Boundary Layer Clouds in the Community Atmosphere Model with a Unified PDF-Based Scheme

Peter A. Bogenschutz[1], Andrew Gettelman[1], Hugh Morrison[1], Vincent E. Larson[2], David P. Schannen[2], Nathaniel R. Meyer[2], and Cheryl Craig[1]

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

Introduction

- CAM5 has been coupled with CLUBB (Golaz et al. 2002)
- CLUBB = Cloud Layers Unified By Bi-normals
- CLUBB is an "Incomplete" third-order turbulence closure centered around a multi-variate assumed double Gaussian PDF (Larson et al. 2002)
- CLUBB should provide a unified treatment of the planetary boundary layer (PBL) and shallow convection
- Goal is for better representation of boundary layer clouds and aerosol effects

Physics	CAM5-BASE	CAM-CLUBB
Deep Convection	Zhang and McFarlane (1995)	Zhang and McFarlane (1995)
Shallow Convection	UW - Park and Bretherton (2009)	CLUBB
PBL	UW - Bretherton and Park (2009)	CLUBB
Macrophysics	Park	CLUBB
Microphysics	Morrison and Gettelman (2008)	Morrison and Gettelman (2008)

Implementing CLUBB in CAM

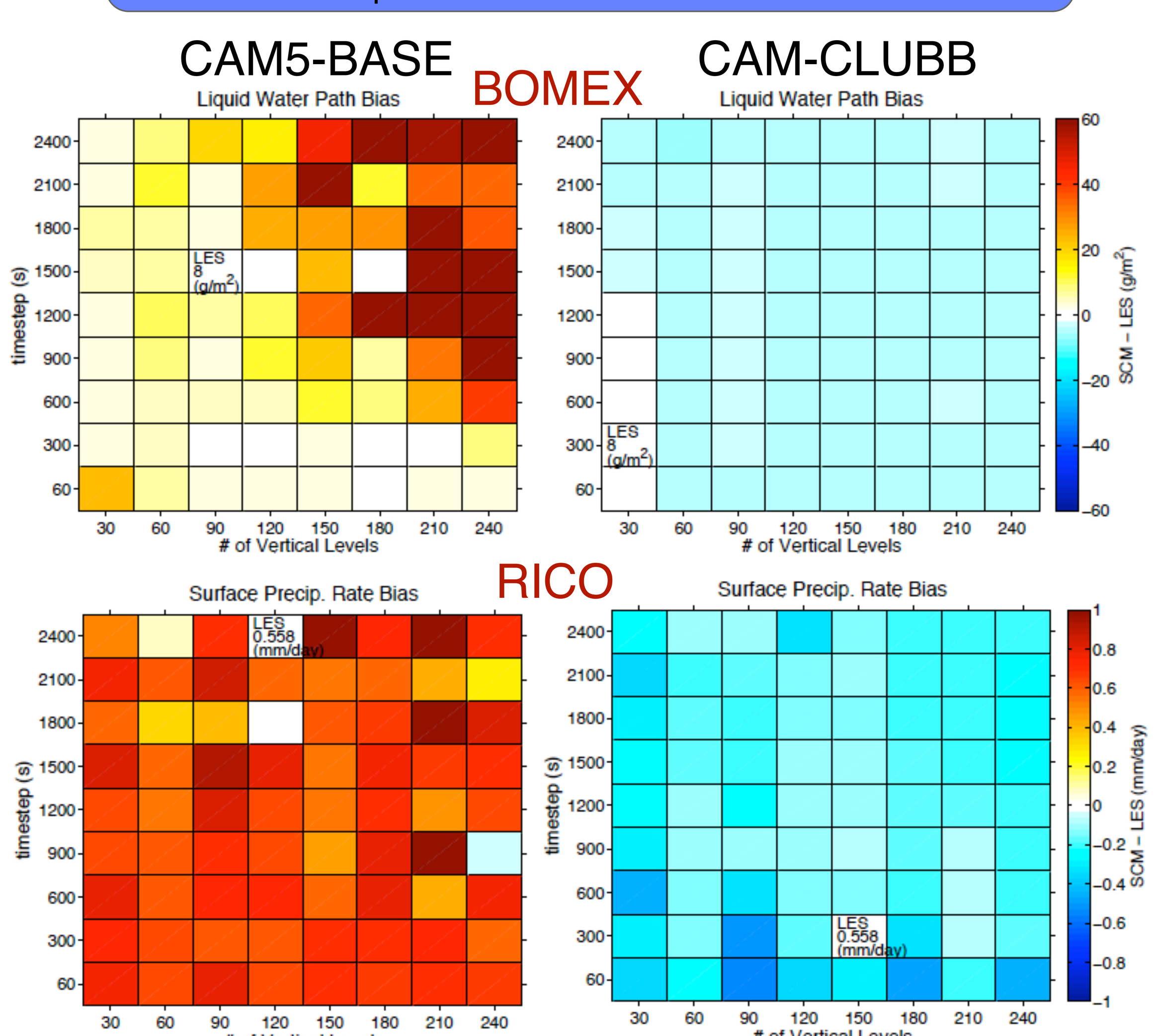
- Called after Deep Convection and before Microphysics
- CLUBB operates with a 5 minute time step (30 min host GCM time step)
- Predicted vertical velocity variance passed from CLUBB to MG for vertical velocity needed for aerosol activation
- CLUBB drives a single microphysics scheme (MG 2008), for both stratiform and shallow convective cloud, for a more consistent treatment of cloud-aerosol interactions

