SCM Evaluation and Error Attribution with Concerted LES Simulations Of RACORO Cumulus Clouds

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Three 3-Day Case Study Periods Selected from RACORO

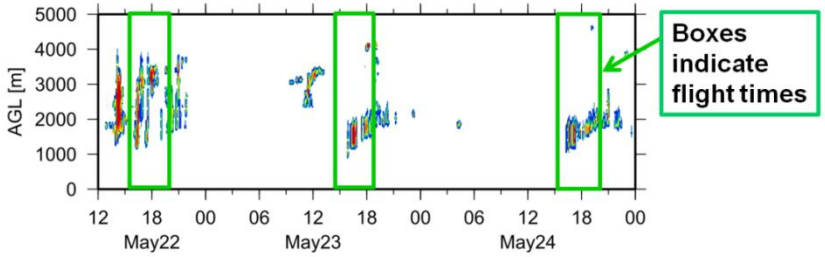
Continental vs. maritime

Capture diverse states:
- Time variation & transitions
- Cloud type (Cu, St, drizzling St)

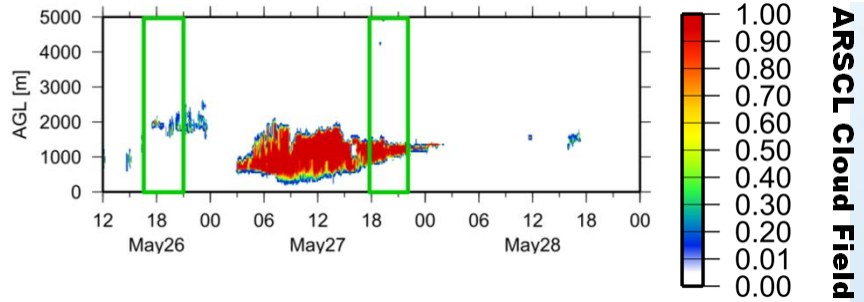
Comprehensive obs
- Aerosol size & CCN
- Cloud microphysics
- Atmospheric state
- Radiation

SGP surface obs & LS forcing

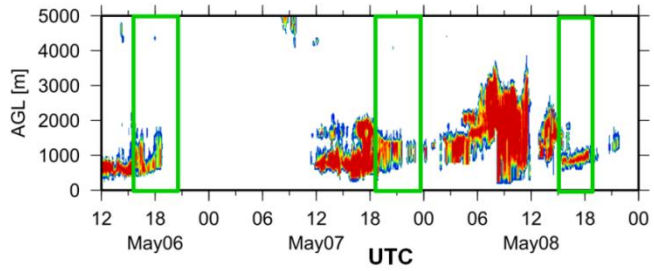
Case 1: Cumulus with Variable Aerosol (May 22-24)



Case 2: Cumulus and Drizzling Stratus (May 26-28)



Case 3: Variable Cloud Types (May 6-8)

