“3D” solar radiative transfer in a CSRM

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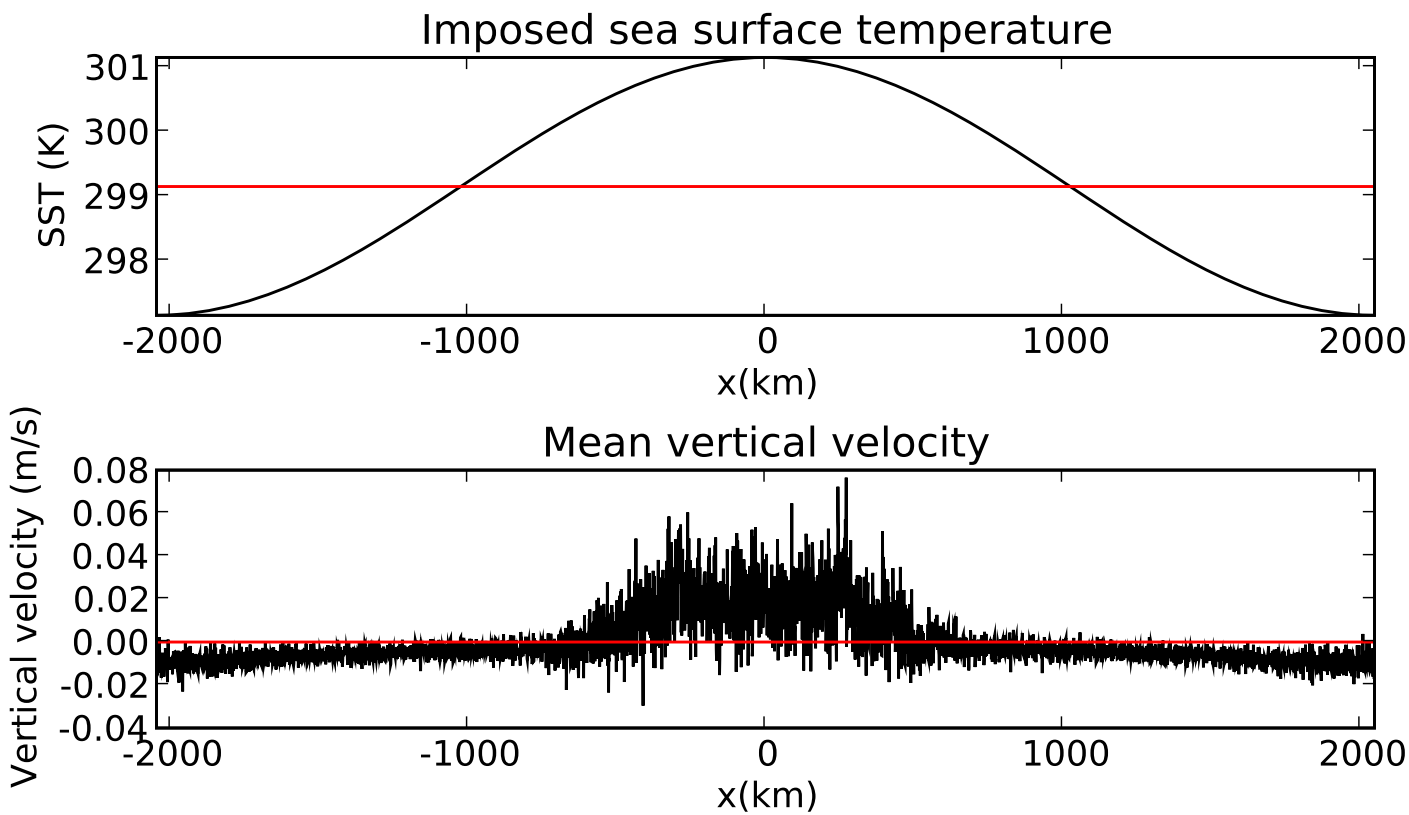
Introduction

