Sensitivity of MMF low cloud climatology to resolution

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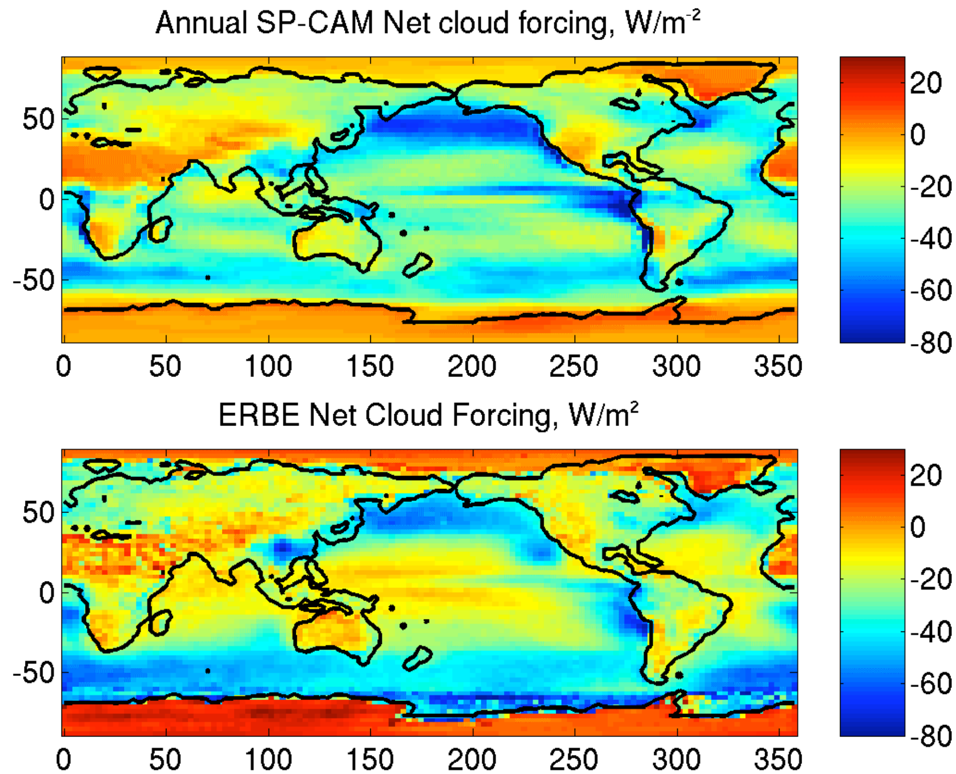
Motivation

- MMF has boundary-layer cloud biases important for climate sensitivity, and coupling with aerosol and ocean.
- Given adequate resolution, 2D CRMs can represent boundary layer and cloud structure well.
- Current MMF under-resolves boundary-layer Cu and Sc.
- Goal: define an MMF configuration affordable for 5 yr runs that minimizes low cloud biases.

