Overview of LES Results for S11 Forcings

Peter Blossey[(#)] and Chris Bretherton, U Washington

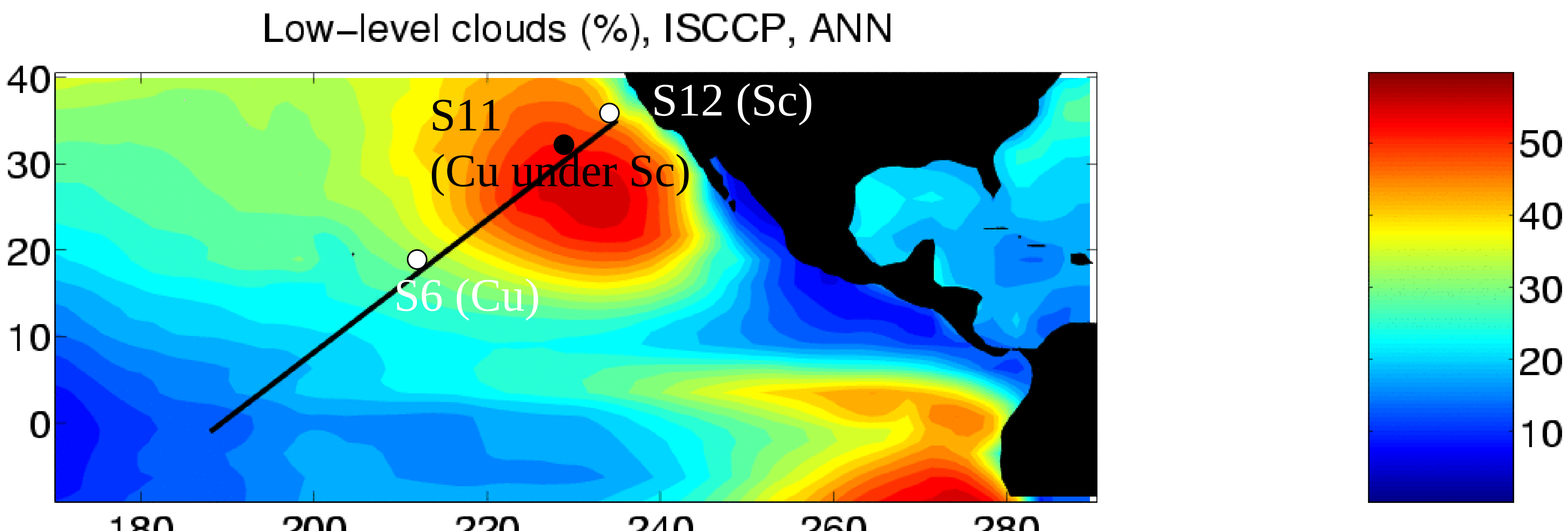
Minghua Zhang and Marat Khairoutdinov, Stony Brook U.

