GCSS4/CPT RCE Intercomparison

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GCSS4/CPT RCE Intercomparison Promise, Problems, A New Proposal

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Original Concept: RCE is a simple (but unobservable) paradigm for tropical climate response easily studied with SCMs, CRMs.

- While CRM studies of RCE have been published (e.g. Tompkins and Craig 1999 *J Climate*), there has been no organized CRM or SCM RCE intercomparison.
- In GCSS, we like to argue that physical parameterization for CRMs is easier and more physically-based than for SCMs.
- Peter Blossey (UW) ran CSU (SAM) CRM …

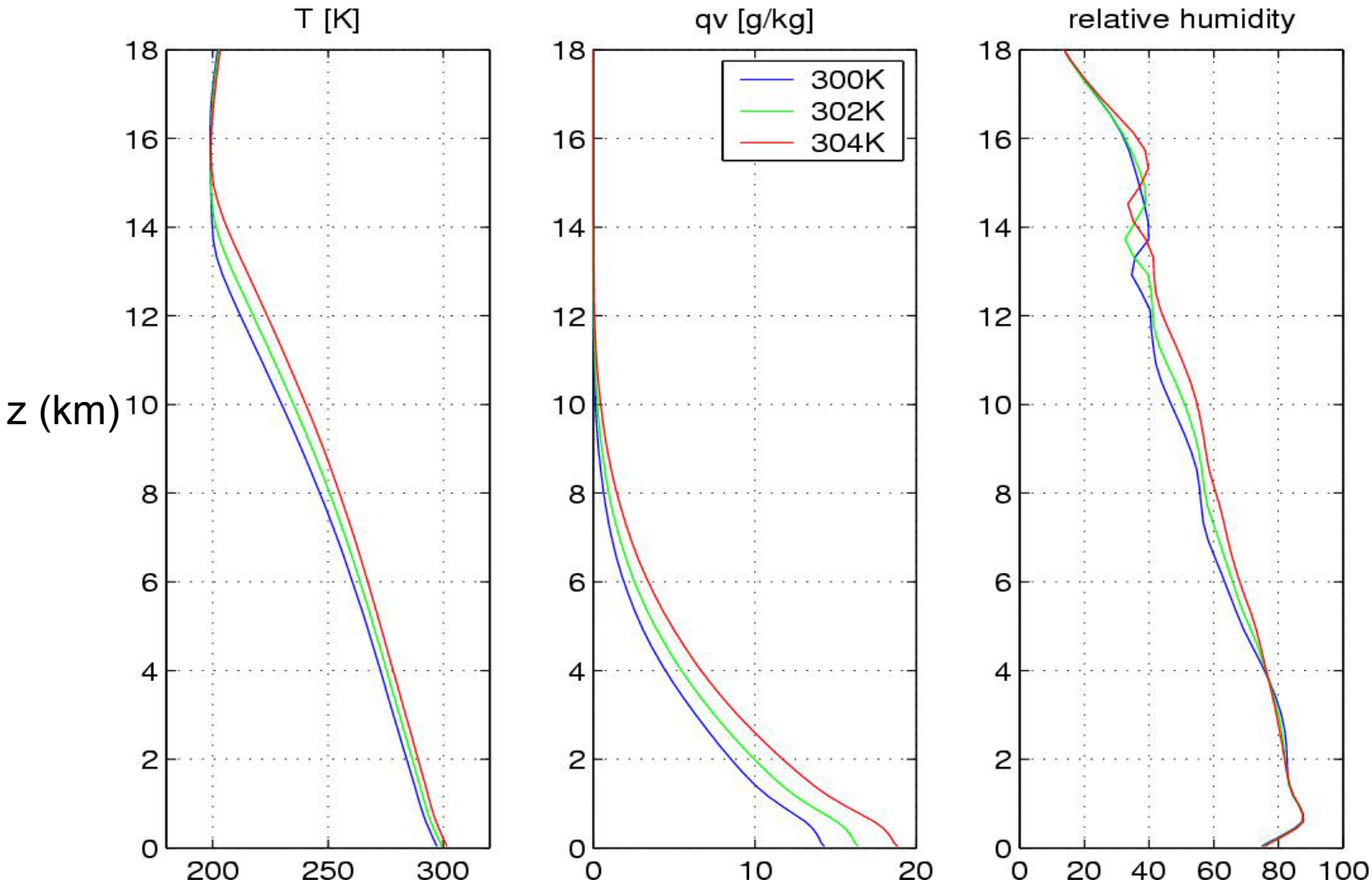
  - 60 day 64x64x27 km run, Δx = 2 km, Δz = 75-400 m

