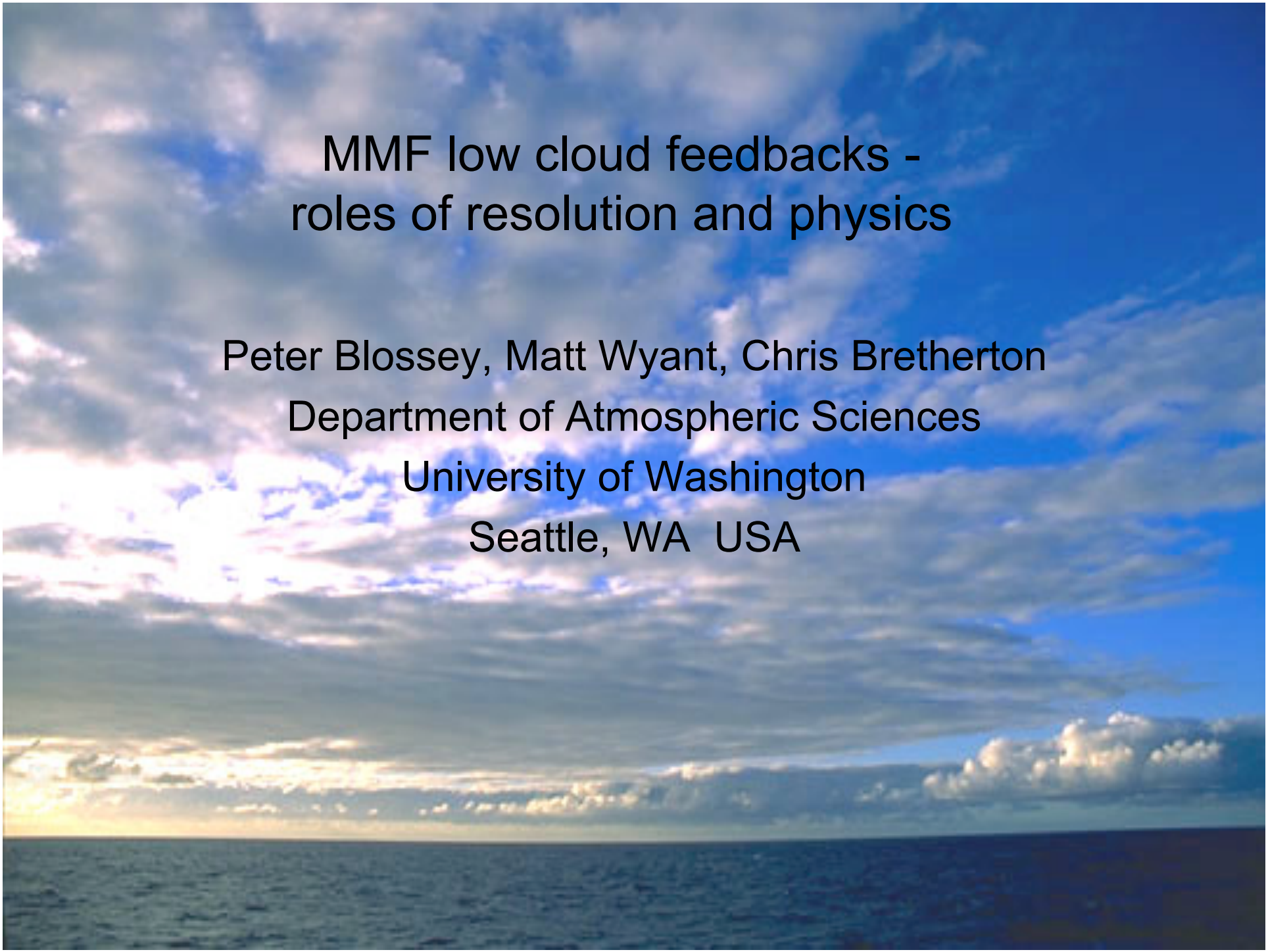
