CLUBB+MF:
Recent Developments

[1]Adam Herrington, [2]Joao Teixeira, [1]Julio Bacmeister and the EDMF CPT Team

[1]National Center for Atmospheric Research

[2]NASA Jet Propulsion Laboratory

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Outline

- CLUBB+MF formulation and new per plume mods
- New merged up code base
- Deep Convection in CLUBB+MF and CAM7
- Incorporating cloud-aerosol interactions

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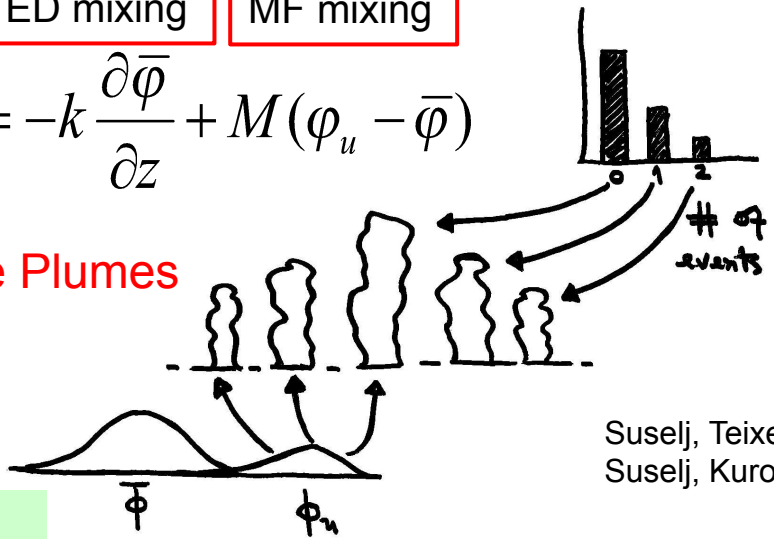
EDMF and moist convection: multiple plumes and stochastic entrainment

ED mixing | MF mixing

$$\overline{w'\varphi'} = -k\frac{\partial\bar{\varphi}}{\partial z} + M(\varphi_u - \bar{\varphi})$$

Multiple Plumes



- Parameterization of PDF of surface layer thermodynamics
- Sampling of PDF to produce multiple plumes
- Different types of convection coexist in the same model grid-box

Suselj, Teixeira & Chung, JAS, 2013
Suselj, Kurowski & Teixeira, JAS 2019a, b

CLUBB+MF:

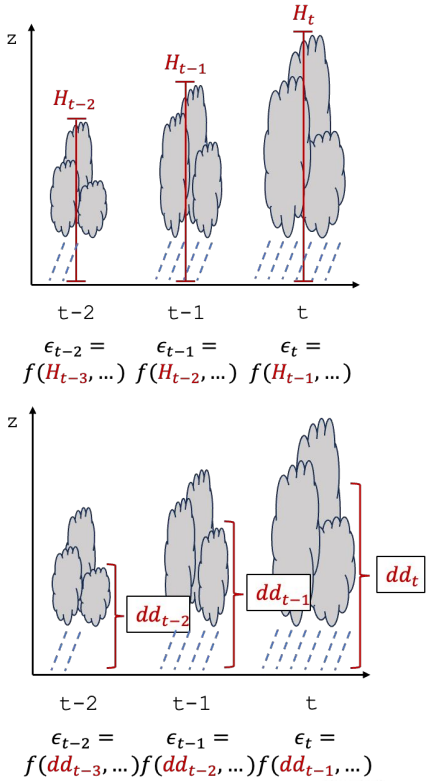
- CLUBB represents double-gaussian mixing while MF adds discrete skewness to the sub-grid PDF
- MF coupled to CLUBB via its 5-diagonal solver for mean fields and turbulent fluxes.

