CGILS LES intercomparison update

Peter Blossey and Chris Bretherton, U. Washington

With results from participating LES modeling groups:

SAM: Peter Blossey (UW)/Marat Khairoutdinov (Stony Brook)

MOLEM: Adrian Lock (UKMO)

UCLA: Irina Sandu (ECMWF)/Thijs Heus (MPI)

LARC: Anning Cheng (LaRC)

DALES: Stephan De Roode (TU Delft)

CFMIP GCSS Intercomparison of LES and SCMs (CGILS)
(a column boundary layer cloud feedback intercomparison)
Leaders: Minghua Zhang and Chris Bretherton

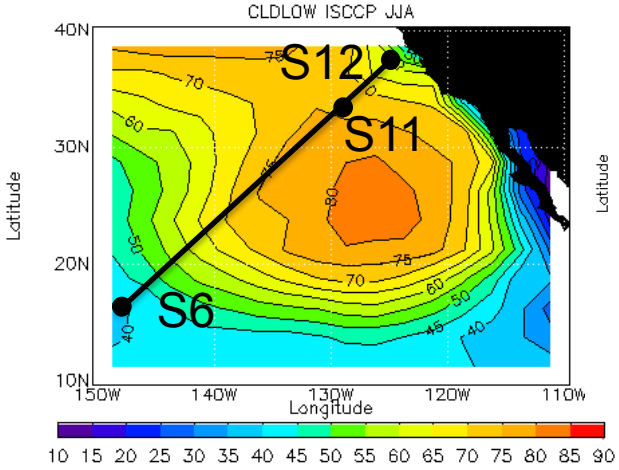
Objectives:

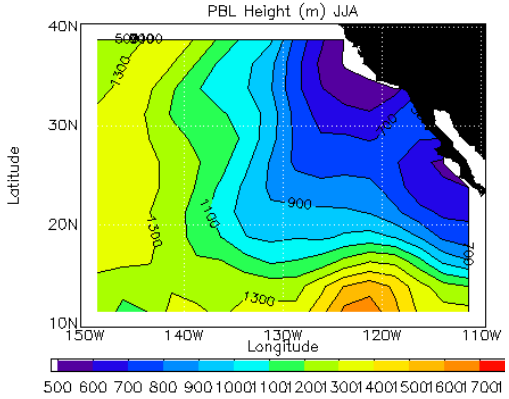
1. To test whether a column analogue to a climate change (+2K SST) reproduces the intermodel variability in AGCM subtropical cloud response.

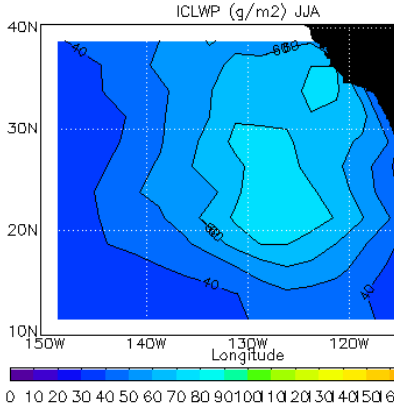
2. To compare SCM with LES/CRM column simulations

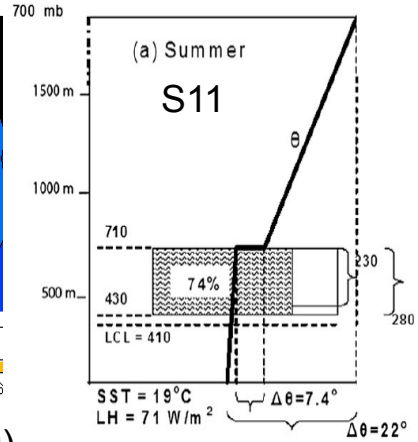
3. To understand the low cloud response mechanisms in the column models and LES simulations.

Control: Force column models with JJA climo from 3 GPCI points (focus on S11)
SST+2K: Start with warmer free-trop moist adiabat, same free-trop RH, .
~same horizontal T,q advection profiles, subsidence reduced ~10%,.
Run models to steady state with diurnally averaged insolation, RRTM radiation.





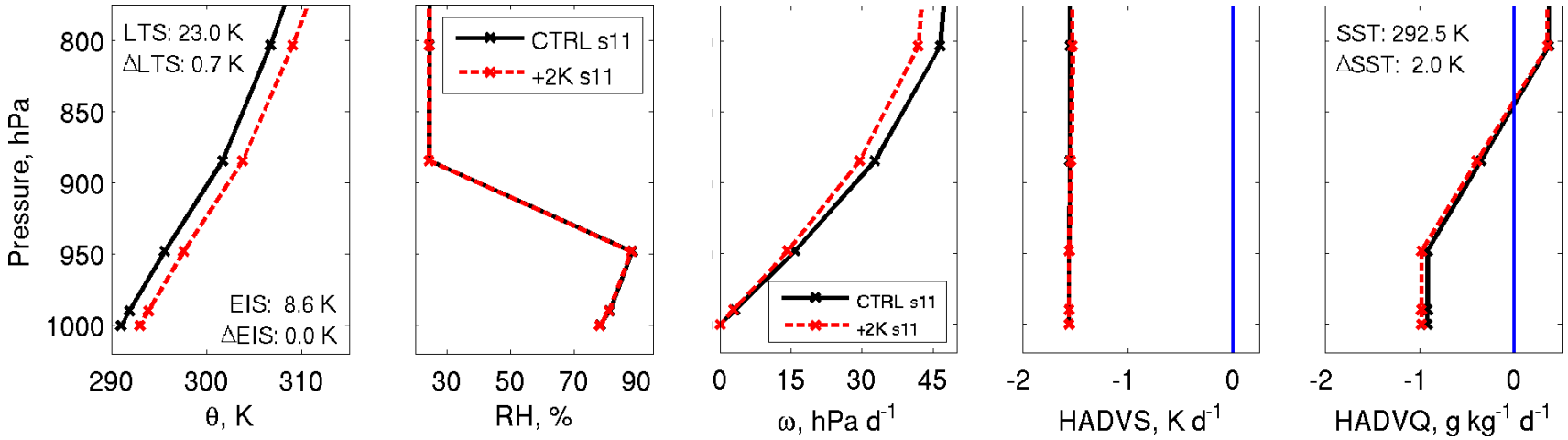




(Lin, Zhang and Loeb, JCL 2010)

Where we were a year ago: LES focus was S11

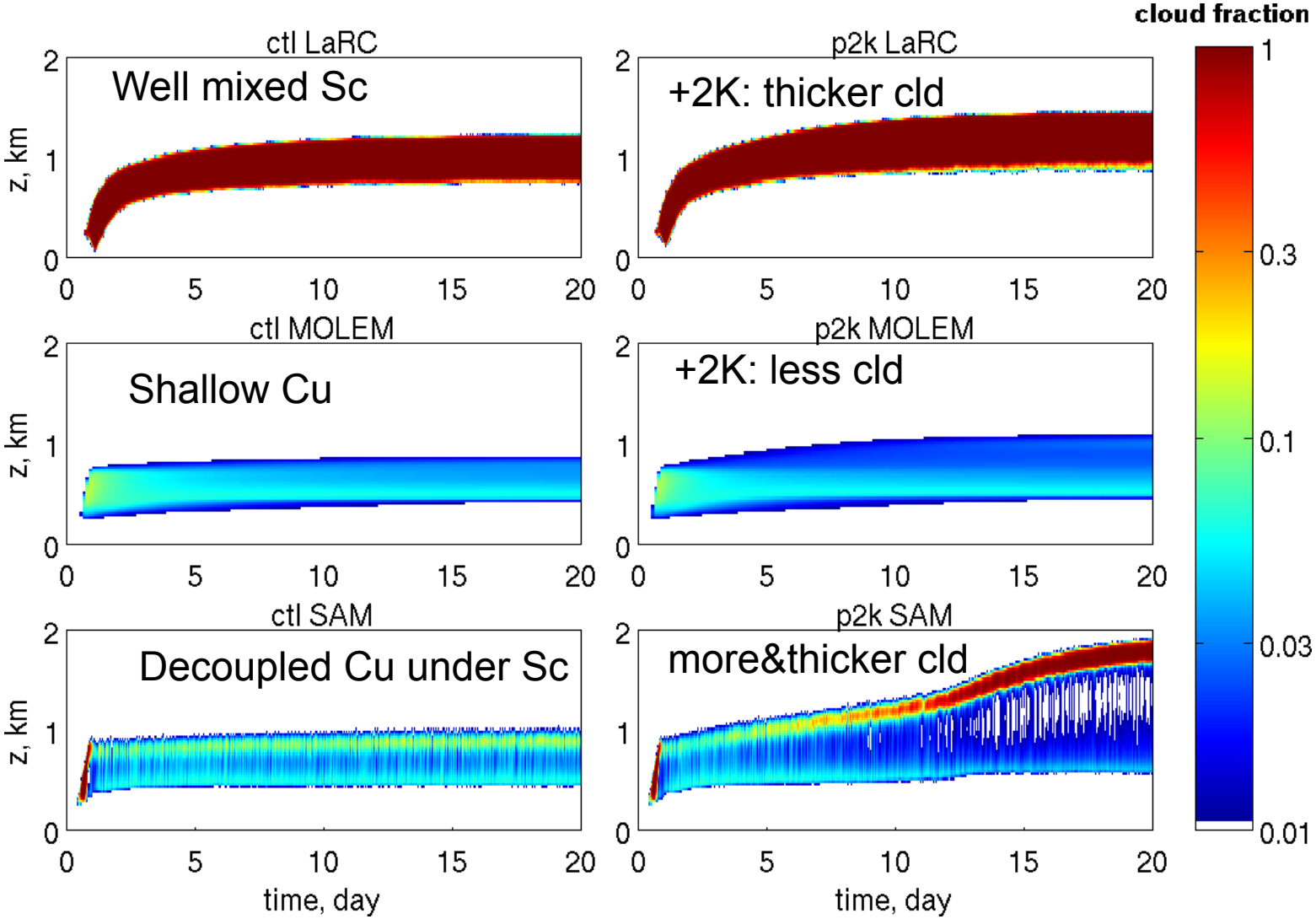
S11 Free-trop T, vertical motion, hadv profiles (SST=292.5 [+2K])



