(MODIS satellite image)

Single-column study of low cloud feedback processes in CAM5 vs. LES

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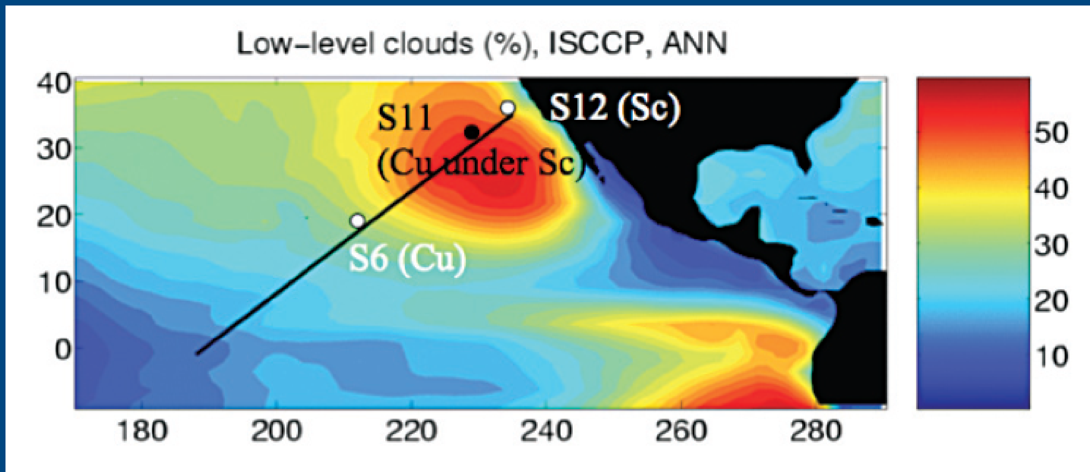
(SCAM5 provided by Sungsu Park, NCAR)

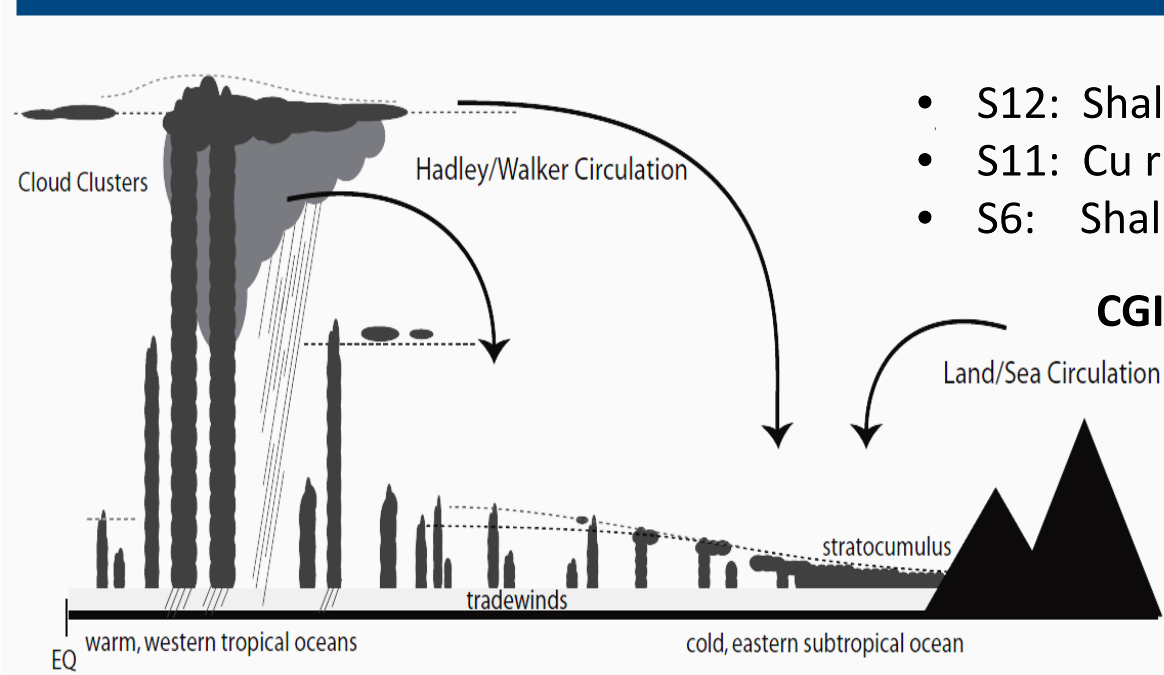
The CGILS Intercomparison

CFMIP/GASS column cloud feedback study: M. Zhang, P. Blossey, C. Bretherton

Zhang et al (2010)



The CGILS intercomparison transect overlaid on the Northeast Pacific annual-mean low cloud amount. Initially, CGILS focused on location S11 (32°N, 129°W) near the northern end of the GCSS Pacific Cross-Section Intercomparison study region. The other two locations are S6 and S12. S11 is near the climatological summertime maximum of low-level cloud cover. S6 is characterized by shallow cumuli, and S12 by shallow coastal stratocumulus.



- S12: Shallow, well-mixed stratocumulus (Sc)
- S11: Cu rising into Sc
- S6: Shallow Cu

CGILS Goal: Compare LES and SCM CTBL simulations of these locations under large-scale forcings representative of present and perturbed climates

CGILS setup and extra S12 sensitivity studies

Basic setup at each location

- Diurnally averaged summertime insolation
- Control: Large-scale forcings: ECMWF JJA mean:
  - SST
  - T, RH well above CTBL
  - CTBL horizontal T,q advection
  - Subsidence
  - Wind profile
- $N_d = 100\ cm^{-3}$
- Models run to steady-state
- LES models harmonized surface flux, radiation schemes
- Show LES, SCAM5 results
- S12: Add UW mixed-layer model