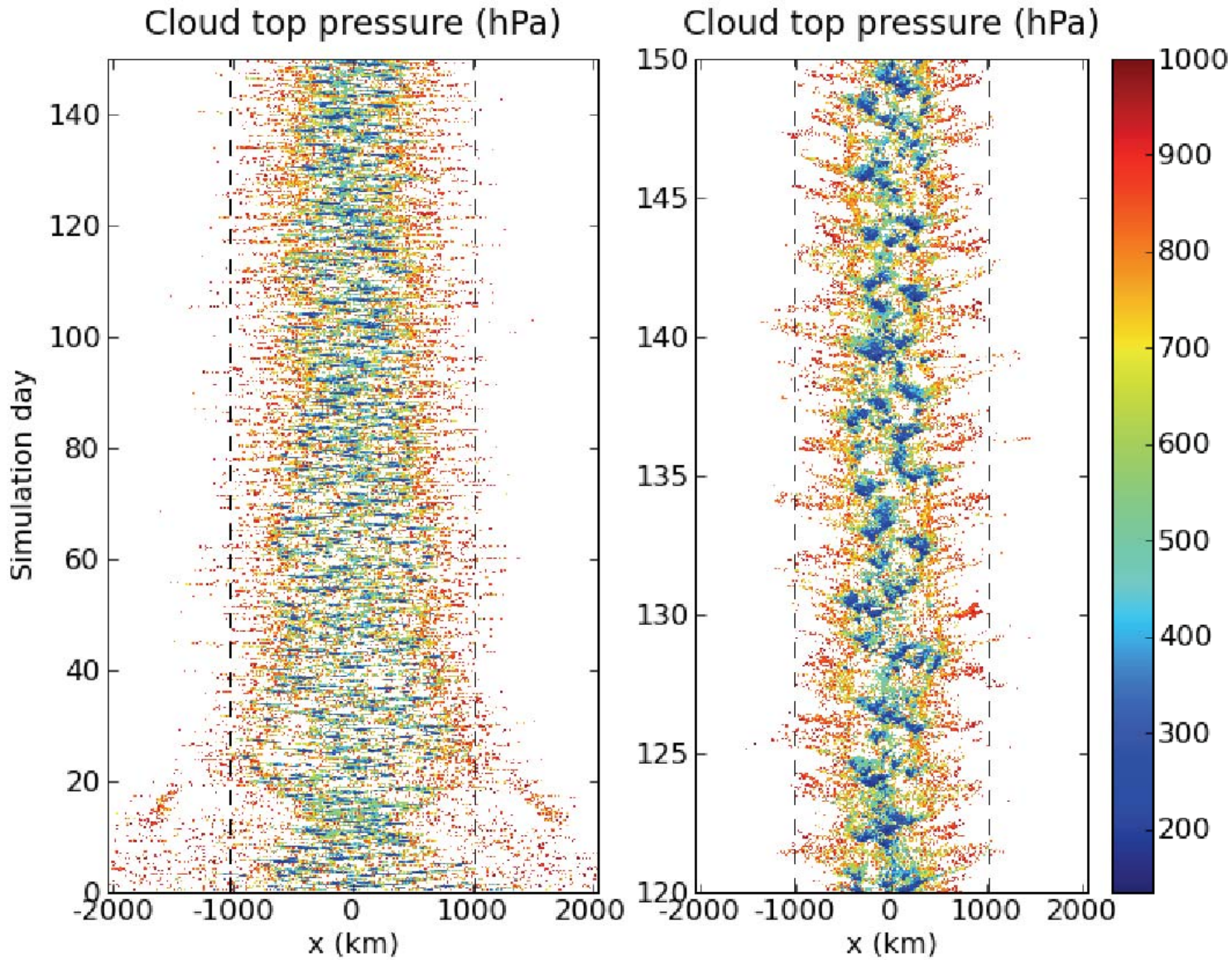
- Most CSRMs use ICA radiative transfer schemes
- Well known biases between ICA and 3D radiative transfer
- Do these instantaneous biases have a cumulative effect?
- Previous studies:
  - Longwave (Mechem, Guan)
  - Shortwave (Koracin, O'Hirok, Dobbie)
  - Shortwave surface effects (Frame, Wapler)
- Mainly shorter integrations for 2D clouds
- Will look at shortwave 3D effect on longer integrations