  - No mean wind, interactive radiation

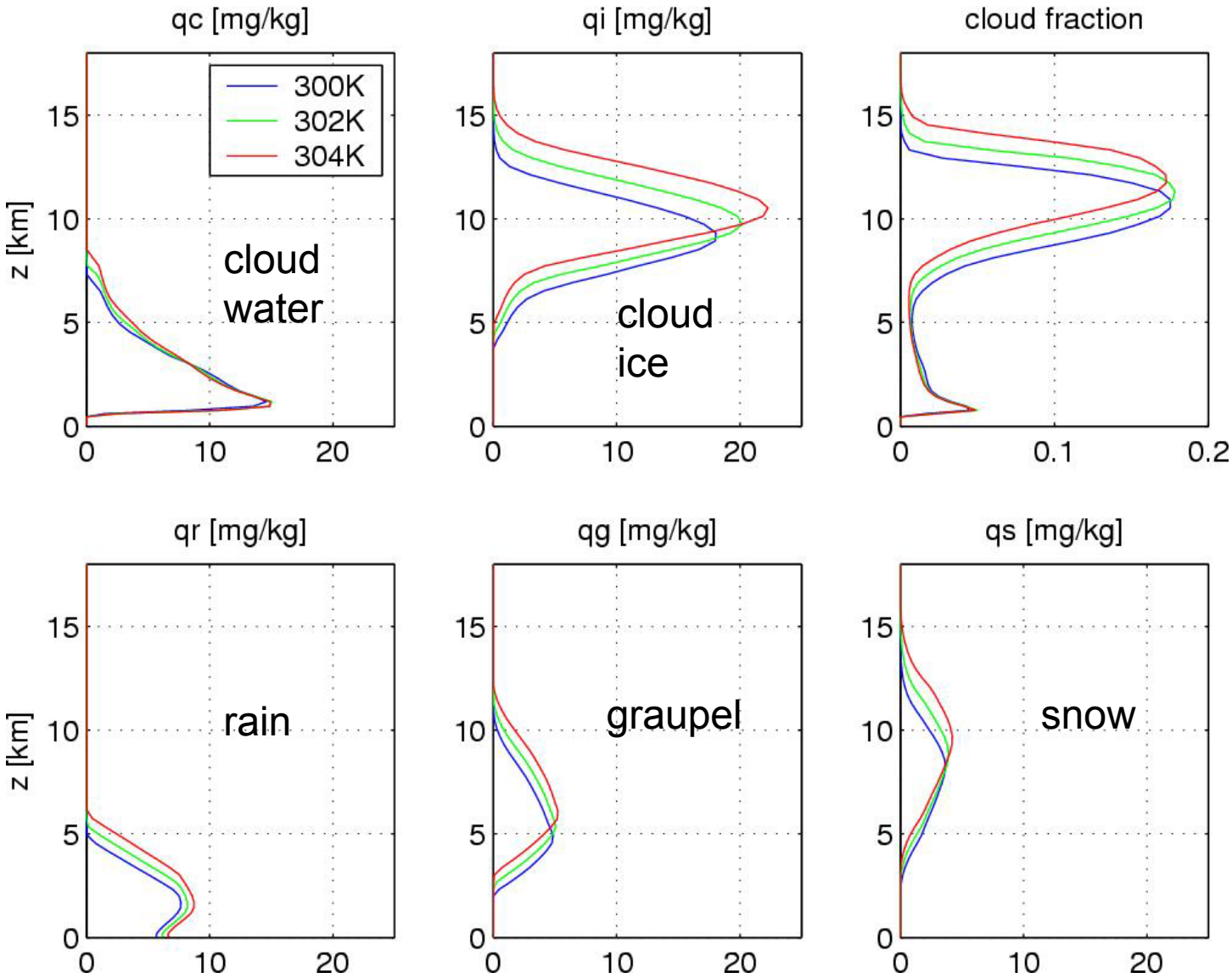
  - SST = 300, 302, 304 K.

SAM RCE results

- Equilibrates within 20 days – show 30-60 day hor. means



Condensate profiles



RCE statistics

- At 302 K: P = 3.05 mm d^{-1} LW_{up}^{TOA} = 246 W m^{-2} K^{-1}
  PW = 51 mm SW_{dn}^{TOA} = 334 W m^{-2} K^{-1}
- Sensitivities (300-304 K)

d/dSST of		clear sky
LW_{up}^{TOA} [W m^{-2} K^{-1}]	1.1	1.5 (ΔLWCF = 0.4)
SW_{dn}^{TOA} [W m^{-2} K^{-1}]	-0.2	0.1 (ΔSWCF = -0.3)
P [% K^{-1}]	5	
PW [% K^{-1}]	8	
cld frac [% K^{-1}]	0.6	

- Results for a 2xCO2 slab ocean analogue show a large decrease of cloud fraction with SST due to decreased tropospheric radiative cooling rate, less mass flux.

