Coupling CAM with a High-Order Turbulence Closure

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Current CAM5 Physics

- Boundary Layer (Bretherton)
- Deep Convection (ZM)
- Shallow Convection (Park)
- Cloud Macrophysics (Park)
- Microphysics (MG)
- Radiation
- Aerosols

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CLUBB

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CLUBB

♣ 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 AM3 as part of CPT initiative
- Should provide unified treatment of PBL and shallow convection
- Goal is for better representation of boundary layer processes and aerosol effects

CAM-CLUBB

- UW PBL (Bretherton and Park), UW Shallow convection (Park and Bretherton), and Cloud macrophysics (Park) are all turned off
  - CLUBB is warm cloud parameterization, therefore still strip out a subroutine from Park macrophysics to compute ice cloud fraction
  - Detrainment of liquid water into environment still computed per Park macrophysics for deep convection detrained liquid
- CLUBB called after deep convection & before MG, currently with a 5 minute sub-timestep
- Predicted vertical velocity variance passed from CLUBB to MG for SGS vertical velocity variance needed for aerosol activation
- CLUBB drives the MG microphysics scheme (for both stratified and shallow convective cloud)

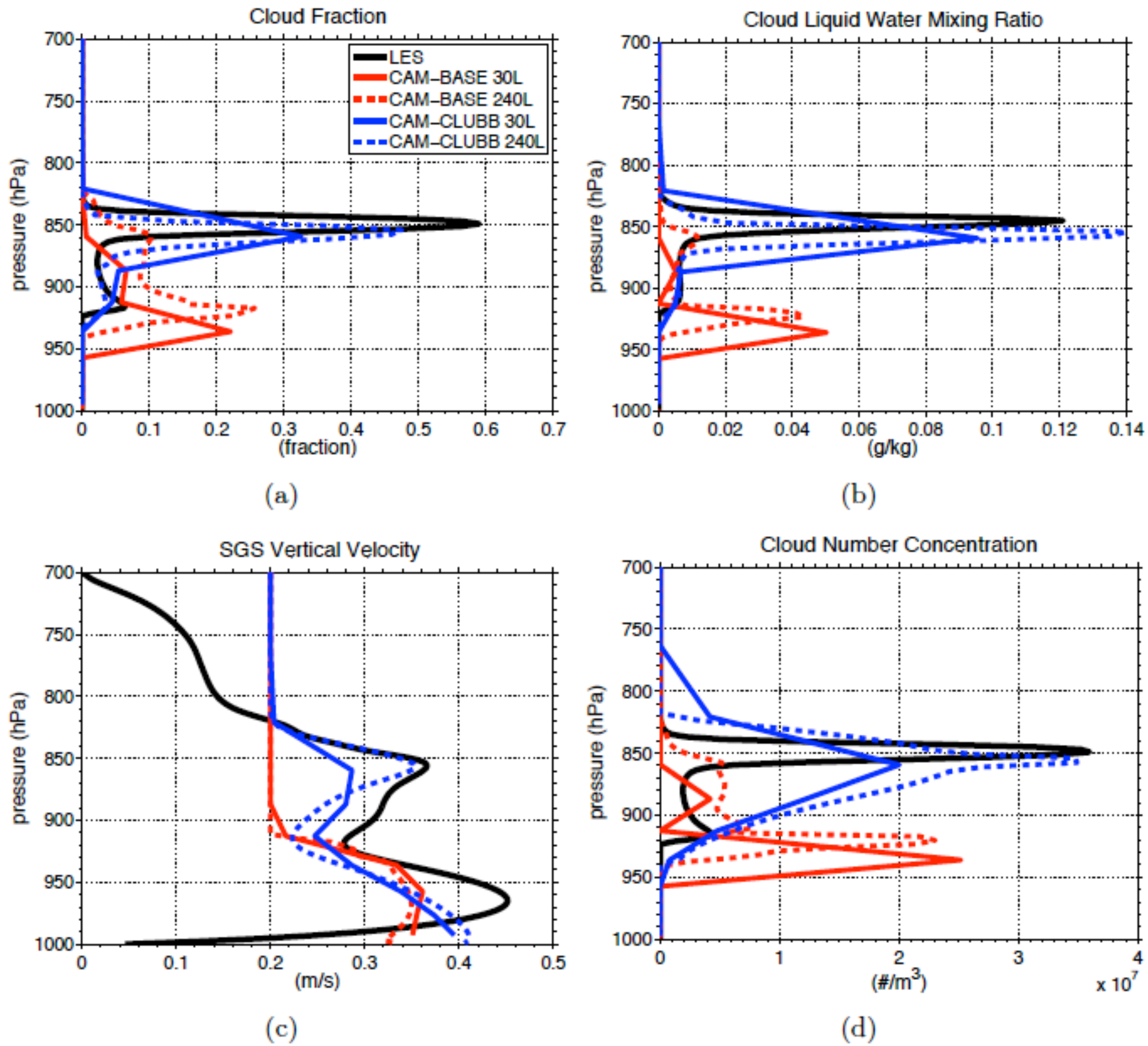
CAM-CLUBB Status

- Produces a credible climate simulation
- Skill scores are competitive with CAM5
- Computational increase is 4% over CAM5
- At the cusp of beginning to perform science experiments (i.e. AIE, climate sensitivity, etc.)
- Currently in code review to get on trunk, as an option
    - to run CAM-CLUBB just add “-clubb_sgs” to configure line

Single Column Testing

- Single column paper (Bogenschutz et al. 2012) submitted to Geo. Sci. Model Dev.
- SCAM-CLUBB tested on many boundary layer & deep convective regimes
  - Cumulus: RICO, BOMEX, ARM_CC
  - Stratocumulus: DYCOMS2RF-01, DYCOMS2RF-02, ATEX
  - Deep convection: GATE, TOGA, ARM97
  - Mixed phase: Storm tracks IOP
- Results show less sensitivity to vertical resolution and timestep compared to CAM5.
- Improved simulation of transitional and shallow convective regimes.

