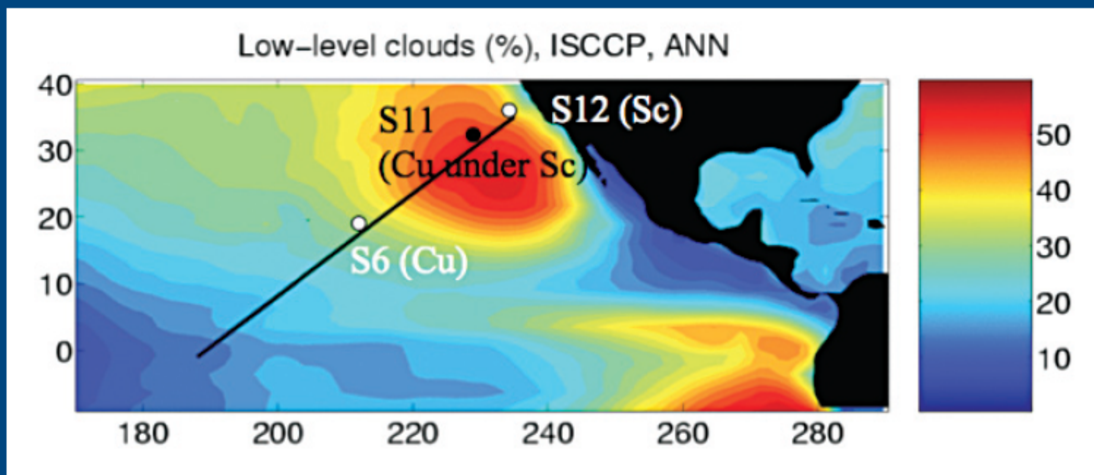
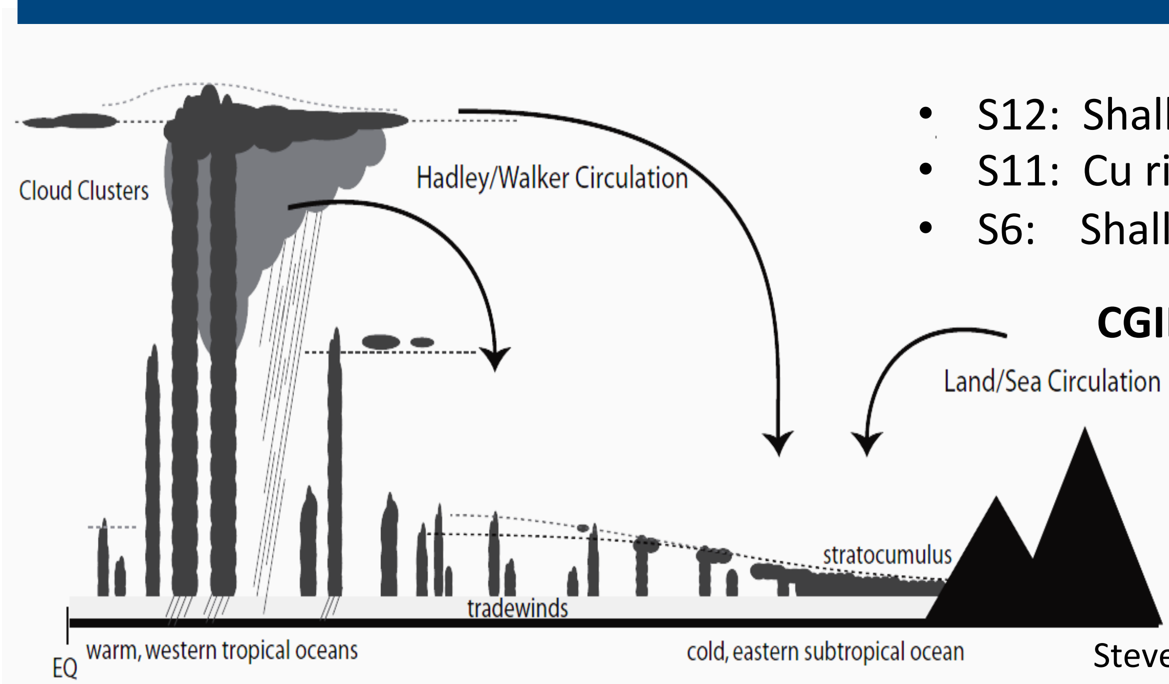
CGILS Intercomparison Update

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

Stevens 2006

CGILS SCM Results

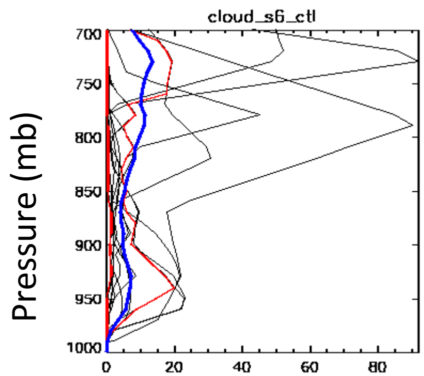
An Update

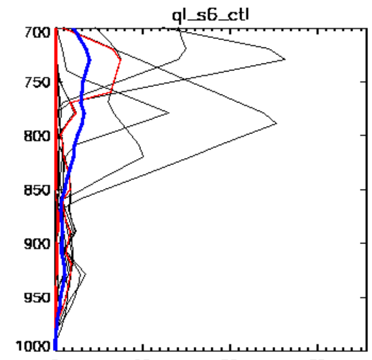
Minghua Zhang

Multi-model Results

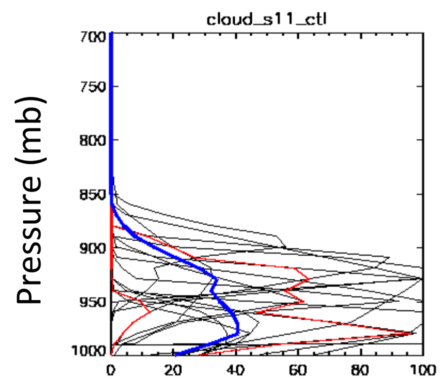
Cloud Amount (%) Cloud liquid water (10^{-2} g/kg)

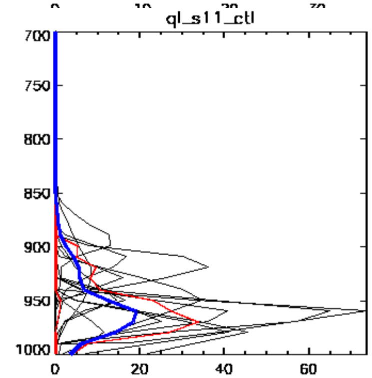
S6



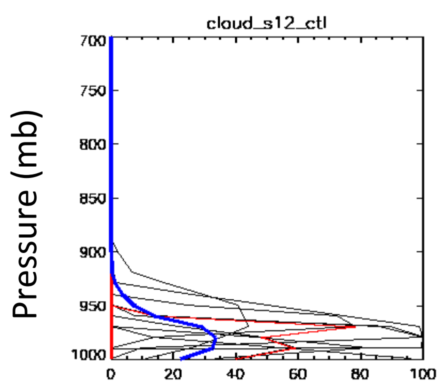


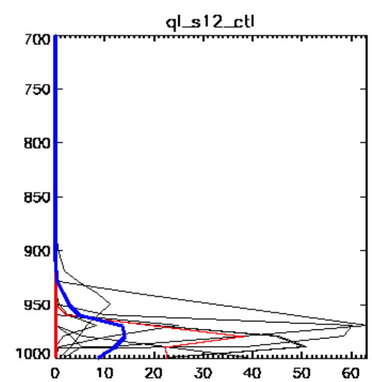
S11

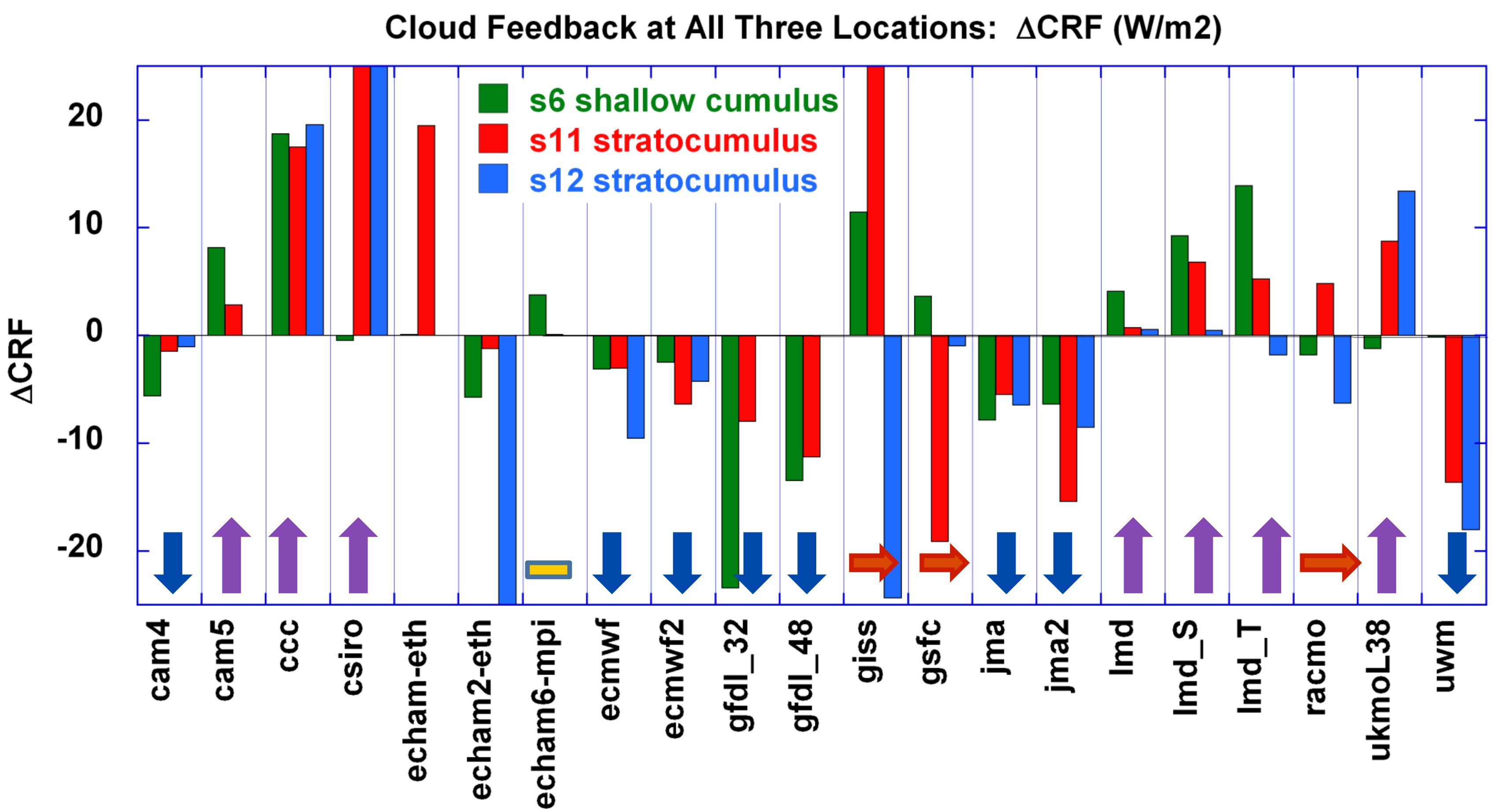




S12







5 models with positive feedback: CAM5, CCC, CSIRO, LMD, UKMO

5 model with negative feedback: CAM4, ECMWF, GFDL, JMA, UWM

1 with little feedback: ECHAM-MPI; 1 to equilibrate ECHAM-ETH

3 models with different signs at the three locations: GISS, GSFC, RACMO

If we use moisture budget to interpret cloud change:

$$\frac{\partial q}{\partial t} = -c + e - \frac{\partial \overline{\omega' q'}}{\partial p} + \left(\frac{\partial q}{\partial t}\right)_{LS} \approx 0$$

