A Unified Cloud/Convection Scheme for CAM: Concept and Preliminary Results

Peter Bogenschutz[1], Vincent Larson[2], Rachel Storer[2], Andrew Gettelman[1], Jack Chen[1], Hugh Morrison[1], and Cheryl Craig[1]

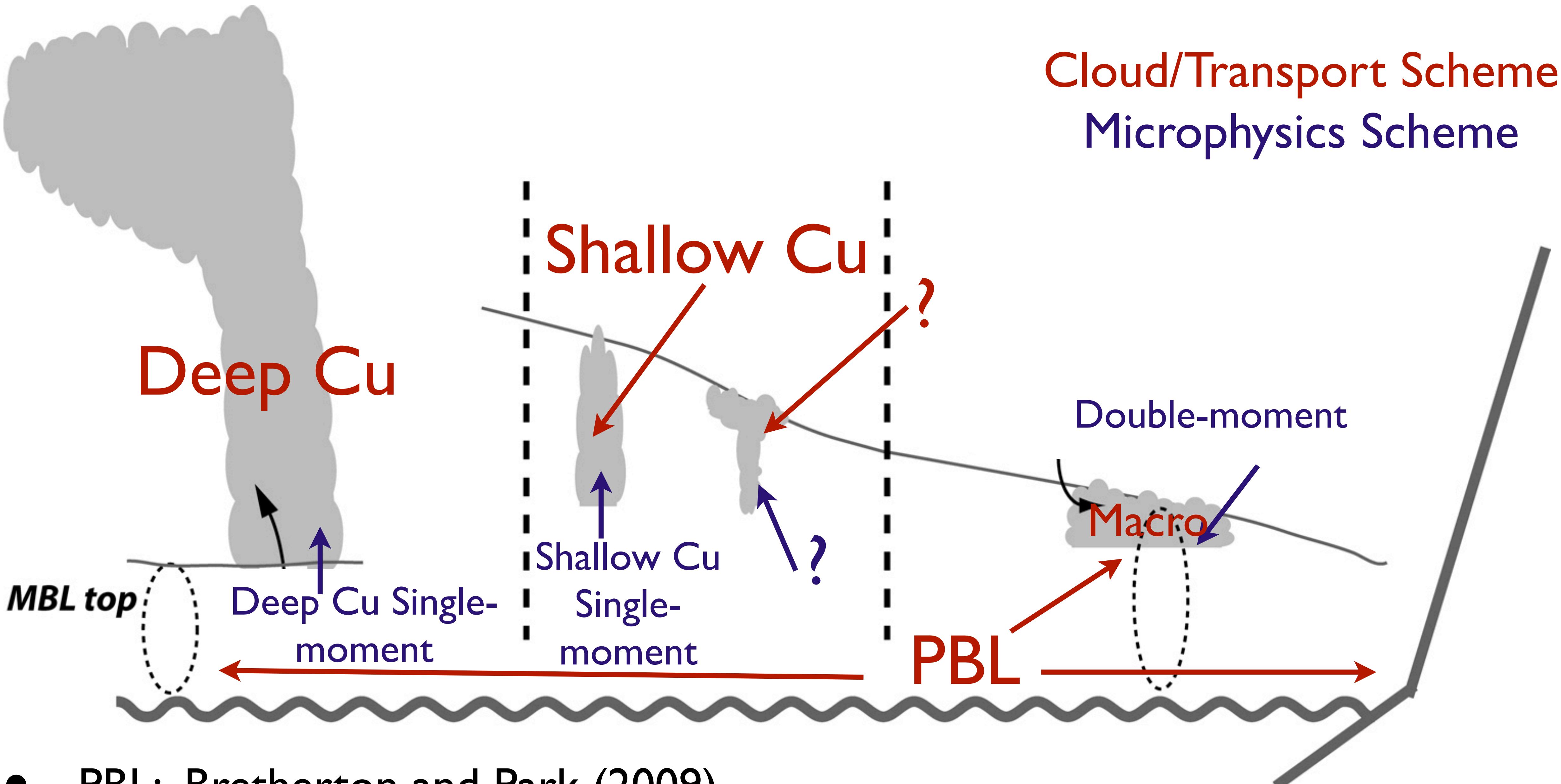
NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

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

UWM
UNIVERSITY of WISCONSIN
MILWAUKEE

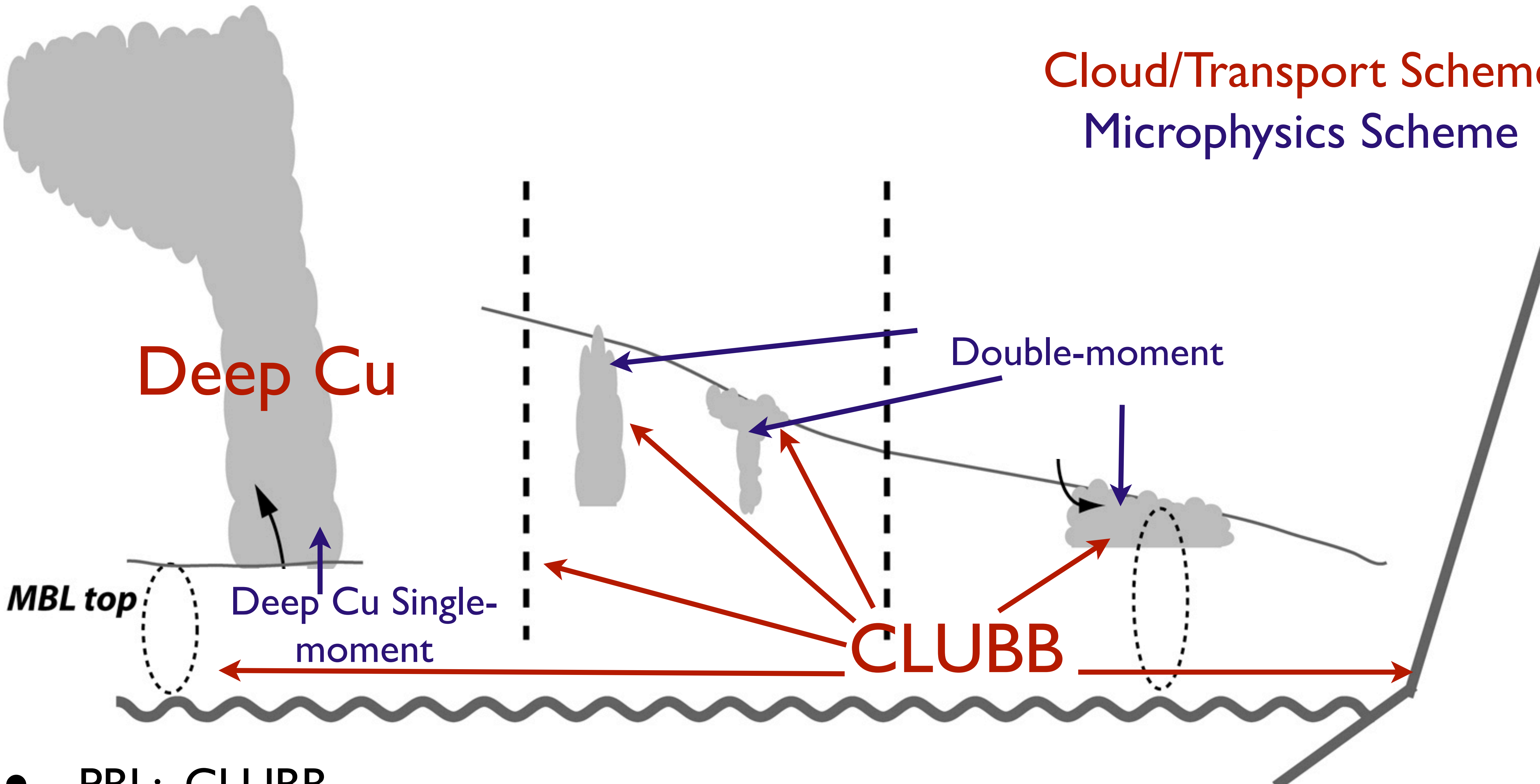
CESM Workshop, AMWG, Breckenridge CO June 19, 2013

