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# A new unified boundary layer and convection parameterization CPT project: The multi-plume Eddy-Diffusivity/Mass-Flux (EDMF) approach

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# EDMF CPT

**Goal:** to reduce key biases related to PBL clouds and deep convection in the NCAR and GFDL climate models.

Will implement and evaluate unified PBL and convection multi-plume Eddy-Diffusivity/Mass-Flux (**EDMF**) parameterization.

**EDMF** is a fully unified turbulence/convection parameterization: represents sub-grid mixing from PBL to deep moist convection with one single parameterization.

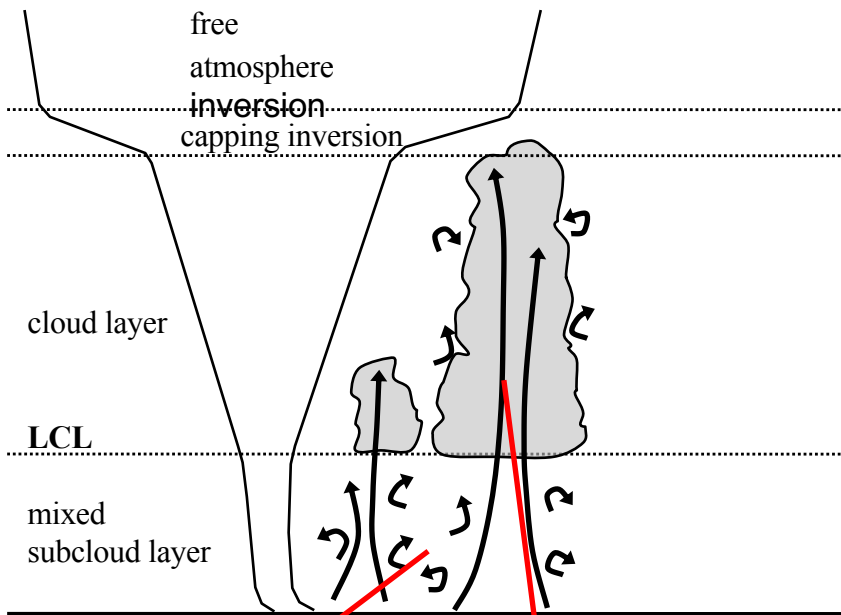
Focused on **PBL and transition to deep convection:**

- (i) Spatial transition over ocean from stratocumulus to cumulus and to deep convection;
- (ii) Temporal transition (diurnal cycle) over land from dry convection, to shallow convection and to deep convection.



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# Unified Parameterization: Eddy-Diffusivity/Mass-Flux (EDMF)



