The Behavior of Two Bulk Microphysics Schemes in Aerosol-Cloud Interaction Simulations

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Aerosol impact on meteorology: It's complicated….

Direct effect: Scattering of solar radiation –> cooling

Indirect effects: Impact on clouds and precipitation processes

- **1st indirect effect** – Increased aerosol -> more, smaller droplets = increased cloud albedo. (Twomey 1974)
- **2nd indirect effect** –More, smaller droplets -> delayed/reduced precipitation if more aerosols (Albrecht 1989)

Semi-direct effect – absorption of solar radiation -> heating -> decrease in cloud amount

- **How important are aerosol-microphysical interactions (indirect effects) to a short-range weather forecast?**
- **How accurate must the aerosol content be?**

Experiment Design

We investigate the impact of varying the aerosol content on two microphysics parameterizations in the WRF model. The microphysics schemes used are the **Thompson** and **Morrison** parameterizations, both of which are available in the UFS via CCPP.

The Thompson-Eidhammer aerosol scheme was implemented in the Morrison parameterization, to allow a fair comparison.

Look at microphysical effects of aerosols only.

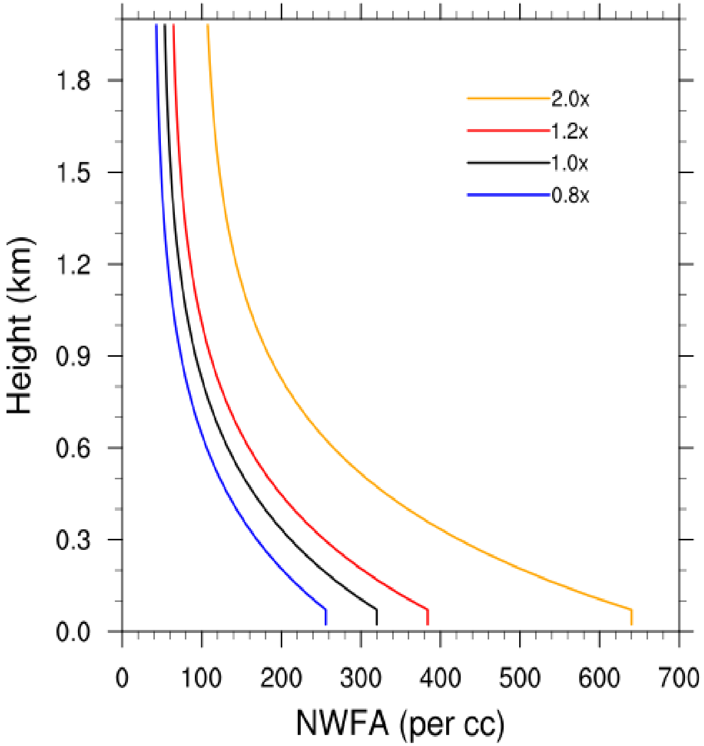
Idealized simulations:

- **2d squall line**: $\Delta x = 1$ km, dt = 3 s, 80 levels, model top at 20 km. Both warm and cold rain processes are present after just 5 minutes. No physics other than microphysics.
- **3d shallow convection case** (warm rain only). $\Delta x = \Delta y = 100$ m, $\Delta z = 50$m, dt = 1 s, 40 levels, model top at 2 km. Includes surface forcing, microphysics; no other physics.

The Aerosol Scheme (Thompson and Eidhammer 2014, JAS)

The Thompson microphysics scheme in WRF includes an option for aerosol interaction with microphysical processes. This method includes:

- Prediction of number concentration for cloud water (Nc)
- Prediction of number concentration of two aerosol types: “water-friendly” and “ice-friendly”
- Default initial profiles of aerosols, dependent on height
- Sources and sinks of the aerosols include activation, wet scavenging and restoration of the available aerosols if evaporation takes place
- Pre-calculated lookup tables of activated fraction of aerosols, based on temperature, vertical velocity, aerosol availability, a specified hygroscopicity parameter, and aerosol radius