CSRM experiment selection

- Large domain and long integration time (large-scale feedback)
- Relatively well documented
- "Mock-Walker" experiment (Grabowski, 2000)
- Convection over warm SST, descent over cooler SST



CSRM experiments



Model configuration

CSRM (following Bretherton et. al., 2006)

- SAM version 6.5
- 2D, oriented west-east
- 4096 km wide, $\Delta x = 1$ km
- Top of model at z=27 km, 64 layers, Δz 100 to 500 m
- Integrate 150 days, starting from RCE profile
- Bulk microphysics

Radiation

- Based on CCCma radiative transfer model
- ICA LW (2-stream with scattering)
- SW is computed using Monte Carlo (various configurations)
- $\Delta t_{rad} = 5$ minute
- Diurnal cycle, azimuth angle fixed along CSRM axis

Sensitivity experiments

2D using 1000 photons per column

- Assume Δy is infinite

Monte Carlo noise

- Computational time proportional to number of photons
- Moderate amount of noise should be O.K.
- Injected 5000, 1000, 500 and $\sim$ 30 per column

Horizontally average SW heating rates

- Should have larger affect than ICA $\Rightarrow$ 2D

ICA using (1000 photons per column)

- Assume Δx is infinite

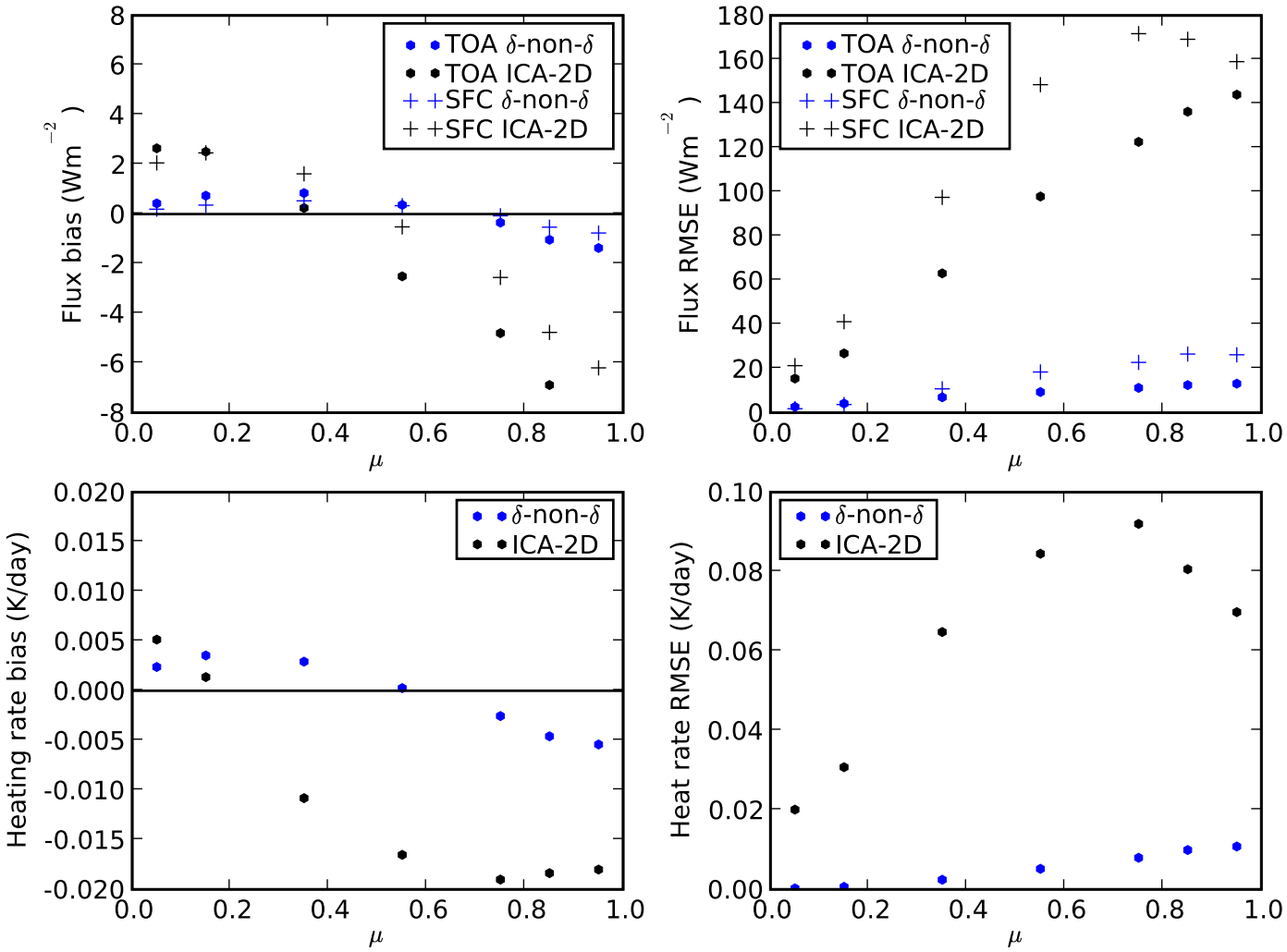
δ-scaling of cloud optical properties

- Reduces computational time by about 30%
- Relatively small biases (diagnostically and interactive)
- Used for all experiments except initial 2D Monte Carlo

Diagnostic radiative transfer

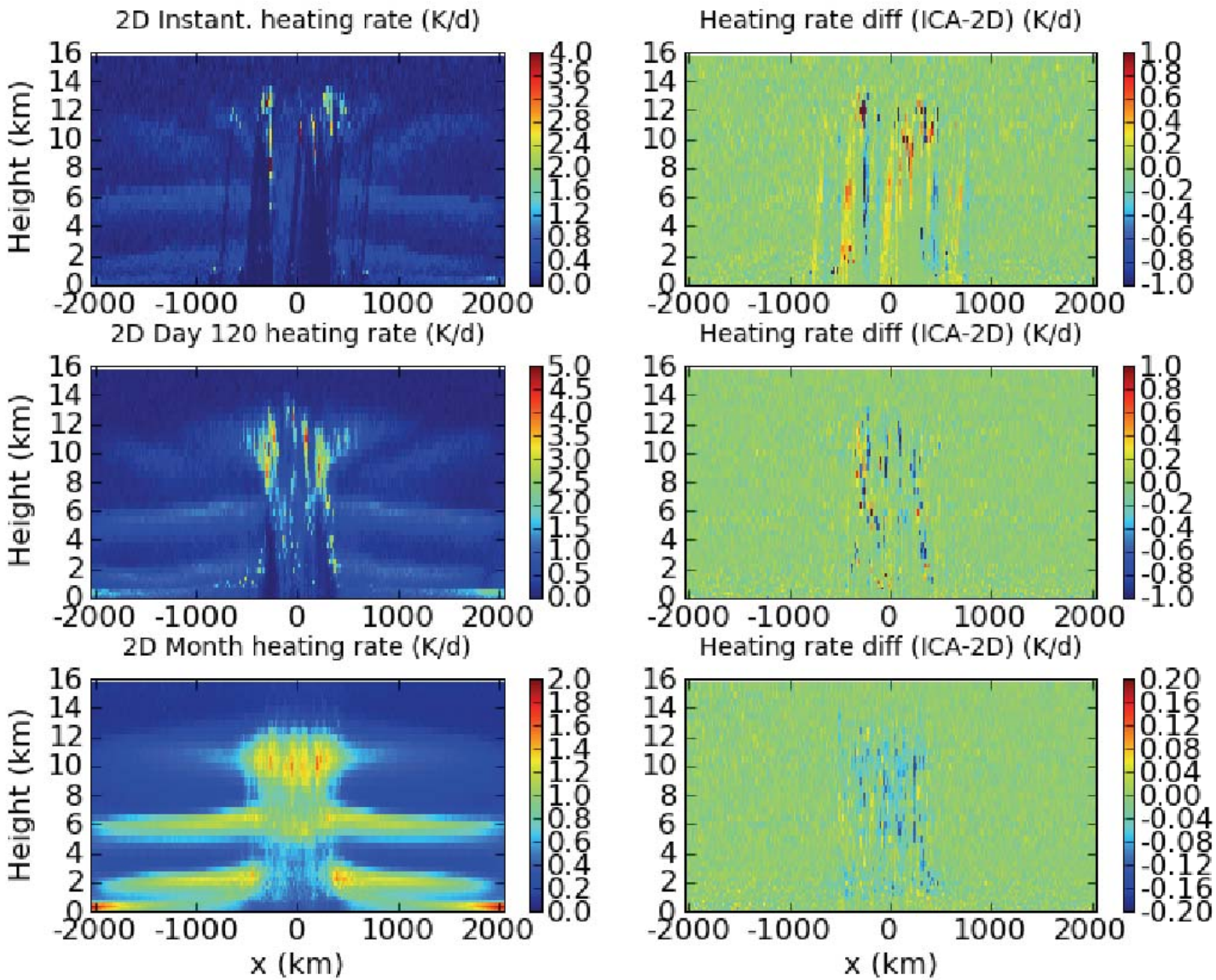
- Use hourly data from last 30 days of simulations
- Inject 50000 photons/column