All LES models used:

- $\Delta x = \Delta y = 50$ m, $\Delta z = 25$ m
- diurnally-averaged RRTM-like radiation
- Rapid wind profile relaxation
- Weak T/q profile relaxation above 2500 m

1/2010 S11 results



- LaRC made thick control clouds; other models didn't
- The LES did not agree on the sign of the predicted low cloud response
- Suspects: Surface flux formulation, coarse Δz, diverse advection/SGS schemes

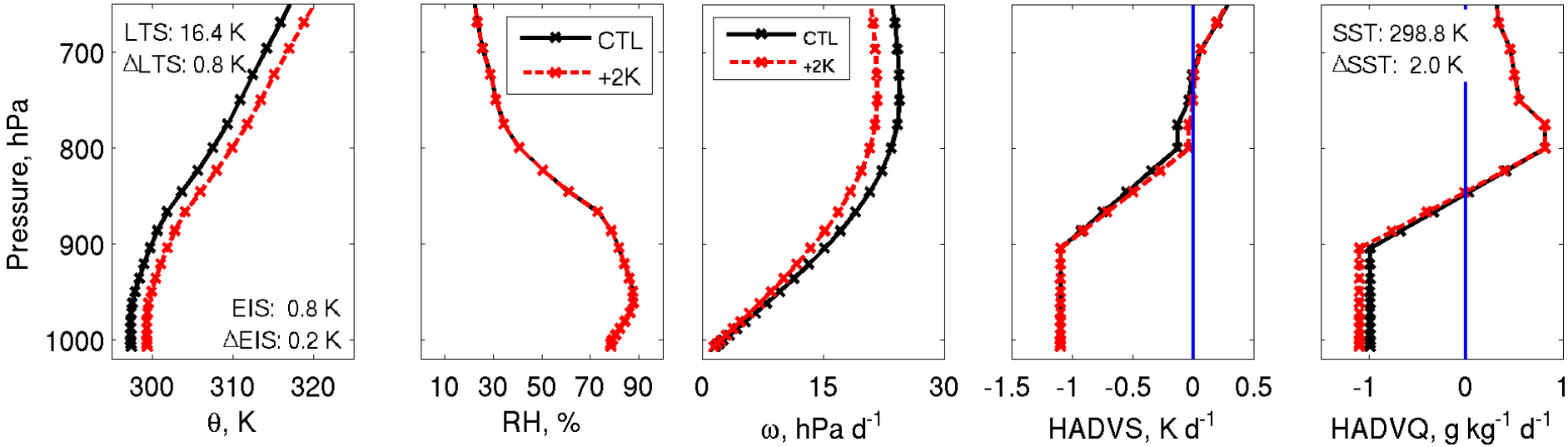
In the last year

- Two further meetings
- Slight forcing changes (ERA40 climo for ctrl T/q/hadv)
- Slight LES refinements: Use of the same bulk surface flux scheme and effective radius for all models.
- S11 experiments with $\Delta z = 5$ m
- Renewed LES interest in Cu (S6) and Sc (S12) cases
- One new LES group (MPI/UCLA)

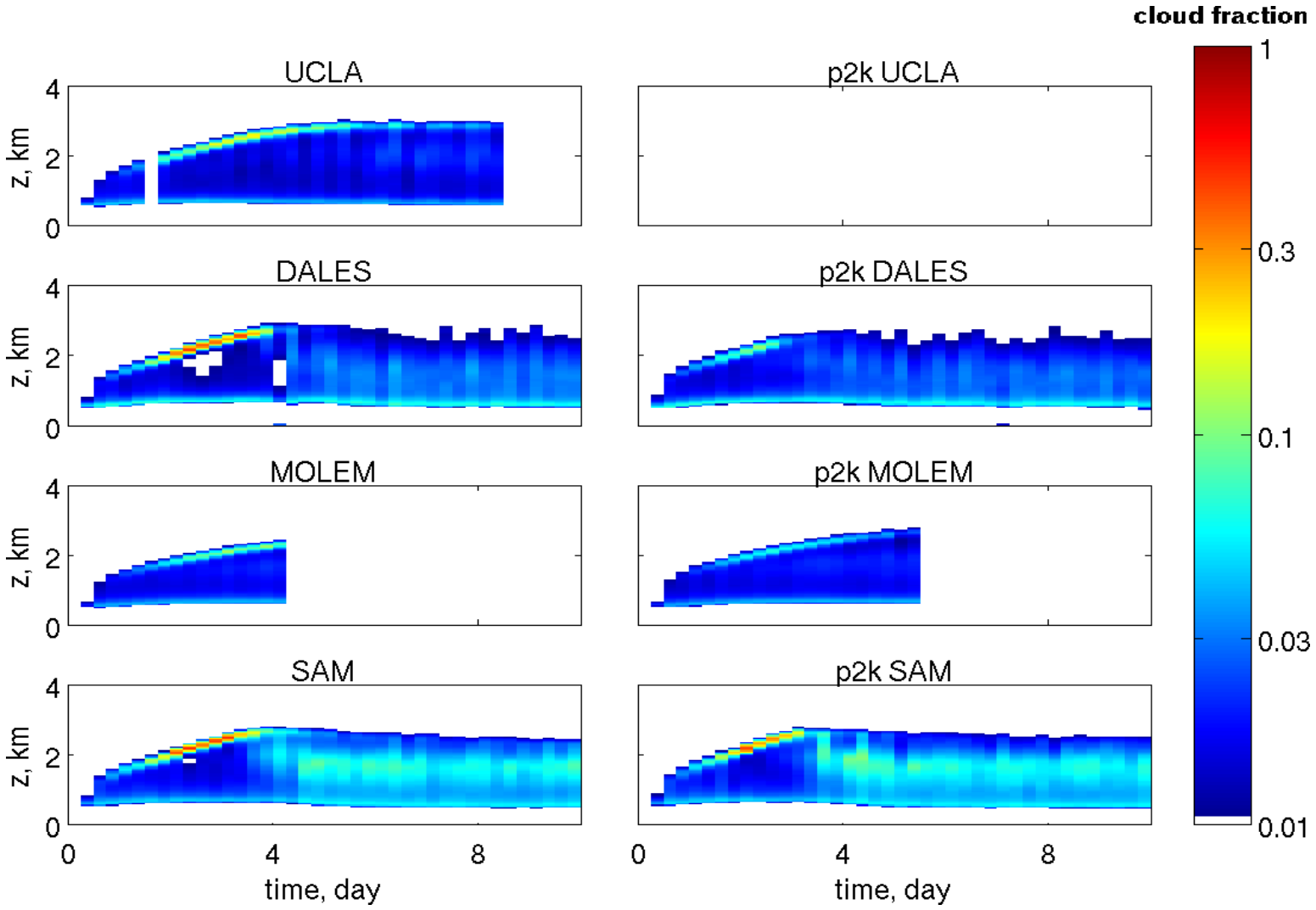
This has clarified the feedbacks story somewhat

A final (fourth) iteration of the LES cases is being run now.

