CAM-CLUBB Progress and Developments

Evolution of Tropical Variability and Consistent Coupling with Radiation Sub-columns

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

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

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CAM-CLUBB

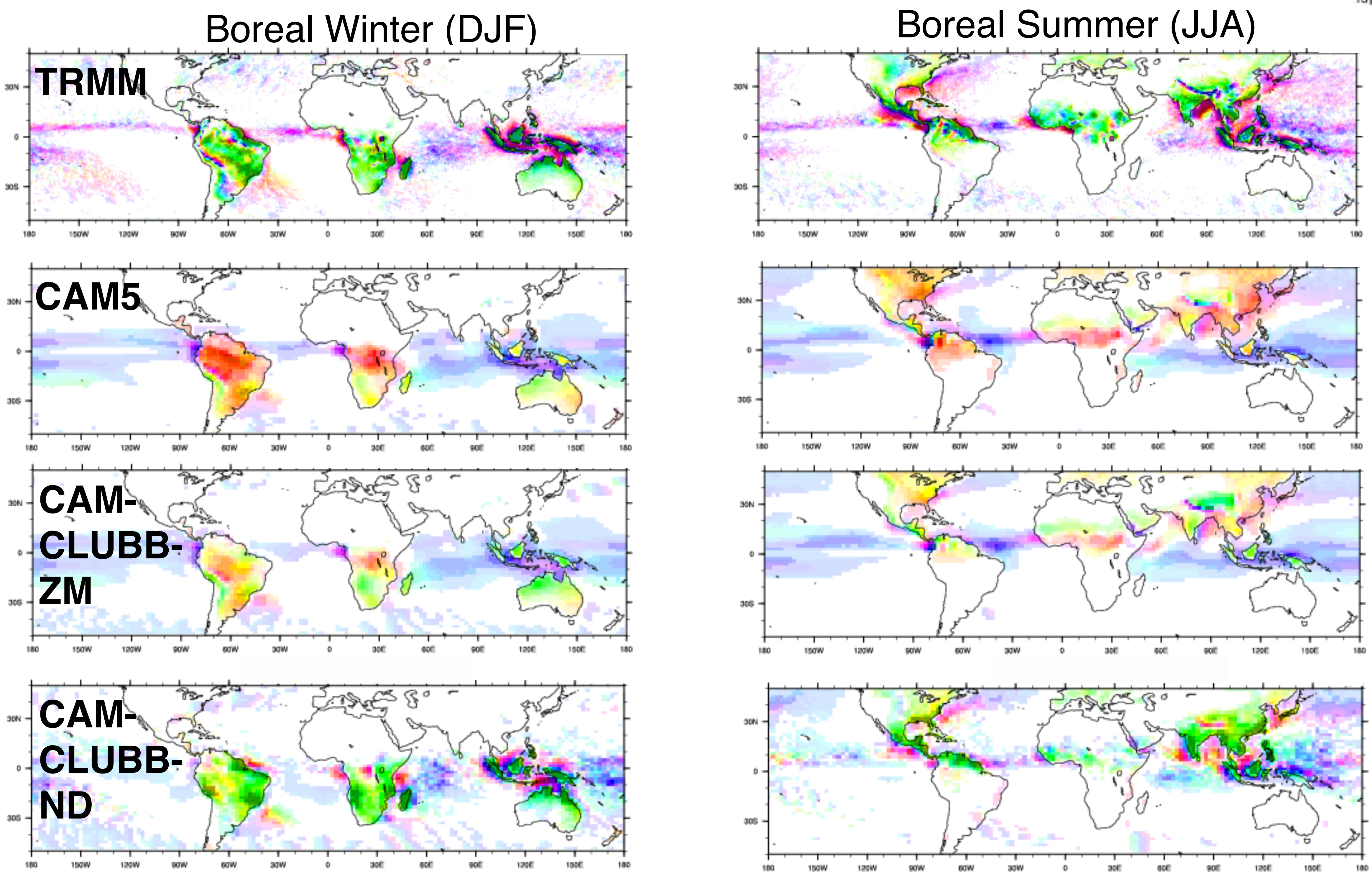
- CLUBB = Cloud Layers Unified By Binormals (Golaz et al. 2002)
- "Incomplete" third-order turbulence closure (predicting 9 second and third order moments), centered around a trivariate assumed double gaussian PDF $P(\theta_l, q_t, w)$
- CLUBB uses assumed double Gaussian PDF to close SGS cloud and turbulent transport to provide a unified treatment of PBL, shallow convection, and cloud macrophysics that drives a single microphysics scheme
- Implemented in CAM5 and AM3 as part of Climate Process Team
- CAM-CLUBB improved mean state climate and Sc to Cu transition documented in Bogenschutz et al. (2013) and Kubar et al. (2014). This talk will focus on tropical variability.