Impact of δ-scaling



Diagnostic radiative transfer

Heating biases as a function of averaging time



Summary of results

Monte Carlo noise

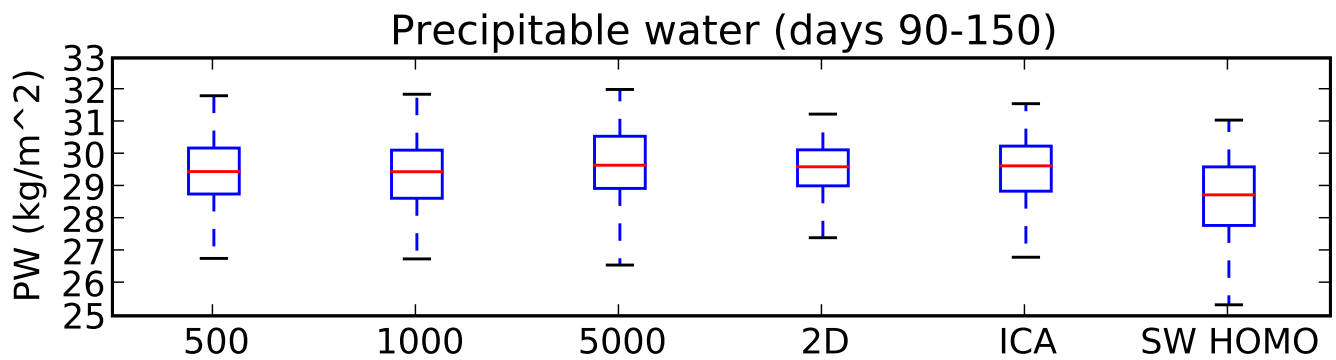
- Little impact when using reasonable number of photons
  - Consistent with results from GCMs (Barker) and LES (Pincus)