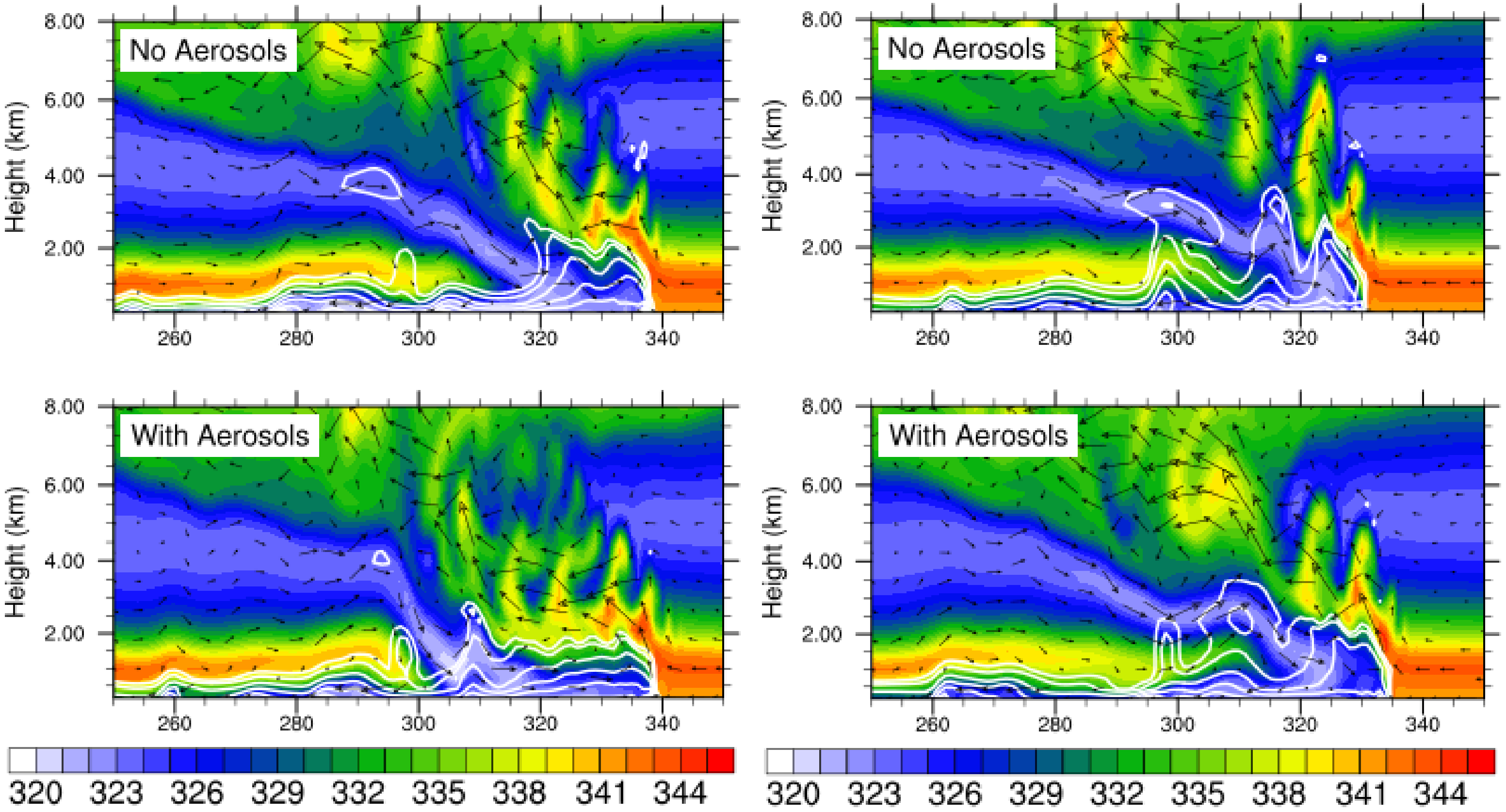


Idealized aerosol profiles

Impact of adding aerosols

Thompson

Morrison

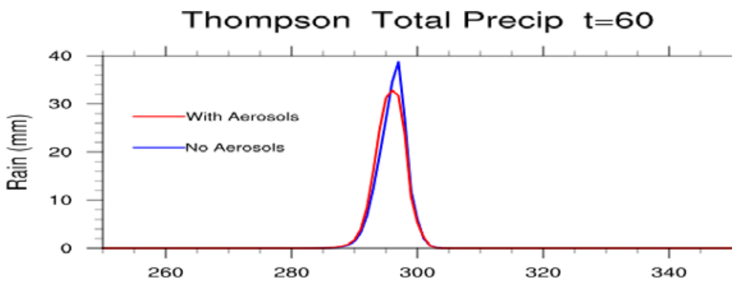


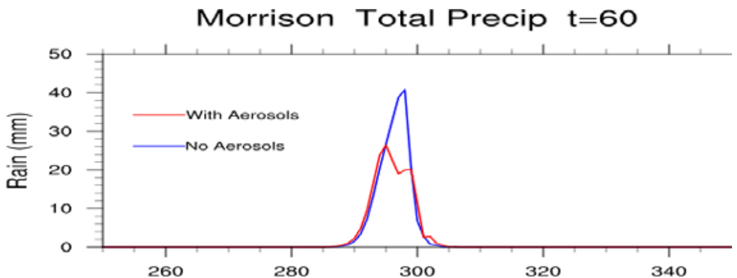
Theta-e (colors), theta’ (white), vectors at t=180 mins

Thompson – little change to front propagation speed, but broader, shallower cold pool