Witte et al, MWR 2022

Convective Memory, Cold Pool Feedbacks

Ensemble of ‘entraining’ plumes:

- Stochastic entrain. - draw from a Poisson distribution determined by the mean entrain. L-scale (L_ε).
  (based on Romps and Kuang 2009)
- L_ε is determined by:
  - Height of the plume ensemble averaged over prior time-step(s) (e.g., H_{t-1}).
  - Cold pool strength averaged over prior time-step(s) (e.g., dd_{t-1}).
- Standard CLUBB+MF: same L_ε applied to entire ensemble.
- Per plume (pp): each plume computes its own unique L_ε.



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Convective Memory, Cold Pool Feedbacks

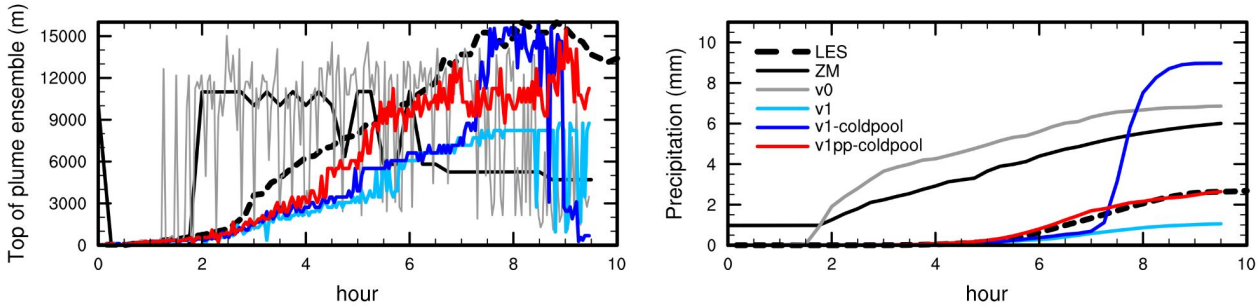
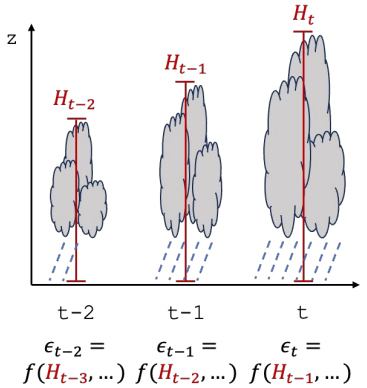
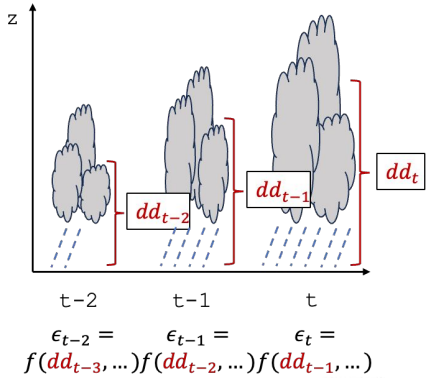


Figure 1. *CAM single column model experiments of the Large-Scale Biosphere-Atmosphere case (LBA), representing the diurnal cycle of moist convection over land. (Left) Top of the plume ensemble, and (right) cumulative precipitation rate. LES refers to large-eddy simulation reference, ZM refers to the operational deep convection scheme in CAM, whereas v0, v1, v1-coldpool and v1pp-coldpool refer to different configurations of CLUBB+MF discussed in the text.*

