Preliminary Simulations of the CFMIP/GCSS LES Intercomparison and Column Modeling of Sc Feedbacks in SP-CAM

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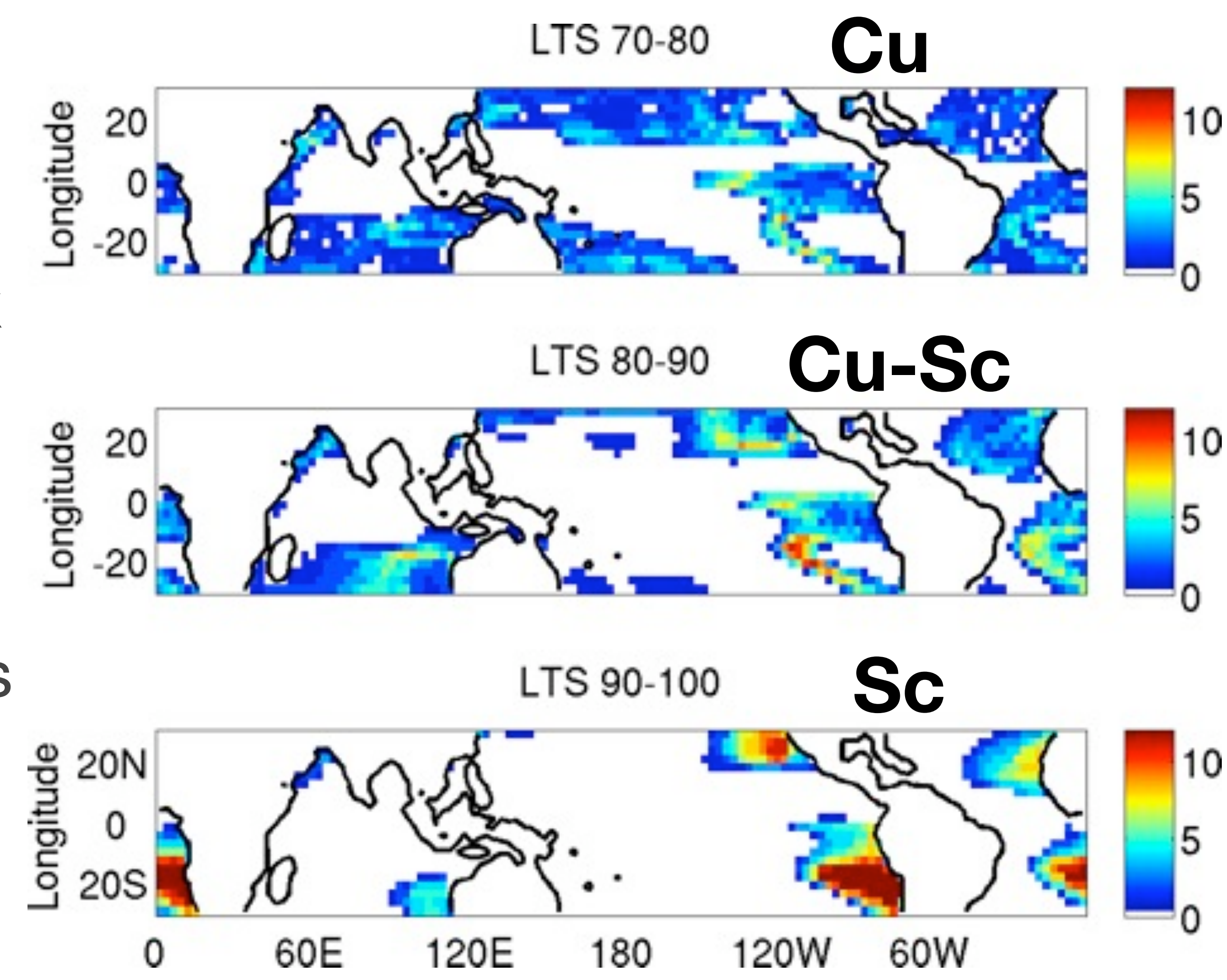
with help from Matt Wyant and funding from CMMAP/NSF.
Thanks to Marat Khairoutdinov for SP-CAM runs, SAM and his drizzle scheme.

Outline

- Column modeling of stratocumulus cloud feedbacks in SP-CAM:
  - Background on column modeling approach, LTS-binning.
  - Focus on stratocumulus region composite using 90-100th LTS percentiles.
  - Column model results: sedimentation, diurnal cycle.
  - Negative cloud feedbacks with most configurations.
- Preliminary simulations of GCSS/CFMIP LES intercomparison (s11 case):
  - Temperature drift above inversion allows additional BL deepening.
  - Omega feedback
  - Drizzle feedback reverses sign of ΔSWCF.
  - Boundary layer structure and cloud feedback are sensitive to configuration.

Column Modeling Approach

- Large-scale context for column model runs is extracted from GCM runs of control and perturbed climates. GCM is SP-CAM. CRM/LES is SAM 6.5, 6.7.
- Large-scale context: SST, soundings, omega, large-scale horizontal advection.
- Monthly SP-CAM output over tropical oceans composited based on deciles of lower tropospheric stability (LTS).
- Column LES/CRM use omega-feedback to simulate the effect of stratified adjustment in the tropics, limits T drift from composite soundings.
- Old work: Column LES/CRM simulations based on SP-CAM's 70-80th & 80-90th percentile composites based on LTS.
- New work: LTS 90-100 from SP-CAM, CFMIP LES intercomparison



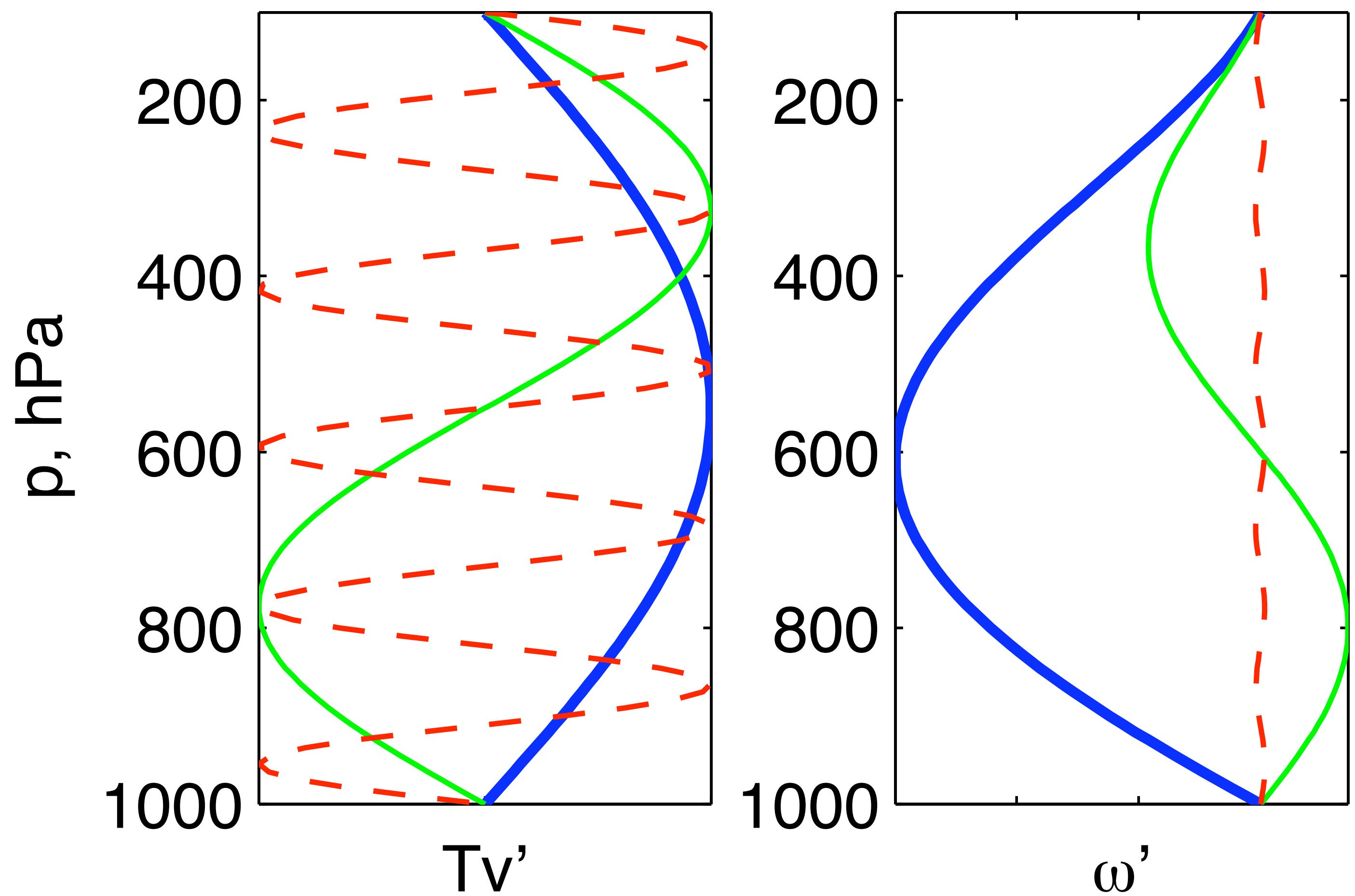
Months per year in given LTS decile

Omega Feedback

- Simulates effect of stratified adjustment: local temperature anomalies are removed by large-scale vertical motion.

