Adventures with CAM-CLUBB

Where we've been, where we're going... and aerosol effects

Peter Bogenschutz[1], Andrew Gettelman[1], Hugh Morrison[1], Vincent Larson[2], David Schannen[2], Cheryl Craig[1]

[1]National Center for Atmospheric Research, Boulder, CO
[2]University of Wisconsin, Milwaukee, WI

AMWG Winter Meeting. February 11, 2013

What is CLUBB?

- CLUBB = Cloud Layers Unified By Binormals
- First developed by Golaz et al. (2002), maintained by University of Wisconsin Milwaukee (Vincent Larson's group)
- "Incomplete" third-order turbulence closure (predicting 9 second and third order moments), centered around a trivariate assumed double gaussian PDF
- Concurrently undergoing implementation into GFDL's AM3 through CPT project
- Should provide a unified treatment of PBL and shallow convection, that drives a single microphysics scheme (Morrison and Gettelman 2008)

Coupling CAM with CLUBB

Physics	CAM5	CAM-CLUBB
Deep Convection	Zhang and McFarlane (1995)	Zhang and McFarlane (1995)
Boundary Layer	Bretherton and Park (2009)	CLUBB
Shallow Convection	Park and Bretherton (2009)	CLUBB
Cloud Macrophysics	Park (2012)	CLUBB
Cloud Microphysics	Morrison and Gettelman (2008)	Morrison and Gettelman (2008)
Radiation	RRTMG (Iacono et al. 2008)	RRTMG (Iacono et al. 2008)
Aerosols	Modal (Liu et al.2012)	Modal (Liu et al.2012)

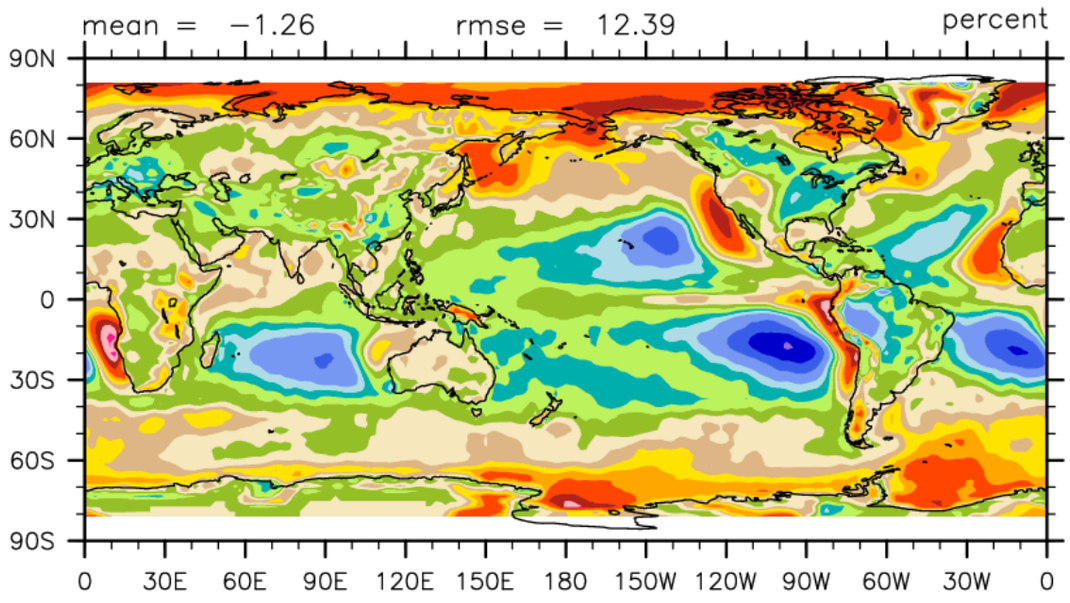
- CLUBB time step is 5 minutes
- CLUBB called directly after deep convection and directly before microphysics
- Predicted vertical velocity variance used for aerosol activation

Where We've Been...

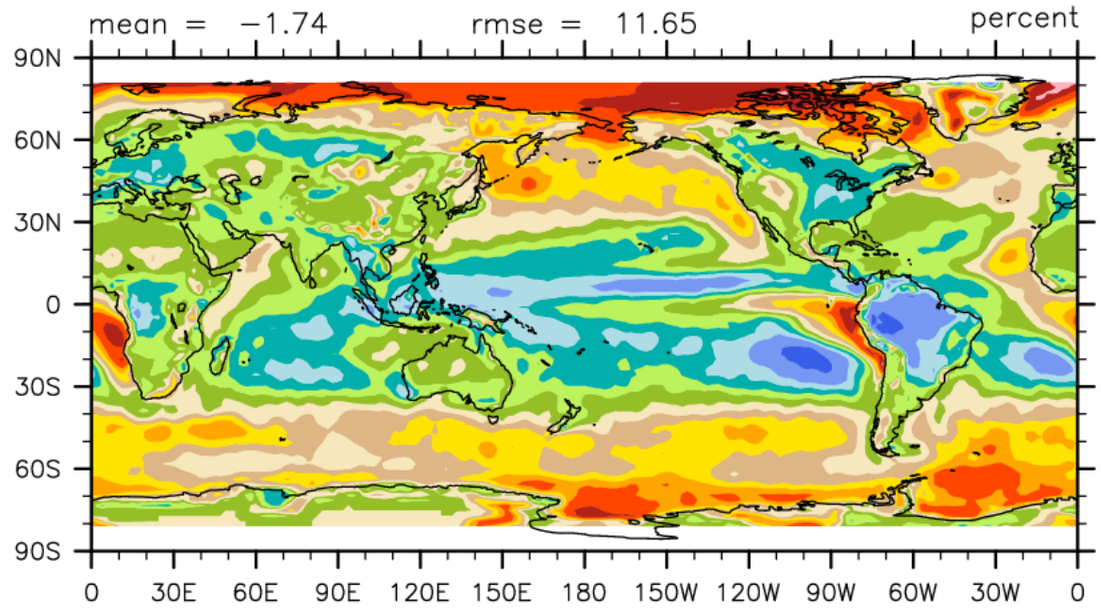
- CAM-CLUBB is overall competitive with CAM5 (a number of improvements, some degradations)
  - Bogenschutz et al. (2012) (*Geosci. Model Dev.*) documents SCM simulations
  - Bogenschutz et al. (2013) (*J. Climate*) submitted, documents global simulations
- Published configuration has been tested preliminarily in CESM
- CAM-CLUBB on development trunk and last CESM release (not the published configuration, yet)