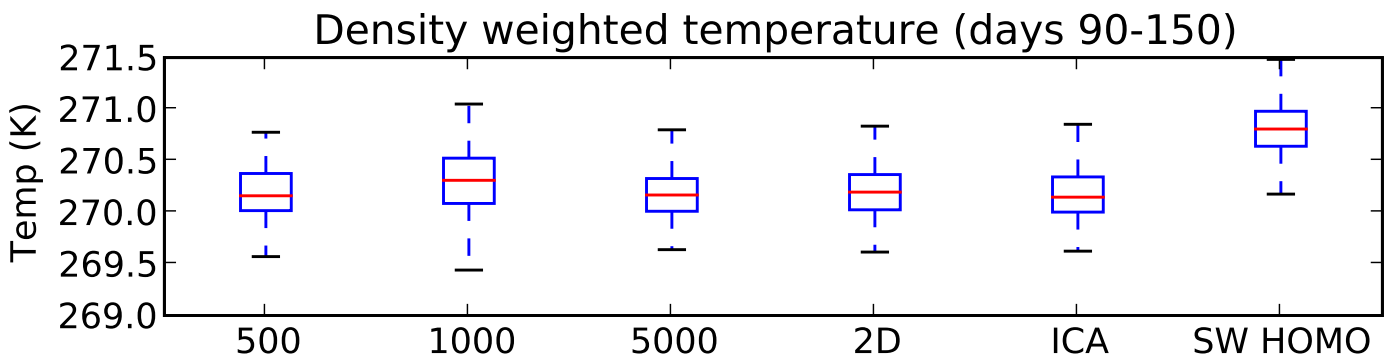
δ-scaling

- δ-scaling of optical properties has small impact

Horizontal averaging

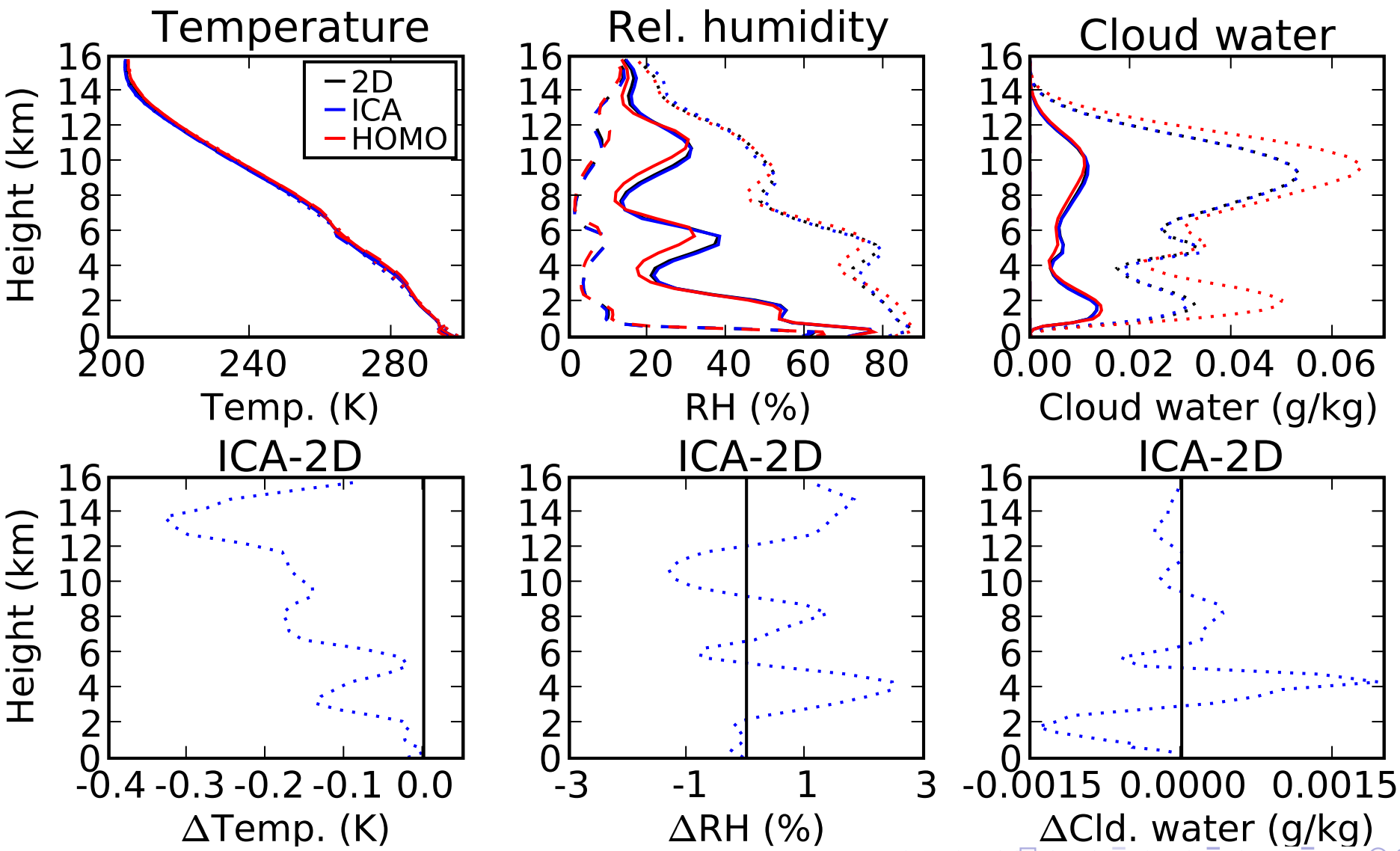
- Smaller effect than averaging total radiative heating