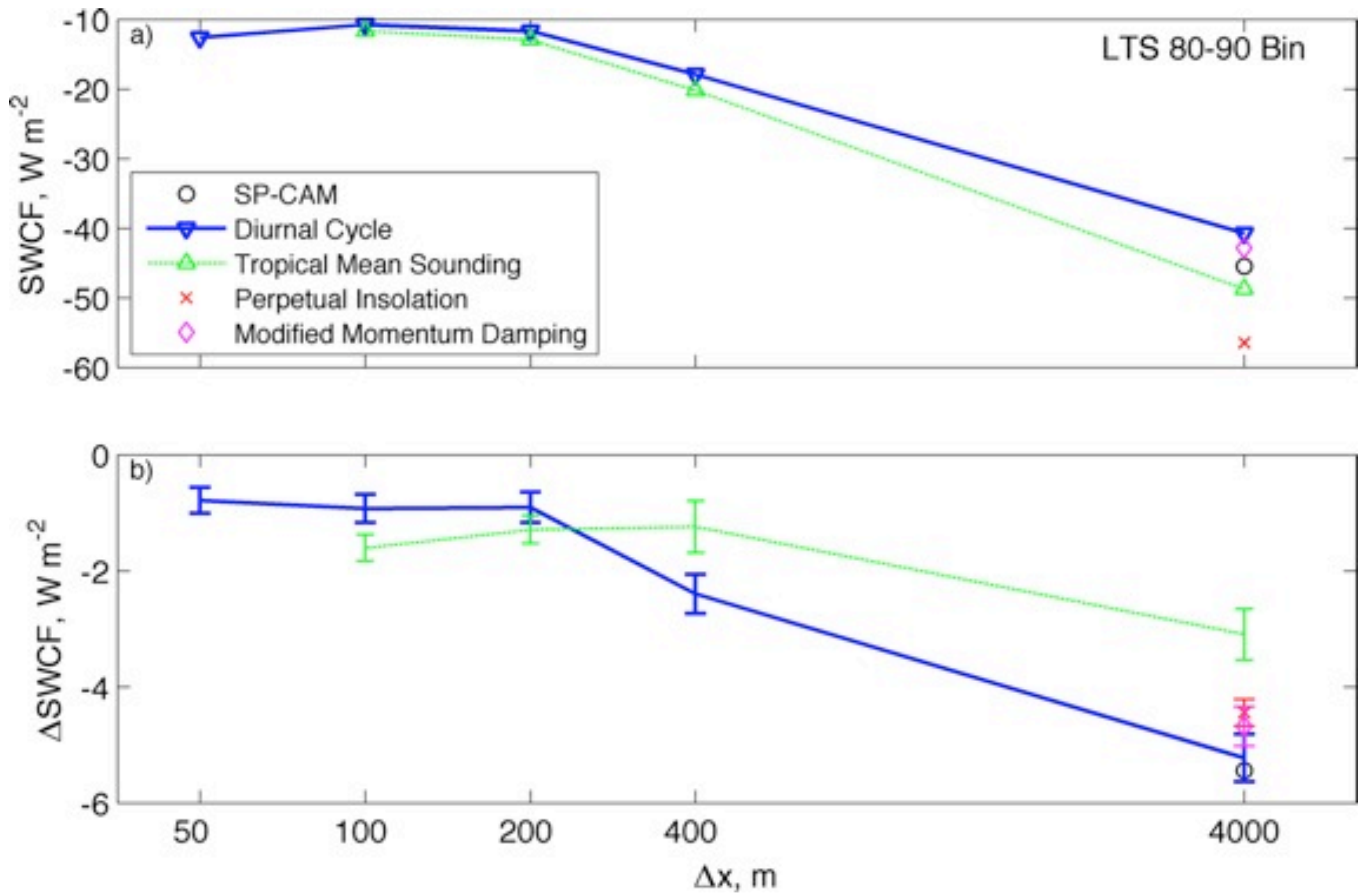
$$\frac{\partial}{\partial p}\left(\frac{f^2 + a_m^2}{a_m}\frac{\partial \omega'}{\partial p}\right) \approx \frac{k^2 R_d}{p} T_v'$$

- Here, T_v' and ω' are anomalies from specified profiles.
- A lengthscale (which fixes *k*) and a profile of momentum damping rate (a_m) must be chosen.



Column Modeling of Composite SP-CAM Trade Cumulus Regimes (Blossey et al. JAMES to appear)

- Column CRM/LES simulations using composite forcings from SP-CAM's 70-80th and 80-90th percentiles of lower tropospheric stability (LTS).
- **CRM/SP-CAM:** Δx=4km, Nz=30. **LES:** Δx=50-400m, Δz=20-160m in BL.
- Column CRM's cloud climatology and +2K cloud response for 70-80th and 80-90th deciles of LTS is broadly similar to SP-CAM.
- Column LES has less cloud and weaker SWCF & ΔSWCF. ΔSWCF<0 for LTS 80-90, ΔSWCF~0 for LTS 70-80.
- Diurnal cycle important.
- CRM/SP-CAM: Radiatively-driven Cu increase.
- LES: more Sc under stronger inversion in +2K runs.



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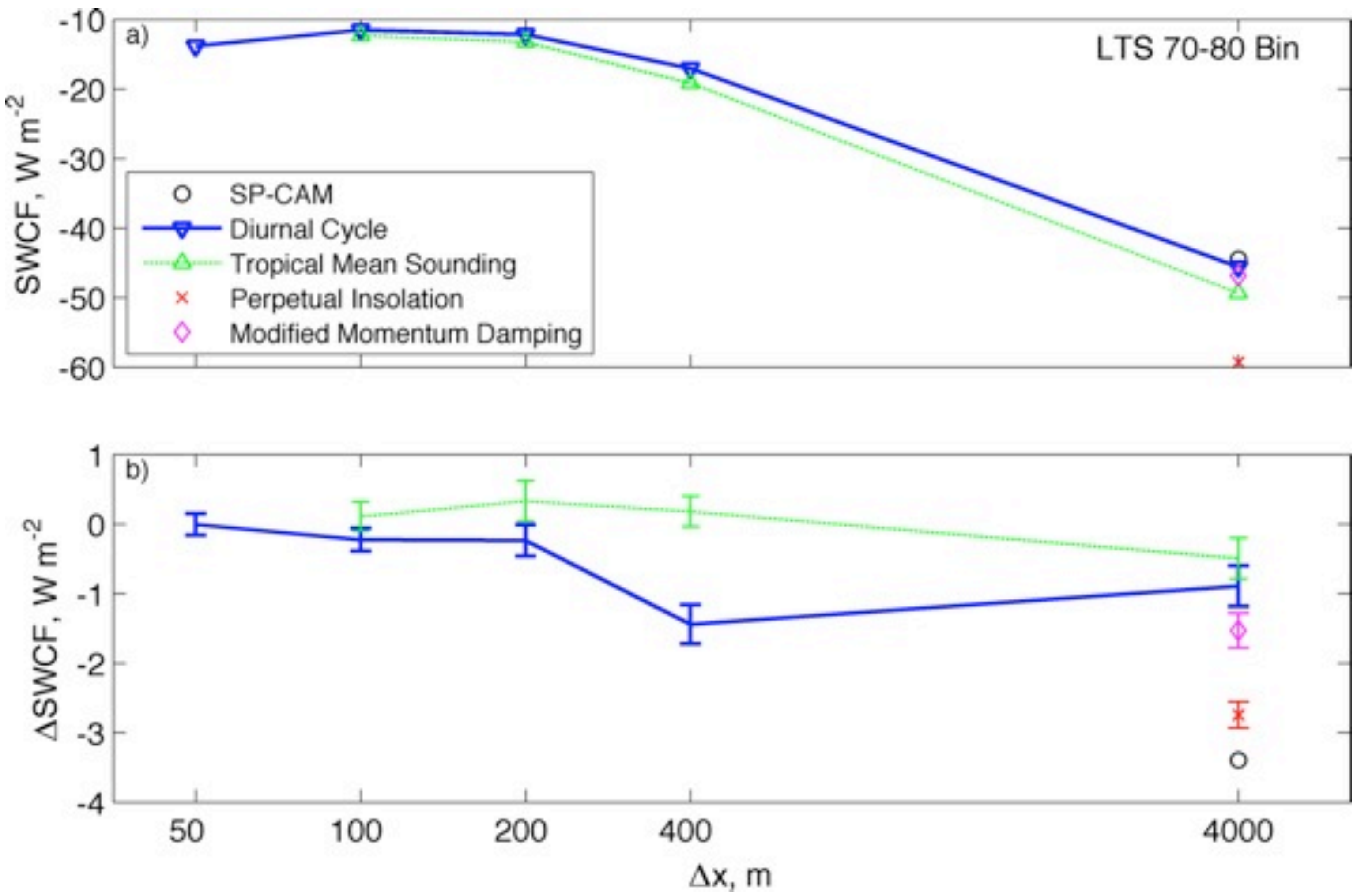
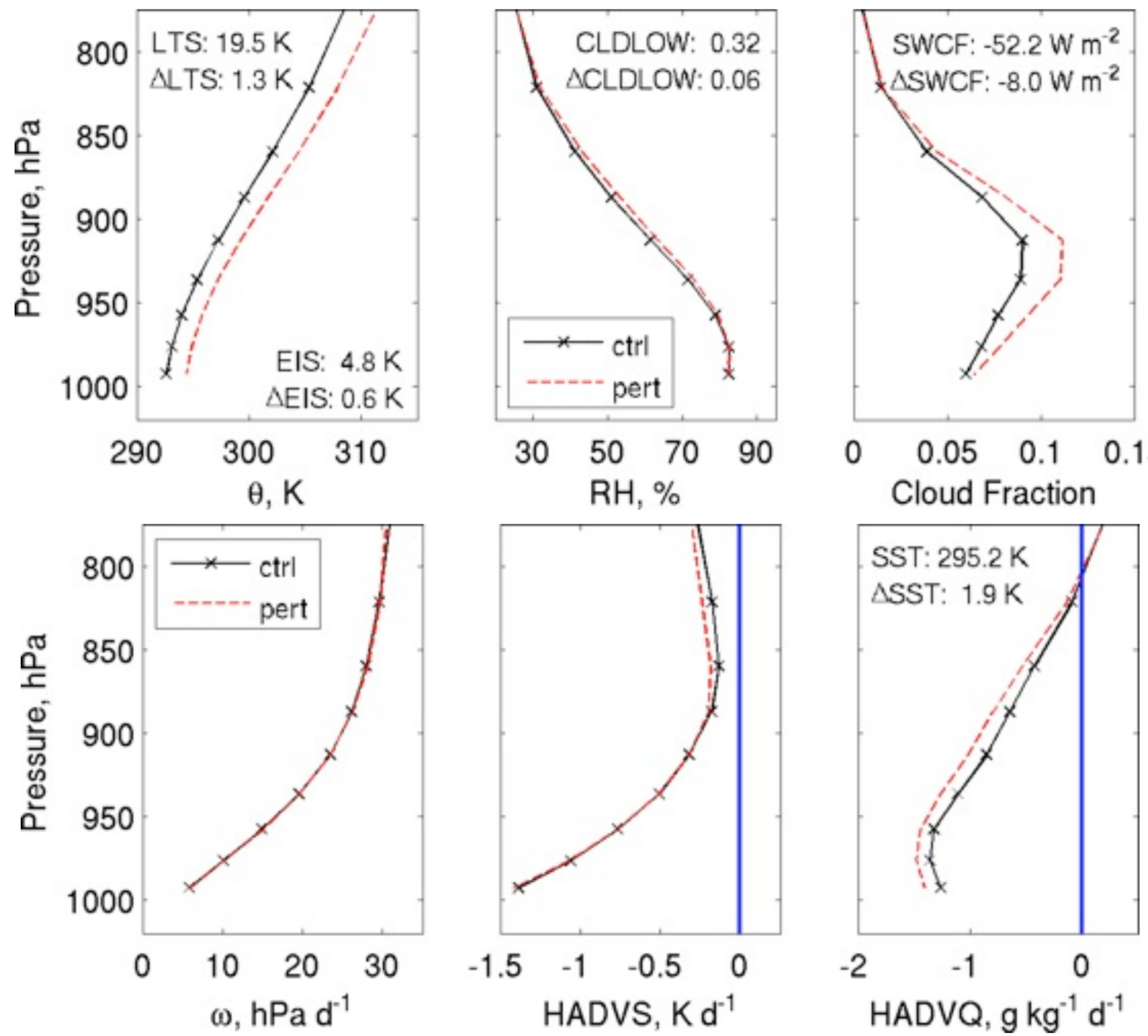