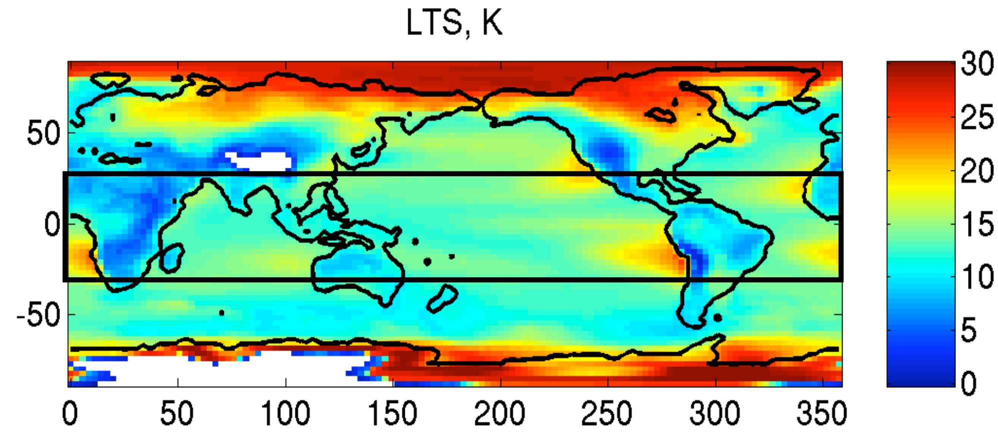


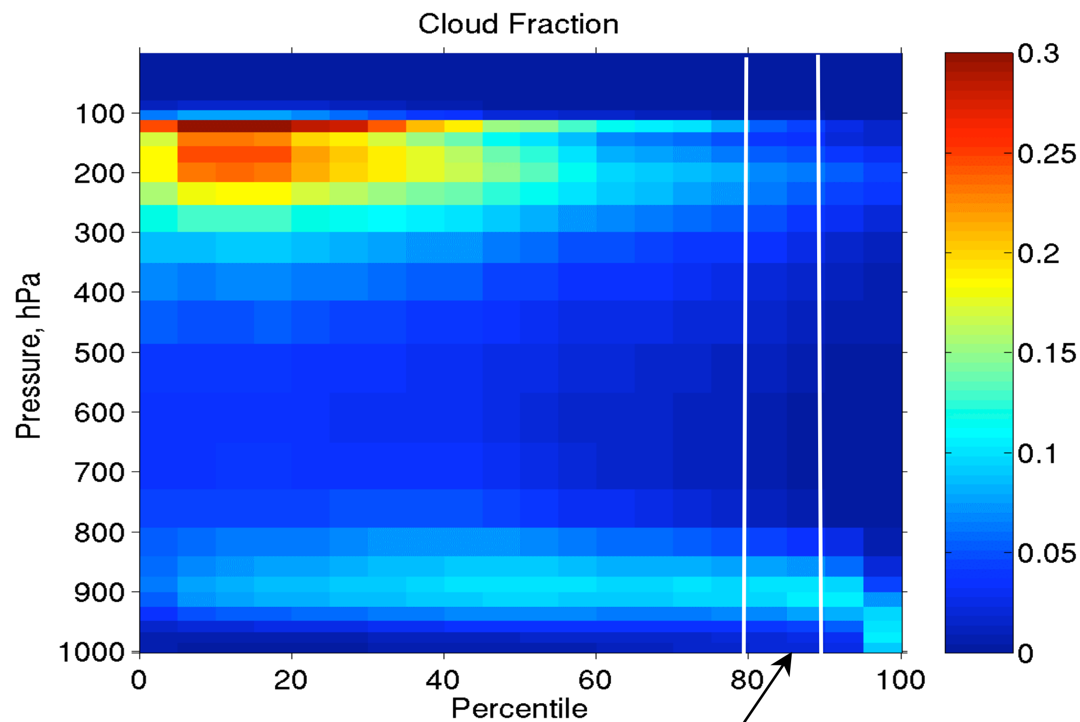
Method

- Separate MMF climatology into regimes
- Use regime-composite large-scale forcing from MMF output to force CRM simulations.
- If the CRM is run to steady state at MMF resolution, does it make similar clouds to MMF regime composite?
- How sensitive are clouds and radiative forcing to increases in CRM resolution?

Regime-composited low-latitude MMF cloud climo

- LTS = $\theta_{700} - \theta_{1000}$ is natural separator between deep Cu, shallow Cu and Sc regimes.
- Bin low-latitude ocean grid columns by percentiles of monthly-mean LTS.