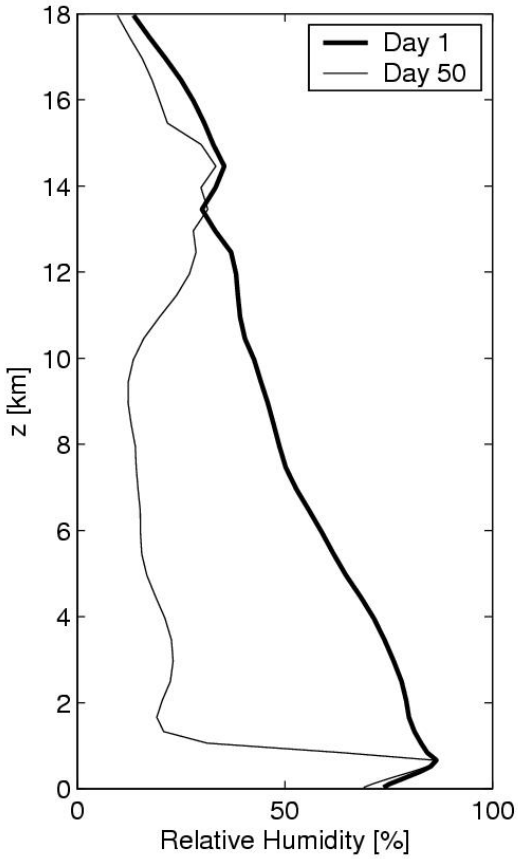
All this looks great, so what's the catch?

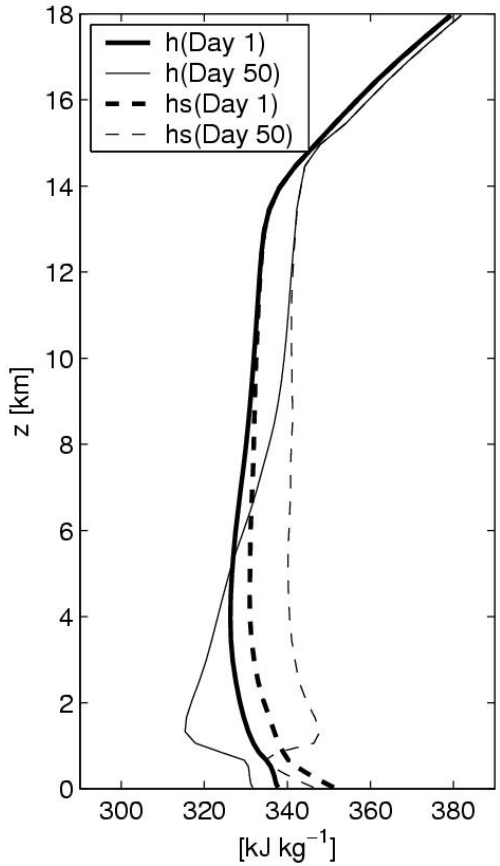
Problem with **well-posedness** due to self-aggregation when domain size increases.

'Day 1' : 96x96 km 301 K RCE steady state.

'Day 50' : …after 50 days of identical 576x576 km run.

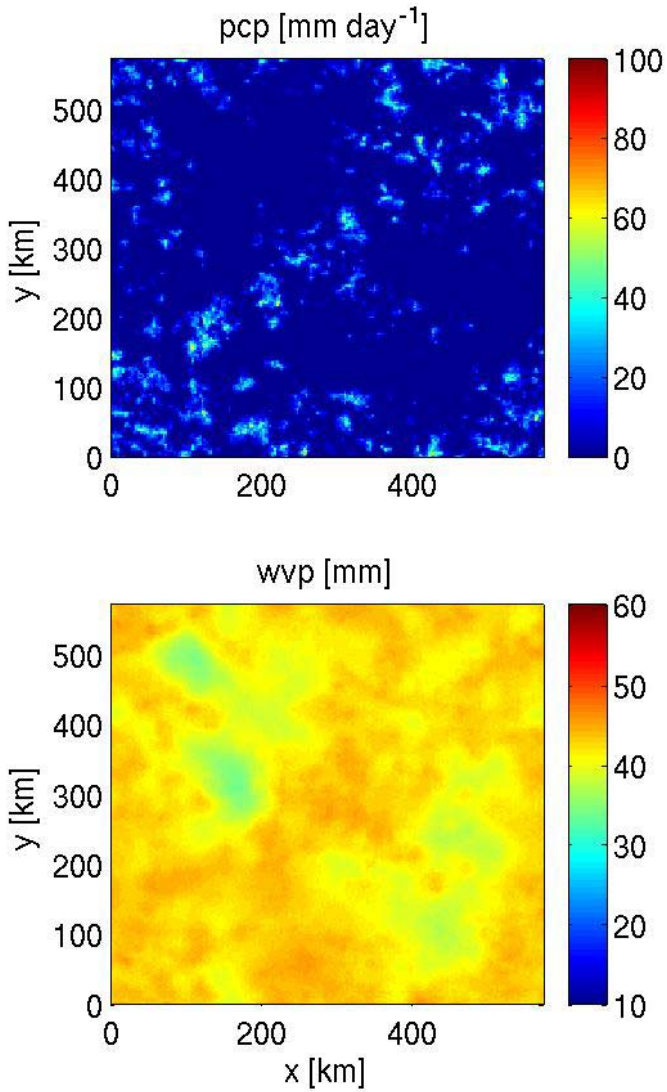
Mean sounding profoundly dries and warms…will the 'real' RCE please stand up?