Small-scale  
ED mixing

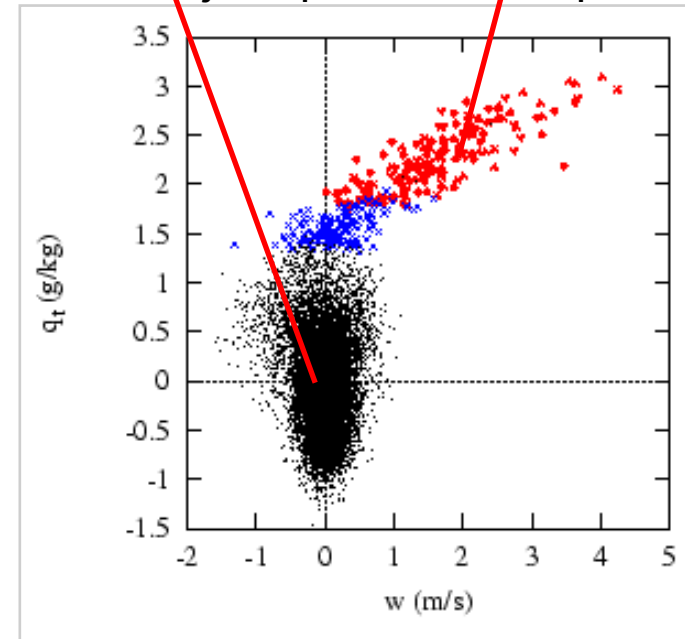
Large-scale  
MF mixing

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

ED mixing

MF mixing

Bimodal joint pdf of  $w$  and  $q_t$





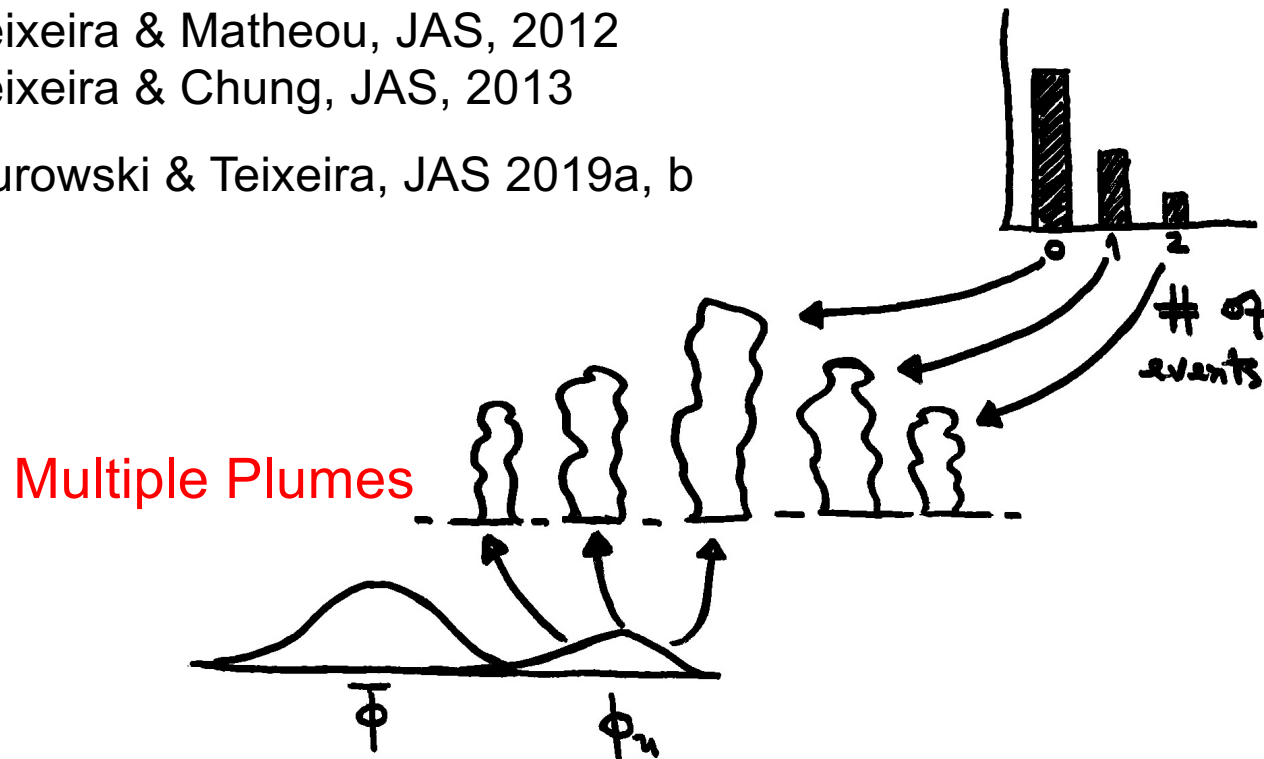
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# EDMF and moist convection: multiple plumes and stochastic entrainment