1) Single Column Experiments

CAM-CLUBB has been extensively tested in single-column CAM (SCAM) on several cases ranging from shallow convection (BOMEX, RICO, ARM), maritime stratocumulus (DYCOMS-RF01 and RF02, ATEX), deep convection (GATE, ARM97, TOGA), and mixed phase cloud (MPACE).

Sensitivity to Vertical & Temporal Resolution

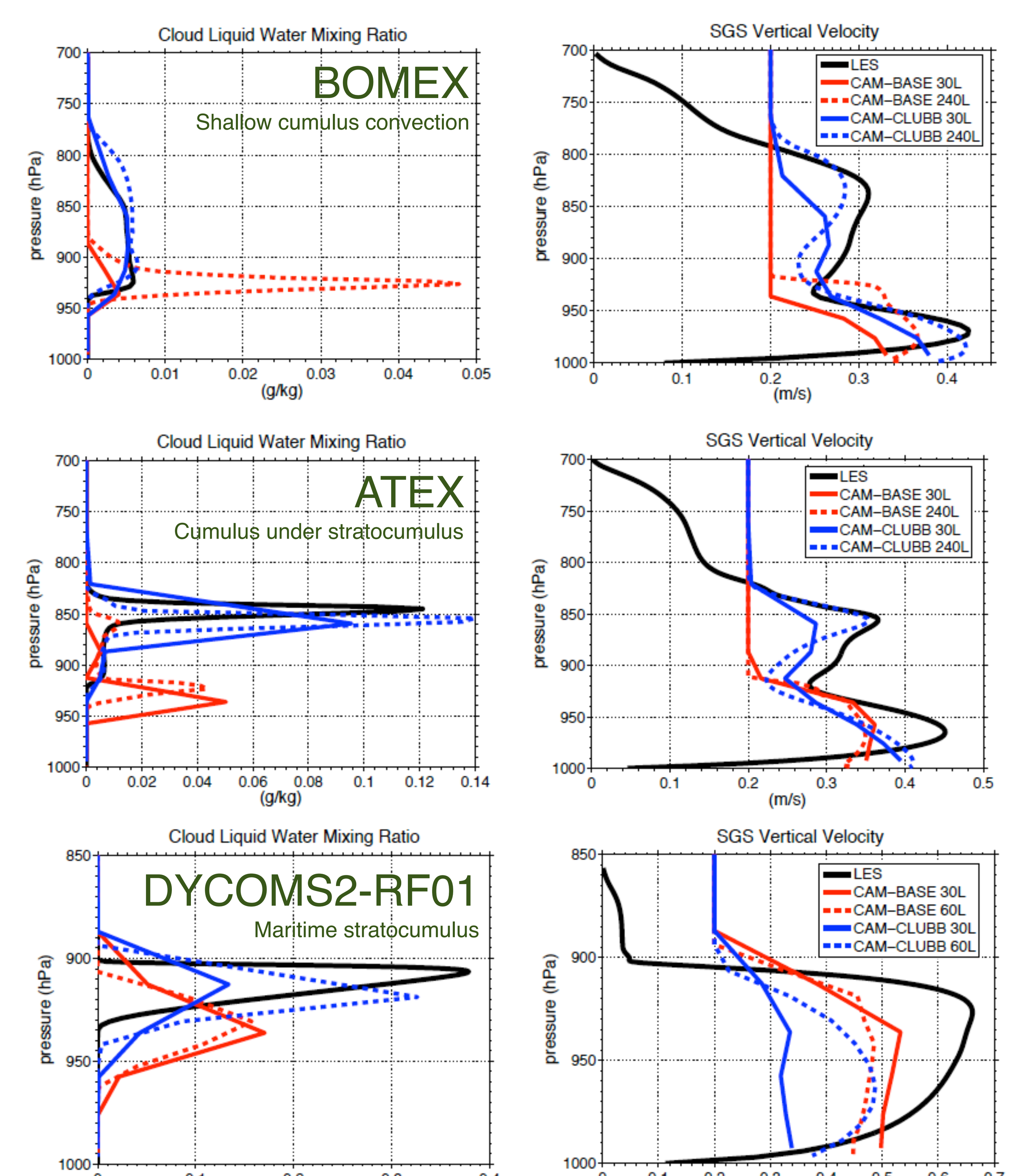
Results below show sensitivity of CAM-BASE & CAM-CLUBB to vertical and temporal resolution for shallow convection. CAM-CLUBB provides results in better agreement with LES and is more robust to changes in vertical and temporal resolution.