Nomenclature

Physics	CAM5	CAM-CLUBB-ZM	CAM-CLUBB-ND
Deep Convection	Zhang and McFarlane (1995)	Zhang and McFarlane (1995)	CLUBB
Shallow Convection	Park and Bretherton (2009)	CLUBB	CLUBB
PBL	Bretherton and Park (2009)	CLUBB	CLUBB
Macrophysics	Park	CLUBB	CLUBB
Microphysics	Morrison and Gettelman (2008) for stratiform cloud only	Morrison and Gettelman (2008) for stratiform and shallow convective cloud	Morrison and Gettelman (2008) for all cloud
Reference	Neale et al. (2011)	Bogenschutz et al. (2013)	In development

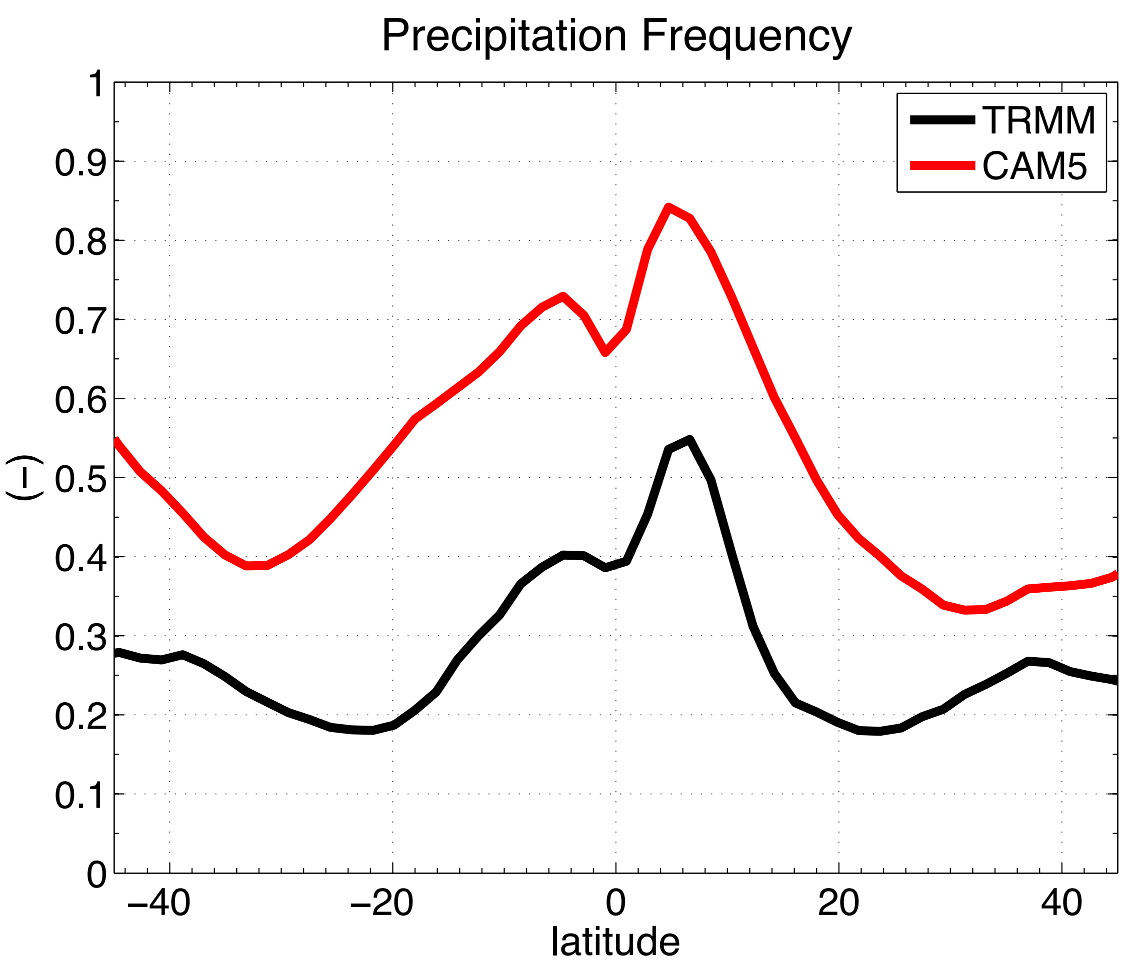
- Microphysics:
  - MG1 (default) = Diagnostic precipitation (Morrison and Gettelman 2008)
  - MG2 (experiment) = Prognostic precip. (Gettelman et al. 2014, see talk)
- Sub-stepping (see Caldwell talk):
  - 1mm (default) = Process split macrophysics/microphysics coupling
  - 6mm (experiment) = macrophysics and microphysics evolves together