S6 (Cu): forcings



S6: LES results (dx/dz = 100/40 m)

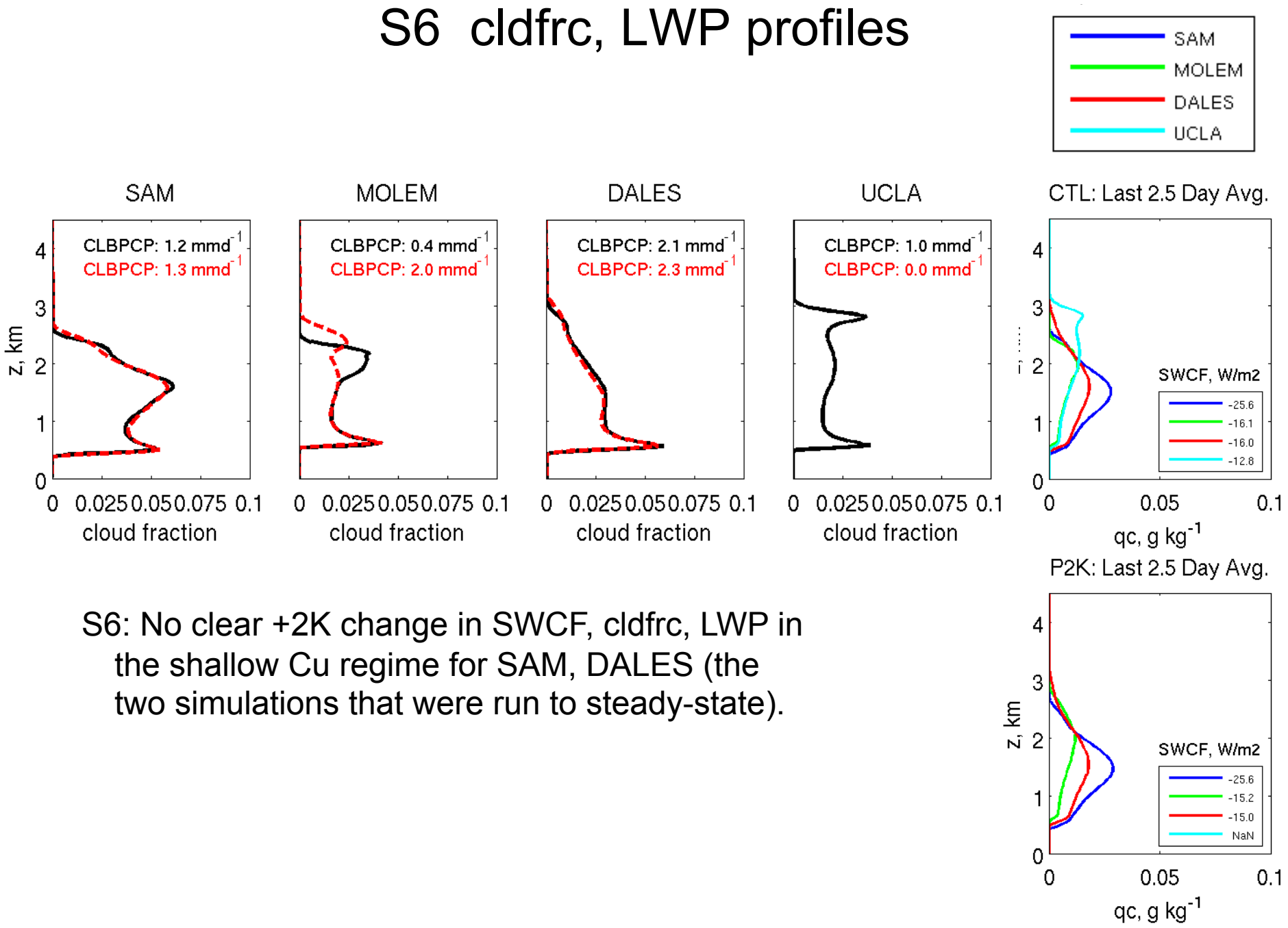


Fair agreement between LES models

Cloud layer deepens; transitions to a Cu-only layer in SAM and DALES

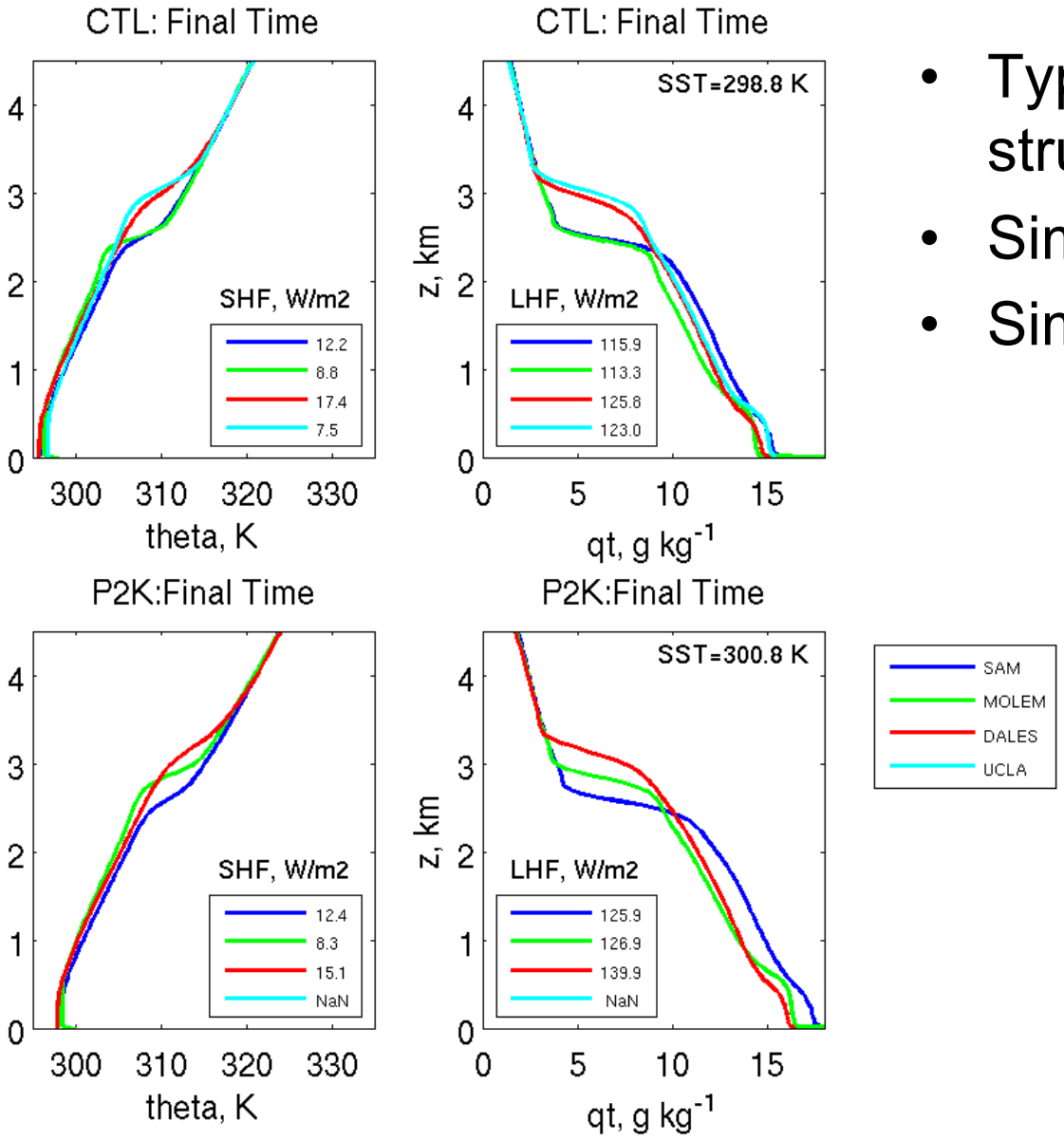
+2K changes are imperceptible

S6 cldfrc, LWP profiles