Community Atmosphere Model version 5 (CAM5)



- PBL: Bretherton and Park (2009)
- Cloud Macrophysics: Park
- Shallow Cu: Park and Bretherton (2009)
- Deep Cu: Zhang and McFarlane (1995)
- Microphysics: Morrison and Gettelman (2008)

CAM-CLUBB standard



- PBL: CLUBB
- Cloud Macrophysics: CLUBB
- Shallow Cu: CLUBB
- Deep Cu: Zhang and McFarlane (1995)
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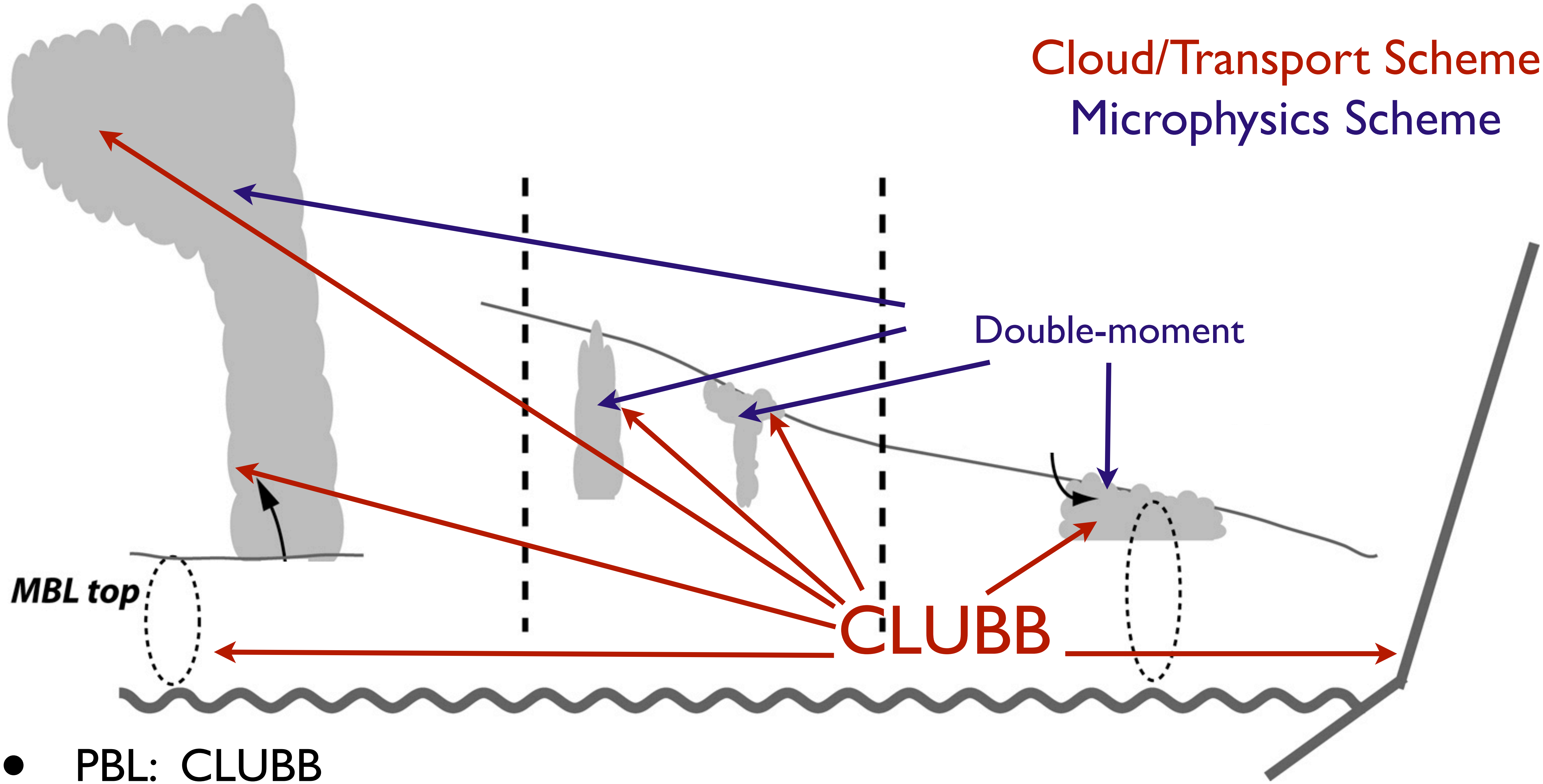
This version of CAM-CLUBB documented in Bogenschutz et al. (2012, 2013)

In CESM release as an option

CAM-CLUBB no deep



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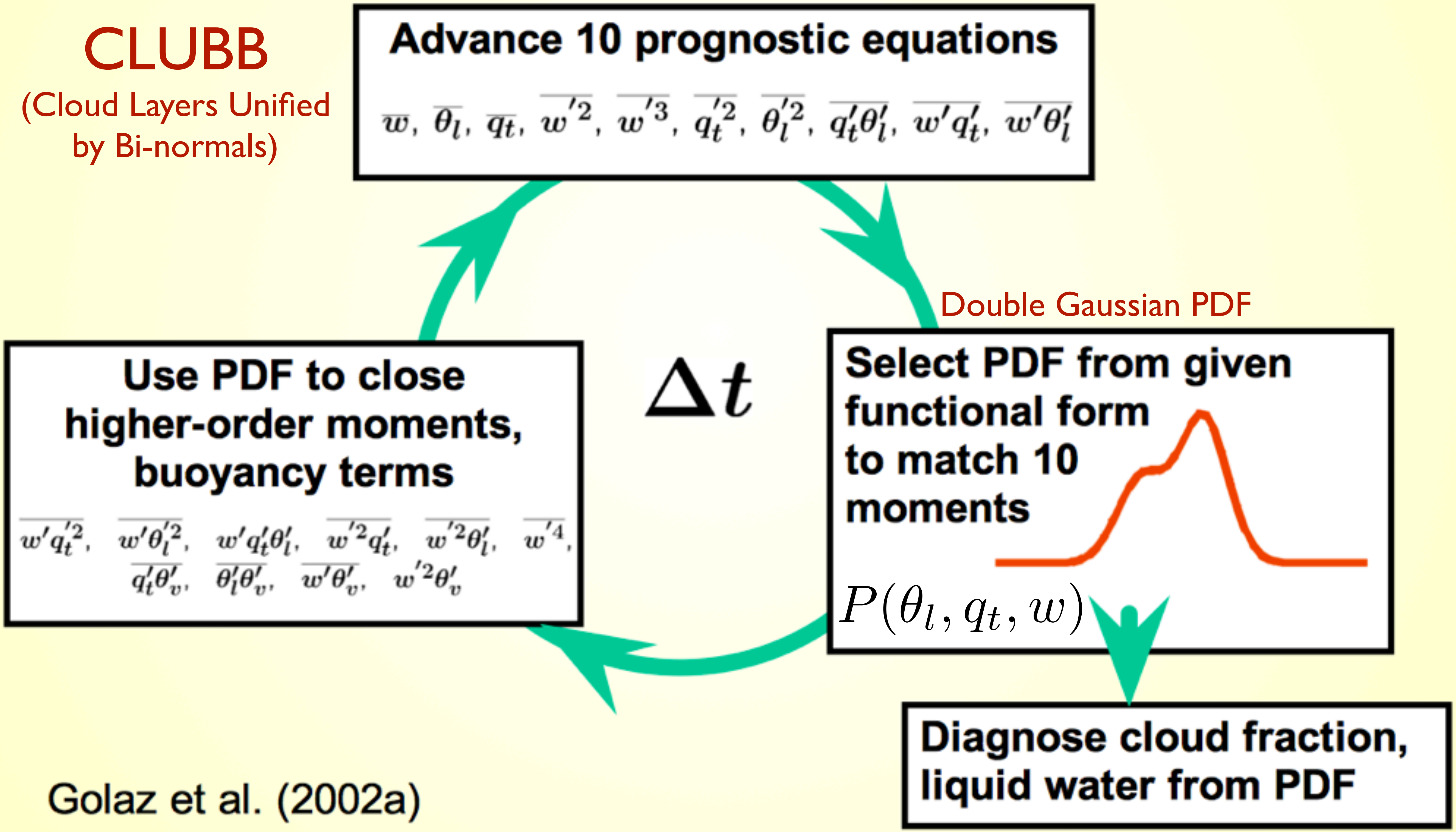
Advantages of Unified Physics in GCMs