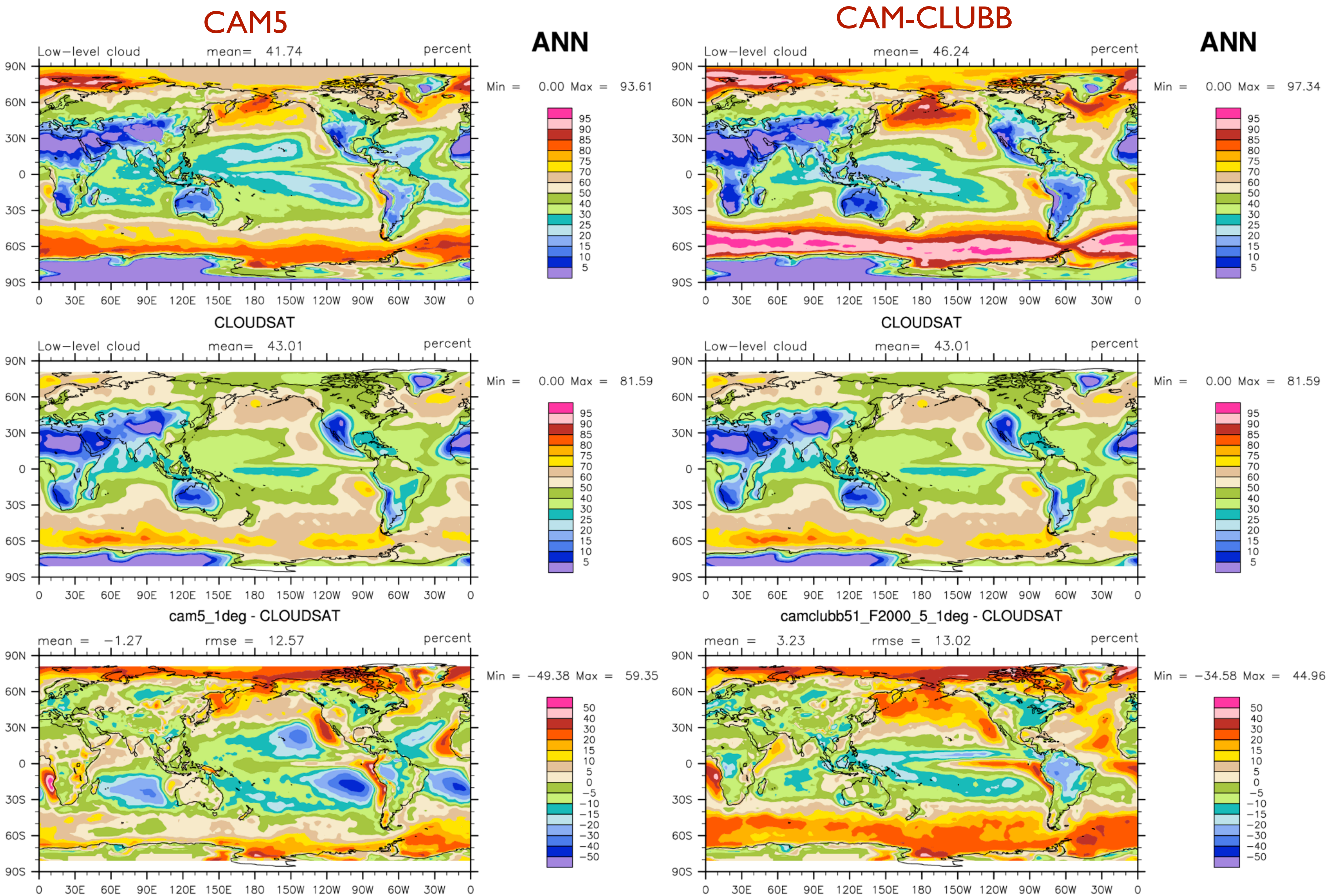
ATEX - Cumulus Under a Strong Inversion



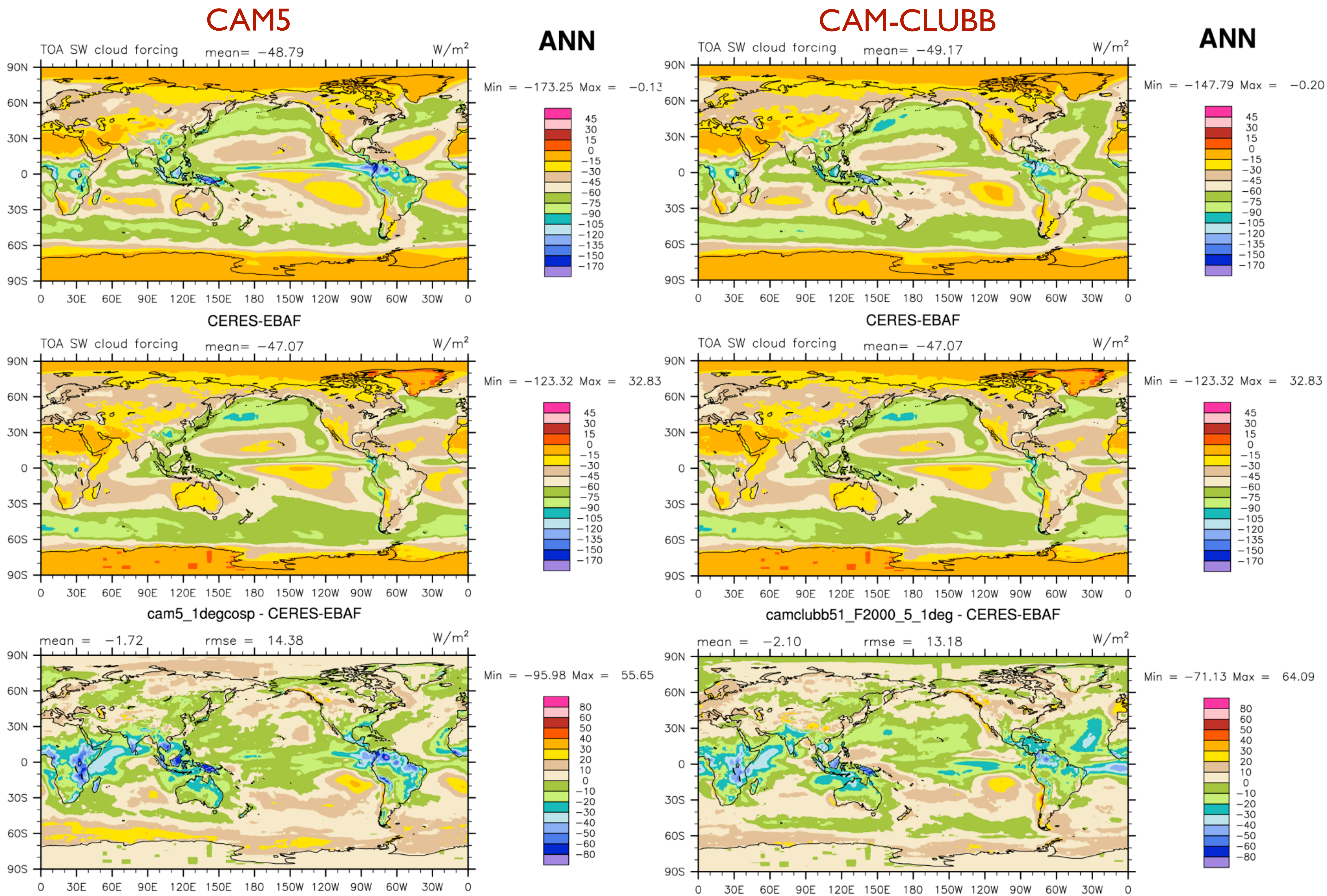
Global Results

- Have been performing two-year testing simulations with the aim of achieving a credible climate simulation
- Testing at both 1 and 2 degree horizontal res, fv dynamical core
- Unless otherwise stated, results shown are from 1 degree simulations
- Julio Bacmeister and John Truesdale have run CAM-CLUBB with SE dycore at 0.25 degree res
- Have run CAM-CLUBB with ZM turned off, results (while preliminary) are encouraging