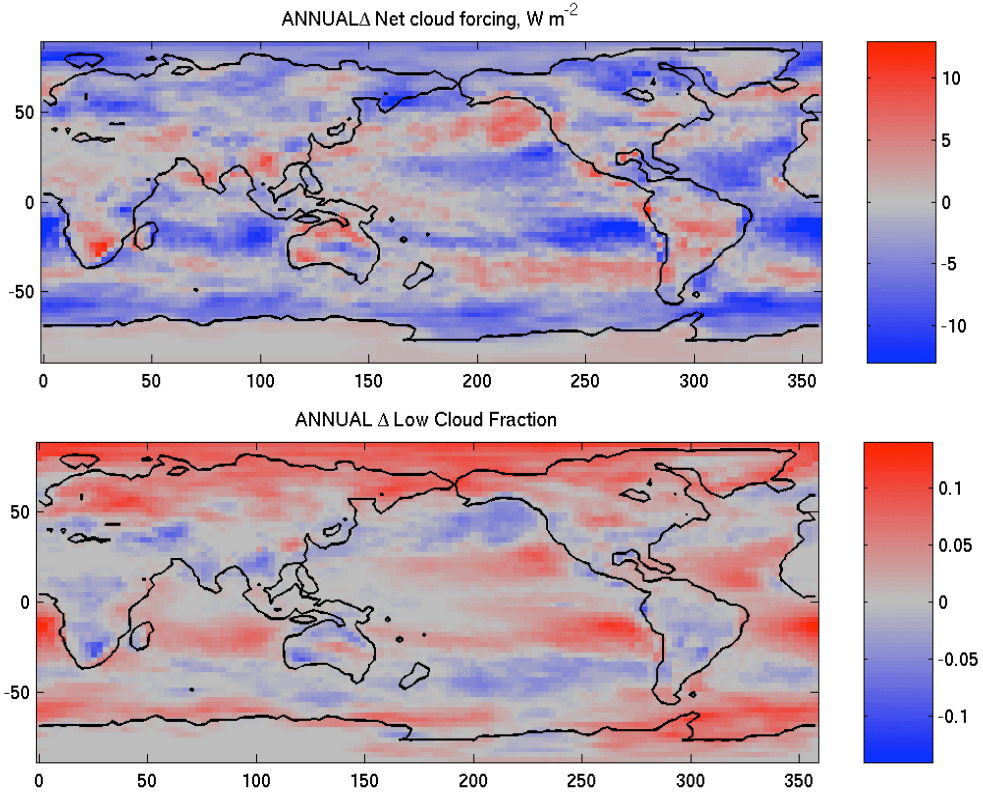