- Inconsistencies are avoided from calling separate parameterizations that may not be compatible with one another
- Atmospheric processes are often times not so distinct in nature (which scheme to call?)
  - Obvious examples: Stratocumulus to cumulus transition; shallow to deep convection transition, etc.
- Convective parameterizations (i.e. shallow and deep convection) often contain their own simplified treatments of microphysics
  - Unified cloud parameterizations can drive a single microphysics scheme (i.e. MG, double moment)
  - More consistent microphysics treatment as well as more consistent treatment of cloud-aerosol interactions

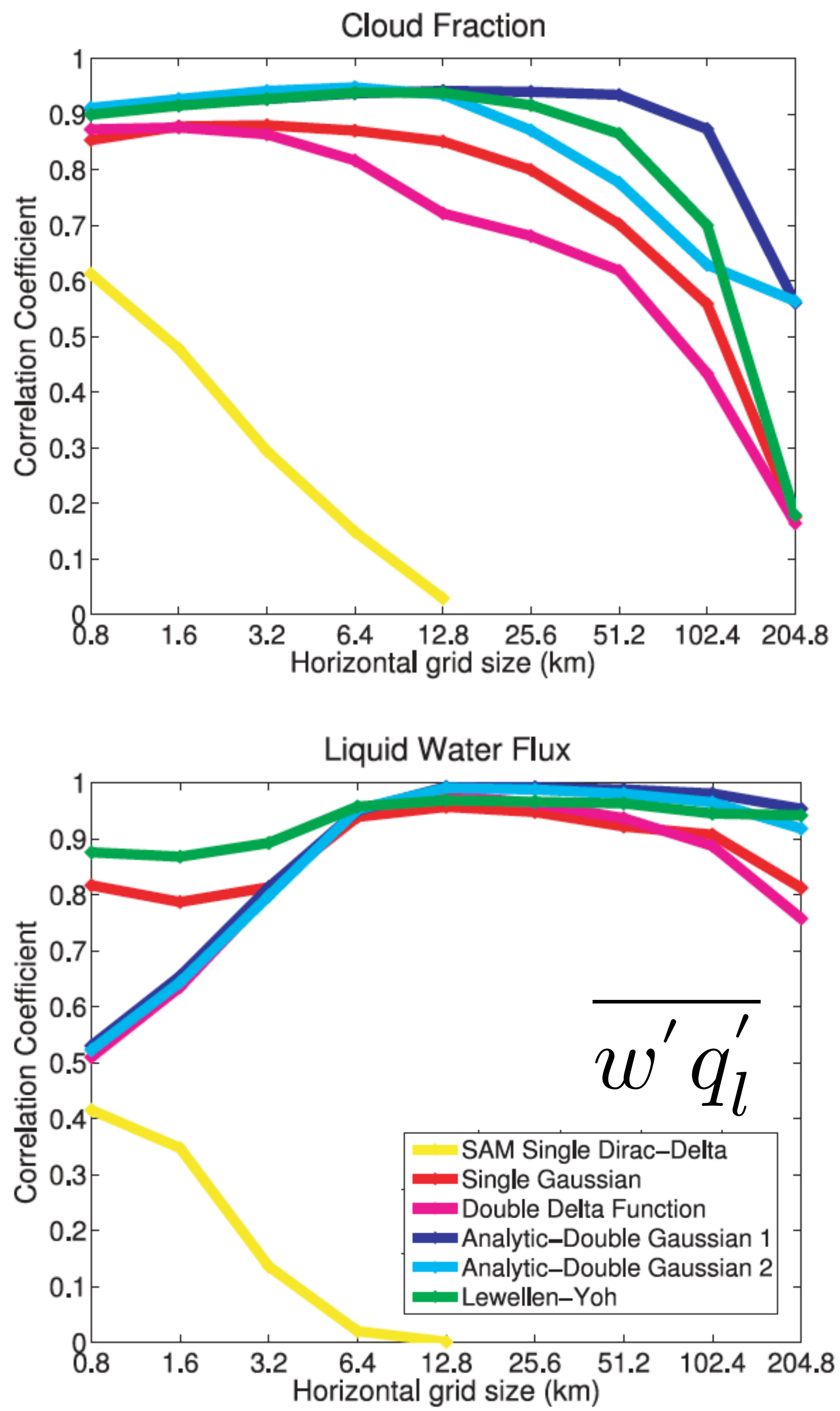
Schematic of the Assumed PDF method



Golaz et al. (2002a)

Is CLUBB suitable for deep convection?

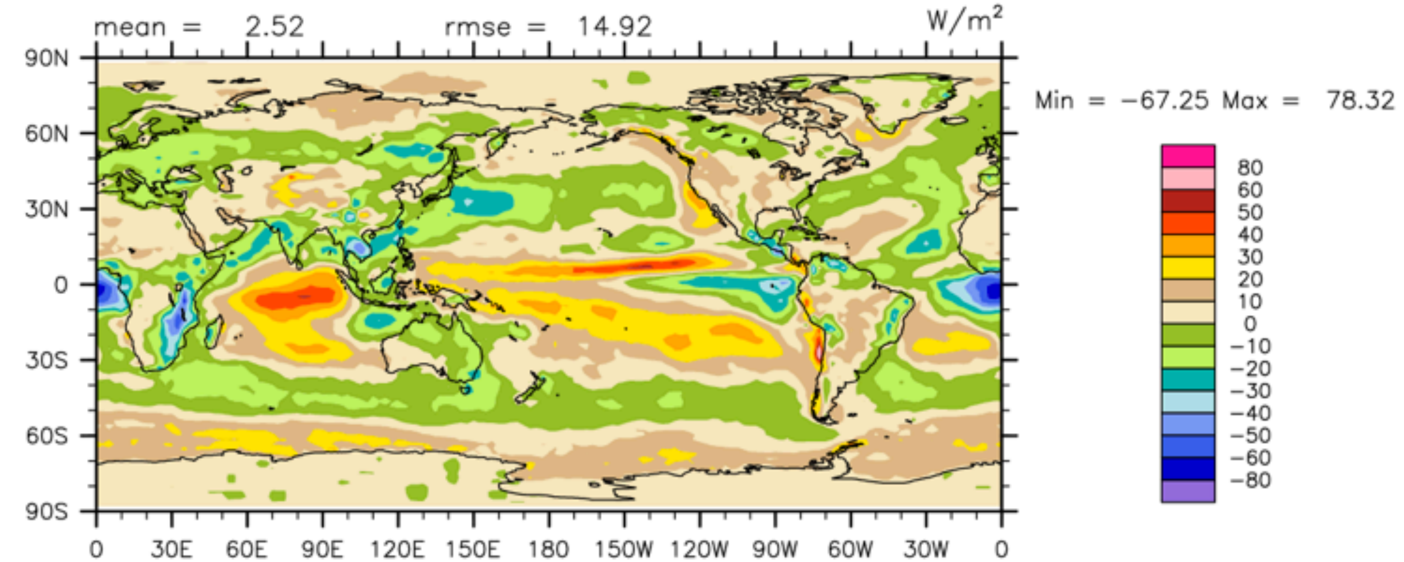
- CLUBB is much different than traditional deep convection schemes
- Non-local formulation of turbulent moments makes CLUBB suitable for simulating both non-local and local transport
- Assumed double Gaussian PDF can faithfully fit deep convective (Bogenschutz et al. 2010), shallow convective, and stratiform cloud (Larson et al. 2002)



Bogenschutz et al. (2010), *a priori* analysis of various assumed PDFs against LES of deep convection

Modifications to CLUBB (and interface)

SWCF bias



Running release version of CAM-CLUBB with deep convection scheme shut off results in lack of robust Hadley circulation

Modifications:

- Include latent heat release of ice into CLUBB's turbulent moments (helps to generate realistic Hadley circulation)
- Sub-step microphysics and CLUBB (helps to bring precipitable water down to reasonable amounts)
- Advecting CLUBB's higher-order moments
- Tendency of rain evaporation for CLUBB's thermodynamic variances
- Various CLUBB tunings (for realistic CRF and implied ocean heat transports)