Morrison – Slightly faster propagation of the front

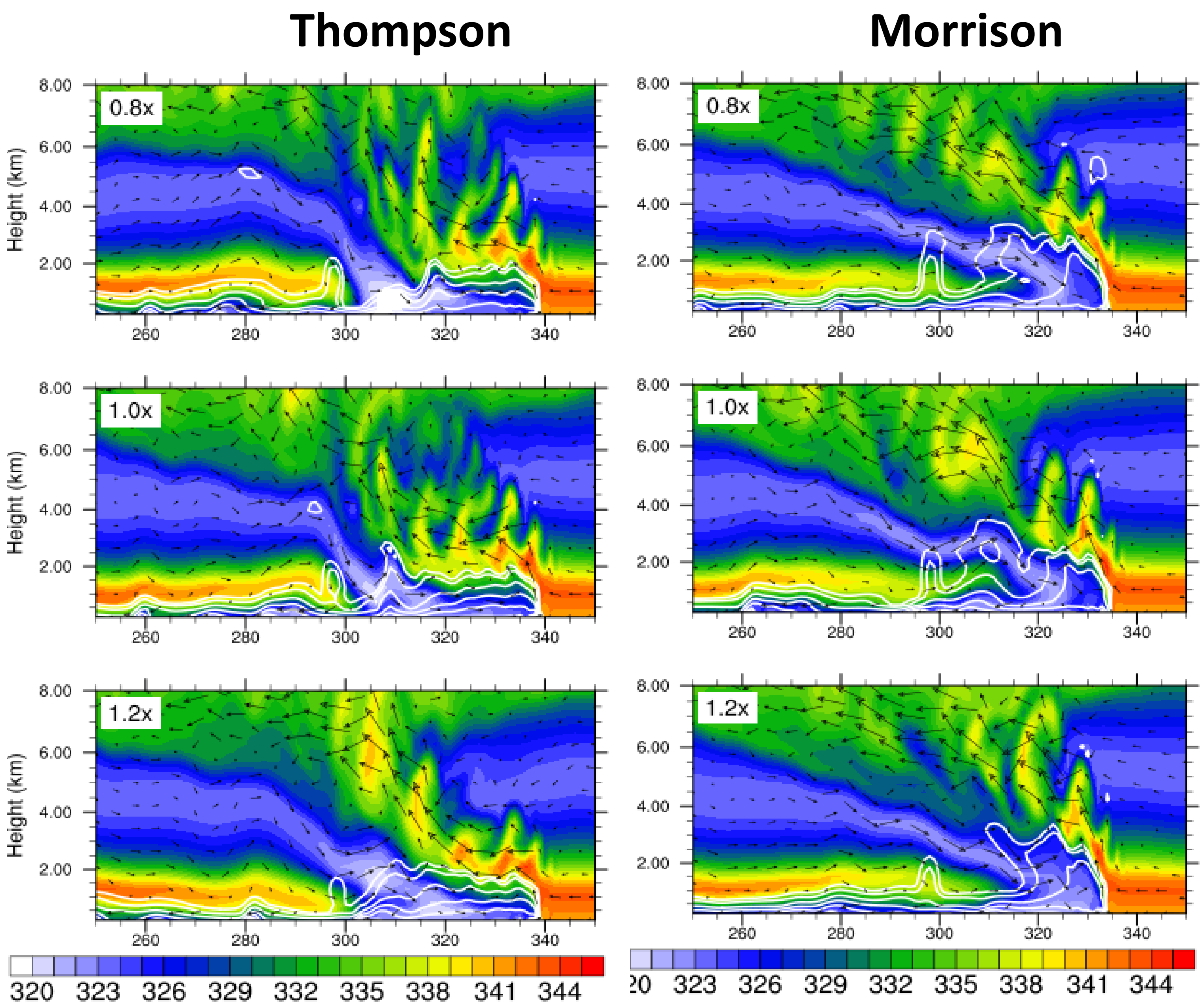
Precip reduced due to aerosols in 1st hour



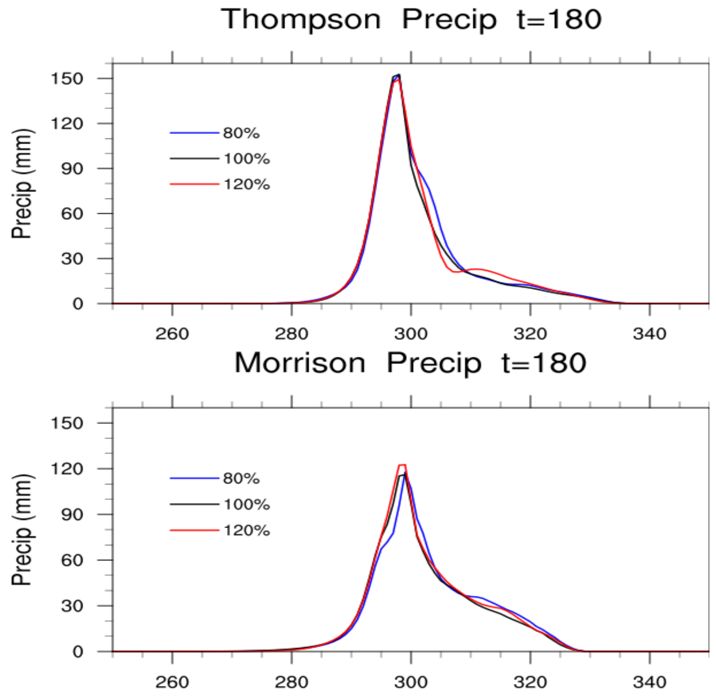


Impact of varying aerosol content by +/-20%

Little difference in propagation speed due to 20% change in aerosol content, but changes in cold pool