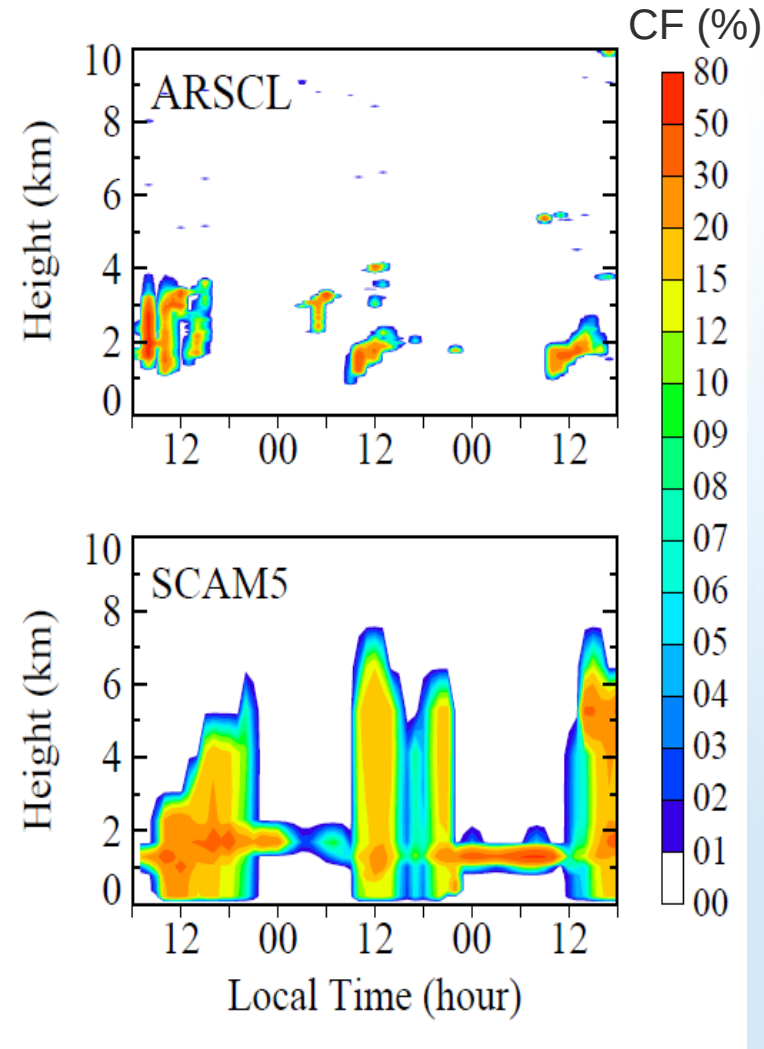


Single-Column Model CAM5 Investigation of RACORO Case 1

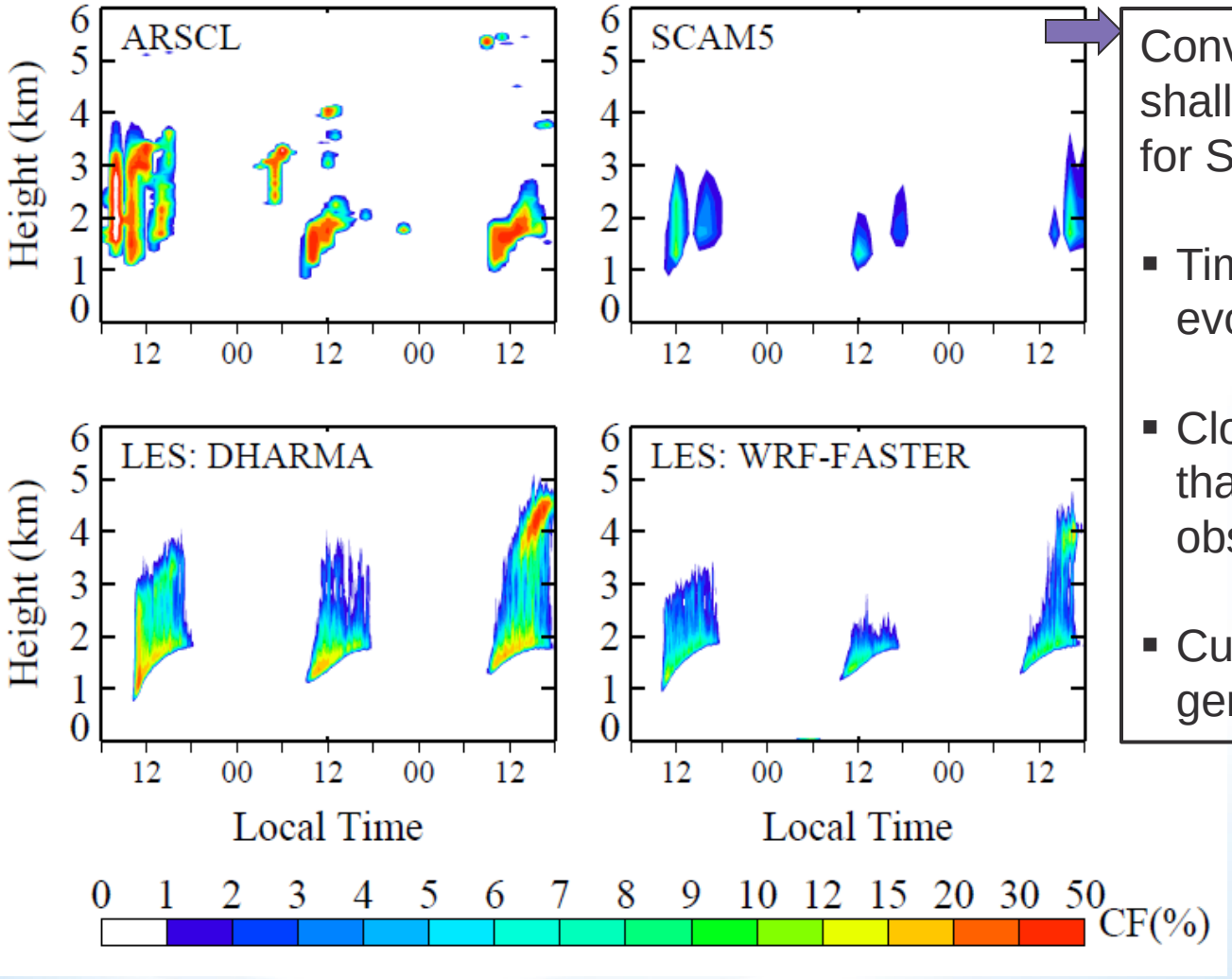
SCAM5 standard configuration driven by ARM forcing for reduced SGP standard domain (Δs=150 km, Δp=10 mb)