Diurnal Cycle of Precipitation

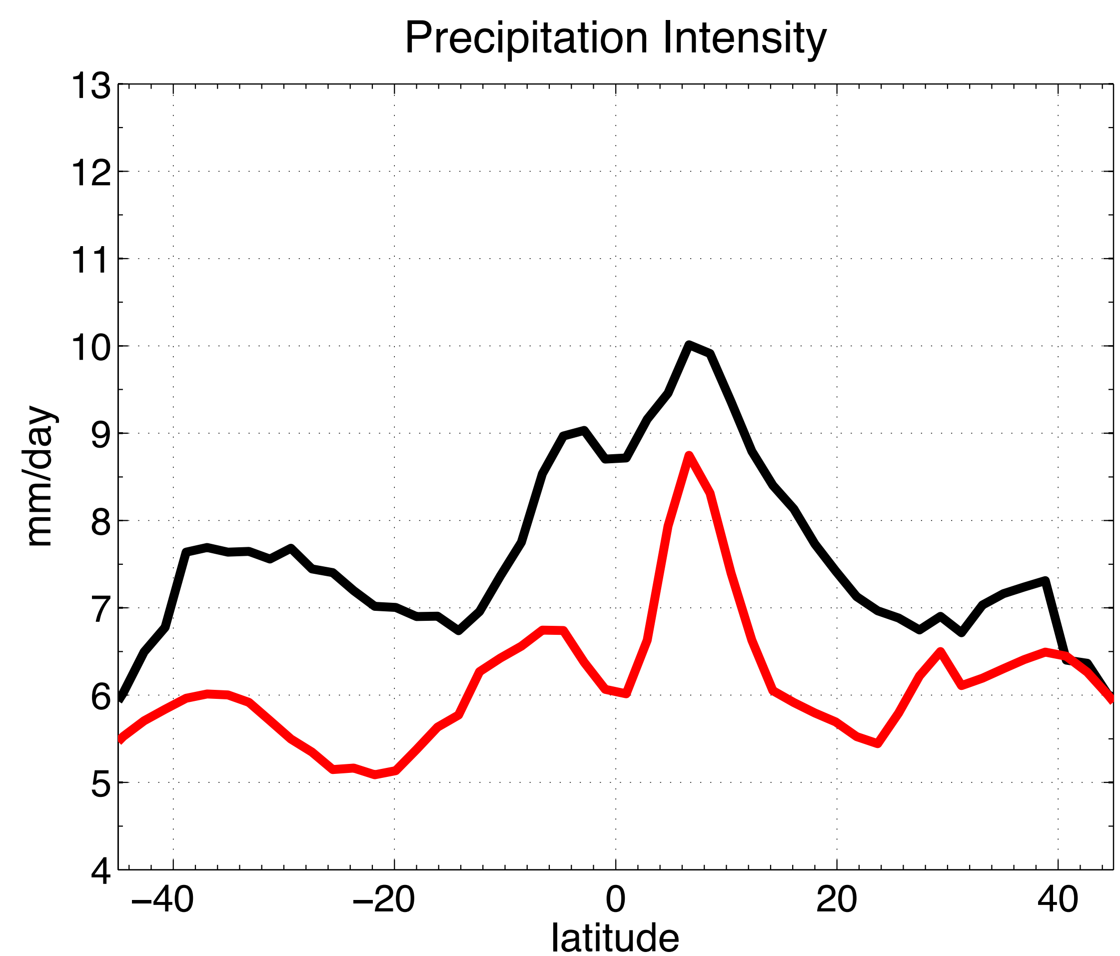


All model configurations shown use MG1 and 1mm. However, these results are robust no matter which microphysics or mm coupling is used.