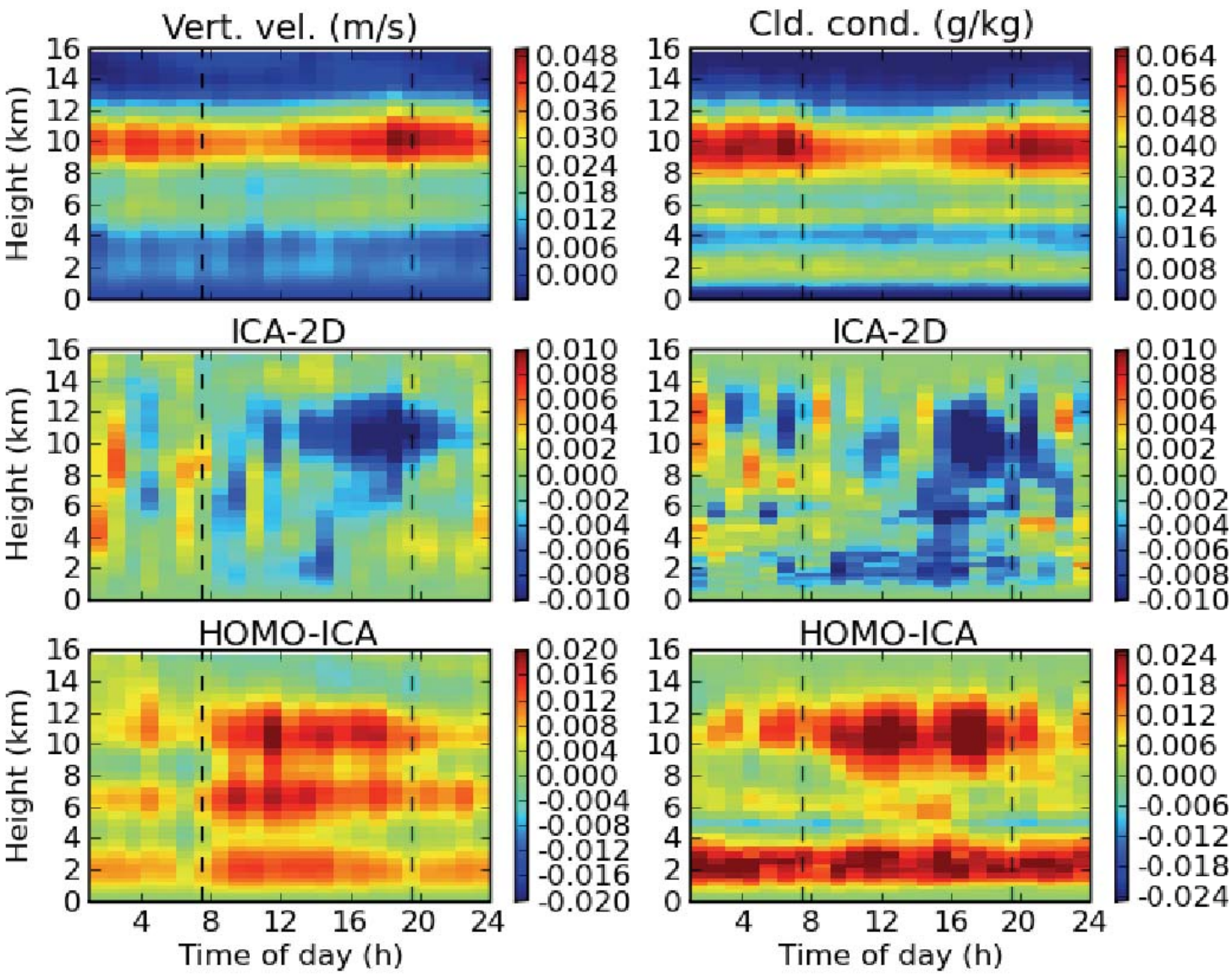
Mean profiles (day 90-150)