MMF low cloud feedbacks - roles of resolution and physics

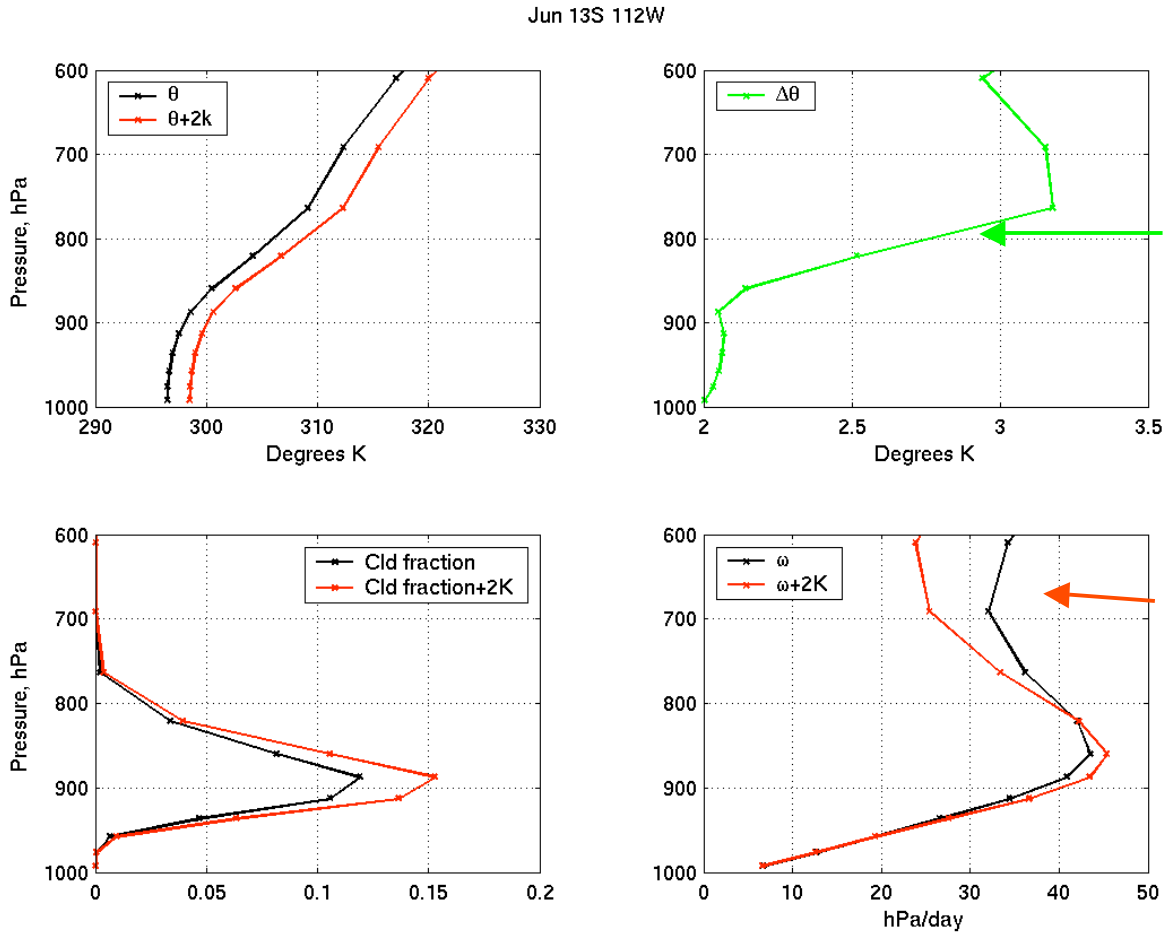
Peter Blossey, Matt Wyant, Chris Bretherton
Department of Atmospheric Sciences
University of Washington
Seattle, WA USA

Motivation

- SST/SST+2K MMF simulations show large increase in low cloud fraction in warmer climate (Wyant et al. 2006).
- However, current MMF (Δx = 4 km, 26 levels) underresolves boundary-layer Cu and Sc. Anning and Marat have showed this biases PBL structure & clouds.
- Use ‘single-column’ SAM simulations to test robustness of +2K response to CRM resolution & explore physics.
- Focus on low latitudes.



Typical MMF vertical structure in trades (SE Pac)



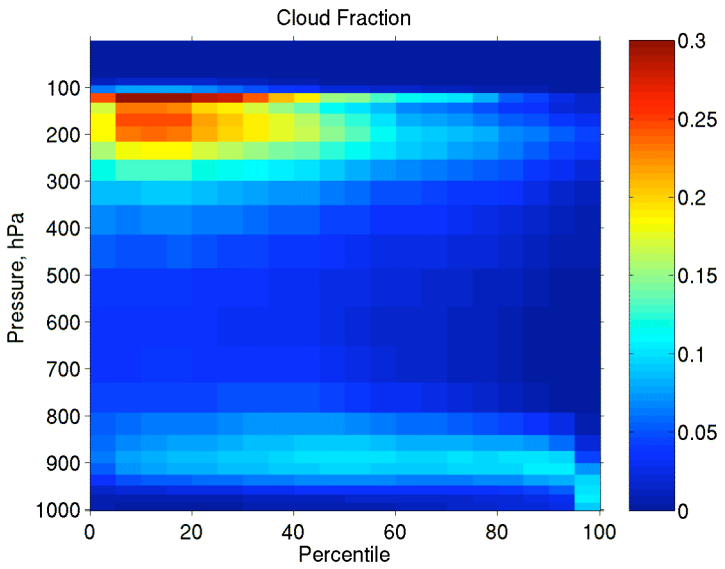
Inversion strengthens

Subsidence changes are location-dependent.