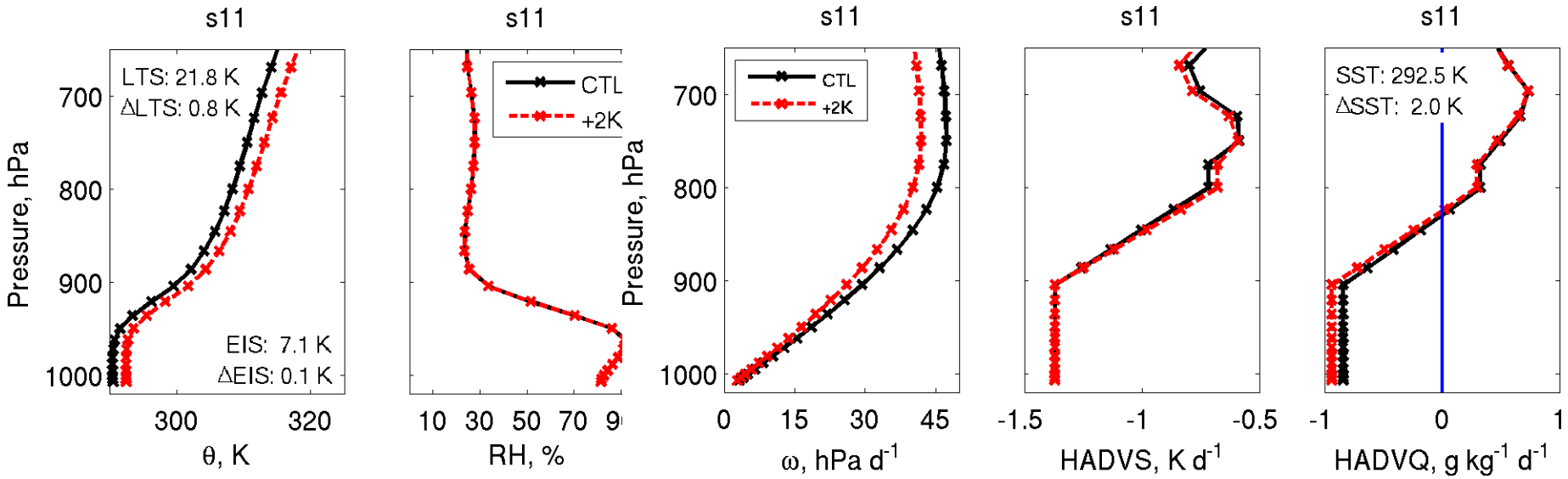
S6: No clear +2K change in SWCF, cldfrc, LWP in the shallow Cu regime for SAM, DALES (the two simulations that were run to steady-state).

S6 θ, q profiles

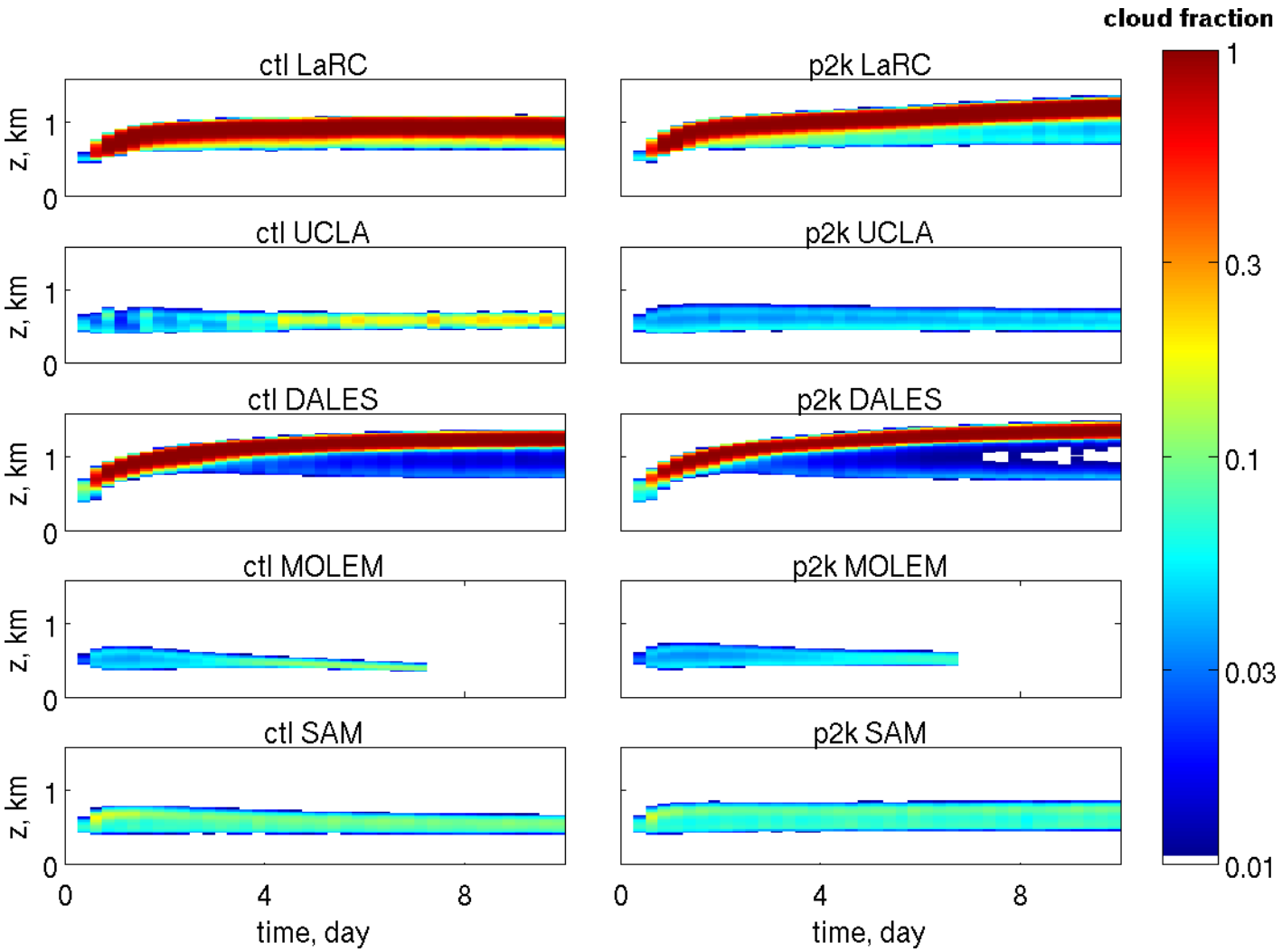


- Typical shallow Cu structure
- Similar between models
- Similar for +2K vs. ctrl