SCM minus LES for BOMEX (top row) liquid water path averaged over hours 4-6 and RICO (bottom row) surface rain rate averaged over hours 18-24 for different combinations of vertical and temporal resolution. Box with LES value indicates the configuration with closest agreement to LES.

Temporally Averaged Profiles

CLUBB should provide a unified parameterization of shallow convection and PBL processes in CAM. Results below suggest that at various vertical resolutions CAM-CLUBB can improve the representation of shallow convection and provide comparable results of marine Sc compared to CAM-BASE.



Temporally averaged profiles of CAM-BASE (red lines) and CAM-CLUBB (blue lines) for operational configuration (solid lines) and high-res configurations (dashed lines) for BOMEX (top row, averaged over hours 4-6), ATEX (middle row, averaged over hours 4-8), and DYCOMS2-RF01 (bottom row, averaged over hours 4-6).

References

Bretherton, C. S. and S. Park, 2009: A new moist turbulence parameterization in the community atmosphere model. *J. Climate.*, **22**, 3422-3448.
Golaz, J. C., V. E. Larson, and W. R. Cotton, 2002: A pdf-based model for boundary layer clouds part I: Method and model description. *J. Atmos. Sci.*, **59**, 3540-3551.
Larson, V. E., J. C. Golaz, and W. R. Cotton, 2002: Small-scale and mesoscale variability in cloudy boundary layers: Joint probability density functions. *J. Atmos. Sci.*, **59**, 3519-3539.
Morrison, H. and A. Gettelman, 2008: A new two-moment bulk stratiform cloud microphysics scheme in the community atmosphere mode, version 3 (CAM3). Part I: Description and numerical tests. *J. Climate.*, **21**, 3642-3659.
Park, S. and C. S. Bretherton, 2009: The University of Washington shallow convection and moist turbulence schemes and their impacts on climate simulations with the Community Atmosphere Model. *J. Climate*, **21**, 3449-3469.
Zhang, G. J., and N. A. McFarlane, 1995: Sensitivity of climate simulations to the parameterization of cumulus convection in the Canadian Climate Centre general circulation model, *Atmosphere- Ocean*, **33**, 407-446.

