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# SP-CAM5 with CLUBB: progress and remaining issues

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U.S. DEPARTMENT OF ENERGY

# The Multi-scale Aerosol-Climate Model (SPCAM5)

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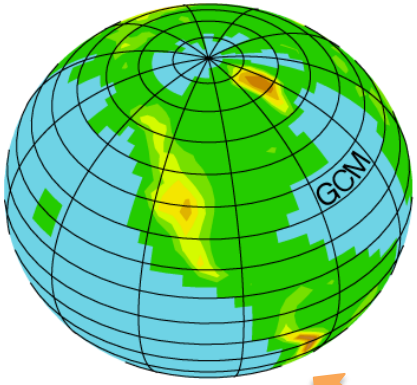
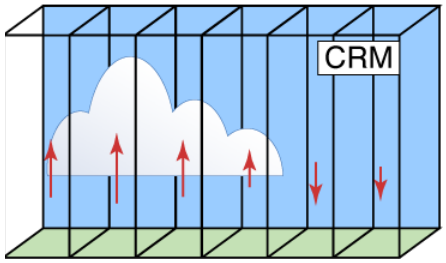
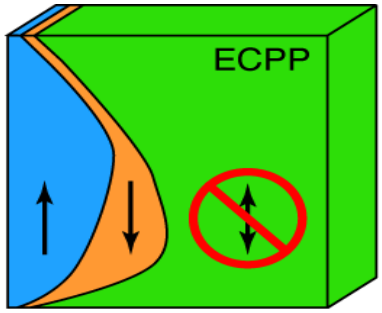
CAM5 with modal aerosols

Two-moment microphysics




MMF




SPCAM5 (PNNL-MMF)

(Wang et al., 2011a, *GMD*; 2011b, *ACP; 2012, GRL;* Randall et al., *2013, EOS*)

*CLUBB: a high-order turbulence/sub-grid cloud scheme*

*(Golaz et al. 2002; Larson et al., 2012)*

CRM cloud/precipitation statistics used for cloud processing of aerosols

# Cloud Layers Unified By Binormals (CLUBB) in MMF



- Low clouds have been underestimated in MMF simulations (4km grid-spacing)
- Improved turbulence/sub-grid cloud treatment is expected to improve the simulation of deep clouds and the transition from shallow to deep clouds as well
- CLUBB in MMF serves as an early test of CLUBB's scale-aware capability
- CLUBB: Assumed PDF approach

$$P = P(w, q_t, \theta_l)$$

$w$, vertical velocity; $q_t$, total water mixing ratio;
$\theta_l$, liquid water potential temperature

# Schematic of the Assumed PDF method

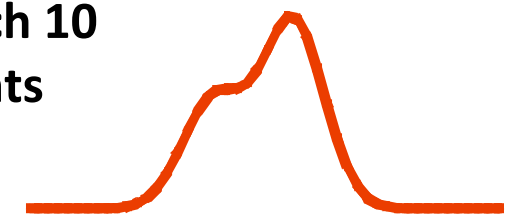


**Advance 10 prognostic equations**

$\overline{w}$, $\overline{\theta_l}$, $\overline{q_t}$, $\overline{w'^2}$, $\overline{w'^3}$, $\overline{q_t'^2}$, $\overline{\theta_l'^2}$, $\overline{q_t'\theta_l'}$, $\overline{w'q_t'}$, $\overline{w'\theta_l'}$

Golaz et al. (2002a)

**Select PDF from given family to match 10 moments**



**Diagnose cloud fraction, liquid water from PDF**

$\Delta t$

**Use PDF to close higher-order moments, buoyancy terms**

$\overline{w'q_t'^2}$, $\overline{w'\theta_l'^2}$, $\overline{w'q_t'\theta_l'}$, $\overline{w'^2q_t'}$, $\overline{w'^2\theta_l'}$, $\overline{w'^4}$, $\overline{q_t'\theta_v'}$, $\overline{\theta_l'\theta_v'}$, $\overline{w'\theta_v'}$, $\overline{w'^2\theta_v'}$

