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The CLUBB+MF Approach: Results from the Unified Mixing Parameterization CPT Project

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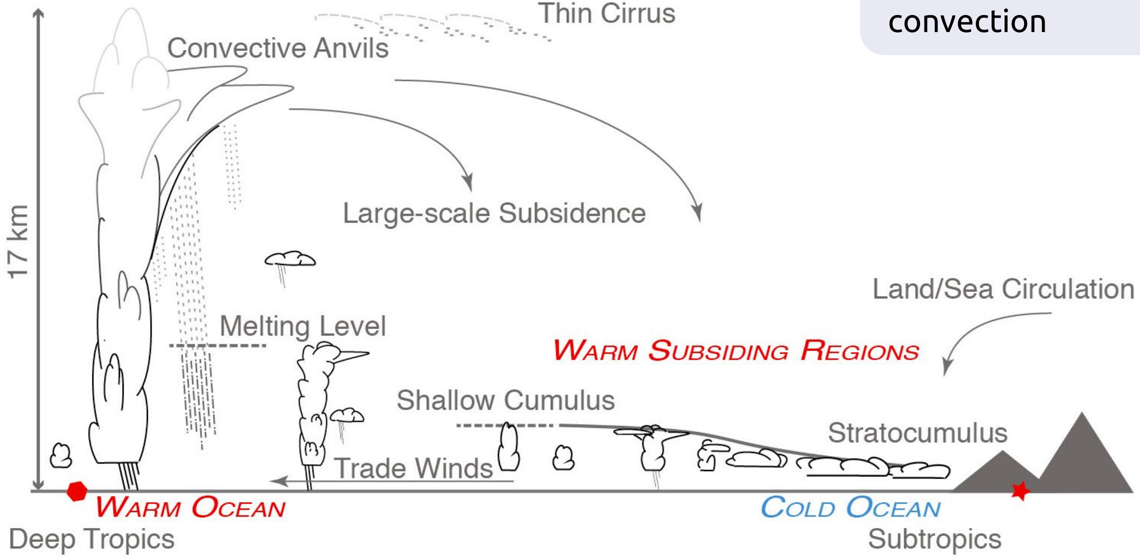
Fully Unified Mixing Parameterization

Convection occurs over a wide-range of scales

Spatial transition over ocean from stratocumulus to cumulus and to deep convection



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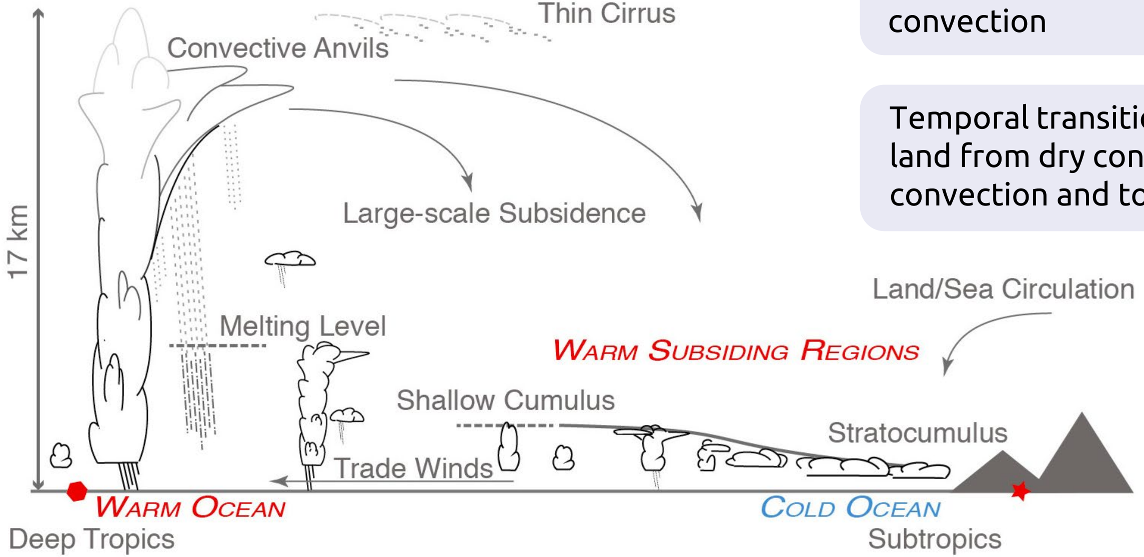

Spatial transition over ocean from stratocumulus to cumulus and to deep convection