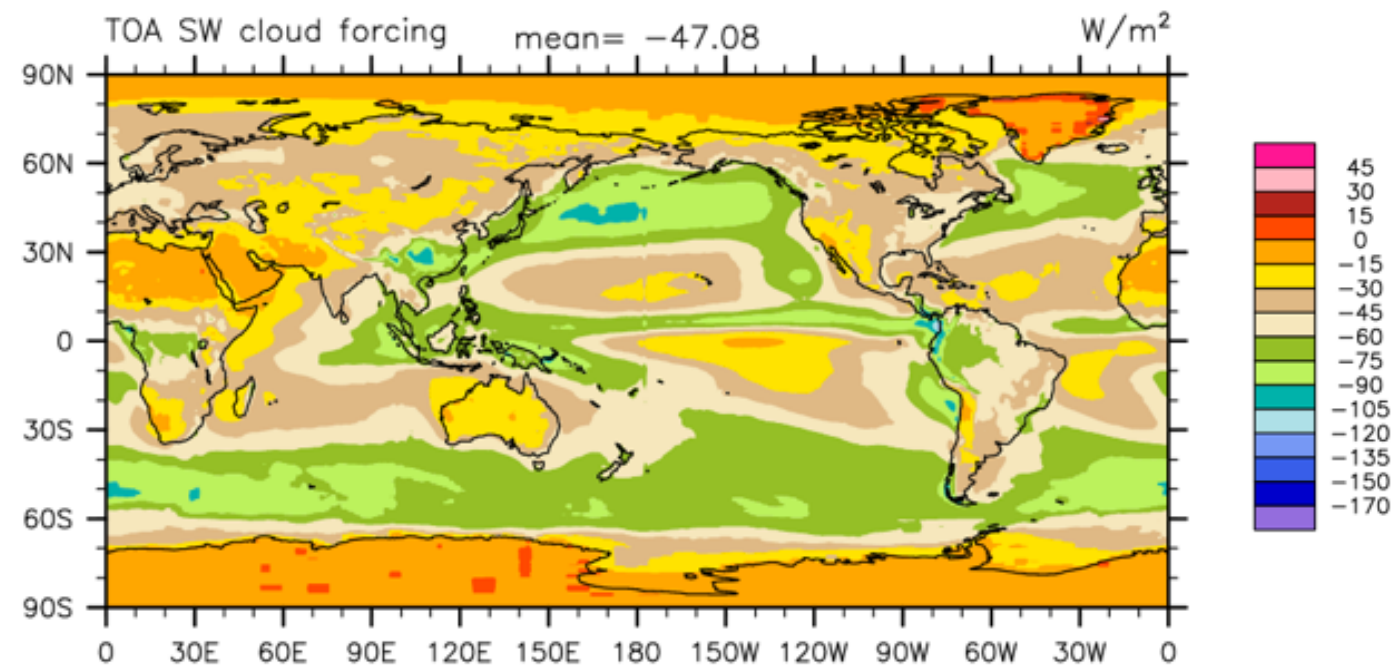
Preliminary Results

Physics	CAM5	CAM-CLUBB-ND
Deep Convection	Zhang and McFarlane (1995)	CLUBB
Boundary Layer	Bretherton and Park (2009)	CLUBB
Shallow Convection	Park and Bretherton (2009)	CLUBB
Cloud Macrophysics	Park	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)

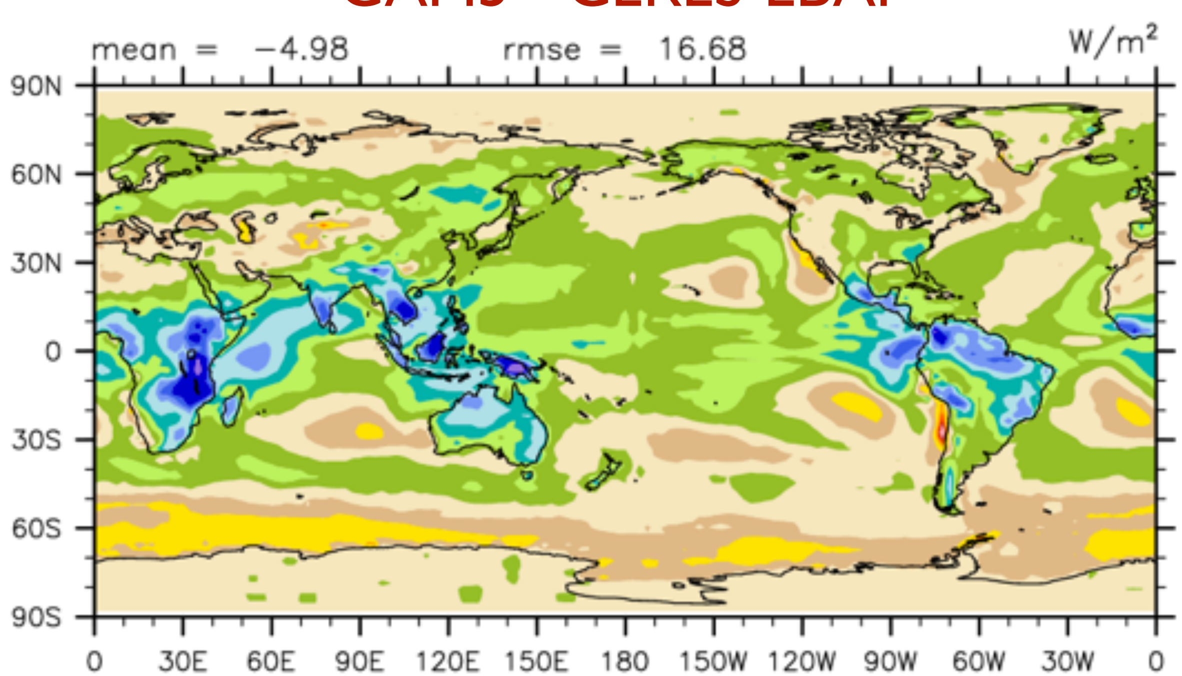
- CAM-CLUBB-ND represents a GCM with one cloud forming physics scheme, coupled with one microphysics scheme
- Results represent 5-year 2-degree AMIP simulations using FV dycore
- CAM-CLUBB-ND is still in proof-of-concept stage. However, a fair amount of score metrics are competitive (or within striking distance) of CAM5

Shortwave Cloud Forcing

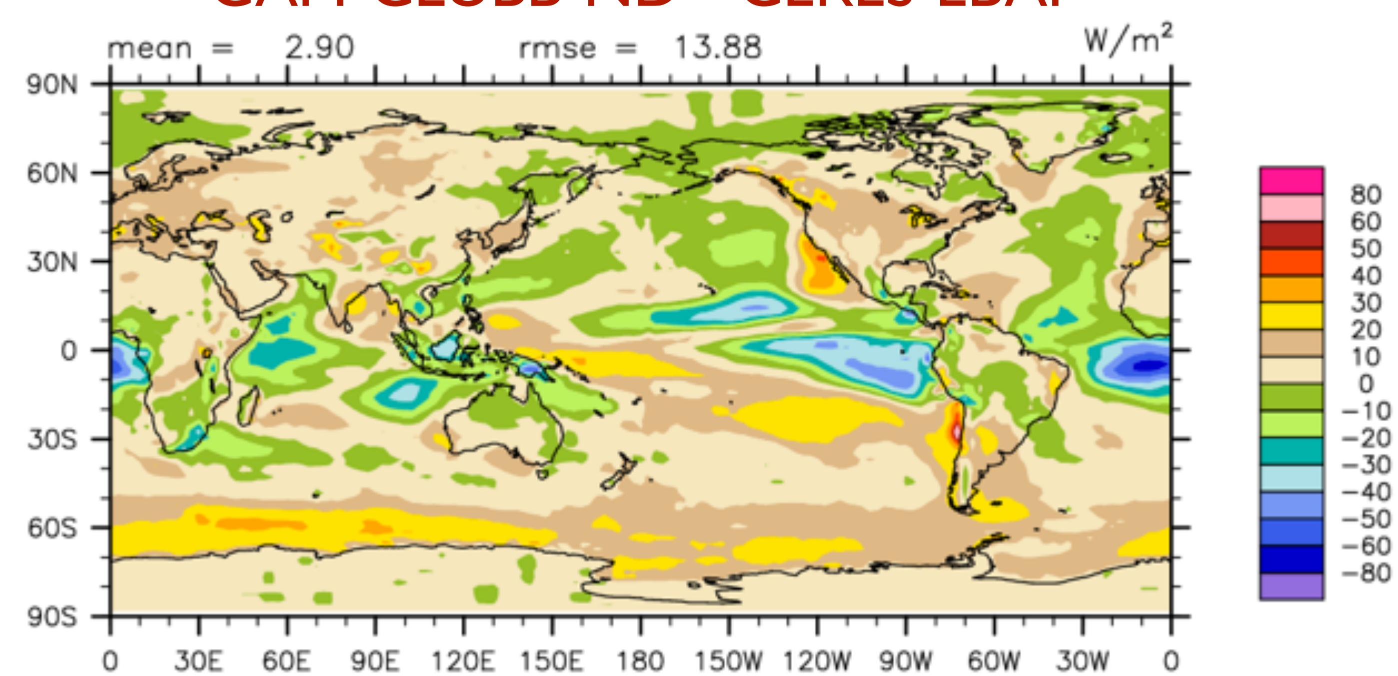
Observations (CERES-EBAF)