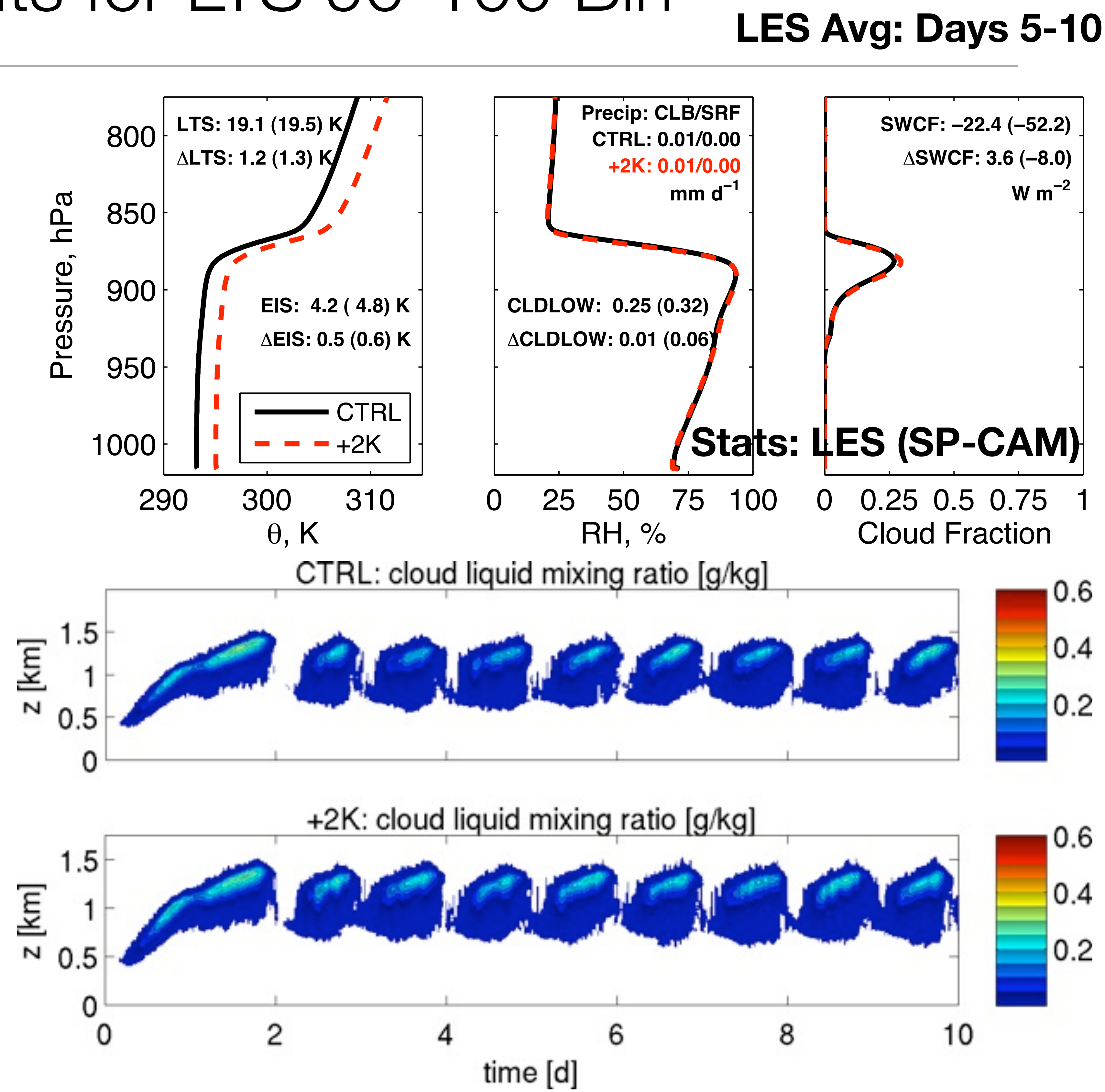
SP-CAM climatology in 90-100th percentile of LTS

- Insufficient resolution leads to imperfect simulation of Sc clouds in SP-CAM.
- SP-CAM shows +2K increase in low cloud and radiative cooling in BL in LTS90-100, also across subsidence regions.
- Subsidence little changed between CTRL and +2K runs. HADVS confined largely to BL.
- Column LES run to equilibrium using steady forcings: no transient variability included in forcings.



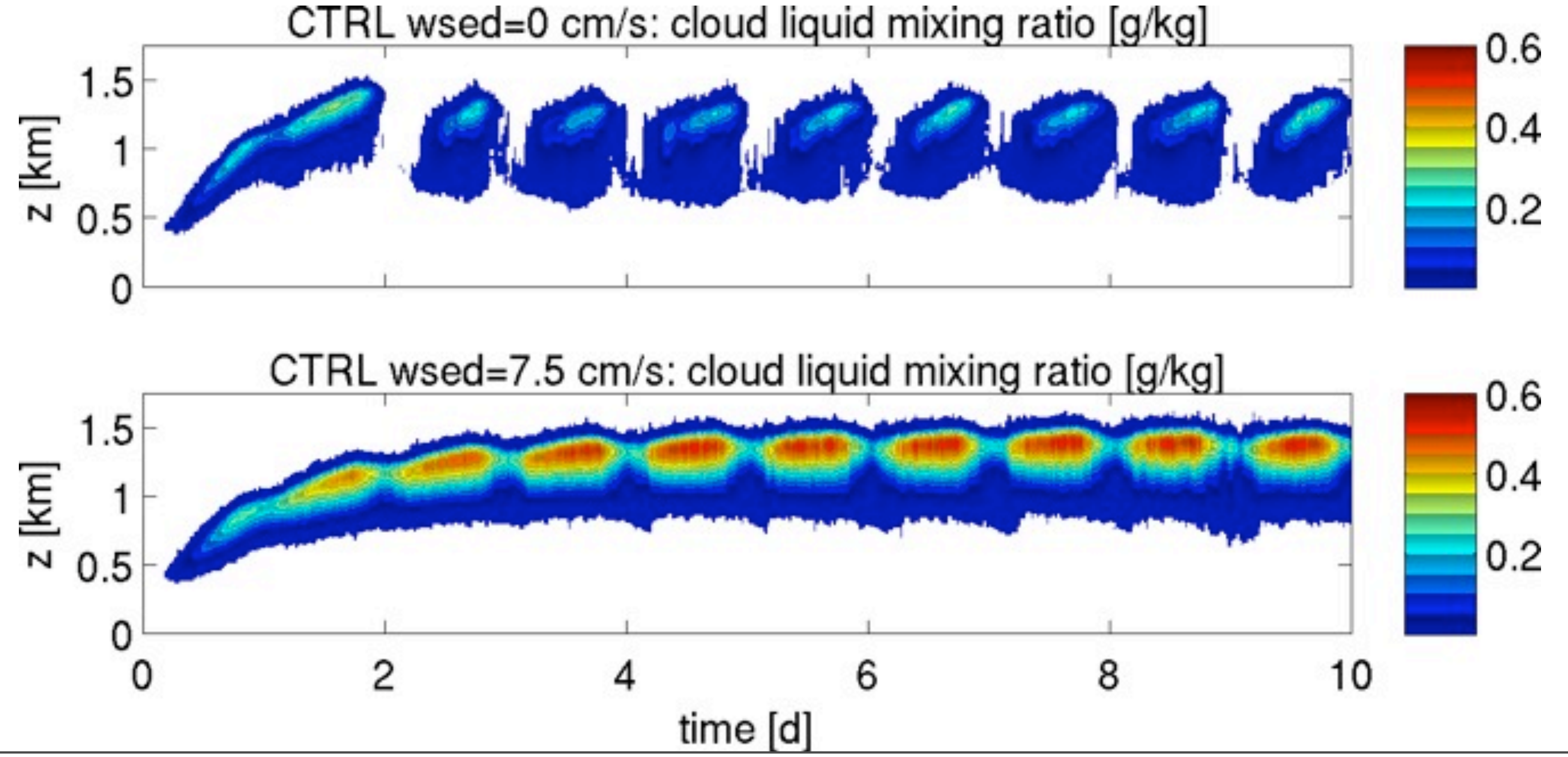
Column LES Results for LTS 90-100 Bin

- LES: 2D, Lx=25.6km, Δx=25m, Δz=5-25m in BL
- Large diurnal cycle in cloud thickness related to daytime insolation leads to weak SWCF compared to SP-CAM.
- Time average too short for trustworthy ΔSWCF.
- Boundary layer shows signs of decoupling.
- Too little Sc due to LES overentrainment?