Temporal transition (diurnal cycle) over land from dry convection, to shallow convection and to deep convection

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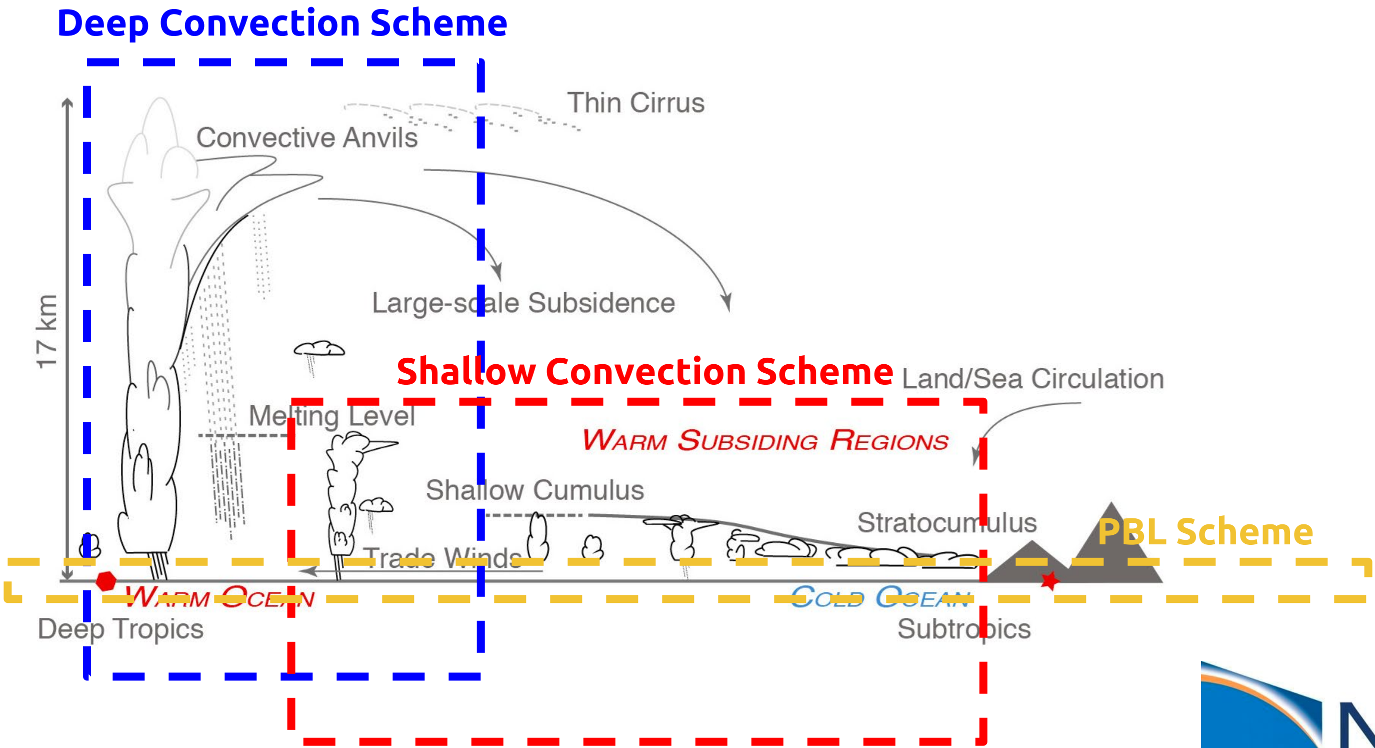
Fully Unified Mixing Parameterization

Current parameterizations are modular



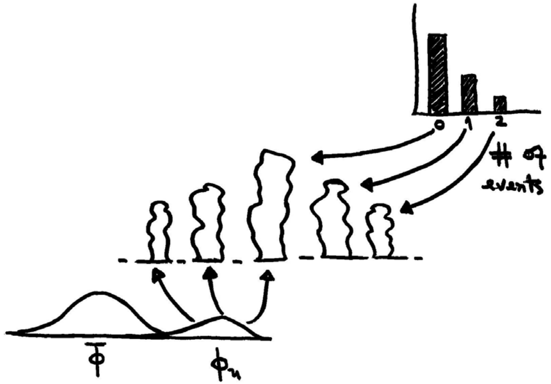
Eddy Diffusivity Mass Flux (EDMF)