S11 (Cu under Sc) forcings



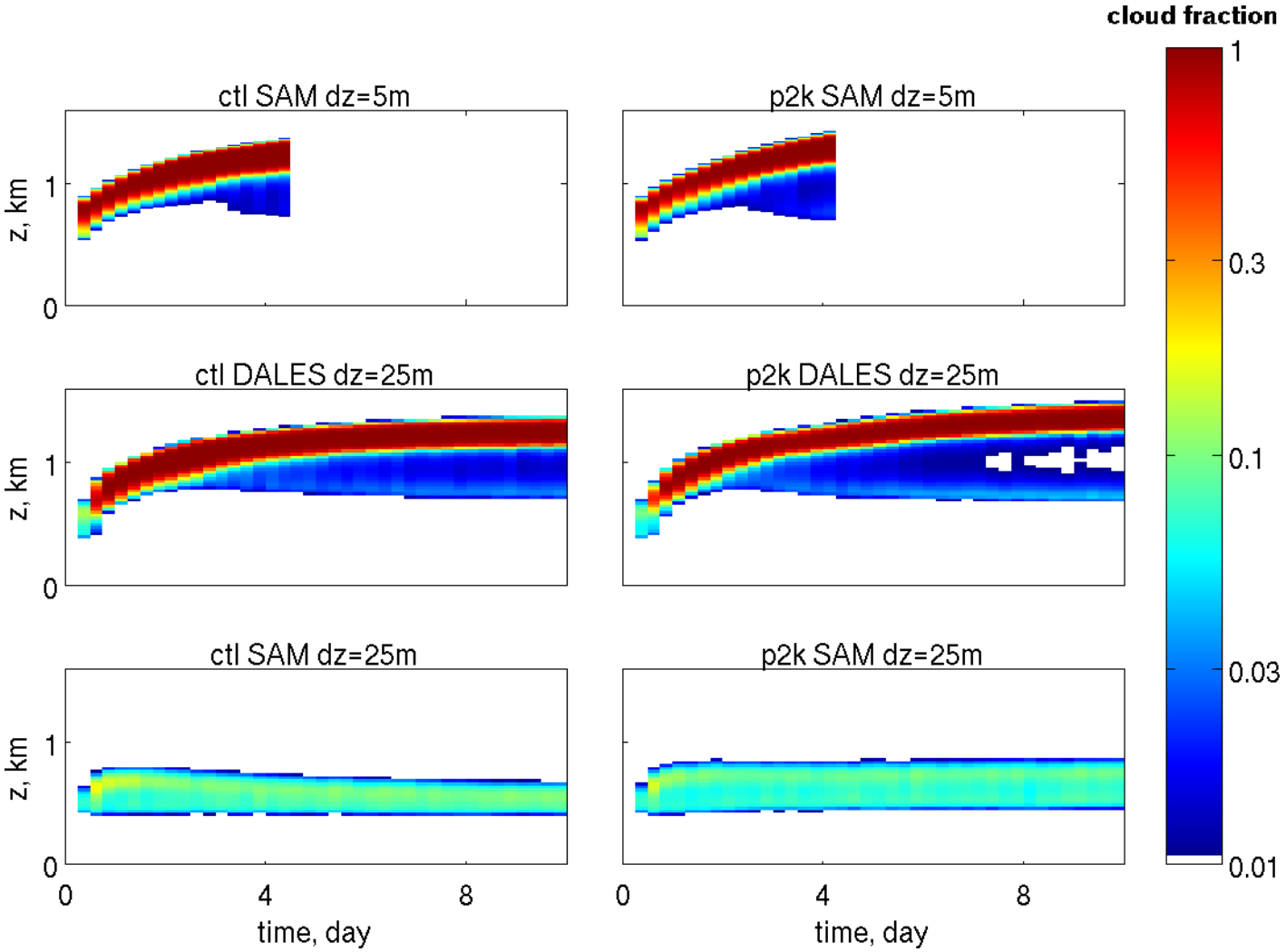
S11 control simulations (dx/dz = 50/25 m)



Simulations split into thin-cloud and solid-Sc regimes

LaRC (Anning) makes either regime with adv scheme switch

…but sensitive to finer dz

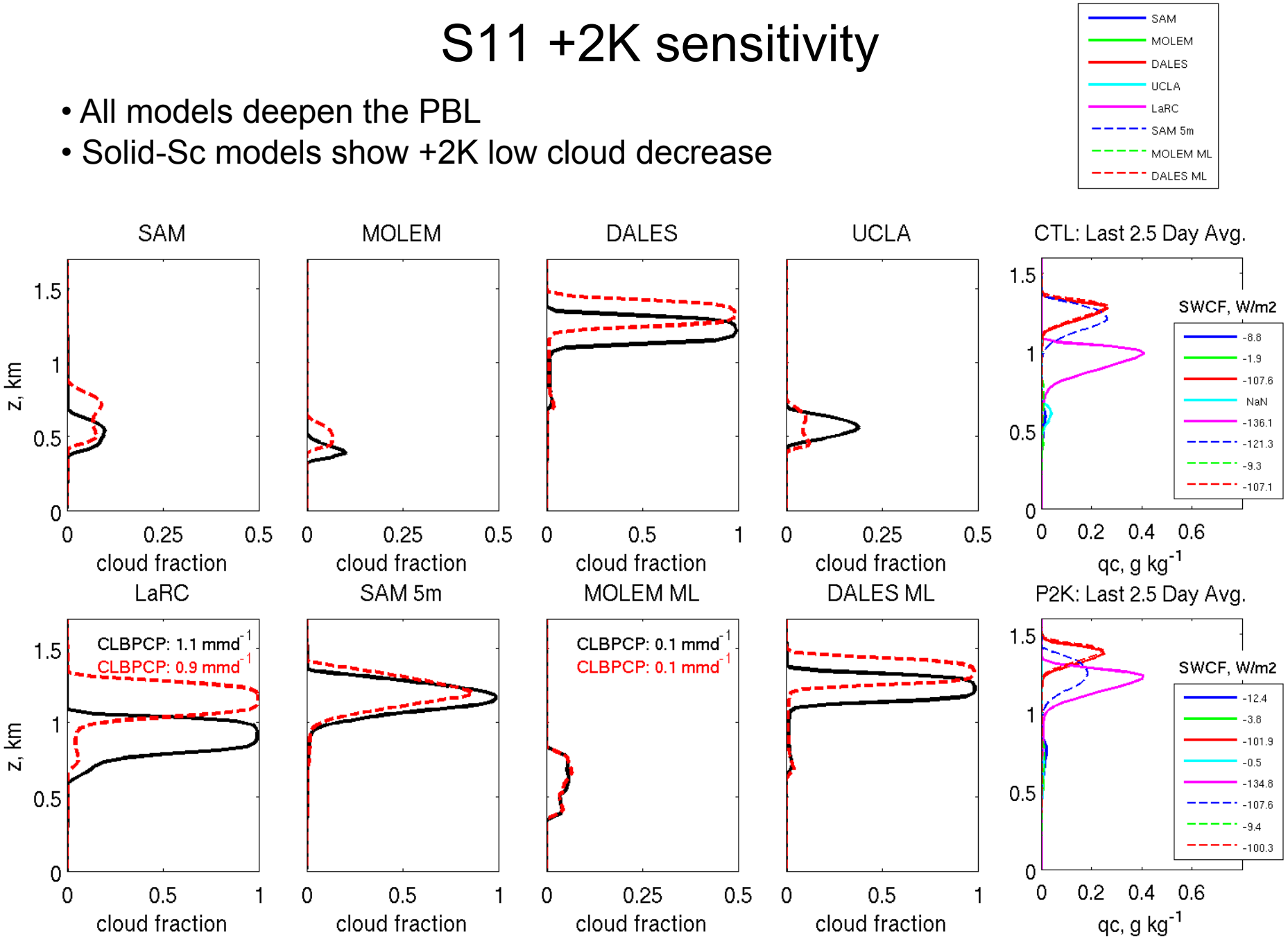


SAM at dz=5 m looks like DALES at dz = 25 m

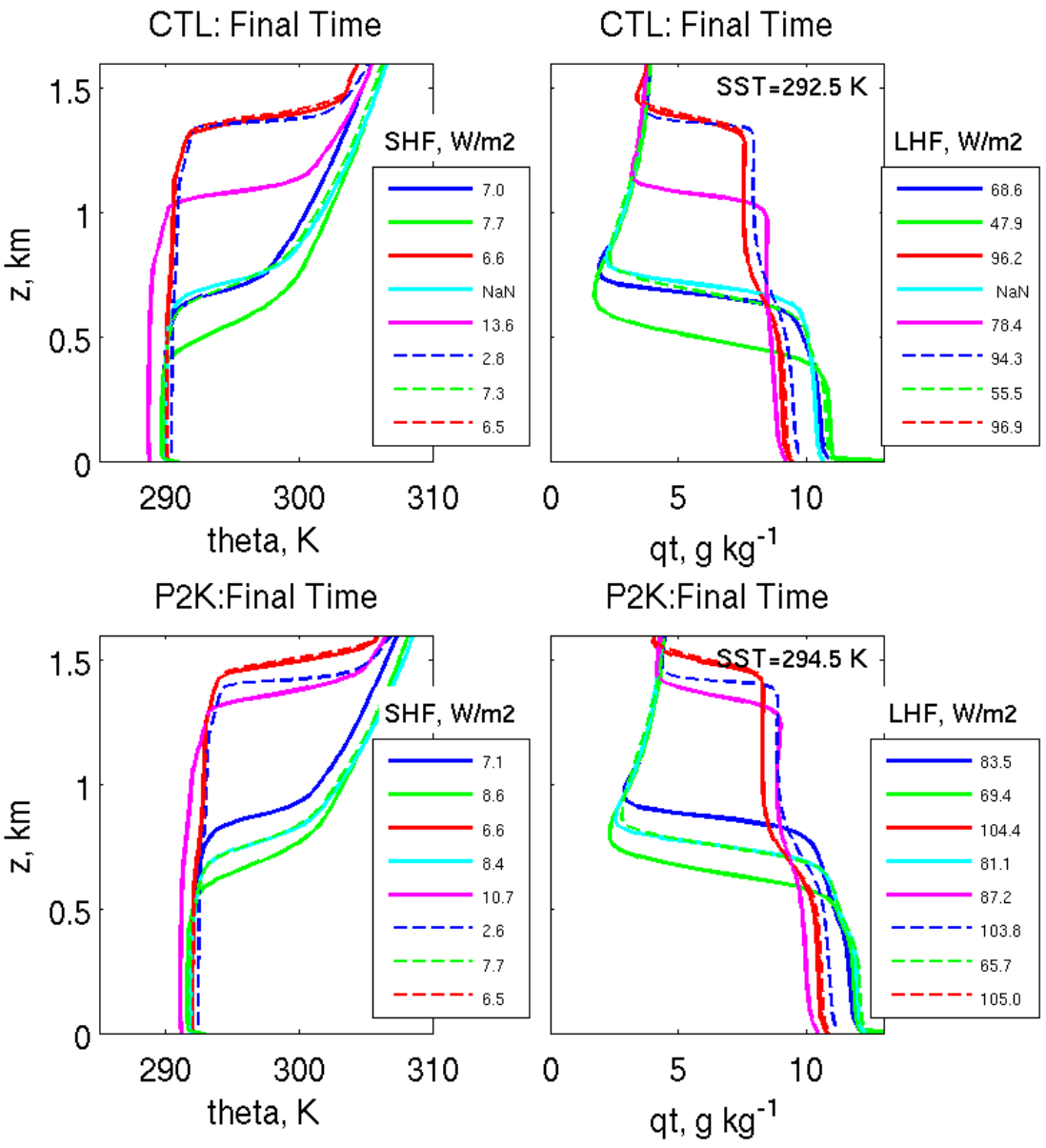
Hypothesis: At fine enough dz, all LESs go to solid Sc state