Sensitivity to Additional Sedimentation

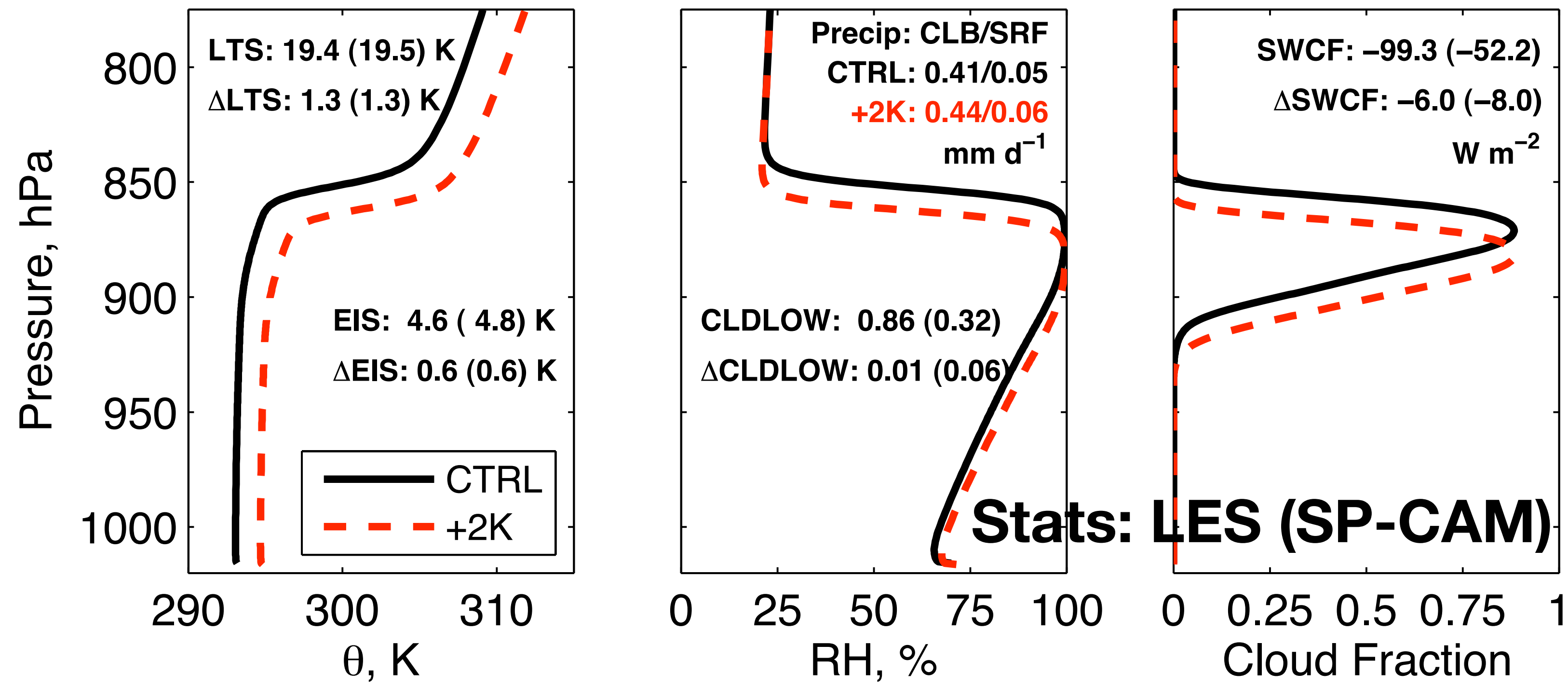
- Many LES models are acknowledged to produce excessive entrainment at sharp inversions like those atop Sc boundary layers.
- Different effects could play a role in this over-entrainment: numerical diffusion, excessive subgrid-scale diffusivity and unmodeled physics (e.g. cloud droplet sedimentation, finite droplet evaporation timescale, partial cloudiness).
- Additional sedimentation (wsed=7.5 cm/s) is added to all cloud water to counteract this. This results in well-mixed boundary layer w/persistent cloud.
- With this amount of sedimentation, SAM simulations of DYCOMS RF01 at this vertical resolution (Δz=5m) settle into an LWP consistent with observations.