Low Cloud Amounts

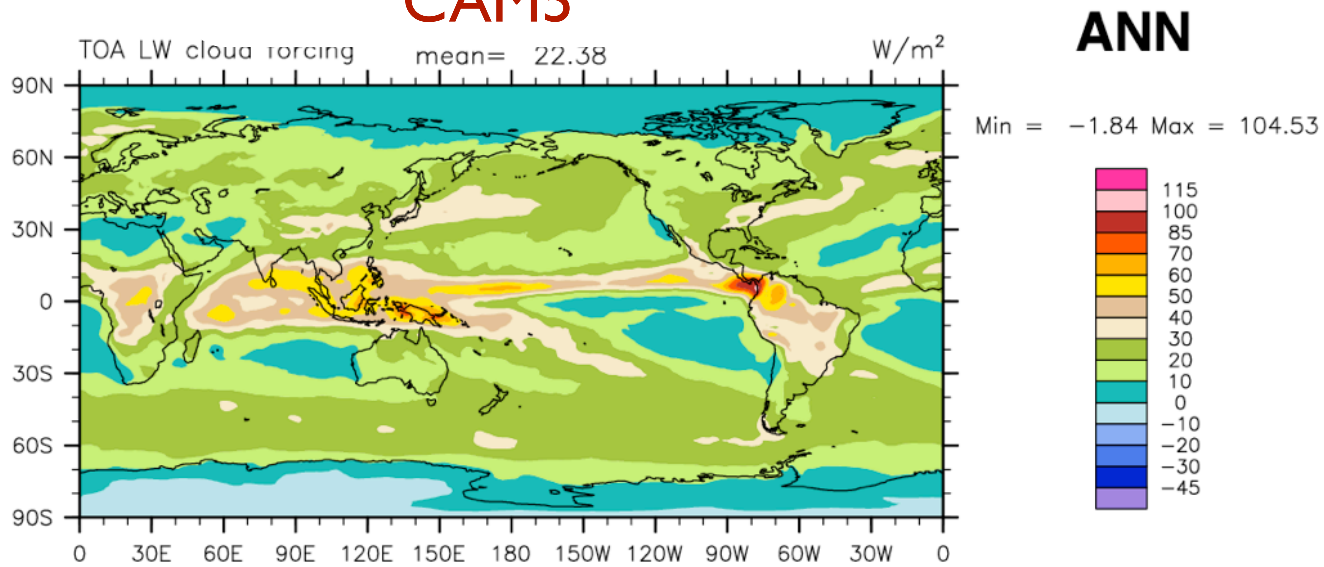


Shortwave Cloud Forcing

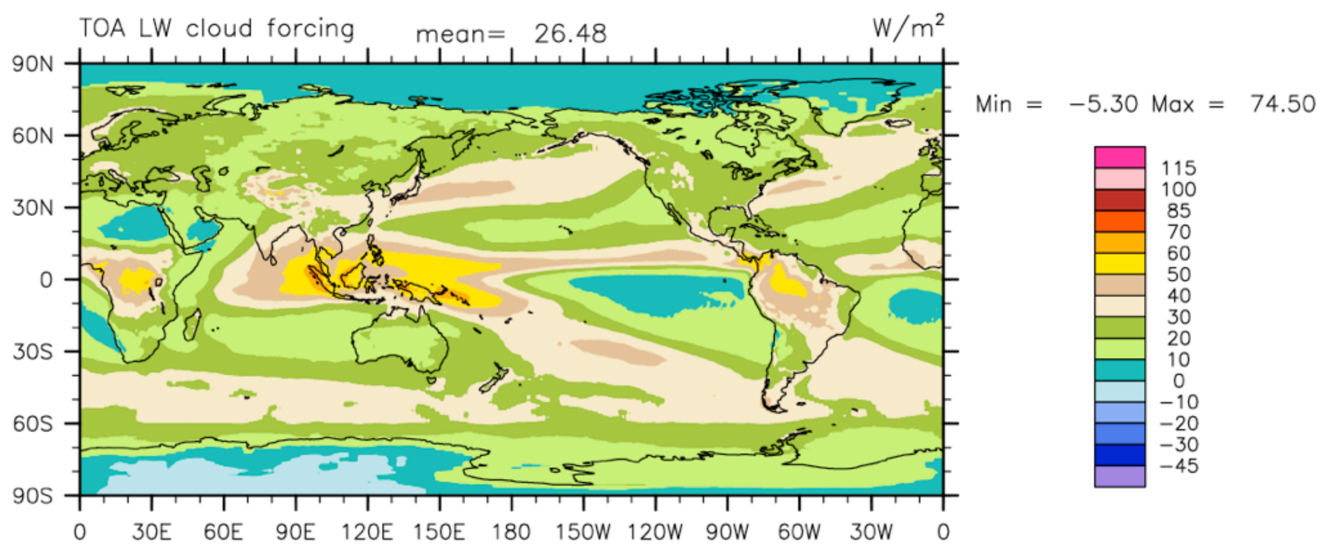


Longwave Cloud Forcing

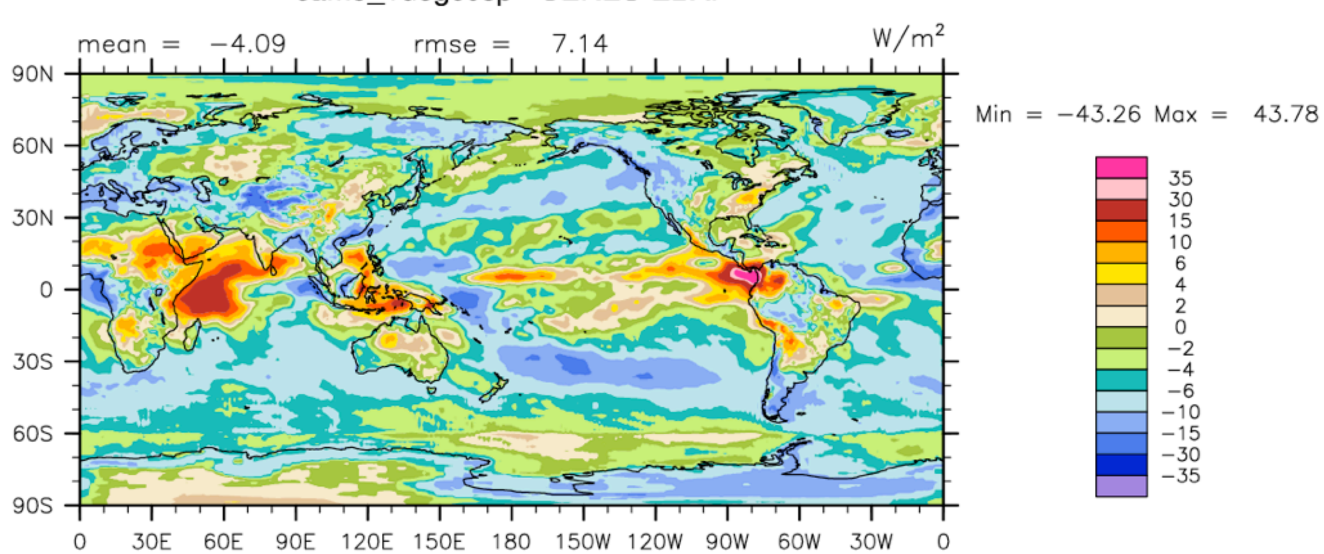
CAM5



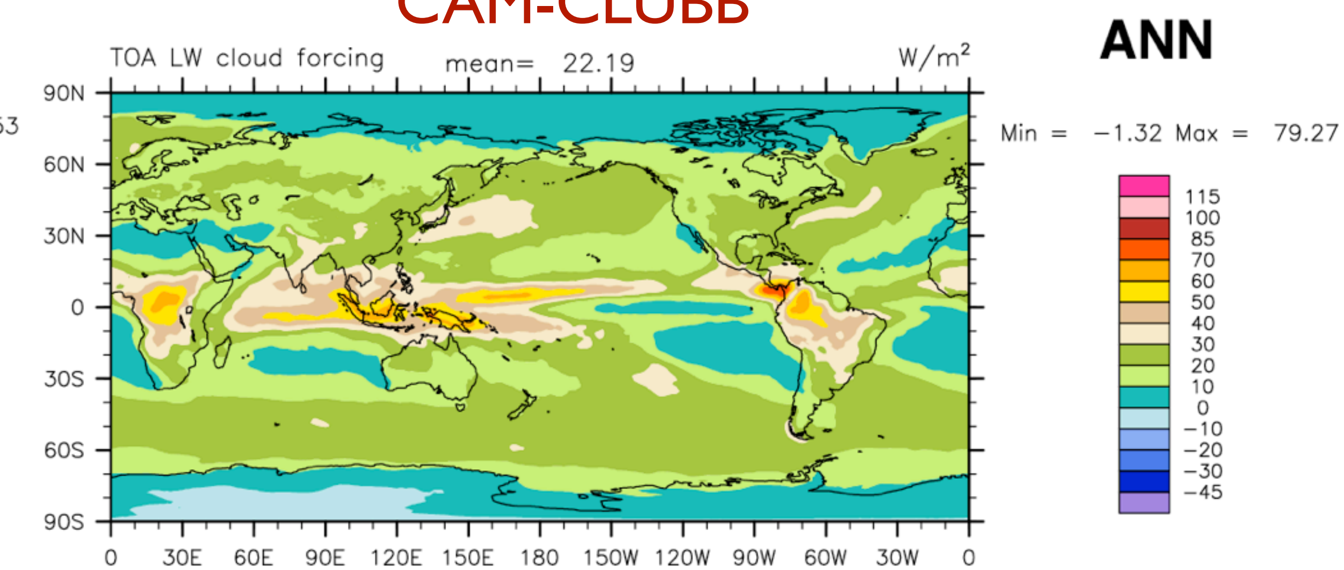