CGILS sensitivity studies

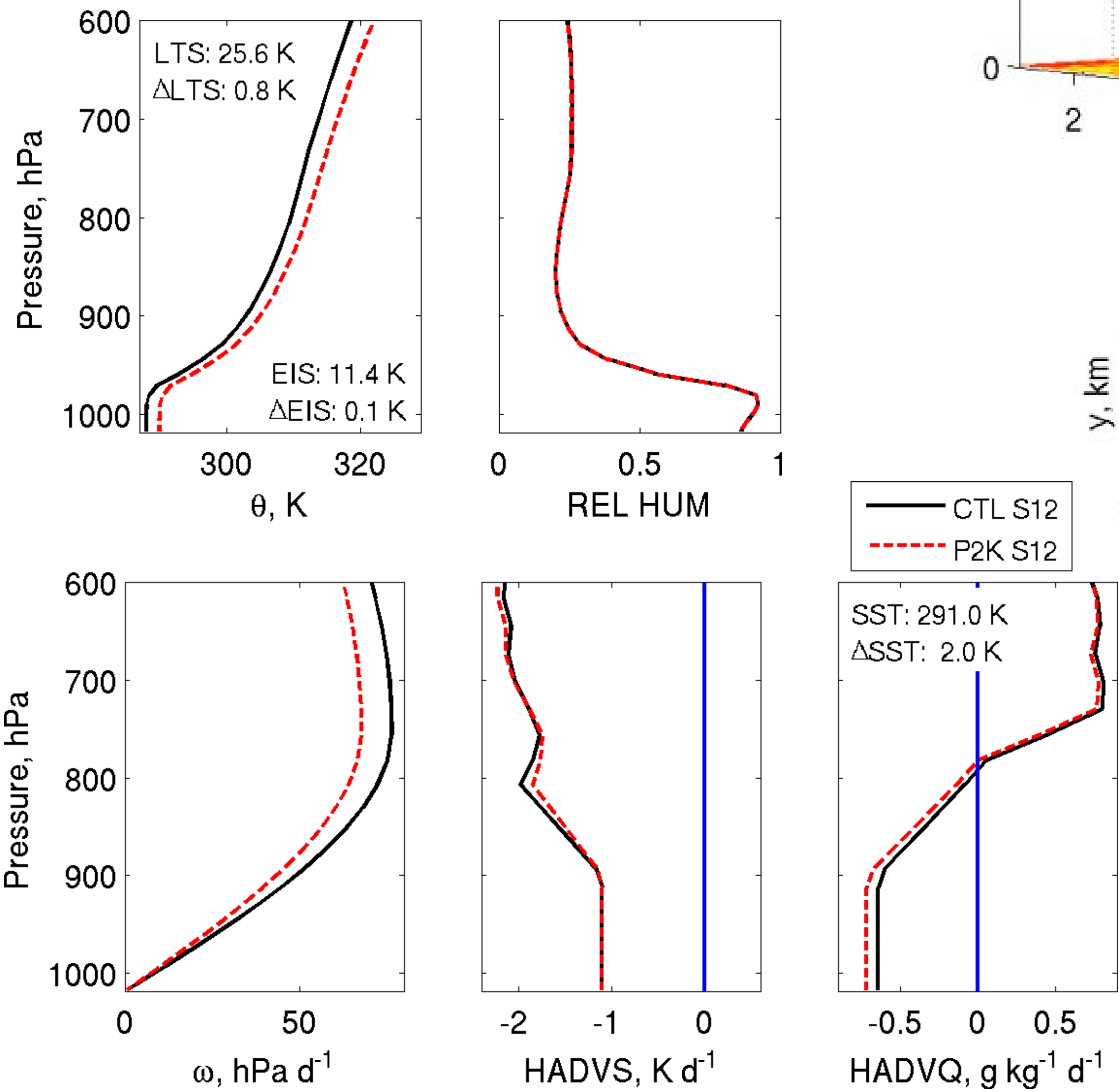
- **+2K SST increase (p2K)**
  - Reduced subsidence
  - Moist-adiabatic increase in warming aloft ($\Delta EIS \approx 0$)
  - Free-trop RH unchanged

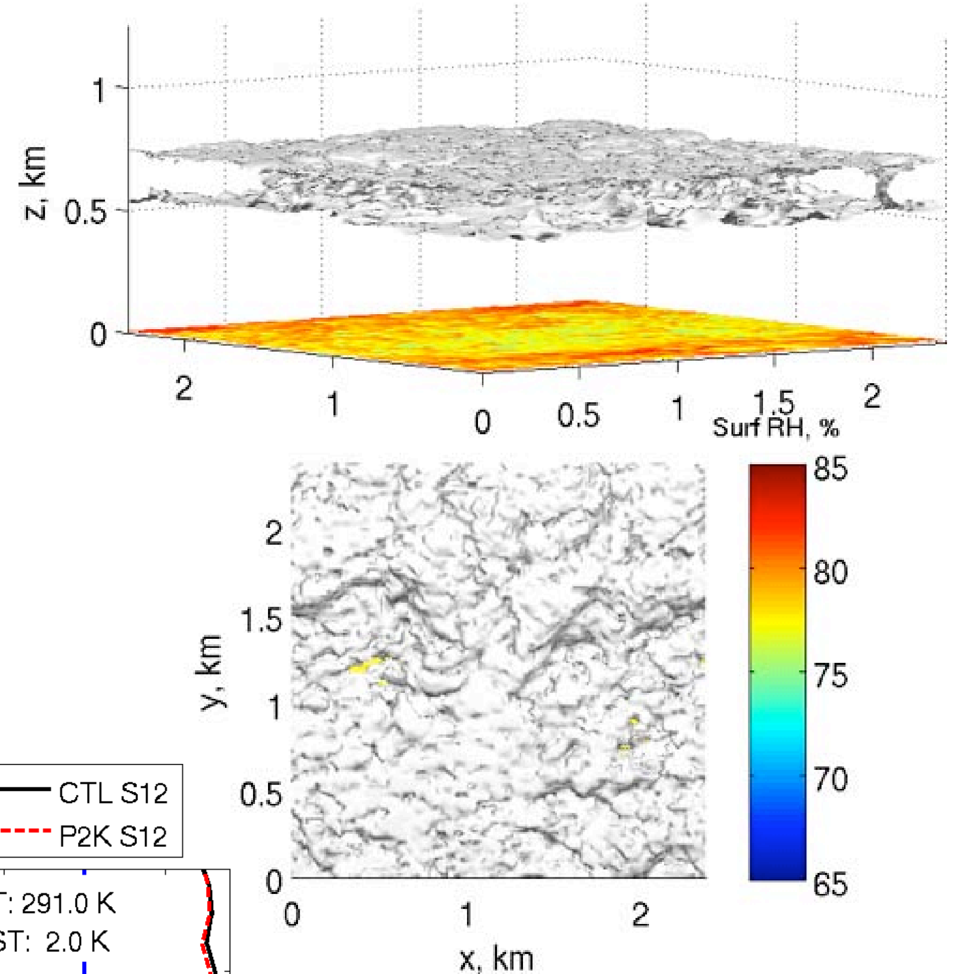
S12 only:

- **4xCO_2 fixed SST**
- **P2K OM0** (unchanged subsidence)
- **P2K FT** (p2K free-trop, fixed SST)