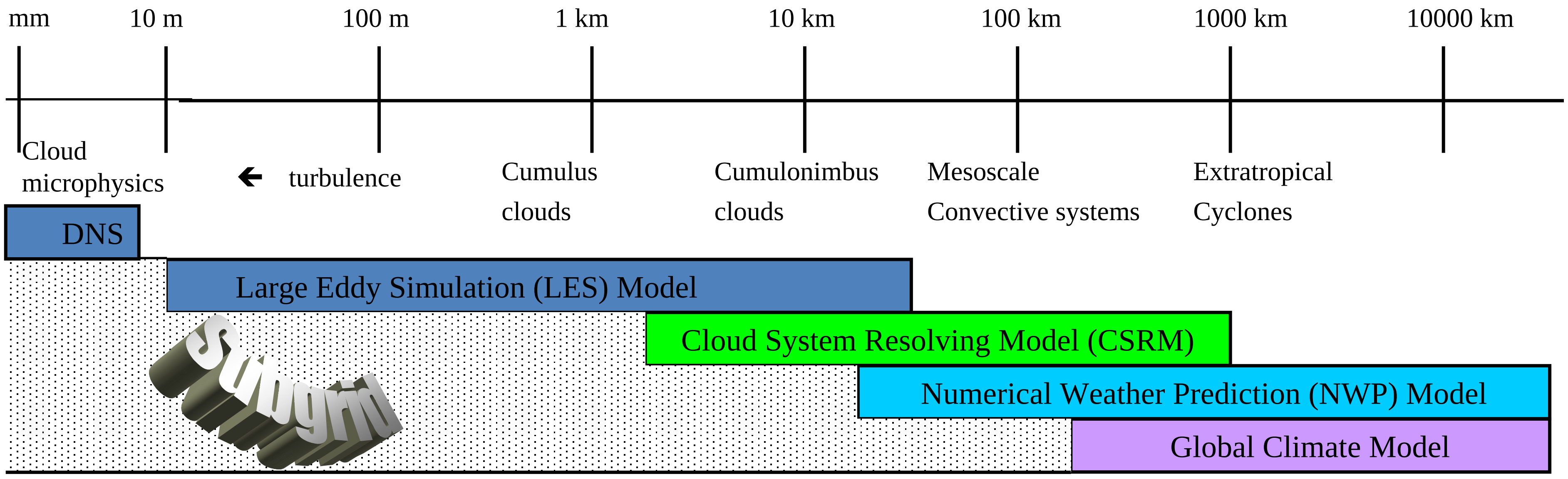
Anning Cheng, NASA LARC

Adrian Lock, UKMO

Stephan de Roode, TU Delft

Irina Sandu and Thijs Heus, MPI



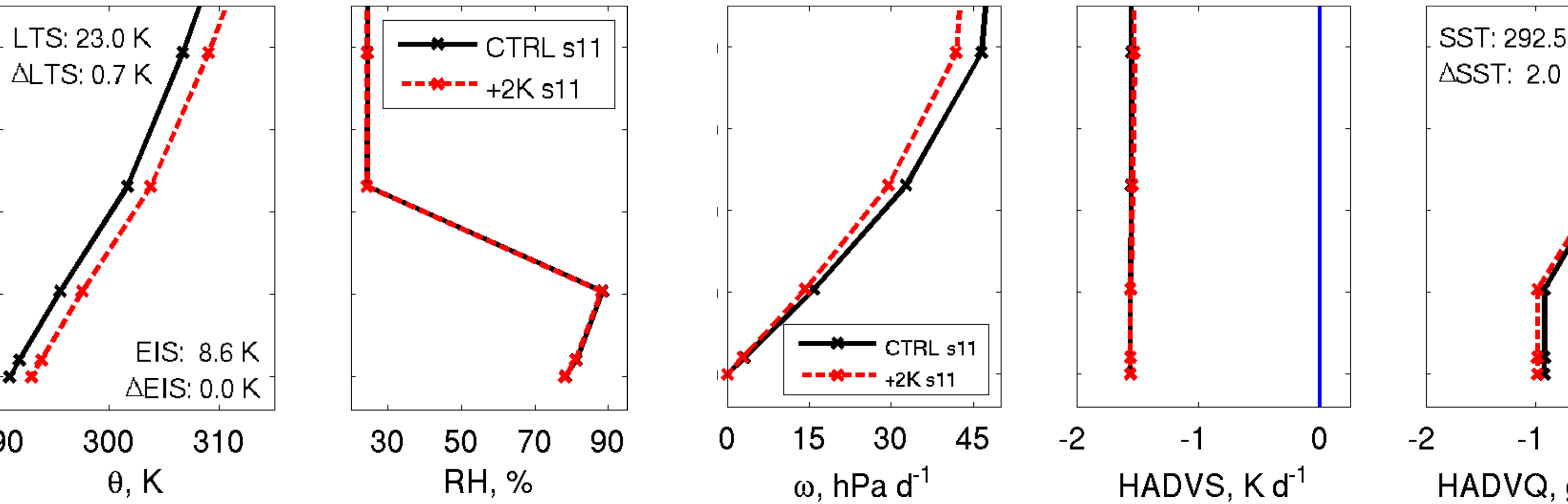


courtesy Pier Siebesma

Length scales that dominate the turbulent transport are explicitly resolved by LES

Subgrid scales (< ~ 50-100 m) are parameterized

Hope: LES as a higher-fidelity benchmark for single column model (and GCM) cloud response



rol Forcings: JJA climatology from 3 GCSS Pacific Cross-section points

o steady state with diurnally-averaged insolation

cal profiles of temperature, humidity and ozone above the LES domain are used for radiative tra

mulation time

- 10 days
- Adaptive time step, dtmax = 10 secs
- Radiation time step = 60 secs

omain size

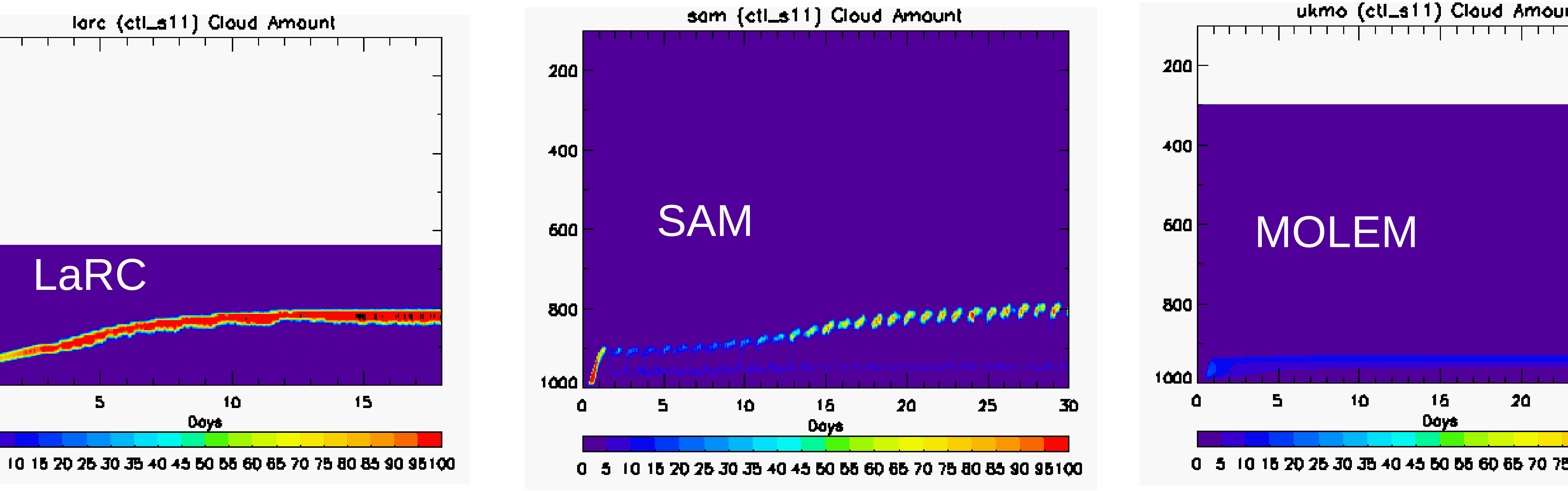
- 4.8 x 4.8 x 4 km^3, 96 x 96 x 128 grid points (Δz = 25 m in lower part)
- Additional layers above LES domain for radiation