CERES-EBAF



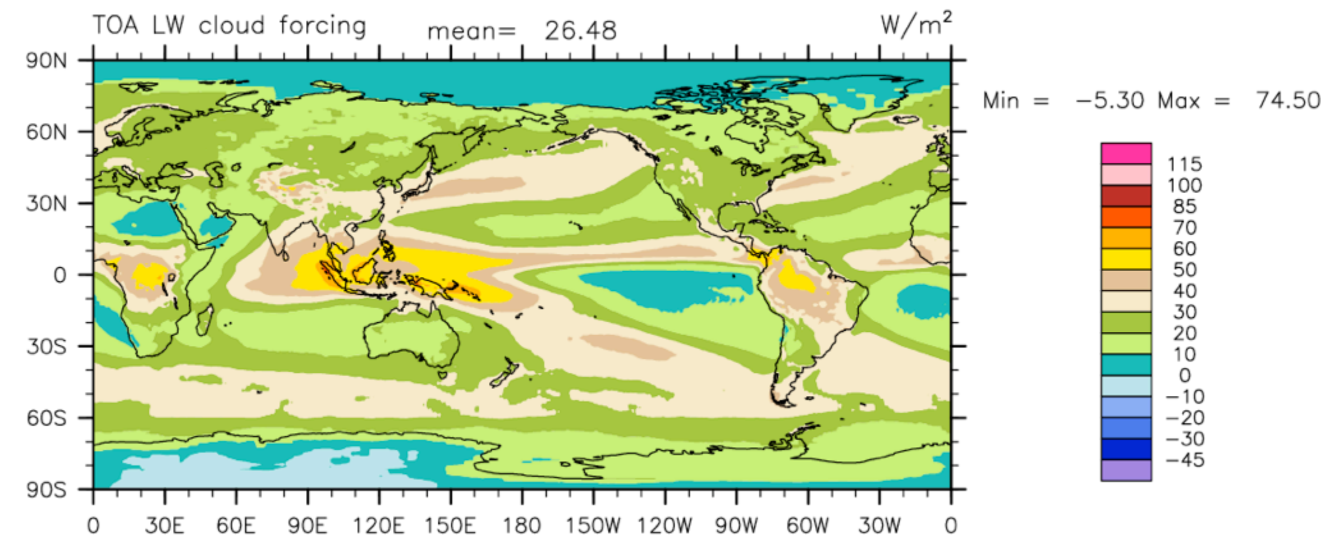
cam5_1degcosp - CERES-EBAF



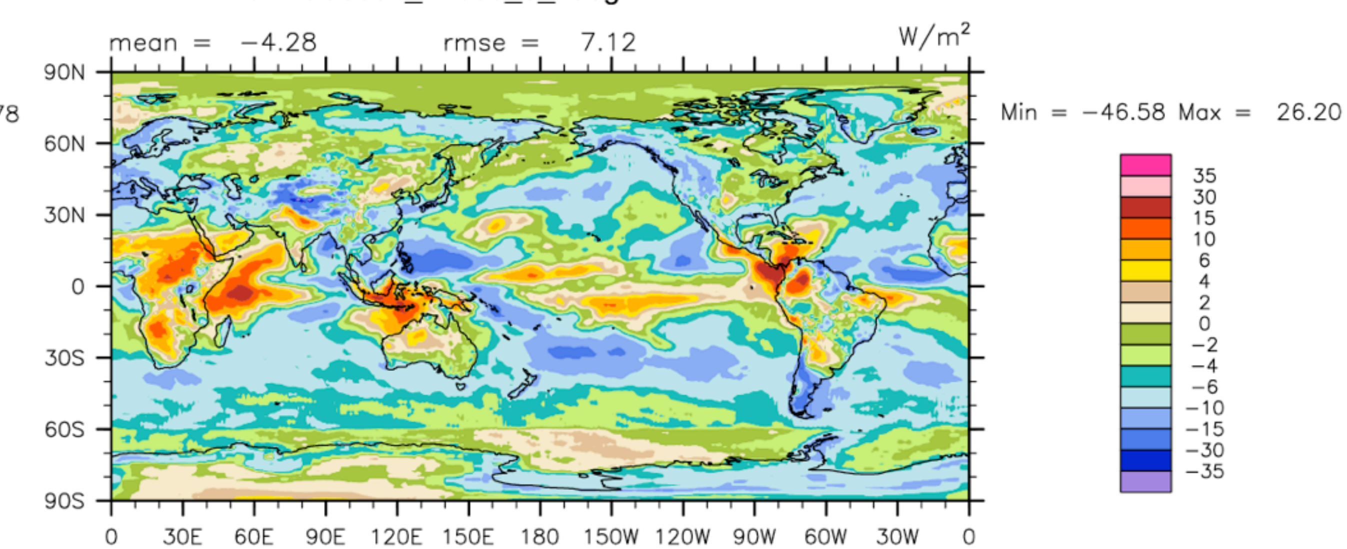
CAM-CLUBB



CERES-EBAF

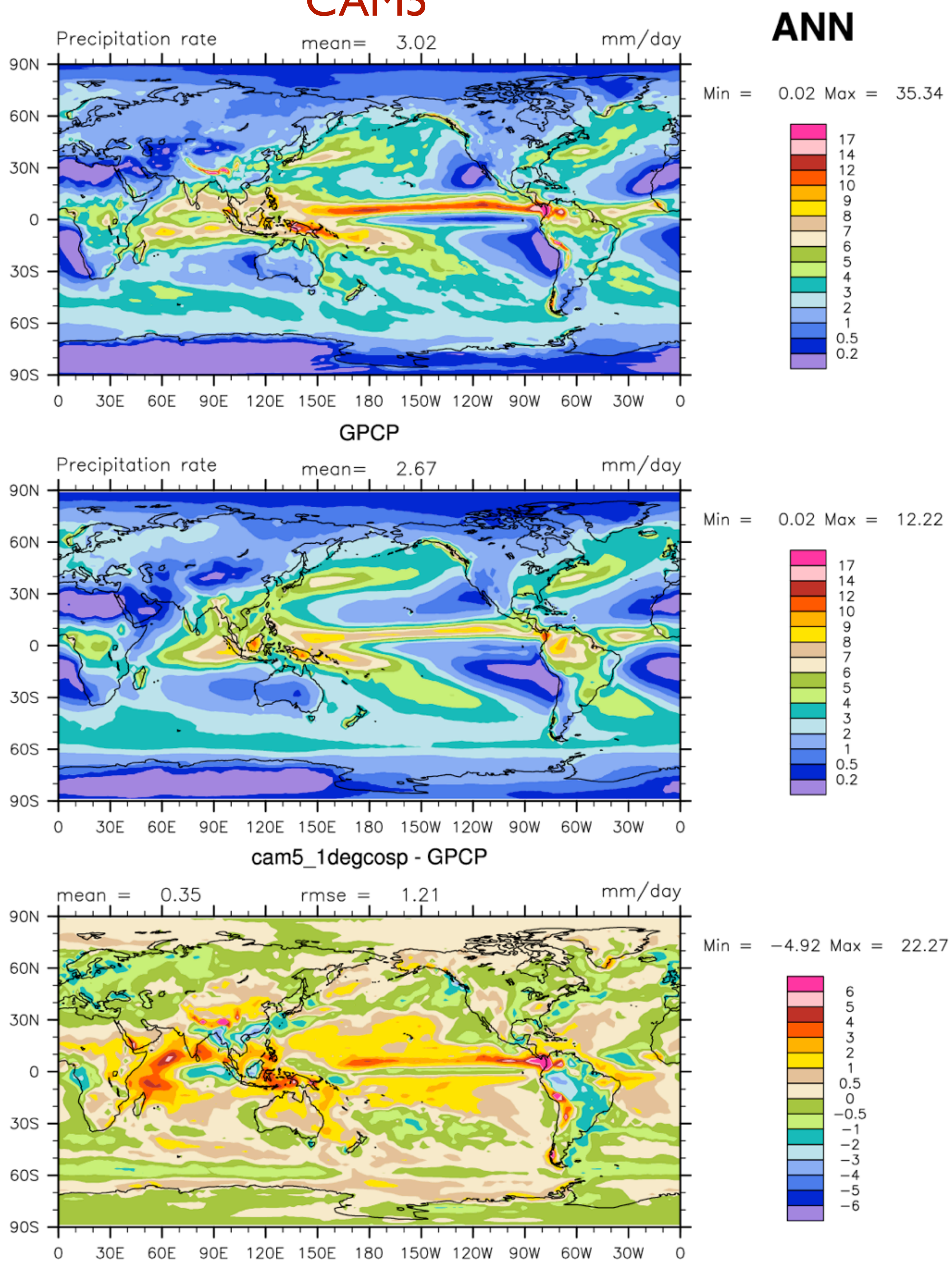


camclubb51_F2000_5_1deg - CERES-EBAF

