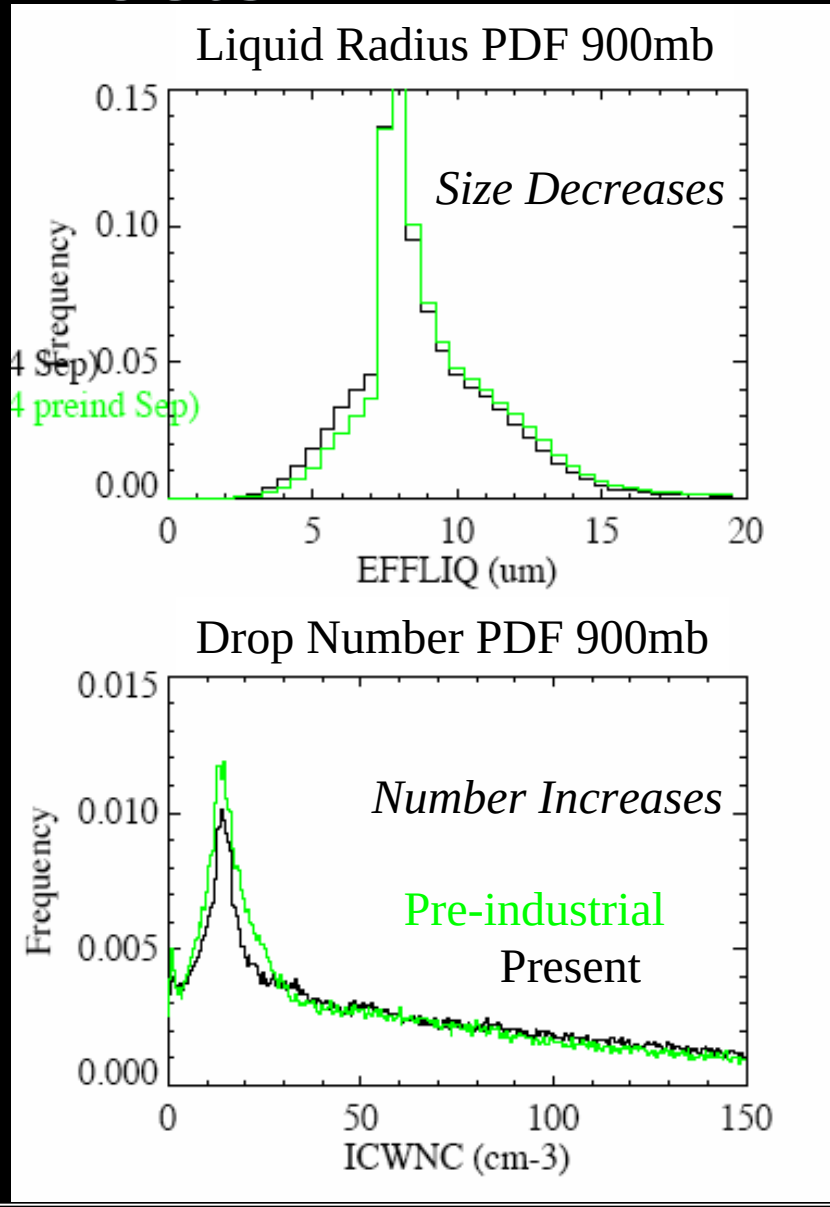
Scale Sulfate by Latitude

- Ratio of Preindustrial/Present Sulfate

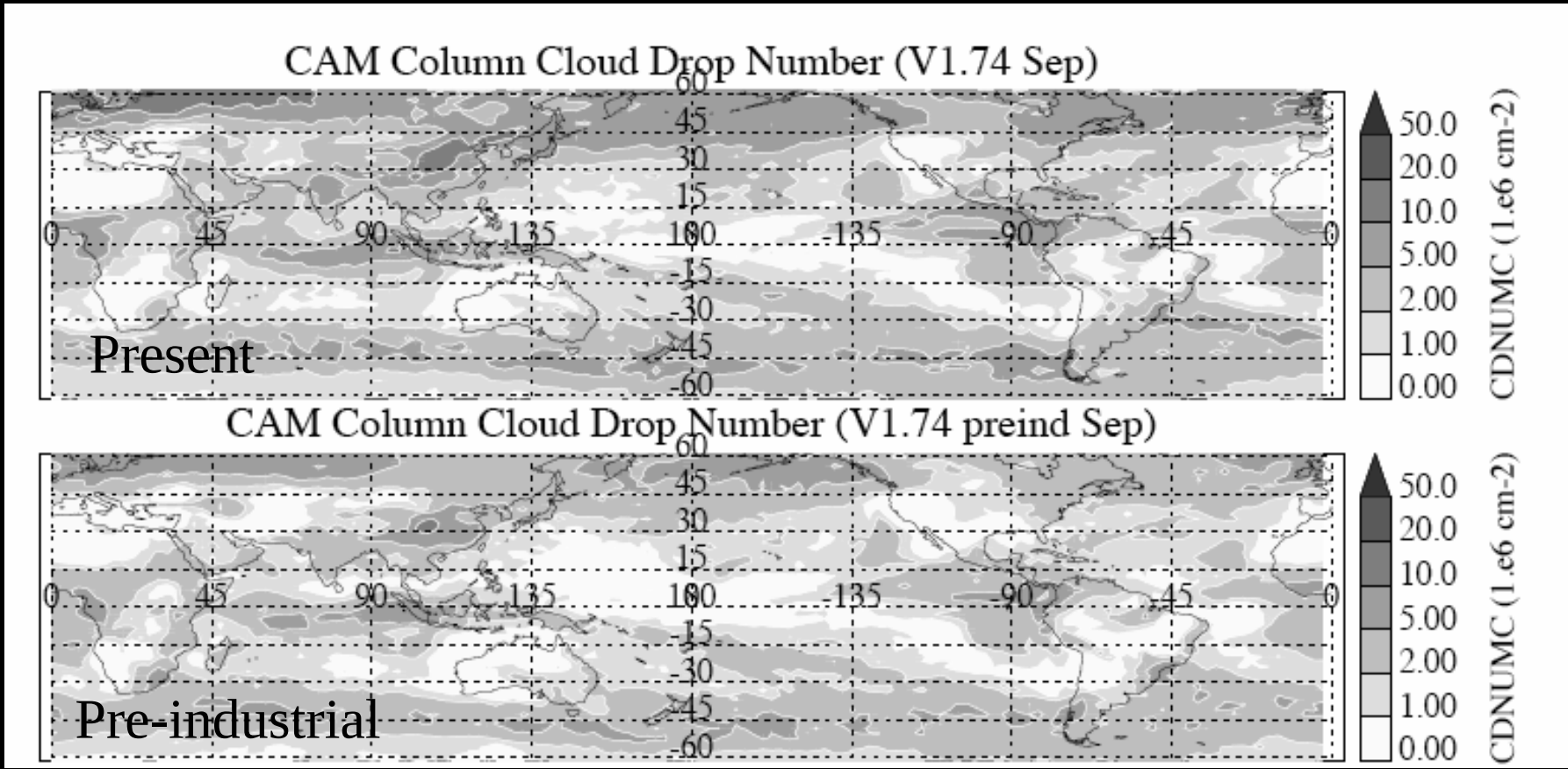


‘Indirect’ Effects

- See differences in:
  - Radiative Forcing
  - Size and number
  - Liquid water path
- Changes to Radiative forcing:
  - 1.7 Wm^{-2} (Direct + Indirect)
  - Working on discriminating
  - Existing diagnostics ‘not quite right’