tal CPU hours on 32 processors

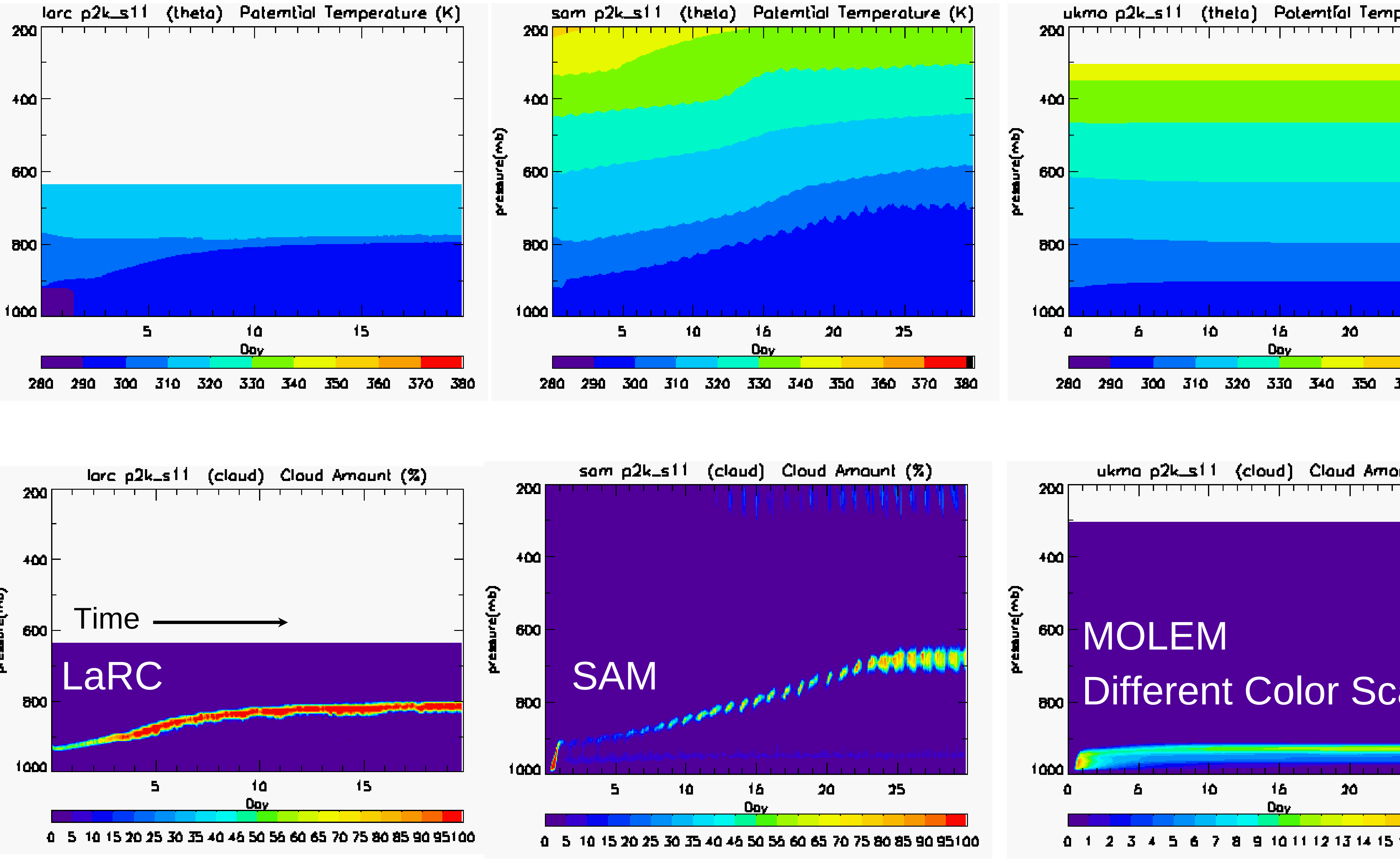
- 2700 hours

und 1 gives large disagreement comparable to variability found in SCM res

Cloud Amount (red color = 100% cloud fraction)



Time ⟶


larc p2k_s11 (theta) Potential Temperature (K)
sam p2k_s11 (theta) Potential Temperature (K)
ukmo p2k_s11 (theta) Potential Temp
pressure(mb)
Day
larc p2k_s11 (cloud) Cloud Amount (%)
sam p2k_s11 (cloud) Cloud Amount (%)
ukmo p2k_s11 (cloud) Cloud Amo
Time
LaRC
SAM
MOLEM
Different Color Sca

Round 2: Case modifications

Nudge temperature above 2500m. Subsidence should help maintain free-trop temperature

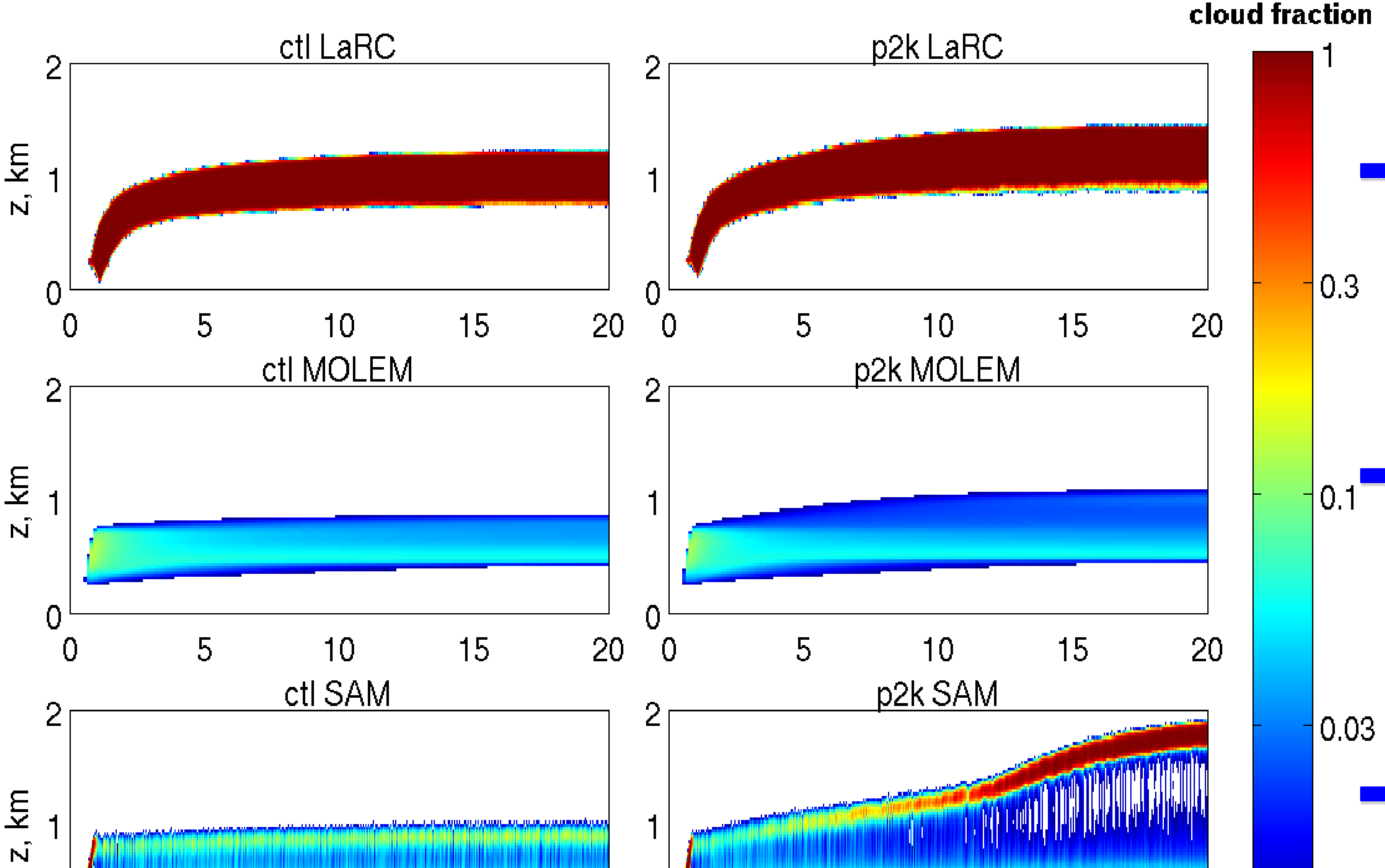
Have models use same radiation scheme (RRTMG)