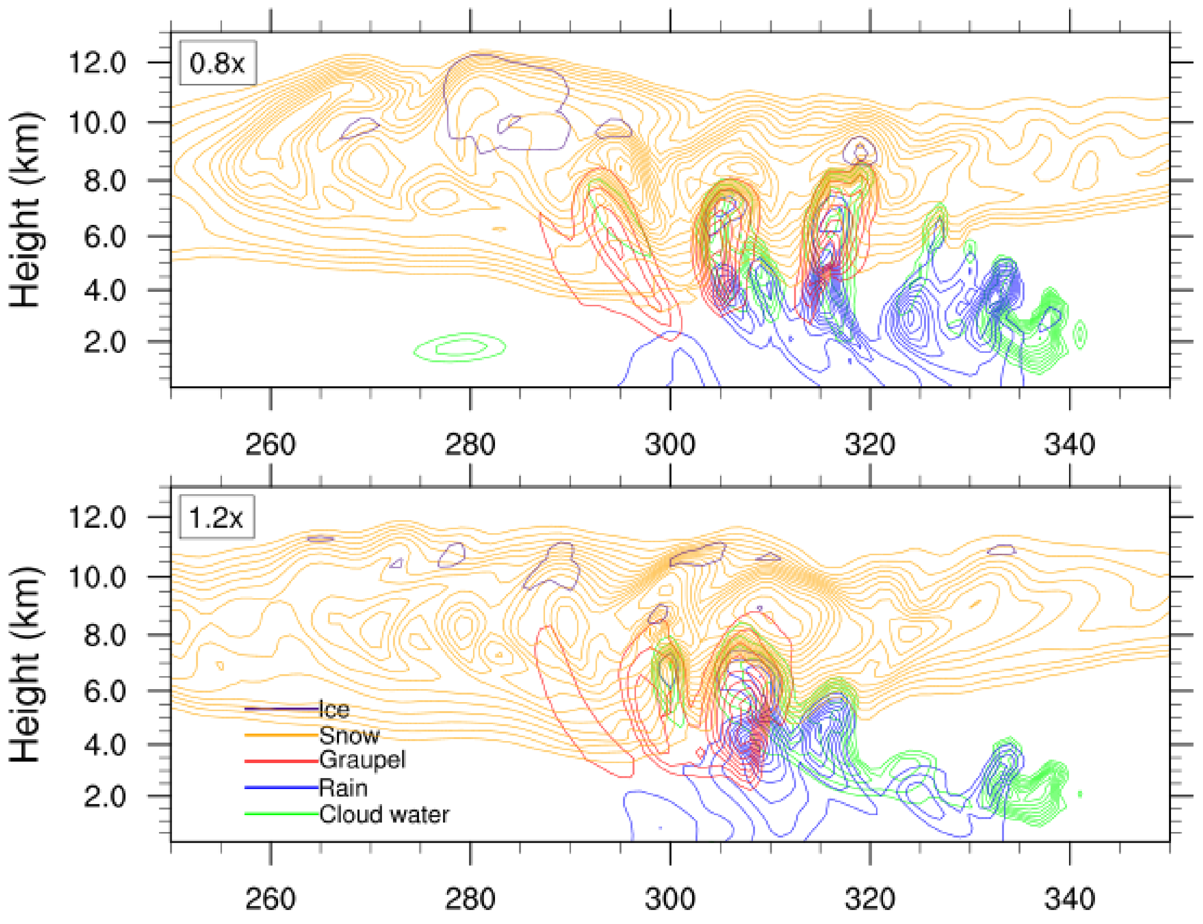


Theta-e (colors), theta' (white), vectors at t=180 mins

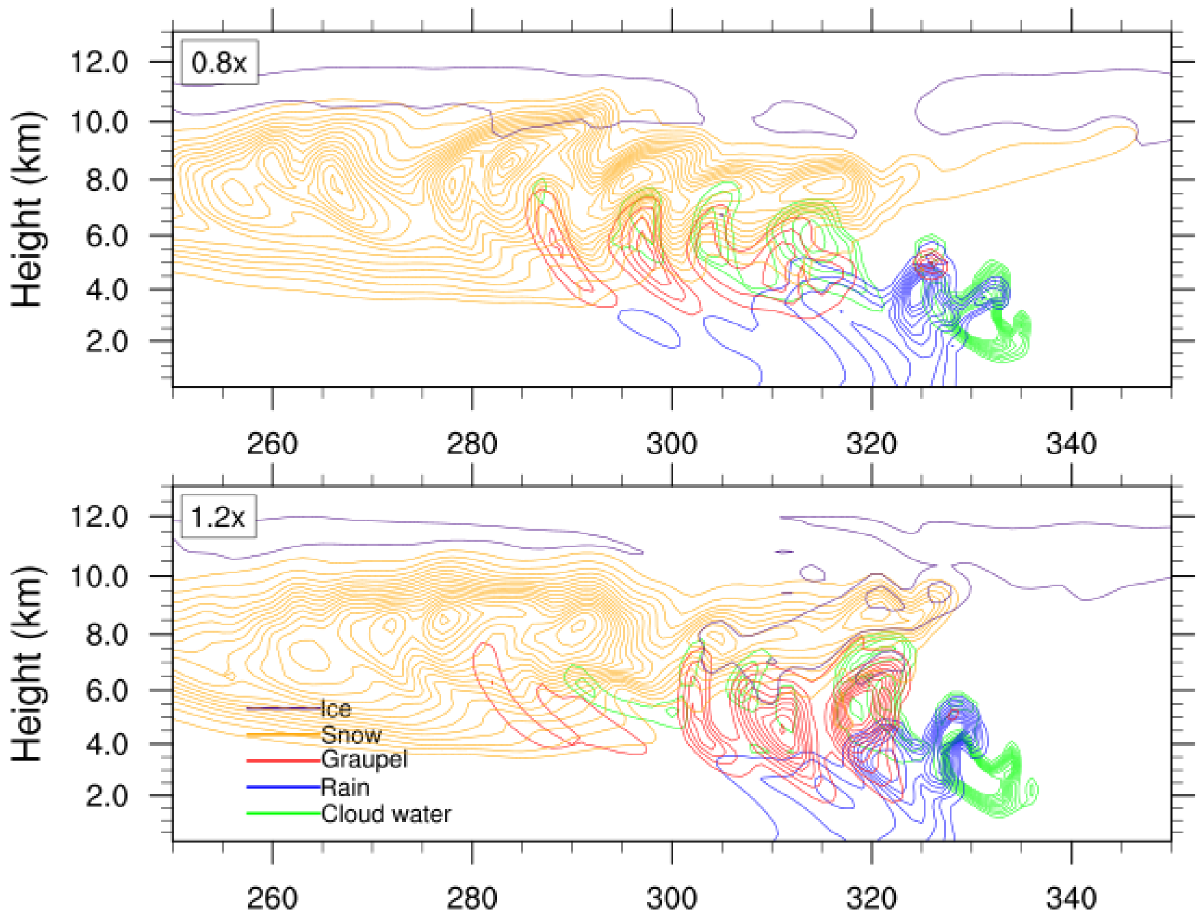


