SCAM5 Simulation of GCSS Stratocumulus to Cumulus Transition

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OUTLINE

I. General Convection Model

II. SCAM5 Simulation of Steady Cases:

- Dry Convective PBL
- Stratocumulus-Topped PBL (DYCOMS-II)
- Shallow Convective Case (BOMEX)

III. SCAM5 Simulation of Transition Case:

- Stratocumulus-to-Cumulus Transition (GCSS Sc-Cu)

IV. SUMMARY

A Strategic Plan for Next Generation CAM6

WRAPPER

Organized Plumes

Stochastic Plumes

CORE

CAM5 Physics Core

Shallow Convection
(CIN Closure)
+
Deep Convection
(CAPE Closure)

CAM6 Physics Core

General Convection Model

I. CAM5 Shallow Convection + Organized Plume : C. Hogen and C. Bretherton
B. Mape and R. Neale

II. General Convection Model : S. Park

Major Remaining Issues in the Parameterization of Convection

I. Unified Treatment of Shallow and Deep Convection

II. Unified Treatment of Dry and Moist Convection

III. Unified Treatment of Forced and Free Convection

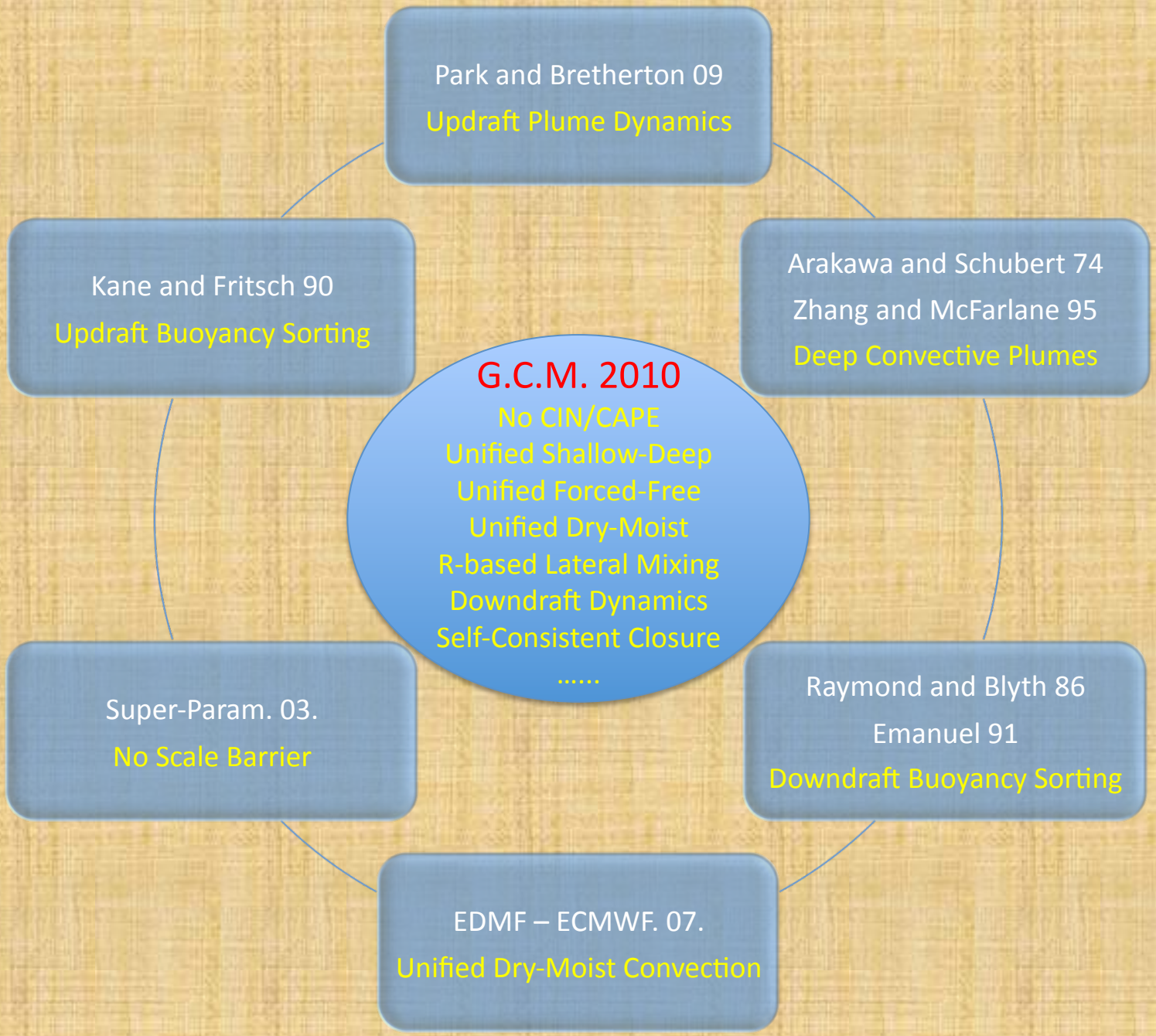
IV. Treatment of Downdraft Dynamics

V. Parameterization of Lateral Mixing

VI. Convection across the Scale Barrier

VII. Cloud Overlap for Microphysics, Radiation, and Aerosol Wet Deposition

VIII. Microphysics interacting with Aerosols


Park and Bretherton 09
Updraft Plume Dynamics
Arakawa and Schubert 74
Zhang and McFarlane 95
Deep Convective Plumes
Raymond and Blyth 86
Emanuel 91
Downdraft Buoyancy Sorting
EDMF – ECMWF. 07.
Unified Dry-Moist Convection
Super-Param. 03.
No Scale Barrier
Kane and Fritsch 90
Updraft Buoyancy Sorting
G.C.M. 2010
No CIN/CAPE
Unified Shallow-Deep
Unified Forced-Free
Unified Dry-Moist
R-based Lateral Mixing
Downdraft Dynamics
Self-Consistent Closure
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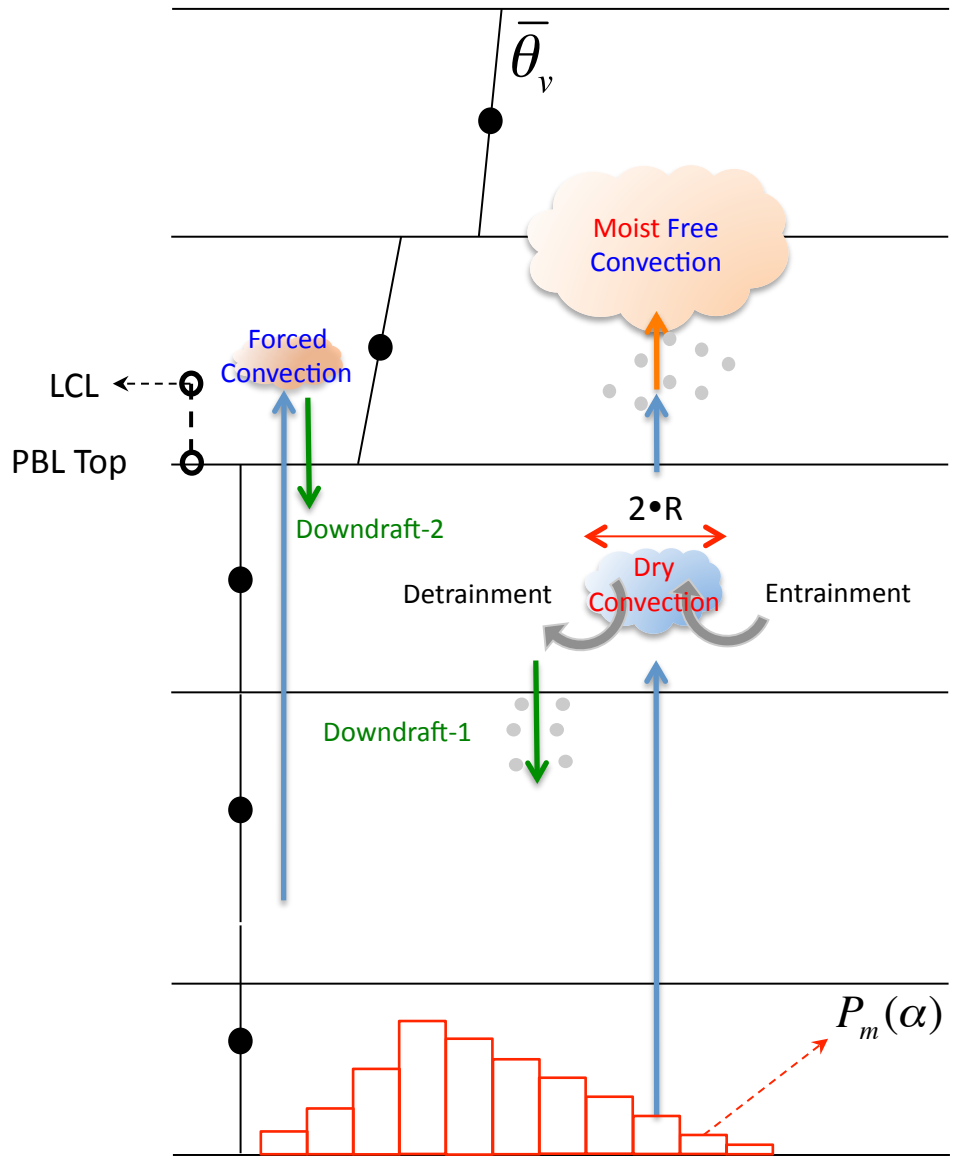
General Convection Model (S. Park 2010)