- Over-triggering of deep convection.
- Persistent night time PBL clouds likely due to stratiform cloud scheme

How do the shallow cumulus and moist turbulence parameterizations, which are more relevant to this case, perform?



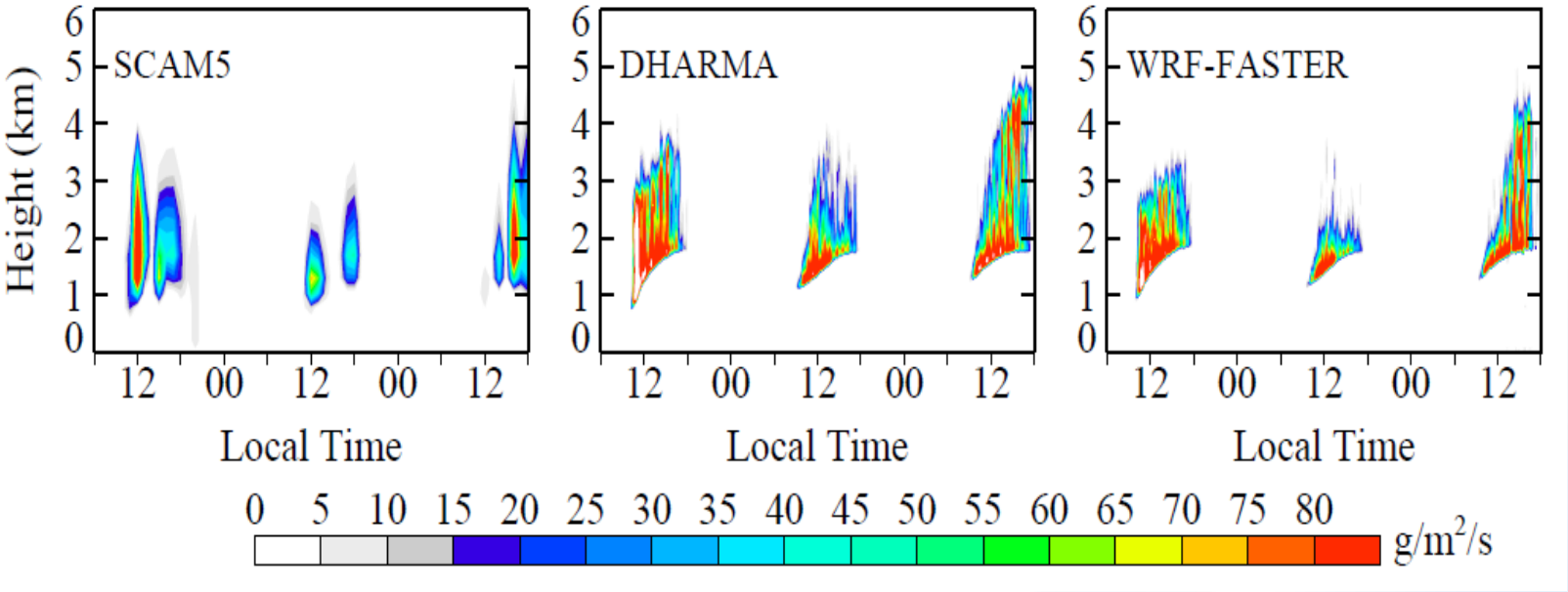
Comparison of shallow cumulus cloud production