Change in Column Number



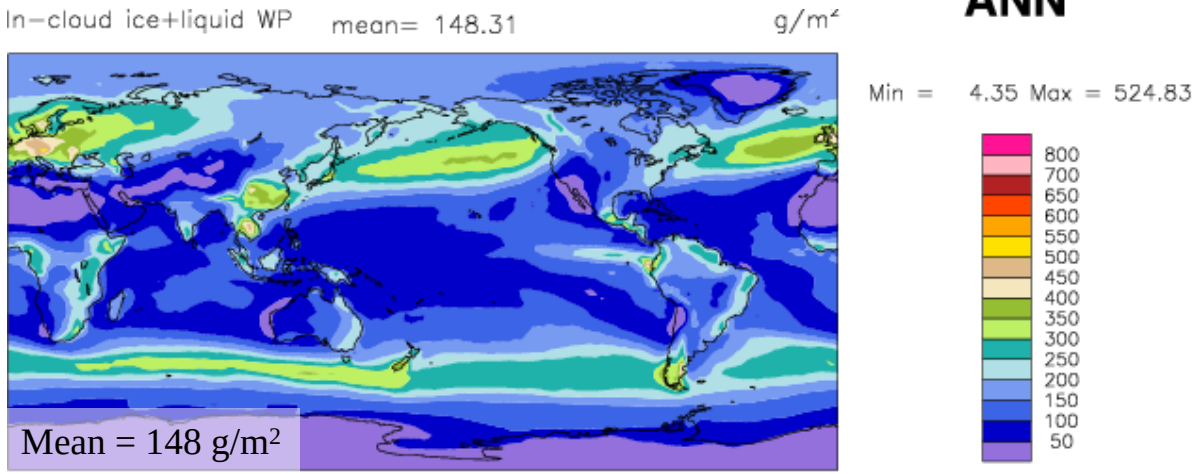
Change in Liquid water

Largest changes in Storm Tracks (where LWP large)

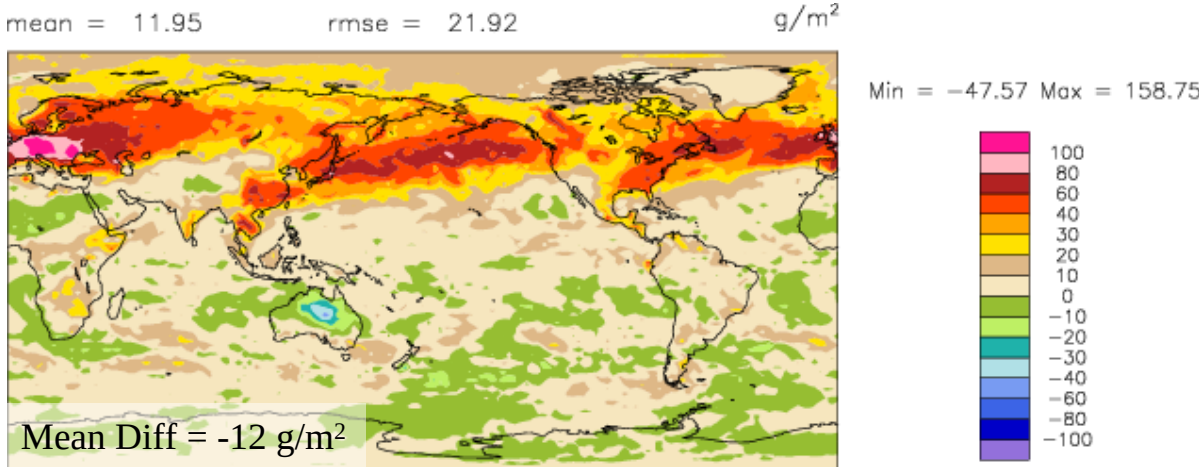
Little change in stratocumulus regions

Differences larger with Larger difference in sulfate

Present Day Liquid Water



Present- Preindustrial



Summary/Conclusions

- New scheme performs well
  - Reasonable drop size distribution
  - Reasonable number distribution
- Aerosols affect clouds
  - Sizes, Number, Liquid water path & Radiation
- ‘Indirect’ effects are still uncertain
  - Strongly dependent on input (background) aerosols

Next steps

- Continue analysis
- Write up scheme
  - Single column model/description
  - Global performance, indrect effects with prescribed aerosol
  - Coupling to interactive aerosol, scavenging
- Move to current dev CAM code
  - With AMWG approval
- Refine aerosol nucleation treatment
- Focus on ice phase

Please Help!

- Diagnostics are available on the web:

  http://www.cgd.ucar.edu/cms/andrew/diag/#microphys

  – Runs v. Obs, Control, Aerosol test case

  – Detailed microphysical comparisons

- Let us know the good, bad and ugly!

  – Also new diagnostics, data sets