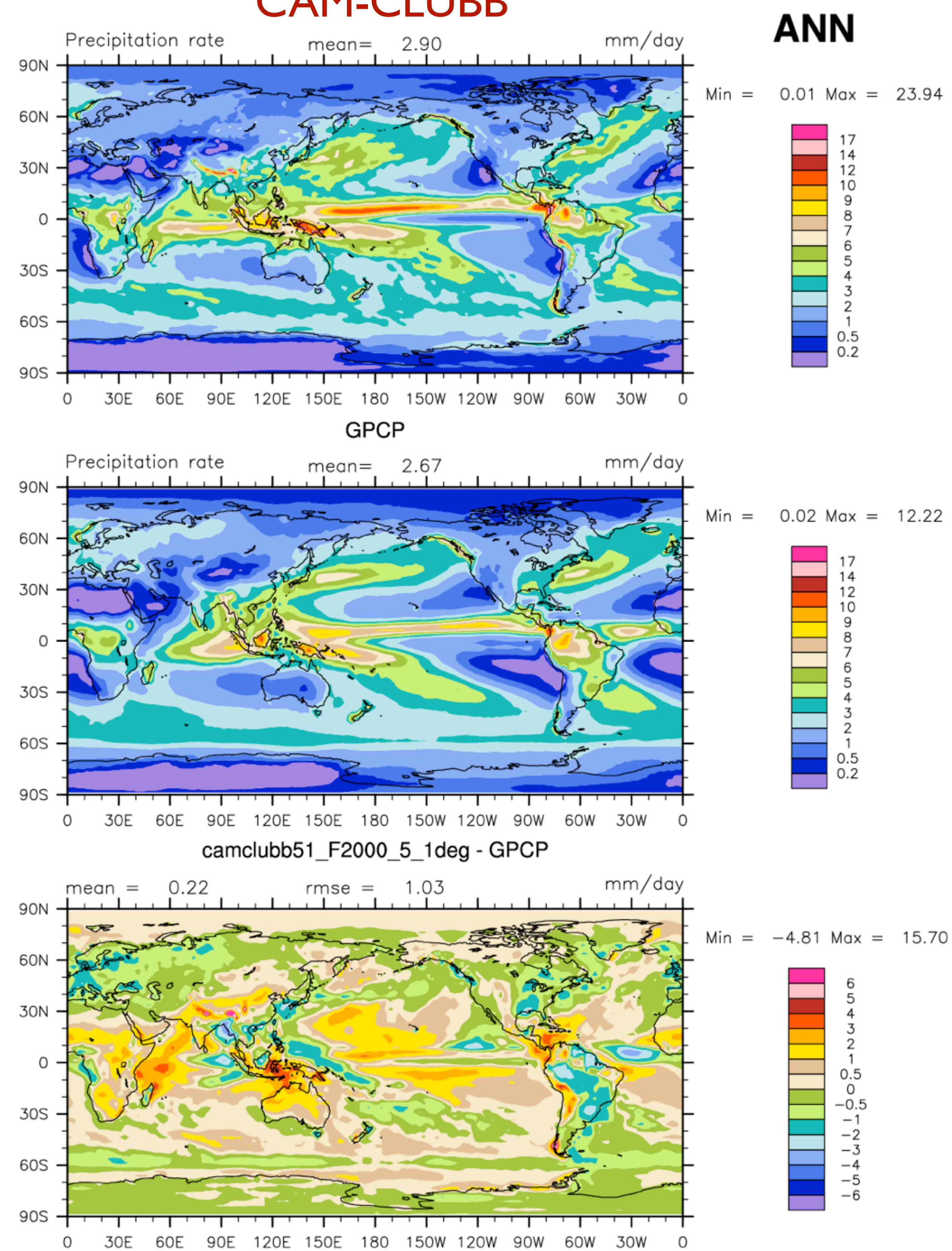


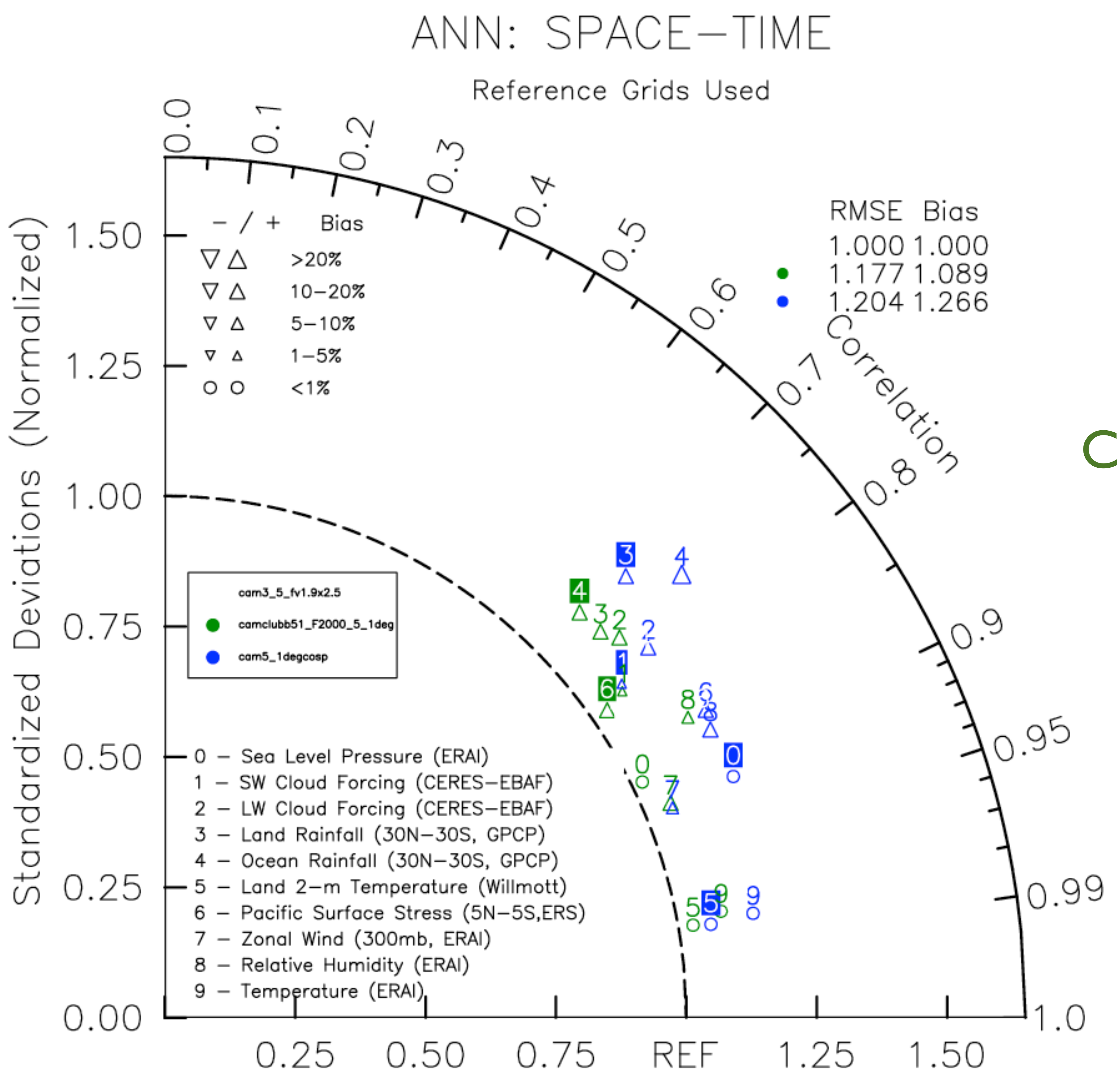
Total Precip Rate

CAM5



CAM-CLUBB





1 degree

CAM-CLUBB

CAM5

Aerosol Indirect Effect

- Preliminary AIE experiment performed with CAM-CLUBB