$$\frac{\pi \cdot R^2}{G} \le a \le 1$$

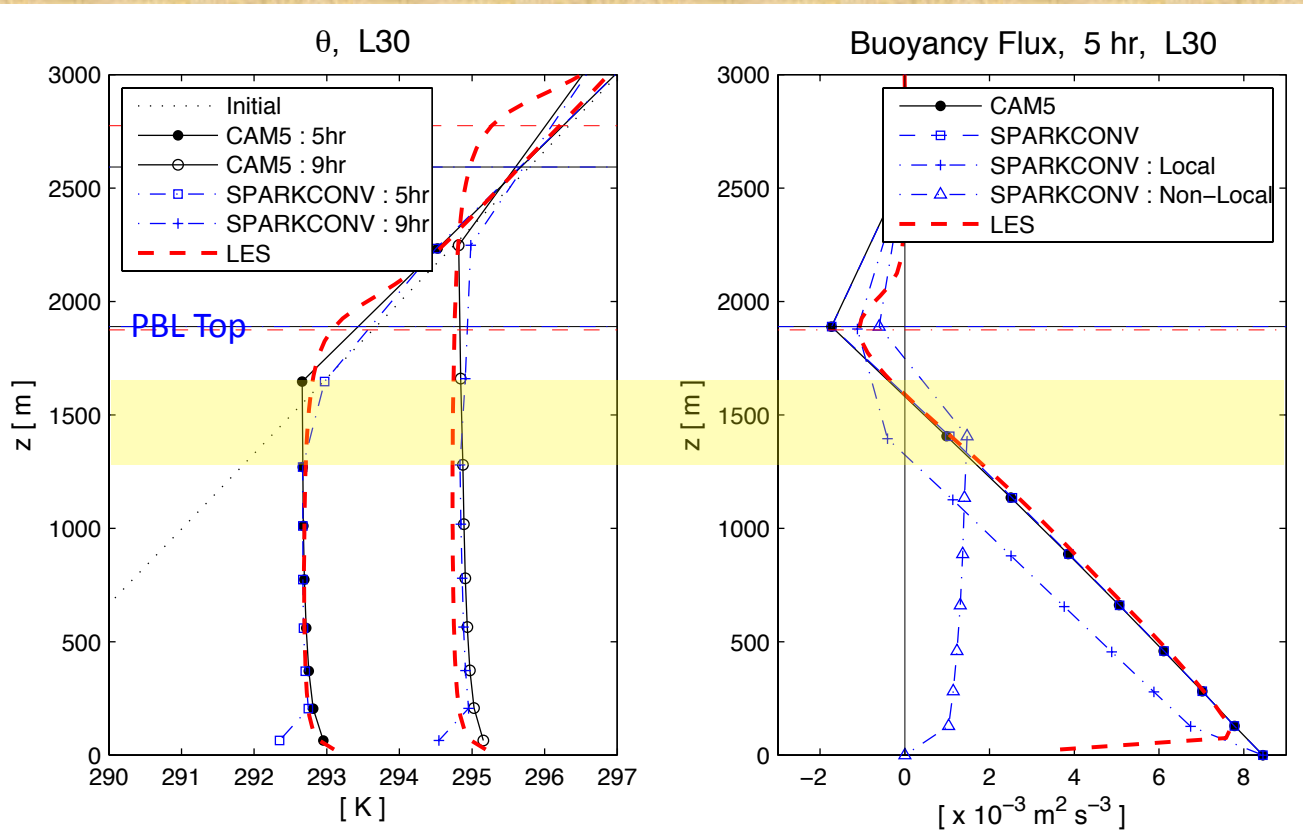
$$\alpha = \left[\frac{\theta(\alpha) - \bar{\theta}(0)}{\sigma_\theta} \right] \quad , \quad \theta = q_t, \theta_l, w, aerosols, R^2$$

Dry Convective PBL

Stratocumulus-Topped PBL

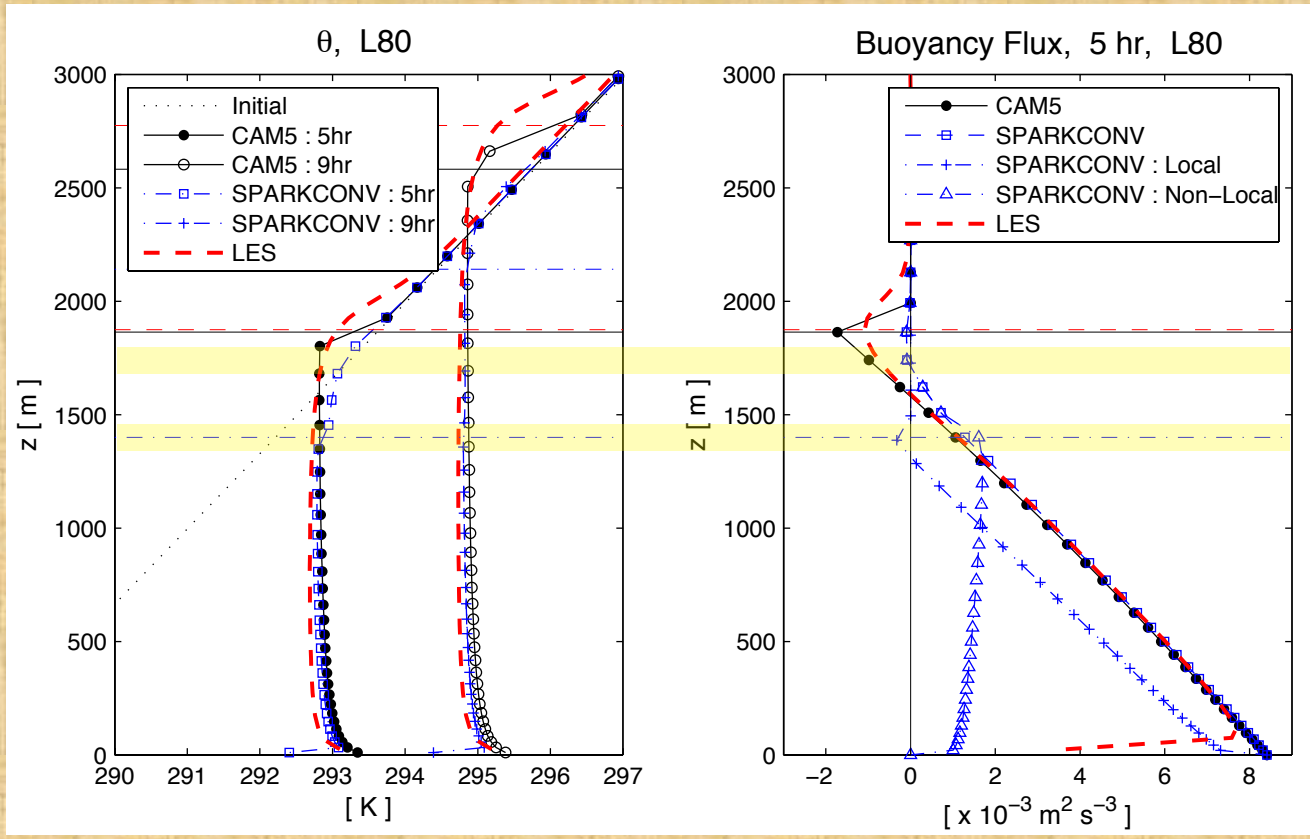
Shallow Cumulus Case

Dry Convective PBL. L30.



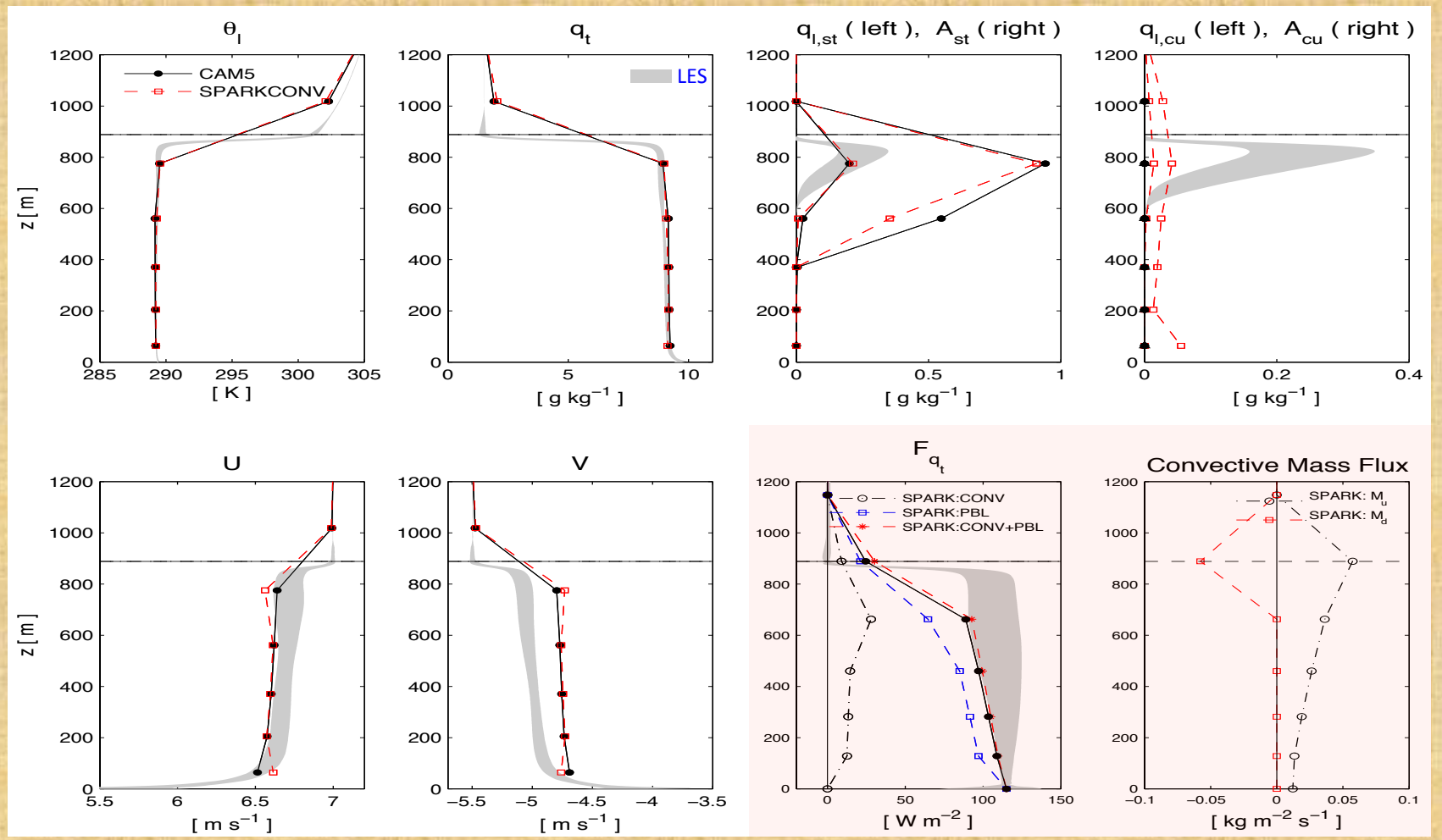
- The non-local transport by the G.C.M. improves the simulation of temperature in the lower and upper PBL.
- The sum of buoyancy flux from the G.C.M and CAM5 PBL scheme is almost identical to the buoyancy flux from the CAM5 PBL scheme alone.

Dry Convective PBL. L80.