low LTS
warm SST
ascent

80-90%

high LTS
cold SST
subsidence

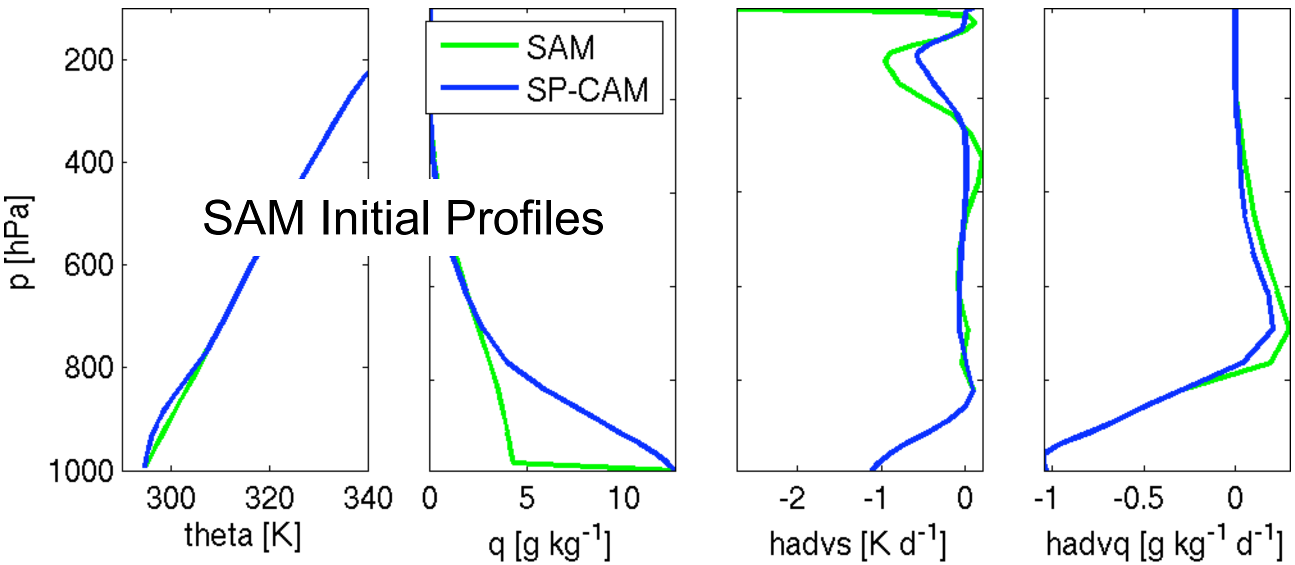
Making regime-sorted MMF-like forcings for SAM

Idea: Steady part of forcings mainly controls mean clouds

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

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

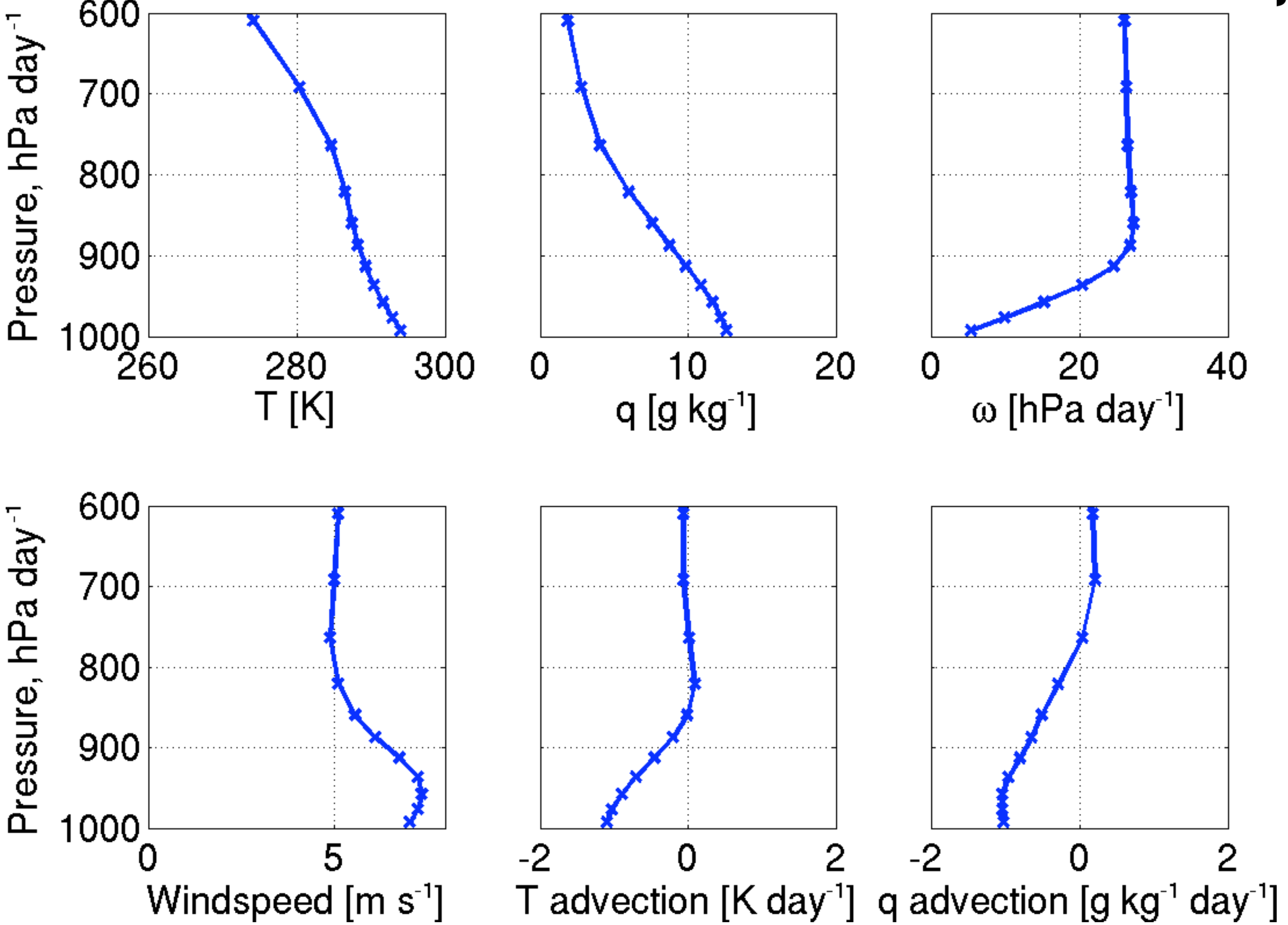
(2) Above ~5 km nudge T,q to MMF composite.