…separate cloud-changing factors

CGILS S12: Coastal Sc





$\Delta x = \Delta y = 25$m

$\Delta z = 5$-15m

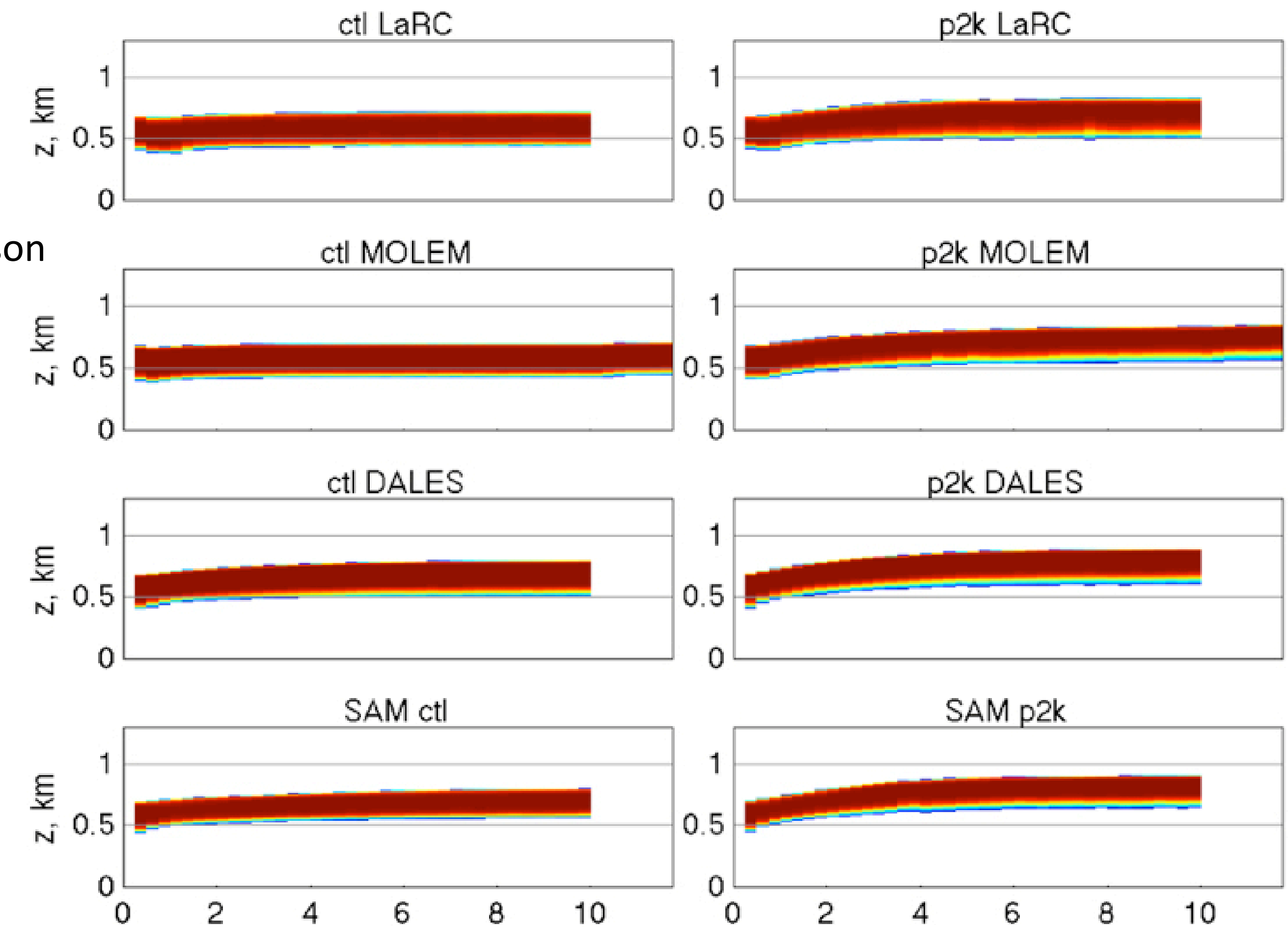
96 x 96 x 320

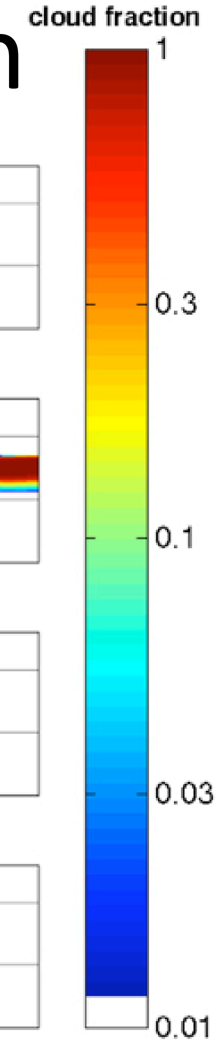
Nudged above 1200 m

S12 Results: Cloud Fraction

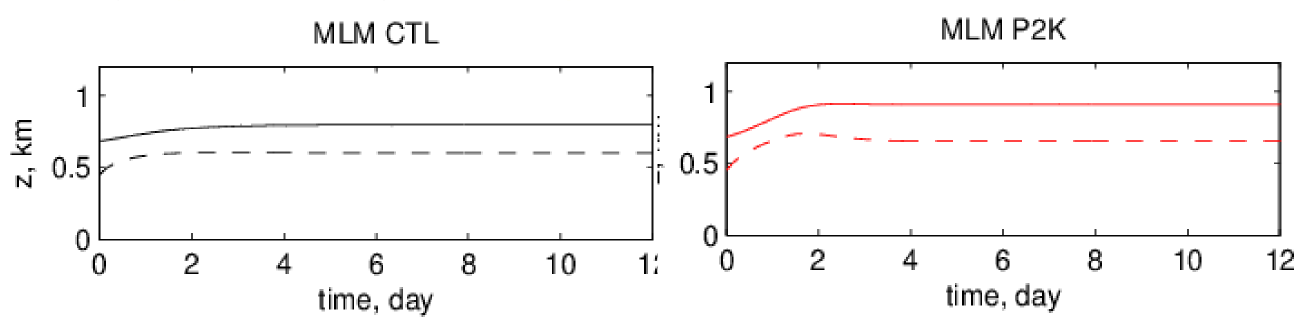
LES Results

from CGILS intercomparison



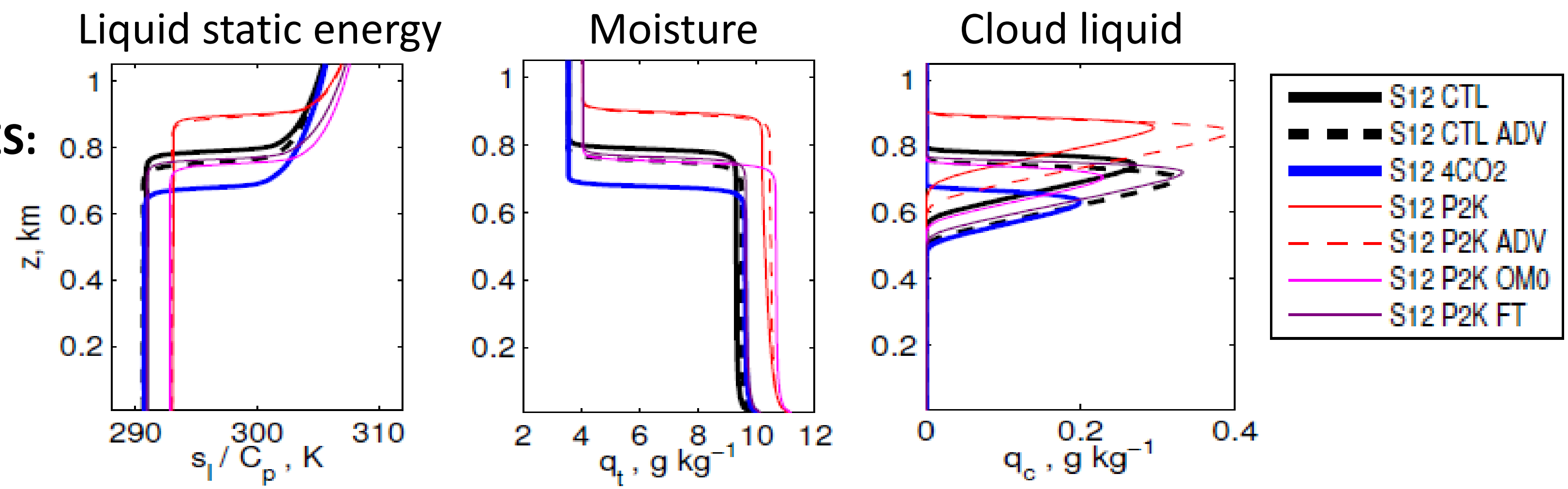


MLM Results



Preliminary S12 Results: Profiles

SAM LES:



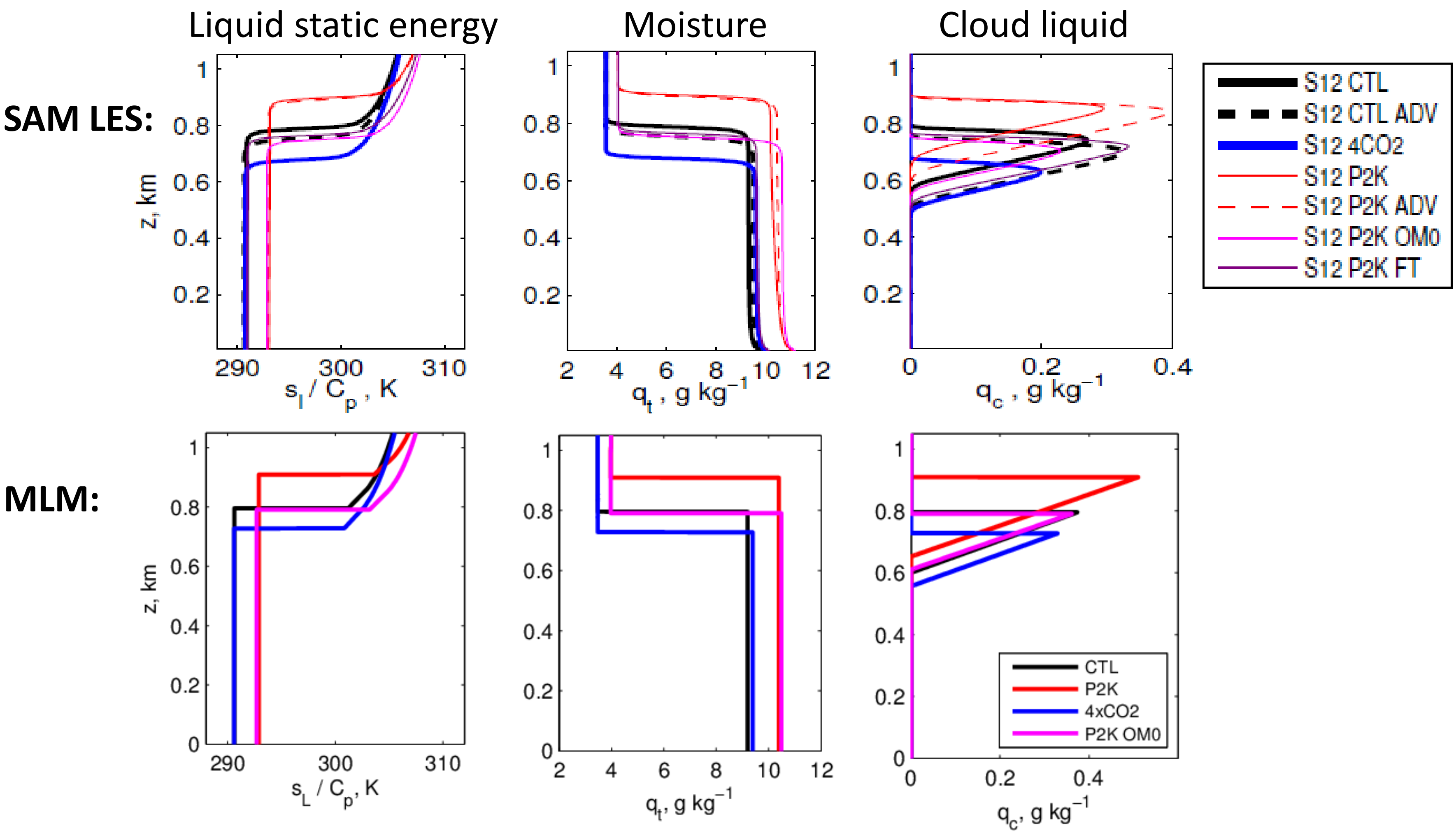
- Simulations appear well-mixed
- New LES advection scheme (ADV) affects control LWP more than its p2K sensitivity
- Cloud response mechanisms:

  Radiative (more emissive free trop cuts CTBL destabilization ➔less turb&LWP)
  (4CO2 and p2K OM0 vs. CTL)

  Dynamic (less mean subsidence raises cloud top ➔ more LWP)
  (p2K vs. p2K om0)

  Thermodynamic (stronger inversion weakens entrainment drying➔ more LWP)
  (p2K FT vs. p2K)