trol

mixed
c

low
u

led Cu
r Sc

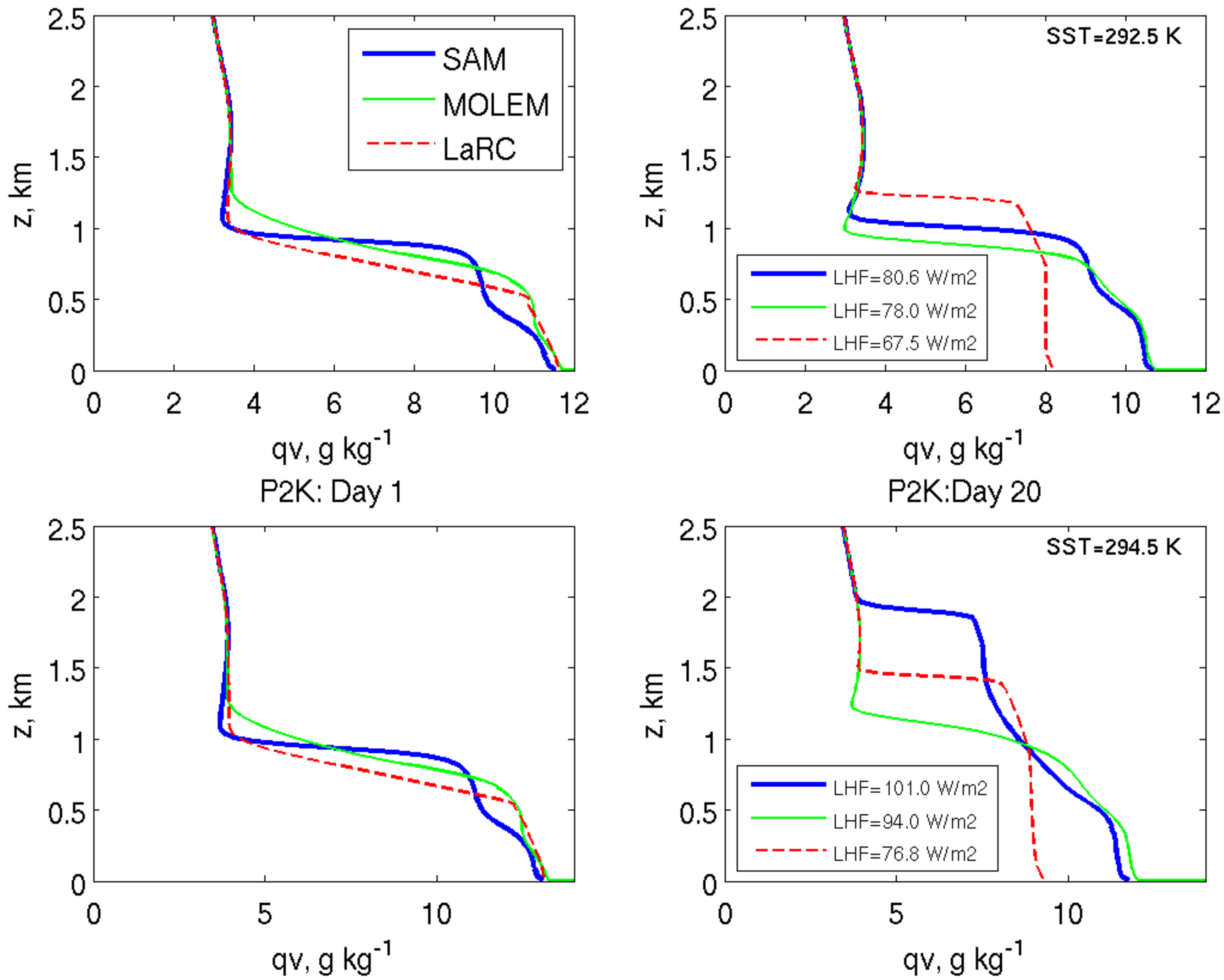


P2

Thicke

Les
clo

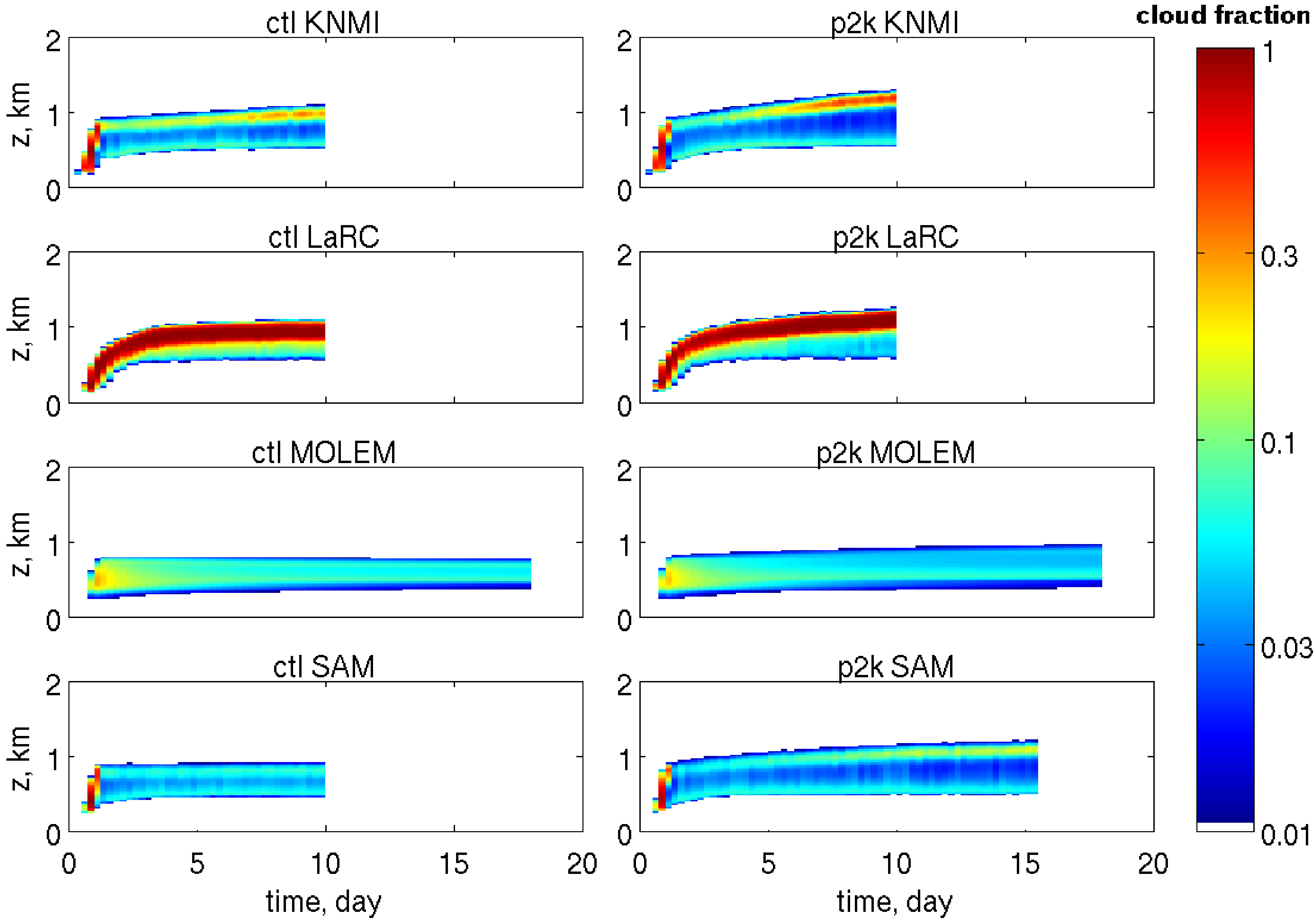
More &
cl



Round 3 modifications

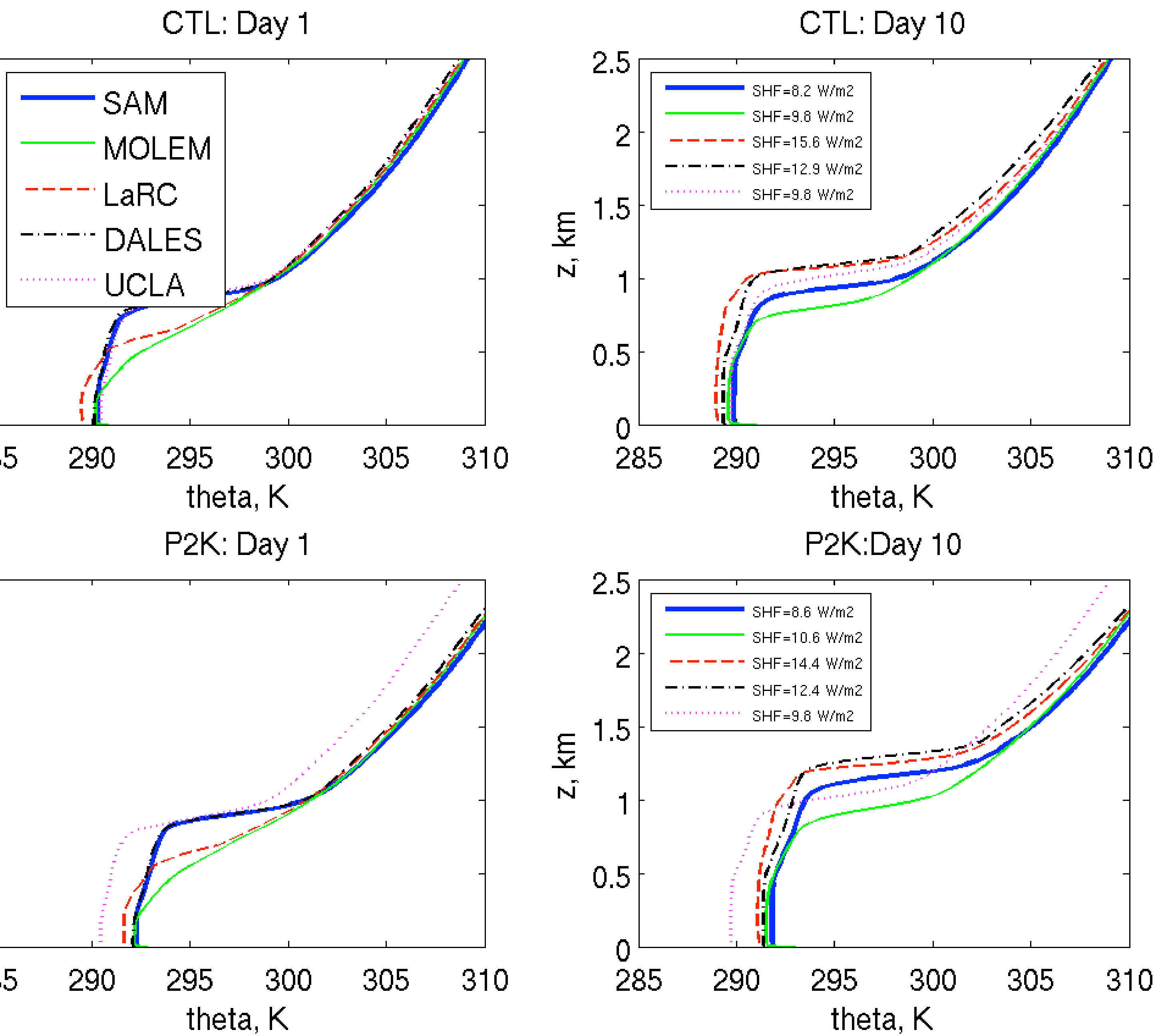
specified surface transfer coefficient:

$$\overline{s'} = C_h(C_pSST - s^{air}_{surf}) \qquad \overline{w'q'} = C_q(0.98q_{sat}(p_{surf}, SST) - q^{air}_{surf})$$

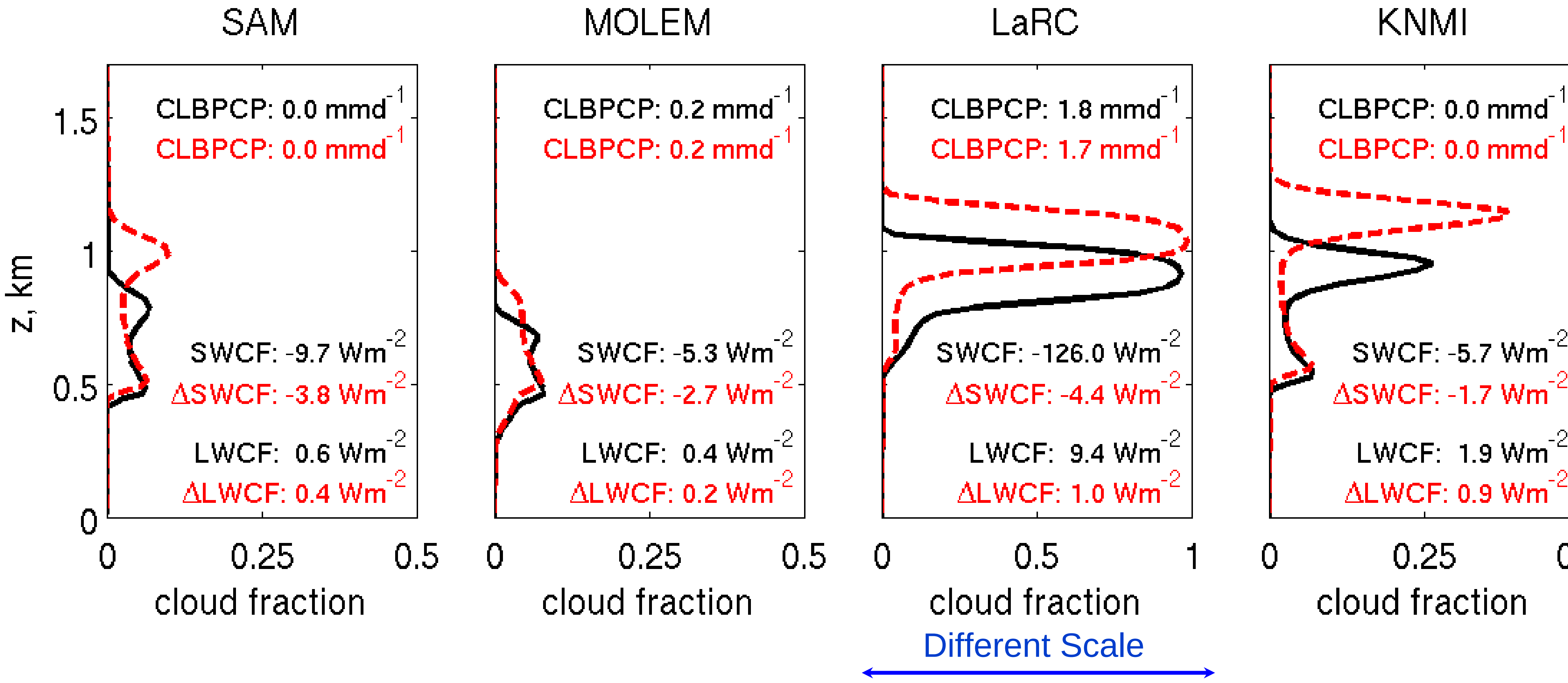


y ten day runs requested while we're working out the final kinks in the setup.