- Cloud fraction increases
- Little change in PBL depth

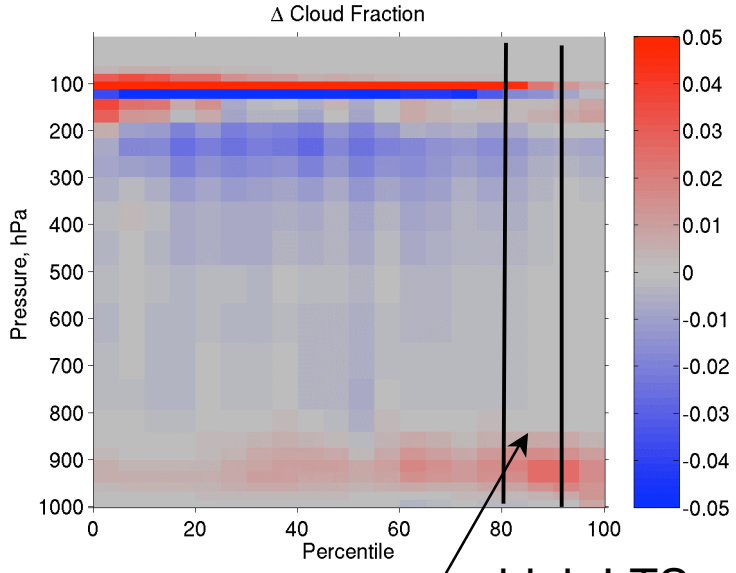
Regime-composited low-latitude cloud feedbacks

- LTS = θ_{700} - θ_{1000} is natural separator between deep Cu, shallow Cu and Sc regimes.
- Bin low-latitude ocean grid columns by percentiles of monthly-mean LTS…as in deep/shallow convection talk
- +2K run shows 10-20% relative increase in low cld fraction across all high-LTS regimes.