S11 +2K sensitivity

- All models deepen the PBL
- Solid-Sc models show +2K low cloud decrease

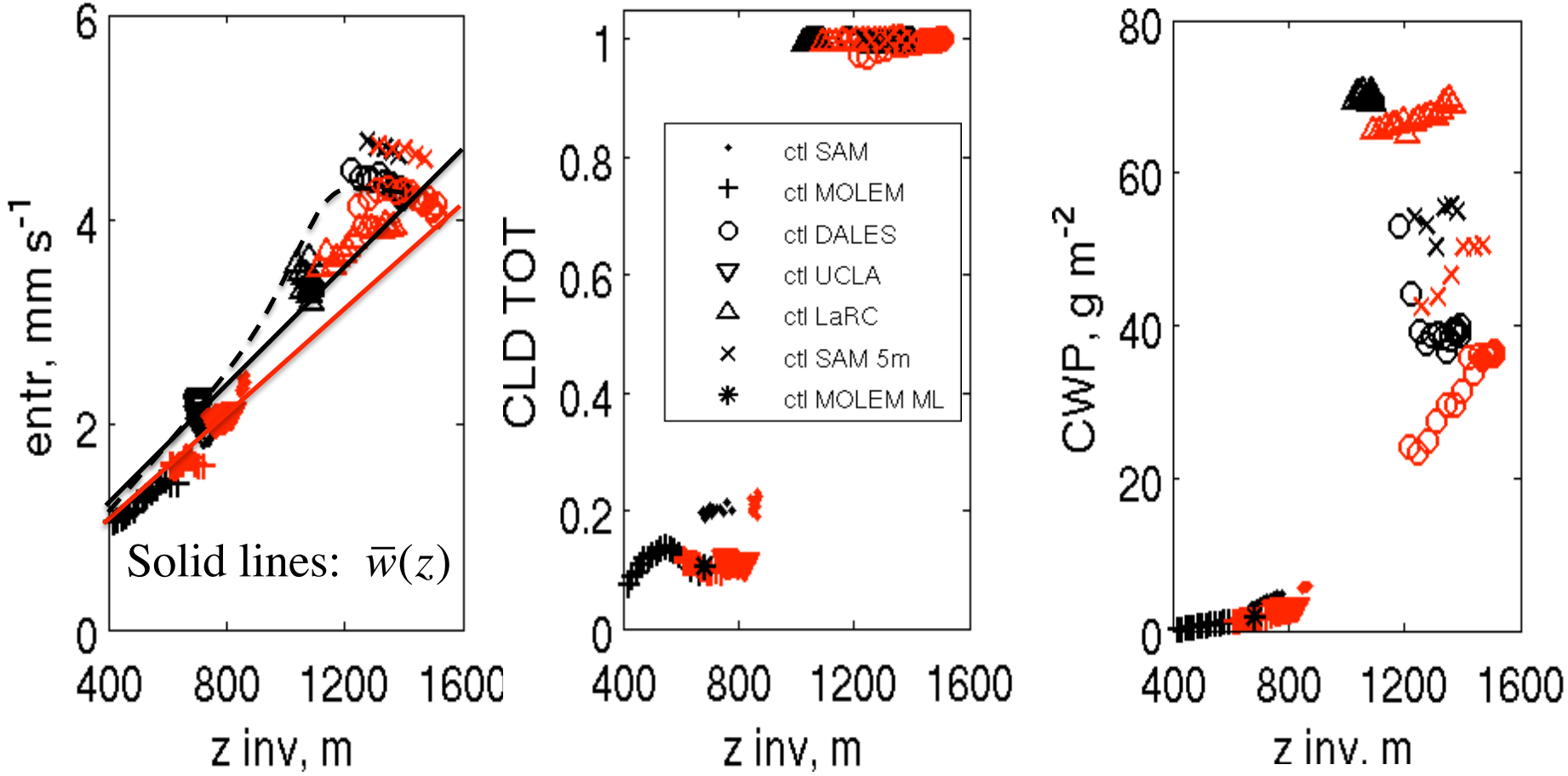


S11 θ and q profiles



- All models show decoupling that is larger for p2k. The p2k cloud thinning (positive low cloud feedback) is supported by the stronger decoupling, driven by larger LHF and perhaps more efficient entrainment.
- Free troposphere too dry when PBL shallows due to dry advection+subsidence
- This leads to excessive entrainment drying and cloud thinning for low z_i

S11 slow manifold analysis (t > 2 days plotted)

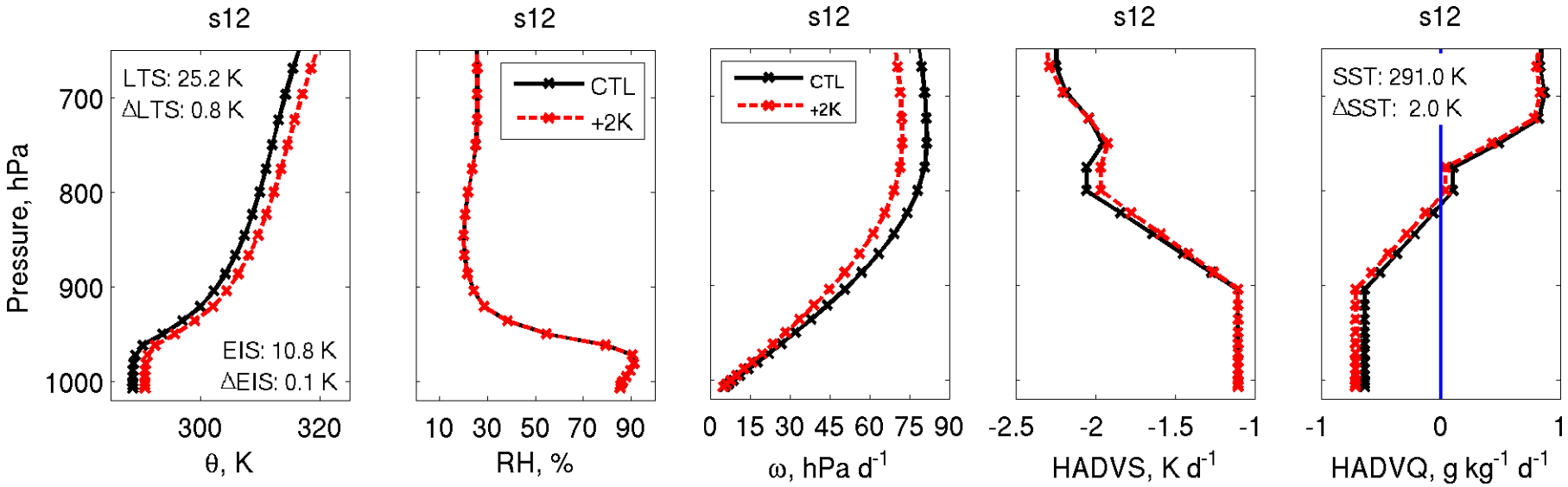


For a given z_i, entrainment rate only varies by 10% between models and is similar in +2K as in ctrl climate.