Suselj, Teixeira & Matheou, JAS, 2012

Suselj, Teixeira & Chung, JAS, 2013

Suselj, Kurowski & Teixeira, JAS 2019a, b

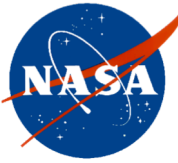


3) Stochastic  
lateral entrainment

Partly inspired by  
Romps & Kuang,  
JAS, 2010

- 1) Parameterization of PDF of surface layer thermodynamics
- 2) Monte Carlo sampling of PDF to produce multiple plumes

- Different types of convection coexist in the same model grid-box
- Total updraft area is just the sum of individual updraft areas

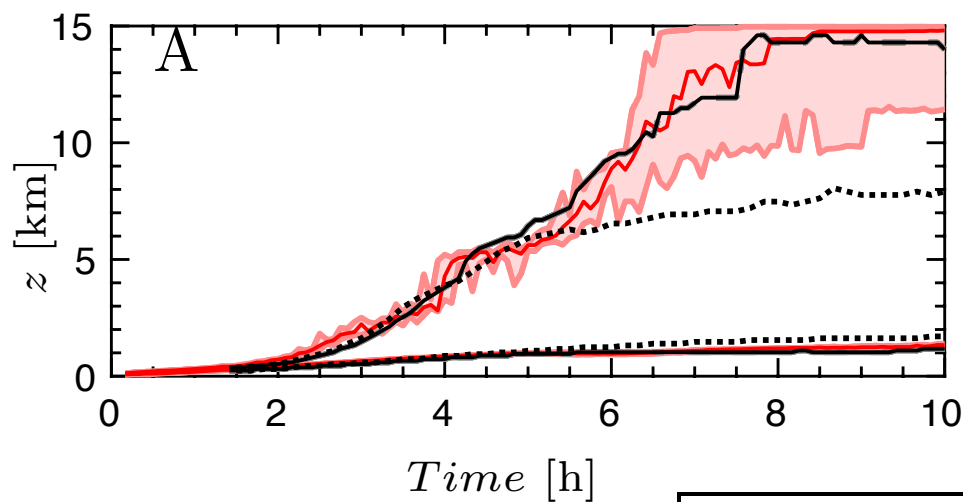


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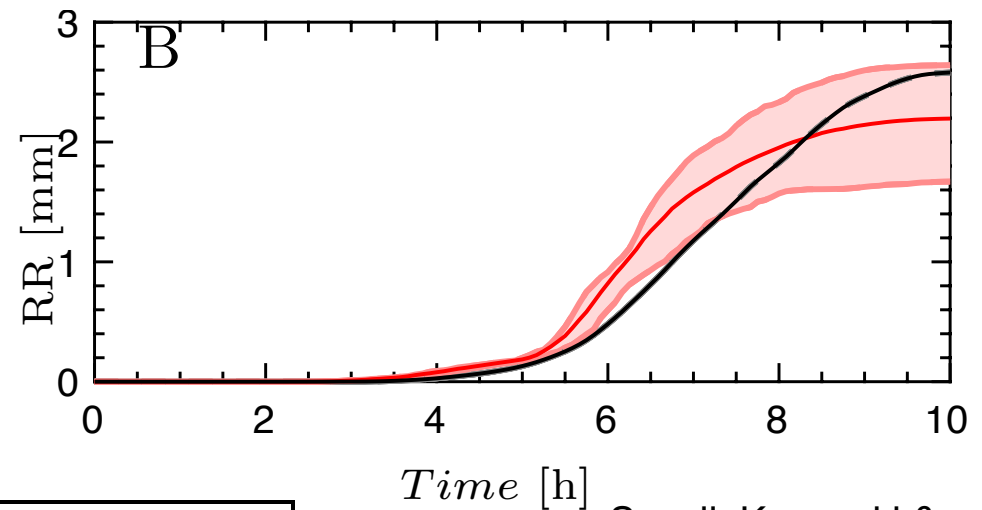
# Diurnal cycle of precipitating tropical convection over land: LBA

Multi-plume EDMF with plume microphysics, downdrafts and  
simplified parameterizations of cold pool effects