CAM5 - CERES-EBAF

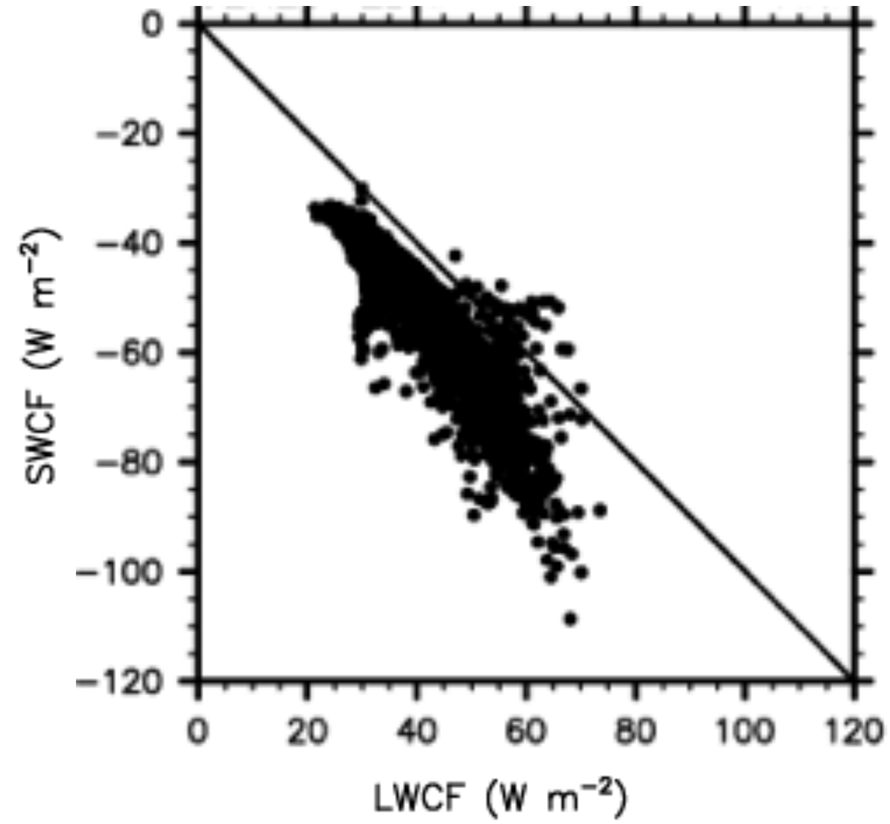


CAM-CLUBB-ND - CERES-EBAF

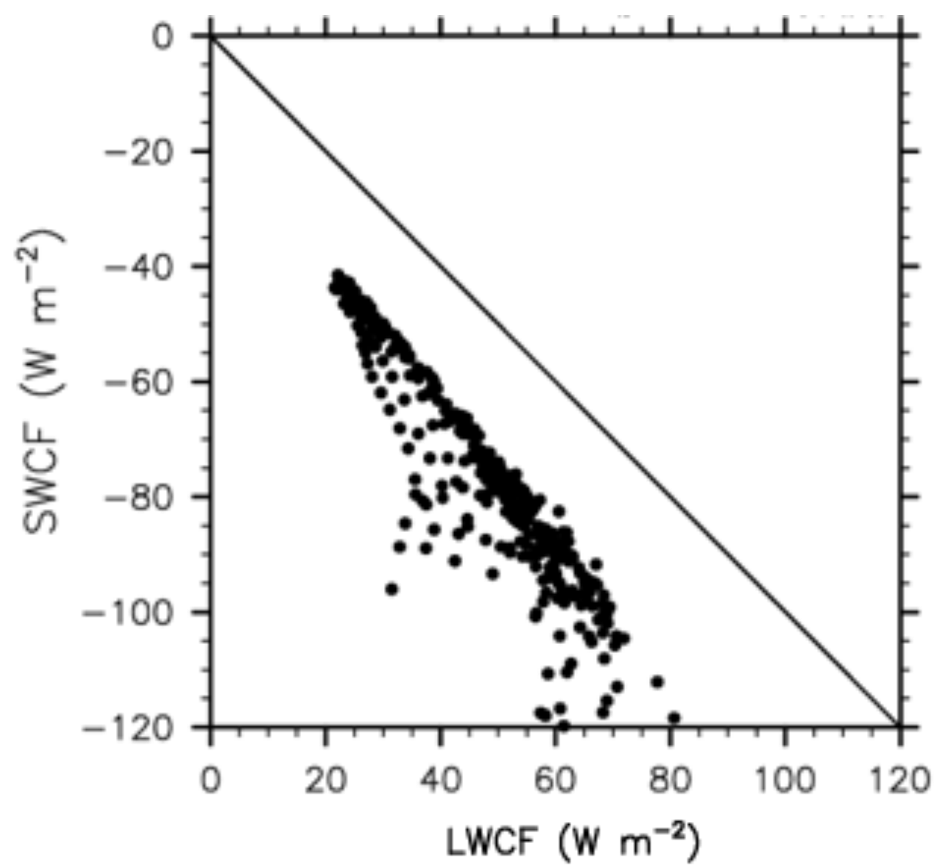


Tropical Pacific Warm Pool SWCF vs. LWCF Relationships