2) Global Simulations

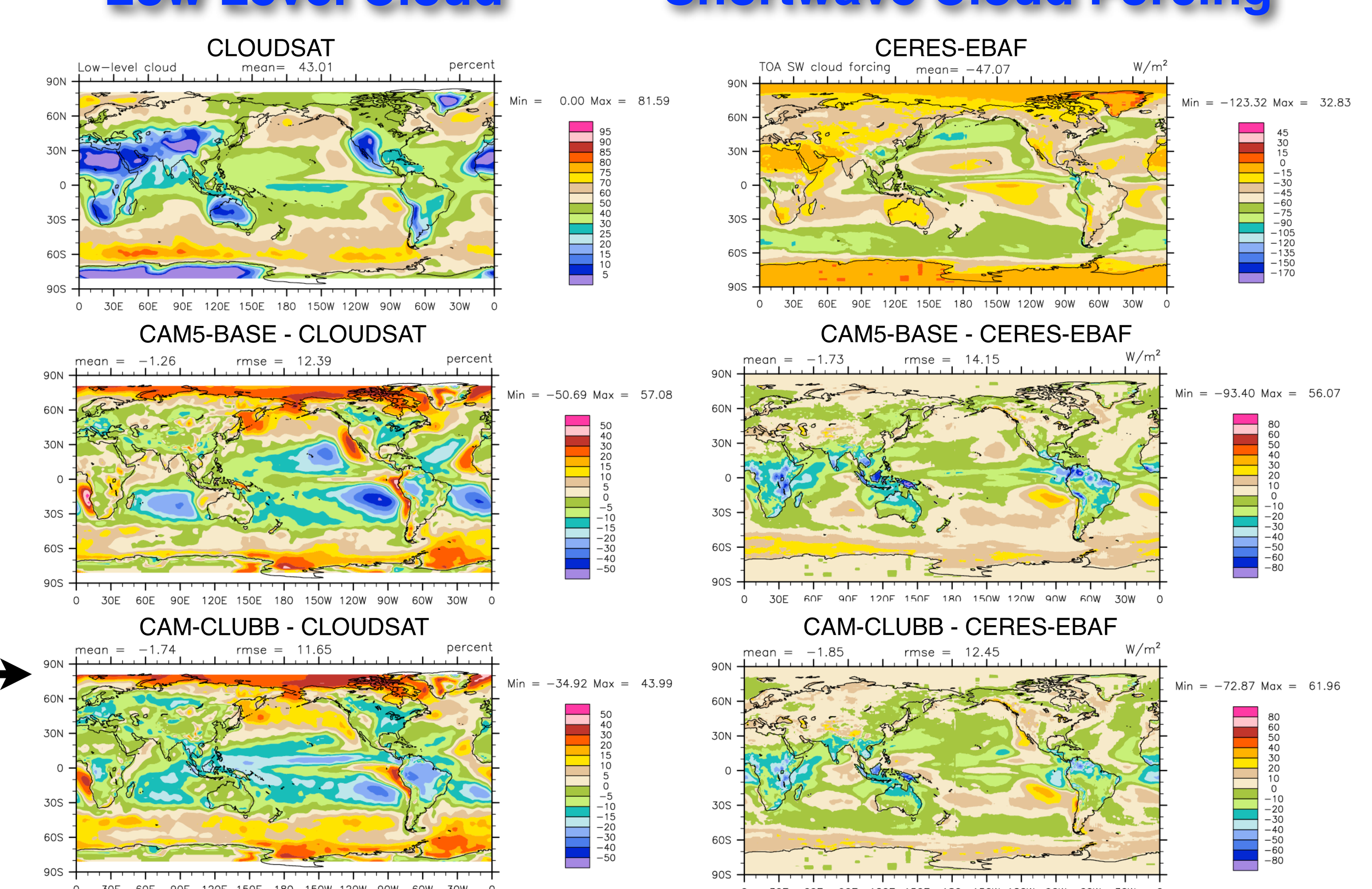
GCM configuration

- Five-year initial testing simulations, present day aerosols
- 1 degree horizontal resolution (finite volume dynamical core)
- Standard 30 vertical levels
- Currently CAM-CLUBB is 15% more expensive than CAM5-BASE