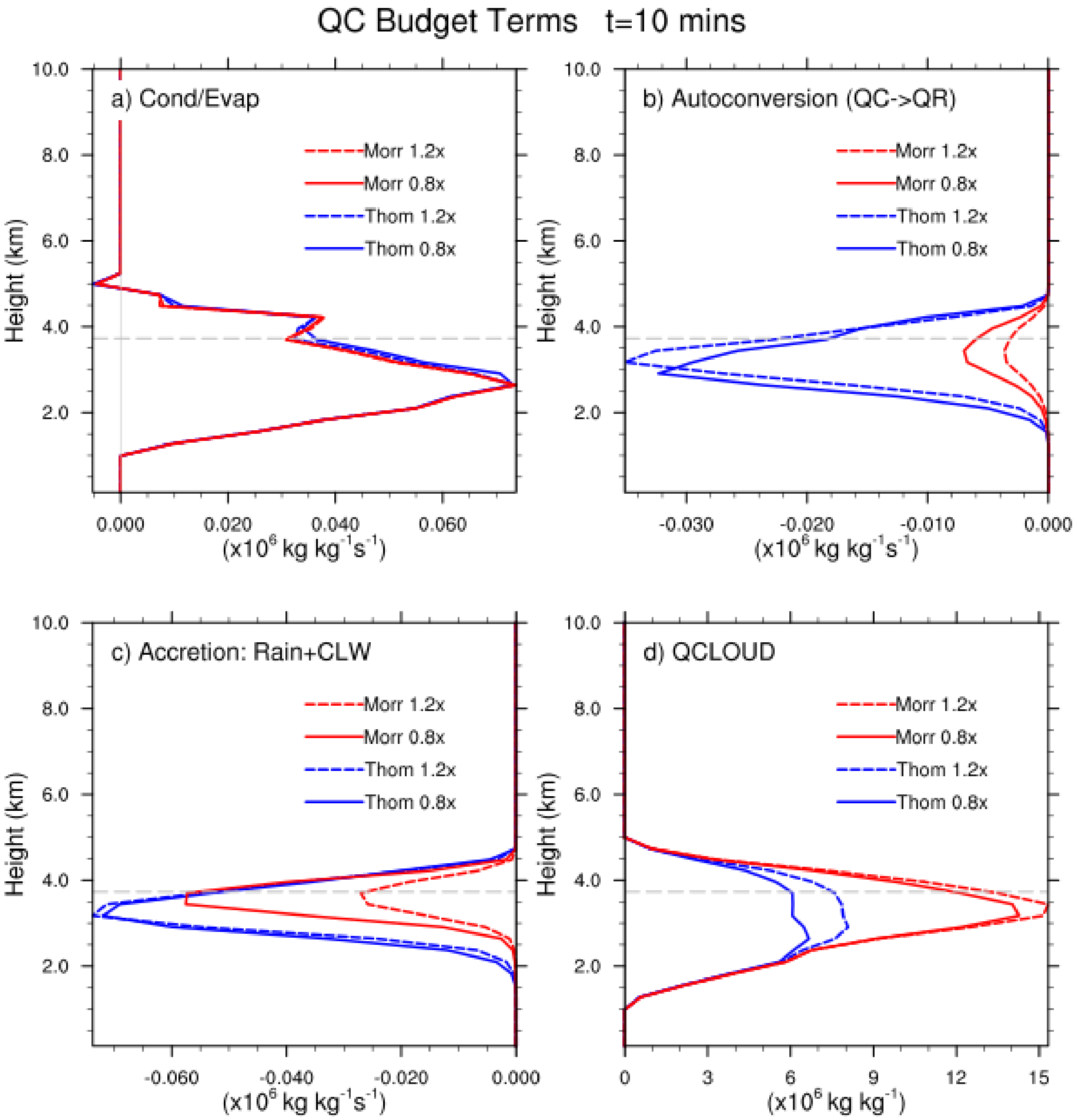
Comparison of Mixing Ratios for each Hydrometeor Species at 180 mins.