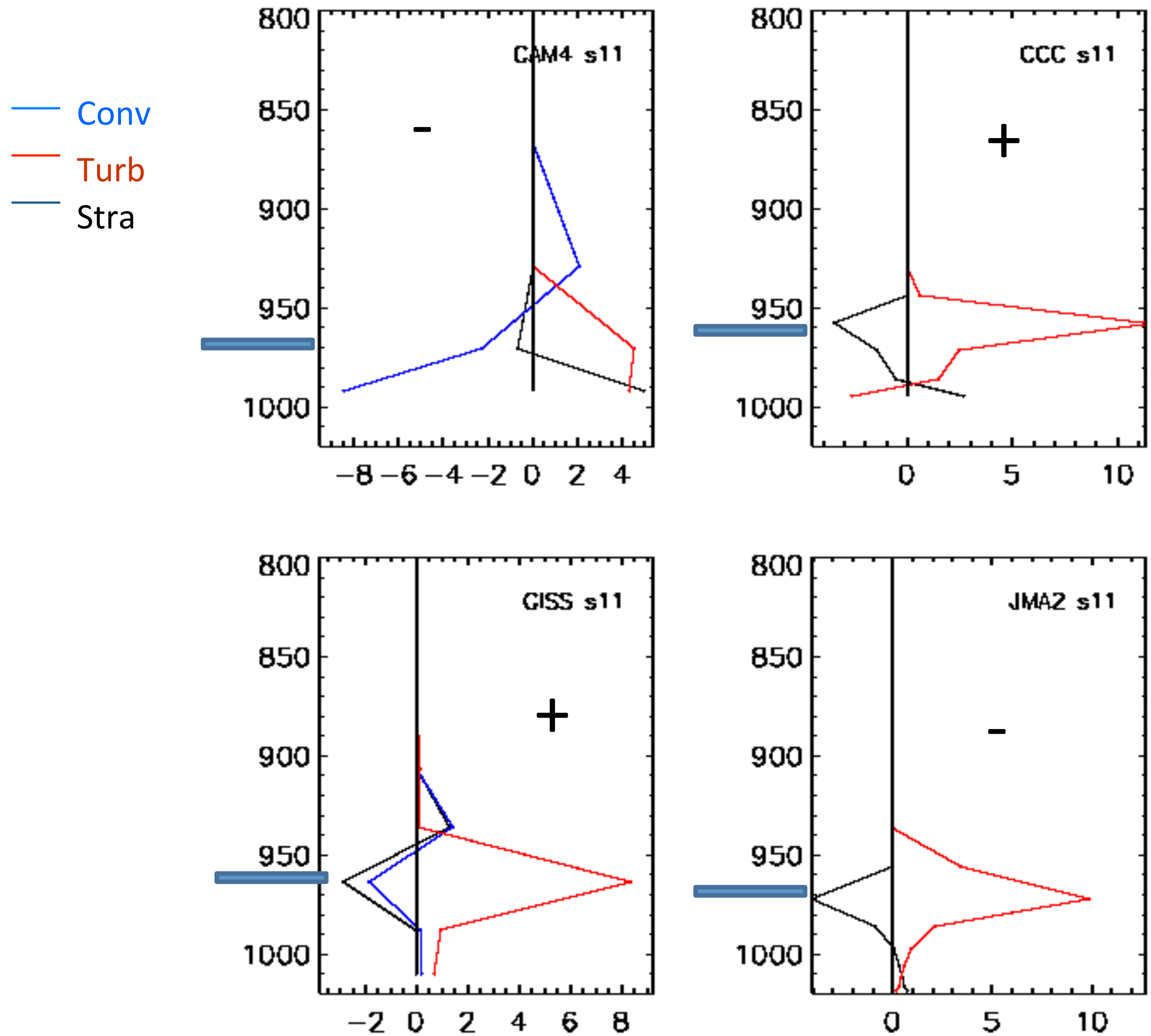
$$c \propto q_l$$

the following parameterizations can be related to *c* and q_l

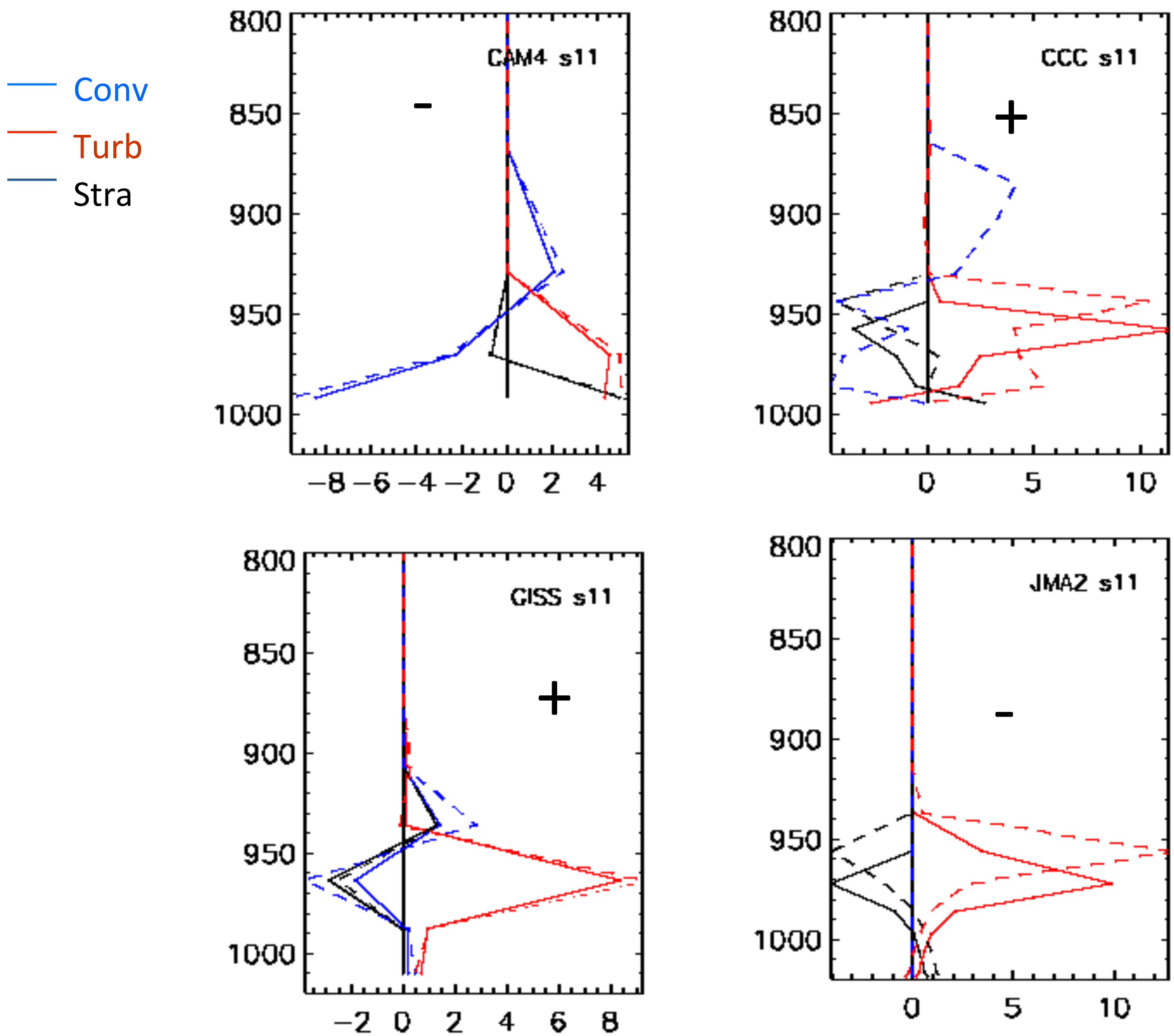
$$\overline{\omega' q'} = (\overline{\omega' q'})_{PBL} + (\overline{\omega' q'})_{Convection}$$