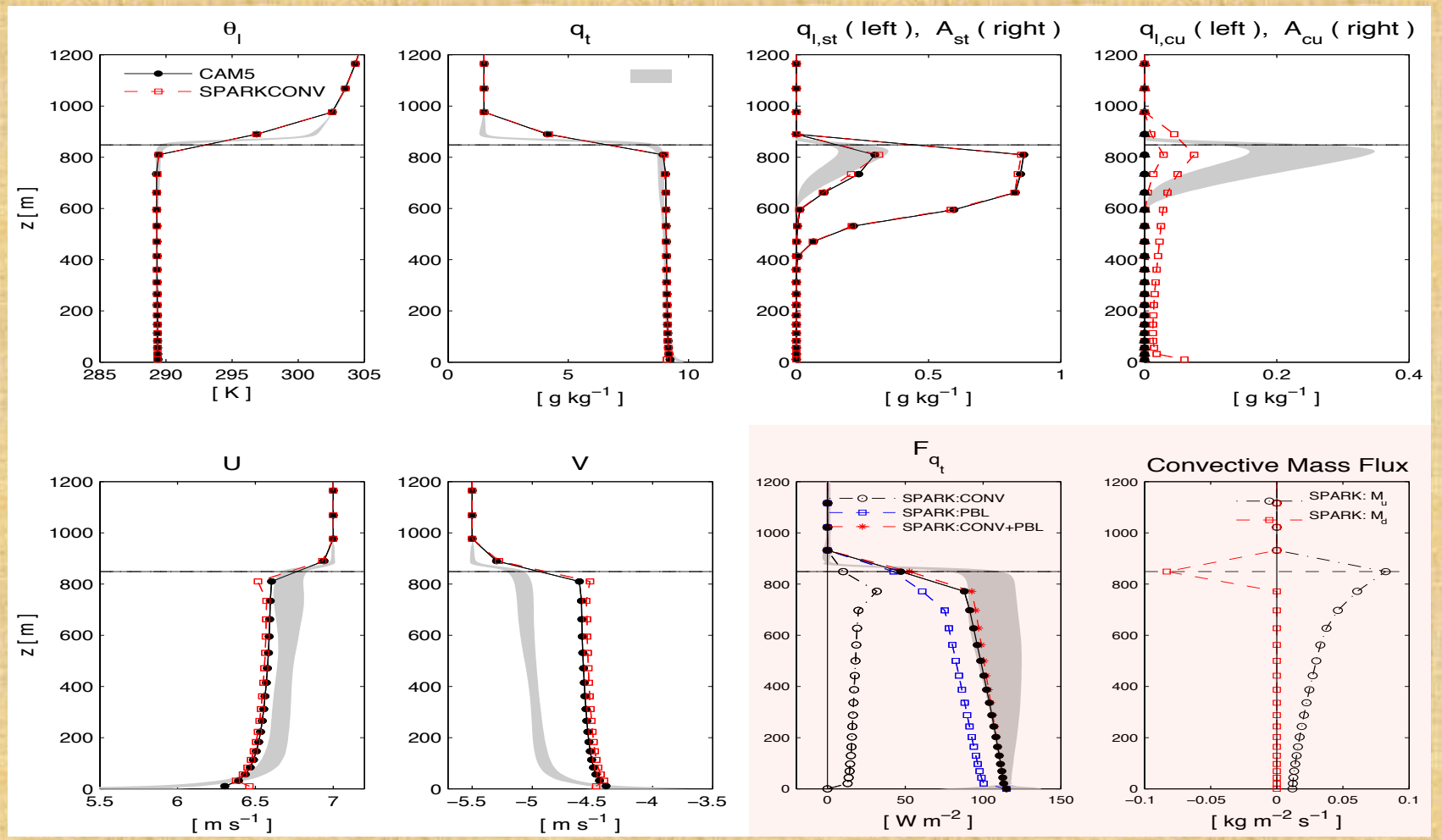
- Due to the enhanced stability in the upper PBL by convective non-local transport, CAM5 PBL scheme underestimates the PBL top height : mismatch between the PBL top height identified from the CAM5 PBL scheme and the base of overshooting zone identified from the G.C.M.
- It is necessary to refine the 'merging criteria' in CAM5 PBL scheme, which will be done.

Stratocumulus-Topped PBL (DYCOMS). L30.



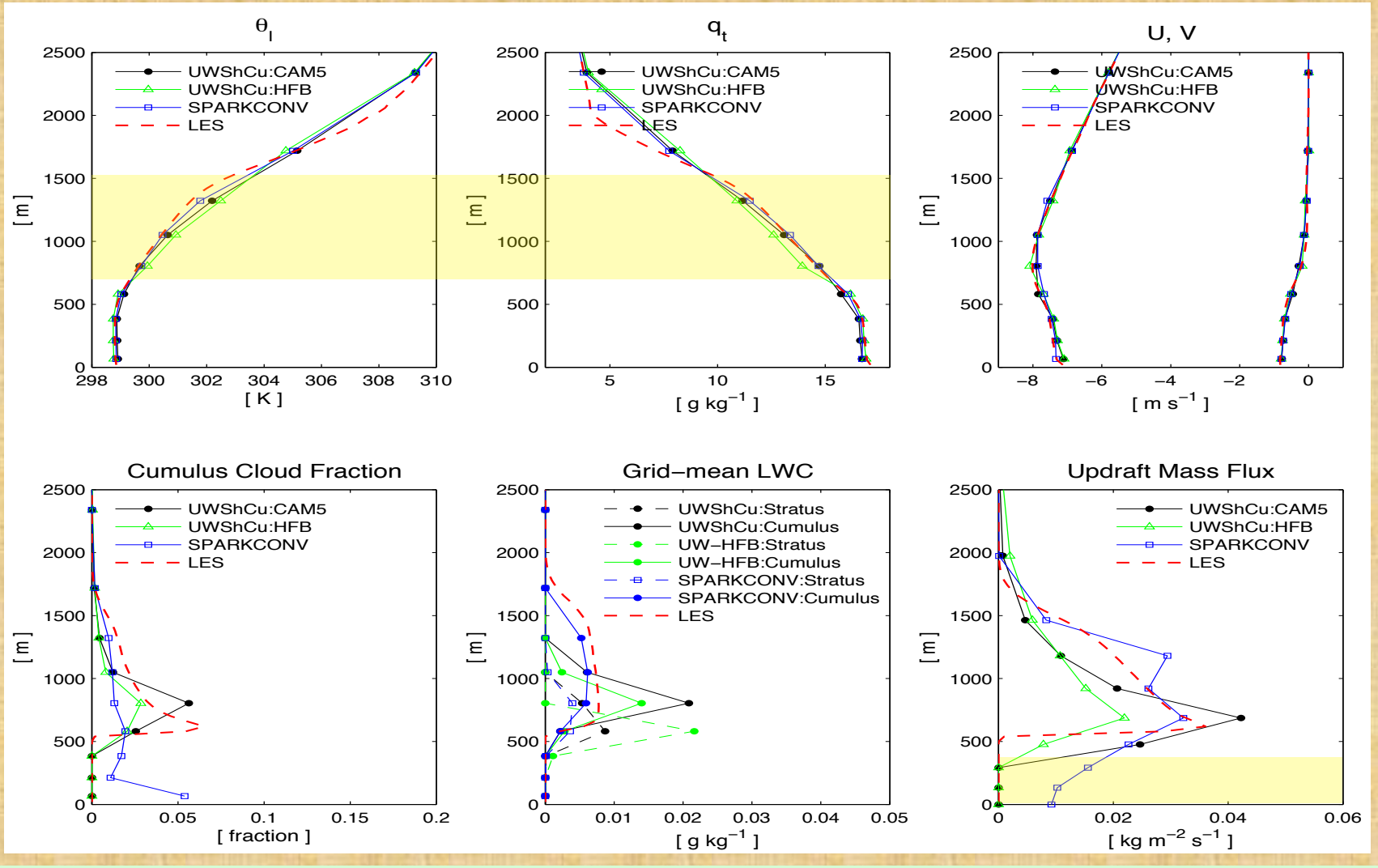
- The G.C.M. is active even in the well-mixed Sc-topped PBL.
- The simulation with G.C.M + CAM5 PBL is quite similar to the one with CAM5 PBL alone.
- The generic convective downdraft in G.C.M. simulates the penetrative entrainment at the PBL top.

Stratocumulus-Topped PBL (DYCOMS). L80.



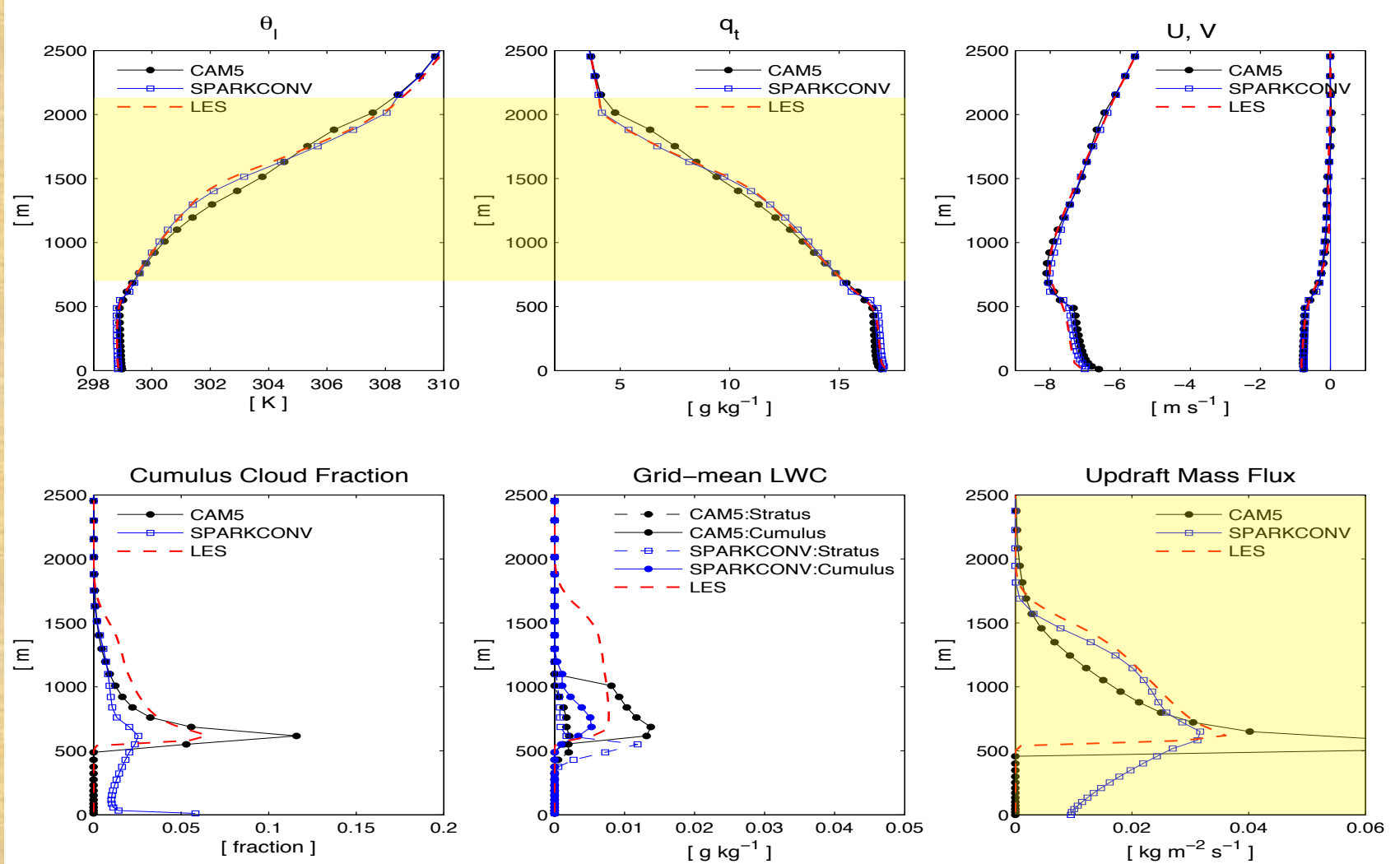
- The G.C.M. is insensitive to vertical resolution.