(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.

80-90 percentile profiles/forcings



Resolutions tested

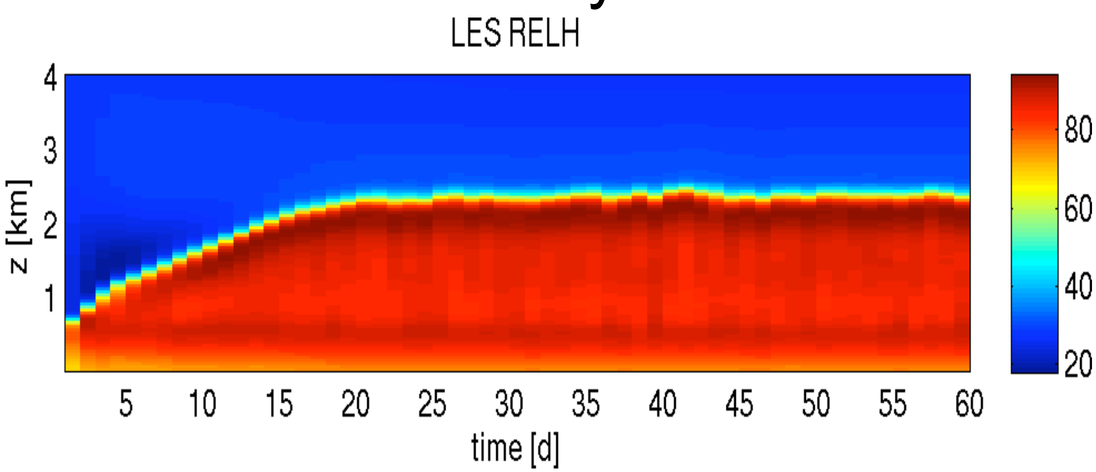
4km (Δx = 4 km, L30, as in MMF)