MI deepening steadily through day 10, with more inversion cloud than SAM, MOLEM.



- Near-surface condit more consistent witl surface transfer coe
- Still a diversity of inv heights, cloud states
- SAM, MOLEM sligh warmer in free trop DALES, LaRC
- Caused by above-c cooling? Radiation scheme? DALES u Fu-Liou (Pincus & Stevens, 2009).

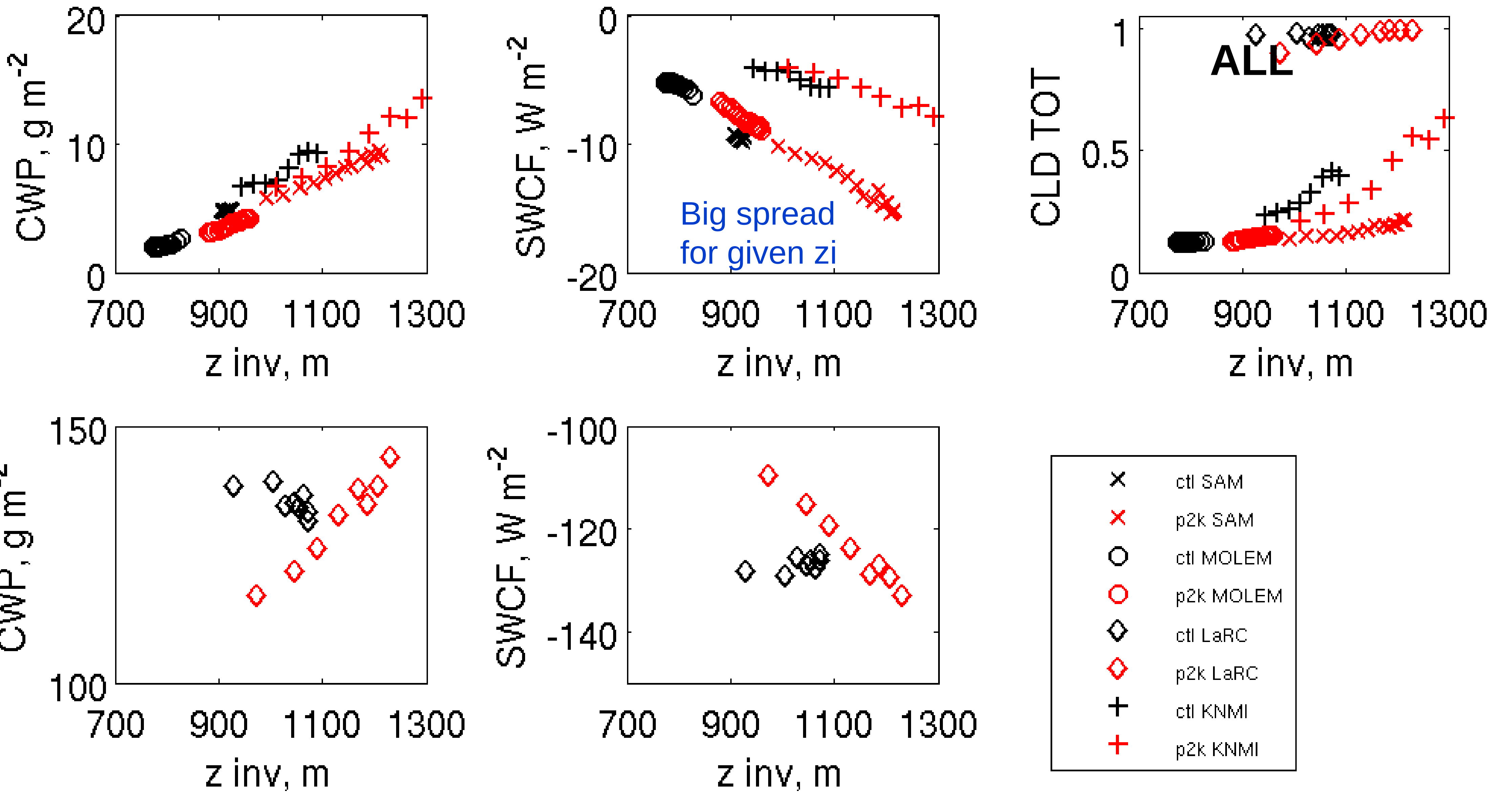


Note: Not equilibrium solutions: day 7.5-10 averages

Inversion deepens in all models

Below-inversion cloud increases in KNMI and SAM

Progress here (certainly compared with last June). However, still a ways to go (not yet equilibri

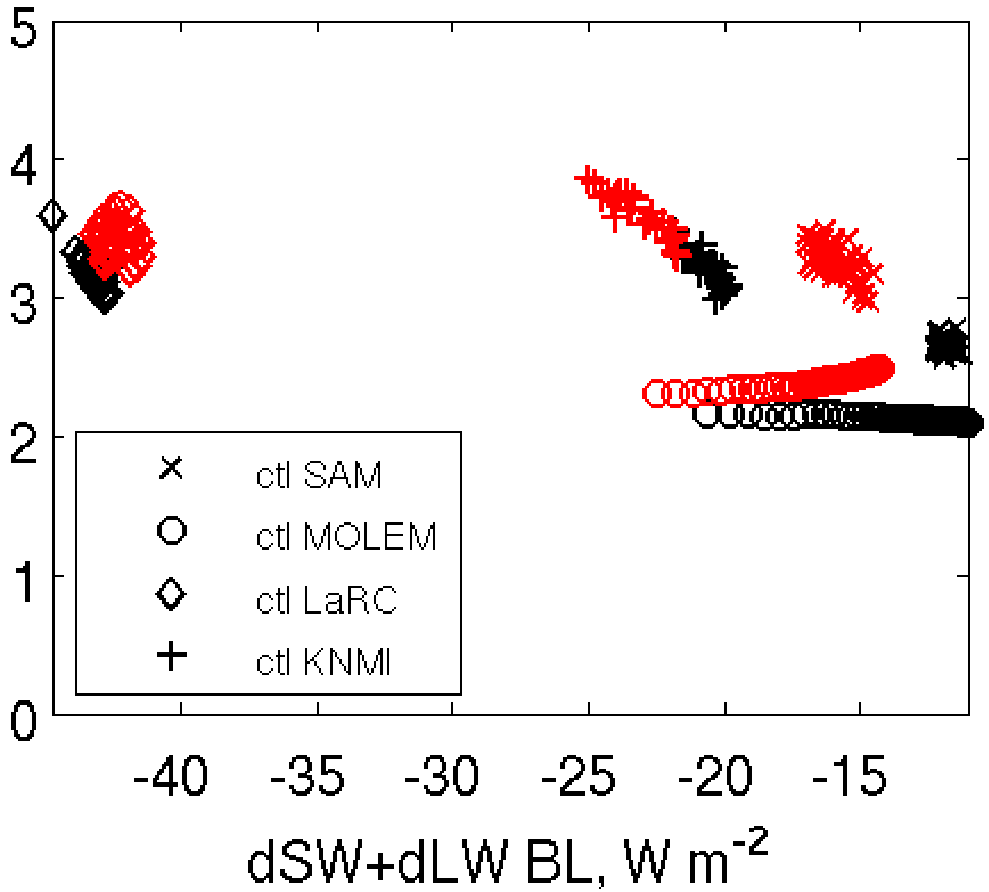


2K runs generally similar for similar z_{inv} after initial transient (Day 3 on)