- ❑ Eddy diffusivity represents mixing by small-scale turbulence
- ❑ Mass flux plumes represent mixing due to asymmetric turbulence
  - ❑ Explicit ensemble initialized by sampling PDF (derived from host model sfc fluxes)
  - ❑ Individual plumes undergo stochastic lateral entrainment
  - ❑ Entrainment length-scale (L_ε) dynamic in time-space
    - ❑ Small L_ε = dry boundary layer convection, moist shallow convection
    - ❑ Medium L_ε = mid-level convection (trade cumulus, congestus)
    - ❑ Large L_ε = deep convection

EDMF

(Suselj, Teixeira & Chung, JAS, 2013)
(Suselj, Kurowski & Teixeira, JAS 2019)

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



Lateral Entrainment (Romps & Kuang 2009)

$$\varepsilon_{u_n}(\Delta z) = \frac{\varepsilon_0}{\Delta z}\mathscr{P}\left(\frac{\Delta z}{L_\varepsilon}\right)$$

Steady-state updraft

$$\frac{1}{2}\frac{\partial w_{u_n}^2}{\partial z} = a_w B_{u_n} - b_w \varepsilon_{u_n} w_{u_n}^2$$

CLUBB+MF

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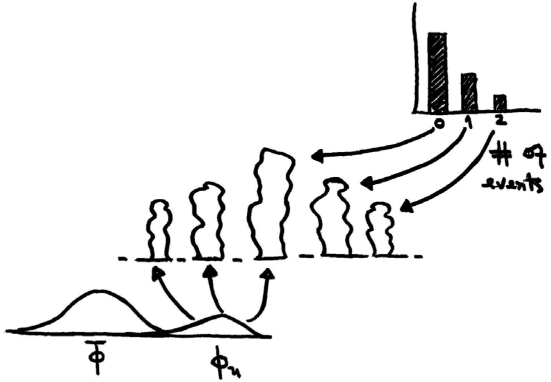
- ❑ CLU... ity with prognostic turbulence
  - ❑ ...laz et al. 2002; Larson and Golaz 2005)



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CLUBB+MF

(Witte et al. 2022)

$$\overline{w'\varphi'} = \overline{w'\varphi'}_{CLUBB} + M(\varphi_u - \overline{\varphi})$$

Coupling MF to CLUBB

Divergence(MF) set to RHS forcing term of the 5-diagonal CLUBB matrix that solves for the turbulent fluxes

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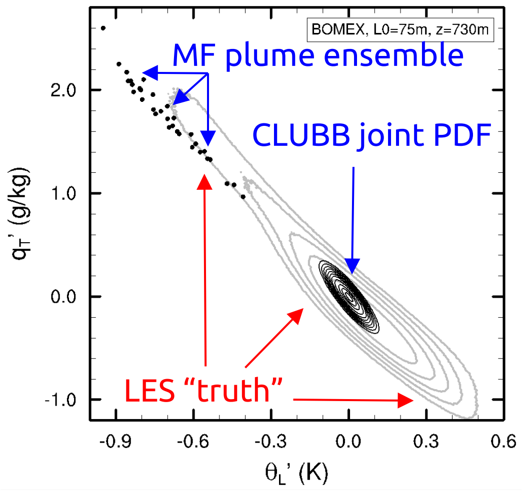
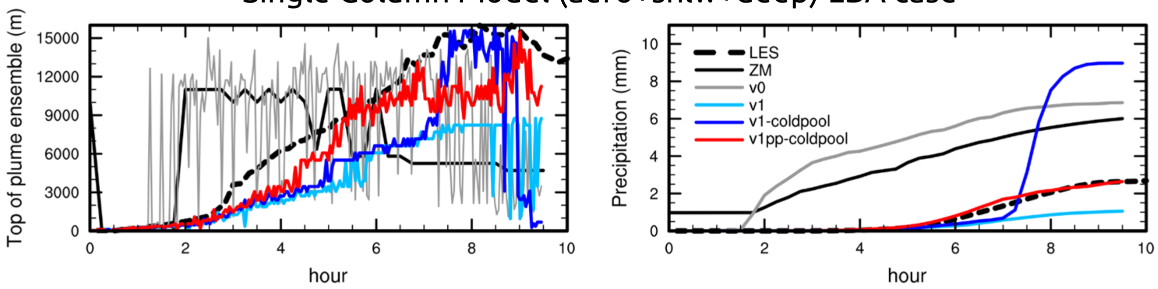
CLUBB+MF: Version History