low LTS
warm SST
ascent

high LTS
cold SST
subsidence

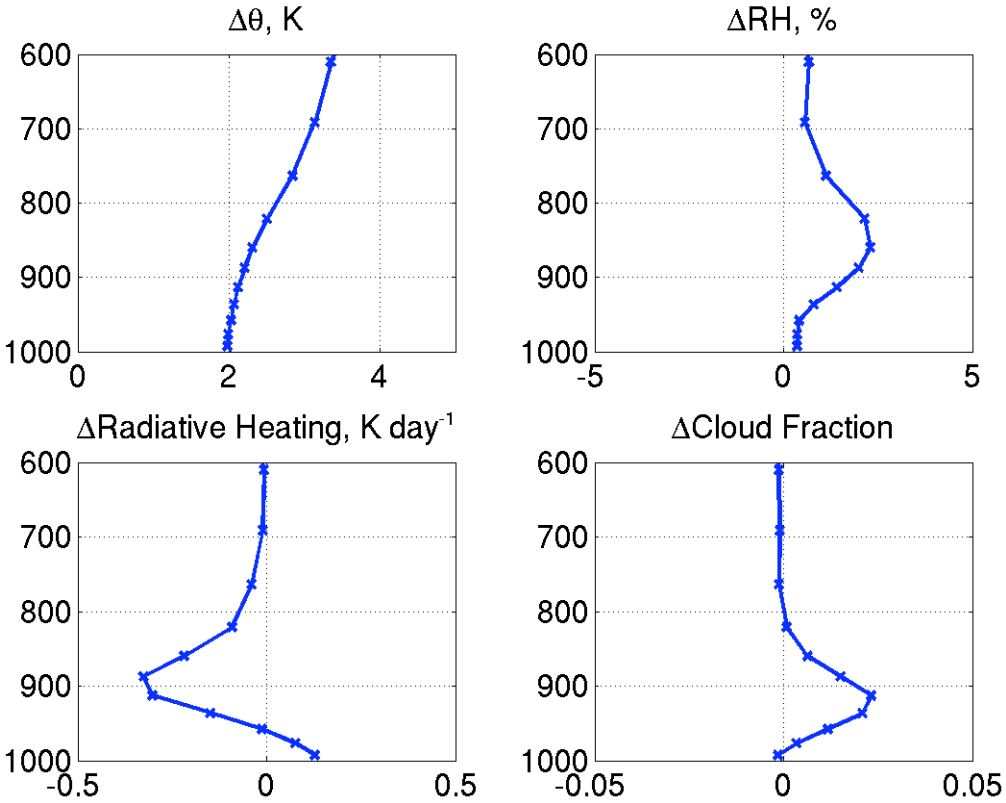


low LTS

high LTS

80-90%

Conceptual model of SP-CAM trade 'Cu' feedbacks



1. Stronger inversion

Stronger inversion

↓

Less efficient entrainment

↓

More Sc

2. Radiative destabilization

Cu layer warmer and moister

↓

Cu layer destabilized by stronger radiative cooling

↓

More Cu clouds

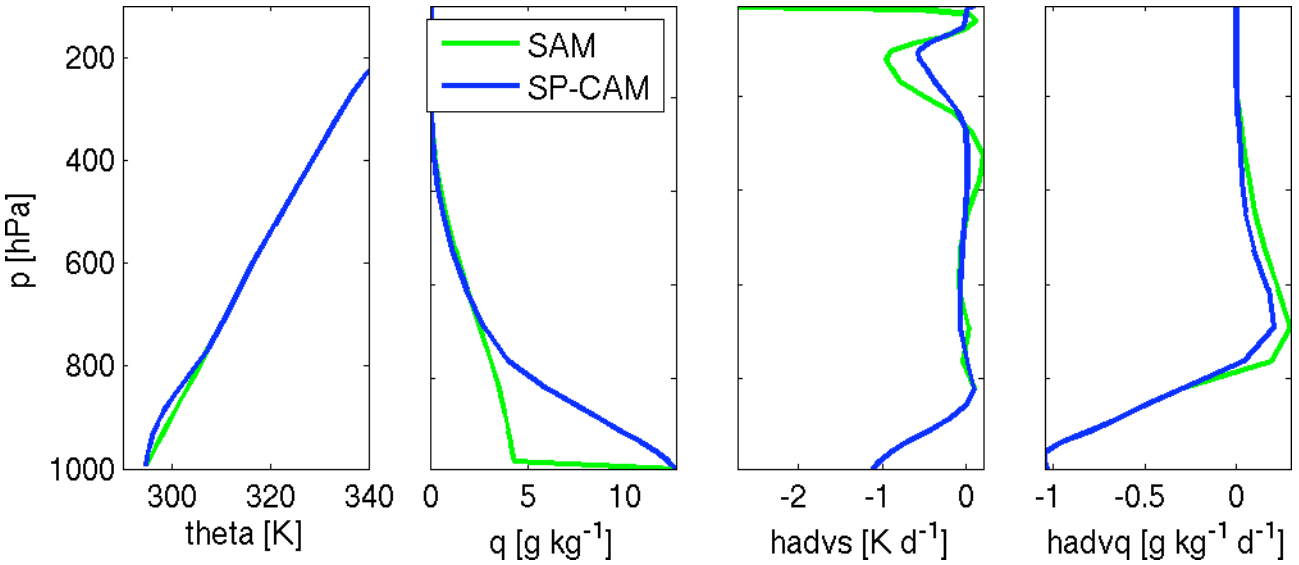
‘Single-column’ SAM and resolution sensitivity (as in deep/shallow convection talk)

To reproduce this response in SAM:

(1) calculate MMF composite for LTS decile (e.g. 80-90%).

(2) Use composite ω, SST, and nudge to composite winds. A realistic wind direction profile is also needed (RICO).