Convective clouds by UW shallow cumulus scheme for SCAM5

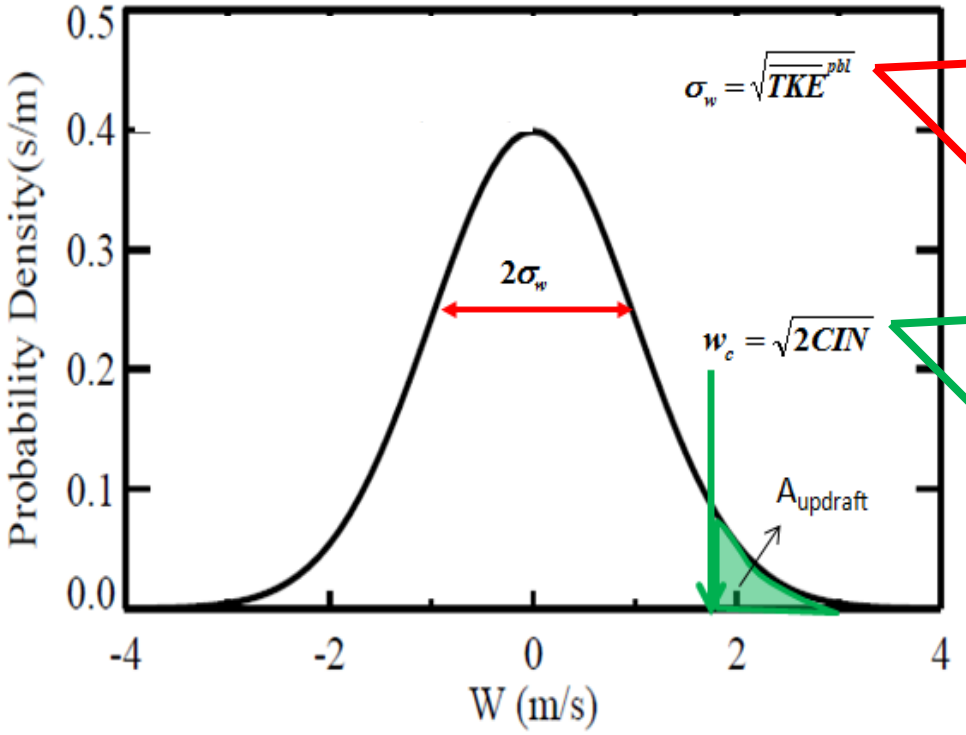
- Timing and temporal evolution reasonable.
- Cloud amount much less than LES simulations or observations.
- Cumulus cloud depth generally thinner.