Thompson

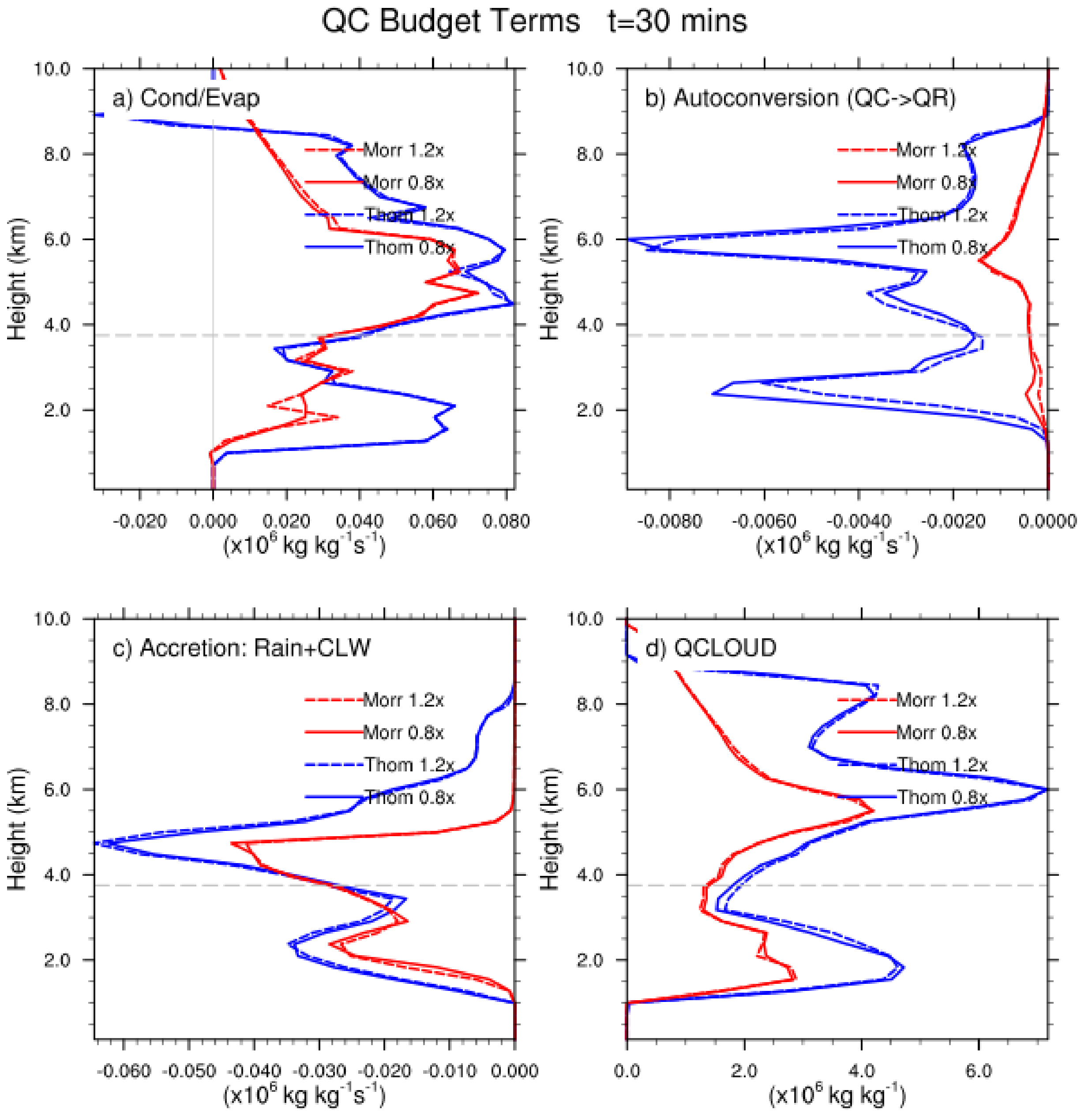


Morrison



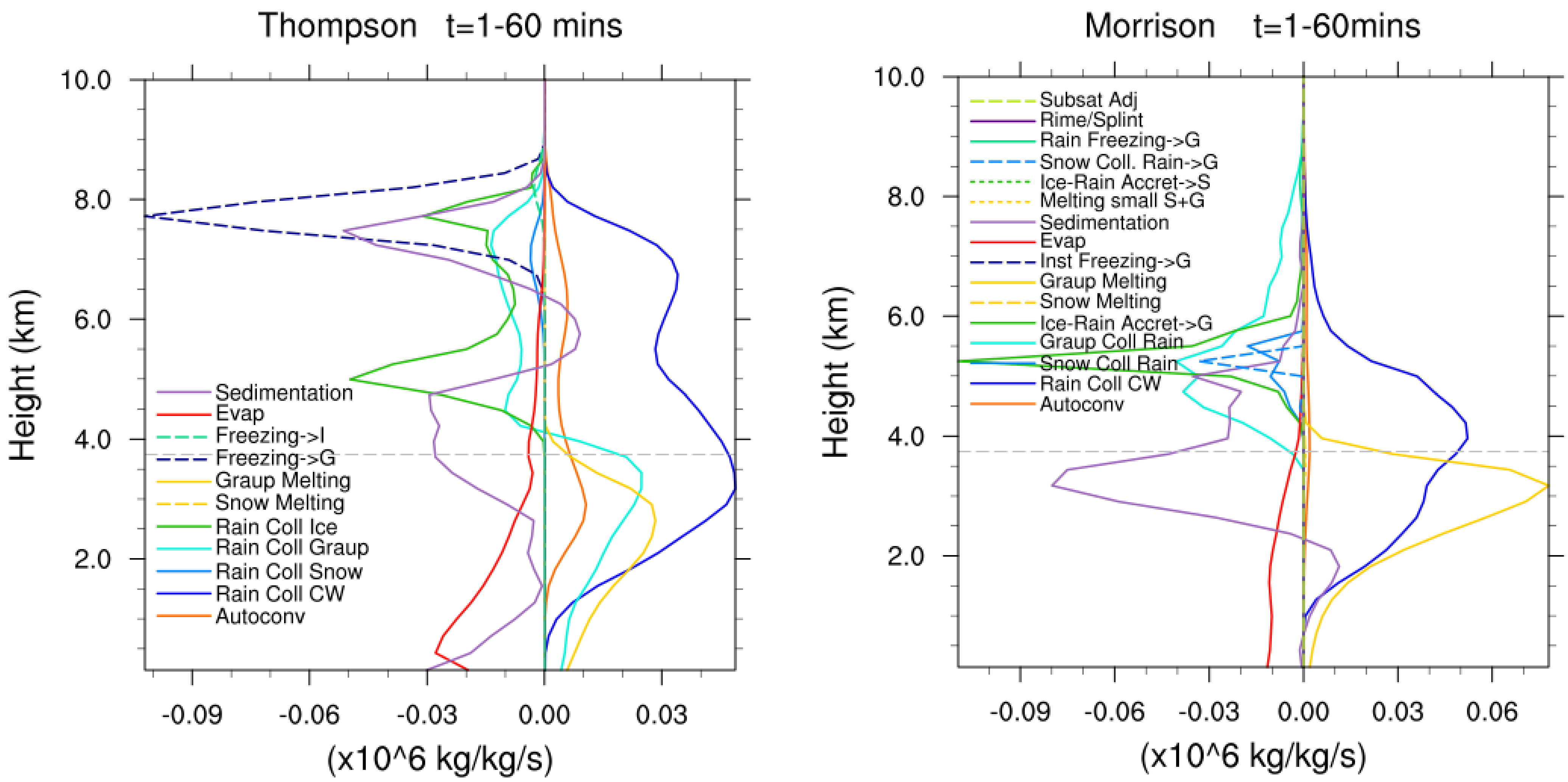


Thompson scheme converts cloud water to rain more quickly than the Morrison scheme initially.