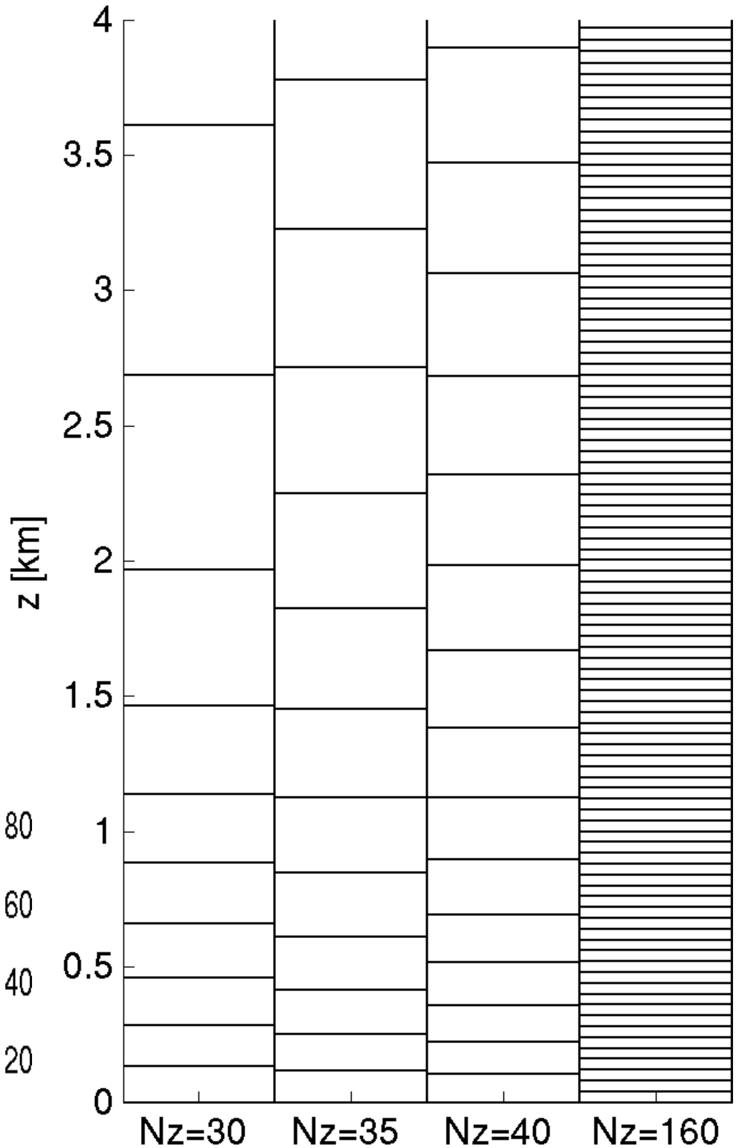
Δx = 1 km, L30, 35, 40

LES (Δx = 100 m, Δz = 40 m).

All simulations are 2D and take ~20 days to reach statistically steady state.

We show 30-60 day means.

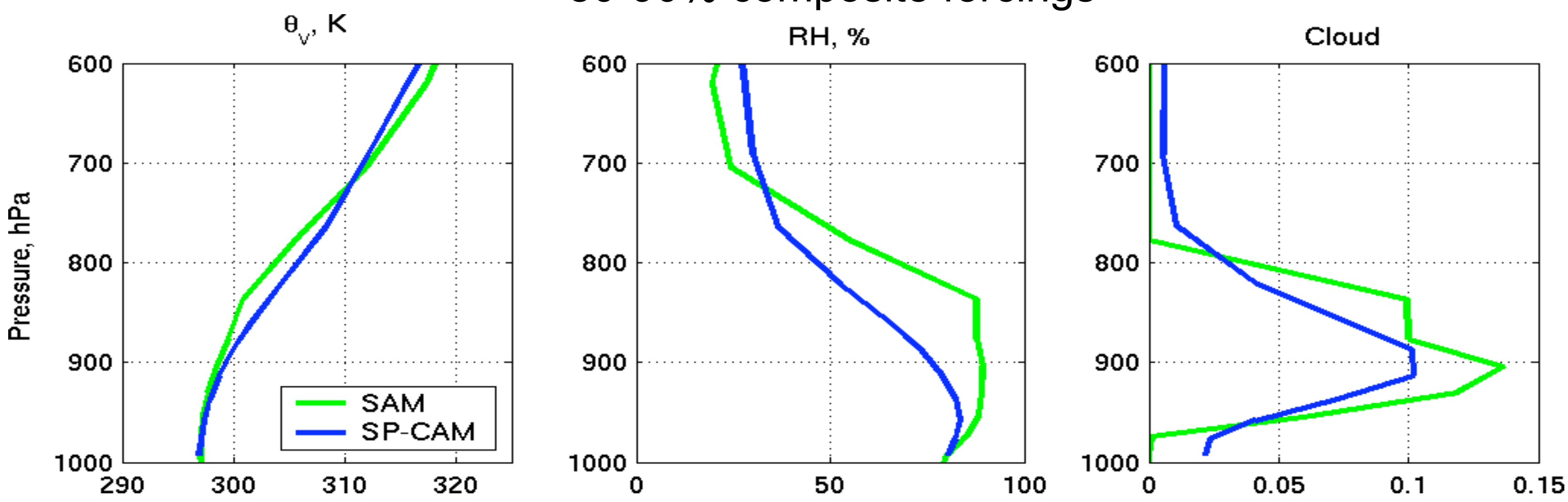




MMF-forced SAM results

- With SP resolution, SAM roughly reproduces composite MMF profiles for 80-90% forcings. Hence it is a reasonable single-column analogue for this case.
- Sharper inversion top in SAM is inevitable consequence of using time-space averaged composite forcing.