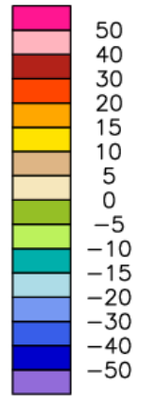
Low Cloud Amount Biases

CAM5 - CLOUDSAT



CAM-CLUBB - CLOUDSAT

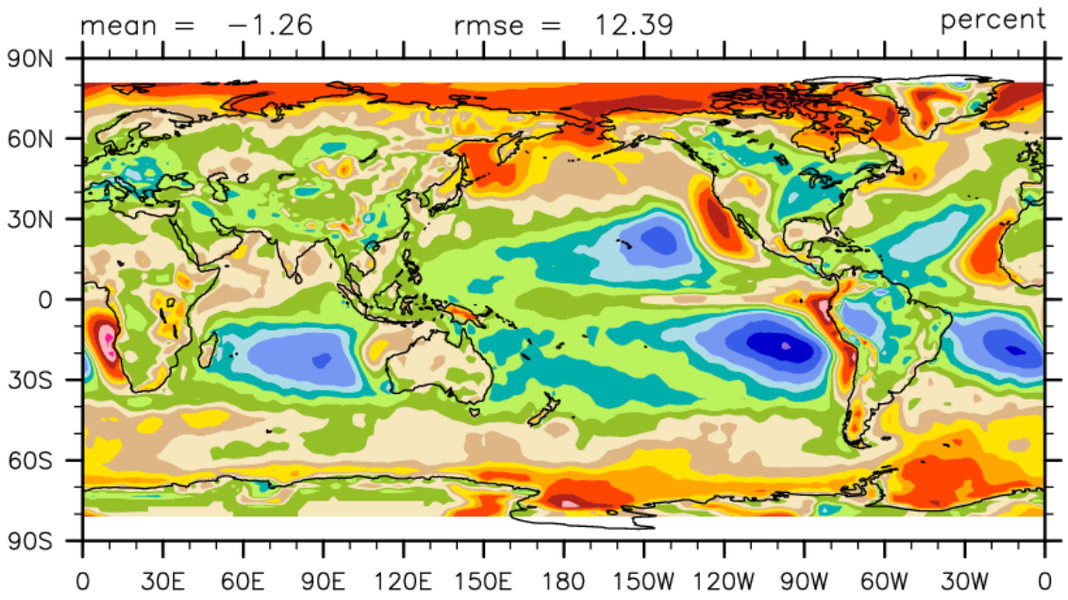




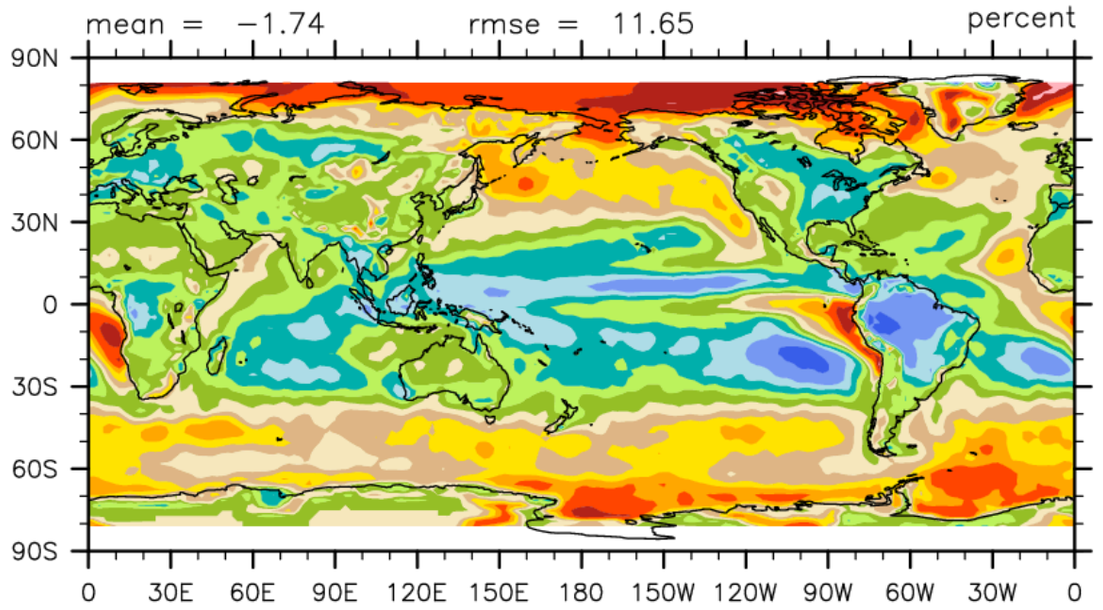
* All runs are 1 degree five-year simulations using FV dy-core