In the next 3 slides, four models are used as example of this interpretation

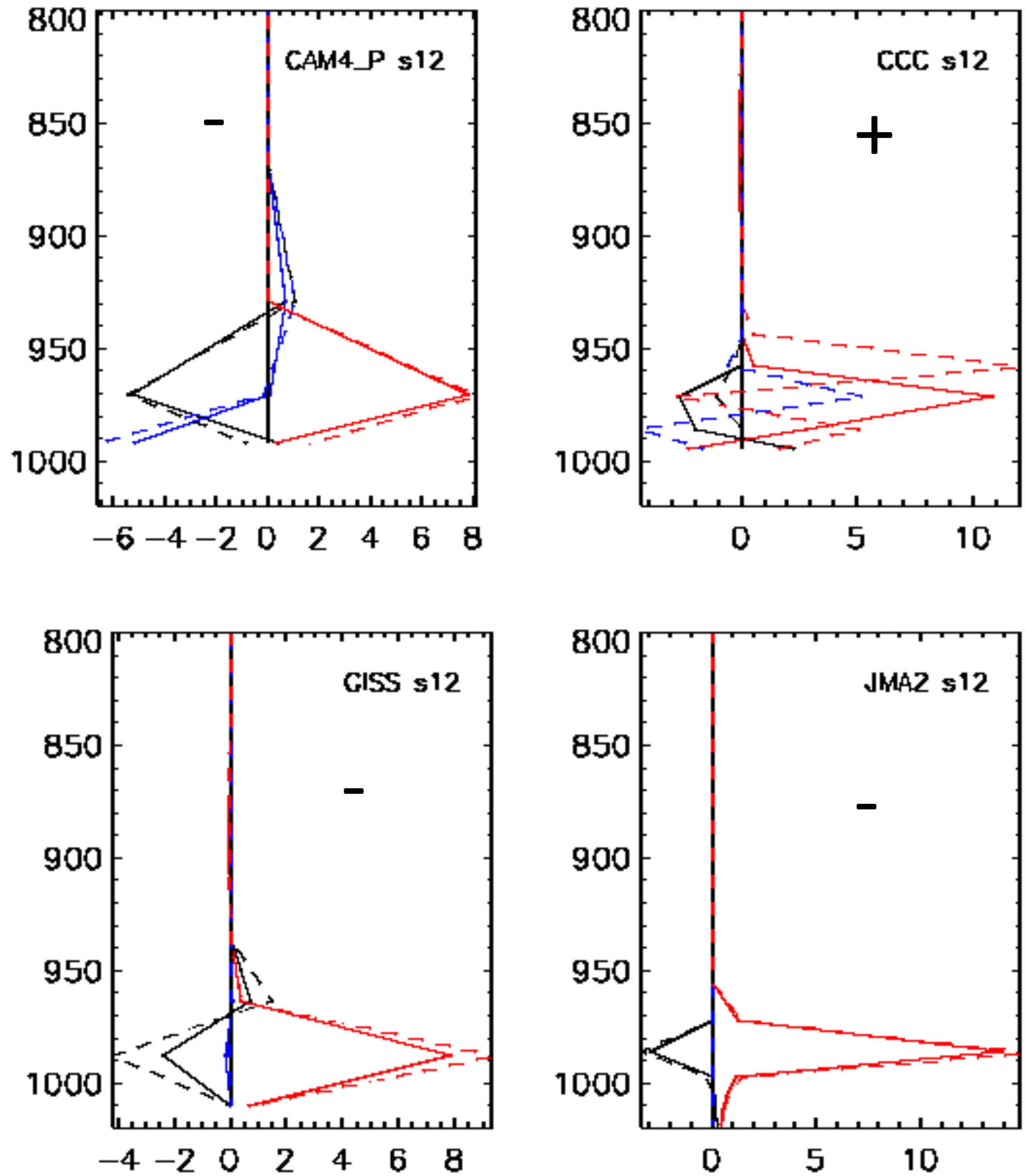
Moisture tendency (g/kg/day) at S11



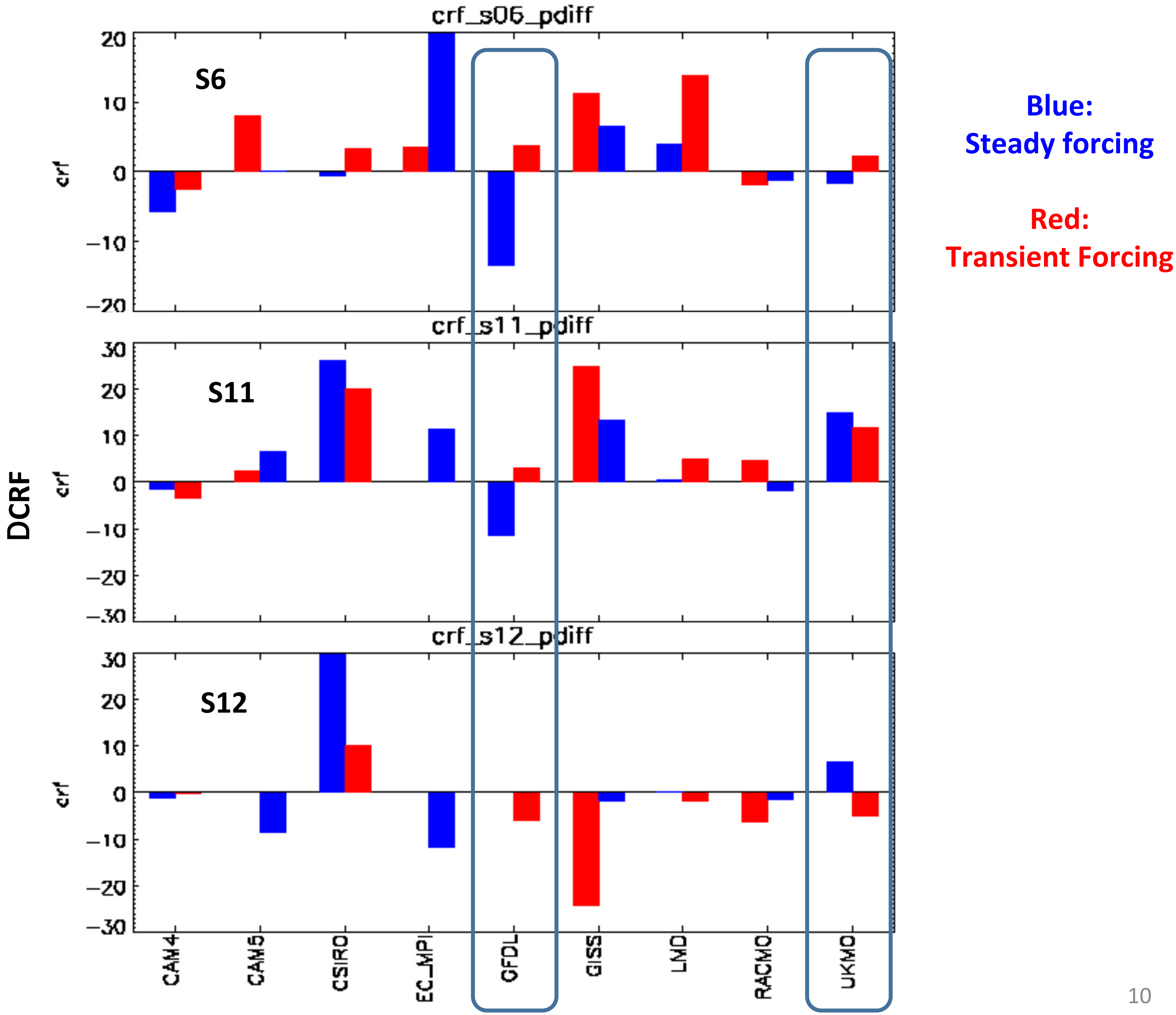
Moisture tendency (g/kg/day) at S11, dashed for warmer climate



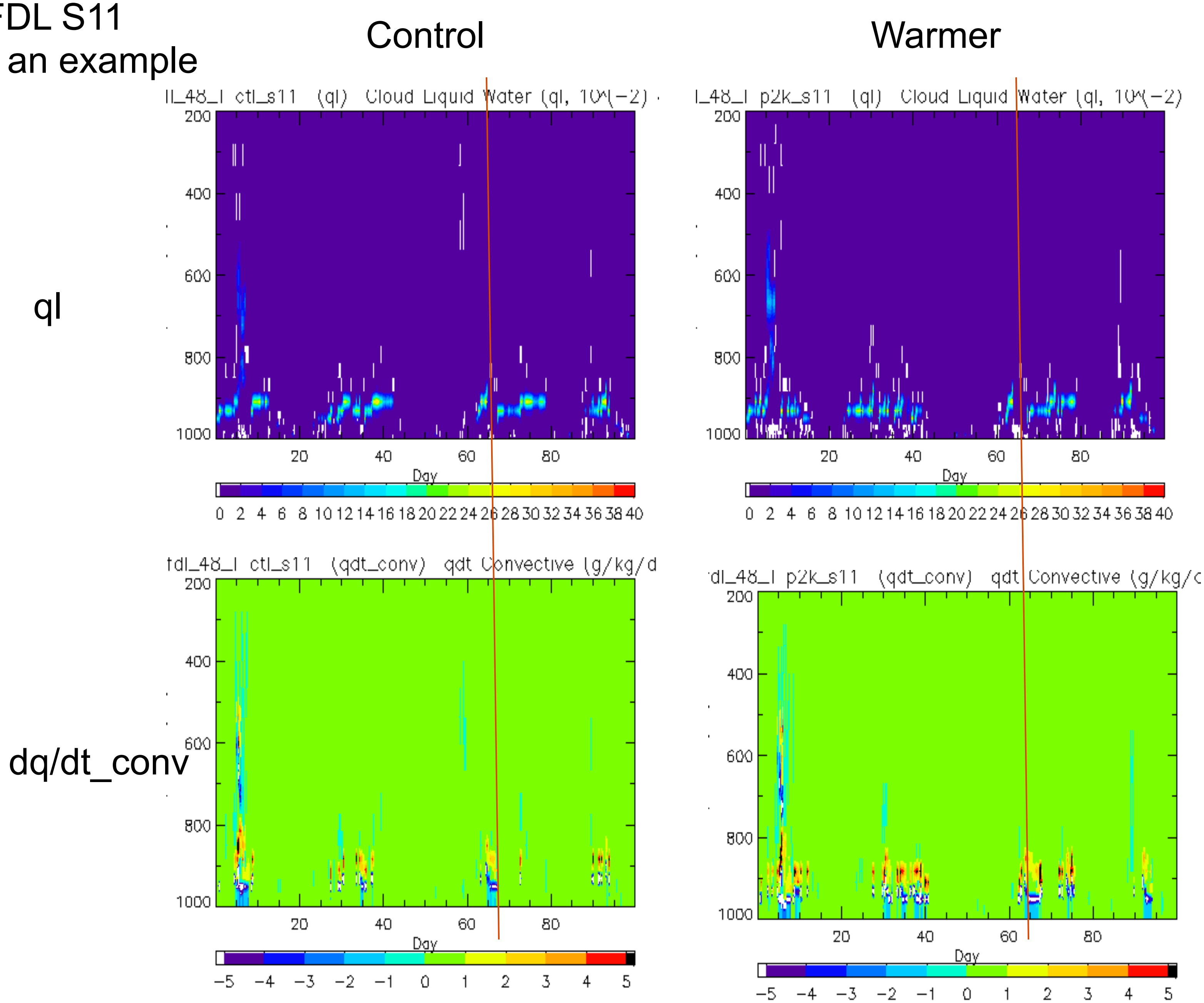
Moisture tendency (g/kg/day) at S12, dashed for warmer climate



Results from Transient Forcing


crf_s06_pdiff
S6
crf_s11_pdiff
S11
crf_s12_pdiff
S12
DCRF
crf
CAM4
CAM5
CSIRO
EC_MPI
GFDL
GISS
LMD
RACMO
UKMO
Blue:
Steady forcing
Red:
Transient Forcing

GFDL S11
As an example



Summary and Plan

1. **Reasonable confidence in interpreting cloud feedbacks from these models in the CGILS cases**

2. **I am still working, and owing you… on the papers!!**

3. **Need to link CGILS results with CFMIP global model results**

CGILS LES update

Peter Blossey and Chris Bretherton, Univ. Washington

DALES:	Stephan DeRoode, TU-Delft
LaRC:	Anning Cheng/Kuan-Man Xu, NASA-LaRC
MOLEM:	Adrian Lock, UKMO
SAM:	Peter Blossey, U. Washington
UCLA:	Thijs Heus, MPI-Hamburg
WRF:	Satoshi Endo/Yangang Liu, Brookhaven Natl. Lab (S6)

Intercomparison Status

April 2012: All groups have submitted final results

July 2012: Planned CGILS LES paper submissions

Sept 2012: Pan-GASS meeting – CGILS Phase II strawman?