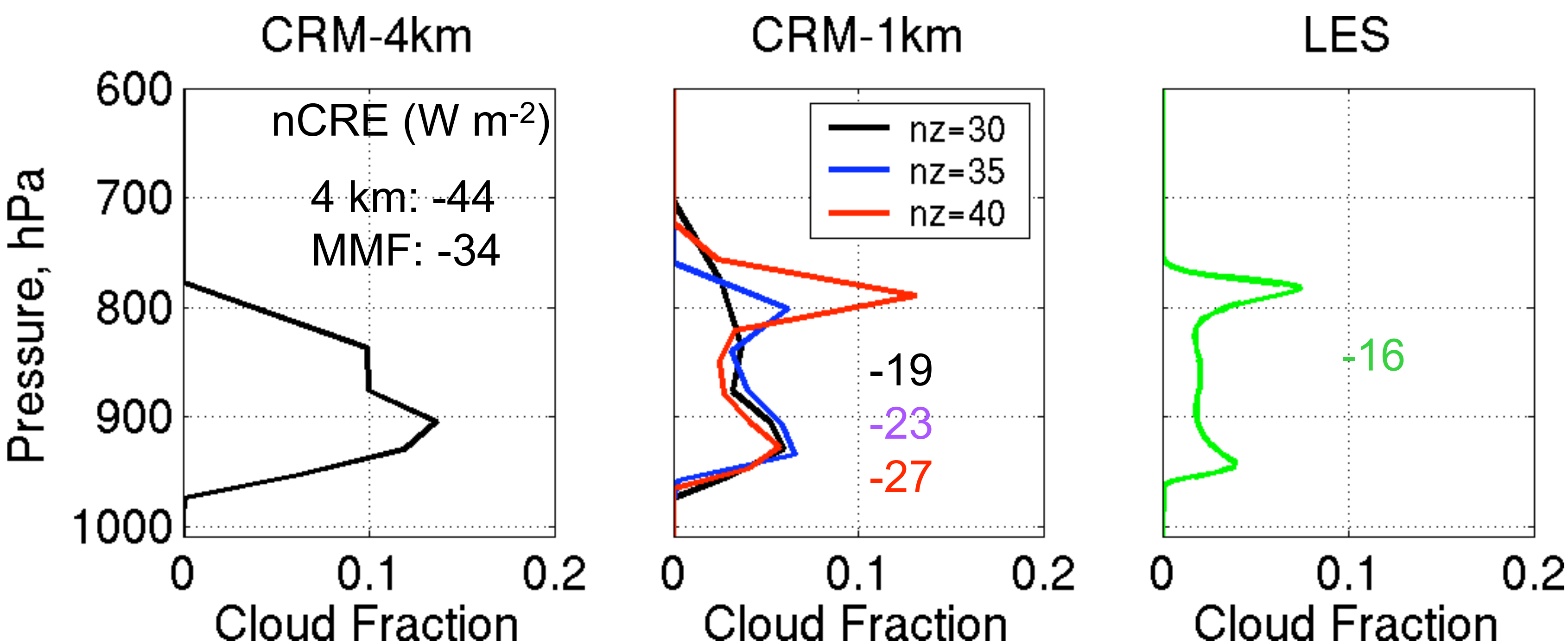
80-90% composite forcings



- 70-80% forcings gave a less successful analogue with too deep a moist layer compared to MMF.

Results II

- With finer horizontal and/or vertical resolution, the PBL deepens with more top-heavy ‘Cu-under-Sc’ cloud profile.
- 1km L40 vertical cloud profiles compare well with LES in shape, but have roughly 50% too much cloud at all levels.
- Net cloud radiative effect (nCRE) is much smaller at LES resolution than in 4 km SAM or the MMF. 1 km runs have intermediate nCRE. Improving vertical resolution with marginal Δx needn’t improve nCRE.



Conclusions

- To credibly simulate the mean structure of low-latitude shallow cumulus regimes, the horizontal resolution of SAM in MMF must be increased.
- Based on our study and Anning's, we suggest a CRM Δx =0.5-1 km. With 64-128 columns, this would still be economical to run in the MMF. Better vertical resolution with this coarse Δx improves vertical distribution of cloud, but may not reduce radiative forcing biases
- This probably won't improve stratocumulus but could help with the 'bright trades' bias in MMF.
- The best way to compare this approach with adding a better parameterization of ShCu and PBL to MMF is to try both and see what happens!