Cloud base and top



Cumulative surface precipitation



— EDMF — LES

Suselj, Kurowski &  
Teixeira, JAS, 2019b

Realistic EDMF transition from PBL to shallow to deep convection

A single scheme able to represent all these types of convection



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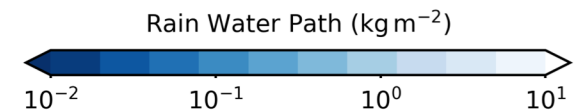
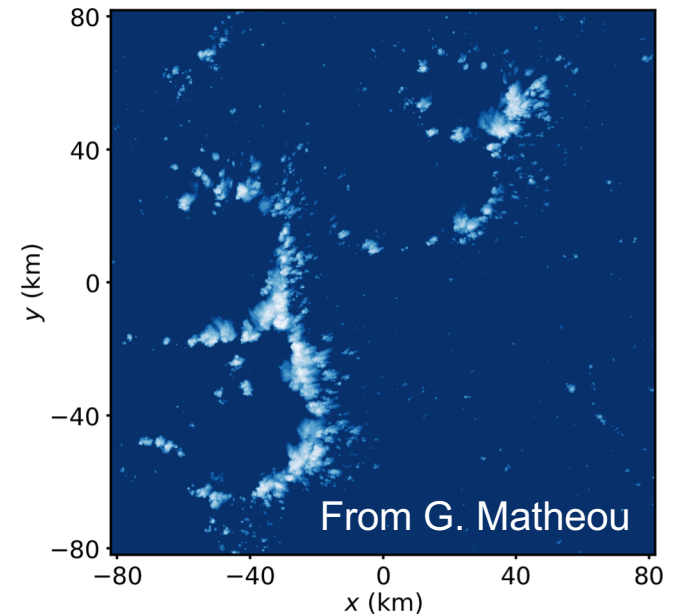
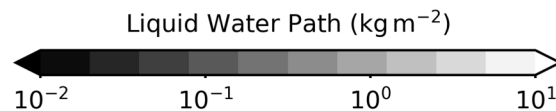
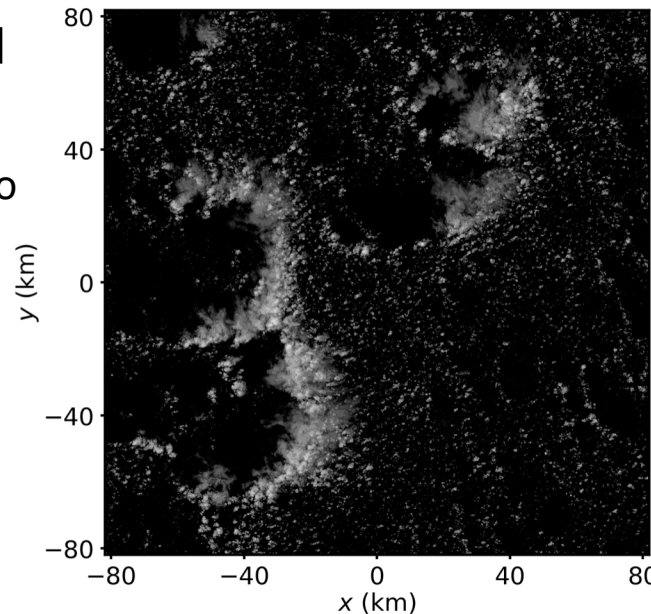
# UConn's Large-Eddy Simulation (LES) model

- LES models solve filtered version of Navier-Stokes equations
- High-resolutions (1-100 m) in all 3 dimensions
- LES models resolve most of the essential turbulence/convection