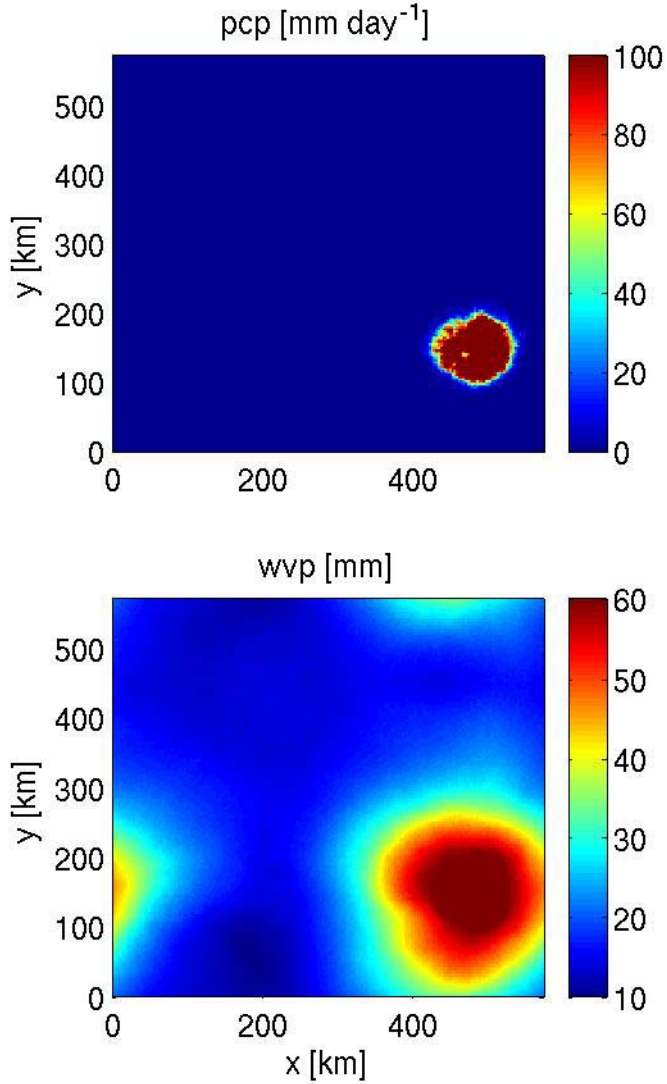


…and how does this happen?