Preliminary S12 Results: Profiles



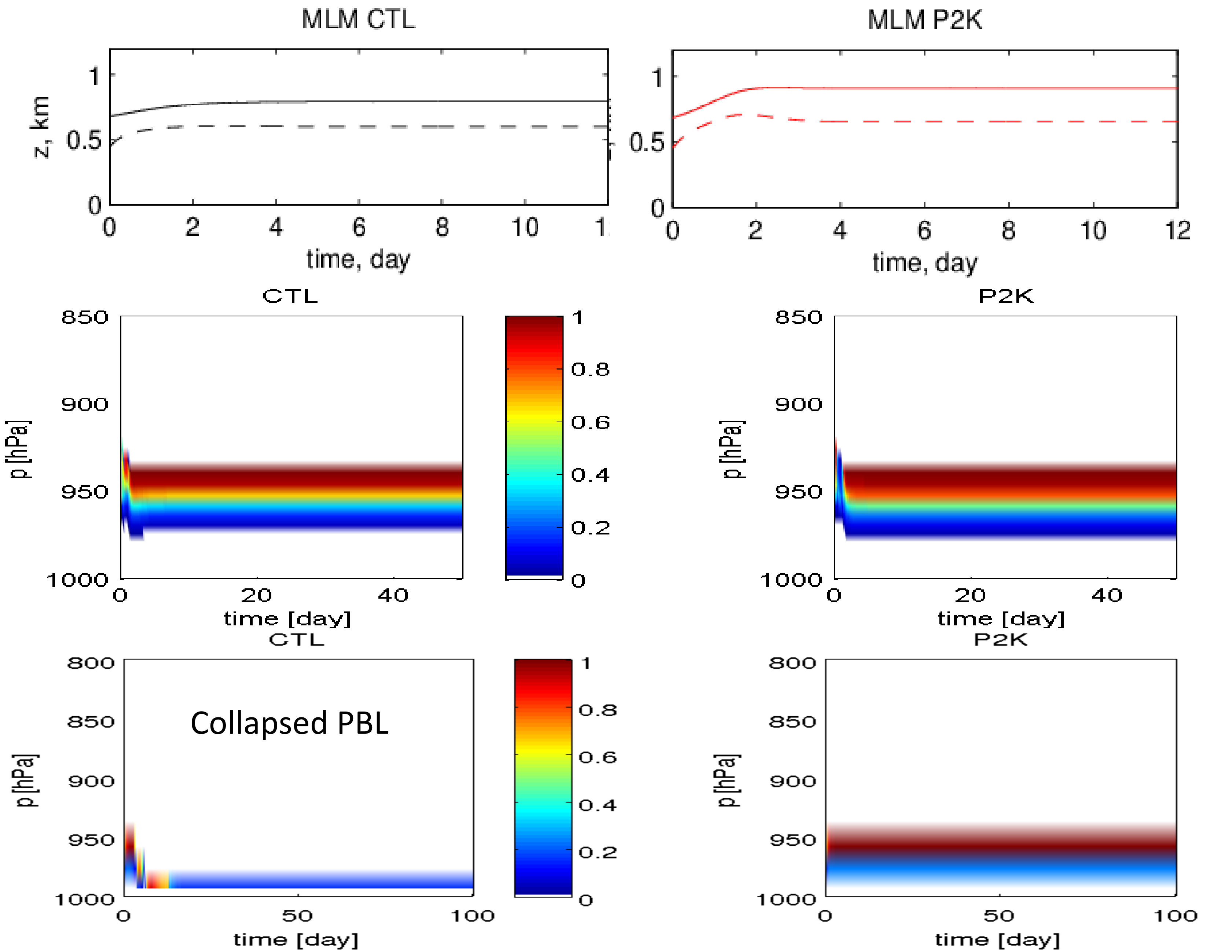
MLM has the same sensitivities as the LES

Comparison of MLM and SCAM5

MLM

SCAM5: L80, 300s

SCAM5: L30, 1200s

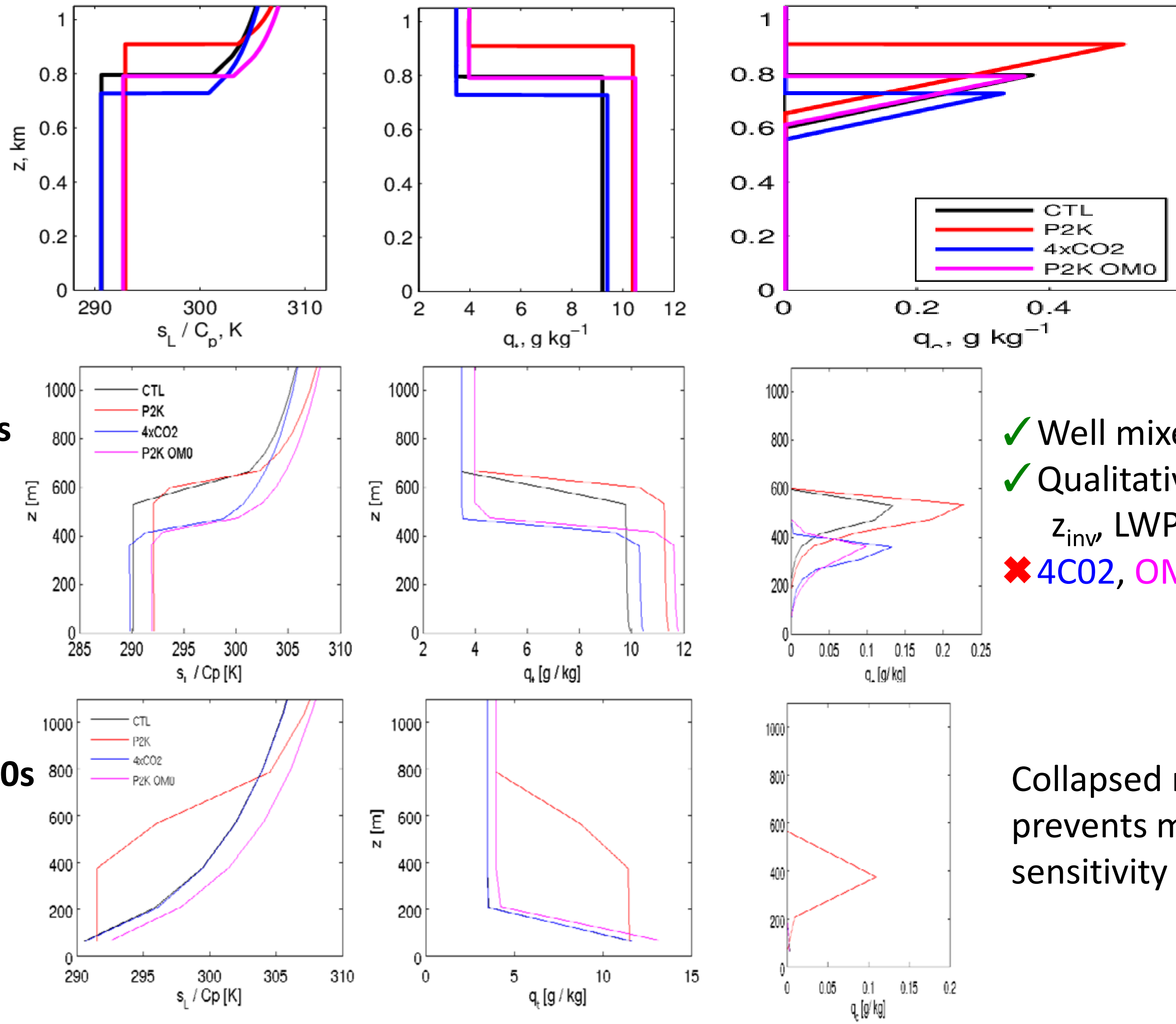


Liquid static energy | Moisture | Cloud liquid

MLM:

SCAM5: L80, 300s

SCAM5: L30, 1200s



✓ Well mixed

✓ Qualitatively-correct z_{inv}, LWP responses

✖ 4C02, OM0 oscillations

Collapsed mean state prevents meaningful sensitivity testing

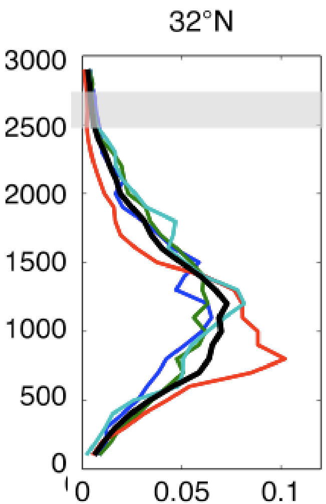
Preliminary S12 Results: Summary

		[m]	[g m^{-2}]	[Wm^{-2}]
$4xCO_2$	SAM (LES)	-111	-13	**+28**
	SCAM5 (L80)	-176	-4	**+28**
	MLM	-68	-9	**+14**
P2K	SAM (LES)	+109	+2	**-2**
	SCAM5 (L80)	+40	+16	**-30**
	MLM	+114	+32	**-30**
P2K OM0	SAM (LES)	-38	-9	**+20**
	SCAM5 (L80)	-180	-5	**+53**
	MLM	-4	-4	**+8**

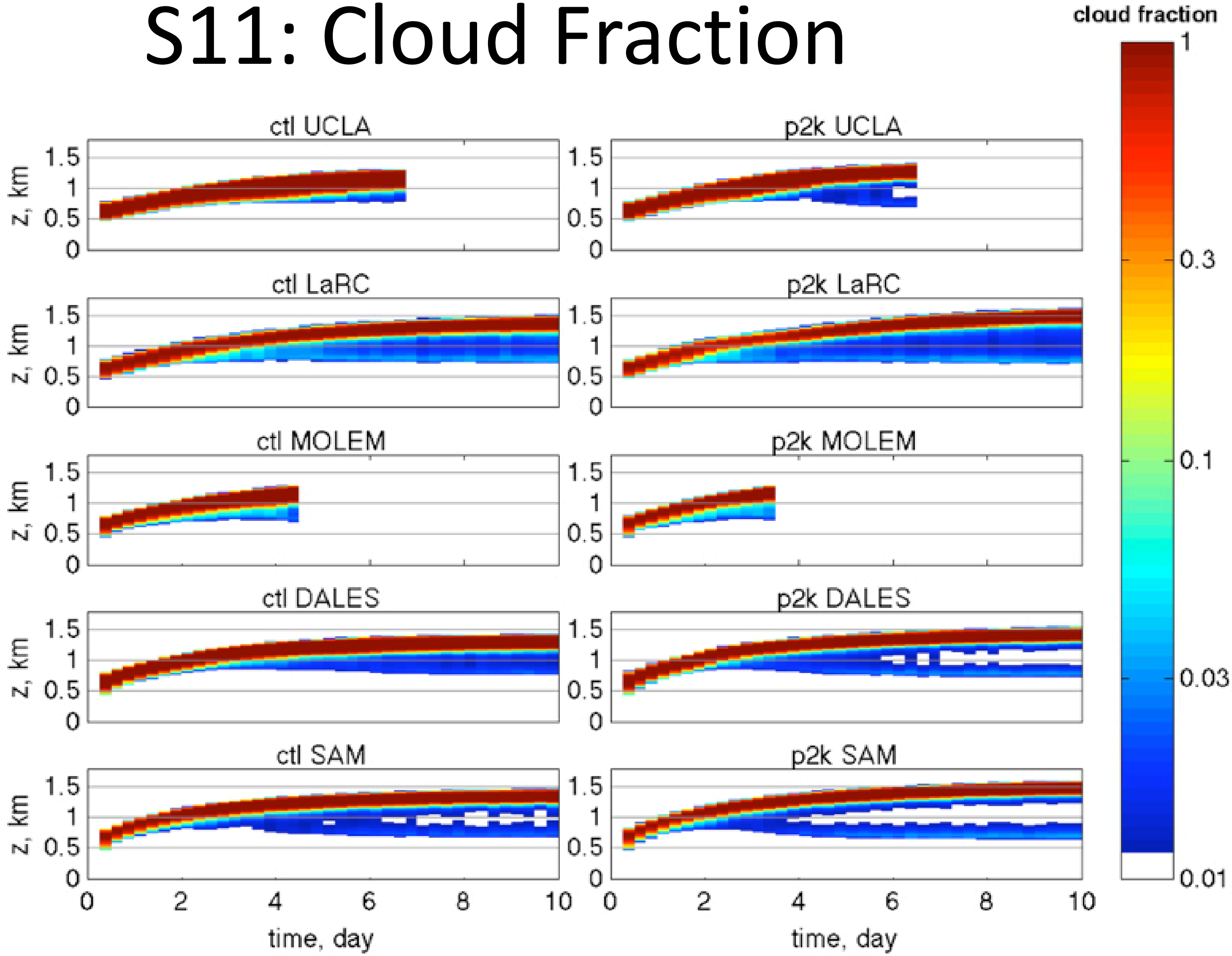
- SCAM5 L80 has qualitatively similar steady-state mean sensitivities to LES, MLM
- Responses are affected by grid-locking and oscillations

  …can UWPBL scheme numerics be improved?
- LWP is too small for precipitation to play any role

S11: Cloud Fraction



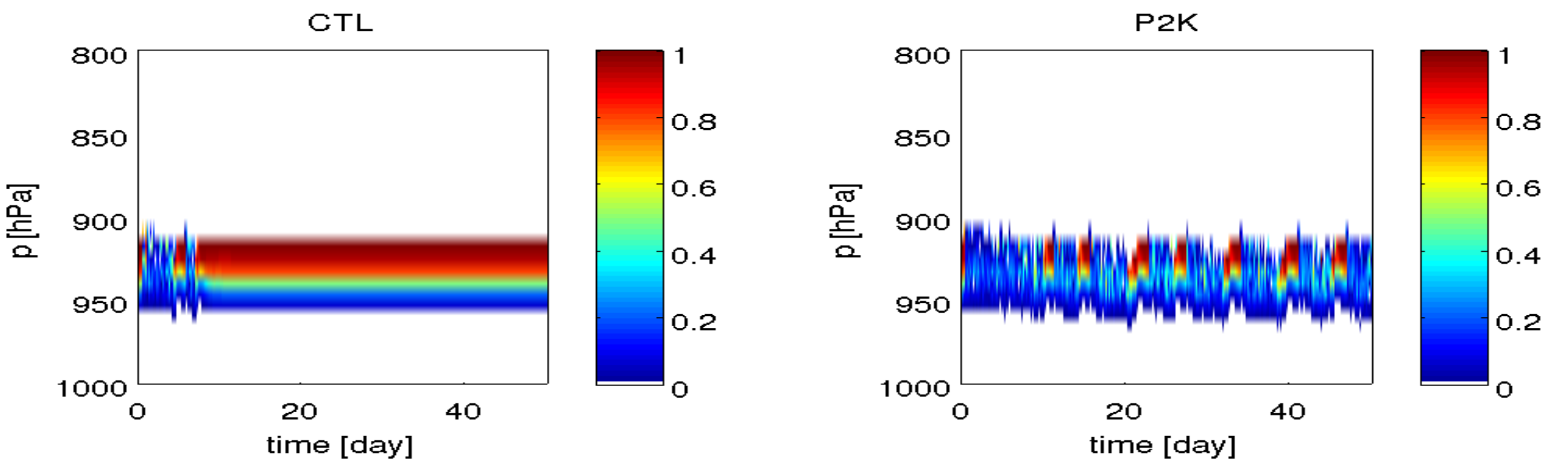
MISR Cloud Top Height PDF Courtesy of J. Karlsson.