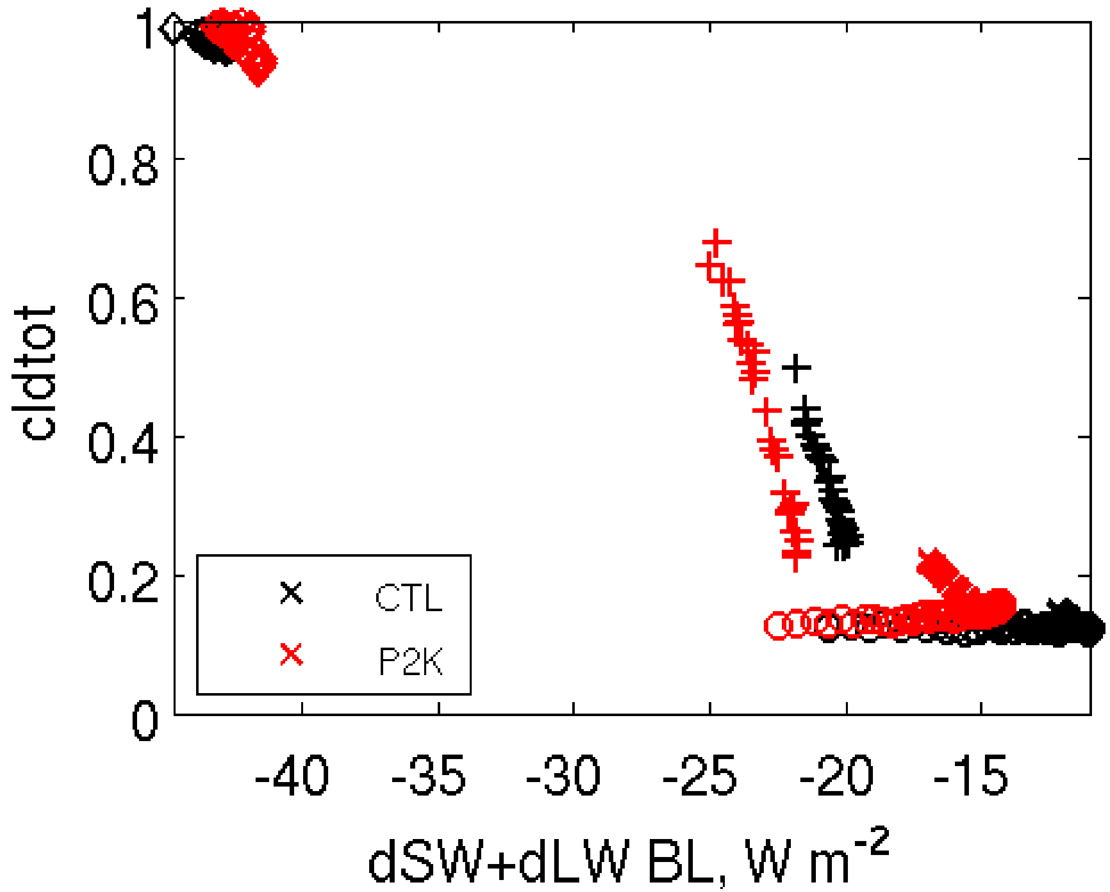
WCF, CWP changes driven in part by increase in inversion height

deepening of inversion in P2K runs exaggerated by artificially large decrease in low-level subsi

rainment rate ∝ radiative cooling (except
aRC)



Radiative cooling ∝
cloud fraction



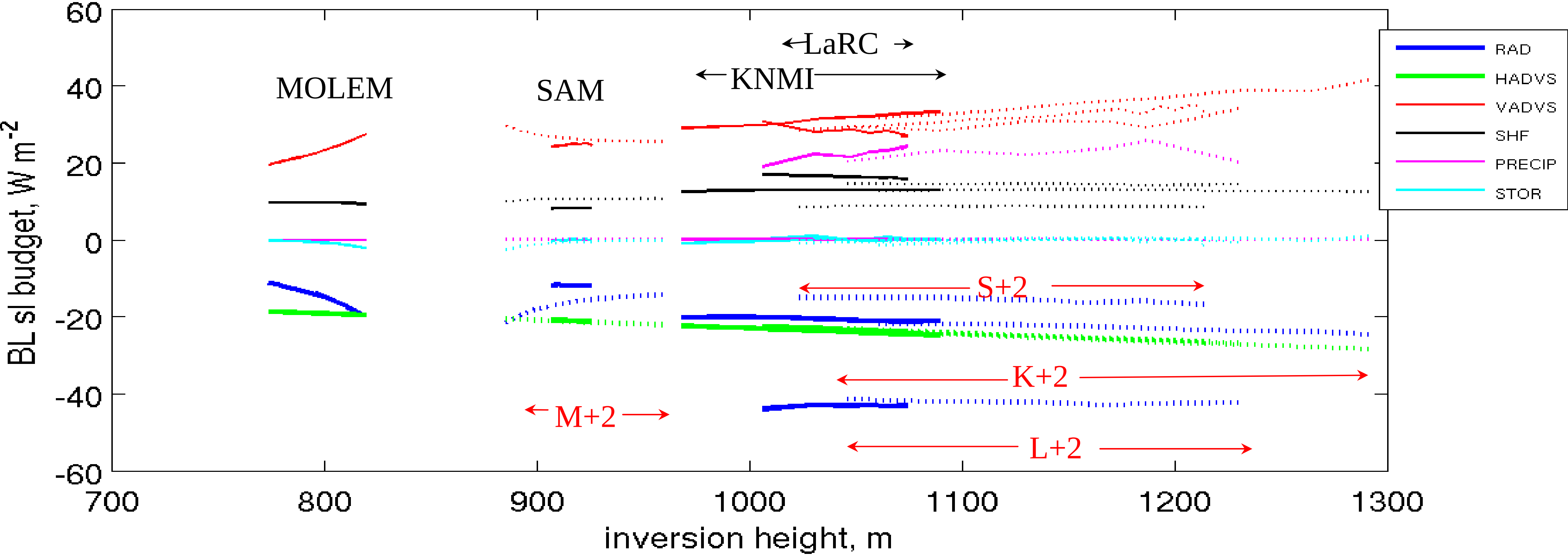
Larger cloud fraction → More BL radiative cooling → More entrainment