Shallow Cumulus Case (BOMEX). L30.



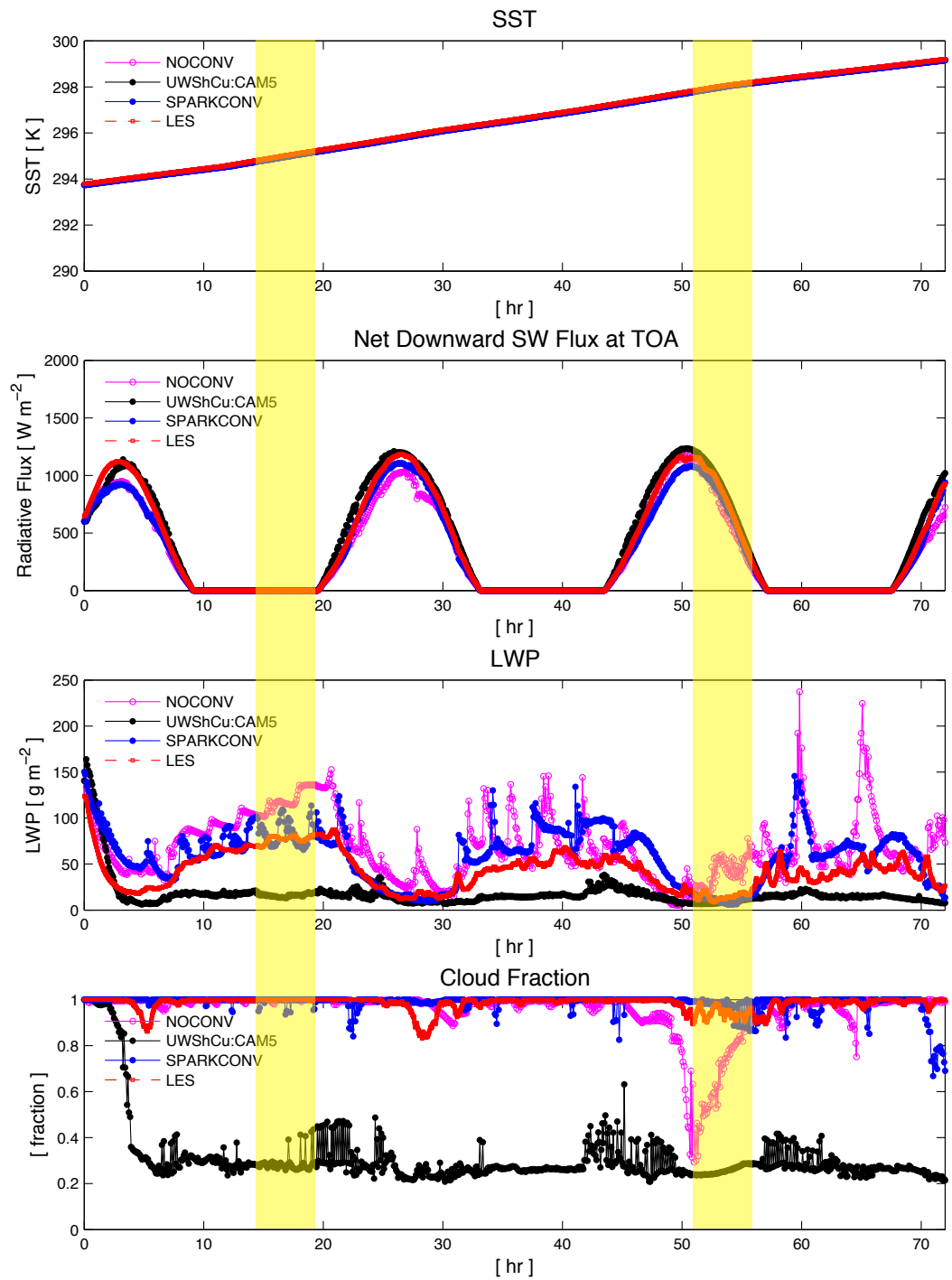
- The modified UW shallow convection scheme by HFB slightly degraded the simulation.
- The G.C.M. is active both above and below the cloud base, i.e., unified treatment of dry and moist convection similar to EDMF.

Shallow Cumulus Case (BOMEX). L80.



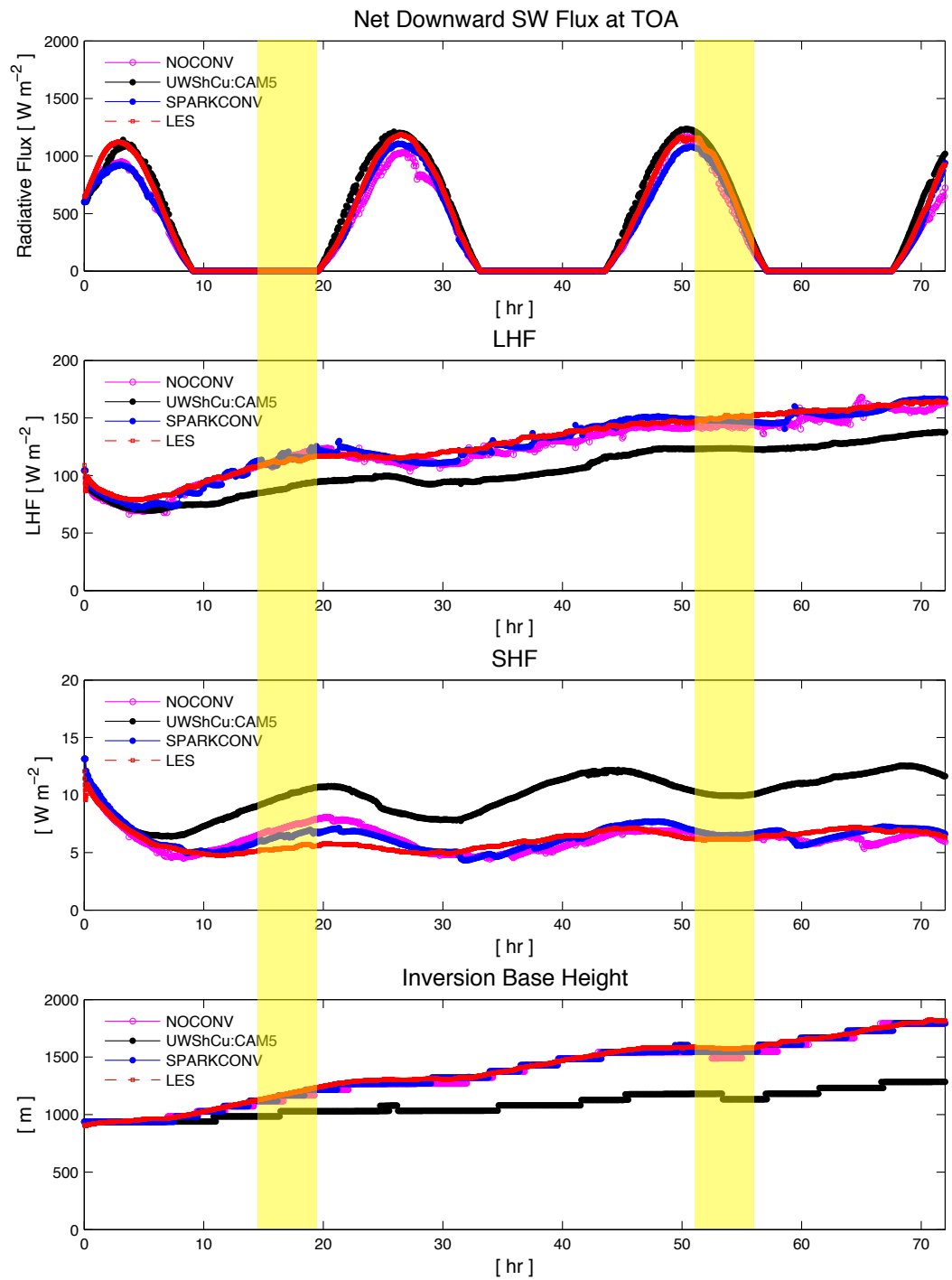
- The G.C.M. very well reproduces the LES.