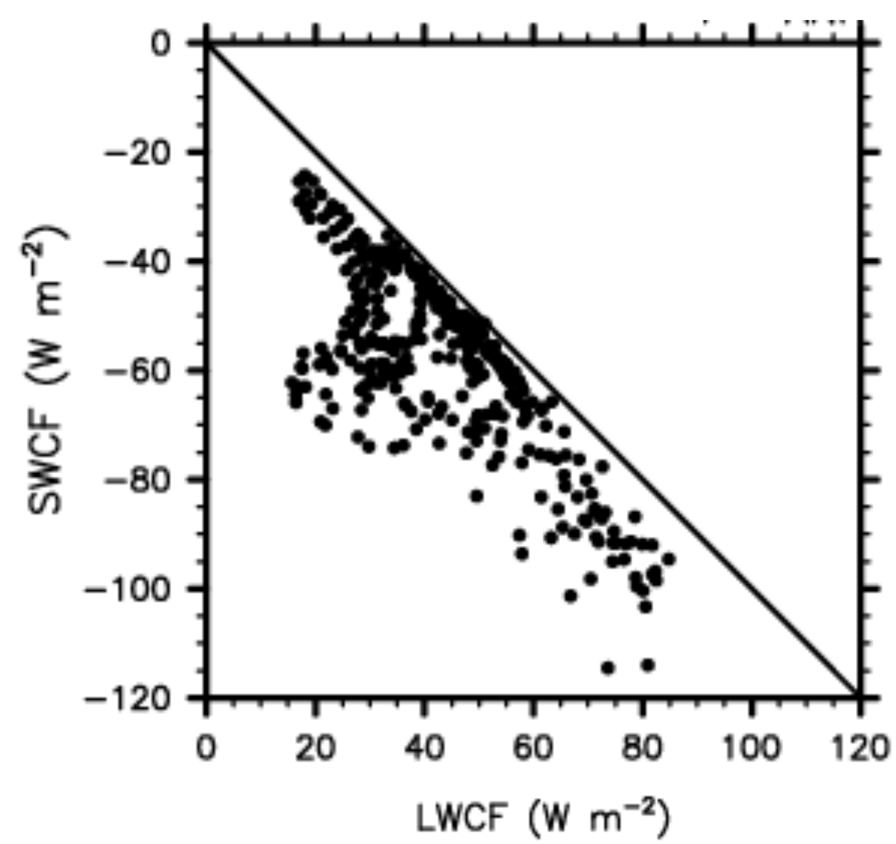
CERES-EBAF



CAM5

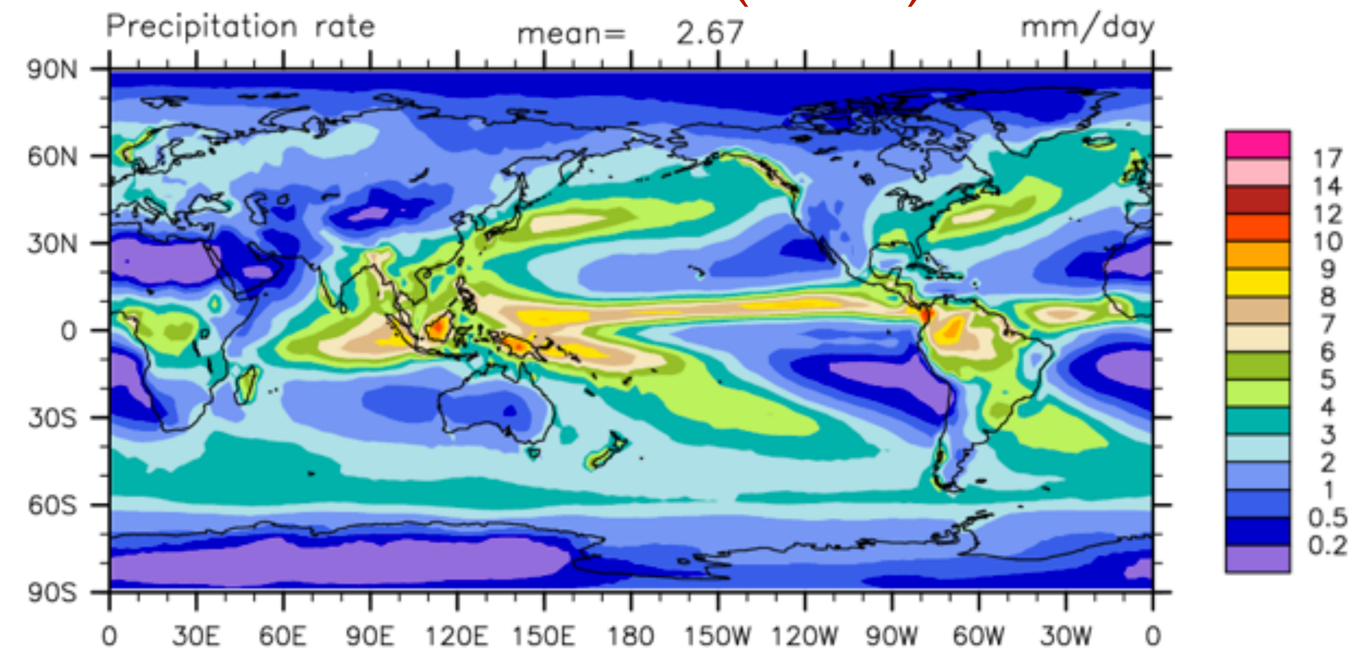


CAM-CLUBB-ND

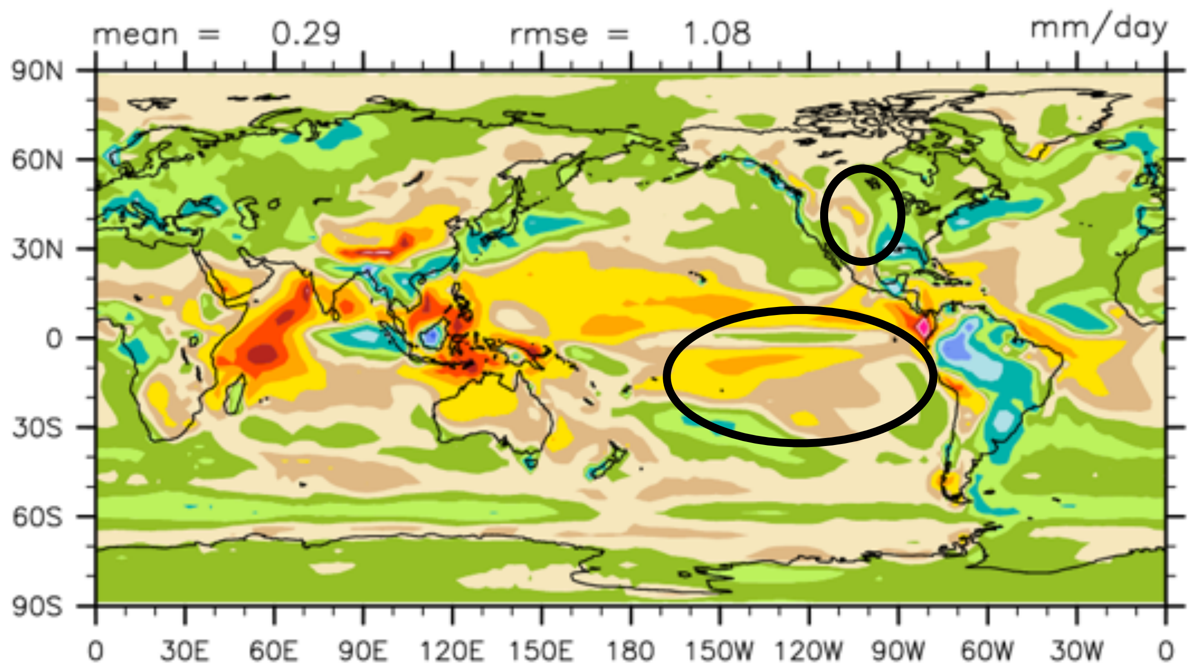


Precipitation

Observations (GPCP)