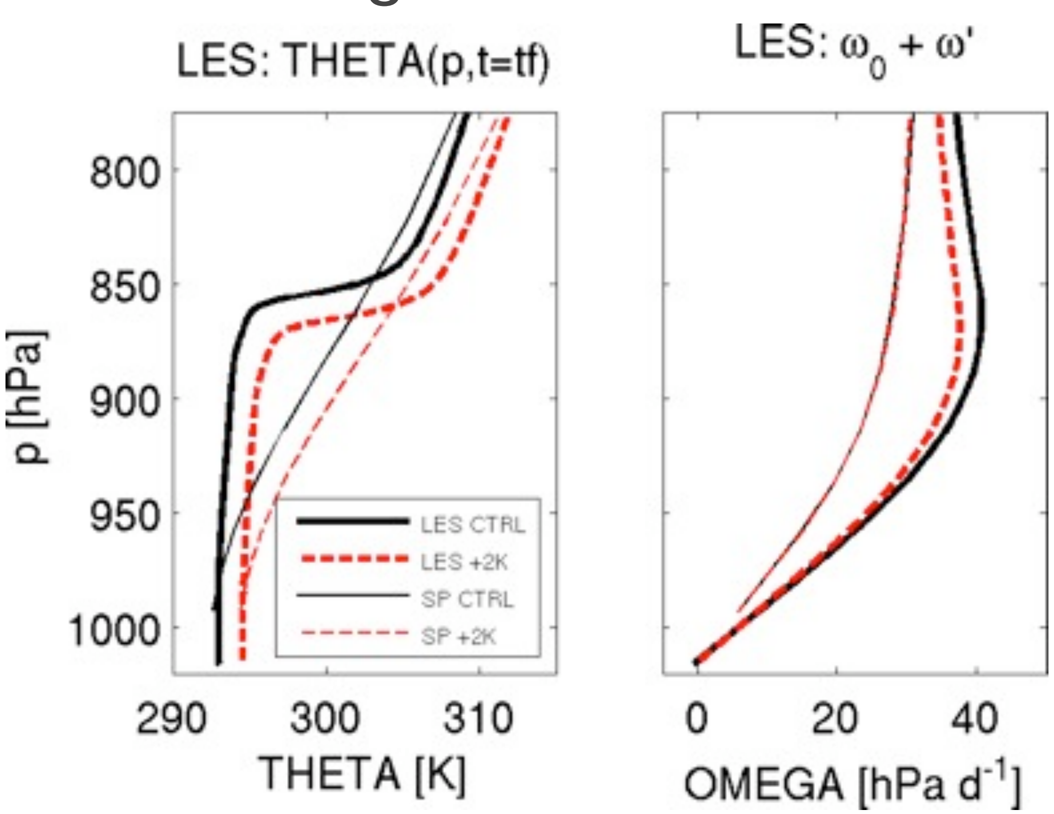


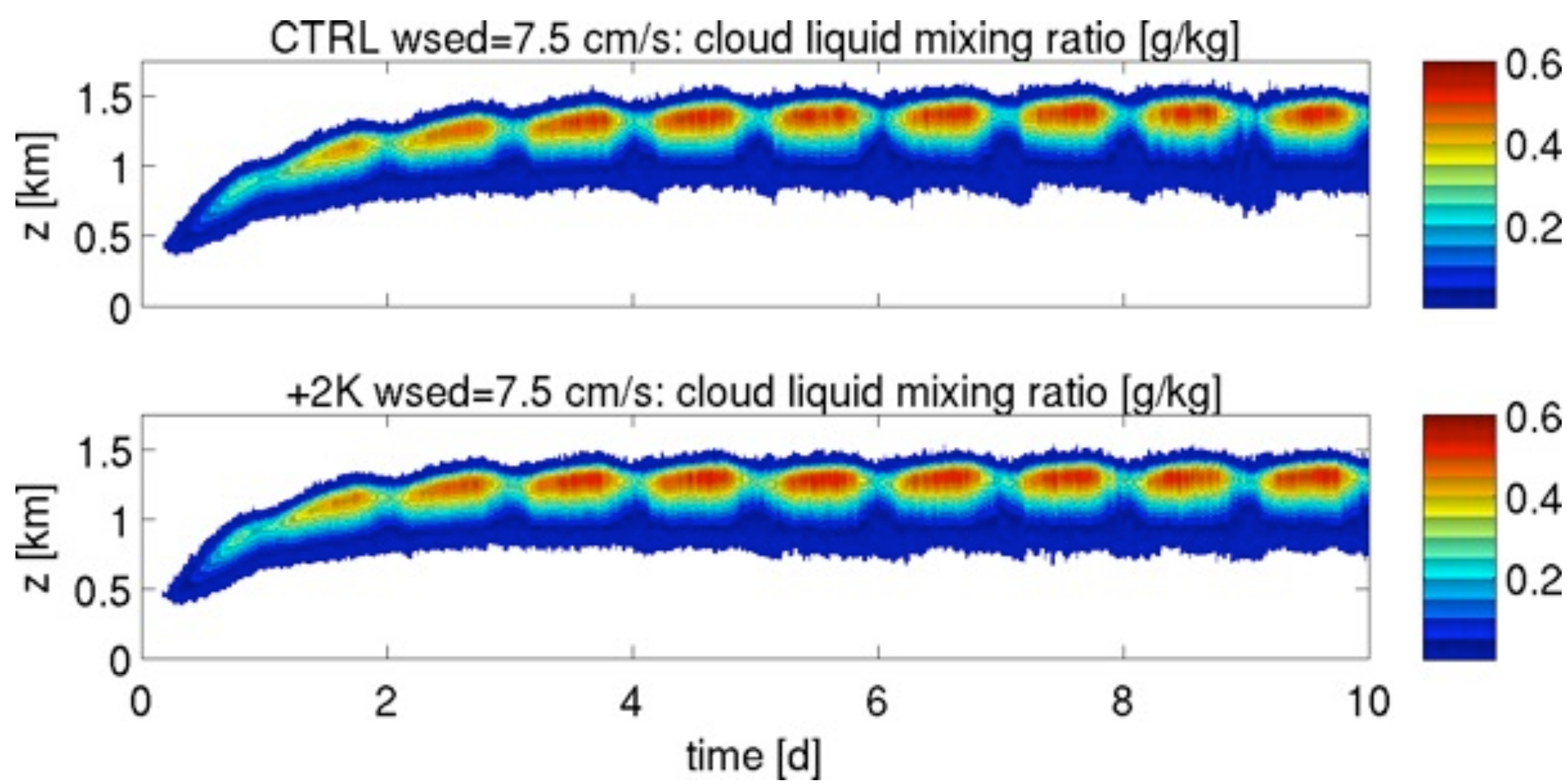
LES Avg: Days 10-30

Column LES Results w/Extra Sedimentation

- Persistent cloud w/diurnal cycle in cloud thickness.
- +2K inversion shallower, has larger LWP during day.
- Negative ΔSWCF is comparable to SP-CAM, even though SWCF is about twice as strong.

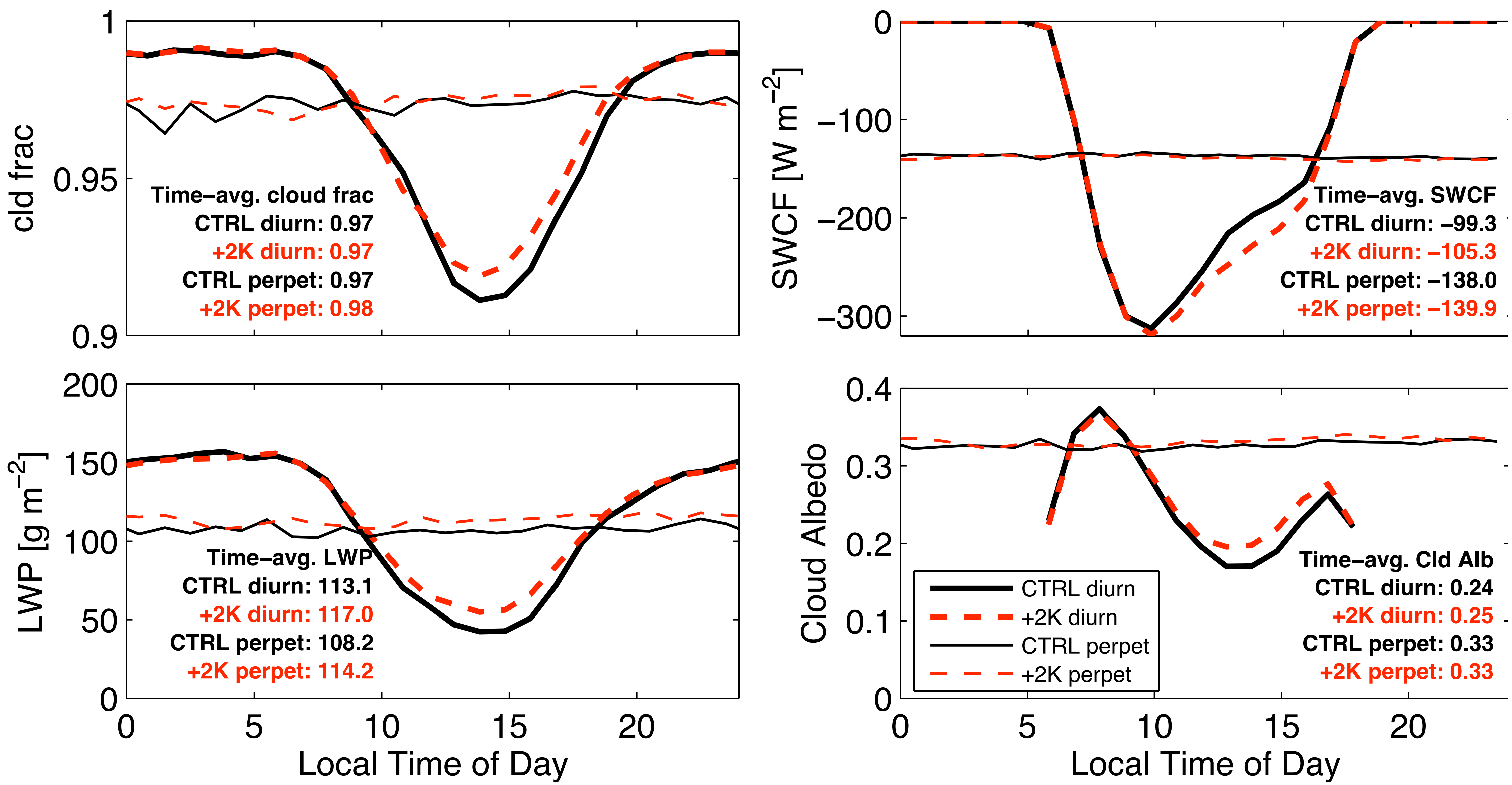






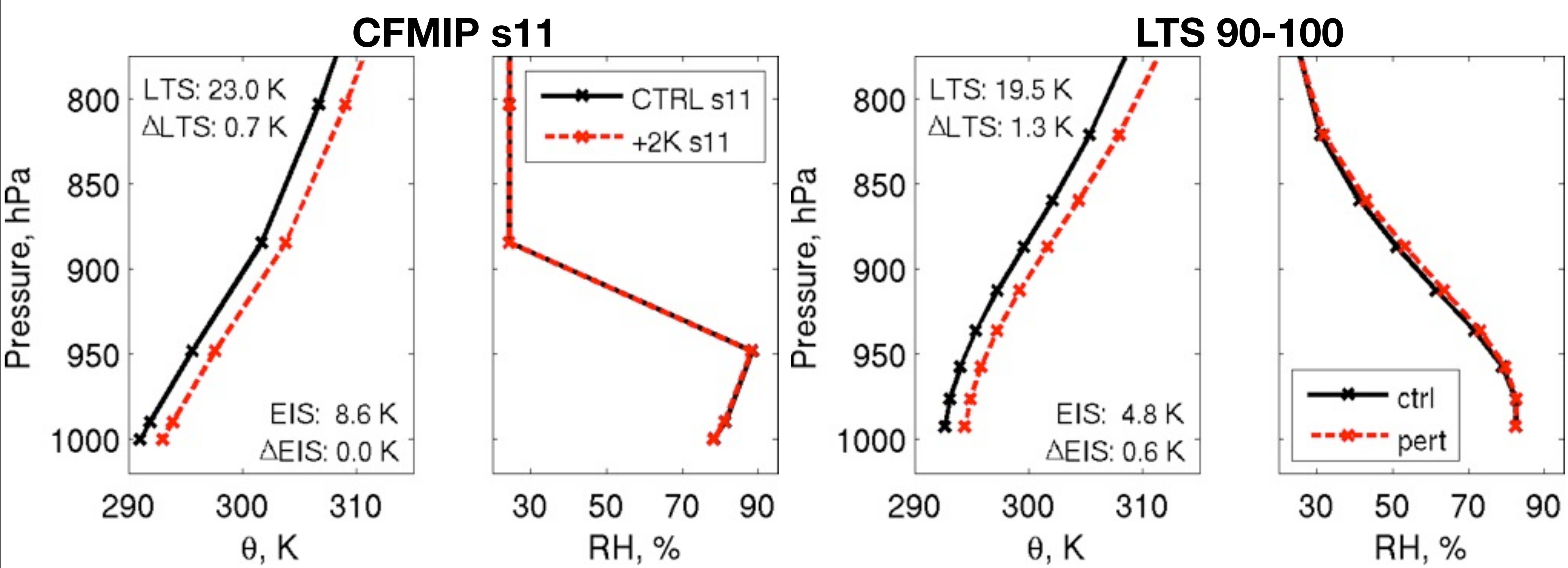
Sensitivity to Diurnal Cycle of Insolation

- Perpetual (diurnally-averaged) insolation has little effect on mean LWP.
- With diurnal cycle, SWCF weaker by >30% due to daytime thinning of Sc cloud.
- Similar phenomena seen in LTS 70-80 and 80-90 bins.