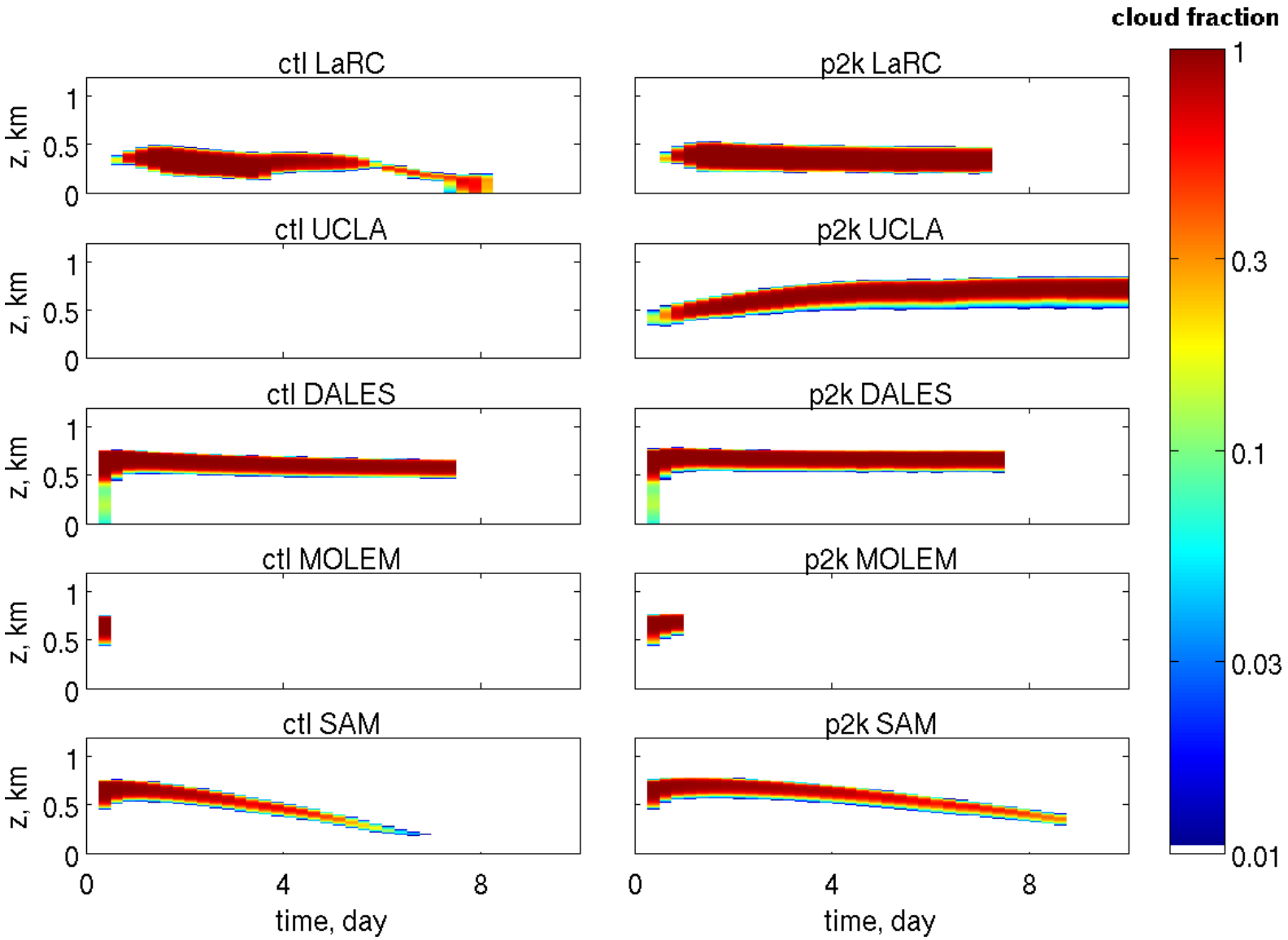
For deeper z_i, Sc is solid, there is more radiative cooling and more entrainment

The LWP needed to drive the entrainment rate varies more in solid Sc regime and is smaller for a given z_i in +2K, more than compensating for +2K z_i increase