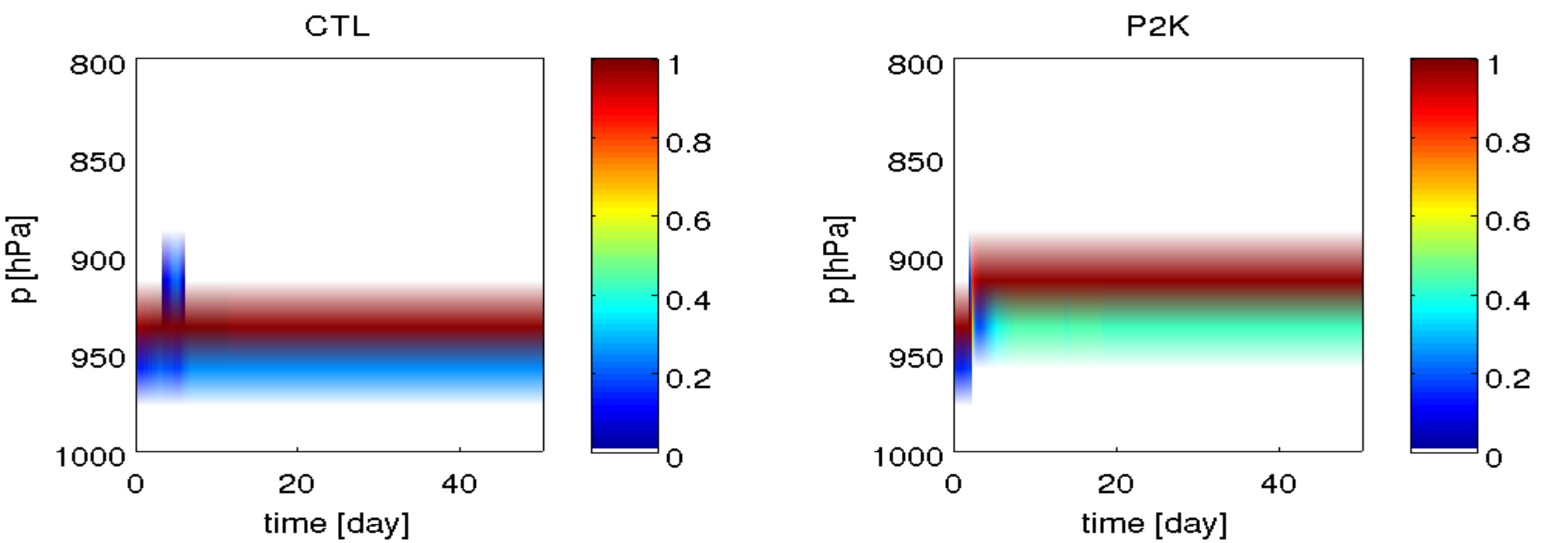
- Models broadly consistent when Δz=5m. (LaRC uses Δz=25m.)
- Initial stratocumulus layer decouples after deepening.
- +2K runs more decoupled with higher inversion; some LES slightly thin cloud.
- Radiative balance and reduced subsidence important to cloud changes as in S12

What does SCAM5 do?

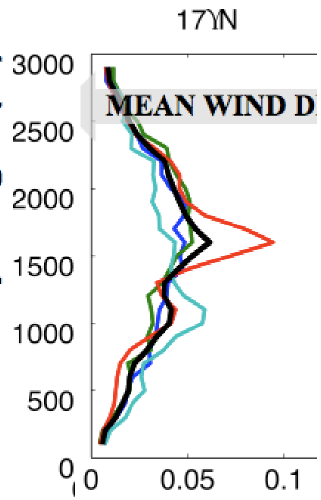
- L80: less cloud in p2K (but oscillations with dt = 600s)



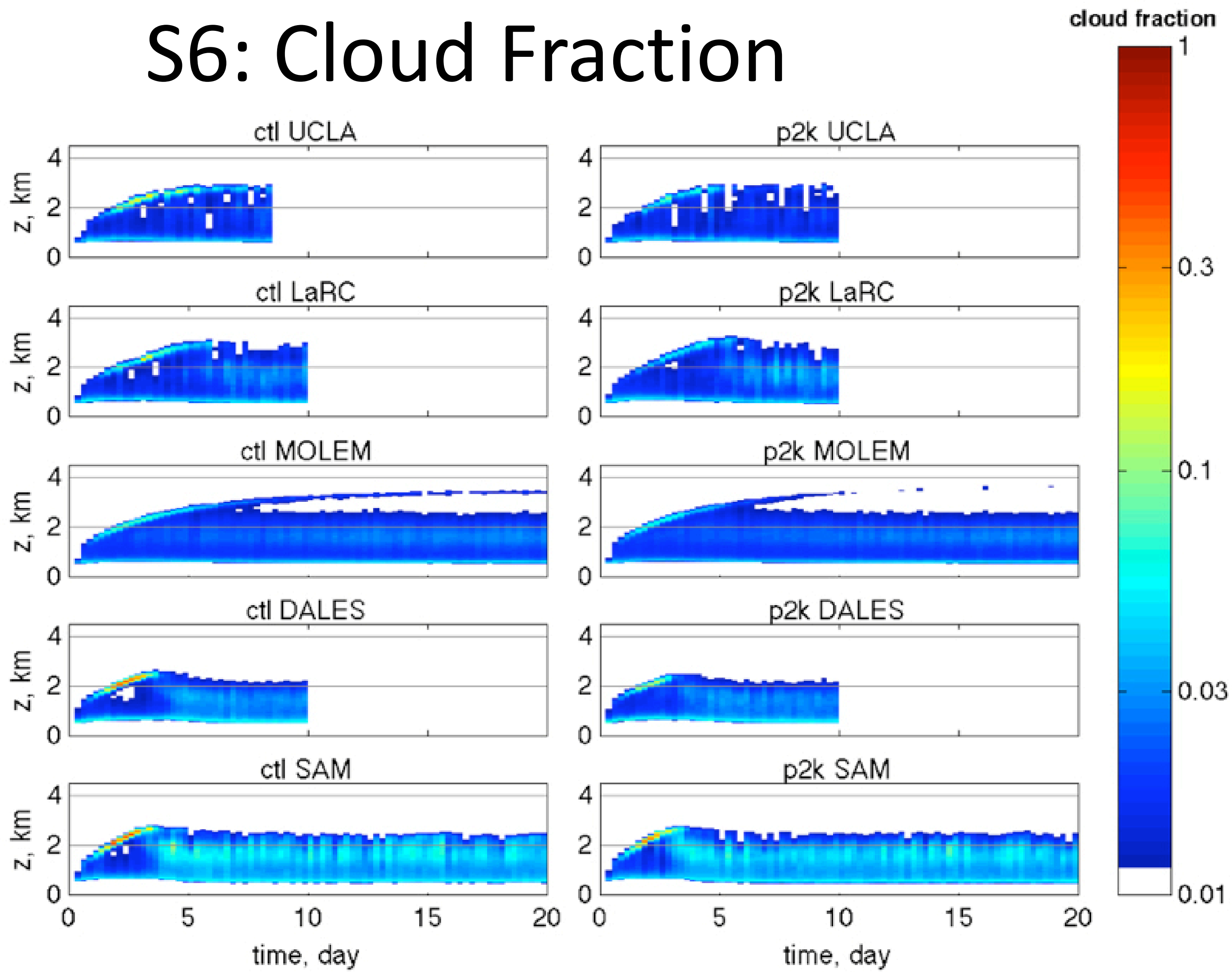
- L30: more cloud in p2K (but no decoupling)