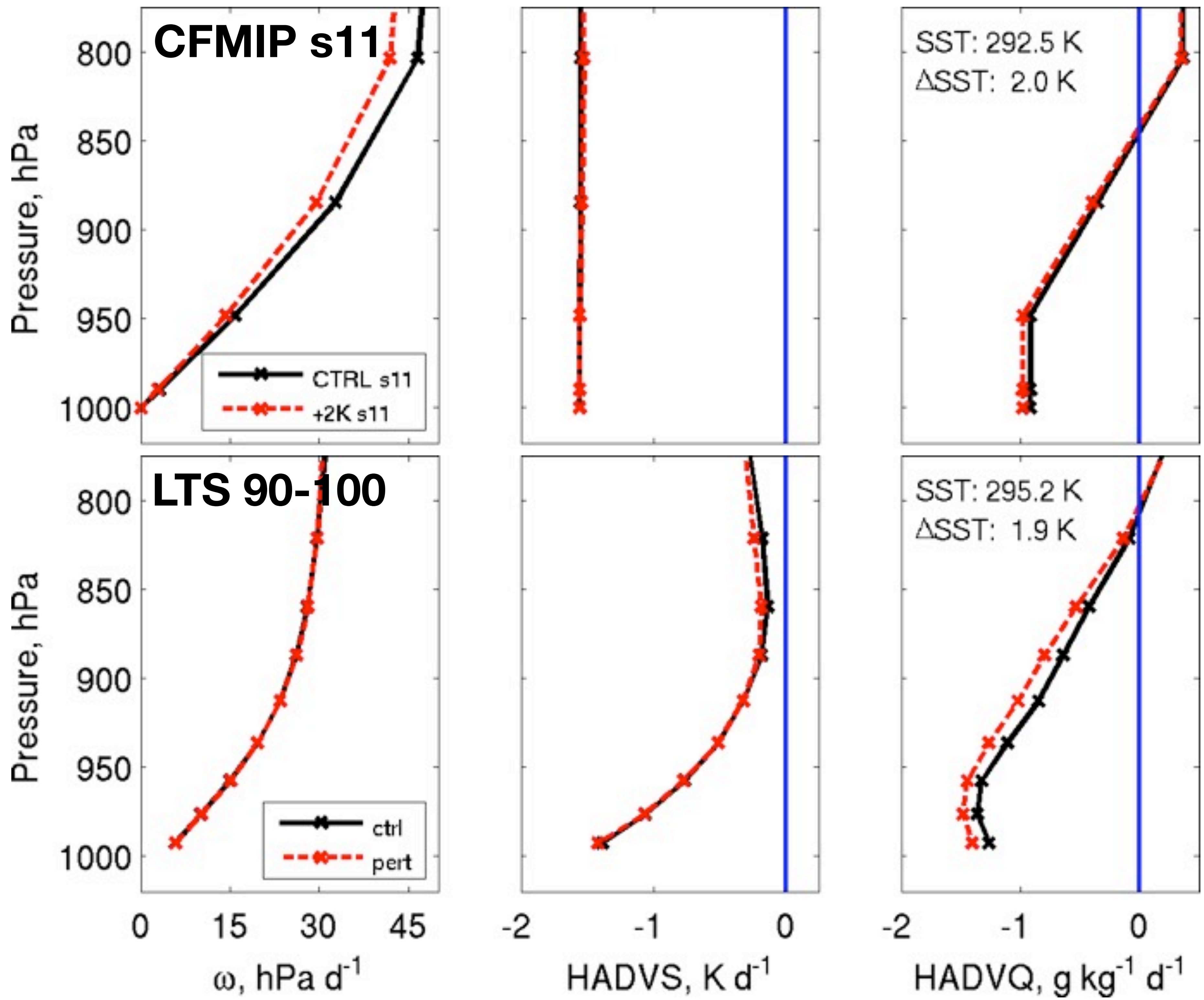
CFMIP LES Intercomparison (s11) vs. LTS 90-100

- Forcings for CFMIP LES intercomparison are intended to represent a **particular location**, while LTS90-100 forcings are a composite over 10% of tropical oceans
- Control sounding stability larger for s11 forcings in both LTS and EIS.
- CTRL→+2K increment in LTS and EIS is smaller for s11 forcings (ΔEIS = 0 K).



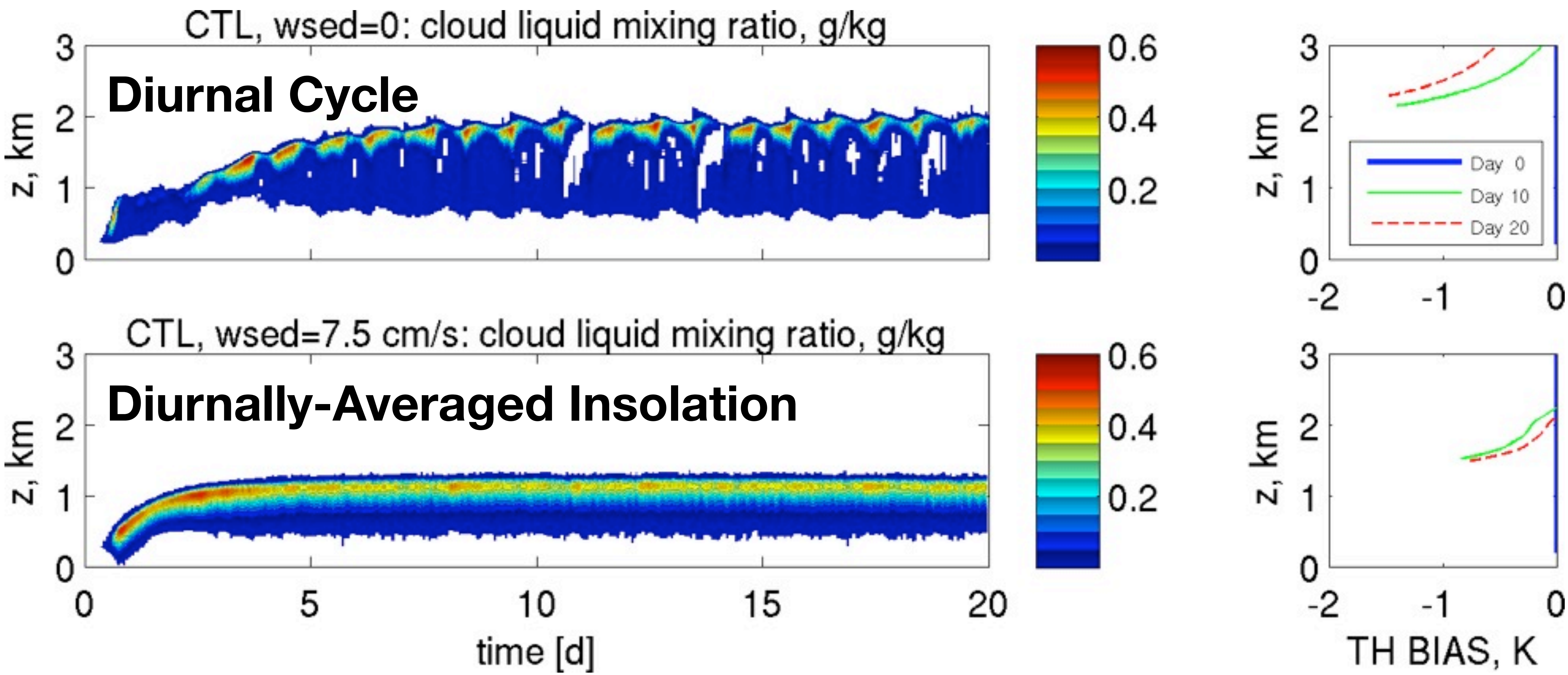
CFMIP LES Intercomparison (s11) vs. LTS 90-100

- CFMIP LES forcings have stronger omega than base LTS 90-100 (similar w/ω-feedback)
- Cool advection much stronger in s11 forcings for deep BL.
- Dry advection profiles similar.
- LES setup same as LTS 90-100: 2D, Lx=25.6km, Δx=25m, Δz=5-25m in BL.



Temperature Drift Above Inversion

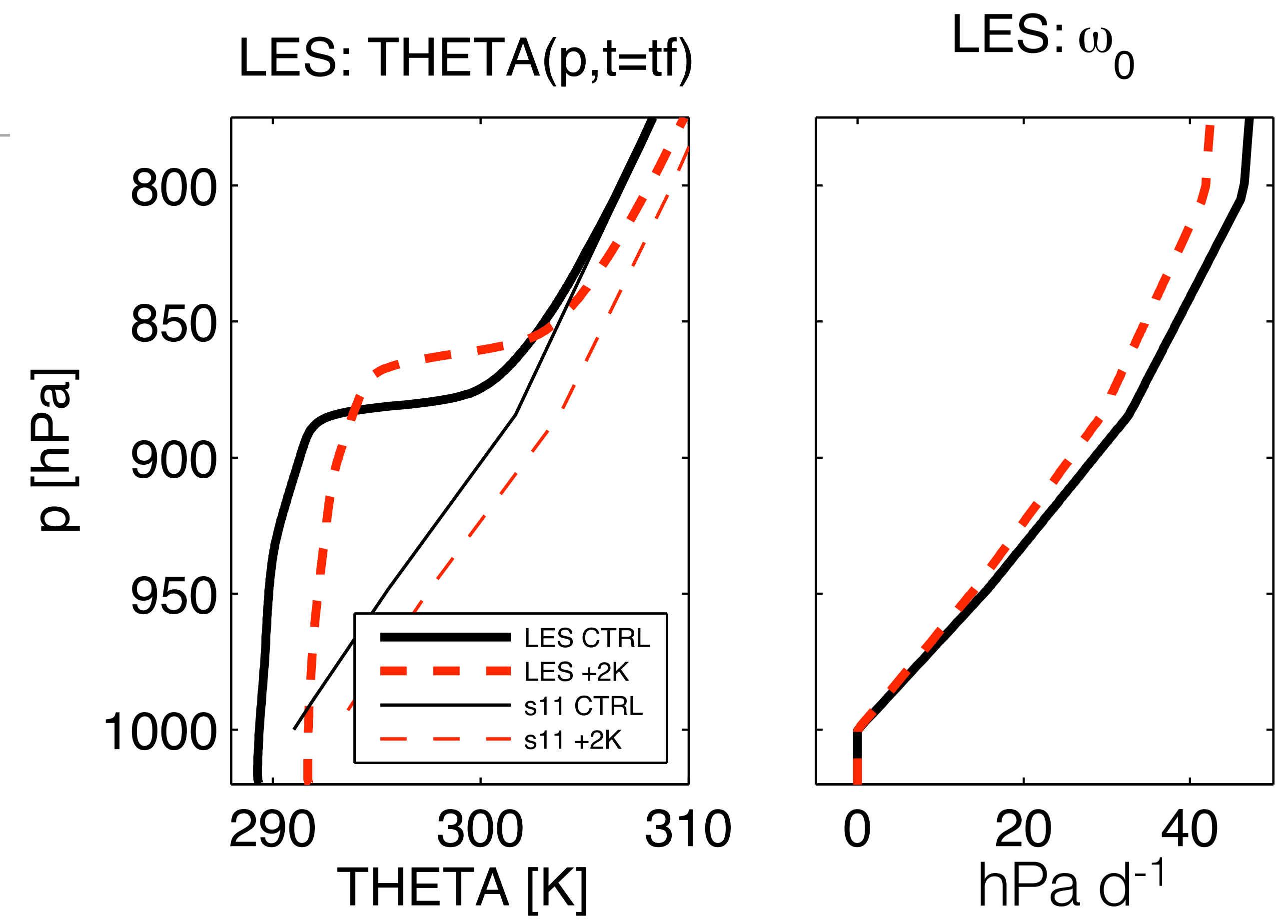
- Temperature drifts cold above inversion, allows boundary layer to deepen substantially. **(TH BIAS plotted starting 200m above cloud.)**
- Sc layer persists with additional sedimentation, decouples without.
- Drift more prominent in +2K runs.