GCSS Stratocumulus to Cumulus Transition



L160

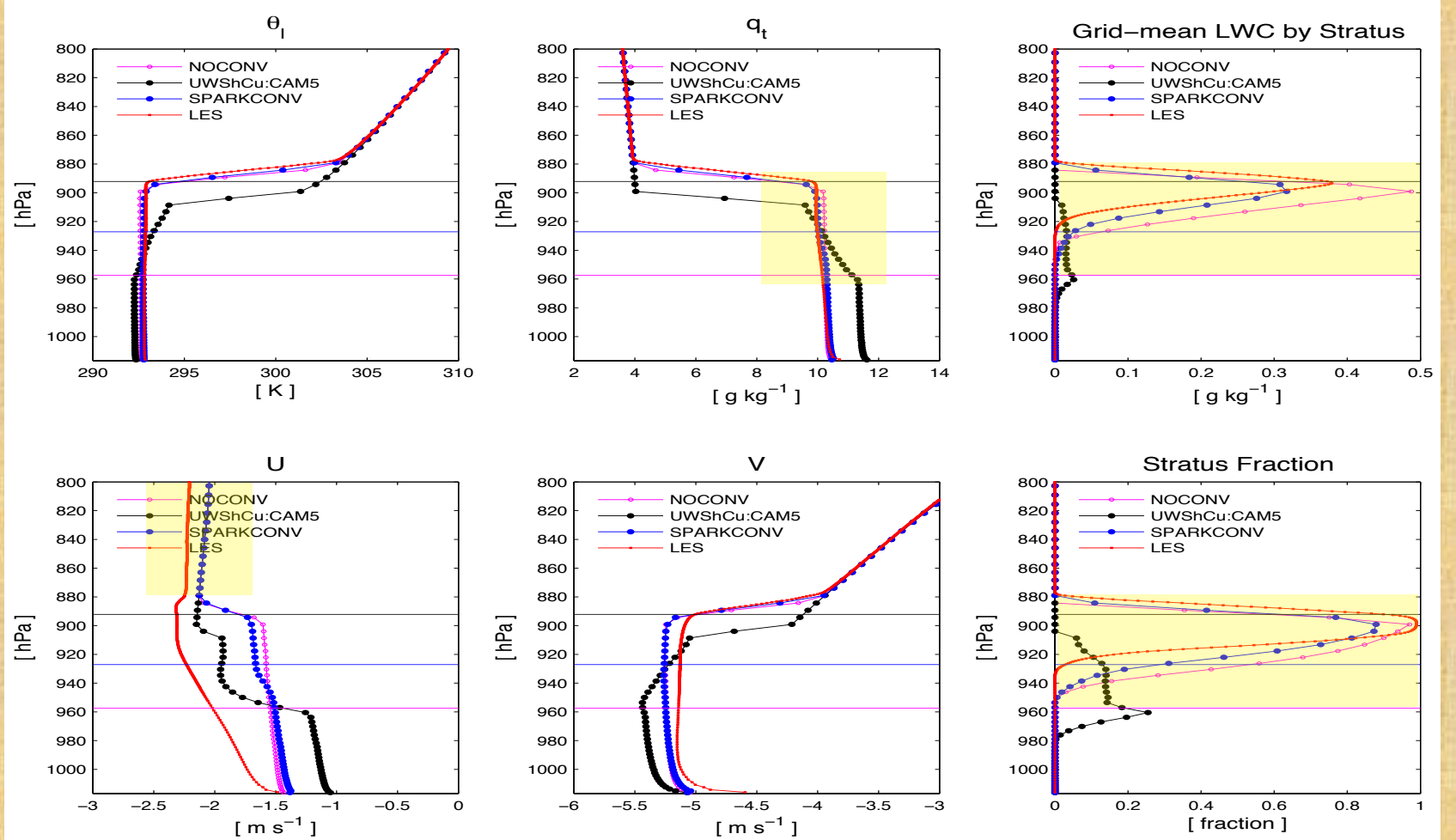
- HR-CAM5 fails to restore stratocumulus from the first night.
- HR-CAM5 with PBL scheme alone well simulates the LES.
- HR-CAM5 with G.C.M. shows even better performance.



L160

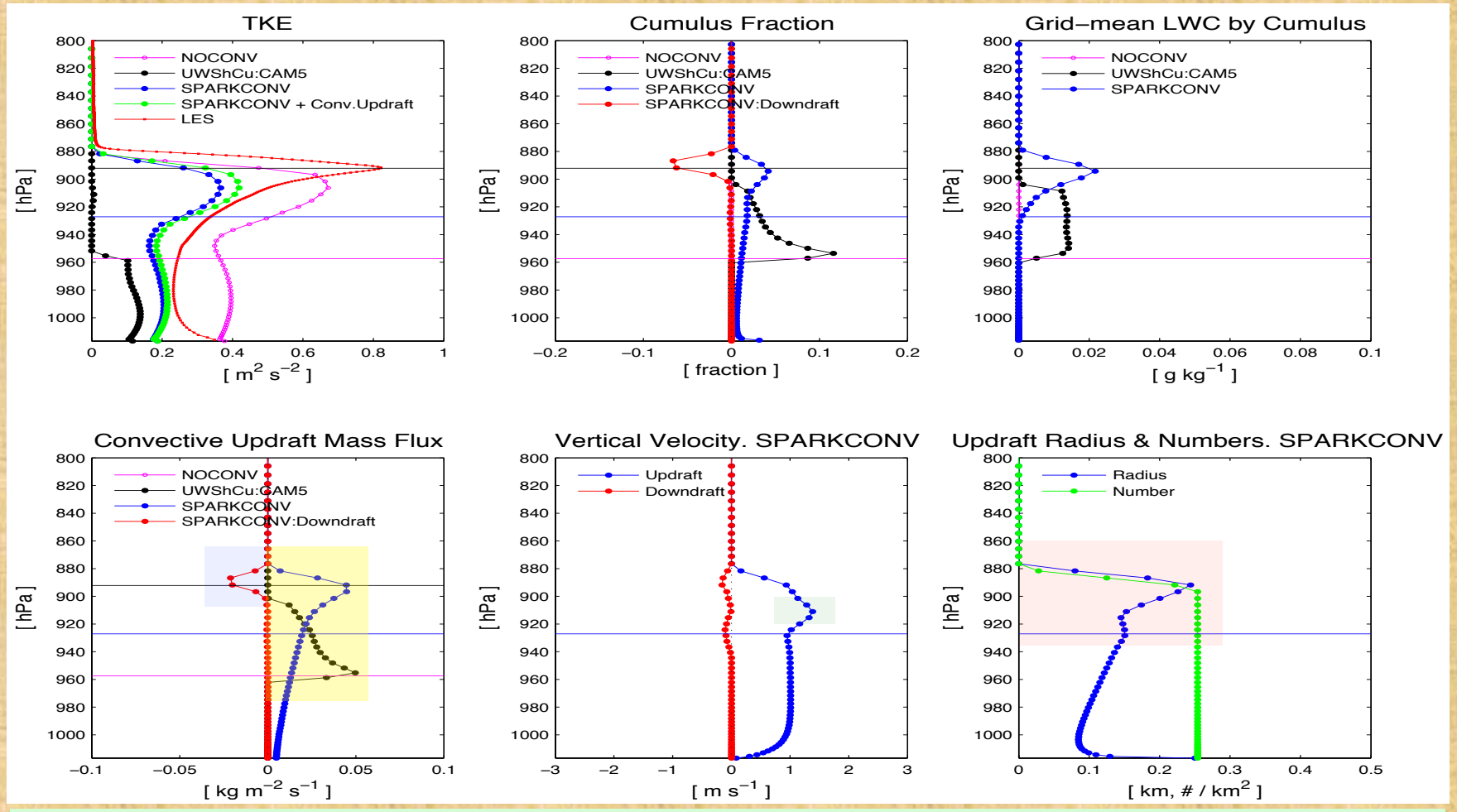
- HR-CAM5 produces too shallow, moist, and cold PBL.
- HR-CAM5 with PBL scheme alone or with G.C.M. shows nice performance.

L160. Hr:15-20. NIGHT



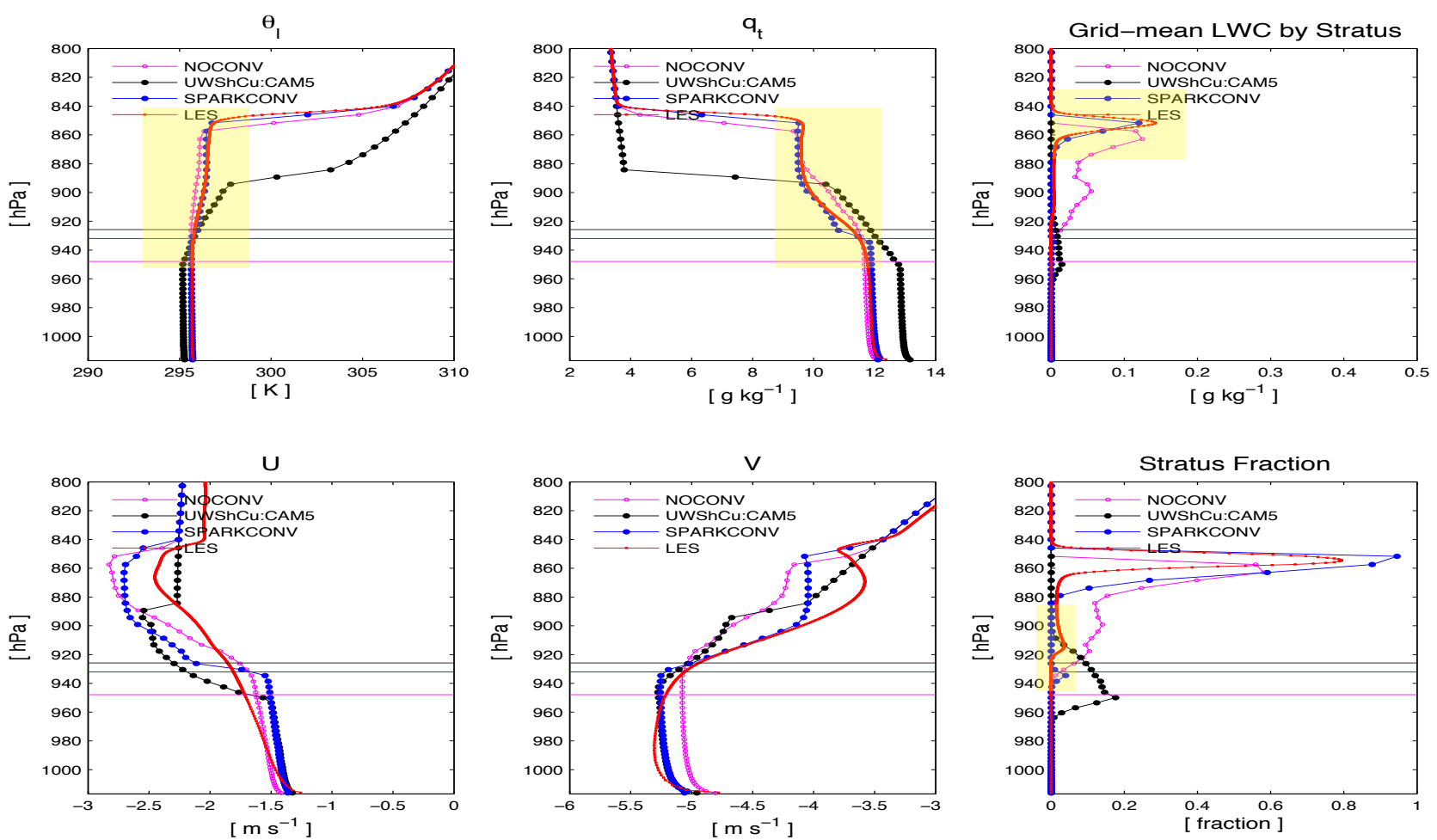
- HR-CAM5 simulates BOMEX-like cumulus layer instead of Sc-topped mixed layer.
- HR-CAM5 with the G.C.M. well reproduces the LES-simulated thermodynamic vertical structures of Sc-topped PBL.
- Zonal momentum (U) shows the largest discrepancy between the LES and SCAM5.