## UConn's LES model (e.g. Matheou & Chung, JAS, 2014)

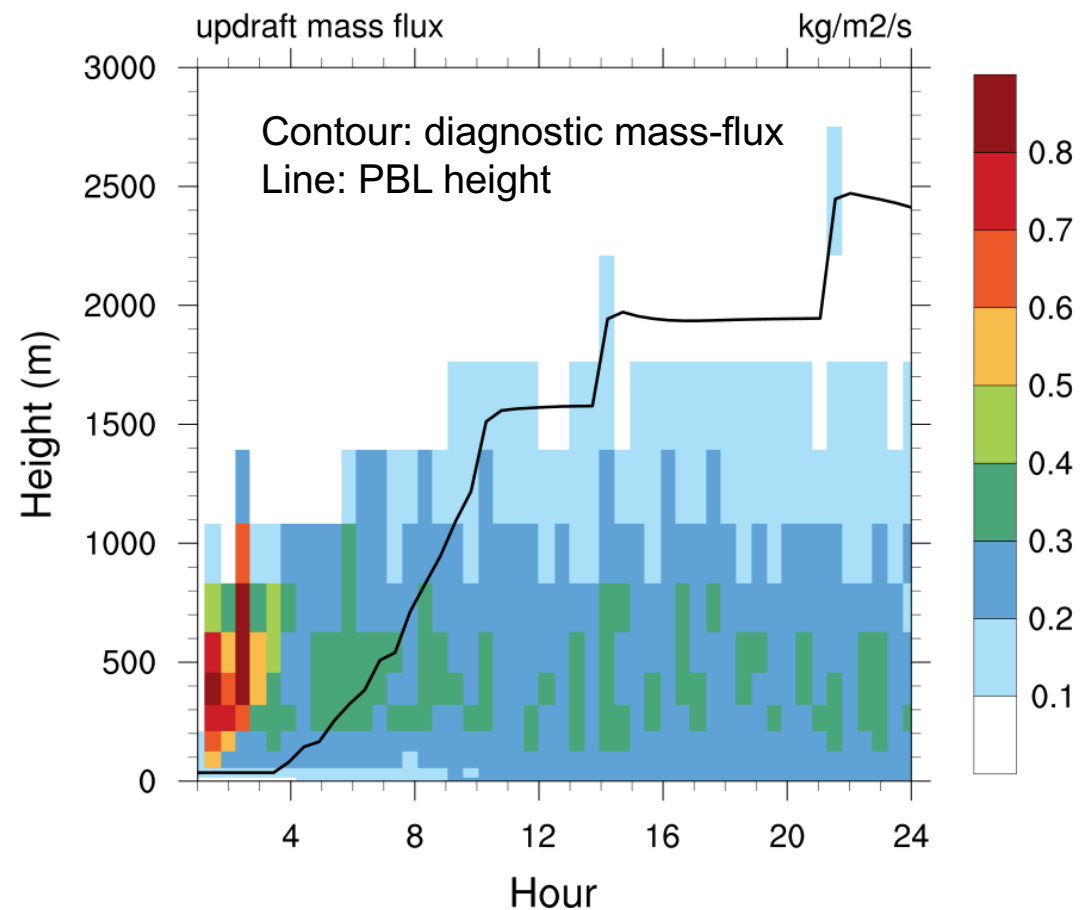
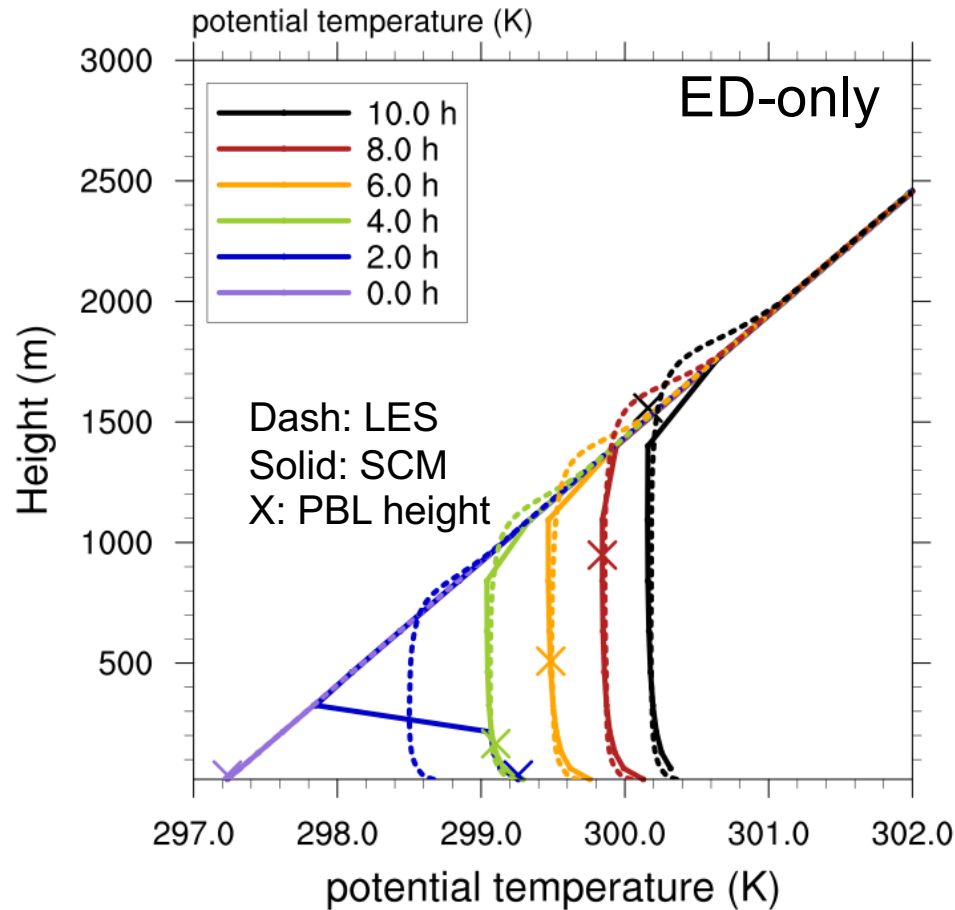
- High-fidelity physics and numerical method
- Physics-based model: No adjustable parameters; No empirical constants
- Grid-resolution independent results
- Simulations over topography use IBM
- Atmospheric dispersion capability