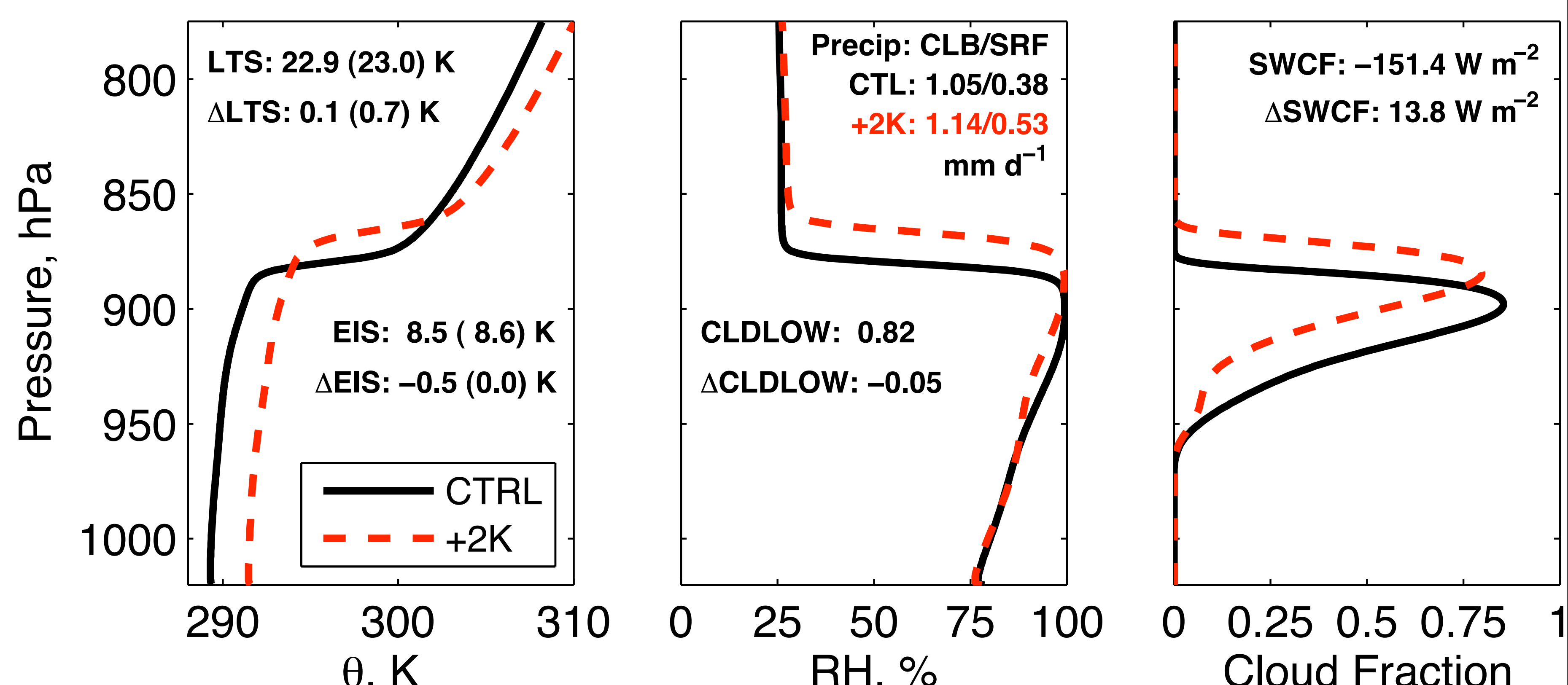


Asymmetric Temperature Drift Above Inversion

Time Avg: Days 5-20

- Simulations without omega feedback, with additional sedimentation.
- +2K run drifts cold above inversion, leads to smaller ΔLTS than base state.
- +2K run slightly decoupled.
- Strong SWCF, strong positive ΔSWCF.