S12 (Sc) forcings

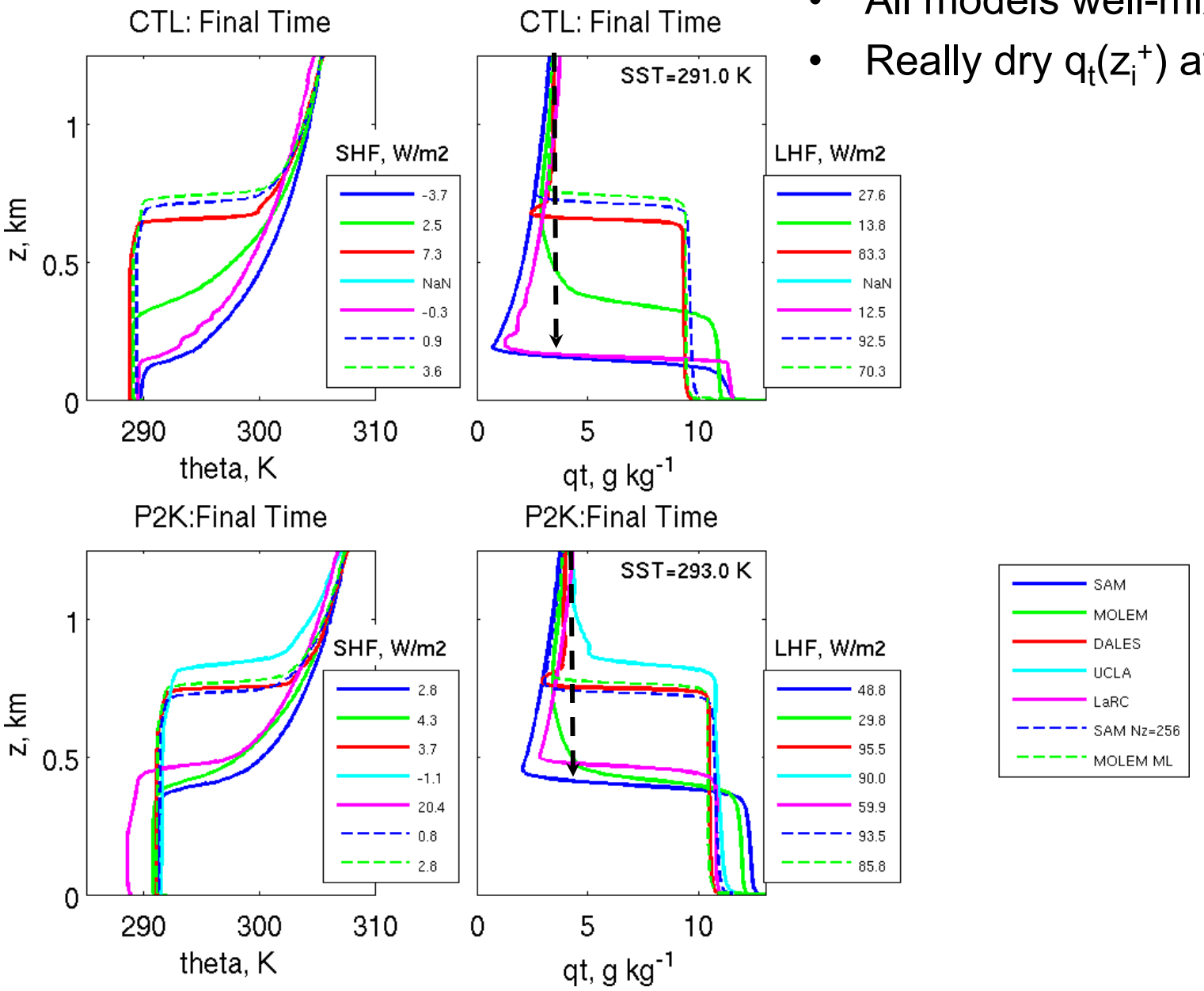


S12: dx/dz = 25/5 m at inversion



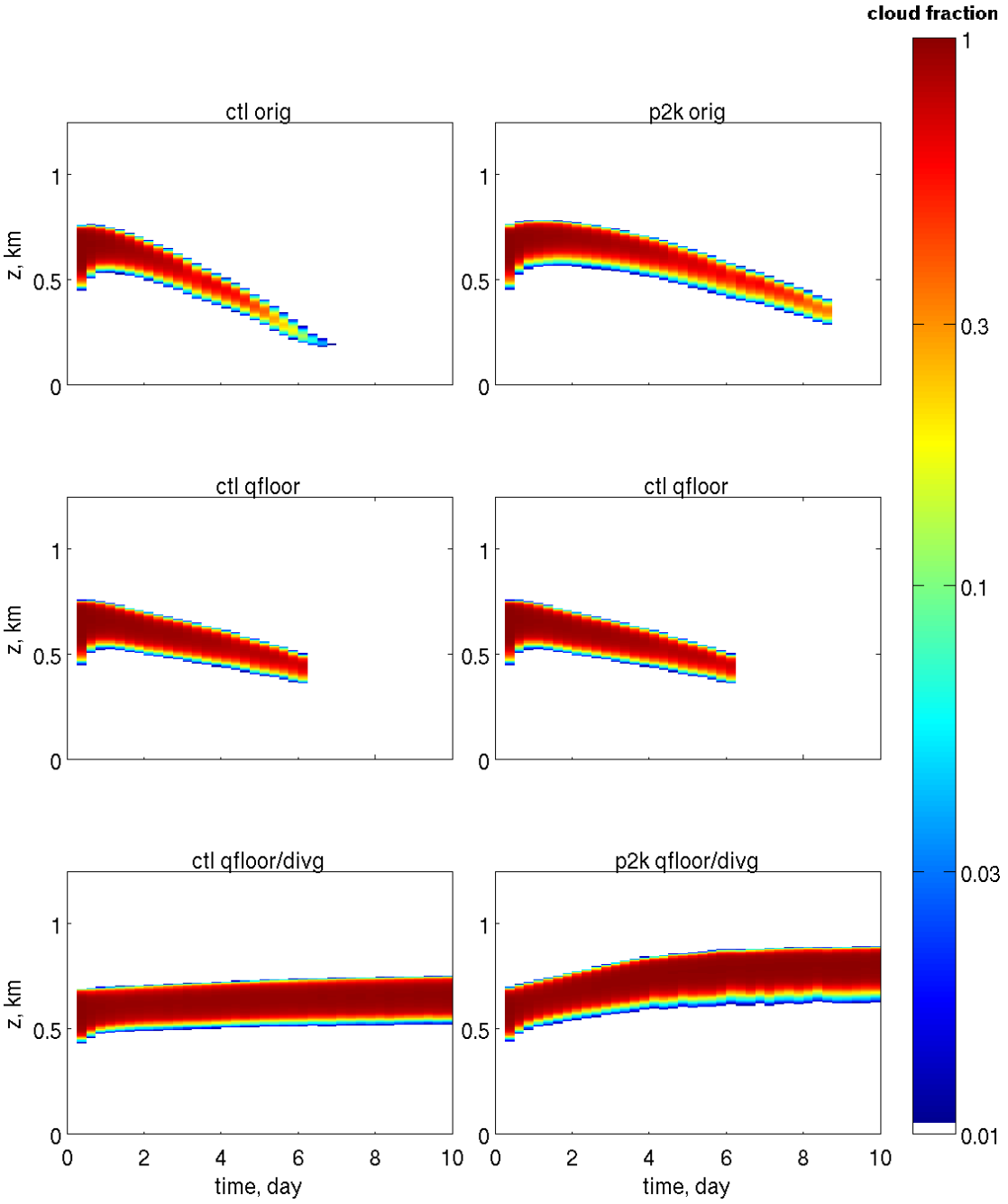
S12 θ and q profiles

- All models well-mixed
- Really dry $q_t(z_i^+)$ at low z_i

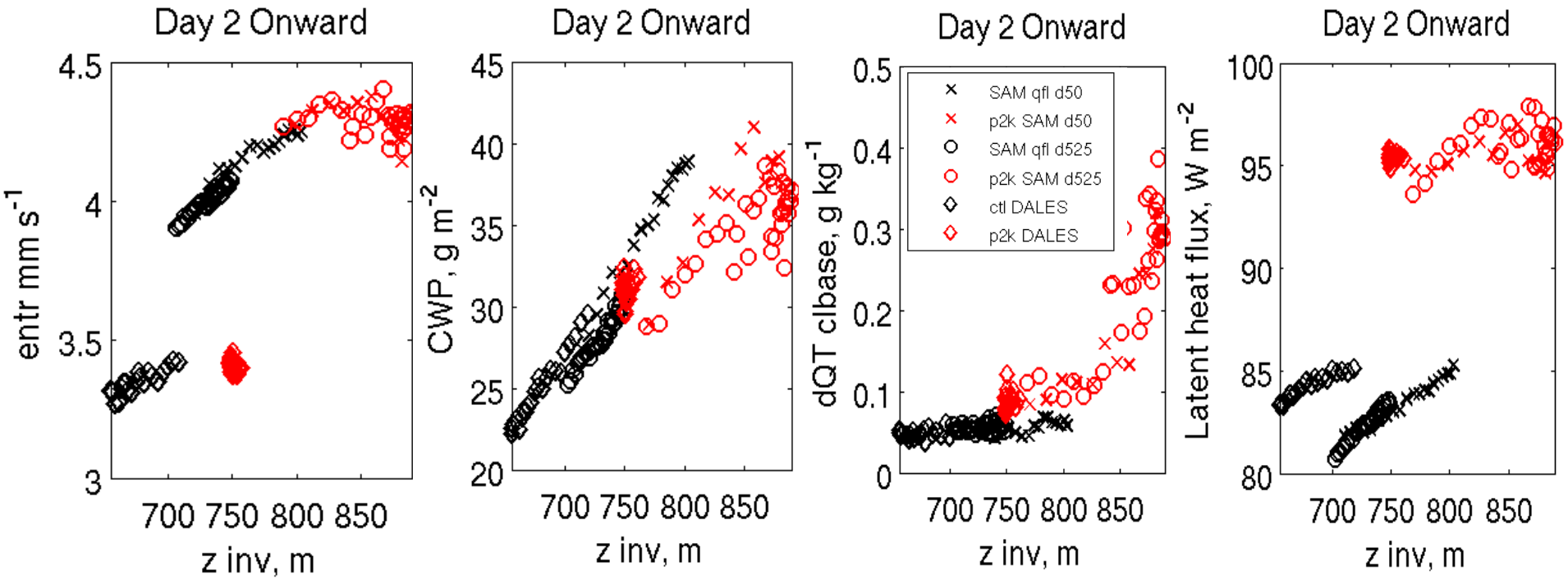


Sensitivity of SAM to slight case spec changes

- NEED!



S12 slow manifold analysis



Entrainment rate 10% higher and LWP 10% lower at given zi for SAM than DALES

Again, little +2K sensitivity of w_e vs. z_i, but LWP reduced 10%

The +2K z_i deepening far more than makes up for this to increase steady-state LWP.

For a given z_i, +2K LHF is 12% larger and the PBL is slightly more decoupled.

S12 LES case refinements

- q_t nudged to 1.2 km value for $z_i < z < 1200$ m
- Mean near surface divergence reduced 5% (still consistent with ERA40 climo).
- With these changes, SAM and DALES (and LaRC, we expect) sustain a steady well-mixed Sc layer at S12 for both ctrl and p2k cases.
- Cloud feedbacks appear to be negative, consistent with mixed-layer model results of Caldwell and Bretherton (2009).
- Feedback mechanism: Cloud thickens in p2k mainly because inversion rises due to less subsidence

Summary of CGILS LES results

Results seem to be finally converging after resolution/setup tweaks

S6 (trade Cu): LES ~ agree at dz/dx = 100/40 m

control PBL is deeper than climo,

+2K cloud response is in the noise

S11 (decoupled Sc):

Some LES make solid Sc with dz = 25m; others require finer dz to do so. Shallowing/FT drying feedback may hinder solid Sc.

+2K cloud thinning in solid Sc models – working on why.

+2K PBL deepening in all models

S12 (well-mixed Sc):

LES make Sc-capped mixed layer.

+2K PBL deepening and cloud thickening

Plans: Gather final model outputs and write up results by next GCSS BLCWG meeting (June 2010). Move on to transient forcing and 4xCO_2 intercomparisons.