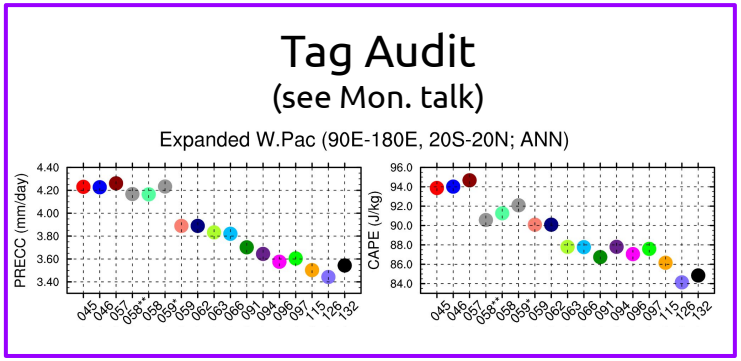




Merge CODE base up

Merge from cam6_3_041 → cam6_3_132

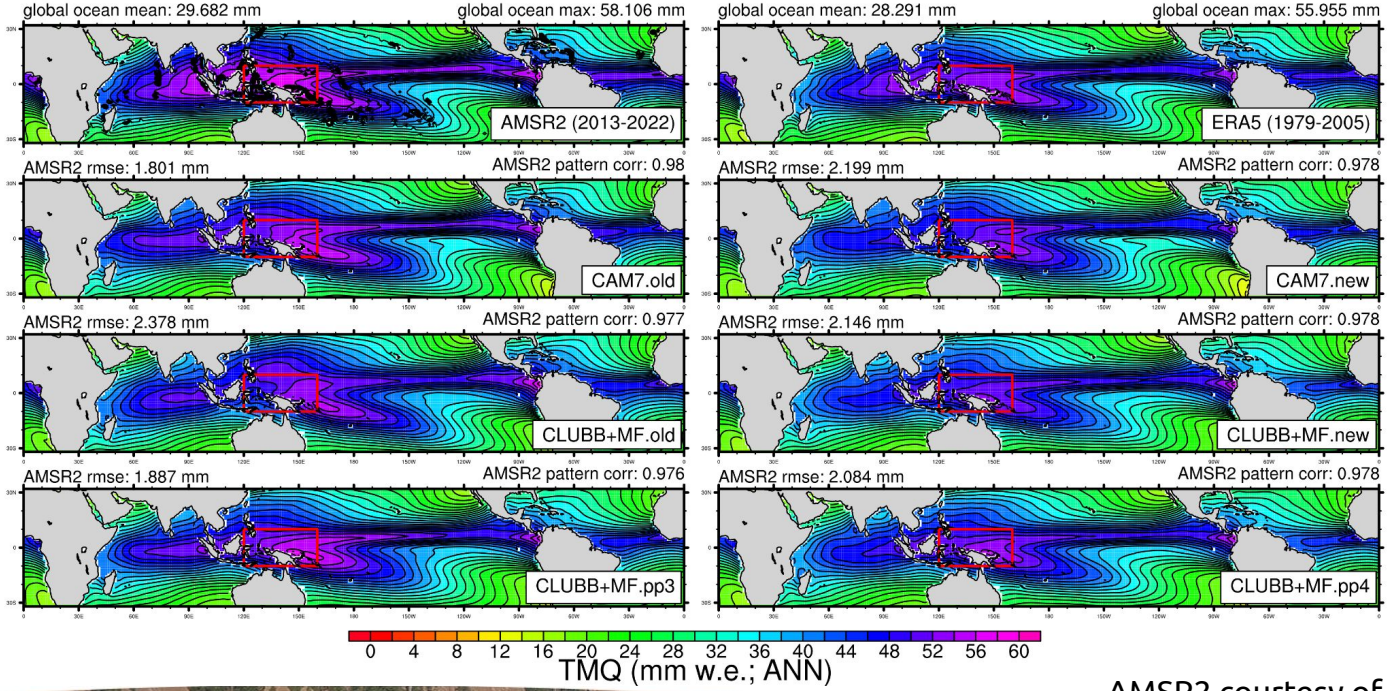
- Git heavy, monotonous.
  (thanks to Ben Stephens for assistance)
- Scientific validation was even more challenging.
  - The solutions changed a lot over these tags →
  - cam6_3_059: **turn-off** downgradient diffusion of Theta_l/Qt by CLUBB (occurs in addition to mixing by CLUBB prognostic fluxes).
  - This ‘triple mixing’ in CLUBB+MF was not intended, nor appropriate given the way that MF plumes are coupled to CLUBB.