$w_e = dz_i/dt - w(z_i)$, $z_i(t)$ = height at which mean RH= 50%

$$\ldots \rho \frac{\partial s_l}{\partial t} dz + SHF - \rho \overline{w' s_l'}\Big|_{z_i+50} - \int_{z_i-50}^{z_i+50} \rho \frac{\partial s_l}{\partial t} dz - \int_0^{z_i+50} \rho w \frac{\partial s_l}{\partial z} dz - \int_0^{z_i+50} \rho \left(\mathbf{u}_h \cdot \nabla_h s_l\right) dz - F_{rad}\Big|_0^{z_i+50} + \ldots$$

orage 'Entrainment' Horizontal advection Radiation Late

Entrainment warming +SHF ≈ Radiative Cooling + Hor. Adv.
(VADVS) (-RAD) (-HADVS)

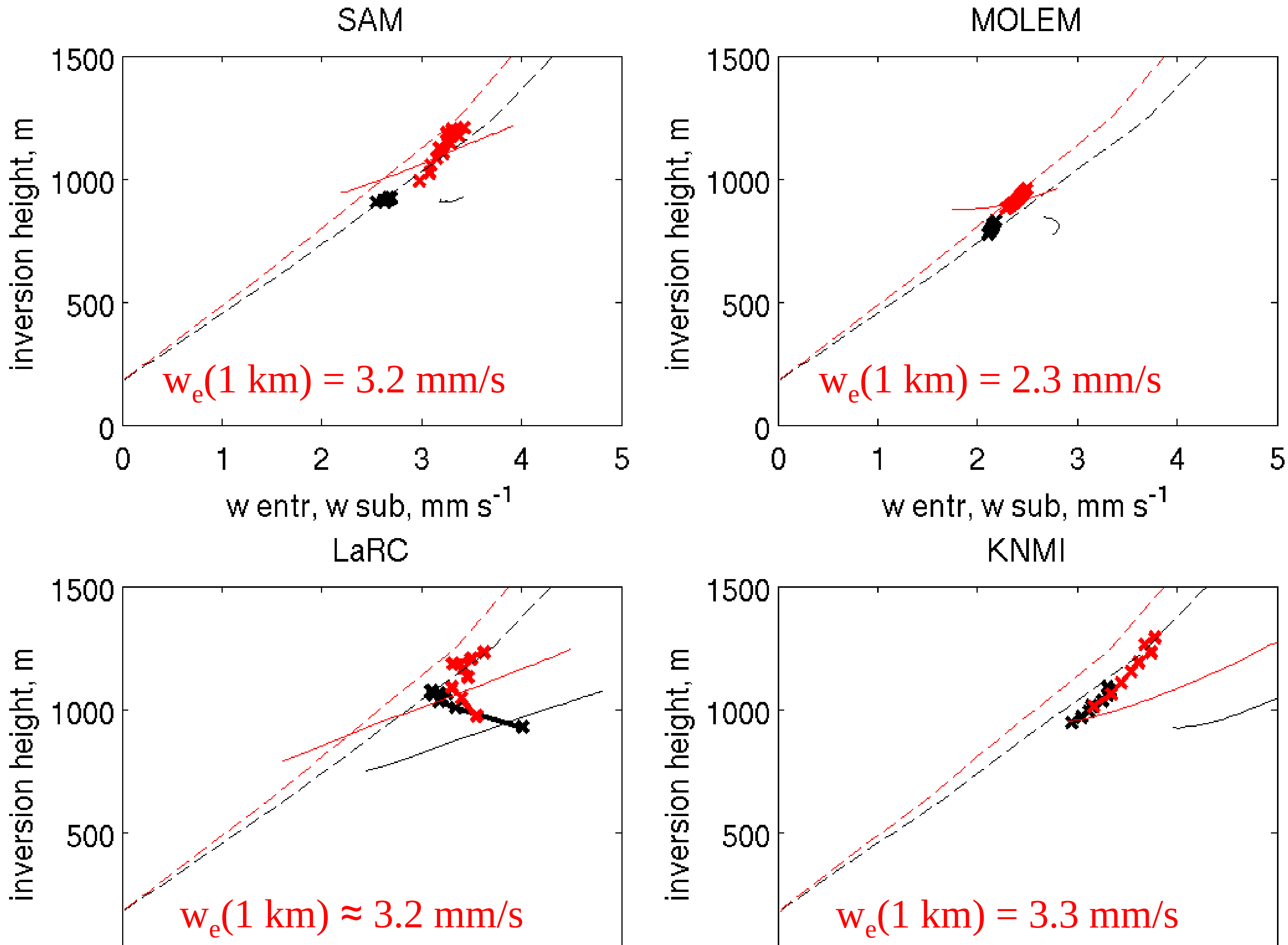


More cloud → more rad cooling → more entrainment → deeper PBL

Only LaRC has a strongly stable steady state.

Other LESs have dw_e/dz_i almost as large as $-dw/dz_i$ (barely stable) because cloud fraction, radiative cooling, adv. cooling increase with

The p2K and ctl runs have surprisingly similar $w_e(z_i)$.



- LES setups have been harmonized:
  - temperature nudged aloft,
  - same surface scheme,
  - mostly same radiation,
  - considerable debugging of setup, inter-model differences.
- Despite diversity of mean BL state, models show similar cloud response.
- Cloud response appears to be driven by increase in z_{inv}
- How much should ω decrease in warmer climate?
- Models still show tendency to deepen gradually...

in changes to the forcing data are:

Temperature and moisture fields from the ECMWF analysis for July 2003 are used as th control case to facilitate comparison with observations. For the warmer p2K temperature and water vapor profiles, moist adiabatic changes and constant relative humidity are used

Vertical resolution in the forcing data is increased to 62 levels as in the ECMWF analysi

recomputing omega consistent with RRTM radiation calculations, with omega going to zero at the surface rather than at 1000 hPa

The setup of the large-eddy simulations is standardized as follows:

un ten days of ctl and p2k for each case.

6: nudge T, q above 4000m, $\Delta x = \Delta y = 100$m, $\Delta z = 40$m up to 4km.

11: nudge T,q above 2500m, $\Delta x = \Delta y = 50$m, $\Delta z = 25$m up to 2500m.

12: nudge T,q above 1200m, $\Delta x = \Delta y = 25$m, $\Delta z = 5$m up to 900m.

CLIPSE actively involved in CGILS-LES experiments

MO (Lock)

D (De Roode)

PI (Sandu/Heus/Rieck)

LES model: Warsaw

-30 September: new results will be presented during the EUCLIPSE/GCSS meeting