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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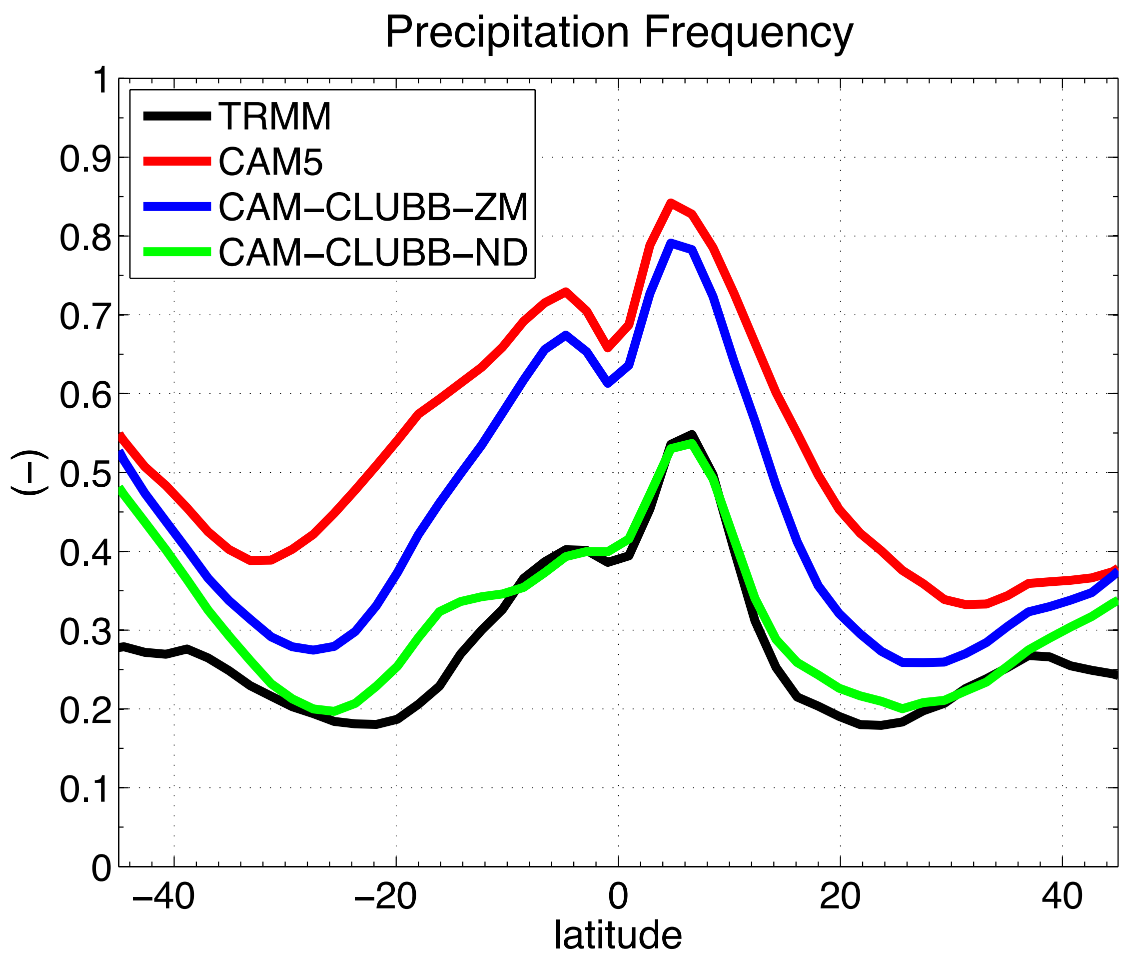