Merge CODE base up & per plume mods (pp)

cam6_3_041 used in xxx.old
cam6_3_132 used in xxx.new

10 Year (1996-2007) AMIP runs



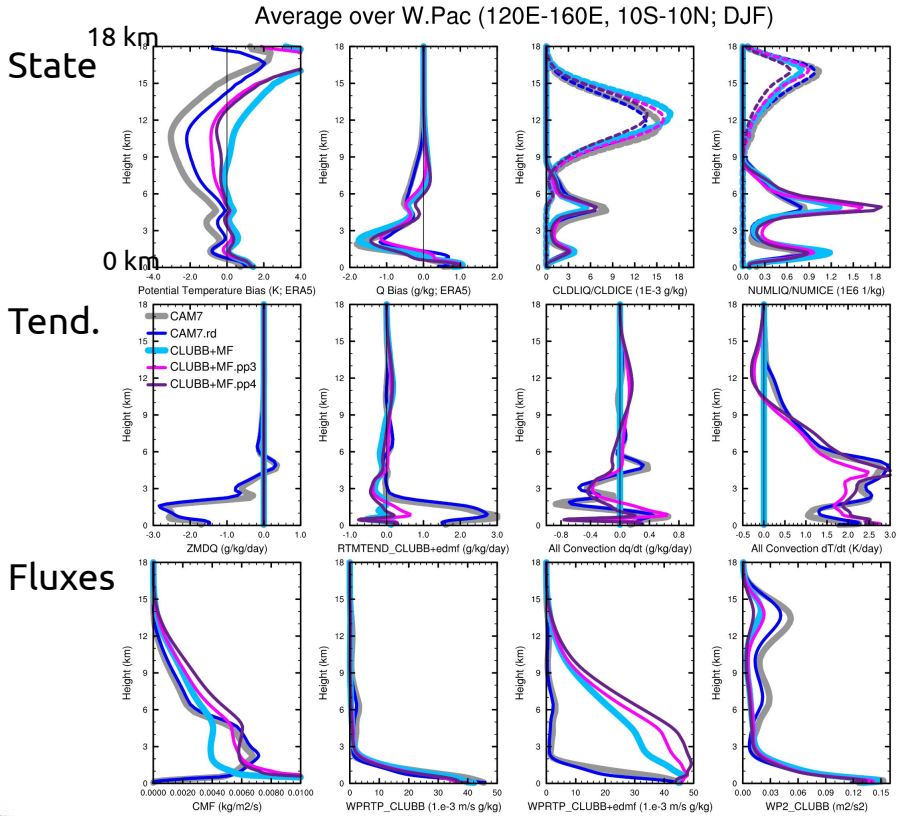
AMSR2 courtesy of Brian Medeiros

CLUBB+MF Convection vs. CAM7 Convection

CLUBB+MF:

- ❏ Warms & moistens the Tropical Atmosphere compared to CAM7.
- ❏ Deep Cu is deeper; detrainment occurs much higher than in CAM7.
- ❏ Magnitude of Deep Cu mass fluxes similar to ZM.
- ❏ PP mods moistens shallow layers more than standard CLUBB+MF.

CAM7.rd = revert CLUBB diffusion on



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CAM7/CLUBB+MF MJO

- MJO propagation phase is ‘there’ in CAM7.
- AMIP has muted amplitudes in both the raw wave spectrum and hovmoller lagged regression coefficients.
- PP is competitive with CAM7.
- Missing processes - gusts, meso-scale heating and momentum transport.