CGILS LES setup and sensitivity studies

Control setup at each location

- Forcings: ECMWF JJA mean:
  - SST
  - T, RH well above CTBL
  - CTBL horizontal T,q advection
  - Subsidence
  - Wind profile
- $N_d = 100\ cm^{-3}$
- Diurnally averaged summertime insolation
- Run 10 d to near steady-state
- LES models harmonized surface flux, radiation schemes

CGILS sensitivity studies

- **P2K (+2K low-lat SST increase)**
  - Reduced subsidence
  - Moist-adiabatic increase in warming aloft (ΔEIS $\approx$ 0)
  - Free-trop RH unchanged

<u>S12 only:</u>

- **P2K OM0** (fixed subsidence)

<u>UW only</u>…other cloud-changing factors

- **4xCO_2 fixed SST**
- **P2K FT** (P2K free-trop, fixed SST)

<u>UW S12 only</u>

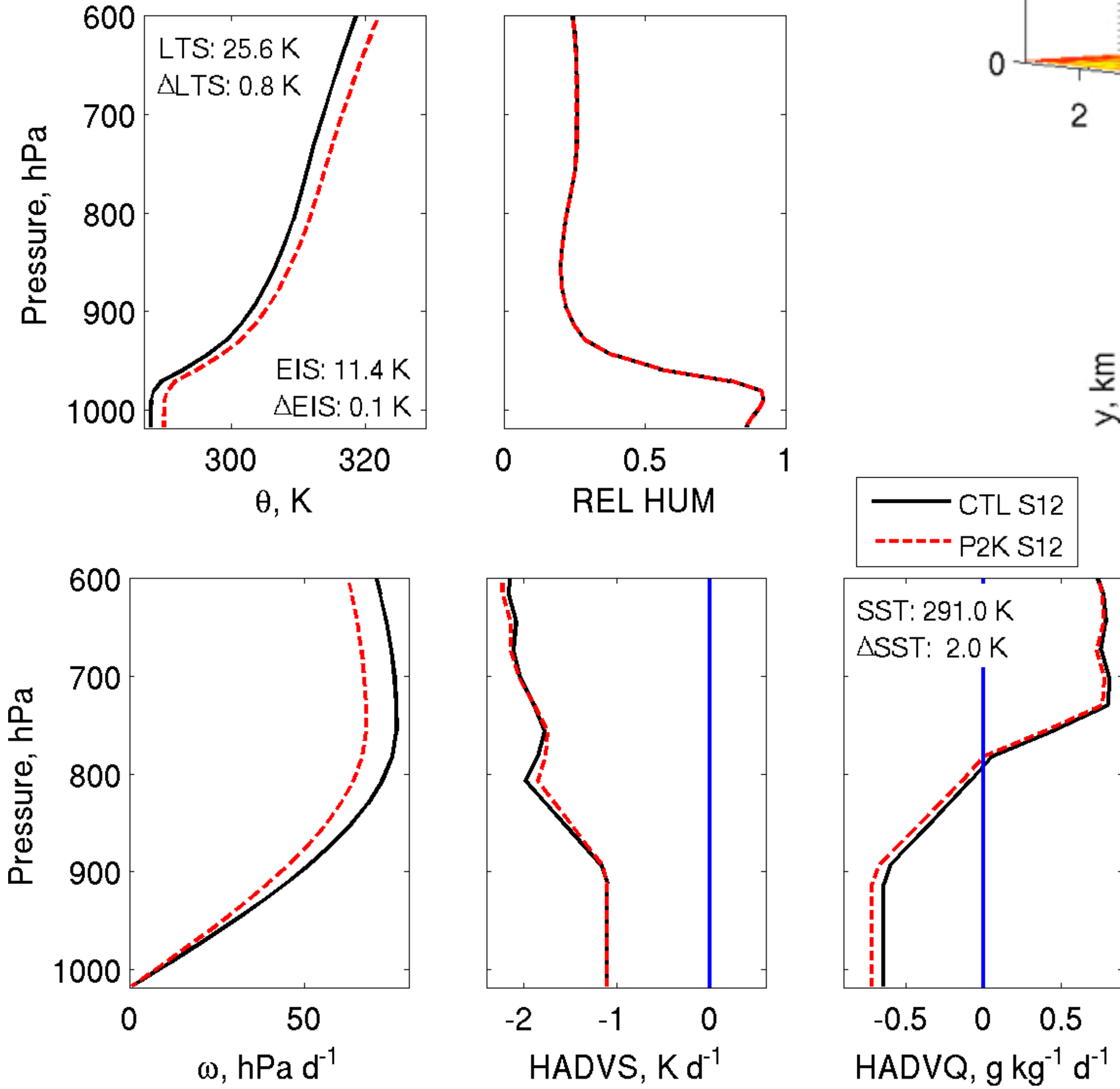
- **dRH** (5% free-trop RH reduction)
- **dWS** (10% wind-speed reduction)
- **DIURN** (diurnally-varying insolation)

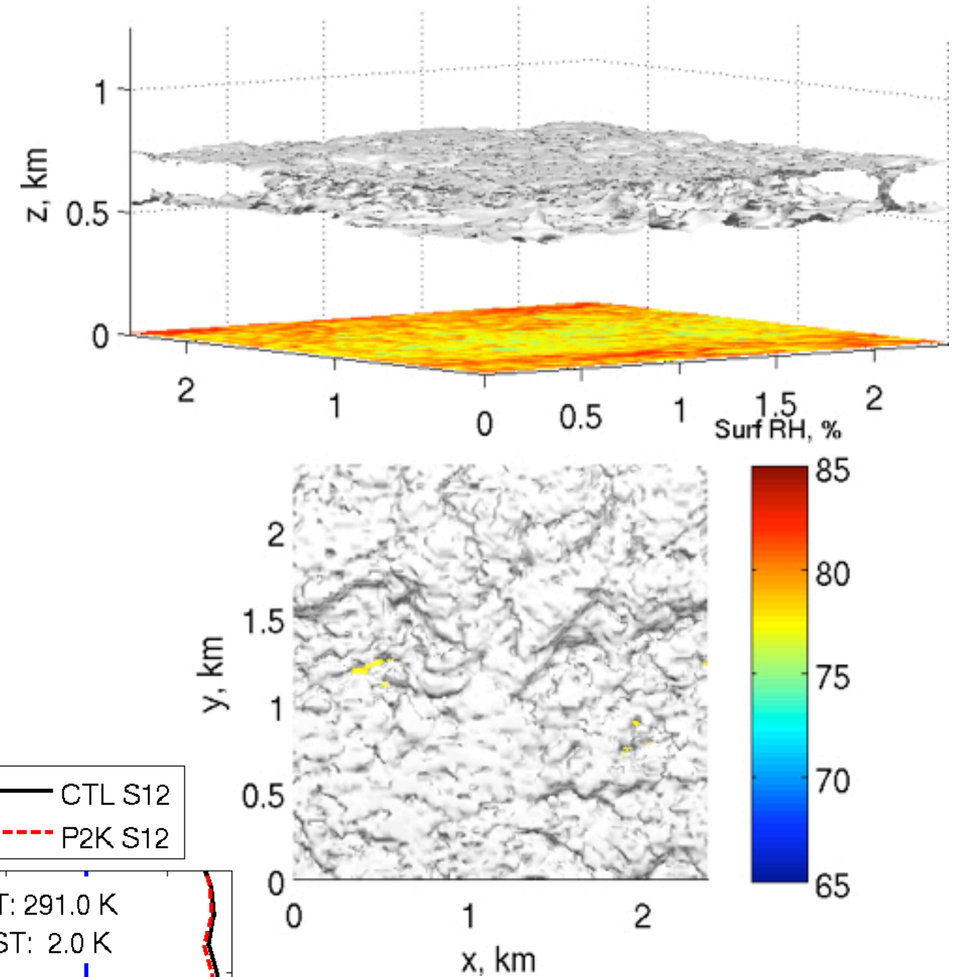
UW mixed-layer model run on all S12 cases

Expected 2xCO_2 subtropical forcing changes from CMIP3

Perturbation	CMIP3	Ref	CGILS	Case
δSST	2.5 ± 0.5 K	IPCC 2007	2 K	P2KOM0
δω(500 hPa)	-5 ± 3 %	Webb et al 2012	-11%	P2K - P2KOM0
δEIS	0.6 ± 0.2 K	Webb et al 2012	2 K	P2KFT – P2K
δRH	-1.5 ± 1 %	Sherwood et al 2009	-5 %	dRH
δ(wind speed)	-1.5 ± 1.5 %	Lu and Cai 2008	-10%	dWS