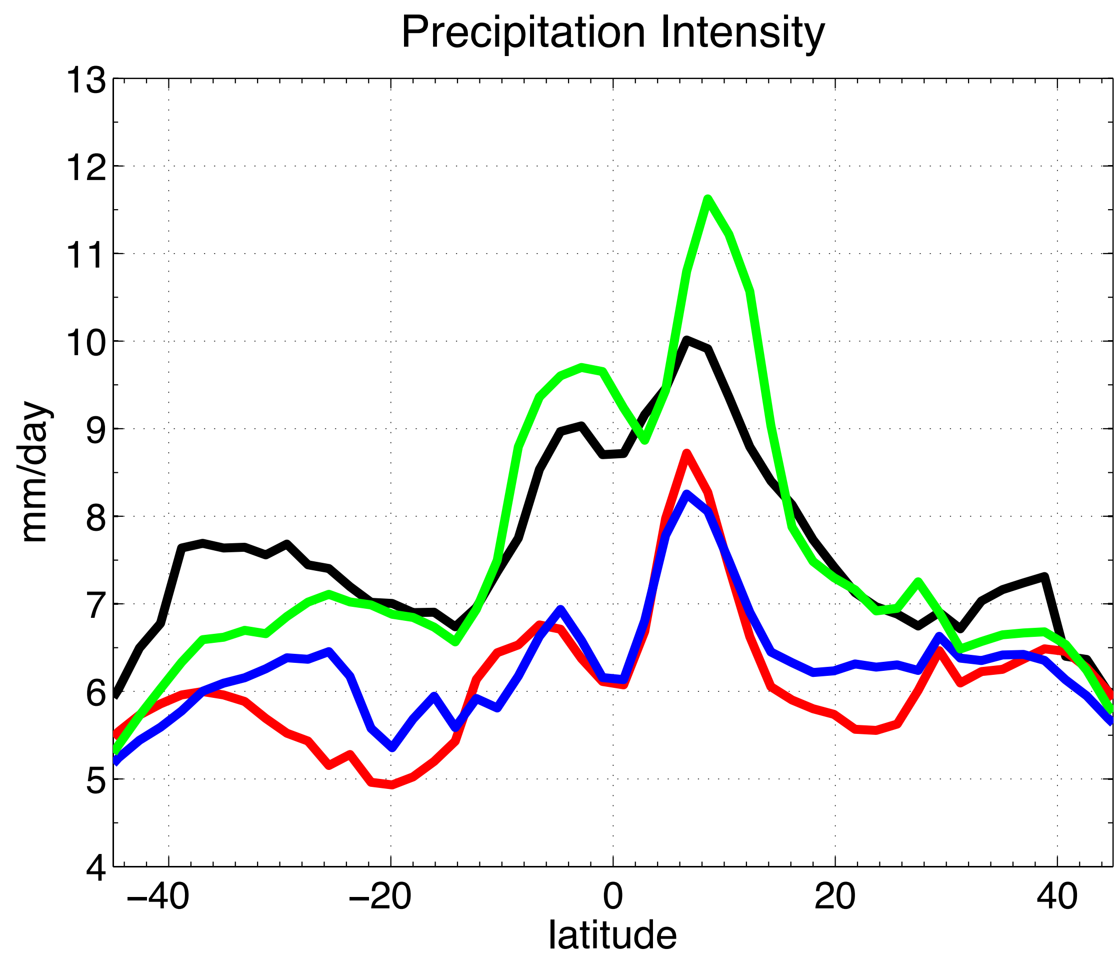

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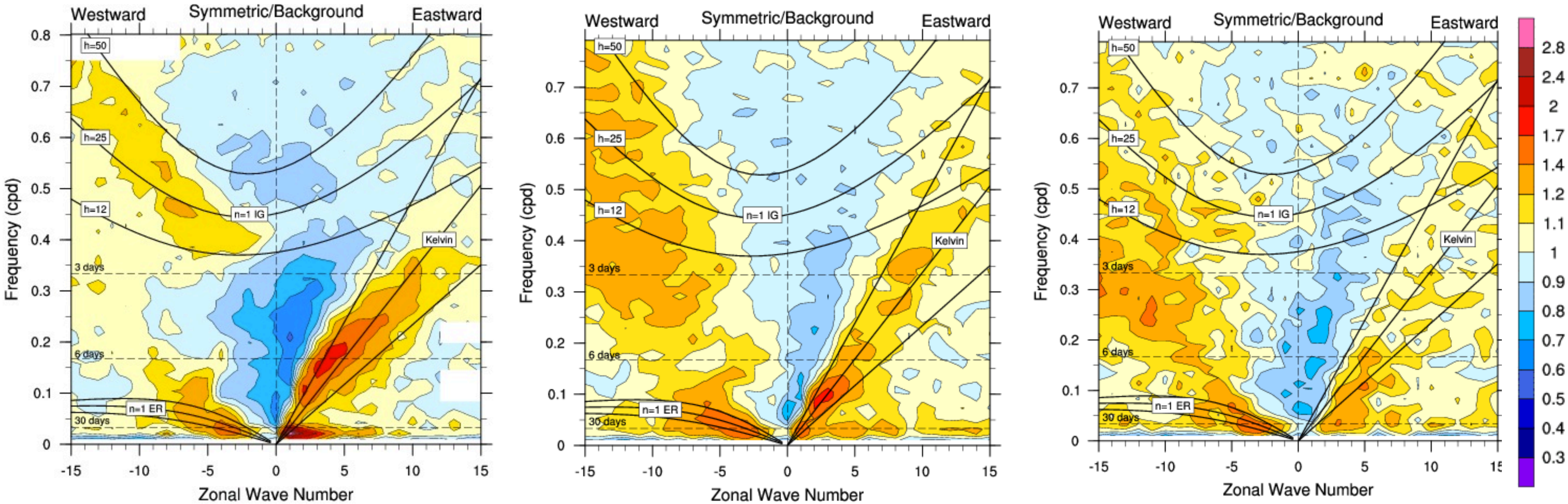
Global Precip RMSE (computed from GPCP)

CAM5: 1.10 mm/day, CAM-CLUBB-ZM: 0.98 mm/day, CAM-CLUBB-ND: 1.30 mm/day

Madden Julian Oscillation (MJO)
OLR Spectra for MG1 (diagnostic precip) simulations