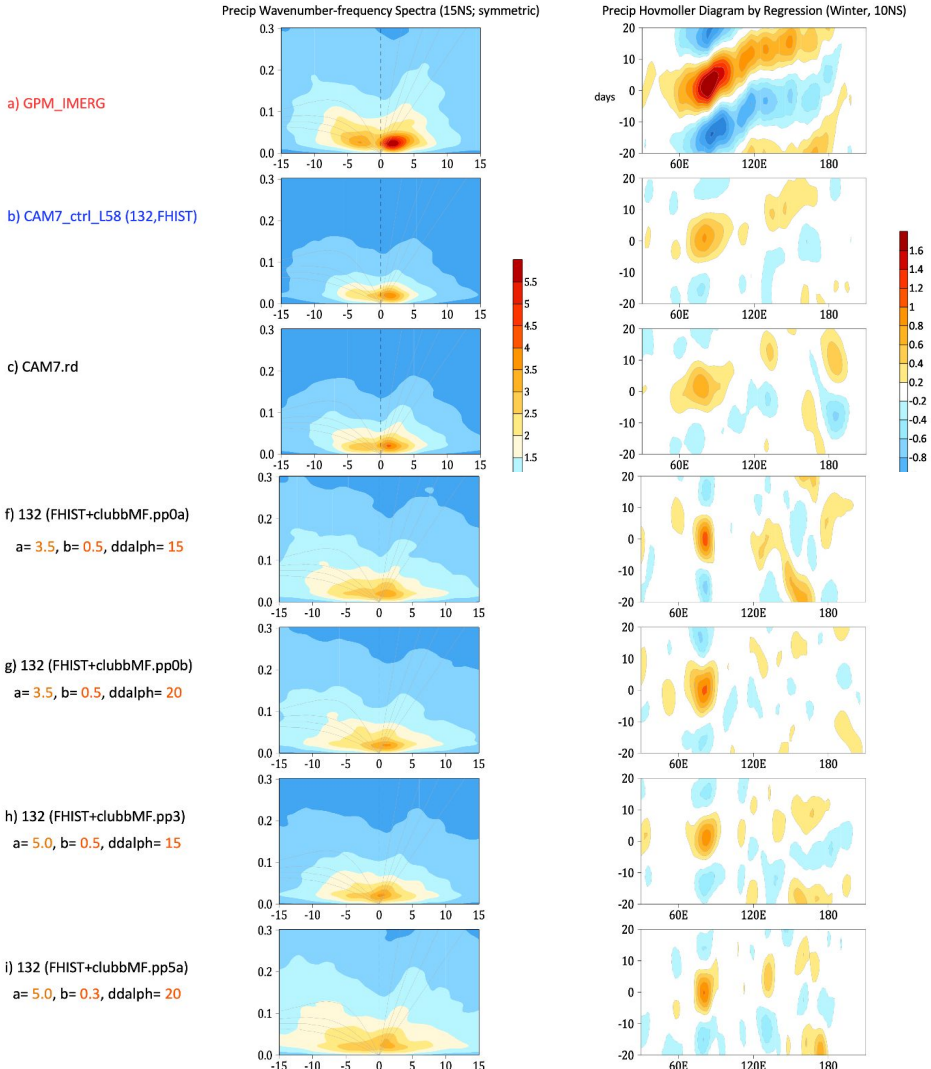


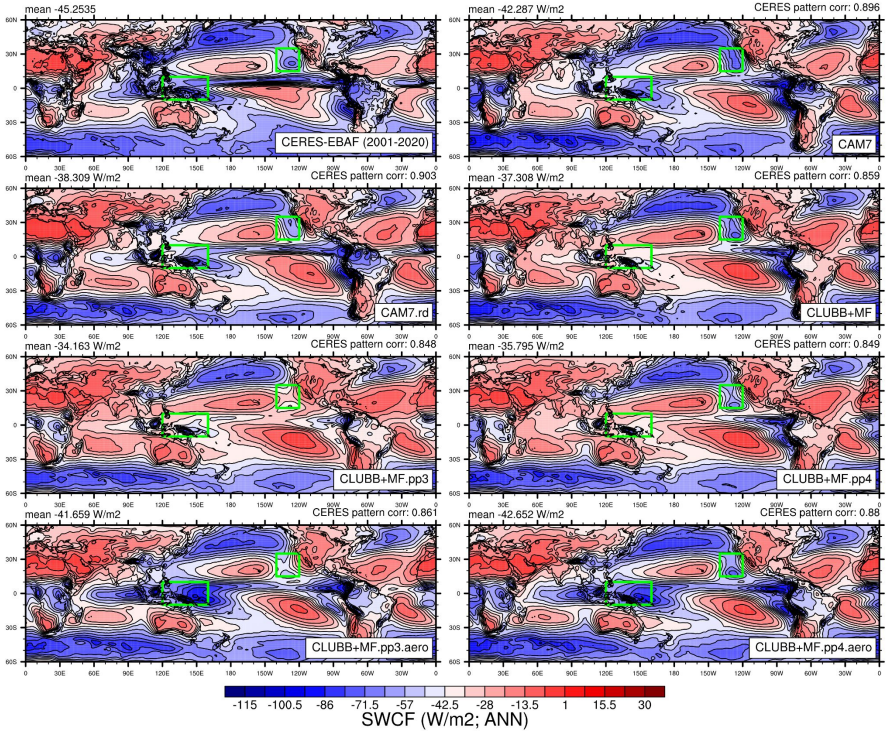
Figure courtesy Xianan Jiang

Coupling CLUBB+MF to aerosols cloud processes

CAM7 cloud-aerosol interactions:

- Aerosol activation: liquid cloud forming on aerosols (Abdul-Razzak and Ghan)
- Ice nucleation: heterogeneous freezing onto aerosols.
- Updraft velocity required in calculation of activation and nucleation.