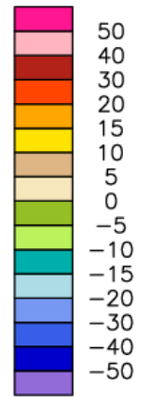
Low Cloud Amount Biases

CAM5 - CLOUDSAT



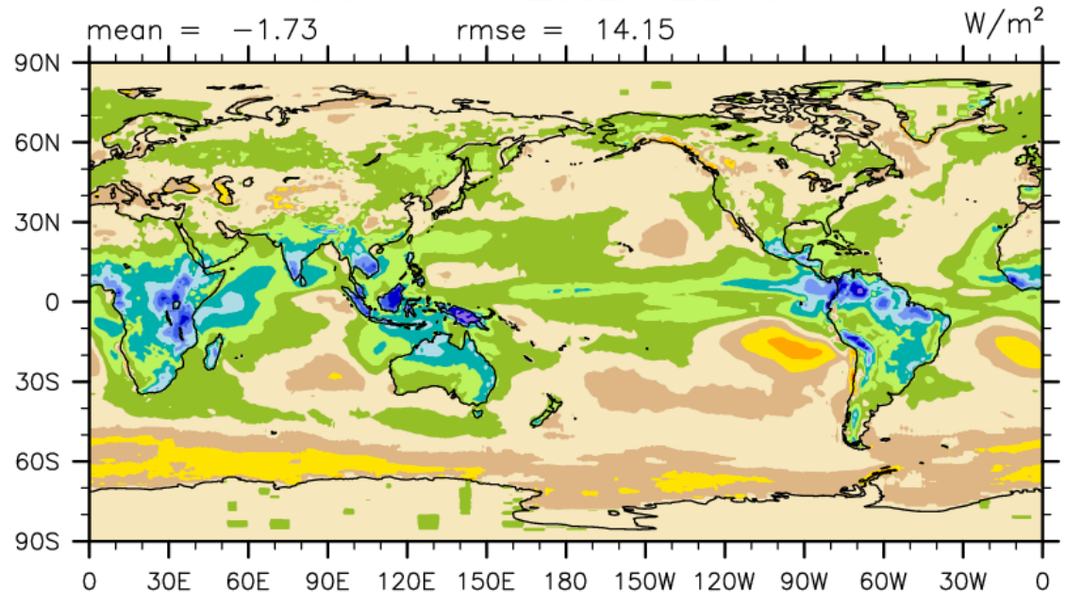
CAM-CLUBB - CLOUDSAT



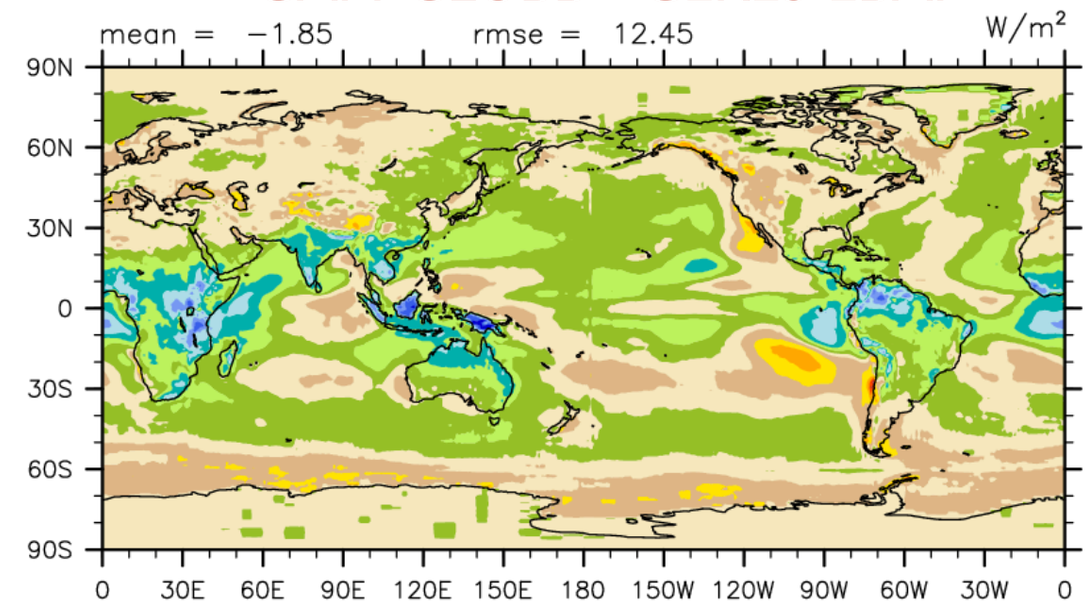


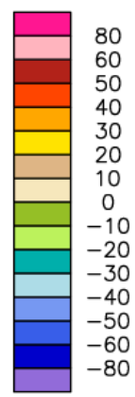
Shortwave Cloud Forcing Biases

CAM5 - CERES-EBAF



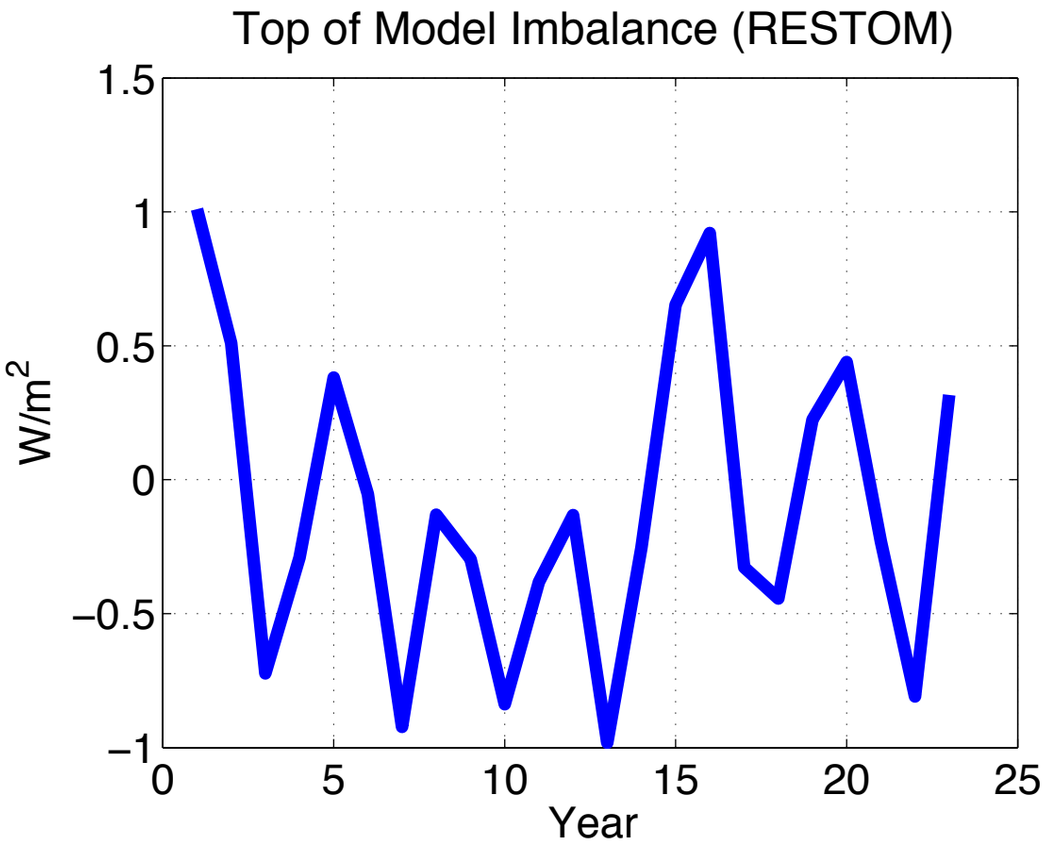
CAM-CLUBB - CERES-EBAF





* All runs are 1 degree five-year simulations using FV dy-core

Preliminary Coupled Simulation (CESM-CLUBB)



- 2 degree coupled simulation, using B1850 compset
- Averaged RESTOM -0.28 W/m2. Can be tuned down.
- No indication of a drifting or runaway climate
- Overall climate metrics seem similar to AMIP runs
- Seems competitive with CESM, similar SST rmse

Where We're Going...

CAM-CLUBB base code

Where We're Going...

CAM-CLUBB base code

↓

Sub-columns

↓

Radiation
(Bogenschutz)

↘

Microphysics
(Thayer-Calder,
Bacmeister,
Gettelman)

Where We're Going...

CAM-CLUBB base code

Sub-columns

Radiation
(Bogenschutz)

Microphysics
(Thayer-Calder,
Bacmeister,
Gettelman)

Have CAM-CLUBB go deep
(Chen, Gettelman,
Bogenschutz)

Where We're Going...

CAM-CLUBB base code

Smaller development projects (i.e. testing with MG2, sub-step CLUBB & MG using "Caldwell" method, etc.)