L160. Hr:15-20. NIGHT



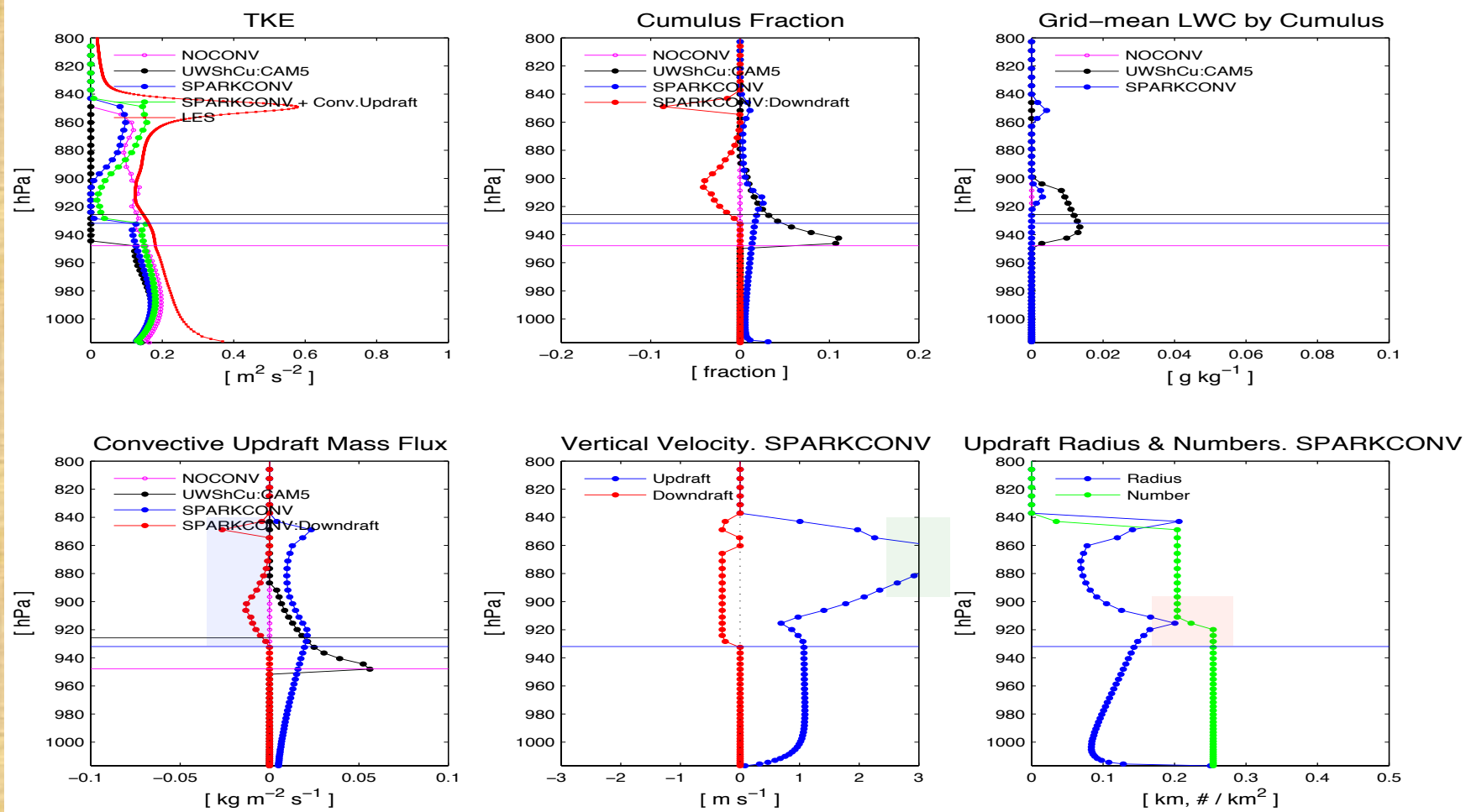
- The shallow convection scheme in HR-CAM5 produces BOMEX-like bottom-heavy updraft mass flux, while the G.C.M. produces to top-heavy mass flux.
- The G.C.M. simulates detailed dynamics of both convective updraft and convective downdraft (i.e., mass flux, vertical velocity, fractional area, and the radius and number density of updraft plumes).

L160. Hr:51-56. DAY



- The G.C.M. nicely simulates thermodynamic structures of decoupled Sc-topped PBL, including vertical distribution of clouds.

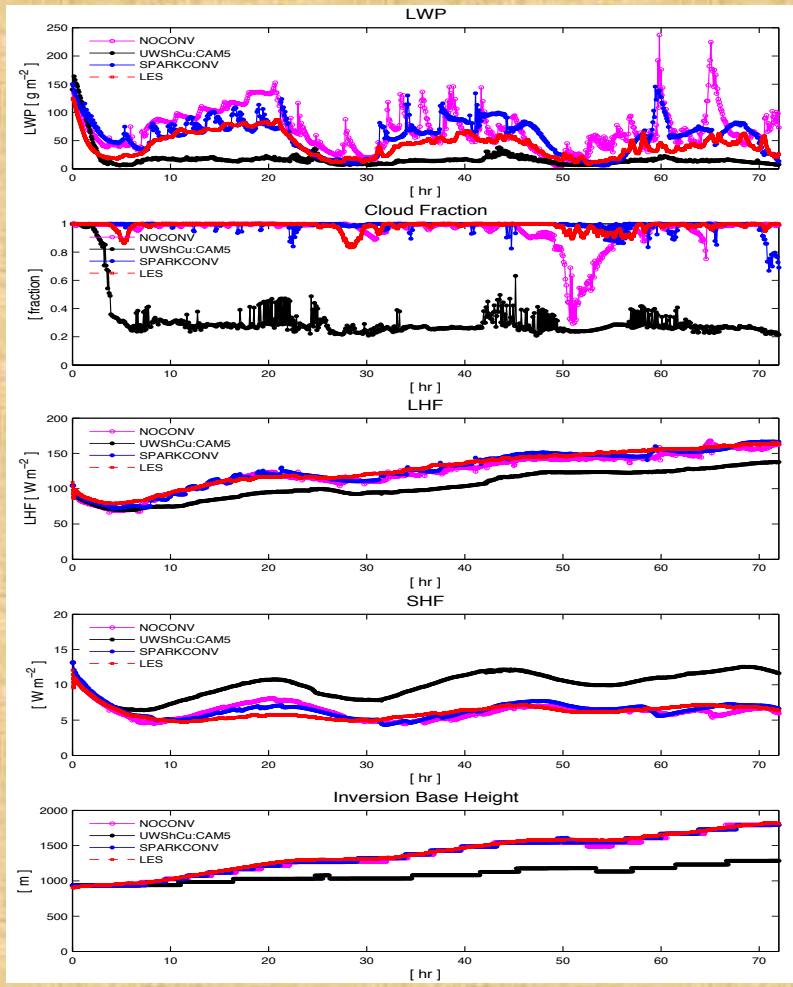
L160. Hr:51-56. DAY



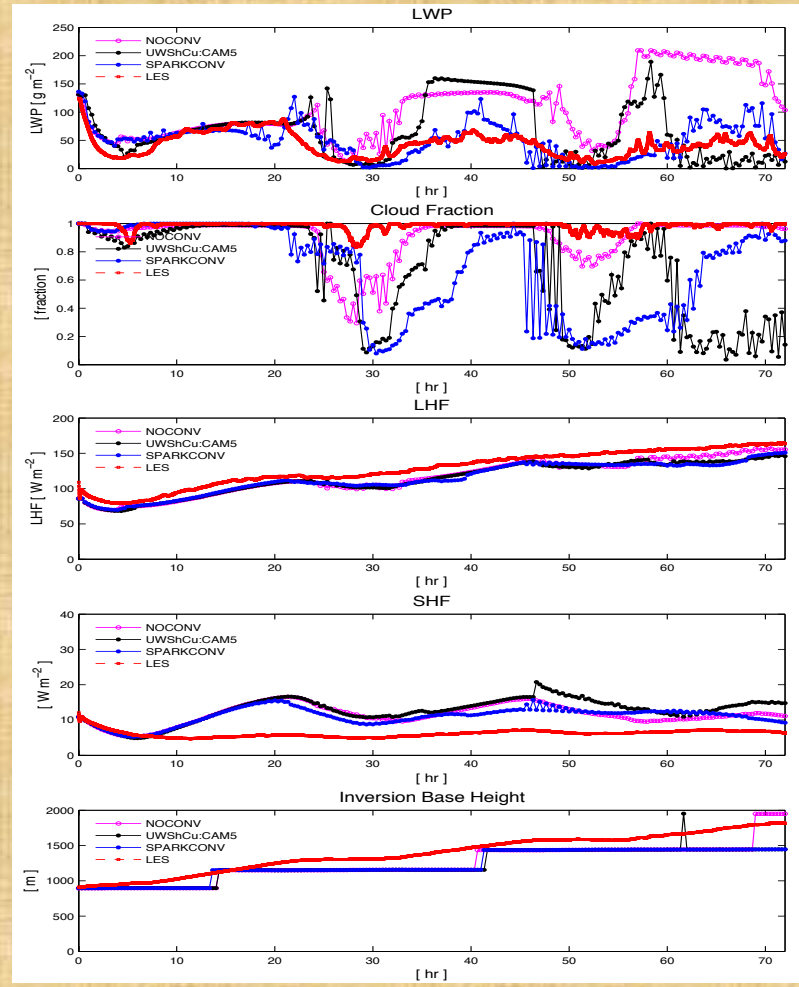
- In G.C.M., generic downdraft simulates both the penetrative entrainment and forced convection (i.e., unified treatment of free and forced convection without separate parameterization for penetrative entrainment process).