- Diffusive transport of aerosols by CLUBB's TKE-based diffusion coefficient.
- Convective transport and scavenging of aerosols by ZM (note ZM is OFF).

Currently evaluating different methods for incorporating MF plumes in the above processes.



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Questions / Comments?

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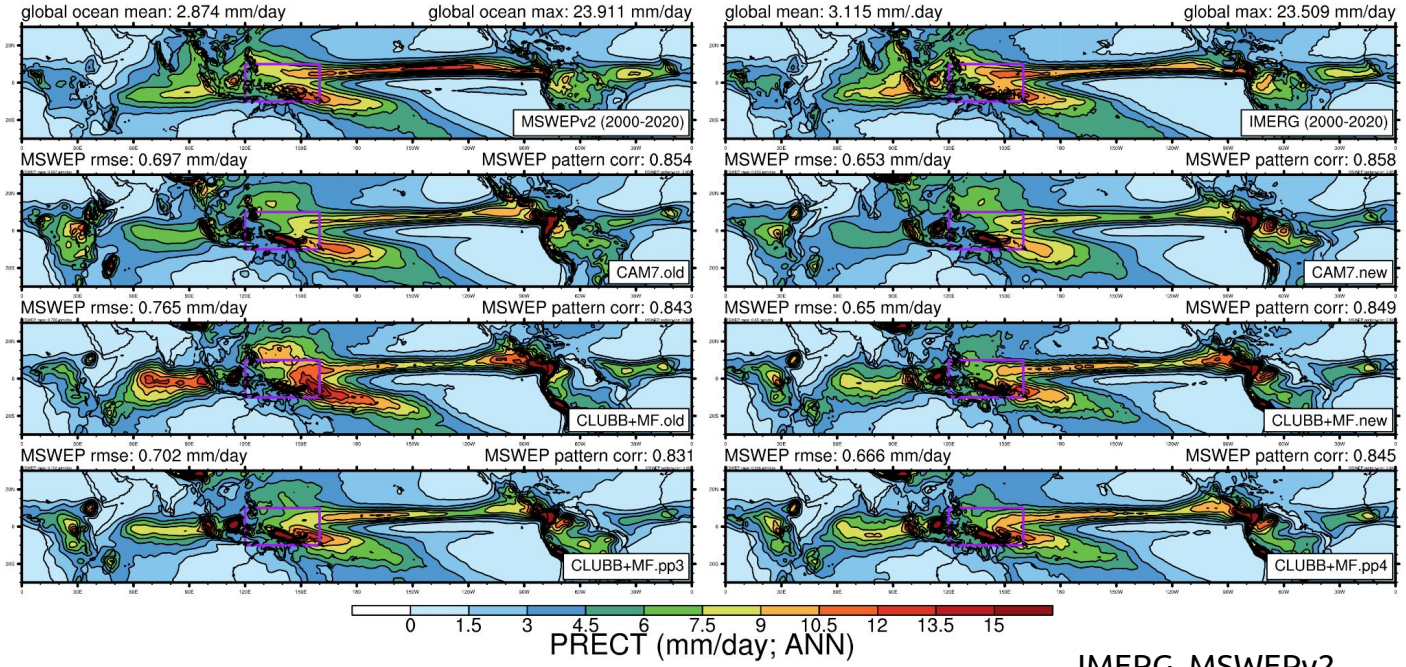