CGILS S12: Coastal Sc





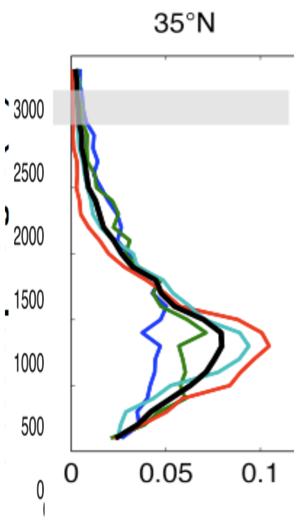
Δx = Δy = 25m

Δz = 5-15m

96 x 96 x 320

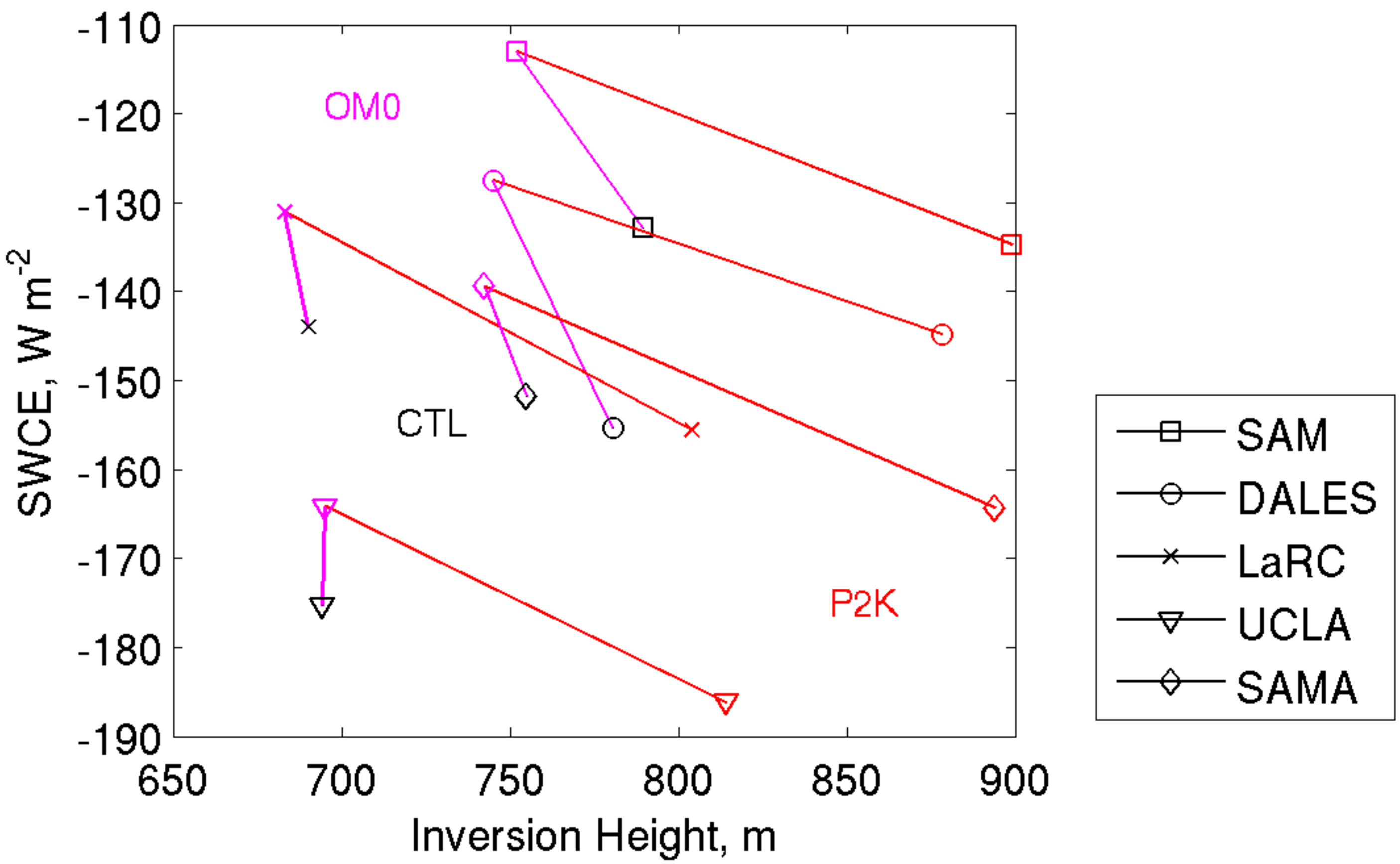
Nudged above 1200 m

S12 LES results



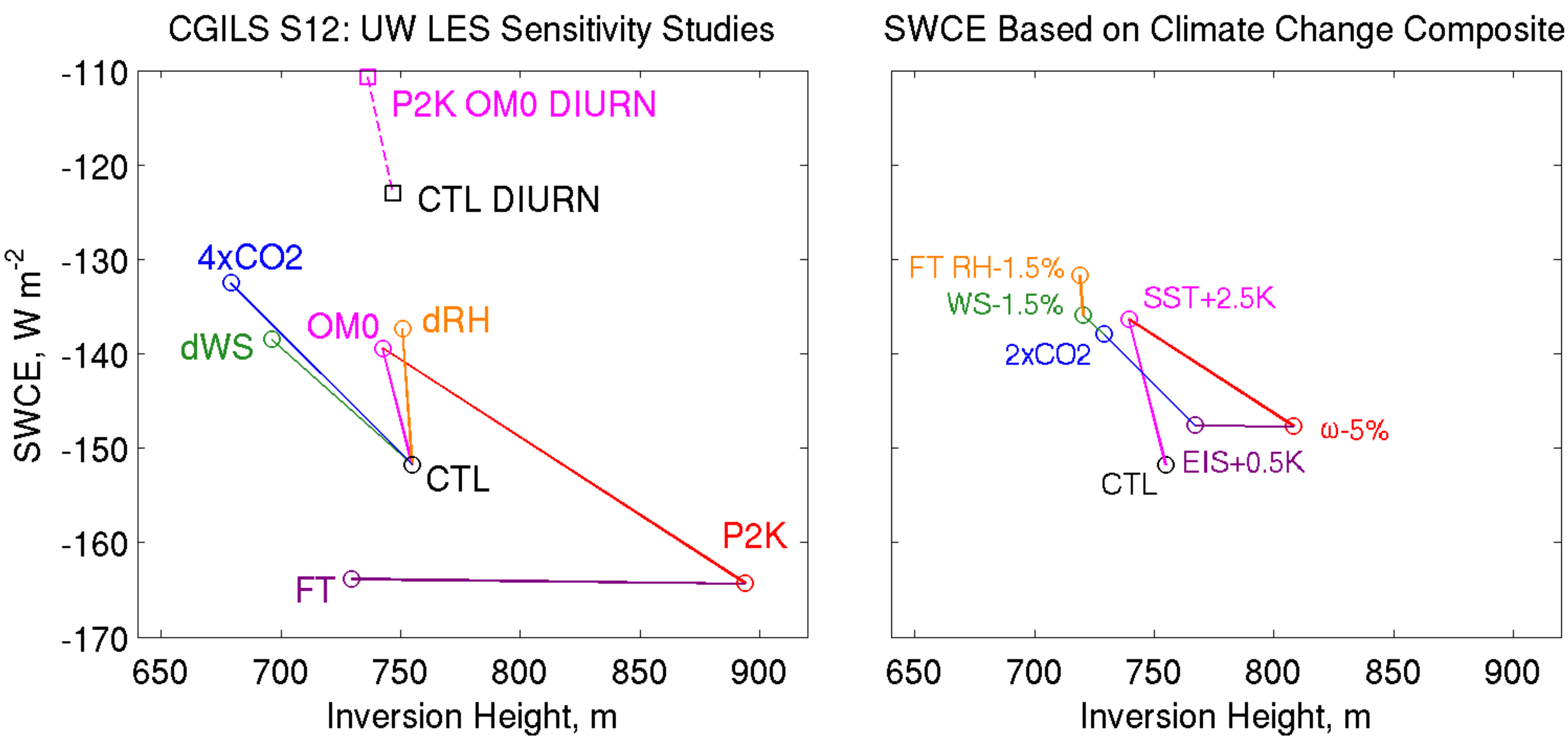
MISR Cloud Top Height PDF Courtesy of J. Karlsson.

Summary of S12 cloud response



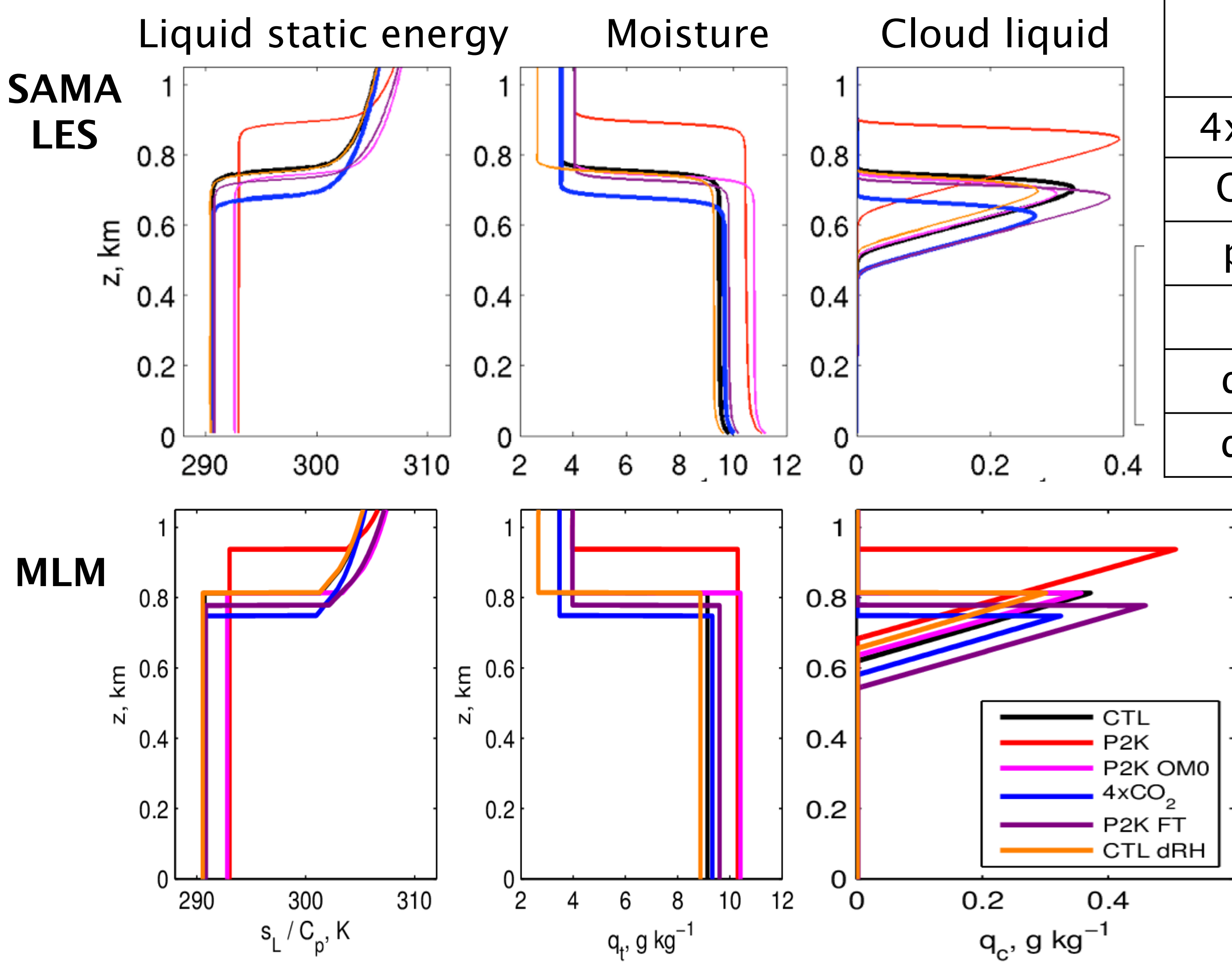
- Reasonable agreement on control cloud SWCRE
- LES all thin the cloud layer (positive feedback) in OM0
- P2K response mixed (marginal decoupling in SAM, DALES)