Day 6 avg.
incipient self-aggregation



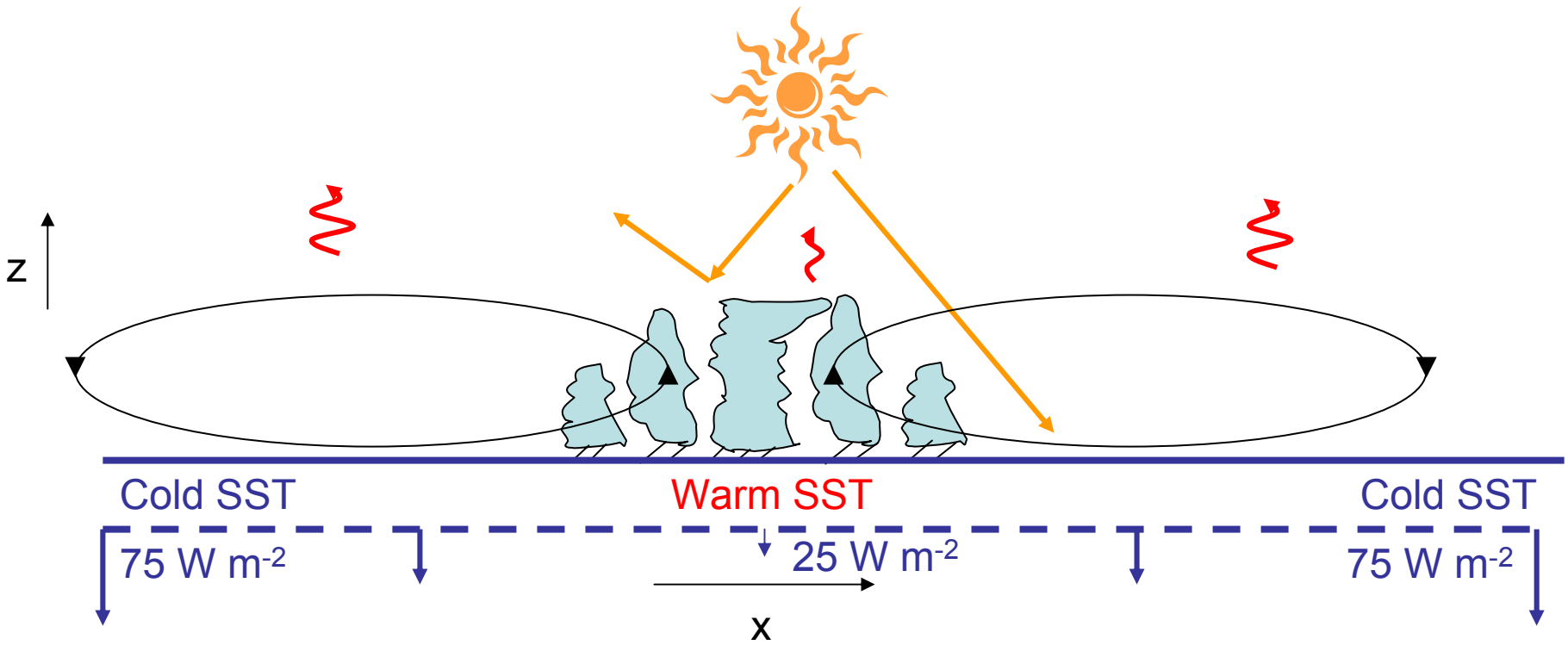
Day 50 avg.
One convective center

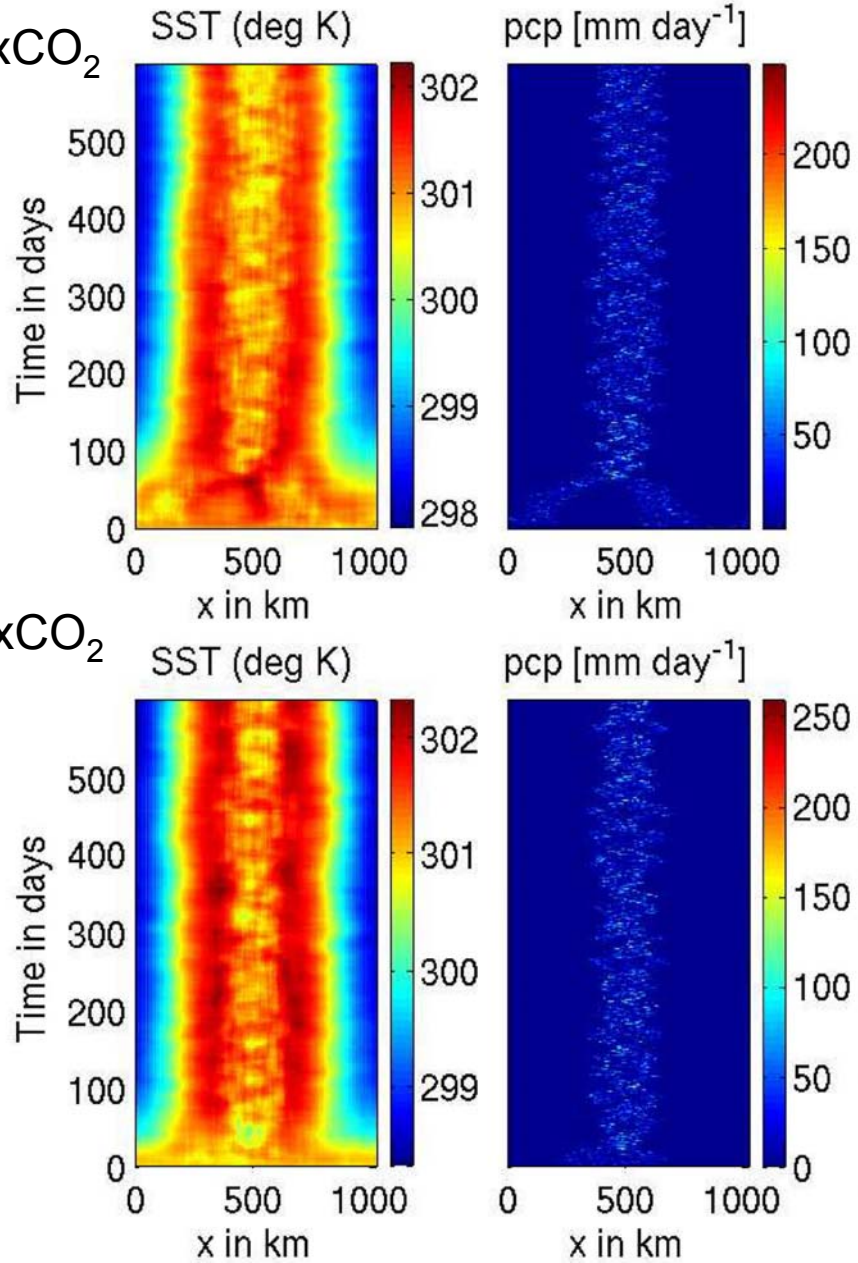


…so is an RCE intercomparison meaningful?