- Precipitating shallow-cumulus convection (RICO)
- LES domain  $163 \times 163 \times 4$  km; Grid resolution 40 m

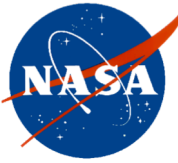




# GFDL SCM simulations: dry PBL convection case



- ED-only leads to small top entrainment and shallow PBL
- Diagnostic Mass-Flux (MF) appears plausible/realistic
- Fully interactive EDMF currently being tested at GFDL

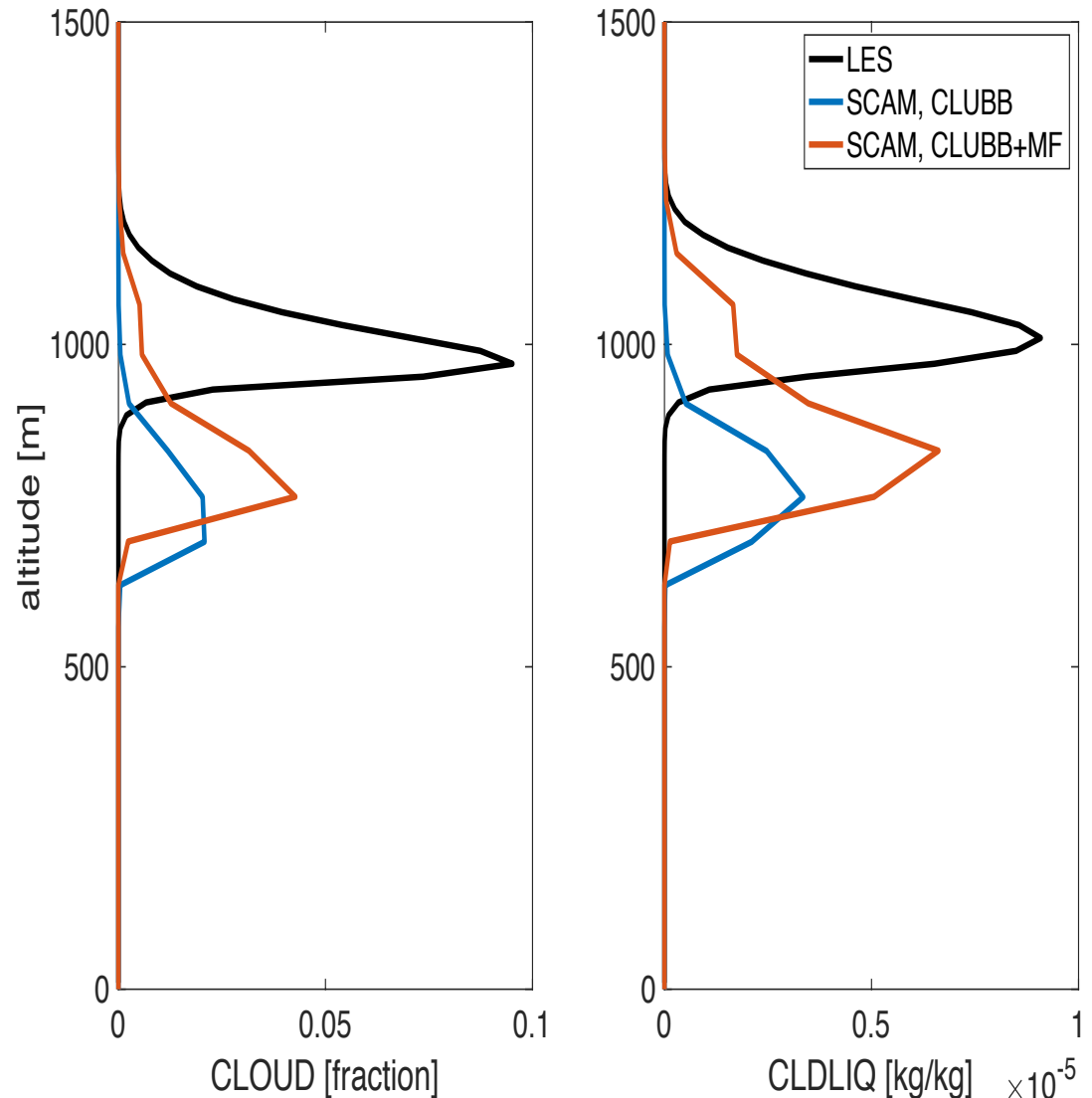


# CAM6: CLUBB+MF

(Mikael Witte, next talk)

- Novel approach combining CLUBB with mass flux (MF) plumes
- Assumption: MF plumes represent additional skewness not parameterized by CLUBB
- MF is coupled to CLUBB as an additional term in CLUBB's numerical solver
- CLUBB+MF agrees well with LES for shallow convection cases