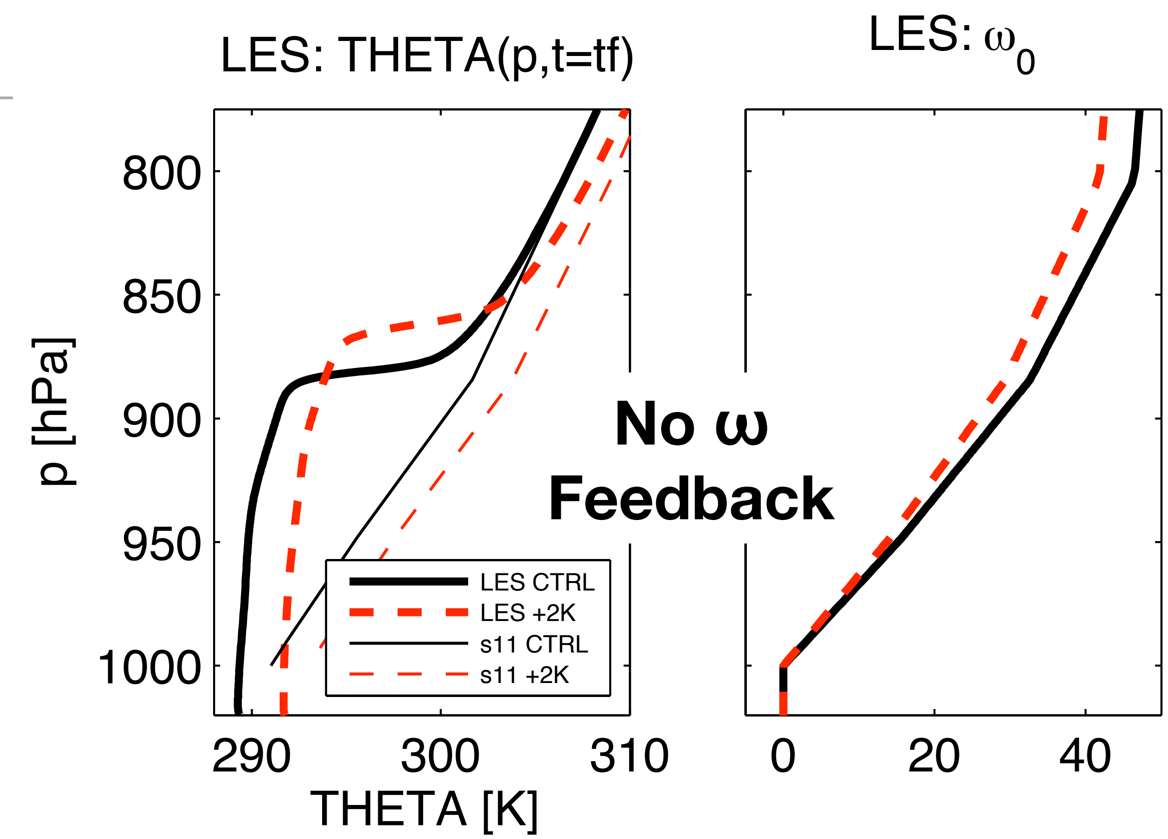


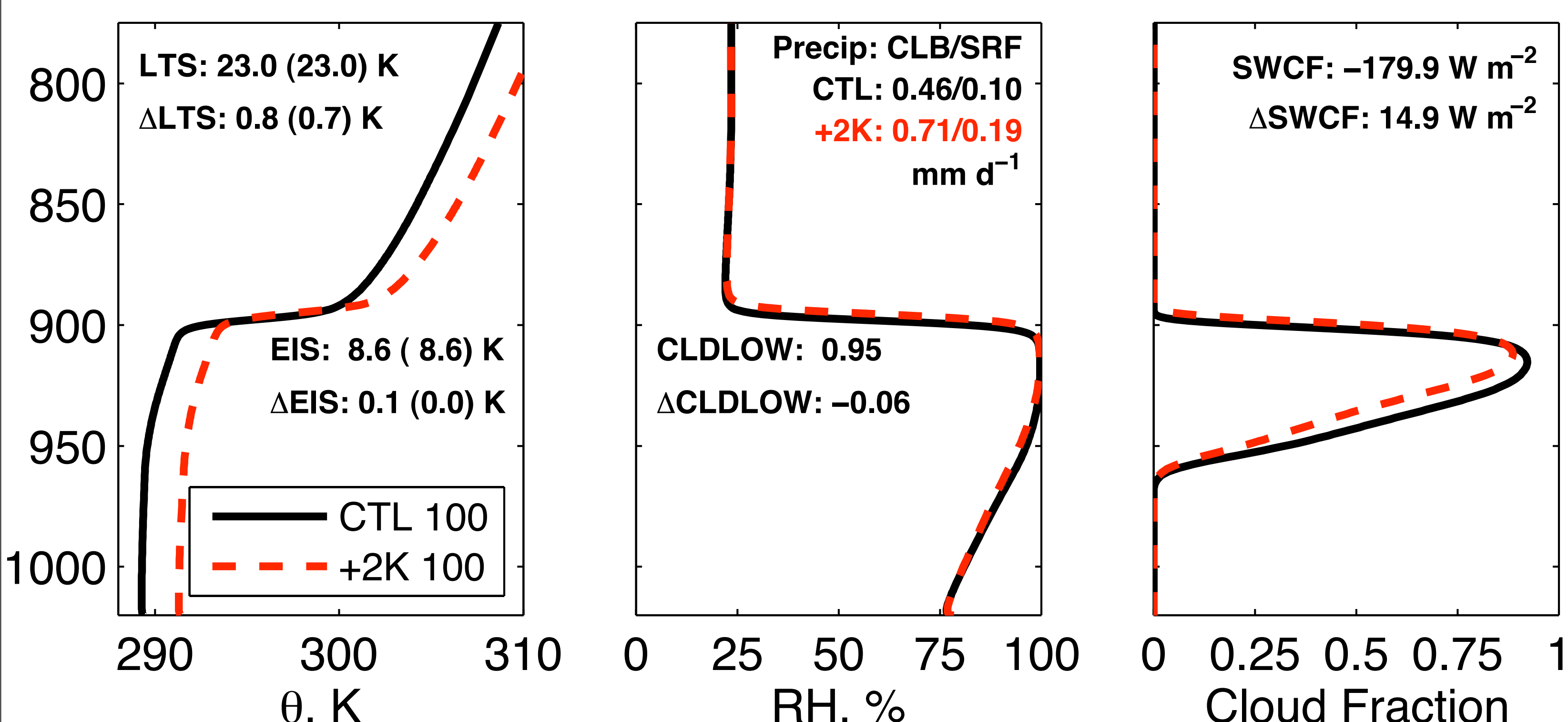


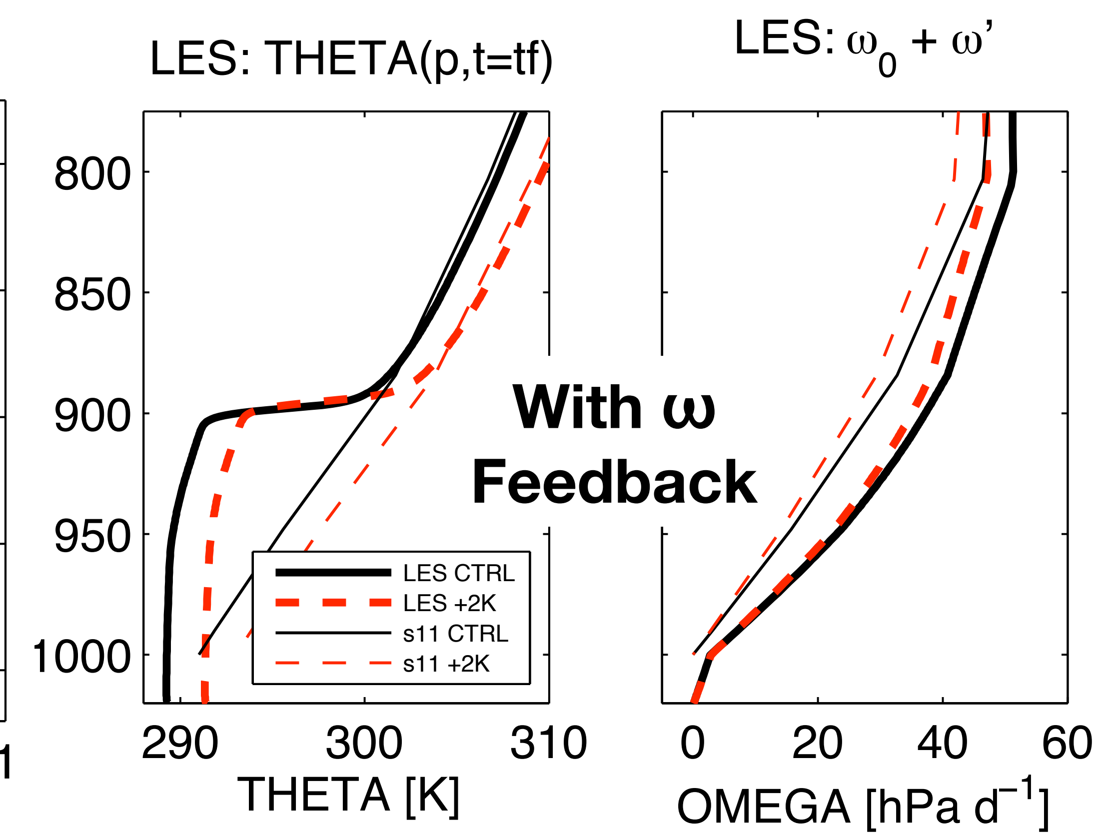
Time Avg: Days 5-15

Effect of omega feedback

- Omega feedback eliminates drift above inversion. LTS, EIS, Δ's consistent w/specs
- Results in more cloud, stronger SWCF than without omega feedback.
- ΔSWCF still positive.

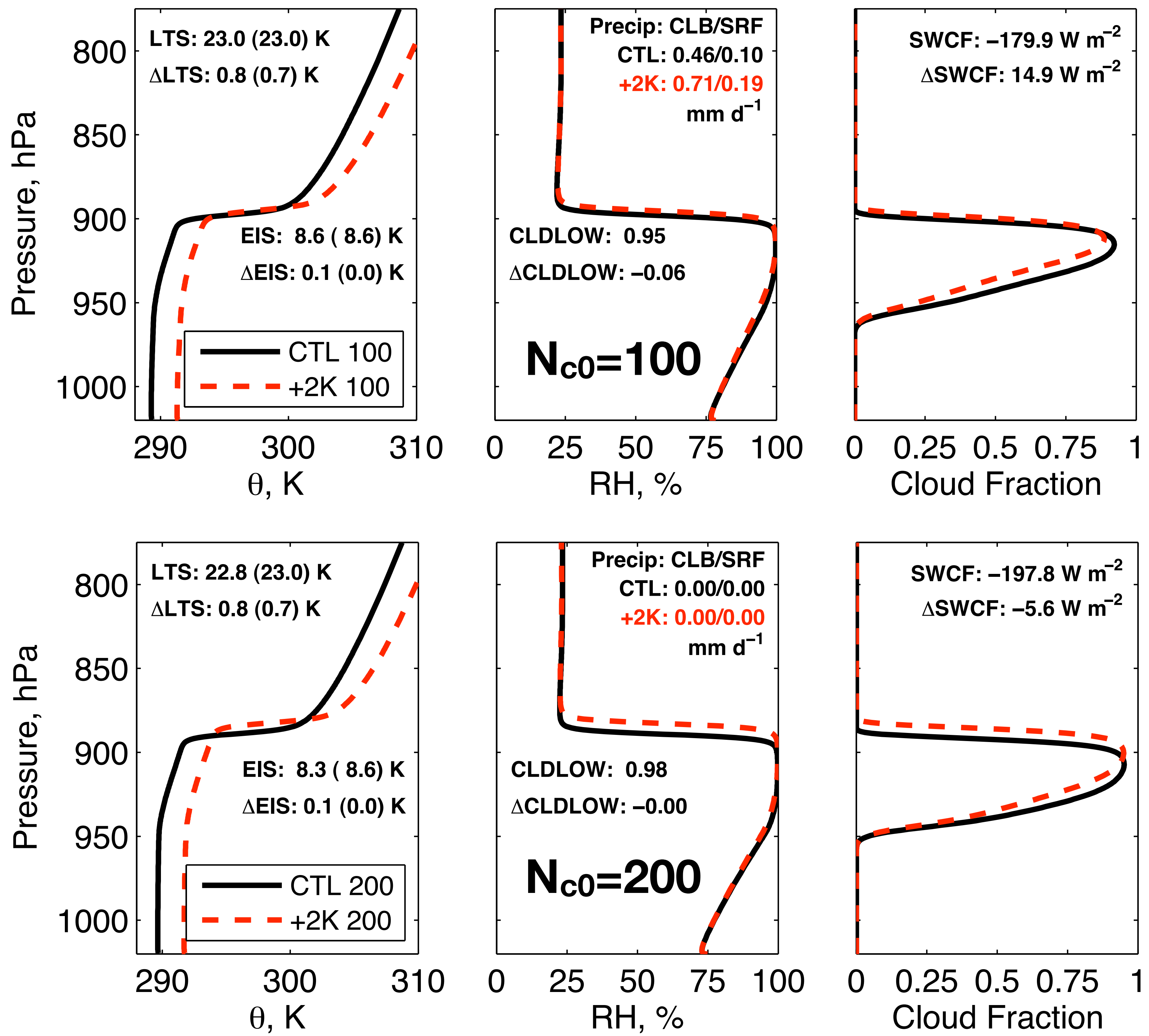






Drizzle Feedback Changes Sign of ΔSWCF

- Sensitivity to cloud droplet number concentration N_{c0}.
- Drizzle-free, N_{c0}=200 simulations have thicker, deeper cloud.
- SWCF sensitivity to +2K change reverses sign with N_{c0} change.
- Diurnal cycle might make drizzle feedback less prominent...



Summary

- Column modeling of stratocumulus cloud feedbacks in SP-CAM:
  - Additional sedimentation required for cloud to persist through daytime.
  - Negative cloud feedbacks with most configurations (ΔEIS>0?).
  - Diurnal cycle of insolation has strong impact on time-mean SWCF.
- Preliminary simulations of GCSS/CFMIP LES intercomparison (s11 case):
  - Temperature drift above inversion allows additional BL deepening.
  - Omega feedback provides consistent environment for evaluating cloud changes.
  - Drizzle feedback reverses sign of ΔSWCF.
  - Boundary layer structure and cloud feedback is sensitive to configuration.