Cumulus mass fluxes from SCAM5 and LES



Cumulus activity in SCAM5 is much weaker than what the LES simulations consistently suggest.

UW Shallow Cumulus Scheme
Determination of convective updraft area at cloud base



PBL Mean TKE

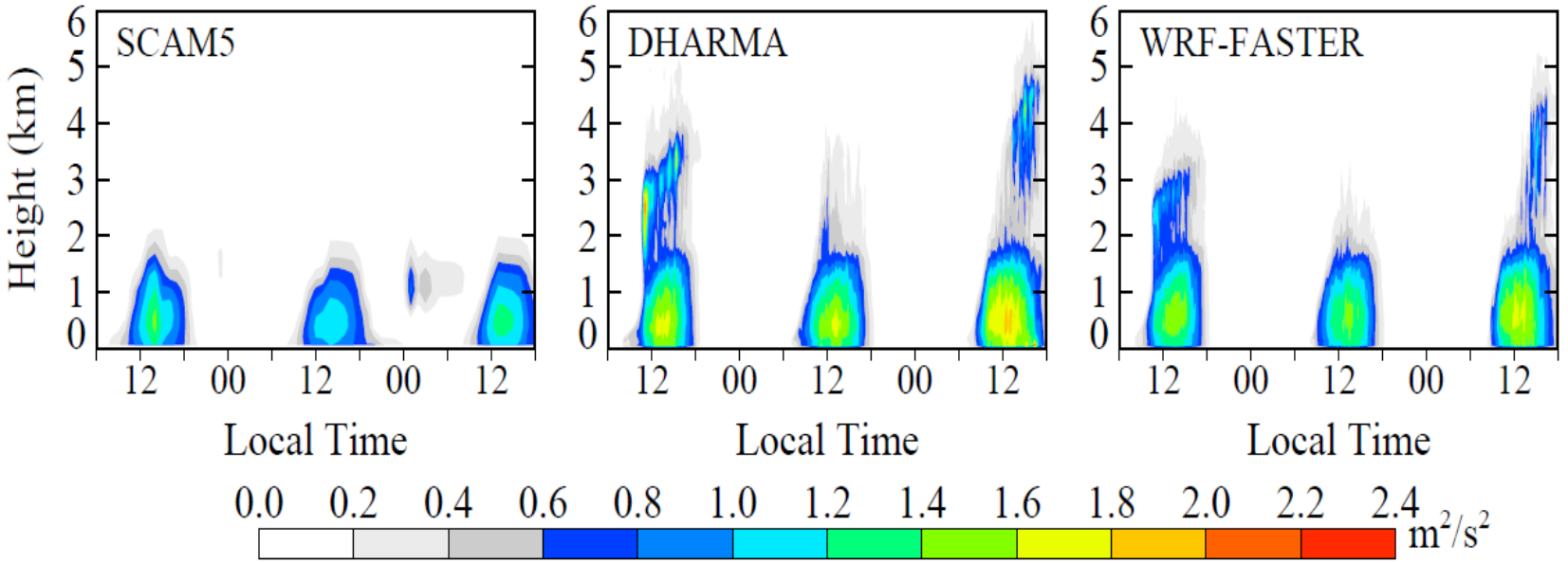
Width of w-pdf (Gaussian)

Convective Updraft Area

Weaker TKE means smaller updraft area, if all else being equal.

Relationship between PBL TKE, w-pdf, CIN, and convective updraft area in UWshcu.

Turbulence Kinetic Energy from SCAM5 and LES



TKE in SCAM5 is much weaker than that in the LES simulations. The boundary layer depth is shallower as suggested by the vertical extent of TKE.