UW S12 sensitivity studies using SAMA LES



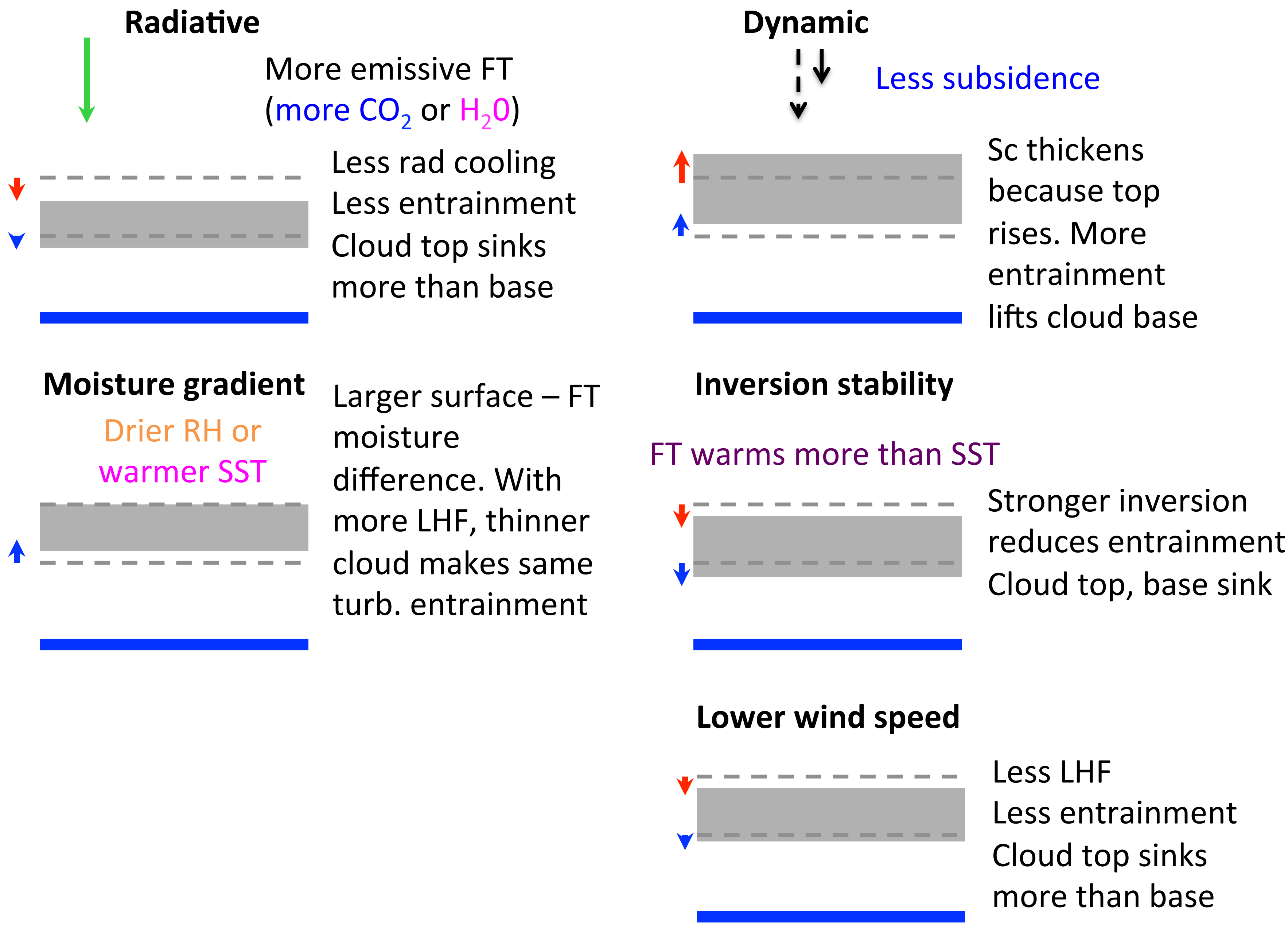
A lot of cancellation, but net 20 W m^{-2} reduction in SWCRE for CMIP3 perturbations.

Comparison with MLM



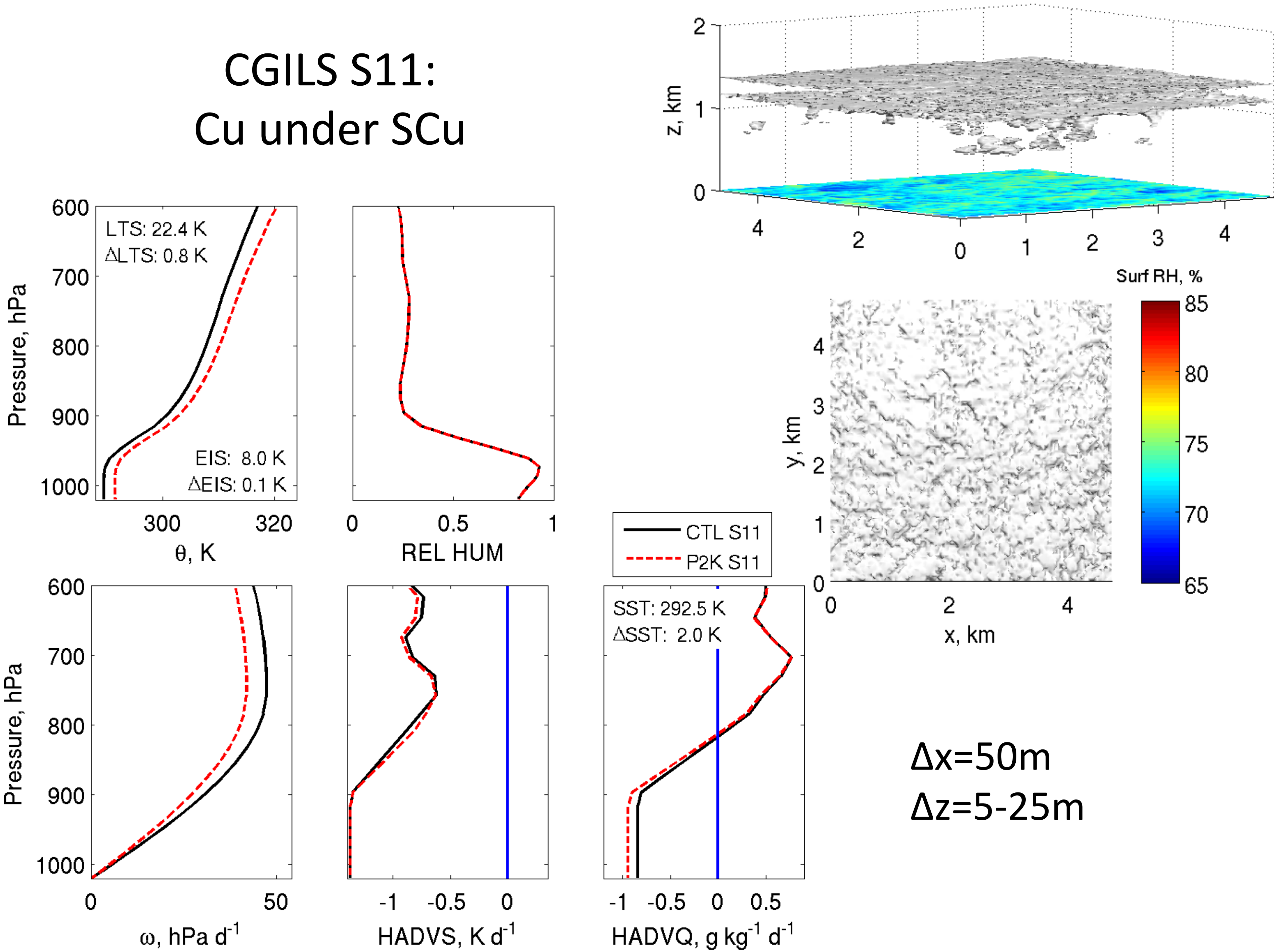
7.5–10 day avg	ΔSWCRE W m^{-2}	
	MLM	SAMA
$4xCO_2$	+16	+19
OM0	+10	+12
p2K	−29	−13
FT	−21	−12
dRH	+21	+14
dWS	+26	+14

MLM has similar sensitivities as SAM ➔ Entrainment is key.



Radiative
More emissive FT
(more CO_2 or H_20)
Less rad cooling
Less entrainment
Cloud top sinks
more than base
Dynamic
Less subsidence
Sc thickens
because top
rises. More
entrainment
lifts cloud base
Moisture gradient
Drier RH or
warmer SST
Larger surface – FT
moisture
difference. With
more LHF, thinner
cloud makes same
turb. entrainment
Inversion stability
FT warms more than SST
Stronger inversion
reduces entrainment
Cloud top, base sink
Lower wind speed
Less LHF
Less entrainment
Cloud top sinks
more than base