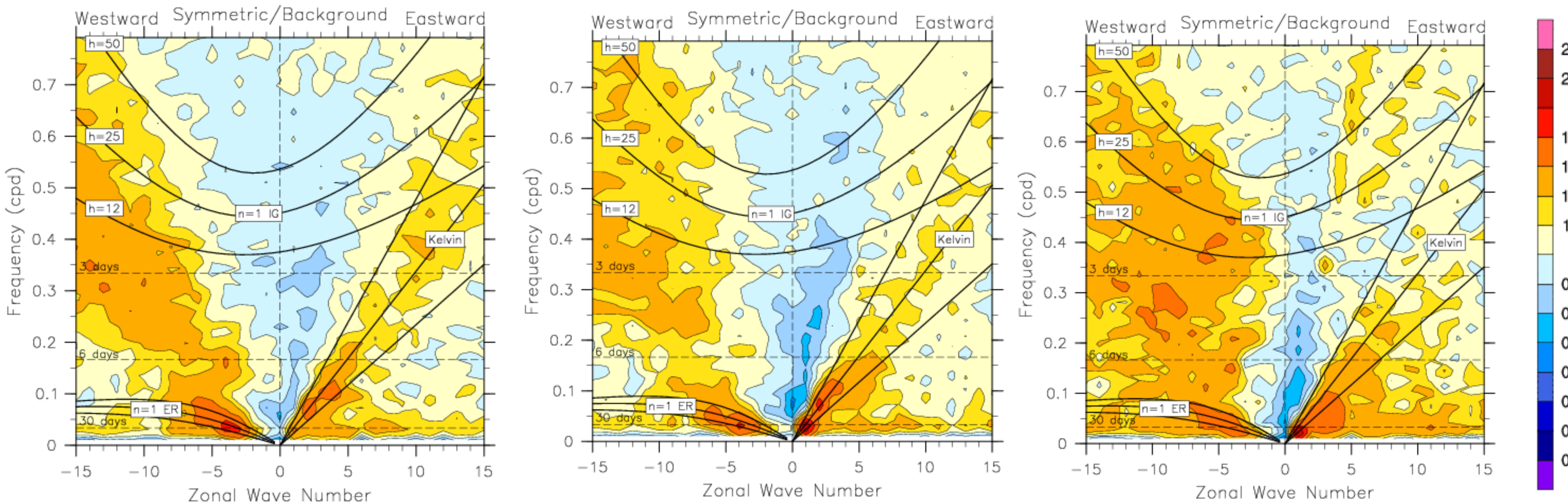
NCEP

CAM5
(CAM-CLUBB-ZM
looks very similar)

CAM-CLUBB-ND

These results are robust, no matter if 1mm or 6mm is used

Madden Julian Oscillation (MJO)
OLR Spectra for MG2-Prognostic Precipitation Simulations



CAM5-1mm or 6mm
(CAM-CLUBB-ZM-1mm &
CAM-CLUBB-ND-1mm looks
similar)