Sub-columns

Radiation (Bogenschutz)

Have CAM-CLUBB go deep (Chen, Gettelman, Bogenschutz)

Microphysics (Thayer-Calder, Bacmeister, Gettelman)

Where We're Going...

CAM-CLUBB base code

Science:
Aerosol Effects
Climate sensitivity
Coupled simulations (etc.)
(Bogenschutz, Gettelman, Morrison)

Smaller development projects
(i.e. testing with MG2, sub-step CLUBB & MG using "Caldwell" method, etc.)

Sub-columns

Radiation
(Bogenschutz)

Microphysics
(Thayer-Calder, Bacmeister, Gettelman)

Have CAM-CLUBB go deep
(Chen, Gettelman, Bogenschutz)

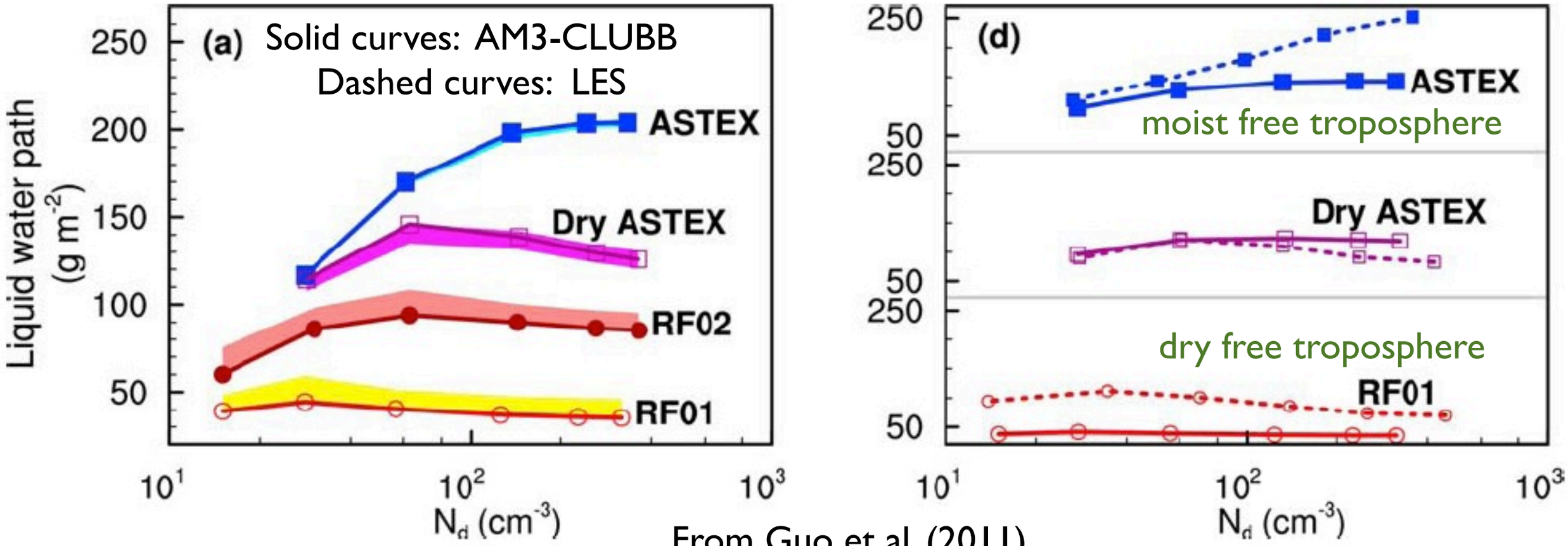
Aerosol Indirect Effect Global Averages

Simulation	RFP	ΔSWCF (present day - preindustrial)	ΔLWCF (present day - preindustrial)
CAM5 30L	-1.5	-1.7	+0.4
CAM-CLUBB 30L	-1.6	-1.8	+0.4

* All units W/m2

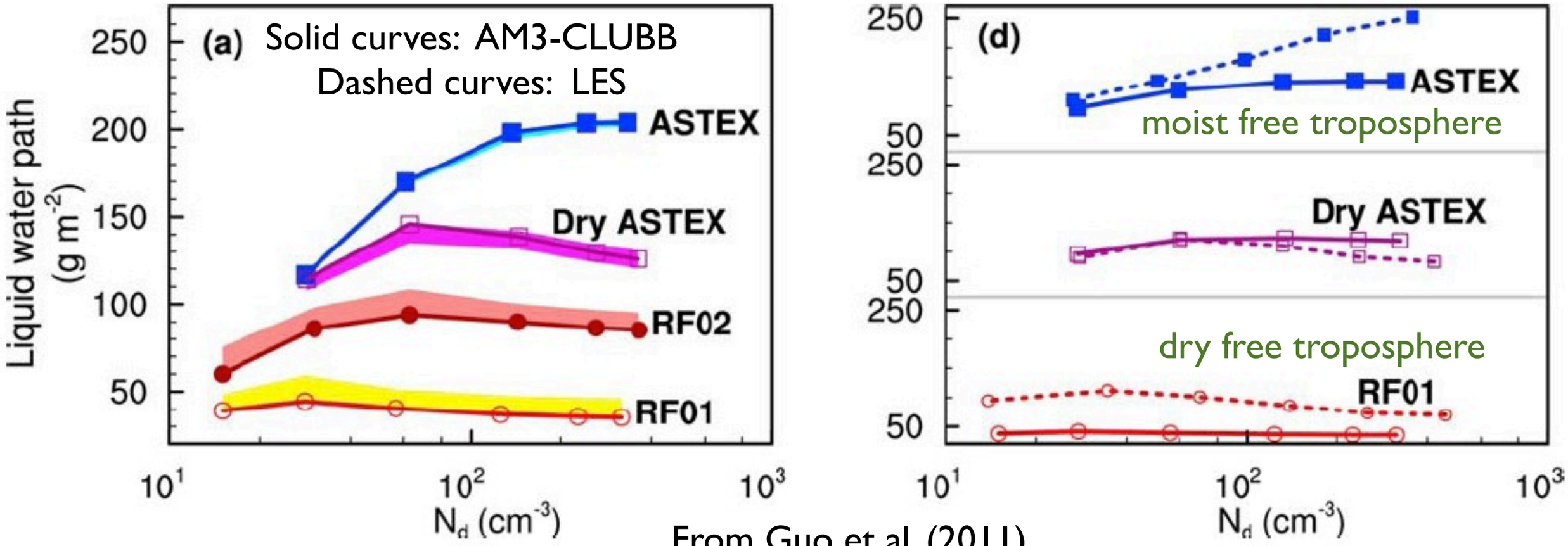
- CAM-CLUBB has roughly same AIE as CAM5 (albeit, bit higher estimates)
- Since CAM-CLUBB and CAM5 have very different formulations of turbulence/ clouds, one could easily conclude that this is exclusively a microphysics problem
- But let's examine this further...