(3) Above ~5 km nudge T,q to MMF composite

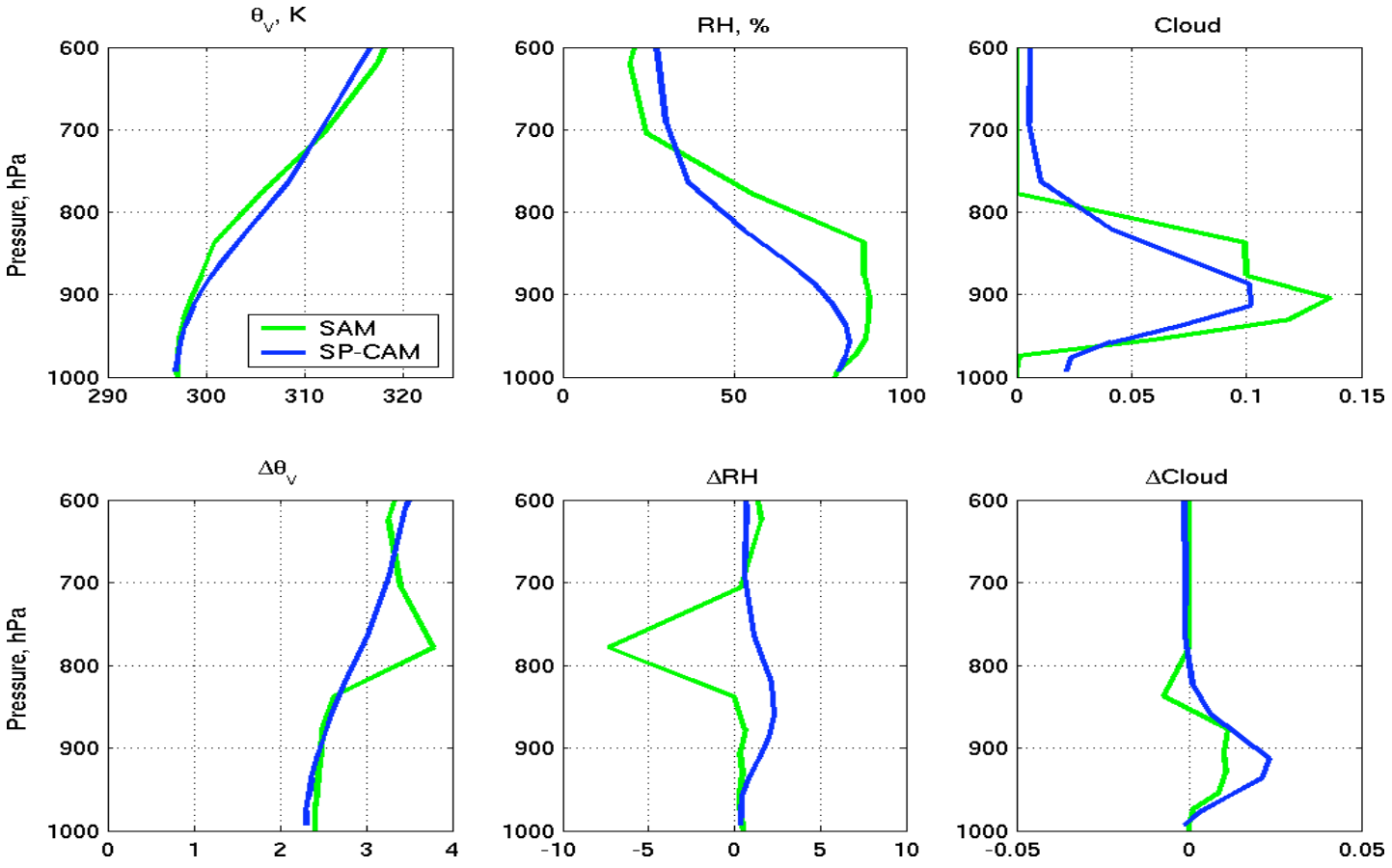


(4) Above 700hPa, adjust MMF horiz. advection to keep free troposphere in steady state. (Assumes synoptic eddies dominate convection there.)

- We did simulations with 70-80% and 80-90% LTS decile composite forcings and various SAM resolutions.