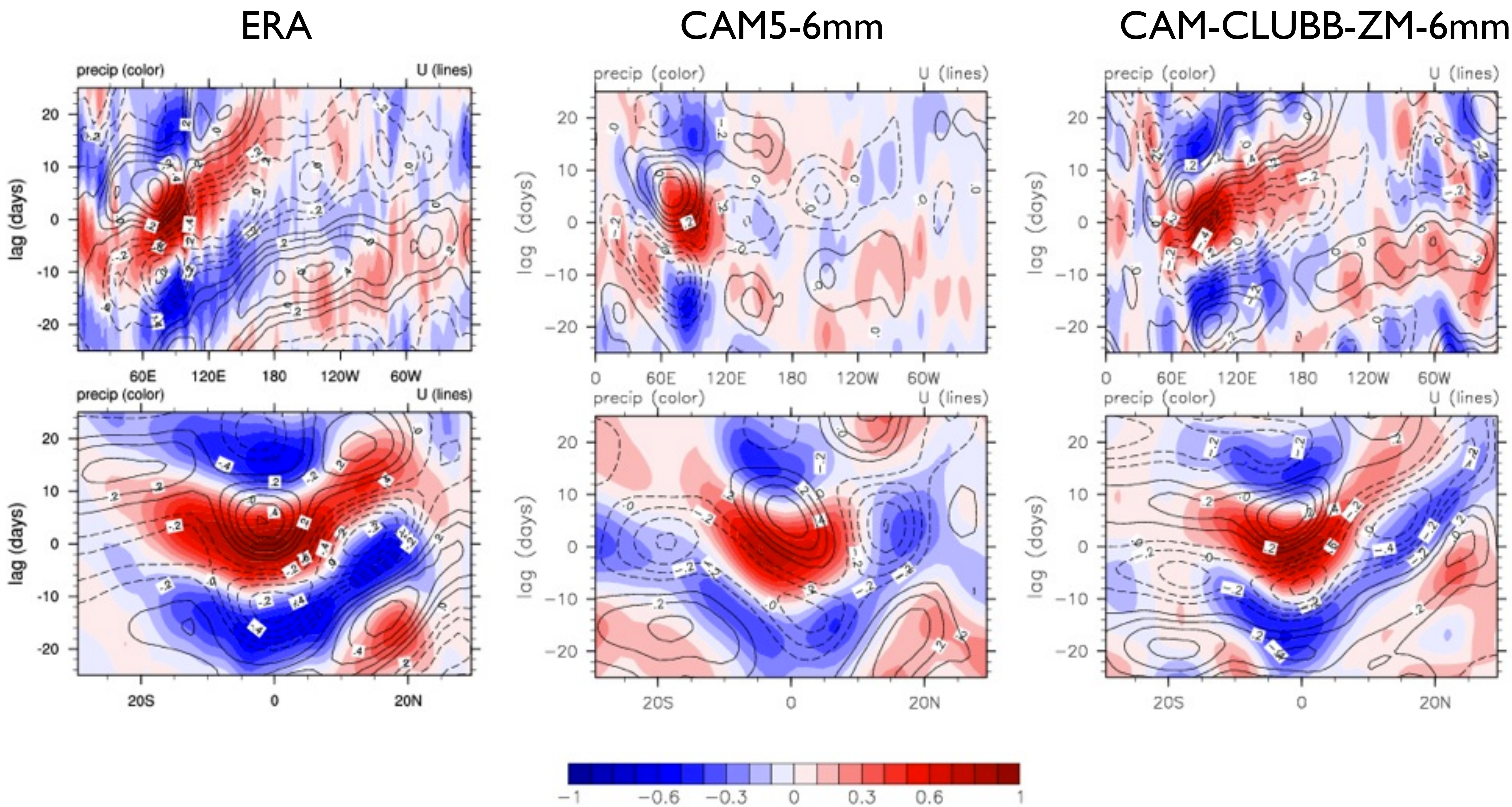
CAM-CLUBB-ZM-6mm

CAM-CLUBB-ND-6mm

Results appear robust

CAM-CLUBB-6mm MJO simulations are NOT at the expense of the mean state climate
(SWCF RMSEs: CAM5 = 16.8 W/m2, CAM-CLUBB-ZM = 13.8 W/m2,
CAM-CLUBB-ND = 14.9 W/m2)

Madden Julian Oscillation (MJO)
Lag correlations for MG2-Prognostic Precip Simulations



Tropical Variability Summary & Discussion

- CAM-CLUBB-ZM appears to improve diurnal cycle of precipitation. Removing ZM parameterization reduces timing biases further.
- Intensity and frequency of precipitation is greatly improved when ZM parameterization is shut off.
- MJO can be simulated in both configurations of CAM-CLUBB given that prognostic precipitation is used as well as tight coupling between cloud evolution and microphysics (6mm sub-steps).
- This raises some provocative questions regarding MG2 simulations:
  - Why can the MJO be simulated robustly with 6mm and not 1mm in CAM-CLUBB?
  - Why does CAM5 variability appear to be immune to MG1 vs. MG2?
  - MJO results for CAM-CLUBB appear very robust given 6mm sub-steps and MG2. However, how robust are these results to changes in resolution and dynamical core?

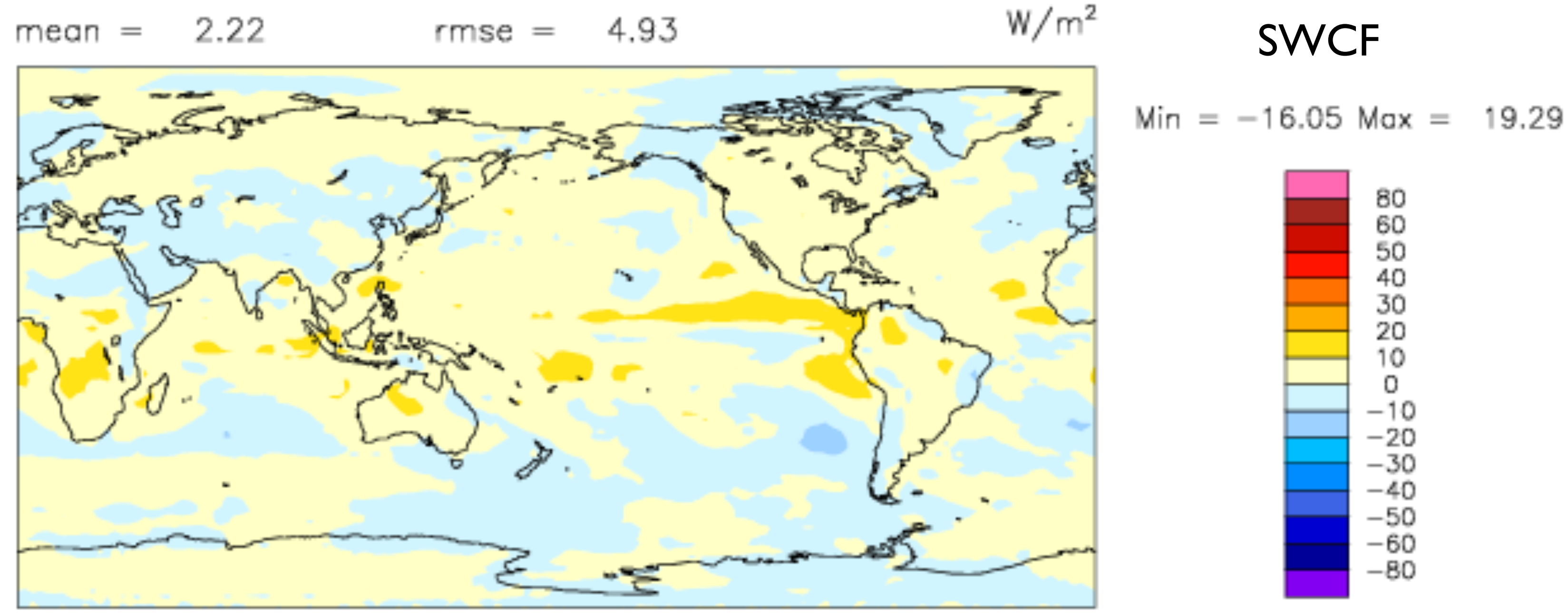
Using CLUBB's PDF to generate sub-columns for Radiation