# Porting the MMF into CESM (SP-CESM)



- SPCAM has been merged with CESM1.1.1, and the SP-CESM1.1.1 has been publicly released (D. Randall, M. Branson, M. Wang, S. Ghan, C. Craig, A. Gettelman, and J. Edwards, 2013, *EOS*) (Supported by NSF/DOE).
- SP-CESM1.1.1 includes two compsets:
  - F_2000_SPCAM_sam1mom (single-moment, non-aerosol)
  - F_2000_SPCAM_m2005 (double-moment, aerosol)
- The PNNL branch of SP-CESM1.1.1 has been merged into SAM 6.10.4 (from SAM 6.8.2), and includes four configurations:
  - sam1mom vs. sam1mom + CLUBB
  - m2005 vs. m2005 + CLUBB (work in progress)

# Single-moment microphysics (1.9x2.5, nlev30):



| | MMF | MMF +CLUBB | Obs |
|---|---|---|---|
| LWP (g/m2) | 93.6 | 103.6 | 50-87 |
| IWP (g/m2) | 47.6 | 54.0 | 10-65 |
| SWCF (W/m2) | -58.0 | -58.4 | -46 to -53 |
| LWCF (W/m2) | 28.6 | 28.8 | 27-31 |
| PRECT (mm/day) | 2.87 | 2.89 | 2.61 |