Sensitivity to Vertical Resolution

L160

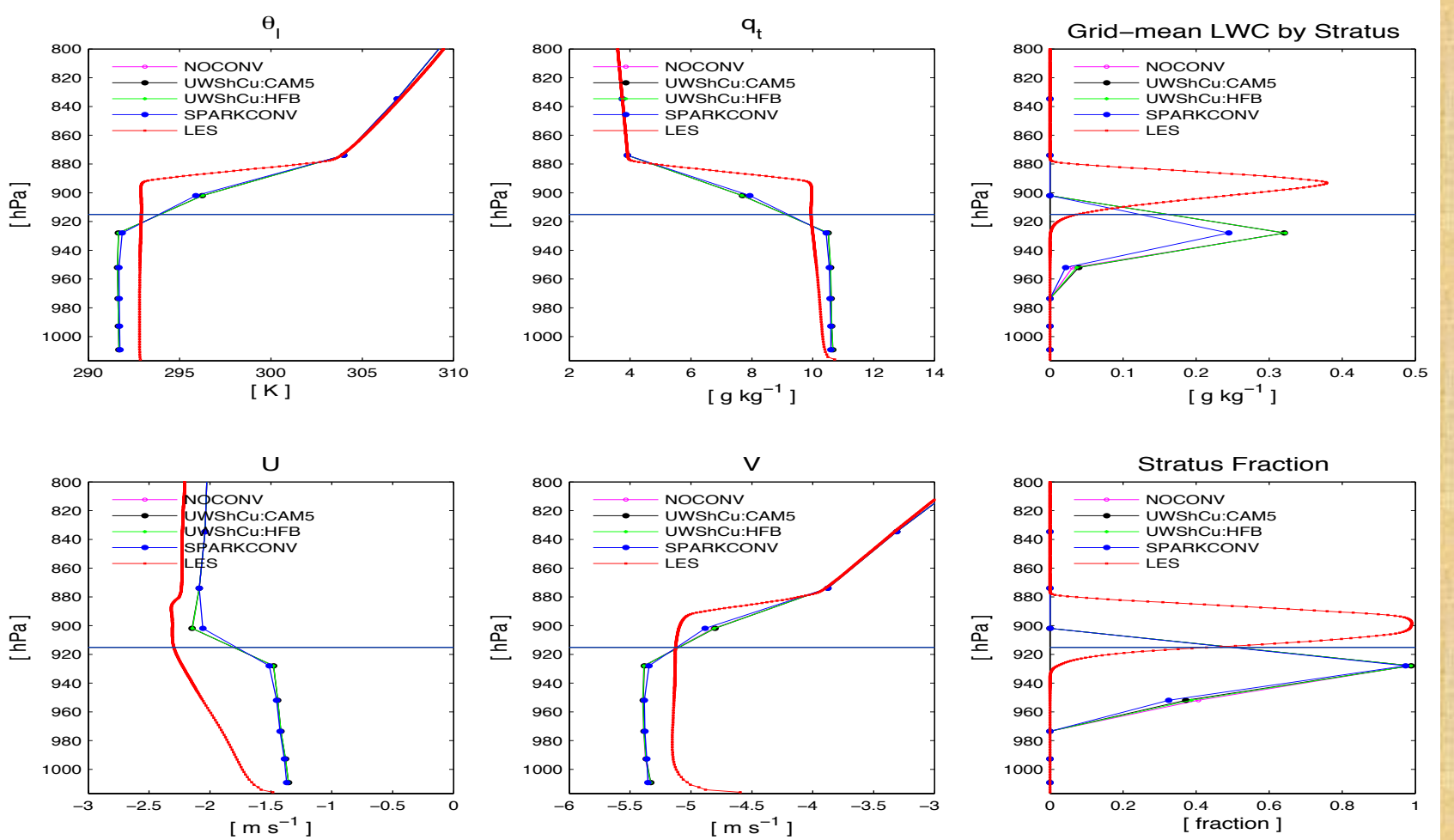


L30



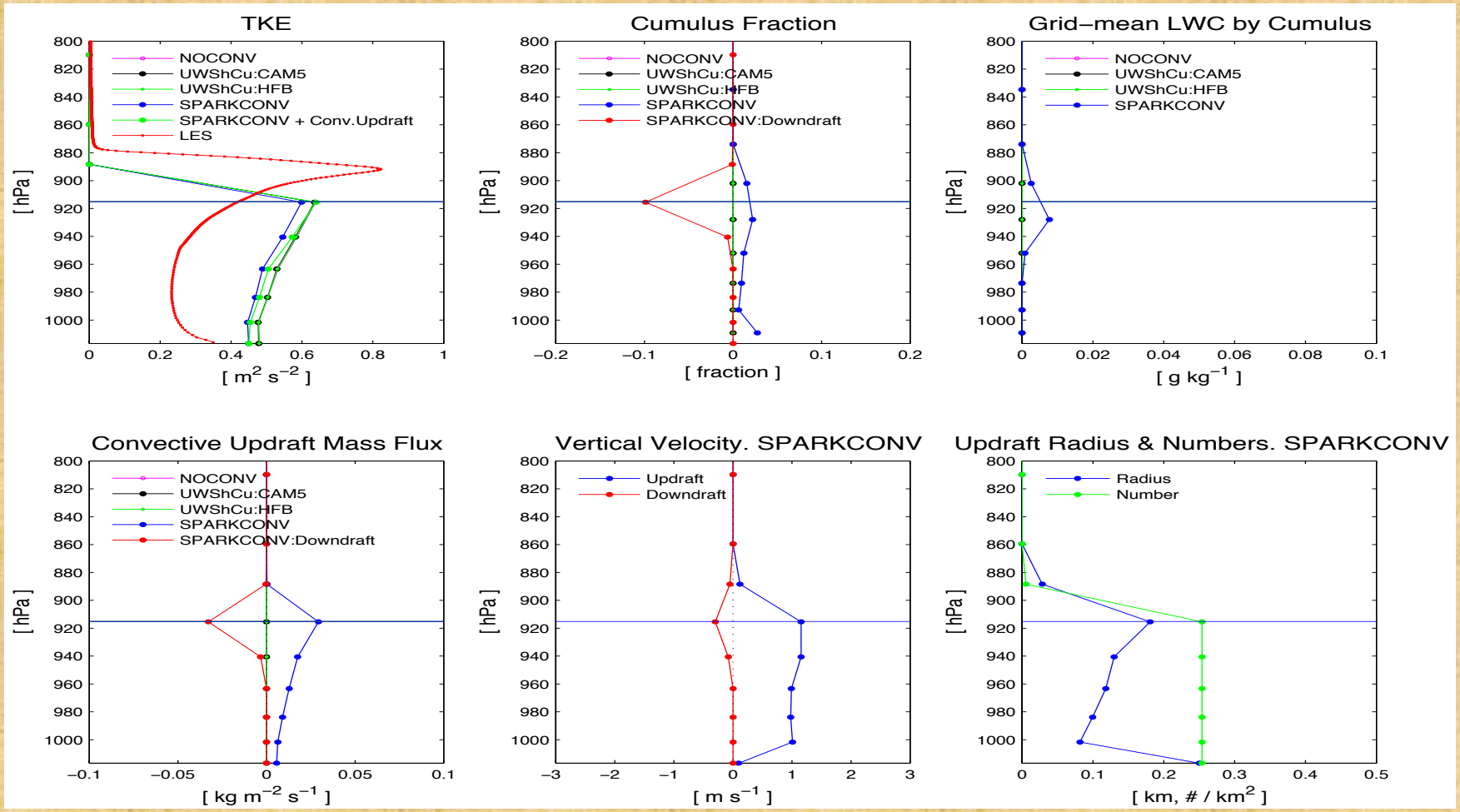
- In the operational low vertical resolution (L30), CAM5 shallow convection scheme shows reasonable performance, similar to G.C.M.
- The G.C.M produces the best LWP with less sensitivity to vertical resolution but the cloud fraction is underestimated in the day time.
- Regardless of convection scheme, LR-CAM5 produces too moist and cold PBL.

L30. Hr:15-20. NIGHT



- Regardless of convection schemes, (1) simulated stratocumulus is located one layer below the right position, and (2) PBL is too moist and cold PBL.
- We may need more strongly-localized radiative flux divergence in the Sc-filled, PBL top layer in order to strengthen moist turbulence within the CAM5 PBL scheme.