IMERG, MSWEPv2
courtesy of Isla Simpson

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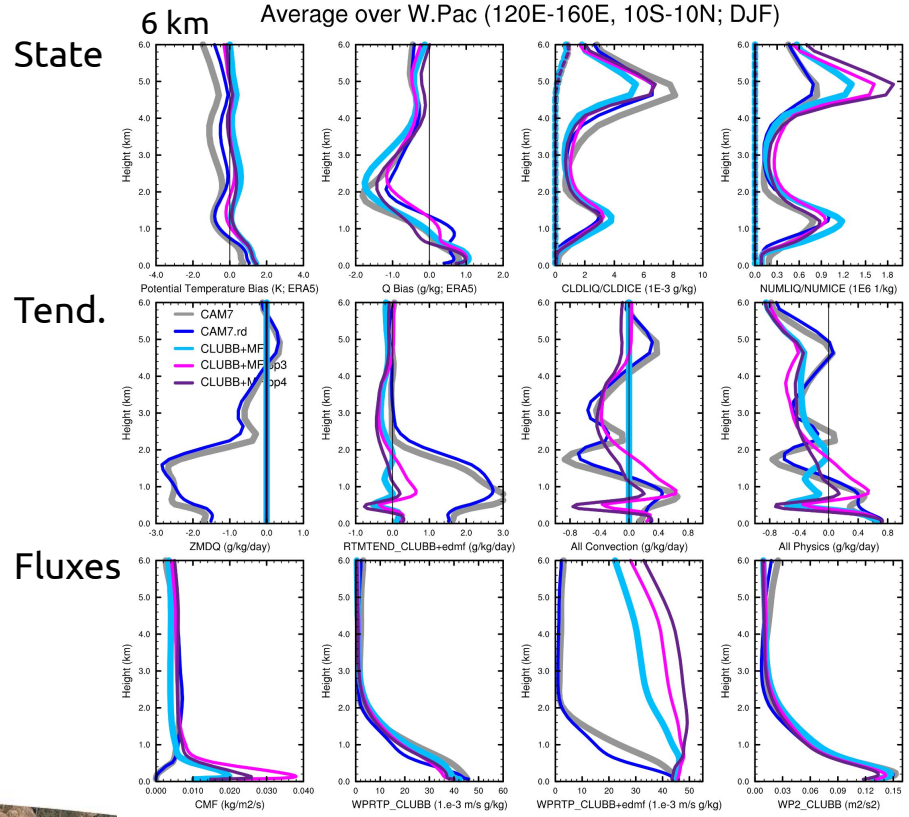

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Merge CODE base up & per plume mods (pp)

CLUBB+MF:

- Subtropical Cu Congestus ~slight moistening of shallower layers compared to CAM7. Mass fluxes magnitudes smaller than ZM.

*CAM7.rd = CAM7 + revert CLUBB diffusion on