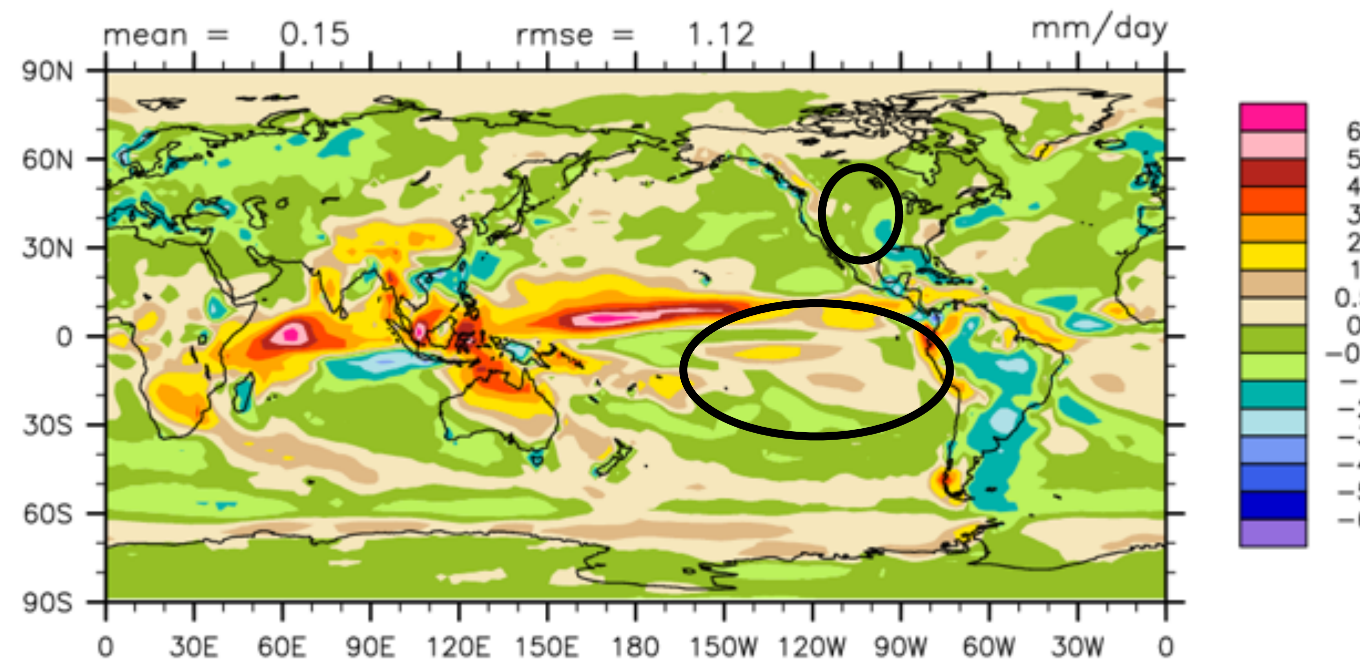


CAM5 - GPCP



Precip generated by three schemes

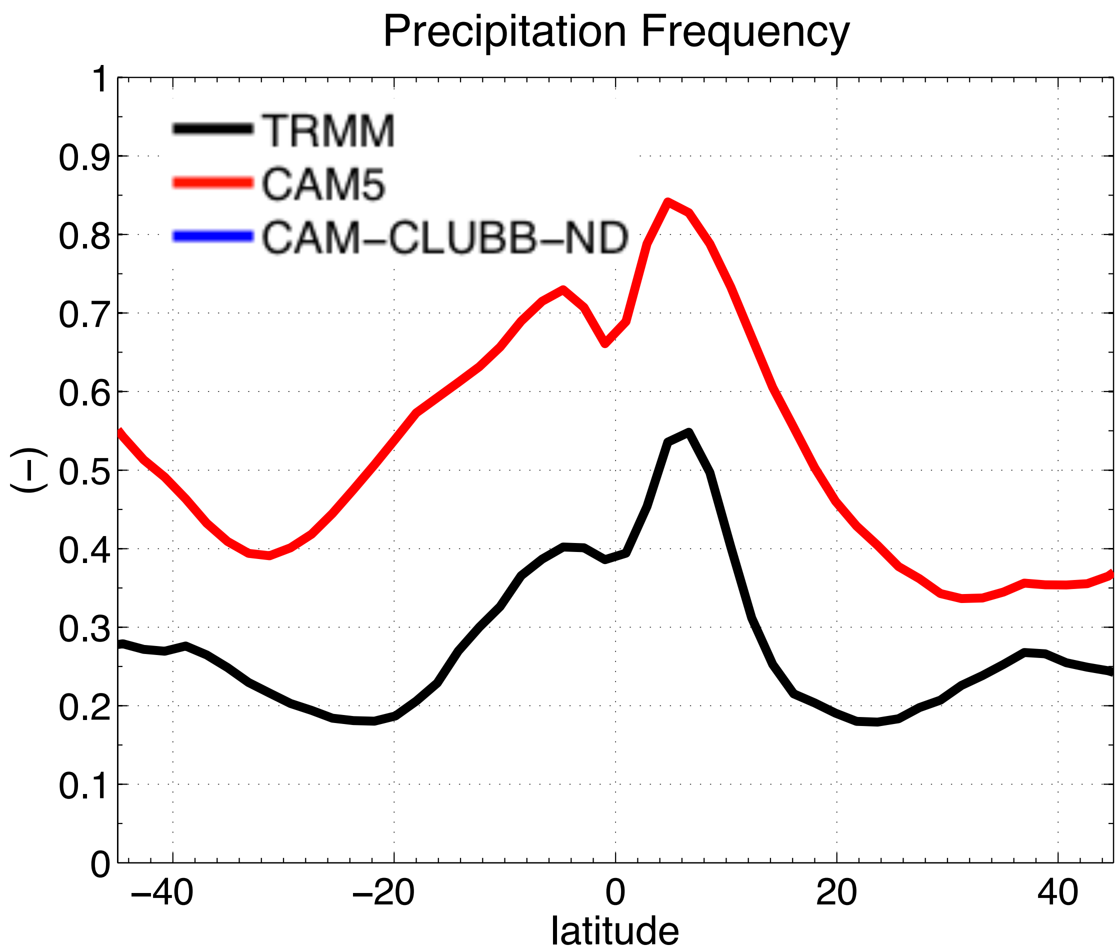
CAM-CLUBB-ND - GPCP



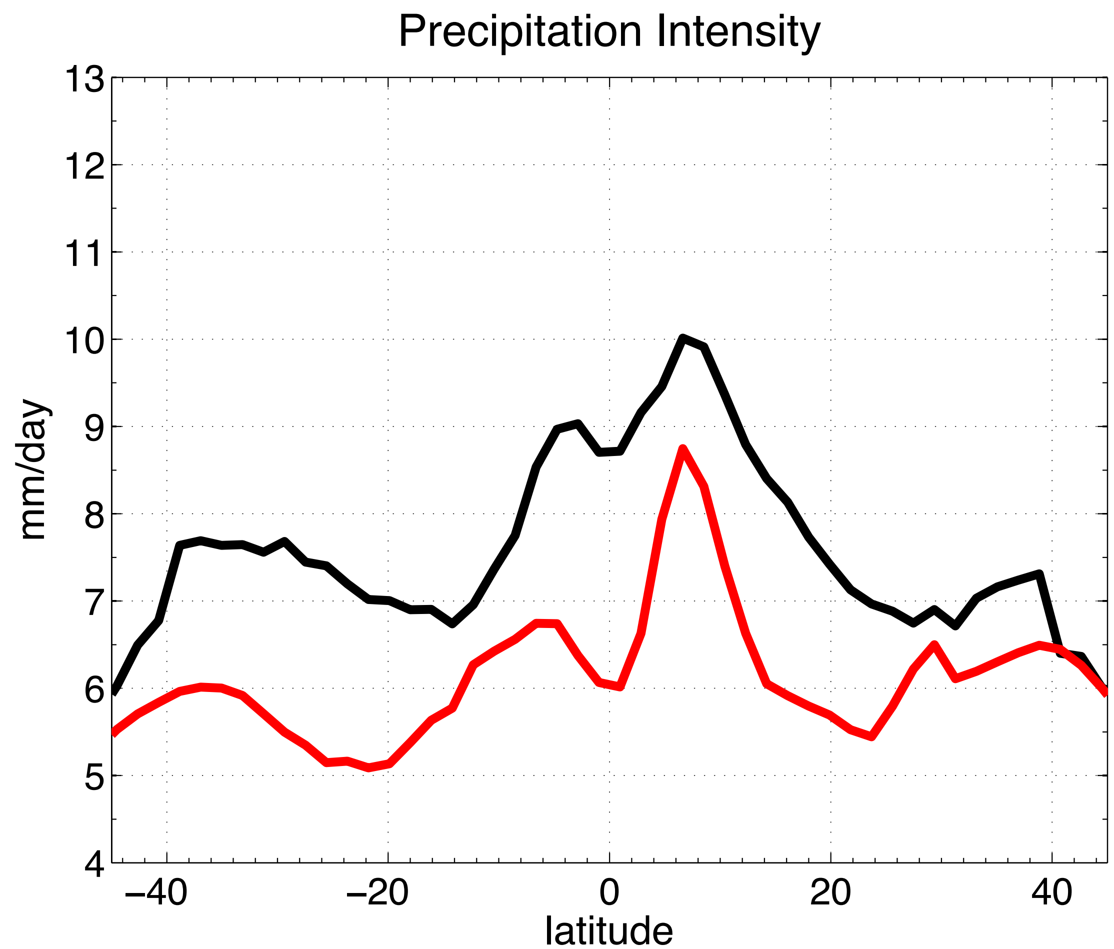
Precip generated by one scheme

Some regional improvements/degradations seen in CAM-CLUBB-ND. However, we have evidence to suggest that some aspects of the variability of the precip is improved in CAM-CLUBB-ND....