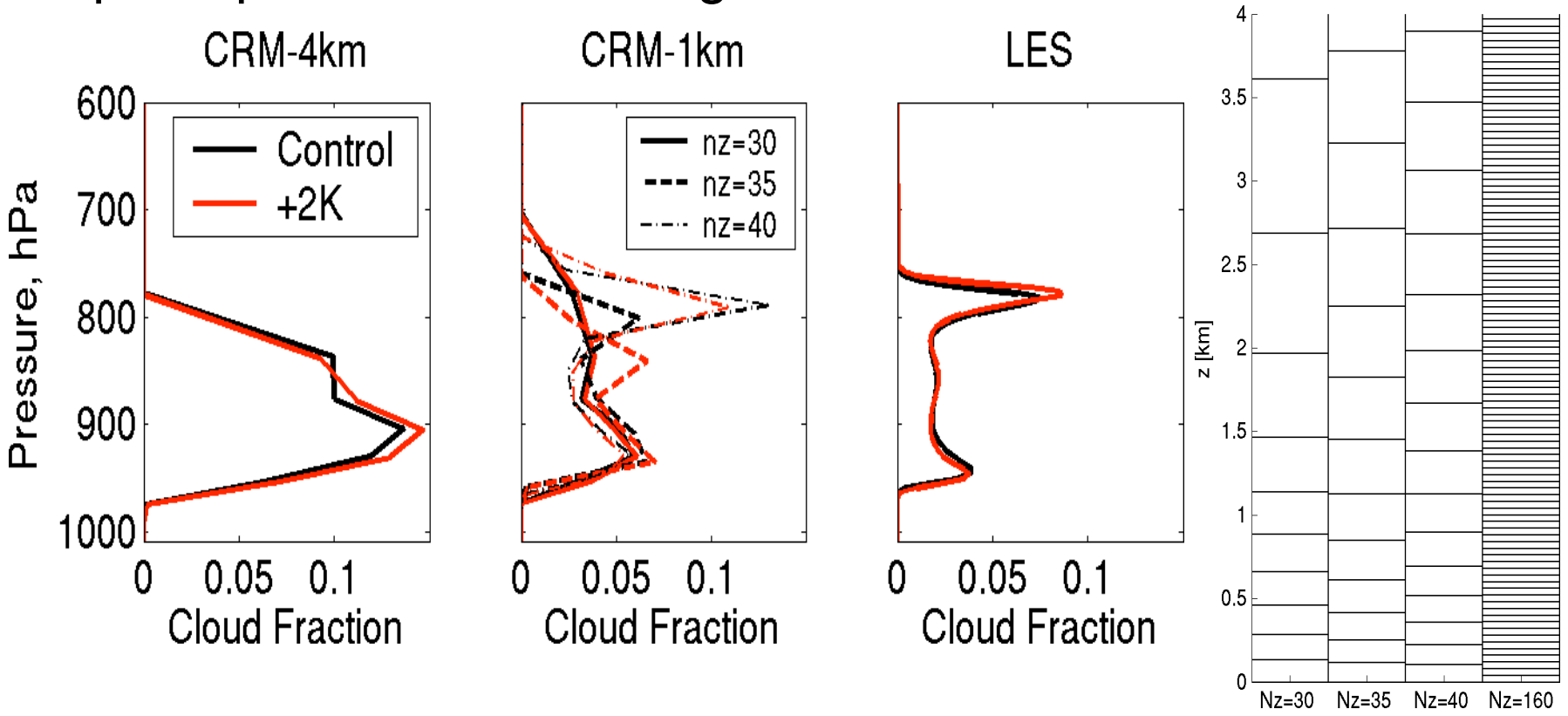
Results I

- With MMF resolution, SAM roughly reproduces composite MMF profiles and +2K sensitivity. Hence it is a reasonable single-column analogue for the subtropical low-cloud feedbacks seen in MMF.