- Ran CAM5 and CAM-CLUBB for two years at 1 degree for both present day (PD) and preindustrial (PI) emissions

	CAM5	CAM-CLUBB
Δ SWCF	-1.6 W/m^2	- 1.8 W/m^2
Δ LWCF	0.5 W/m^2	0.4 W/m^2
Δ(SWCF + LWCF)	-1.1 W/m^2	- 1.4 W/m^2
RFP	-1.4 W/m^2	- 1.6 W/m^2

- Reasonable results for a preliminary investigation. Detailed analysis is needed

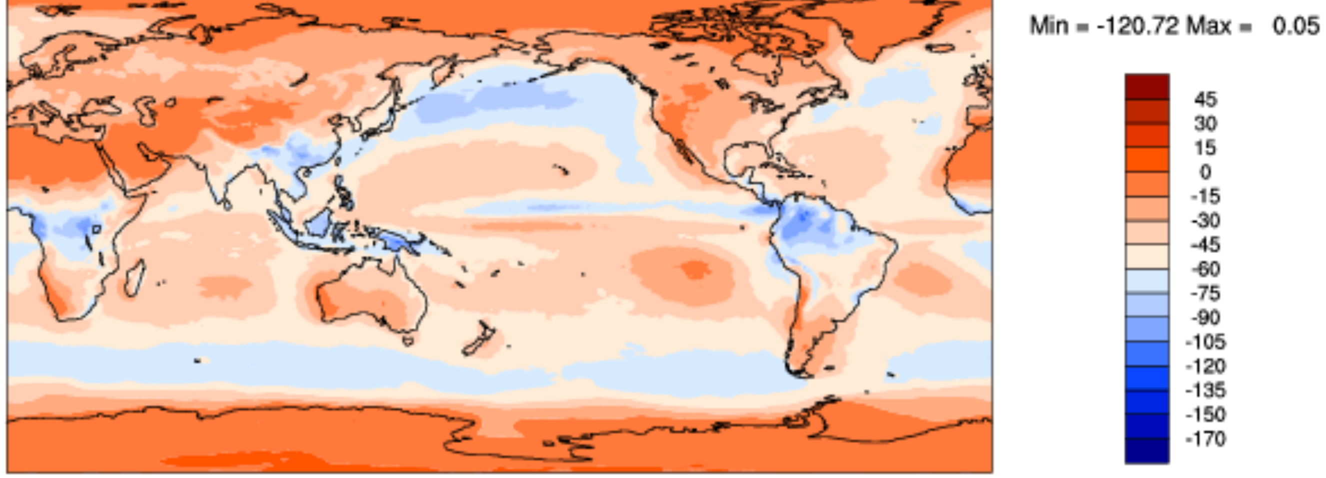
Simulations at 0.25 degree, HOMME

(courtesy Julio Bacmeister and John Truesdale)