Convective (dotted)- Average between -250 and 250 km
Descent (dashed)- Average between 1798 and -1798 km



Mean diurnal cycle (day 90-150)

Diurnal cycle in convective region



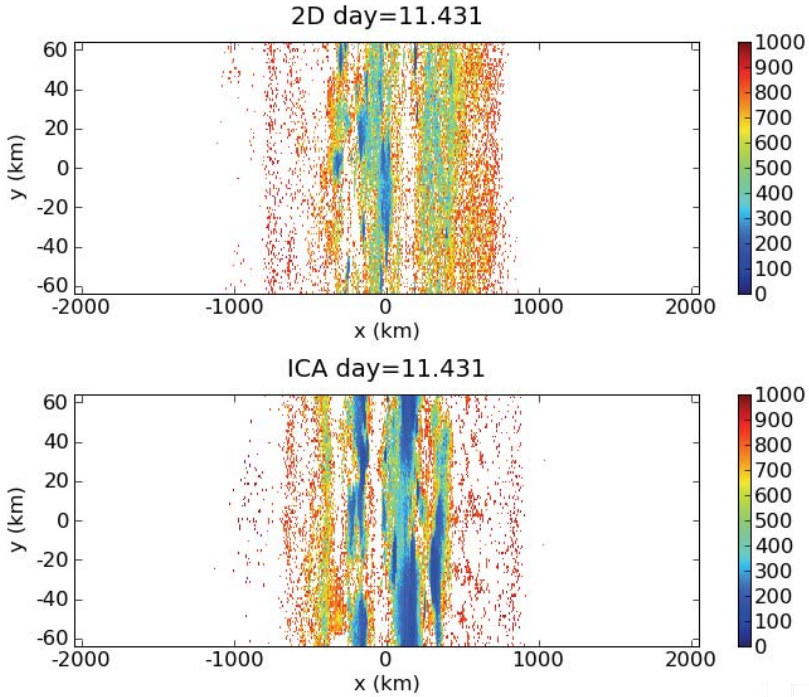
Future work

Did not consider 3D LW radiation

- Might be important for cirrus

Robustness of results

- What if more complex microphysics were used?

Issues with 2D simulations

- Ability of 2D CSRM to represent convection
- Shortwave 3D effect (over estimated)
- Started 3D CSRM simulations