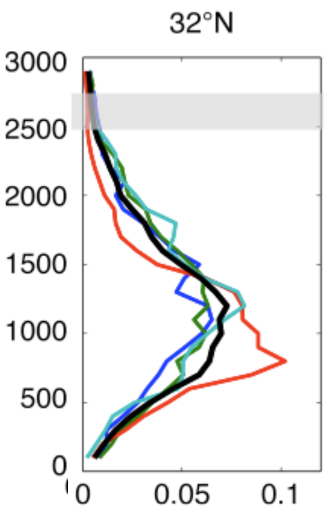
CGILS S11: Cu under SCu



Δx=50m

Δz=5-25m

S11 results



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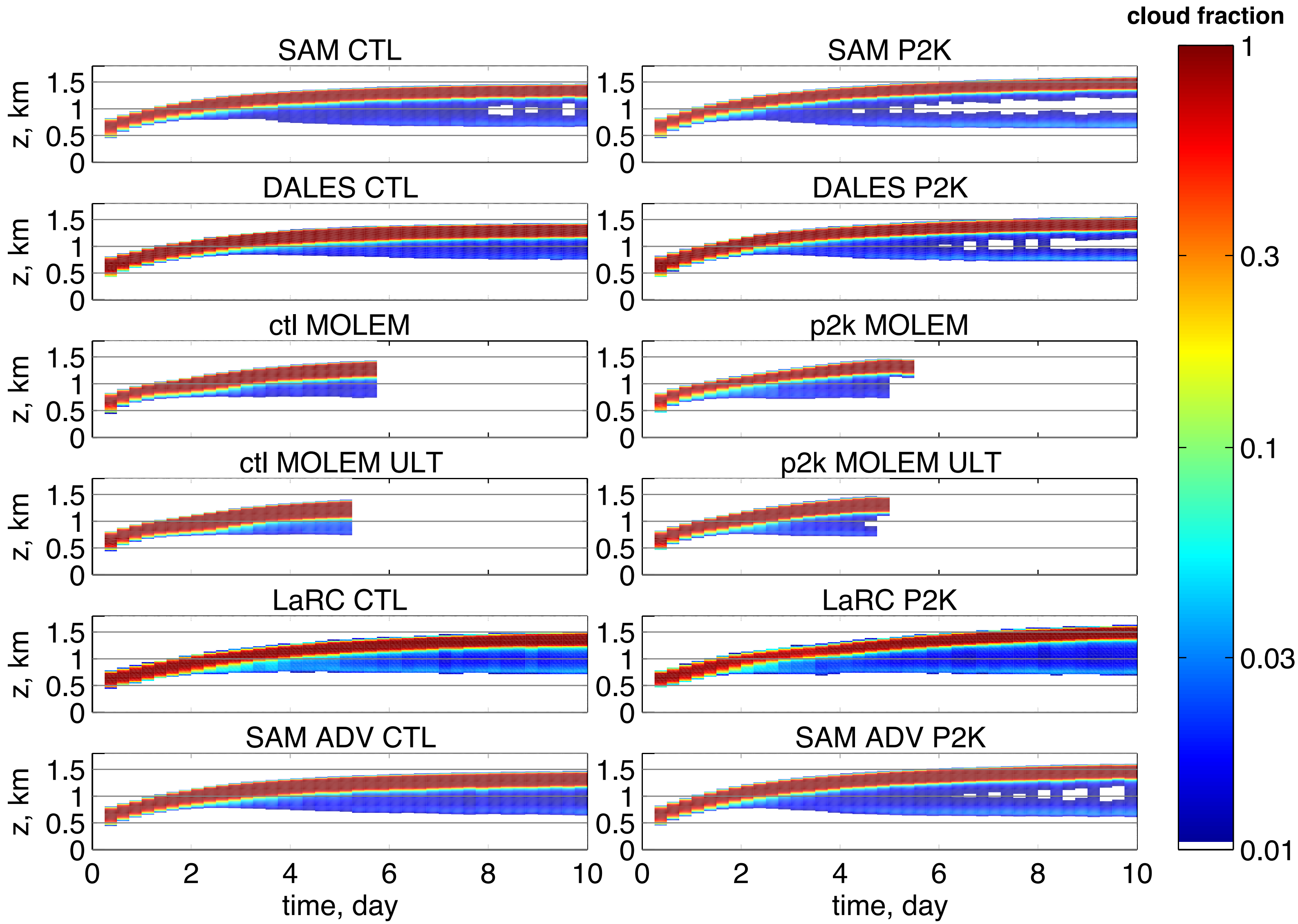
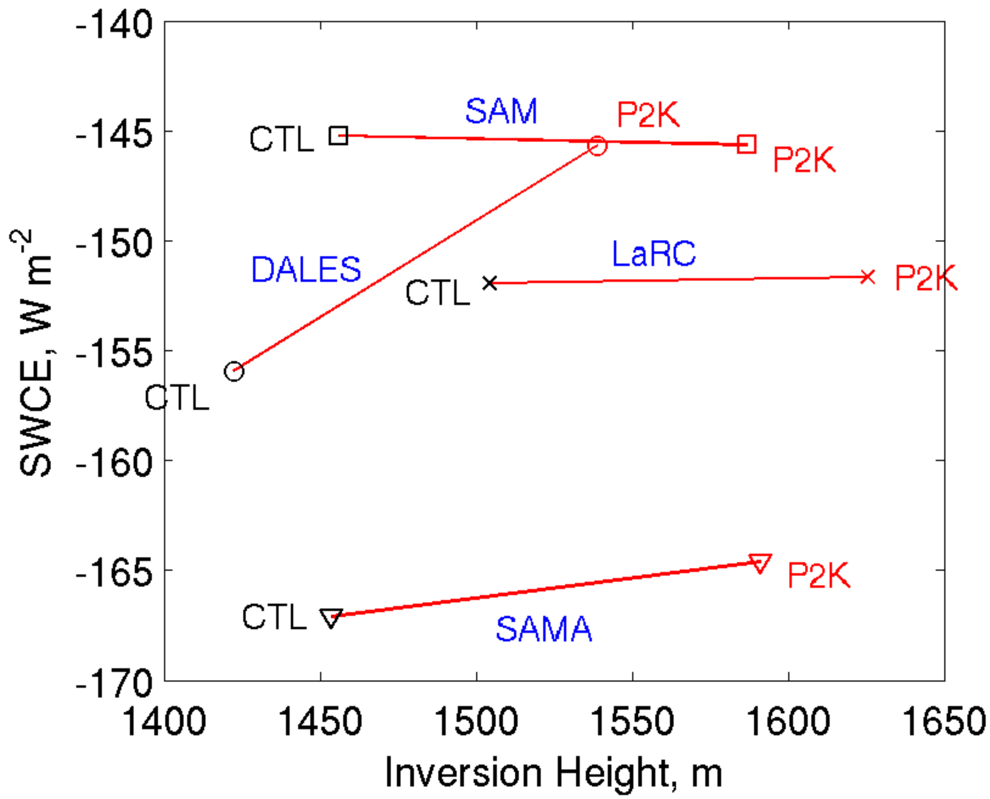
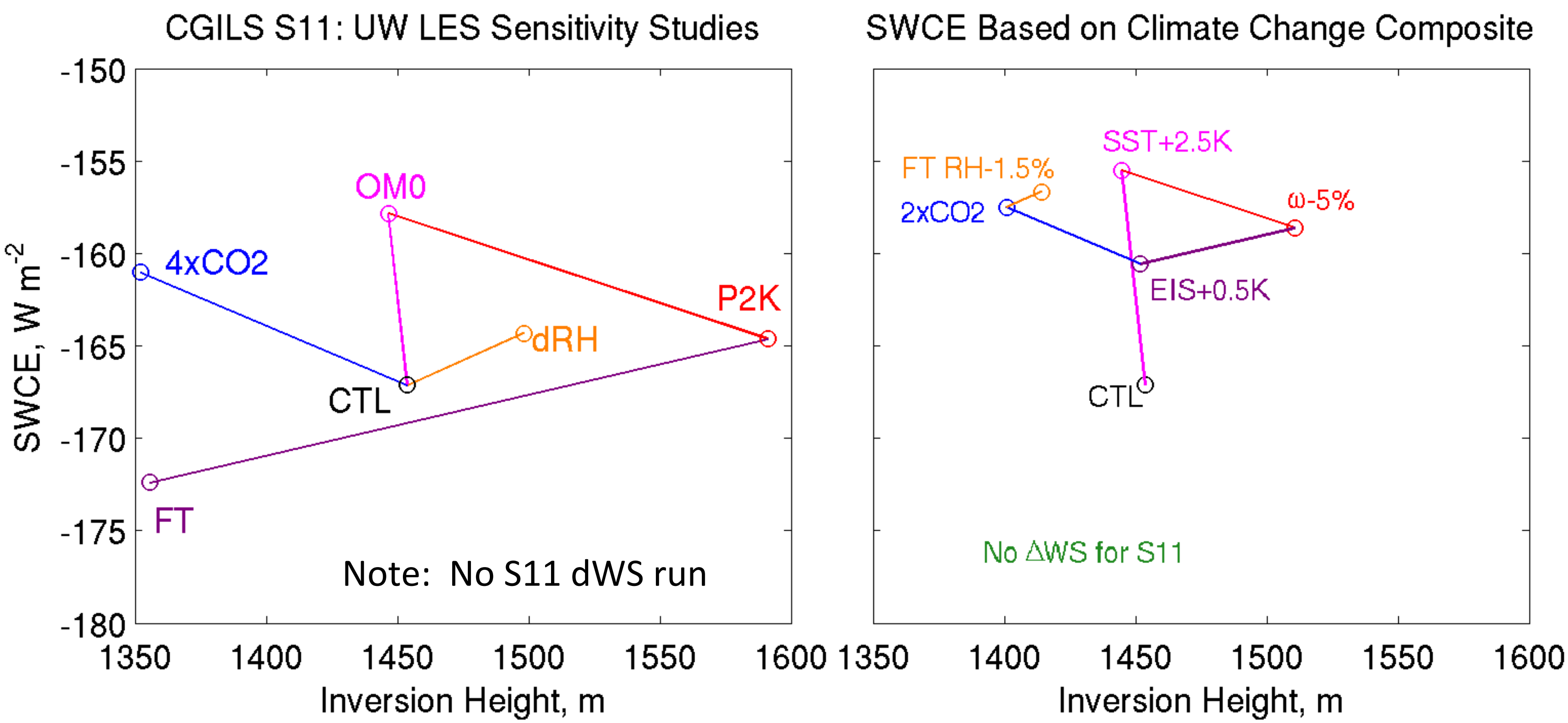


Summary of S11 cloud response



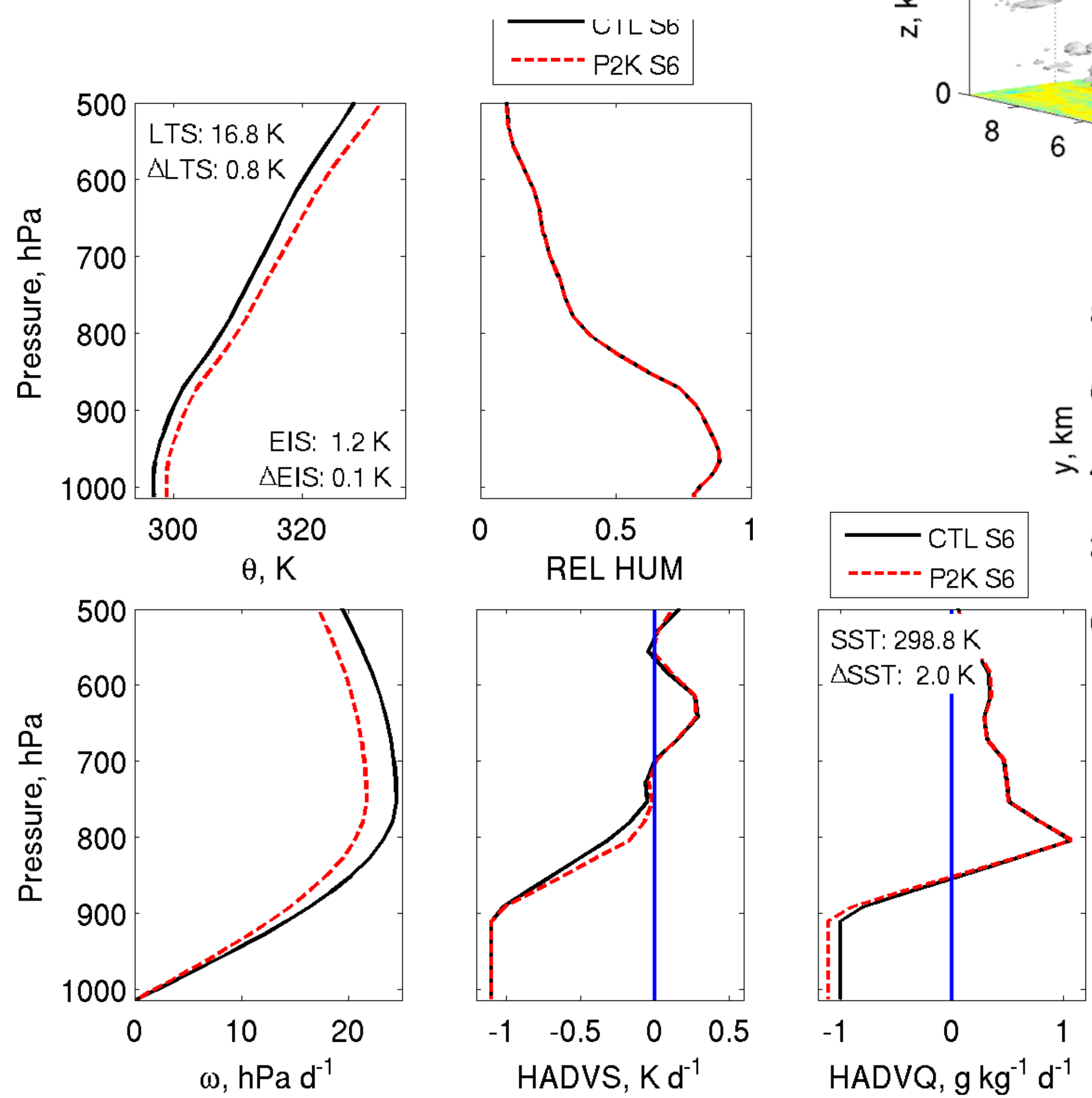
- Very good agreement on control cloud thickness
- P2K response: neutral to positive ΔSWCRE