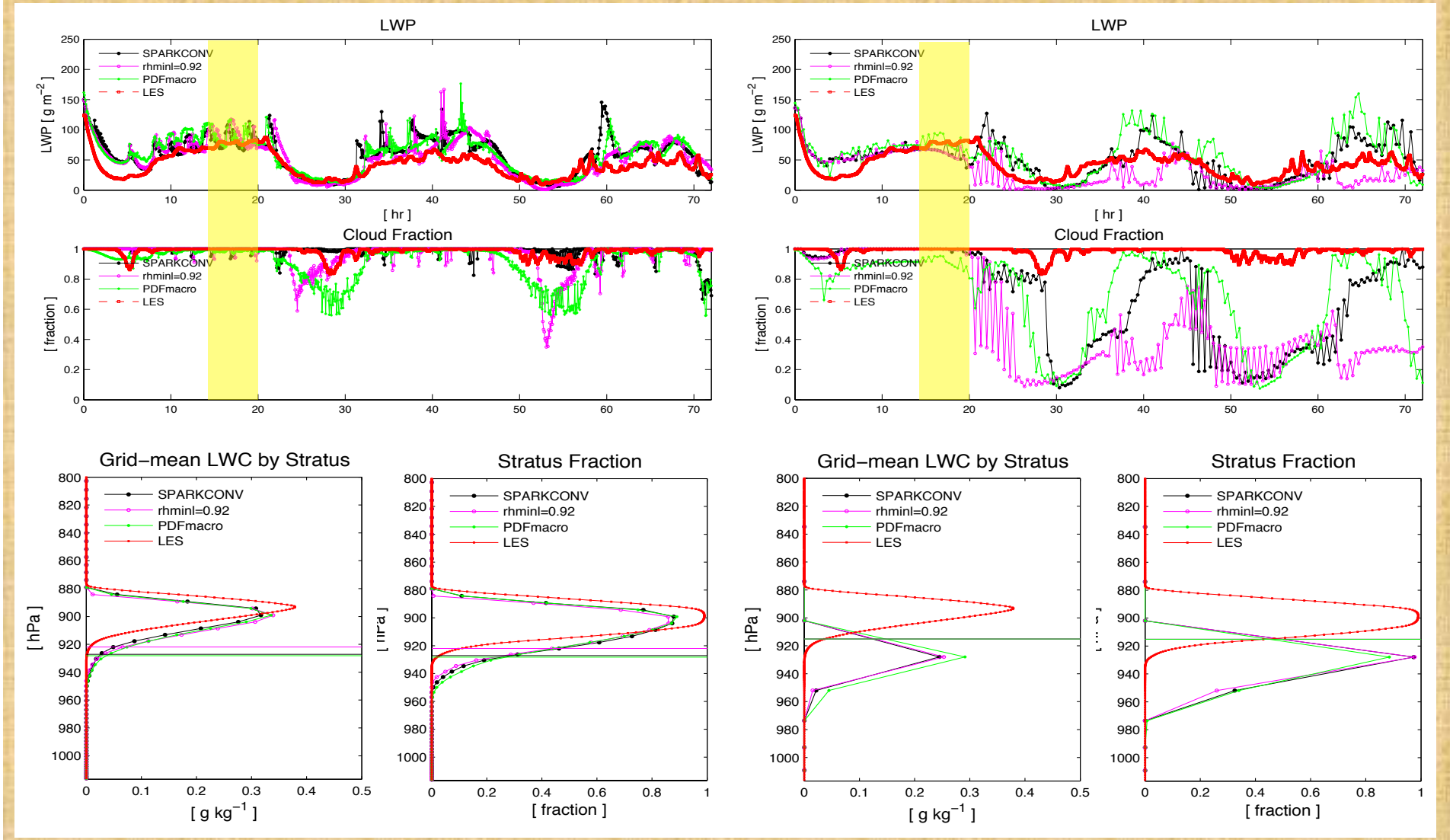
L30. Hr:15-20. NIGHT



Sensitivity to Cloud Macrophysics

L160

L30



- PDF-macrophysics produces very similar results to default CAM5 prognostics macrophysics, but with (1) smaller cloud fraction during daytime in the HR simulation and (2) less oscillation in the LR simulation.

SUMMARY

- CAM5 well simulates DCBL, DYCOMS, BOMEX both in LR and HR, and GCSS Sc-Cu transition case at operational LR.
  However, it does not generate enough stratocumulus in the HR simulation, due to overactive shallow convection scheme.

- The newly-developed General Convection Model (G.C.M. or SPARKCONV) shows promising performances in all the 4 cases above with less sensitivity to vertical resolution.
  Further tests for deep convective cases as well as global simulations are being performed.

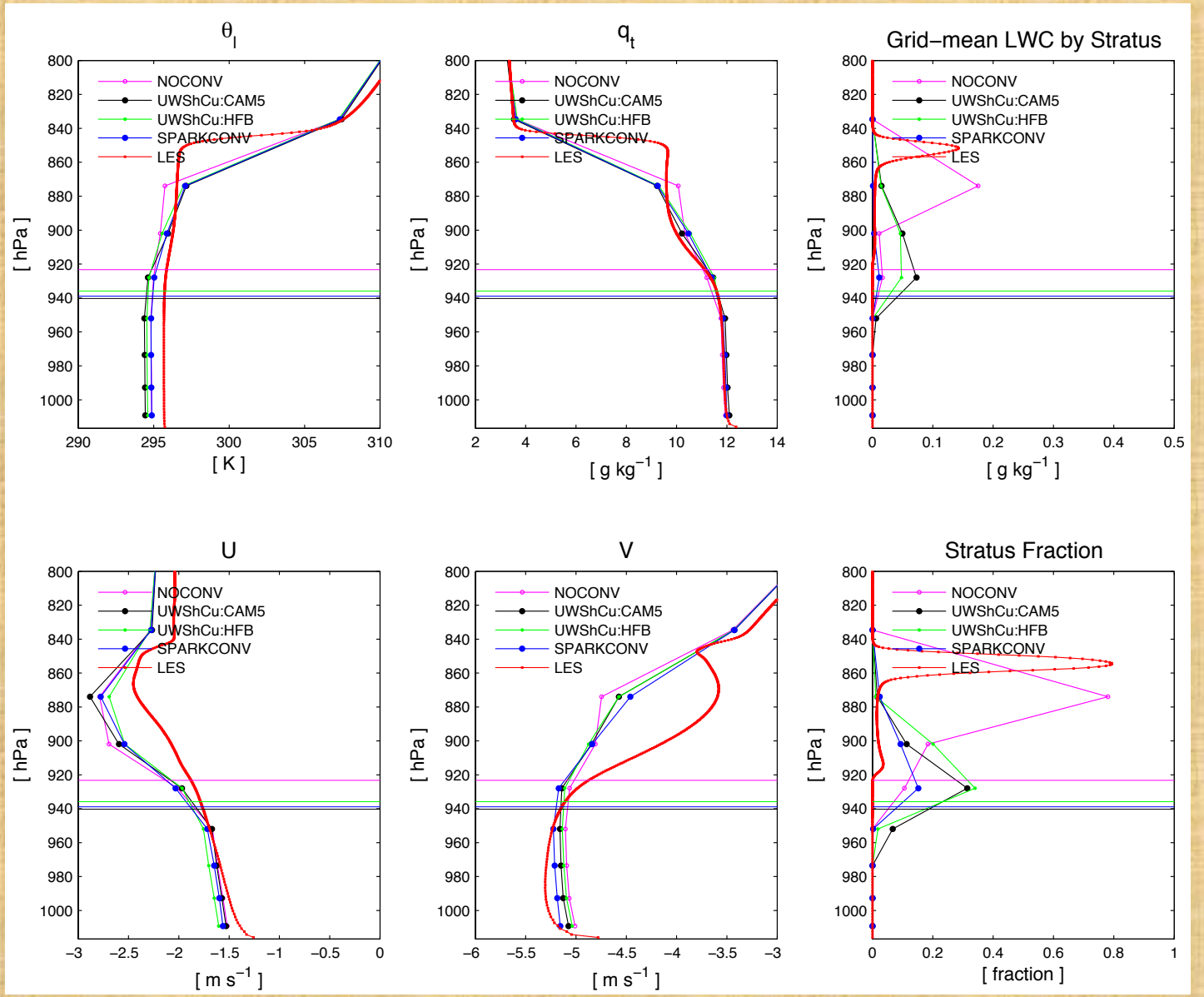
- Slight refinements of CAM5 PBL scheme may be necessary (CL-merging criteria, the fraction of radiative flux divergence confined near the top interface of Sc-filled layer) in order to further deepen the PBL.

- PDF-macrophysics shows performance very similar to the CAM5 prognostic macrophysics in the GCSS Sc-Cu transition case.

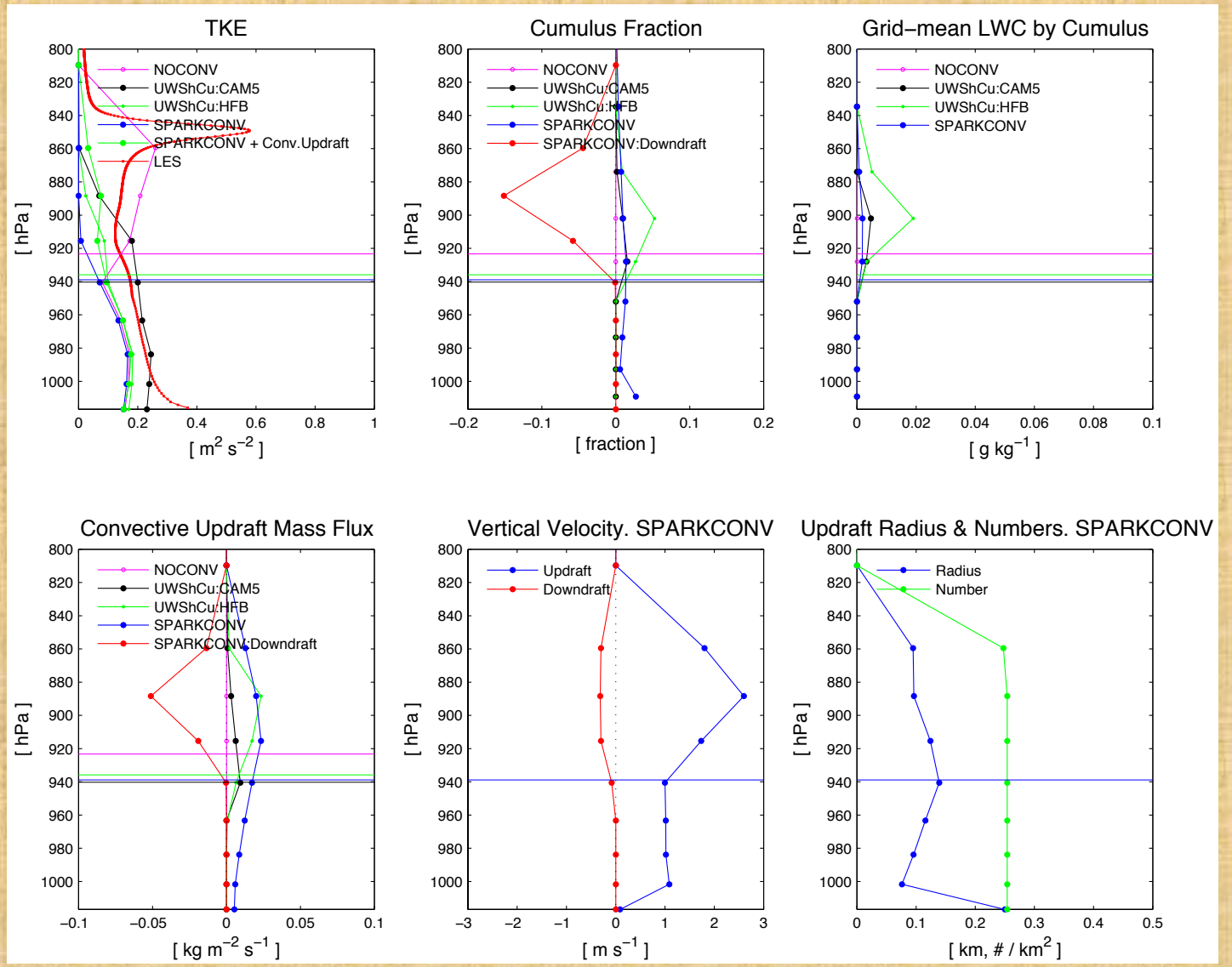
L30

Hr:51-56

DAY



L30

Hr:51-56

DAY