- CLUBB+MF (shlw)
  - Fixed entrainment length scale L_ε
  - Witte et al. 2022
- CLUBB+MF (shlw+deep)
  - Dynamic L_ε – function of environ. RH and CLUBB TKE
  - Paper in progress
- CLUBB+MF (aero+shlw+deep)
  - Dynamic L_ε – function of plume history
  - Downdraft ensemble
  - Cold pool feedback on L_ε
  - Cloud-aerosol interactions
  - Convective initiation aloft

Single Column Model (shlw)



Single Column Model (aero+shlw+deep) LBA case



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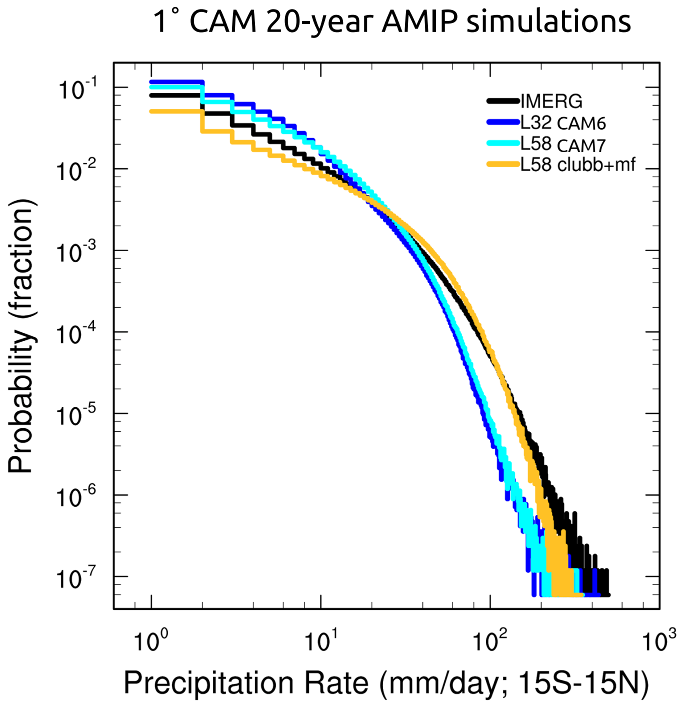
CLUBB+MF: shlw+deep

AMIP simulations with the unified convection scheme reduces light precipitation (the drizzle problem) and increases extreme precipitation rates



CLUBB+MF: shlw+deep

AMIP simulations with the unified convection scheme reduces light precipitation (the drizzle problem) and increases extreme precipitation rates

Ratio of convective to total precipitation rates more similar to IMERG (~50% in the tropics) compared to CAM (~80%)

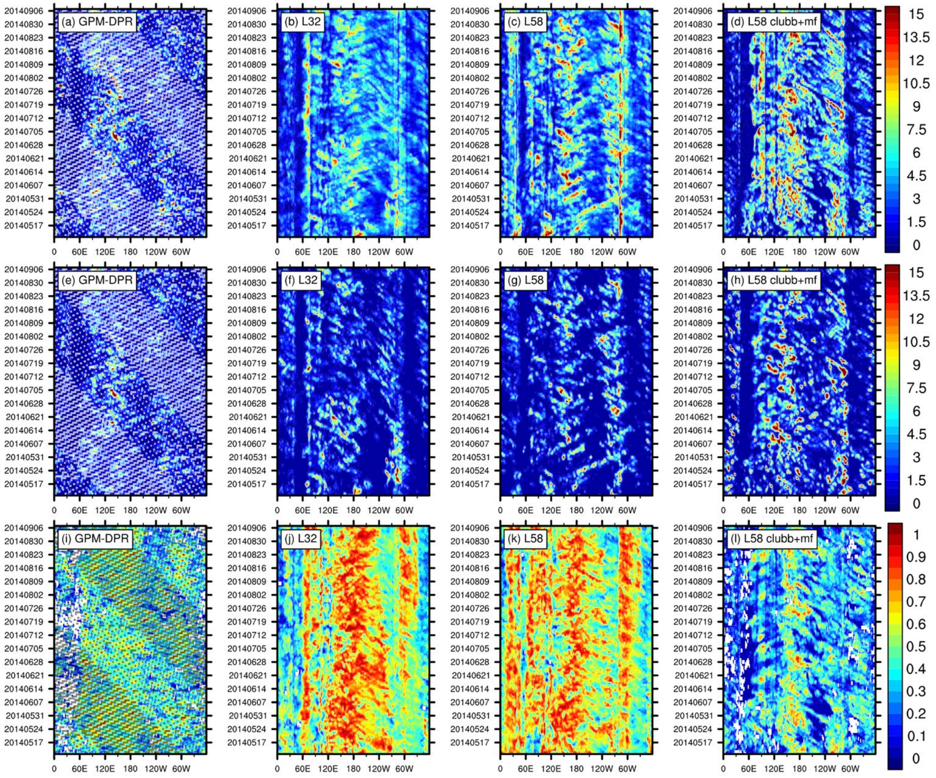
Hovmoller Plot

GPM-DPR | CAM6 (L32) | CAM7 (L58) | CLUBB+MF (L58)