# Shortwave cloud forcing (sam1mom)

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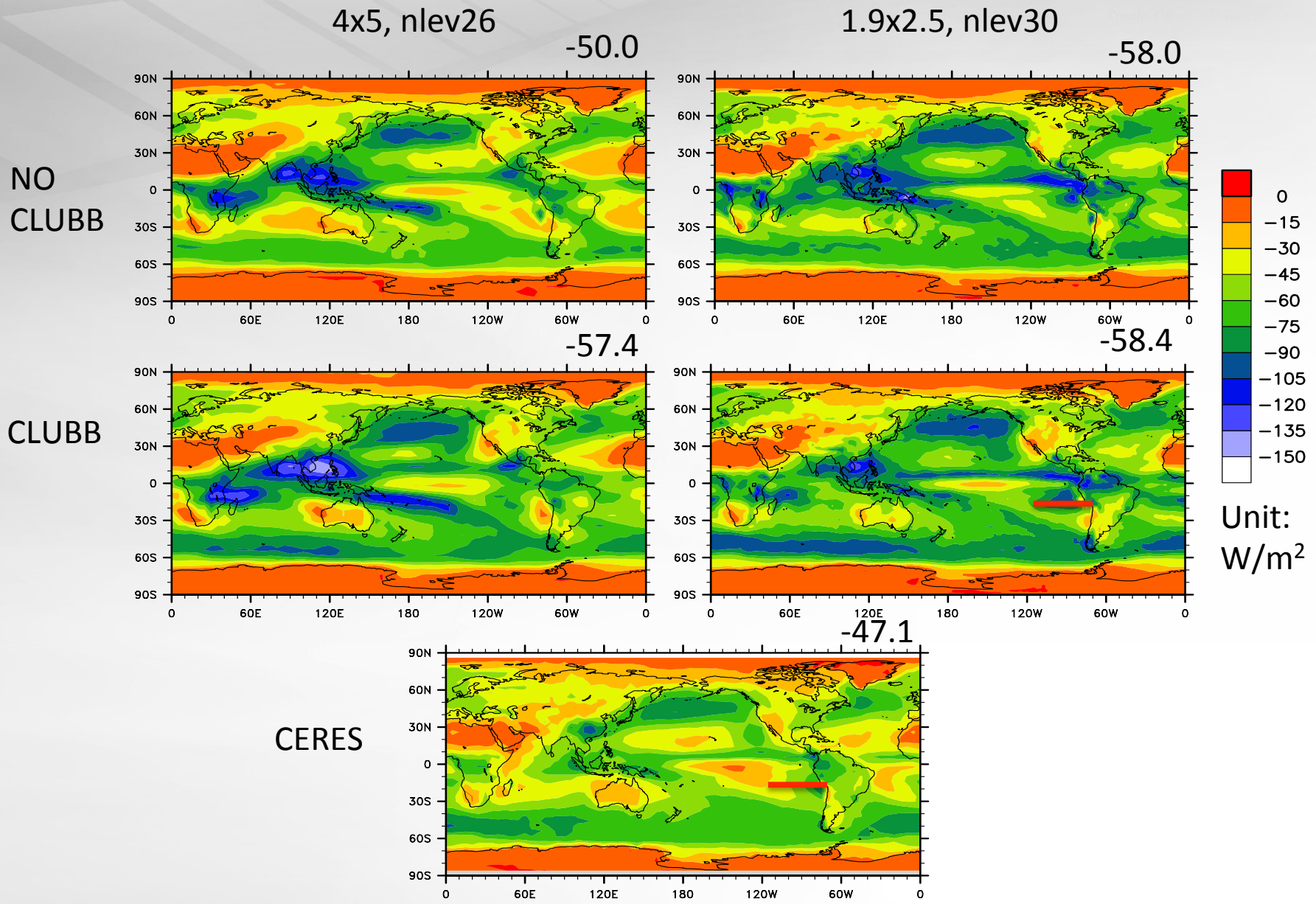
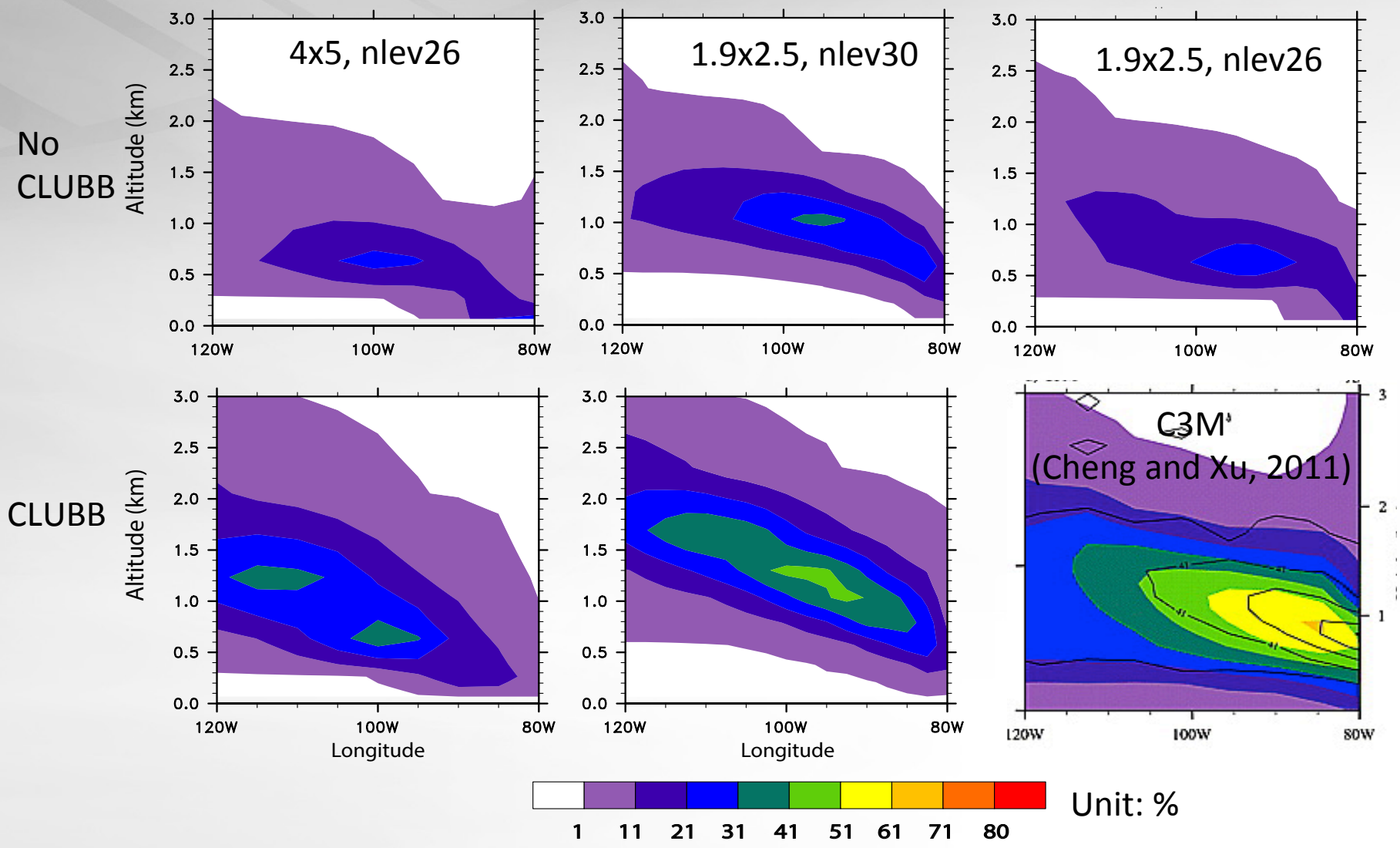