ARM shallow convection diurnal cycle case







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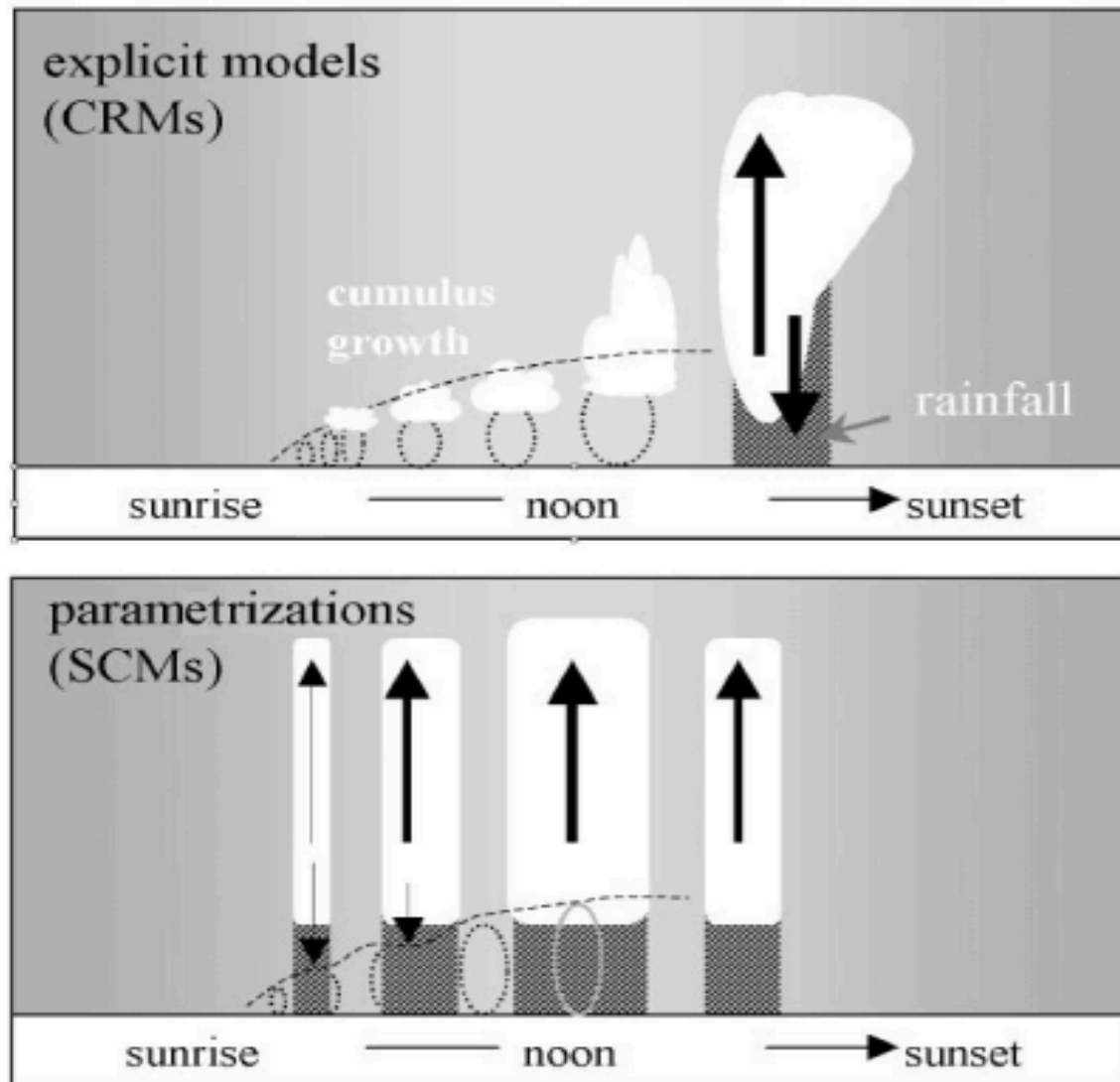
# Summary

- EDMF combines ED and MF to represent in a unified way turbulence and convection in atmospheric models
- EDMF addresses key questions: counter-gradient flux, top entrainment, skewness of vertical transport in cumulus
- New EDMF CPT project is implementing and evaluating EDMF in the NCAR and GFDL models
- Preliminary results: 1) diagnostic MF plumes implemented in GFDL; 2) fully interactive EDMF being tested at GFDL; 3) MF added to NCAR CLUBB numerical solver – **see next presentation**



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# Diurnal Cycle of Convection over Land: Transition from Shallow to Deep Convection



Guichard et al,  
QJRM, 2004

Climate and weather models are unrealistic