Results II

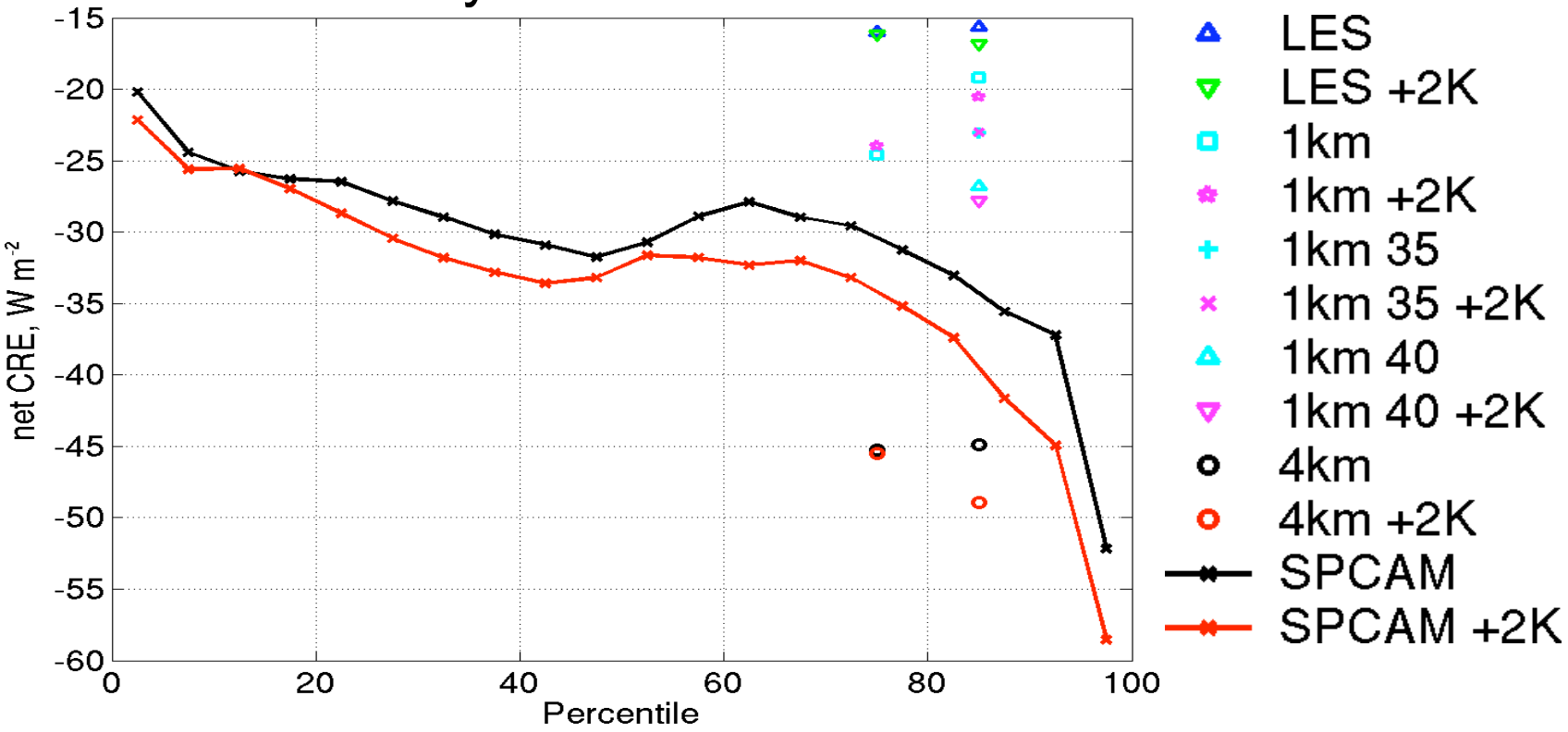
- With finer horizontal and vertical resolution, the PBL deepens with more top-heavy ‘Cu-under-Sc’ cloud profile.
- Low cloud still increases, but much less than in MMF. Instead, the main response is a slight PBL deepening, perhaps due to the stronger radiative destabilization.



Cloud radiative effect

The net CRE from the MMF-resolution SAM runs (and their +2K sensitivity in the 80-90 bin) both resemble the MMF.

The LES run looks much more cumuliform and show less sensitivity in net CRE. 1 km runs have stronger CRE but similar sensitivity to the LES.



Conclusions

- To credibly simulate cloud feedbacks from low-latitude shallow cumulus regimes, the horizontal resolution of SAM in MMF must be increased.
- We hypothesize that the resulting MMF will show weak increases in low cloud in a +2K climate.
- We suggest a CRM Δx =0.5-1 km. With 64-128 columns, this would still be economical to run in the MMF.
- 5-10 more vertical levels would improve PBL cloud vertical structure, but effects on cloud feedbacks are hard to predict.
- MMF low cloud feedback seems correlated with +2K changes in the temperature profile, which strengthen trade inversion and PBL radiative cooling.
- MMF climate sensitivity simulations with $2xCO_2$ above a slab ocean might give somewhat different cloud feedbacks.