S6: Cloud Fraction



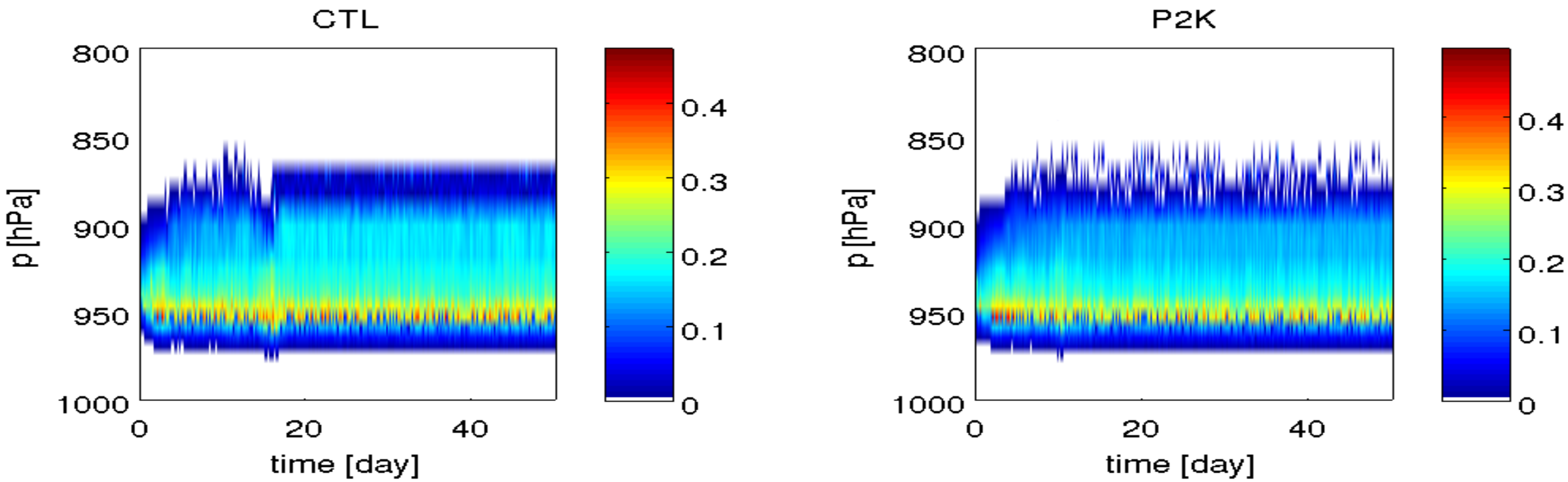
MISR Cloud Top Height PDF Courtesy of J. Karlsson.



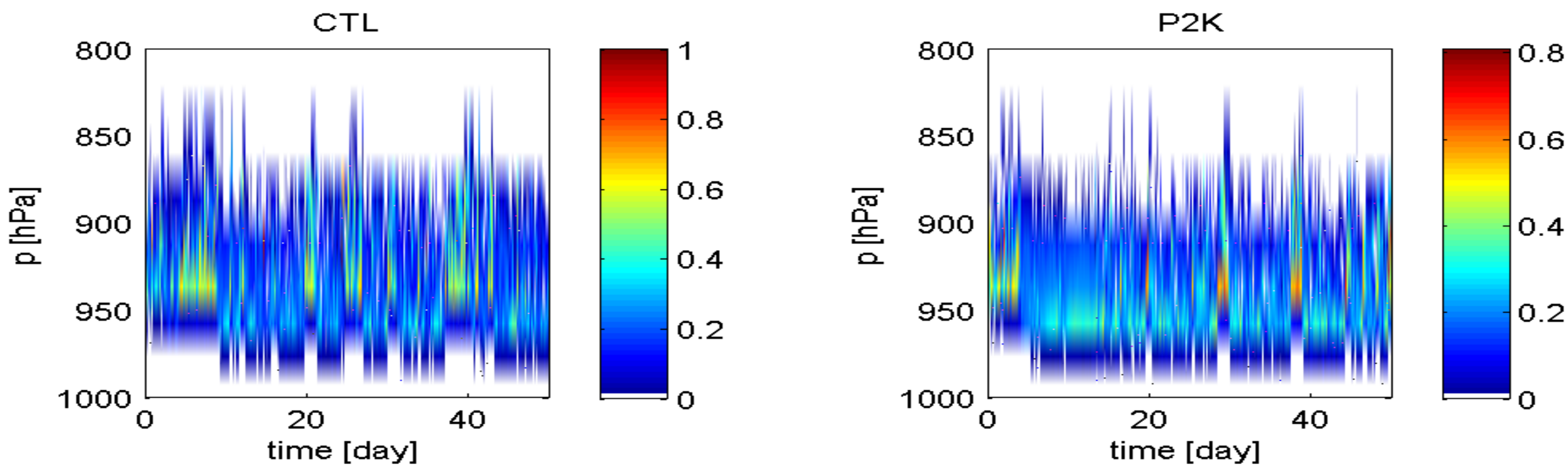
- Fair agreement between LES models in BL structure, depth.
- Initial Sc-over-Cu layer deepens and transitions to a Cu-only layer.
- +2K changes are weak; cloud layer depth is regulated by precipitation

What does SCAM5 do?

- L80: Nice Cu layer, too much cld, slightly less SWCF in p2K



- L30: Bursty Cu layer, too much cld, slightly less SWCF in p2K



Conclusions

- The CGILS cases are very challenging (even for LES, but especially for SCMs).
- For Sc cases, oscillations and grid-locking are important to control cloud and its response to climate perturbations.
- SCAM5 simulations look better at L80 than L30.
- L80 SCAM5 qualitatively reproduces important cloud responses to radiative, dynamical and thermodynamical perturbations in a well-mixed Sc regime.
- L80 SCAM5 also qualitatively matches consensus sign (but not magnitude) of LES feedback in all three CGILS p2K cases:

  S12: Well-mixed Sc – cloud thickening (negative feedback)

  S11: Decoupled Sc – cloud thinning (positive feedback)

  S6: Shallow Cu - cloud reduction (positive feedback)