- CAM5 generates McICA sub-columns stochastically using total cloud fraction
- We can sample from CLUBB's PDF to generate these sub-columns for internal consistency (see Thayer-Calder talk for microphysics sub-column consistency).
- Fairly easy to add sampling to generate these sub-columns from CLUBB's PDF. Trickier part was being consistent with other CAM cloud type that is NOT generated by CLUBB.
  - PDF sampled from CLUBB (Monte Carlo sampling)
  - CLUBB Liquid water arranged in sub-columns based on max/random overlap
  - CLUBB cloud optical properties then computed on each sub-column
  - Non-CLUBB cloud then added in using traditional stochastic methods
- Code modifications add 20% to computation. Code optimization is needed.

CAM-CLUBB McICA experiments (five years)

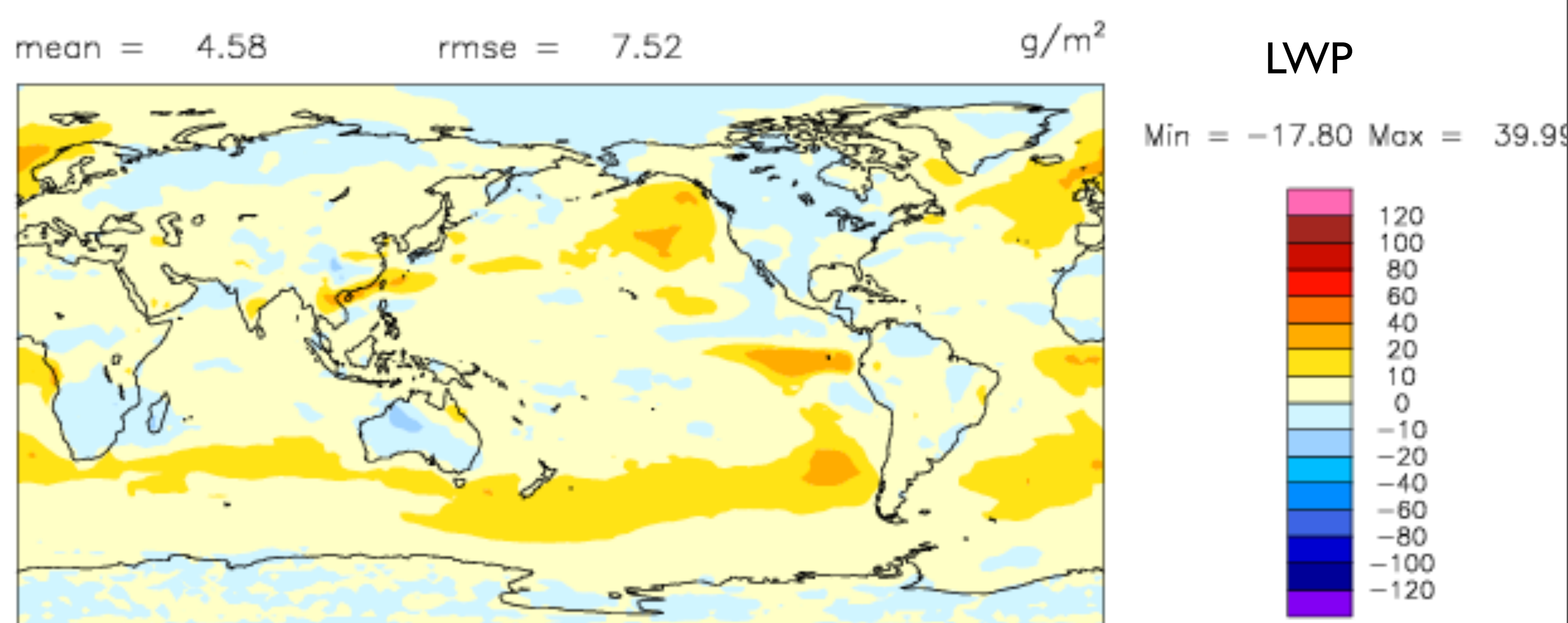
Shortwave Cloud Forcing
Experiment: -45.32 W/m2
Control: -47.54 W/m2

Experiment - Control



Liquid Water Path
Experiment: 46.75 g/m2
Control: 42.17 g/m2

Experiment - Control



Results are robust among several pairs of experiments