Summary of Error Attribution Guided by LES

Other than spurious deep convection

Shallower PBL & Weaker Turbulence

↓

Narrower w-pdf

↓

Smaller Convective Updraft Area

↓

Weaker Cumulus convection *

↓

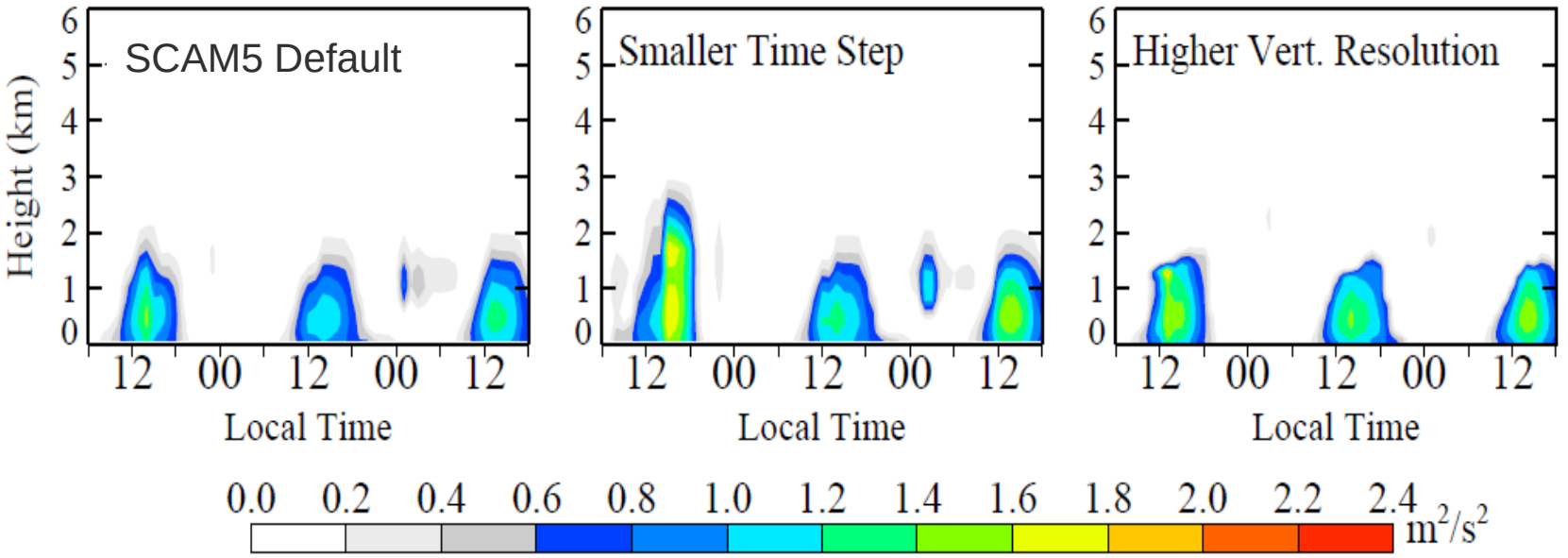
Weaker PBL ventilation

↓

More stratiform clouds (esp. nighttime)