Most GCM's precipitate too frequently and not hard enough (Stephens et al. 2010)



$$\frac{\textbf{Number of rainy days (>1 mm/day)}}{\textbf{Total number of days}}$$



$$\frac{\textbf{Total amount of precipitation}}{\textbf{Number of rainy days (>1 mm/day)}}$$

Methodology follows Dai et al. (2007)

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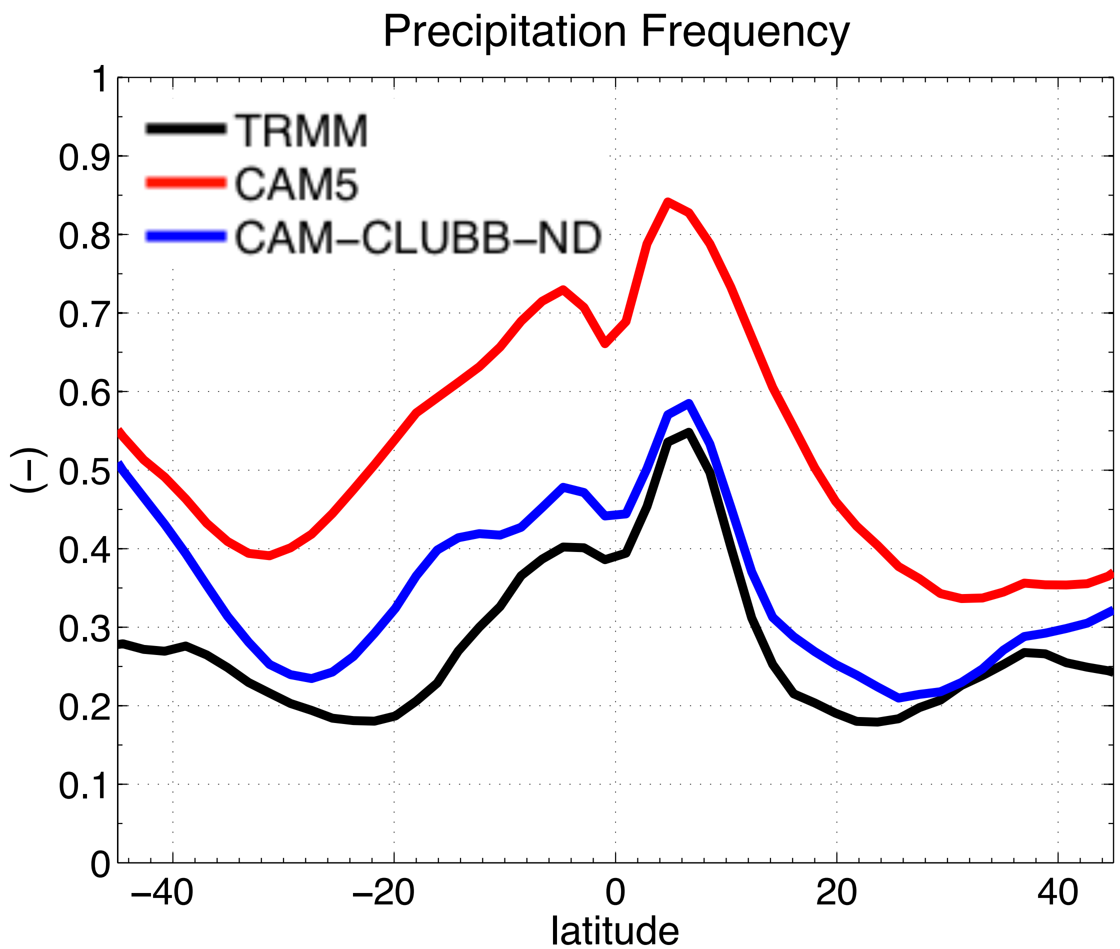

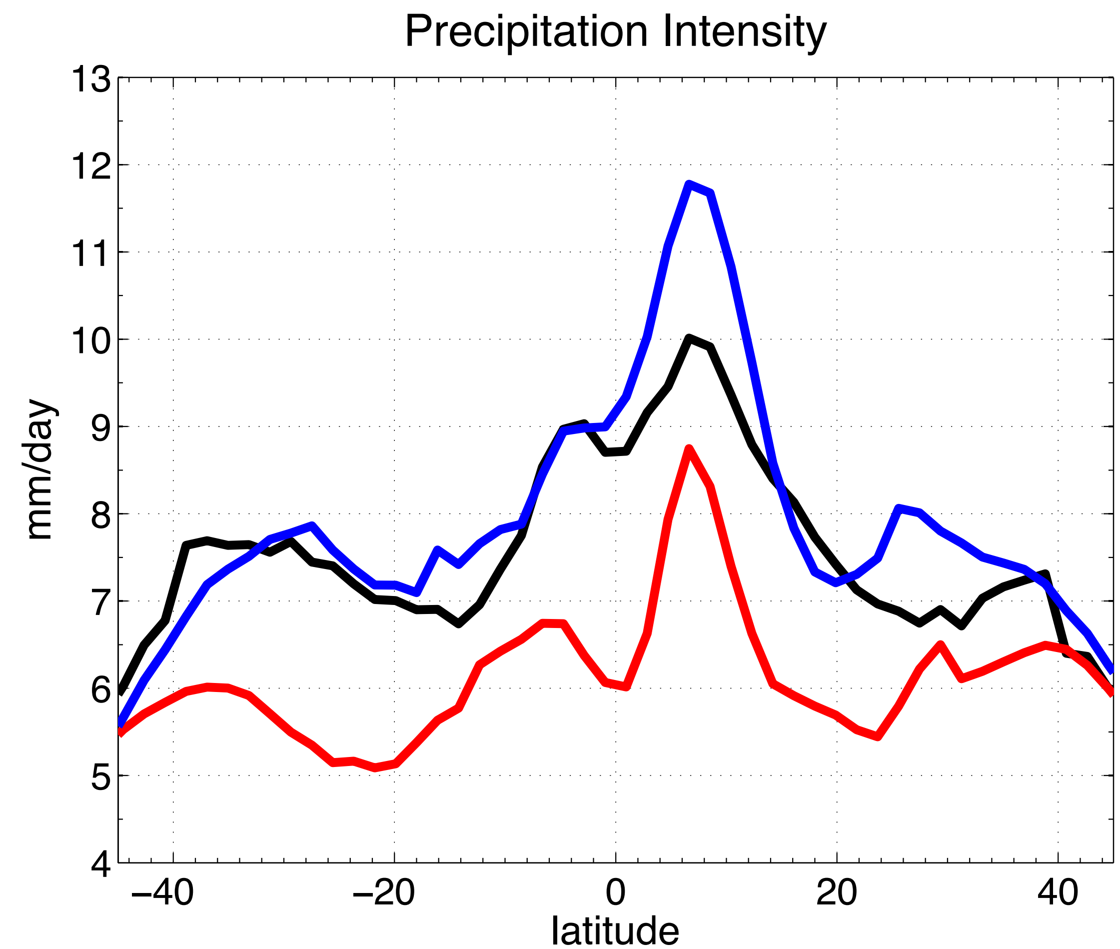

$$\frac{\text{Number of rainy days (>1 mm/day)}}{\text{Total number of days}}$$

$$\frac{\text{Total amount of precipitation}}{\text{Number of rainy days (>1 mm/day)}}$$

Methodology follows Dai et al. (2007)

Despite this improvement, the diurnal cycle of precip over land in CAM-CLUBB-ND is still poorly simulated.

Summary and Future Work

- CAM-CLUBB-ND represents a GCM with one cloud forming scheme coupled with one microphysics scheme
- CAM-CLUBB-ND is producing reasonable mean state climate simulations for this proof-of-concept version. Model still very premature
- Some regional biases need to be ameliorated, tuning extremely difficult
- Simulating variability (MJO, diurnal cycle of precip, etc.) will be a focus and necessary prerequisite for success
- Future work will entail implementing various physical upgrades (i.e. prognostic precipitation, sub-columns) to improve mean state and climate variability