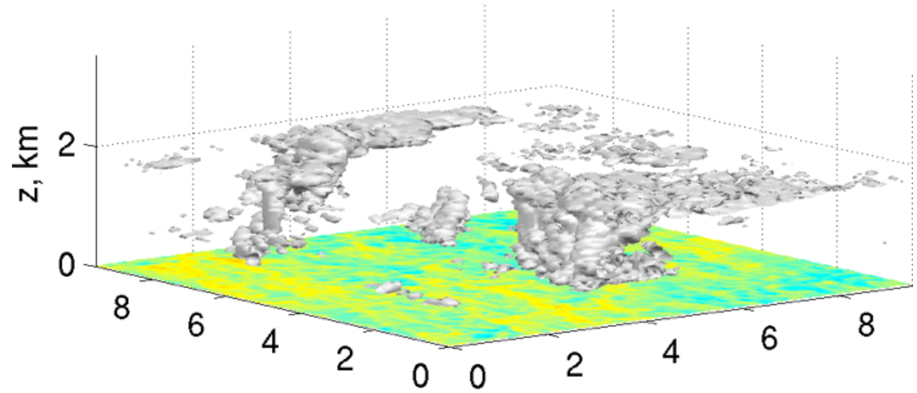
UW S11 sensitivity studies using SAMA LES

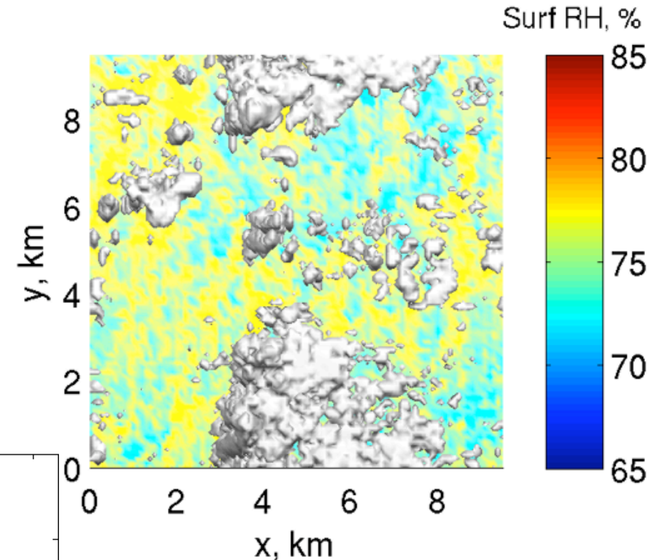


- Net 9 W m^{-2} reduction in SWCRE for CMIP3 perturbations.
- Less cloud thinning than S12 due to CO_2, less thickening from ω
- As with S12, positive cloud feedback is mostly from 2K SST increase.

S6: Trade cumulus regime

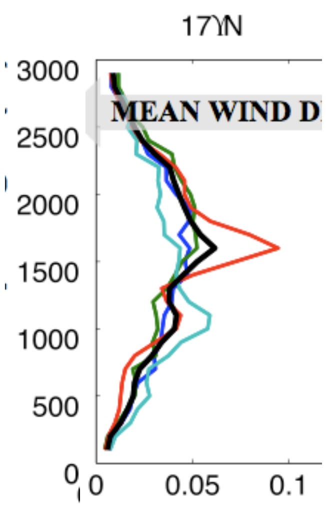






Δx=100m
Δz=40m

S6: Cloud Fraction



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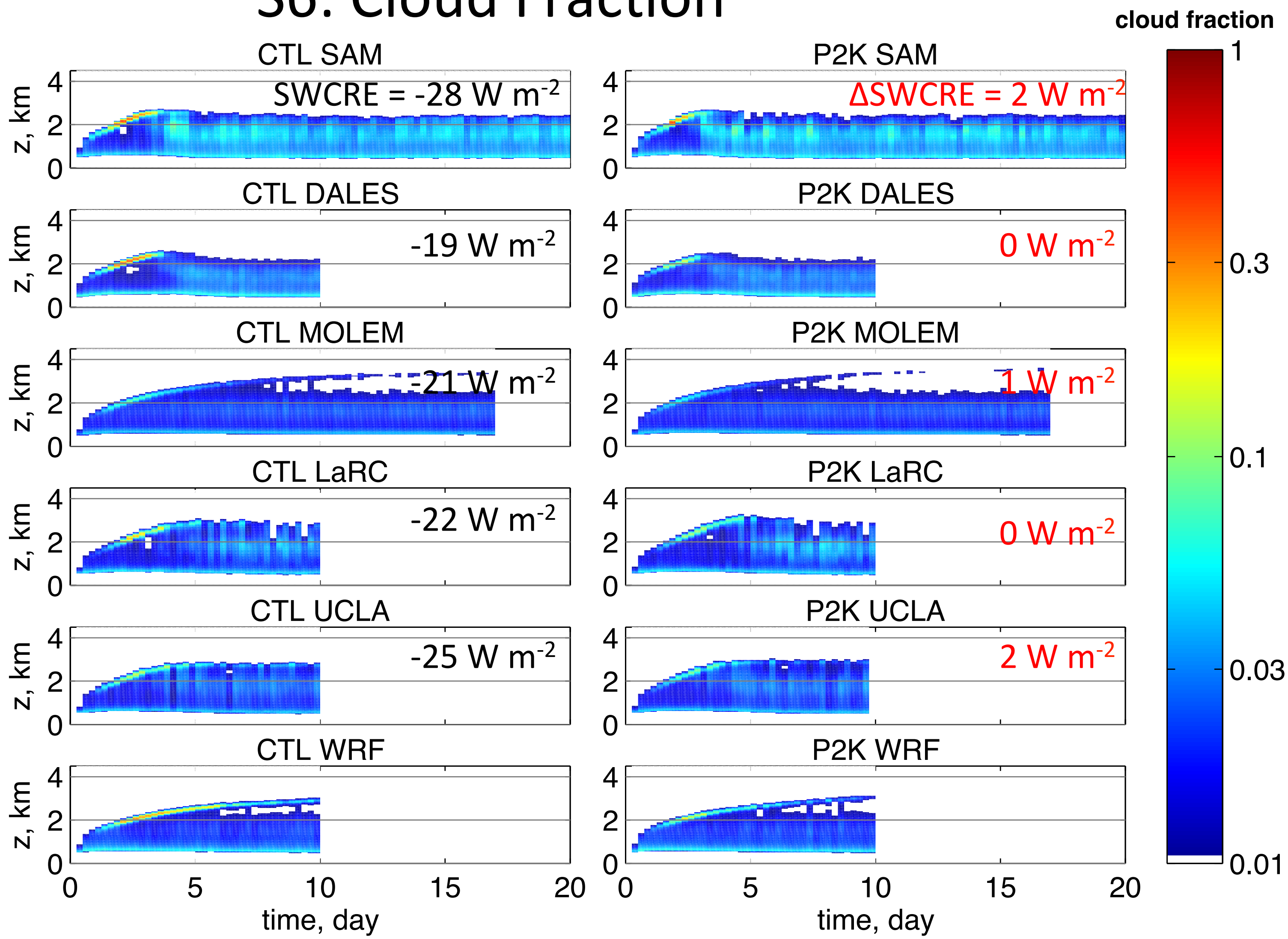

- Fair agreement between LES models in BL structure, depth.
- Initial Sc-over-Cu layer deepens and transitions to a Cu-only layer.
- +2K changes are weak; cloud layer depth is regulated by precipitation

CGILS LES conclusions

- Four competing effects of climate perturbations on Sc clouds:
  1. Larger surface – free trop moisture jump thins Sc
  2. More emissive free trop (CO_2, H_20) or less wind thins Sc
  3. Less subsidence thickens Sc (mostly for S12)
  4. Stronger inversion thickens Sc (mostly for S11)

  Effect 1 has largest ΔSWCRE , but 2 and 3 nearly as important.
- For P2K case, LES don't agree on sign of ΔSWCRE.
- However, for combined CMIP3 2xCO2 forcing changes, LES suggest Sc ΔSWCRE > 0 (+ cld feedback) at S11 and S12.
- For shallow Cu case, precipitation buffers cloud depth/response, yielding slight positive ΔSWCRE > 0.

Summary of S12 cloud response

	CTL		P2K OM0		P2K	
LES	LWP g m^{-2}	SWCRE W m^{-2}	ΔLWP g m^{-2}	ΔSWCRE W m^{-2}	ΔLWP g m^{-2}	ΔSWCRE W m^{-2}
DALES	51	−155	−17	+28	−6	+10
LaRC	48	−144	−7	+13	+13	−12
UCLA	57	−175	−7	+11	+16	−10
SAM	35	−133	−9	+20	+2	−2
SAMA	49	−152	−7	+12	+14	−13

- Good agreement on control cloud thickness
- LES all thin the cloud layer (positive feedback) in OM0
- P2K response mixed (marginal decoupling in SAM, DALES)

Summary of S11 cloud response

	CTL		P2K	
LES	LWP g m^{-2}	SWCRE W m^{-2}	ΔLWP g m^{-2}	ΔSWCRE W m^{-2}
DALES	52	−156	−6	+11
LaRC	50	−175	+2	0
SAM	43	−145	+1	0
SAMA	63	−152	−1	+4

- Very good agreement on control cloud thickness
- P2K response: neutral to positive ΔSWCRE