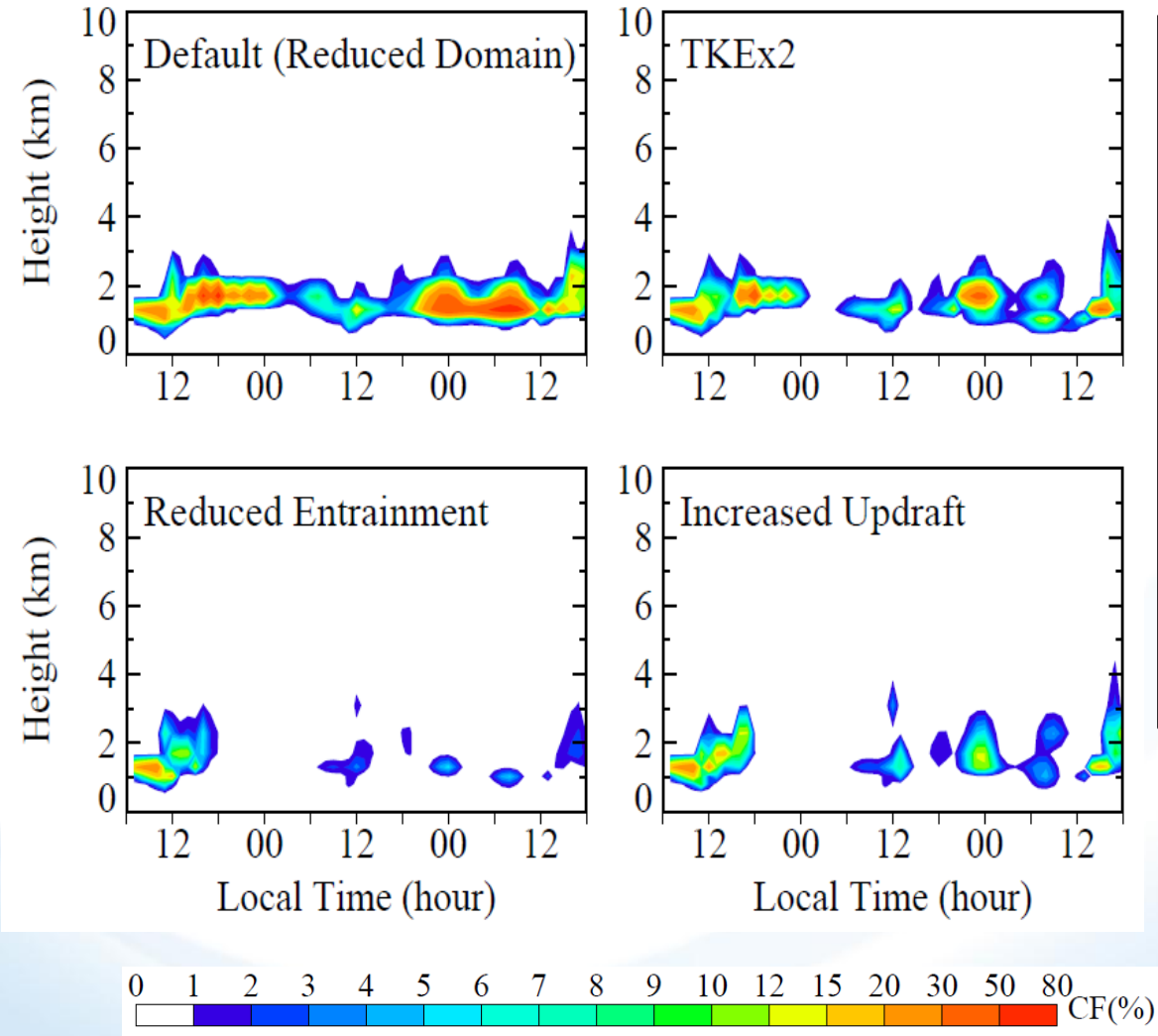
** Other factors, such as entrainment and max allowed updraft area in the UWshcu scheme also contribute to weaker cumulus activity*

Ways to improve the Simulations of PBL TKE



The existing PBL scheme in SCAM5 deliver improved results at higher horizontal and/or vertical resolutions (*e.g. application in* ***future models***).

Sensitivity experiments with the cumulus scheme and the impact of cumulus activity on PBL clouds



Overall model PBL clouds highly sensitive to shallow cumulus activities.

Sensitivity exps. suggest in SCAM5:

- Entrainment too strong.
- Updraft area too small

Future Works

- Derive entrainment and detrainment rate profiles from LES simulations

  Indirect methods with mass fluxes and conservative variables (e.g., Lu et al. 2012; Siebesma and Cuijpers 1995)

- Evaluate the entrainment and detrainment rates simulated by SCAM5 against the LES results.

- Derive observational references/bounds for PBL TKE and entrainment profiles in cumulus layer using ground based lidar/radar and aircraft measurements (e.g., *w, q*).