# Cross-section (15°S, cloud fraction)





# Two-moment microphysics (m2005) (4x5 degree, one-year simulation)



| | NO CLUBB | CLUBB |
|---|---|---|
| IWP (g/m2) | 11 | 7 |
| CLDHGH (%) | 28 | 21 |
| LWCF (W/m2) | 27 | 22 |
| AOD | 0.13 | 0.06 |
| soot burden (Tg/yr) | 0.16 | 0.09 |

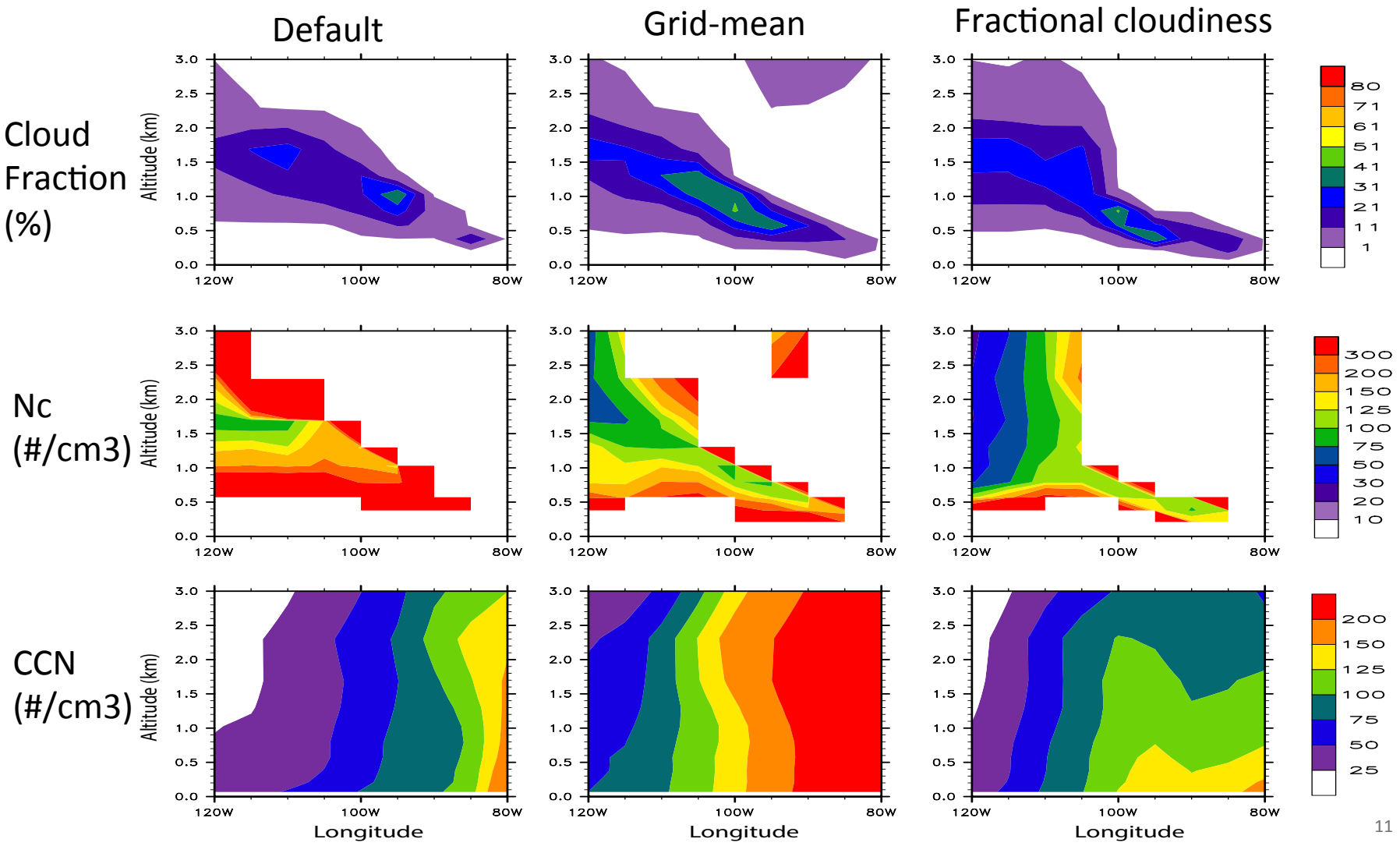
# Sensitive to the coupling between CLUBB and microphysics (m2005) (4x5, October)