Alternative paradigm – a forced Walker circulation

- No rotation, uniform insolation, periodic BCs
- 20 m deep slab ocean with specified cooling $S^{ocn}(x)$ whose mean is chosen to make mean SST near 300 K.
- Compare 1xCO_2 (360 ppm) and 2xCO_2 'steady states', i.e. after 100+ days of integration.





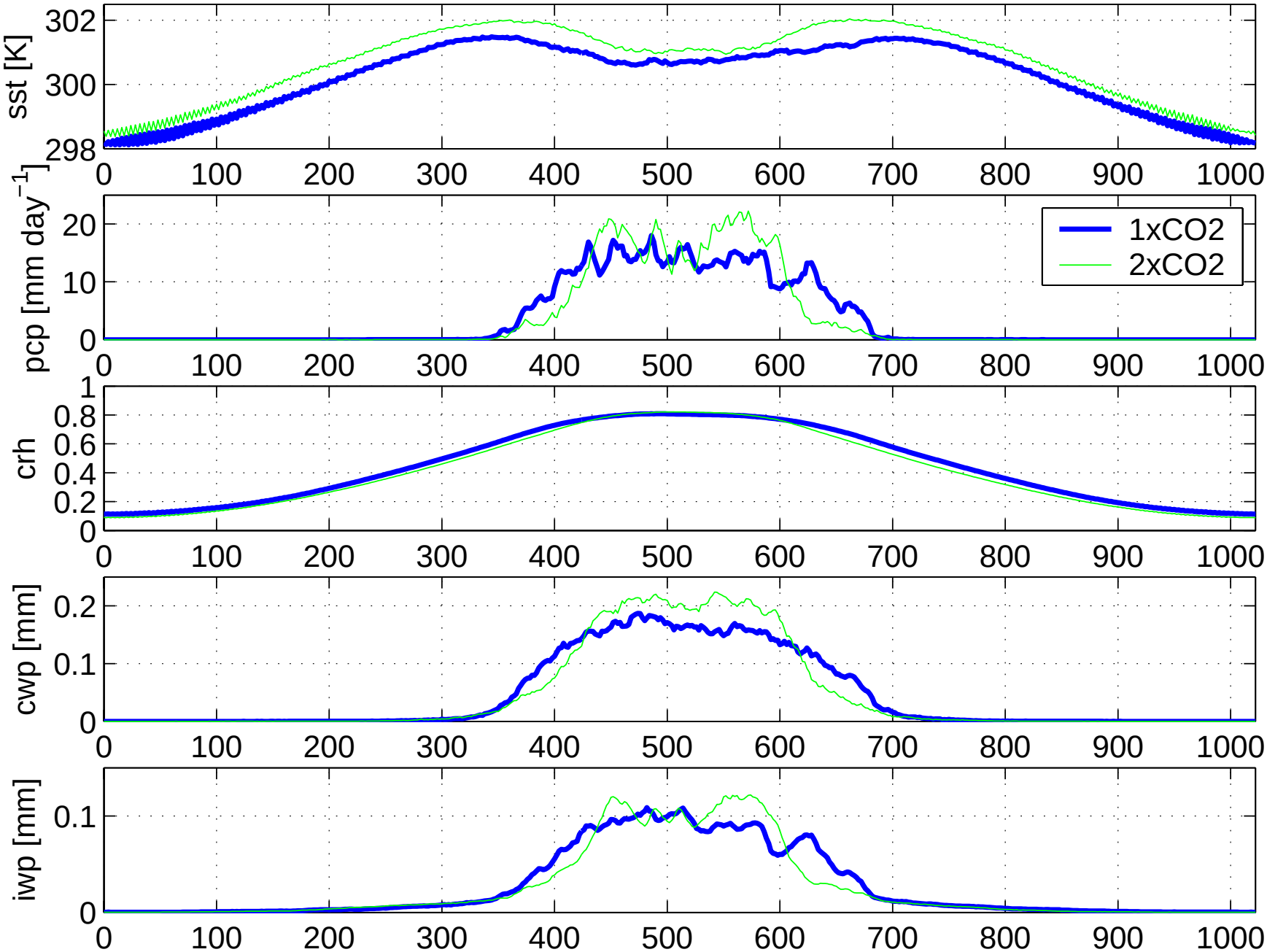
Walker circulation in 2D CSU CRM

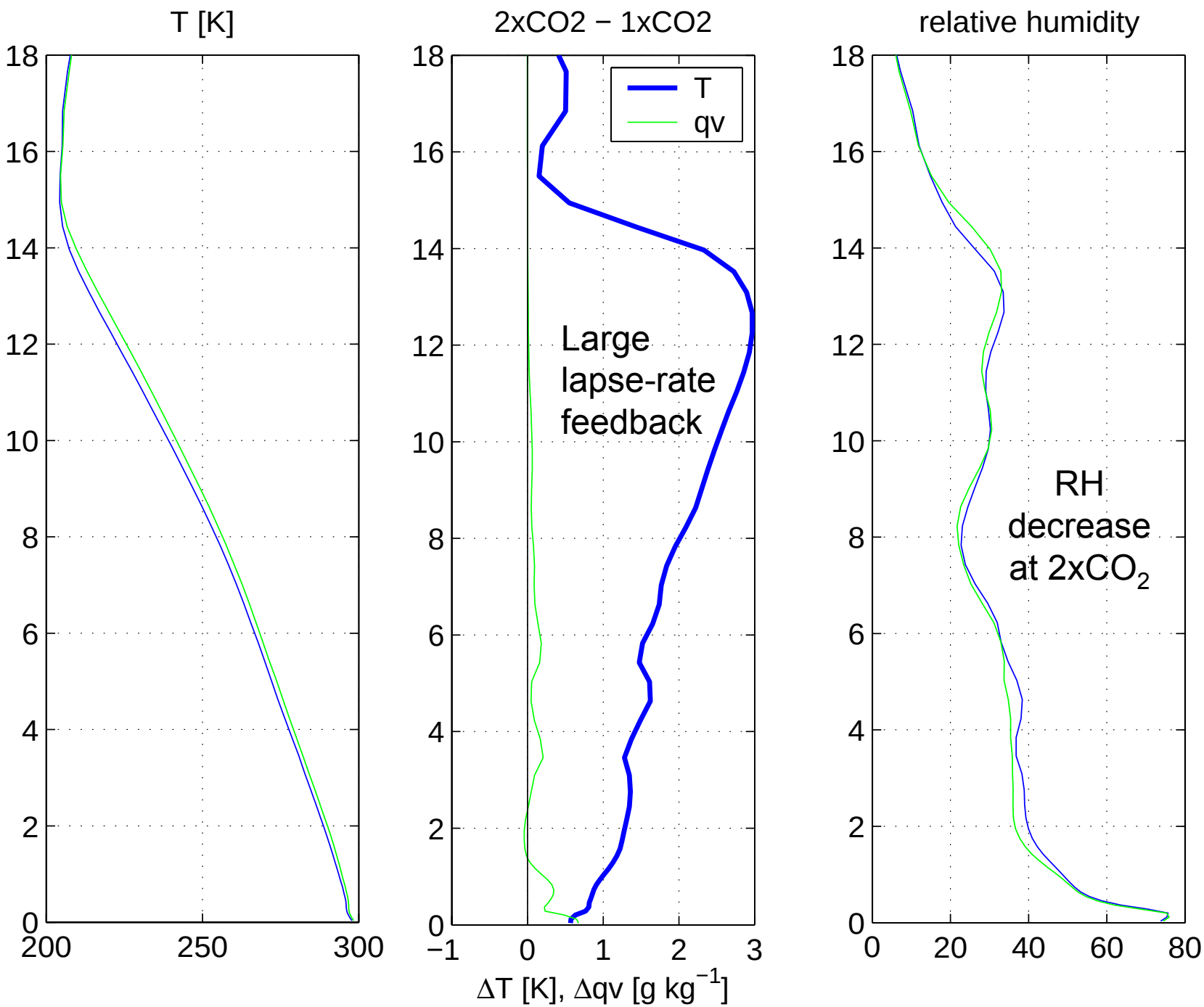
25-75 W m^{-2} ocean cooling

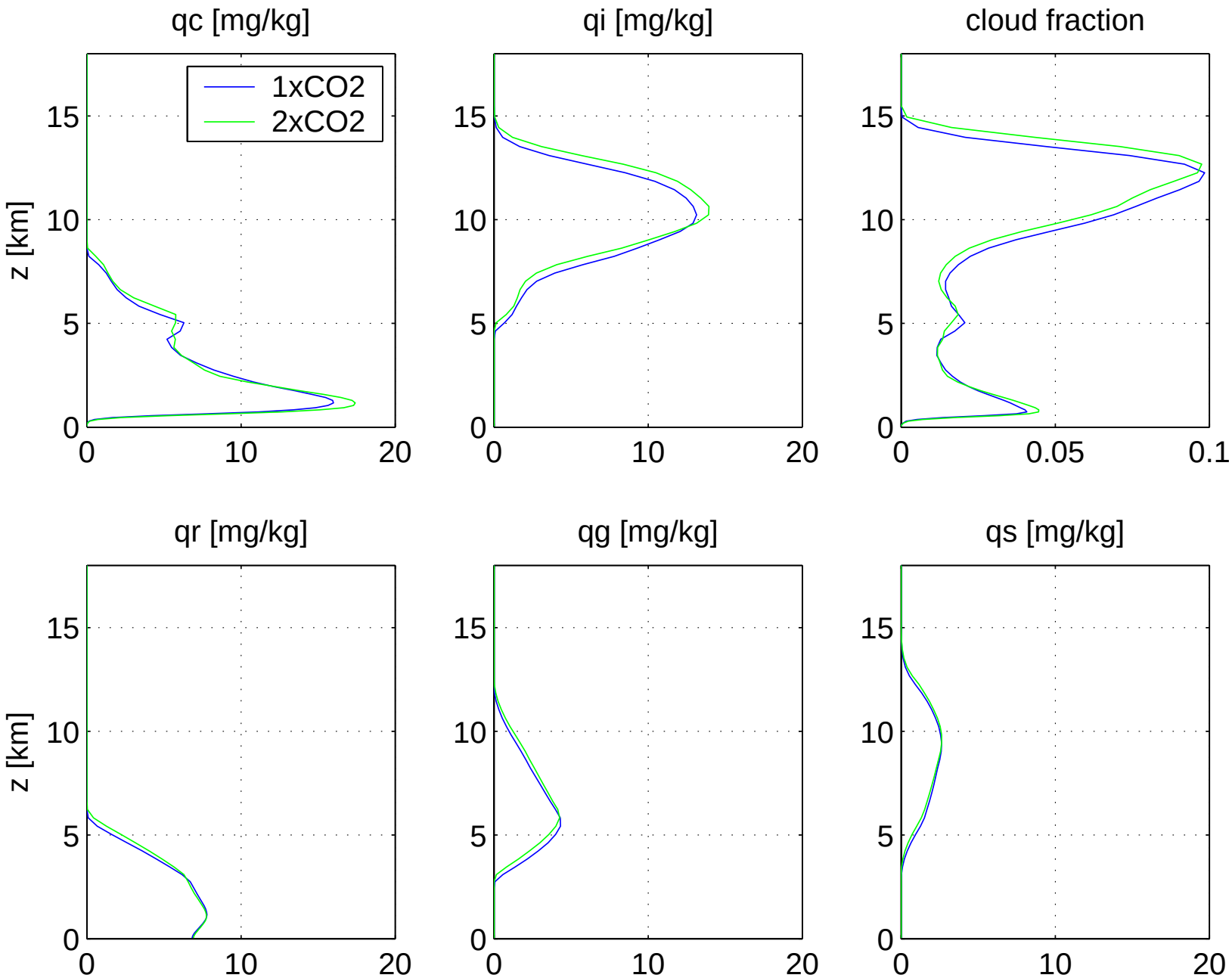
Δx = 2 km, 64 vertical levels

Quasisteady after 80 days.

Could run 3D ‘bowling alley’ (1024x64 km) in 2-4 days on UW 32-CPU linux cluster


sst [K]
302
300
298
0
100