Aerosol Effects in AM3-CLUBB



From Guo et al. (2011)

Aerosol Effects in AM3-CLUBB



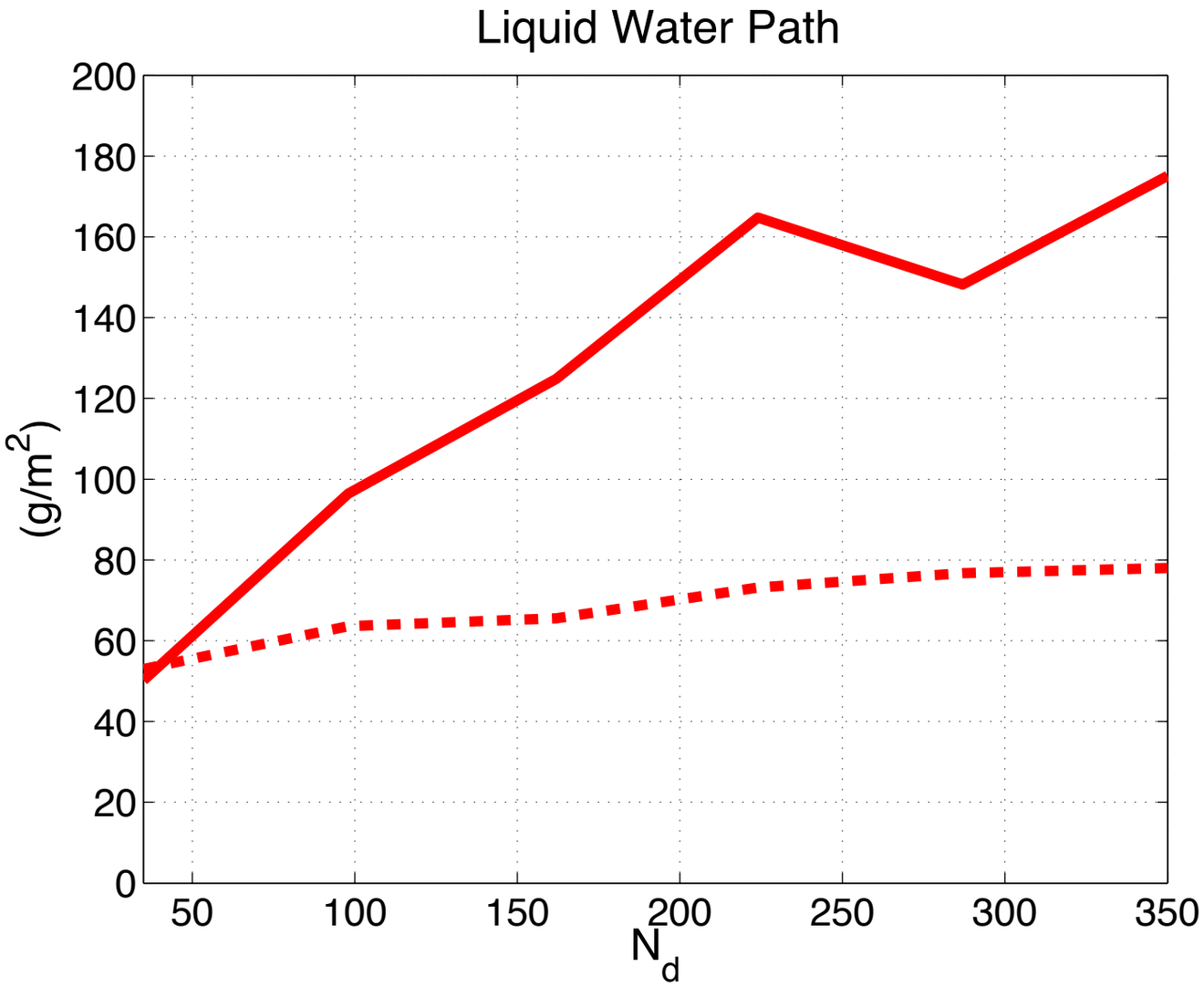
From Guo et al. (2011)

Questions:

1) Can CAM-CLUBB and/or CAM5 replicate this?
2) What vertical/temporal resolution is required?
3) Does sub-stepping CLUBB/macrophysics in concert with MG help replicate this behavior for CAM-CLUBB/CAM5?

DYCOMS2-RF01

(Sc with very dry free troposphere)



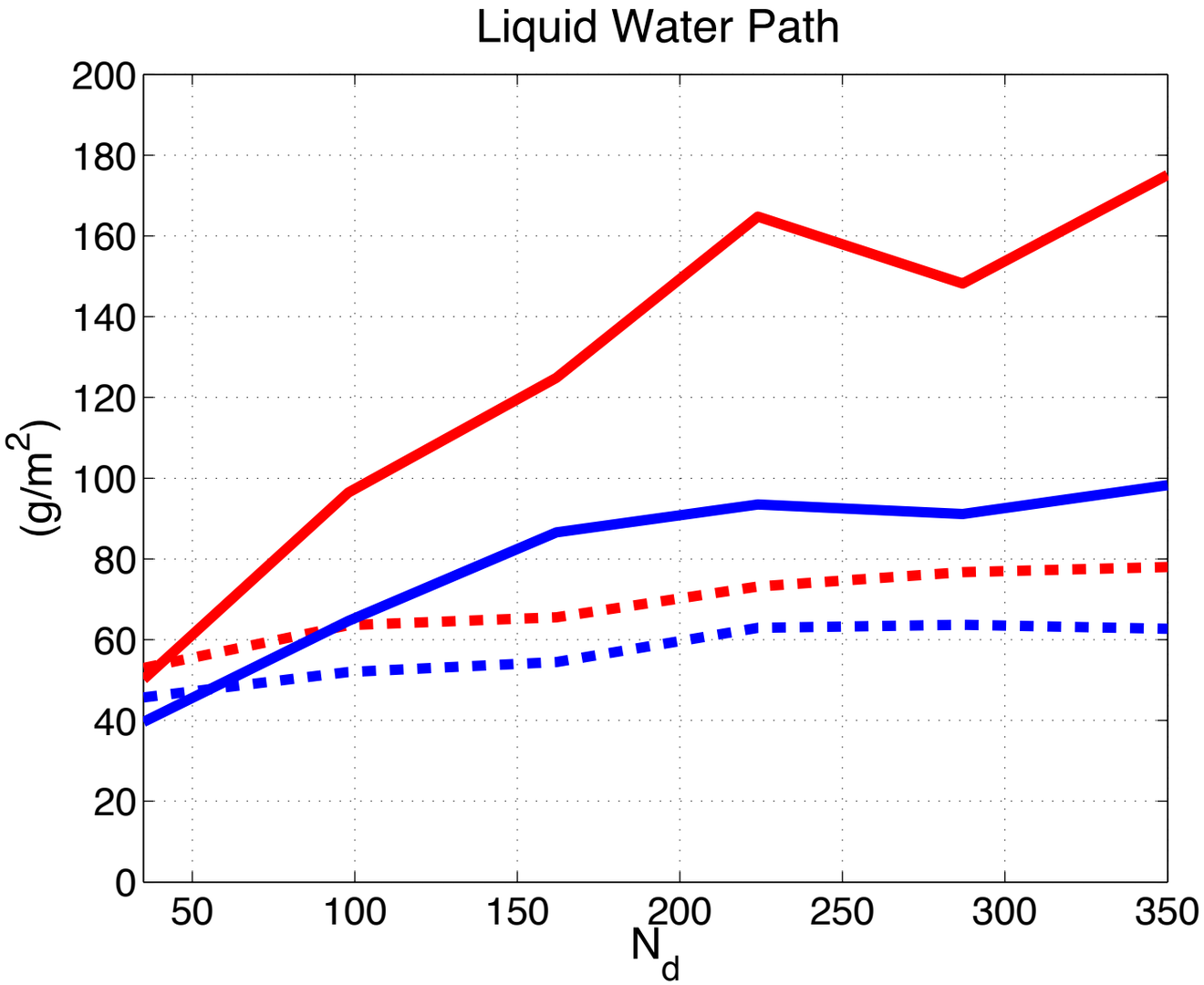
Solid curves: CAM-CLUBB
Dashed curves: CAM5