| | Default (CLUBB) | Grid mean (CLUBB) | No CLUBB |
|---|---|---|---|
| LWP (g/m2) | 47.7 | 83.6 | 51.2 |
| IWP (g/m2) | 6.1 | 15.3 | 12.0 |
| SWCF (W/m2) | -44.4 | -59.5 | -48.0 |
| LWCF (W/m2) | 19.6 | 27.8 | 26.7 |
| Nc (#$10^{10}$/m2) | 4.43 | 3.61 | 1.96 |
| AOD | 0.067 | 0.14 | 0.12 |

# Cross-section (15°S, 4x5, Sept 26th-Oct 5th )





# Summary and Future work



- MMF-CLUBB with single-moment microphysics works reasonably well, and substantially increases low cloud amount and improves the simulation of shortwave cloud forcing in the subtropics
- MMF-CLUBB with Morrison microphysics increases low cloud amount. However, simulated clouds and aerosols show strong sensitivity to how CLUBB and Morrison scheme is coupled. Further work is needed to explore this coupling
- CLUBB's impact on low clouds and on aerosol-cloud-precipitation interactions will be further examined

**Poster: Global Simulation of Ice Nucleation in an aerosol-enabled Multi-scale Modeling Framework model**

**Jill Chengzhu Zhang** (UCSD), Minghuai Wang (PNNL), Hugh Morrison (NCAR) and Richard Somerville (UCSD)

# Assumed, dynamics-PDF approach



$$P = P(w, q_t, \theta_l)$$

$w$, vertical velocity; $q_t$, total water mixing ratio;
$\theta_l$, liquid water potential temperature

- Dynamics-PDF: distinct from a more commonly used PDF approach (moisture but not $w$), and allows us to couple subgrid interactions of *turbulence* and *cloud or microphysical processes* (Randall et al, 1992).
- *Assumed* PDF Method: *assume* a *functional form* of the PDFs, and determine a *particular instance* of this functional form for each grid box and time step. (a double Gaussian PDF is used) (e.g., Manton and Cotton, 1977)