200
300
400
500
600
700
800
900
1000
pcp [mm day^{-1}]
20
10
0
1xCO2
2xCO2
crh
1
0.8
0.6
0.4
0.2
cwp [mm]
0.2
0.1
iwp [mm]
0.1


T [K]
2xCO2 − 1xCO2
relative humidity
T
qv
Large
lapse-rate
feedback
RH
decrease
at 2xCO2
ΔT [K], Δqv [g kg−1]


qc [mg/kg]
qi [mg/kg]
cloud fraction
qr [mg/kg]
qg [mg/kg]
qs [mg/kg]
1xCO2
2xCO2
z [km]
0
5
10
15
20
0.05
0.1

Statistics

Strong Iris effect due to narrowing of convective region

At 1xCO2: SST=300.2K

P = 3.56 mm d^{-1} LW_{up}^{TOA} = 287 W m^{-2} K^{-1}

PW = 31 mm SW_{dn}^{TOA} = 337 W m^{-2} K^{-1}

Sensitivities (2xCO2) – fluxes not quite steady-state.

		clear sky
SST [K]	0.5	
LW_{up}^{TOA} [W m^{-2}]	-1.0	-1.3 (ΔLWCF = -0.3)
SW_{dn}^{TOA} [W m^{-2}]	-0.7	0.0 (ΔSWCF = -0.7)
P [%]	1.5	
PW [%]	5	

…significantly different than either SST+2 or 2xCO2 small-domain CRM simulations.

Conclusion

- The US clouds CPT has already decided we'll do the Walker intercomparison rather than straight RCE.
- This intercomparison is only slightly harder for CRMs and is expected to have smaller 2D/3D differences.
- It is more difficult for SCMs due to need to have connected SCM columns. However, this also produces a more useful analogue to real tropical atmosphere.
- We would like to invite GCSS WG4 to participate in and comment on this Walker intercomparison – discussion?