30 Layers

- At operational configuration, excessive sensitivity to lower Nd's for CAM-CLUBB
- CAM5, much less sensitivity but no sign reversal of LWP at higher Nd's

DYCOMS2-RF01

(Sc with very dry free troposphere)



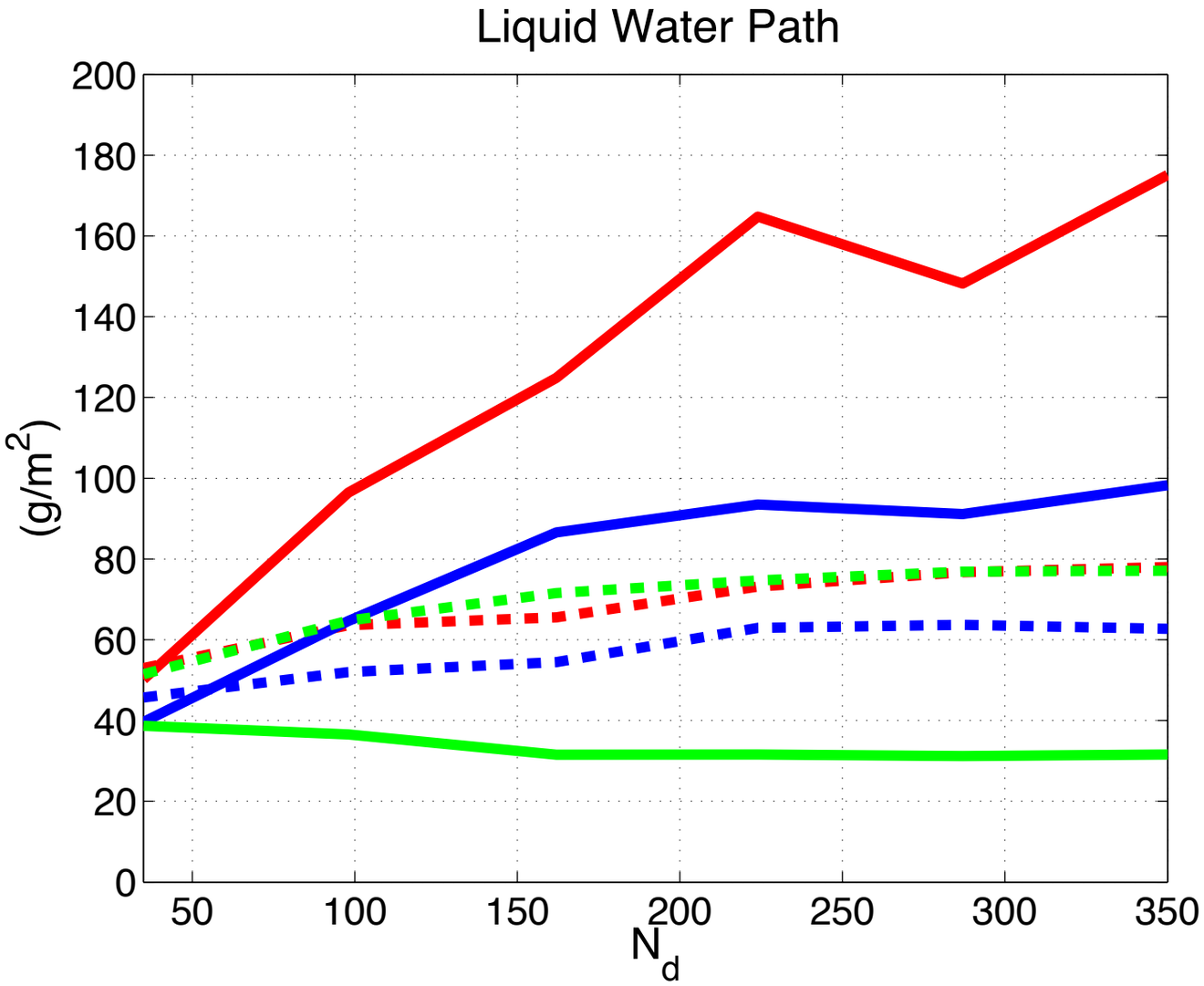
Solid curves: CAM-CLUBB
Dashed curves: CAM5

30 Layers 60 Layers

- 60 layer grid helps reduce LWP sensitivity to Nd, but still too large & robust no sign reversal
- CAM-CLUBB still much more sensitive than CAM5

DYCOMS2-RF01

(Sc with very dry free troposphere)