CAM-CLUBB

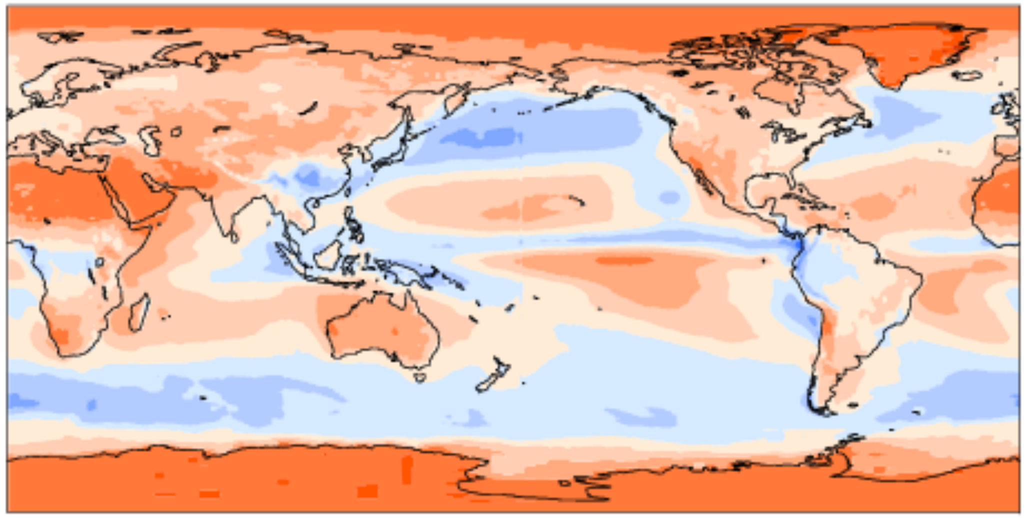
ANN

TOM SW cloud forcing mean= -41.38 W/m²



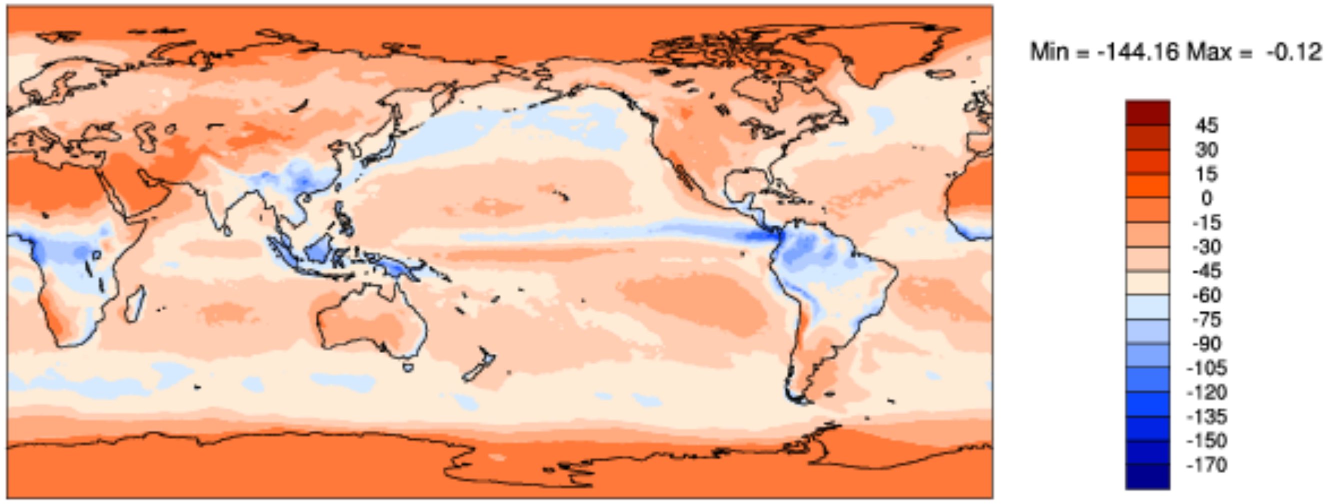
CERES-EBAF

TOA SW cloud forcing mean= -47.07 W/m²



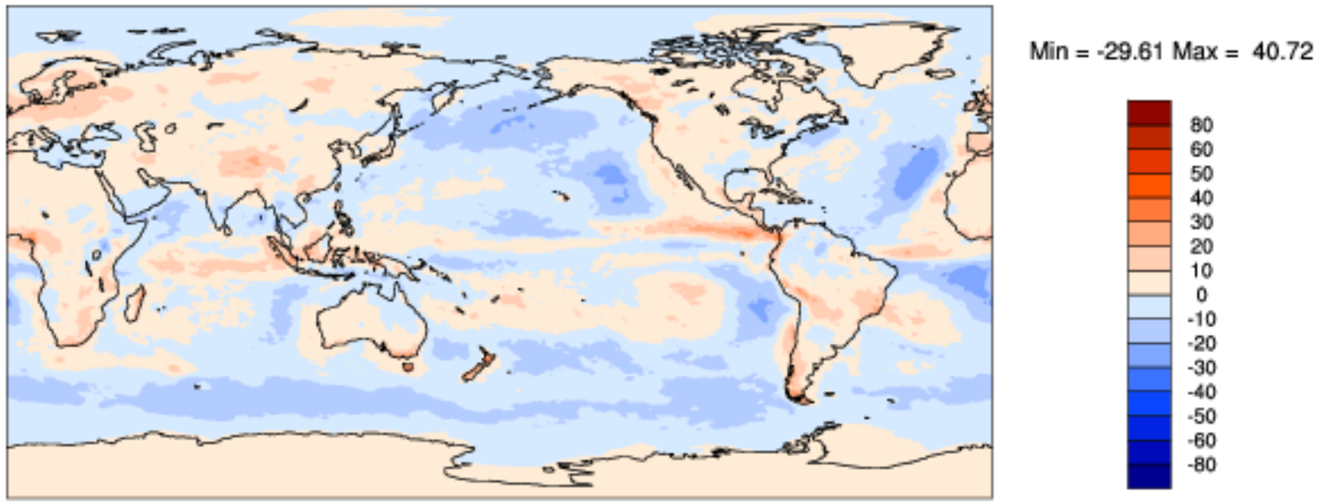
CAM5

TOM SW cloud forcing mean= -40.10 W/m²



ERS.ne120_g16.FC5.titan_pgi.clubb.3200 - ERS.ne120_g16.FC5.titan_pgi.61208

mean = -1.28 rmse = 7.93 W/m²



Summary & Future Plans

- CAM-CLUBB is alive and competitive with CAM5
- Evidence that CAM-CLUBB may provide a more "scale aware" solution with increasing resolution
- Testing of longer simulations is needed
- Detailed analysis/validation of low clouds, precipitation, AIE, etc. is planned
- Doing science with CAM-CLUBB (aerosol effects, climate sensitivity)
- Move on to sub-columns for microphysics
- Fully coupled CESM simulations with CAM-CLUBB