PRECC

PRECL

RATIO – PRECC / (PRECC+PRECL)



PRECC
Convective Precipitation

PRECL
Stratiform Precipitation

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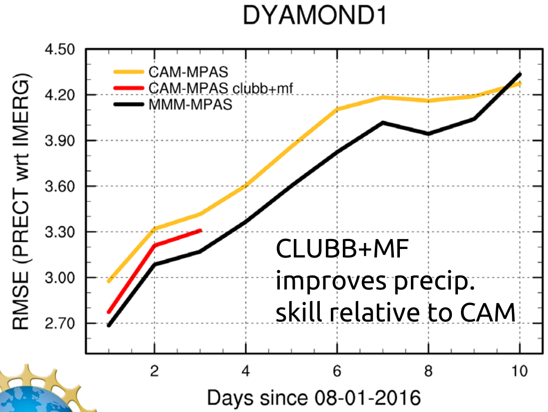
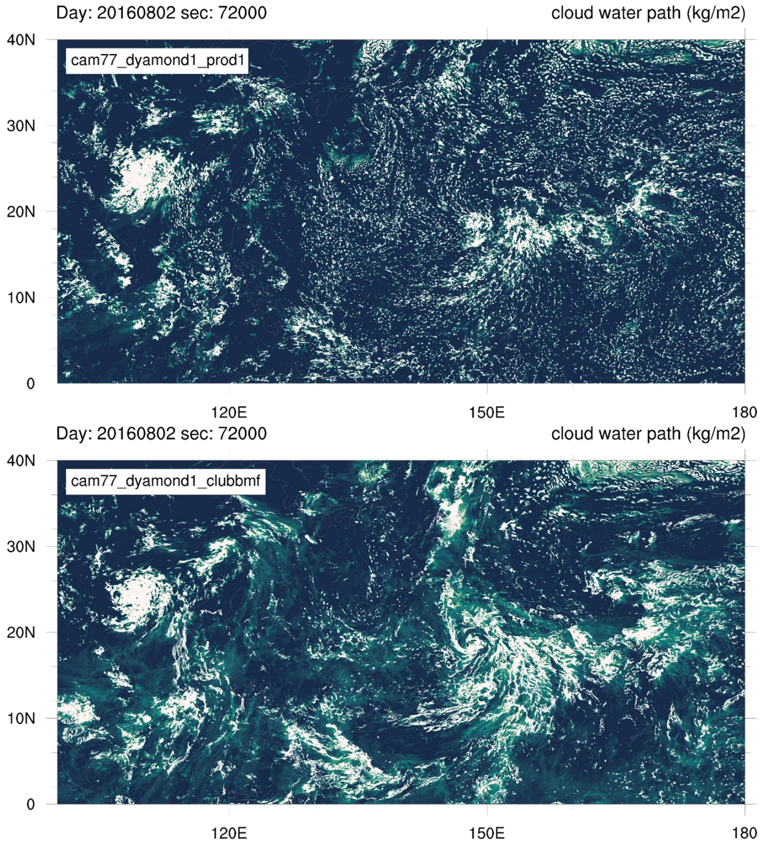
CLUBB+MF: aero+shlw+deep

In ~3 km models, lateral entrainment is not resolved, rather it's "parameterized" by implicit/explicit numerical diffusion. This representation of convection can only support an undilute deep mode, and therefore parameterized convection is still necessary to represent transitional regimes (e.g., shallow cumulus, mid-level congestus).



3.75 km CAM-MPAS simulations*



In the control (top panel), CLUBB is the only convection scheme active (CAM's deep scheme is off)

Turning on CLUBB+MF (bottom panel) results in less 'patchy' deep convection and a more realistic spectrum of clouds

Click here for a precipitation viz

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*km-scale capabilities are a joint collaboration between CESM, SIMA & EarthWorks