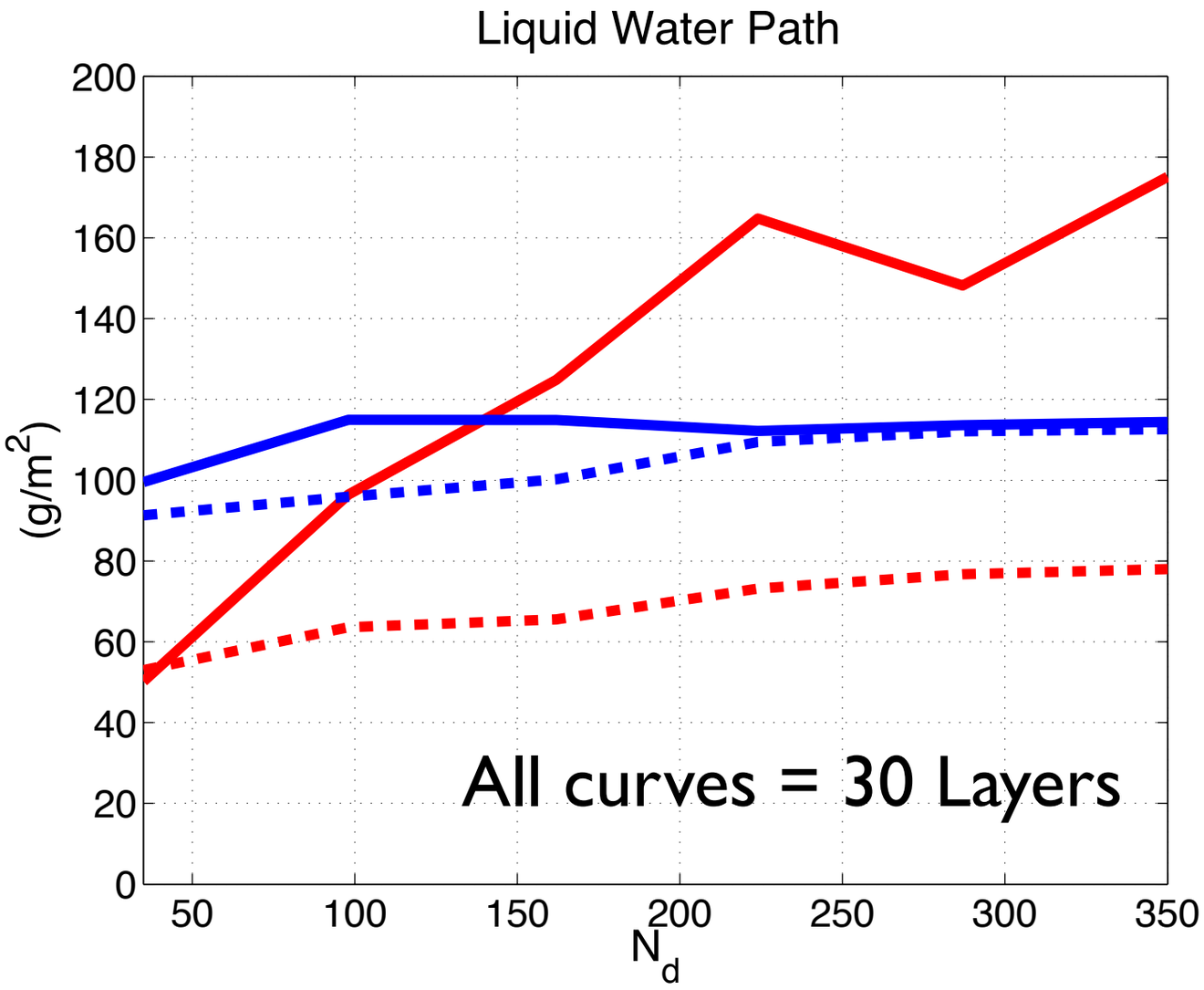
Solid curves: CAM-CLUBB
Dashed curves: CAM5

- 90 layer grid:
  - CAM5 still fairly sensitive & no sign reversal (insensitive to time step)
  - CAM-CLUBB, sign reversal and reduced sensitivity
  - What does it take to get CAM-CLUBB to replicate this behavior at 30 L?

30 Layers 60 Layers 90 Layers

DYCOMS2-RF01

(Sc with very dry free troposphere)



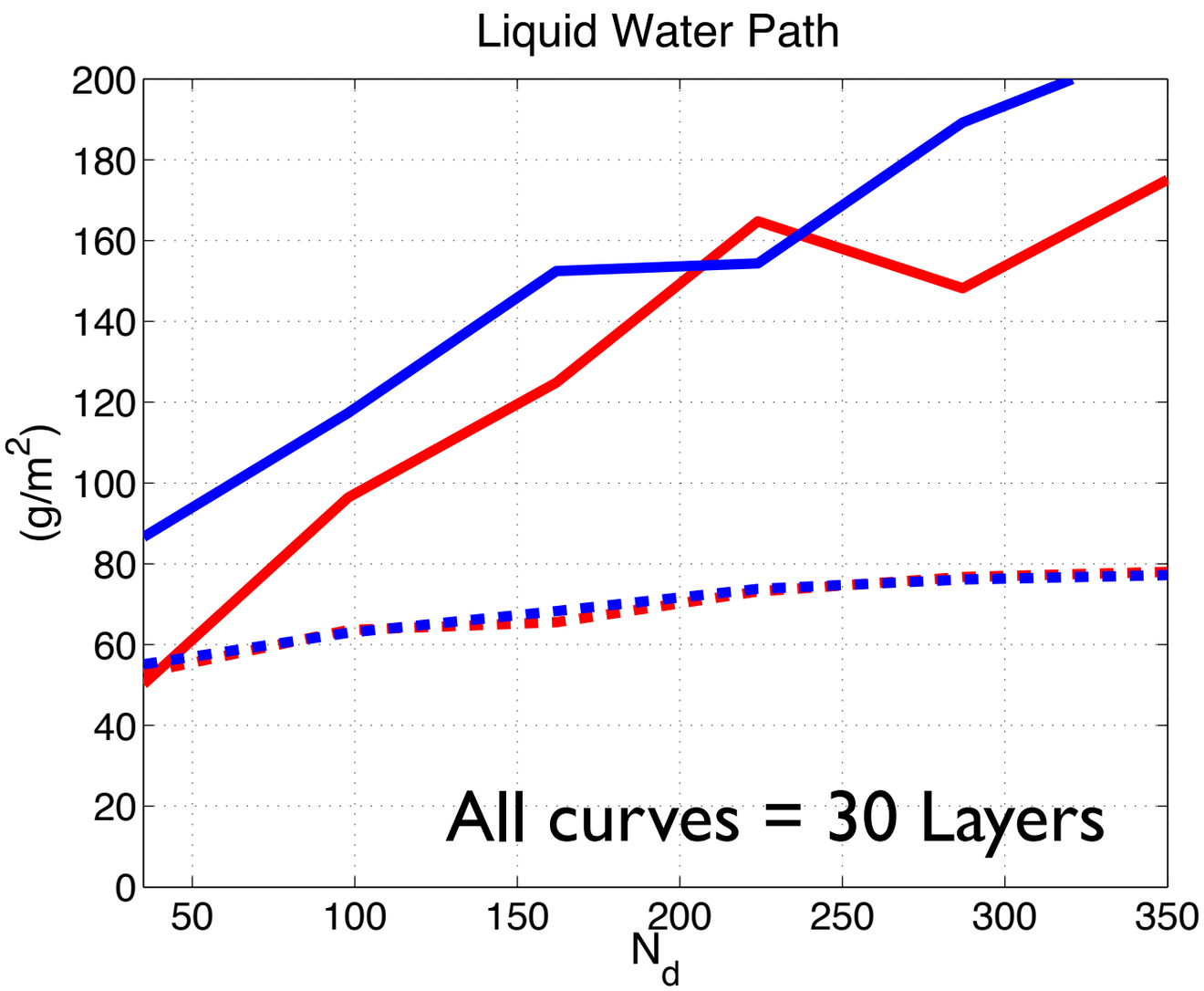
Solid curves: CAM-CLUBB
Dashed curves: CAM5