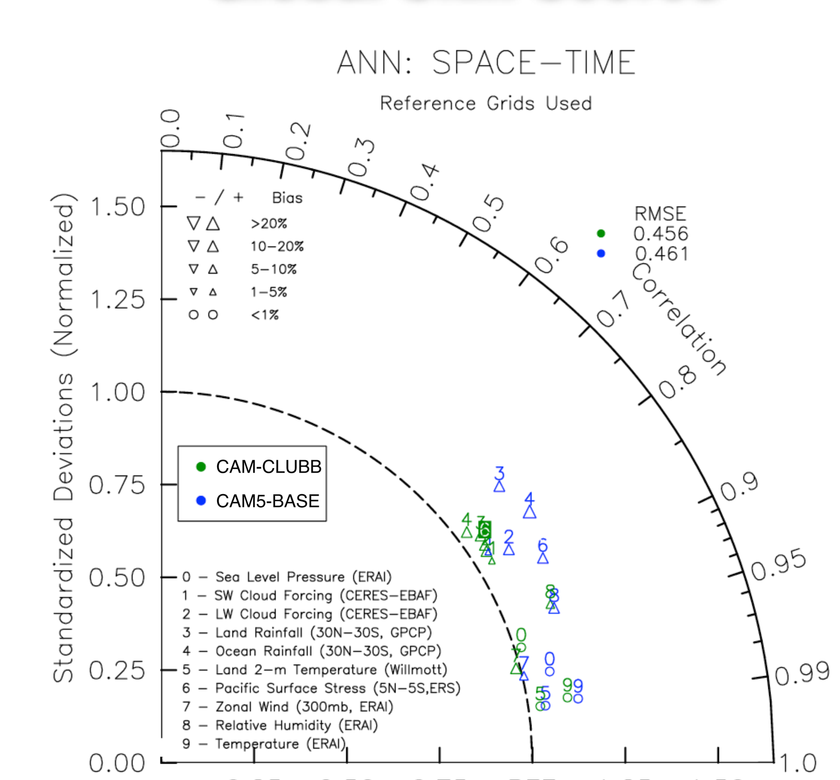
CAM-CLUBB can produce a realistic low cloud climatology. The sharp gradients seen in the transition areas from Sc To Cu in CAM-BASE are greatly improved in CAM-CLUBB.

RMSE for SWCF in CAM-CLUBB is reduced compared to CAM-BASE. Improvements arise in Sc to Cu transitions, storm tracks, as well as continental deep convective areas.

Low Level Cloud / Shortwave Cloud Forcing

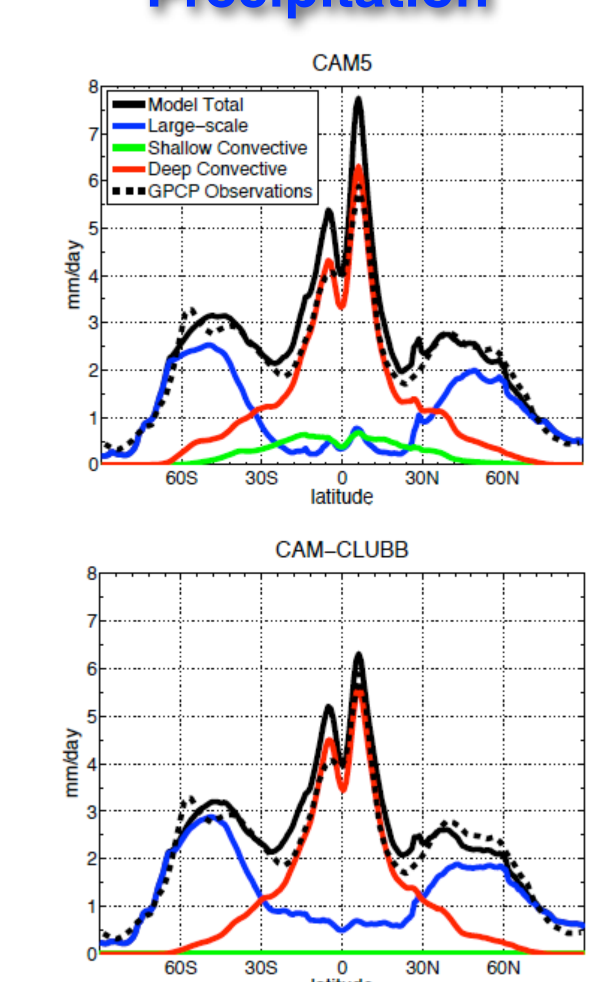


Global Skill Scores



While CAM-CLUBB improves low cloud representation, it is not at the expense of the mean state climate as it improves slightly upon CAM5-BASE.

Precipitation



Compared to GPCP obs, CAM-CLUBB RMSE is significantly less than CAM-BASE for surface precipitation rate (0.98 vs. 1.20 mm/day, respectively) with most of the improvement arising from the ITCZ. CAM-CLUBB only has two precipitation types (deep convection + large scale), whereas CAM5-BASE has three.

Summary & Future Work

- The initial results of the coupling of CAM with CLUBB show promise from both a single-column and global perspective
- Largest improvement in CAM-CLUBB seen in stratocumulus to cumulus transition areas. However, issues with cloud macrophysics ice closure still remains.
- Future work will involve implementing sub-columns for microphysics and radiation computation
- Future versions of CAM-CLUBB will allow CLUBB to provide deep convective tendencies