dt = 20 min dt = 3 min

- Reducing time step reduces LWP sensitivity to Nd
- CAM-CLUBB is able to capture the LWP sign reversal with small dt (anything from 3 min or finer)
- 3 min and 60 s time step is too expensive for global simulations
- Can sub-stepping CLUBB and MG produce comparable results (i.e. Caldwell method)?

DYCOMS2-RF01

(Sc with very dry free troposphere)



Solid curves: CAM-CLUBB

Dashed curves: CAM5

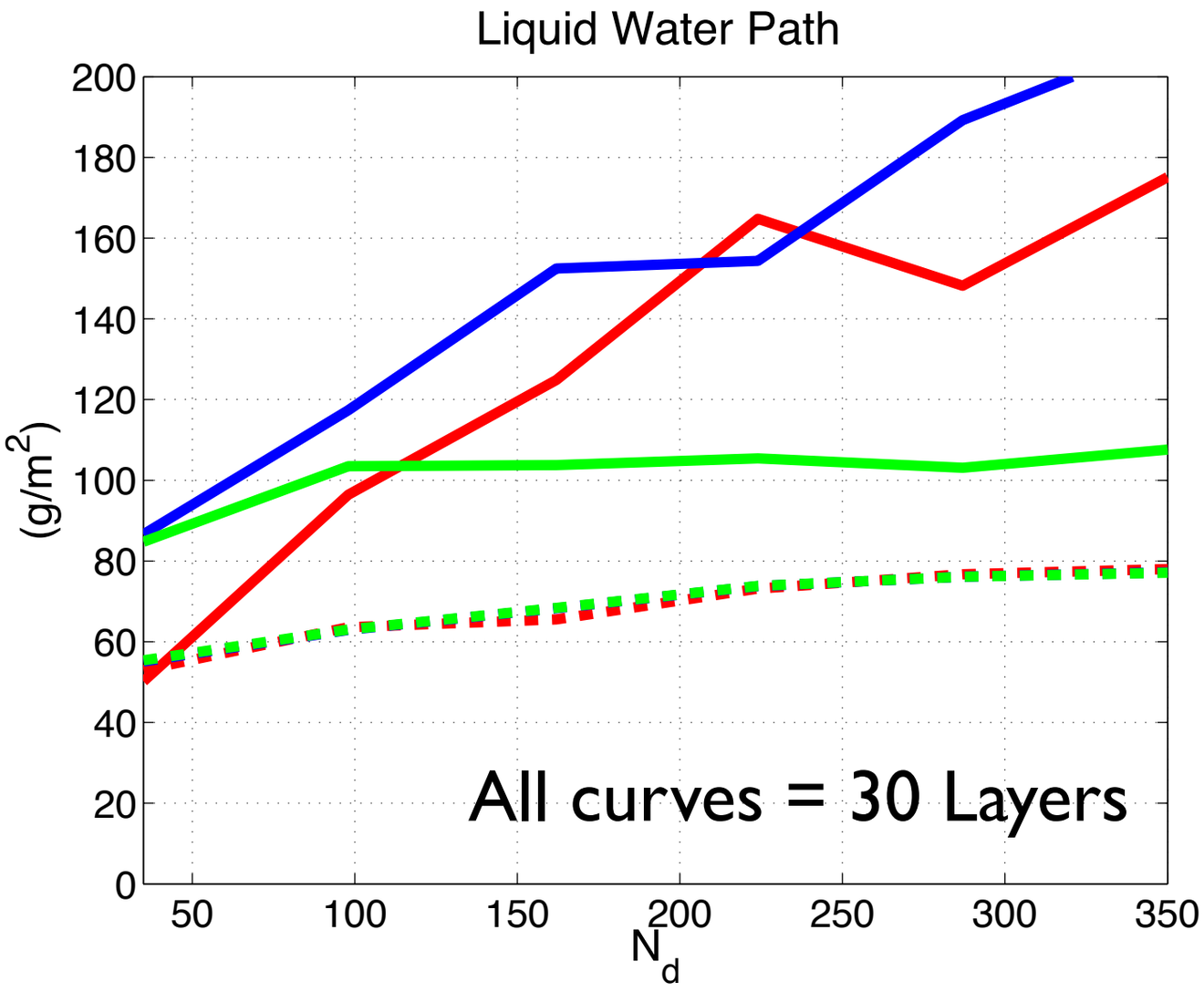
dt = 20 min (no subcycle)

dt = 20 min (5 min subcycle)

- Substepping CLUBB/MG together at five minutes actually worsens sensitivity
- CAM5... No big changes

DYCOMS2-RF01

(Sc with very dry free troposphere)



Solid curves: CAM-CLUBB
Dashed curves: CAM5

- Substepping CLUBB/MG at 2.5 minutes, leads to reduced sensitivity and hints of LWP sign reversal
- Virtually no changes for CAM5
- Why is CAM-CLUBB more responsive to sub-stepping?
  - CAM5 substeps only macrophysics and MG
  - CLUBB is unified parameterization therefore turbulence/entrainment is evolving with MG, along with macrophysics

dt = 20 min (no subcycle)

dt = 20 min (5 min subcycle)

dt = 20 min (2.5 min subcycle)

Summary & Future AIE Work

- CAM-CLUBB is very much alive and with fruitful development ahead
  - Competitive with CAM5, appears to behave in coupled simulations
  - More validation needed for climate variability
- Concerning aerosol effects, preliminary experiments raise more questions than answers.
  - Probably not exclusively a microphysics problem (but likely part of it)
  - To what degree are the different entrainment formulations between CLUBB and UWMT playing a role in different LWP responses?
  - What are the effects of sub-cycling CLUBB/MG on global AIE?
  - What will the effect of prognostic precip (and activation fix) be for CAM5 and CAM-CLUBB?