There is more difference between the schemes than between the runs with varying aerosol load.

Rain Budget Terms

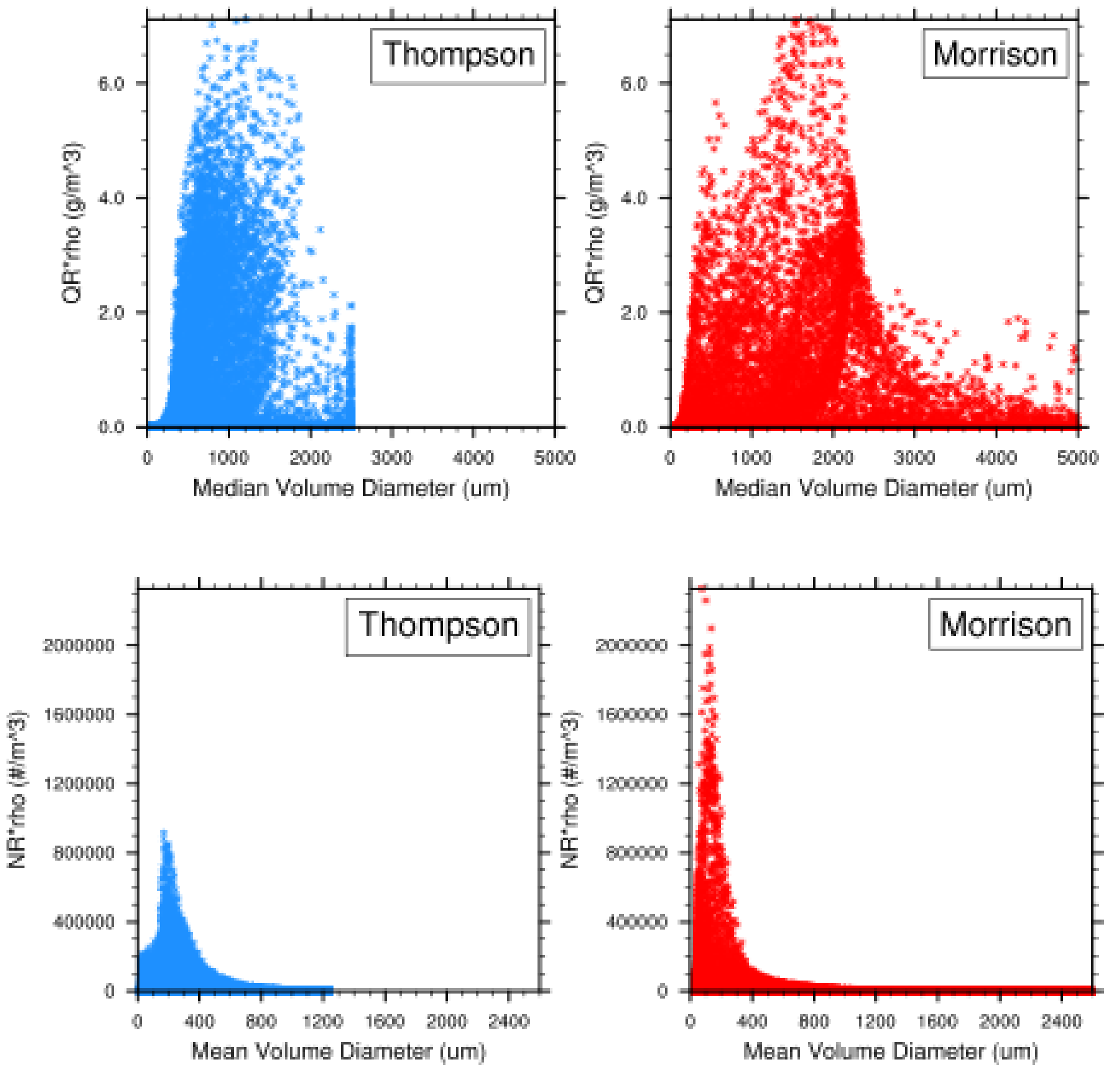


Microphysical budget analysis for rain production in the two schemes during the first hour of the squall line simulations (time averaged). More evaporation of rain in the Thompson scheme enhances the low-level cooling and therefore the squall line propagation.

Rain Drop Size Distributions

Rain Content vs Median Volume Diameter

Rain Number Conc. vs Mean Volume Diameter



Differences in rain drop size distributions between the schemes.

Results are for the control (1*aer) runs and include all grid points with rain water during the first hour of the simulation.

Changing the aerosol load leads to small changes in the drop size distribution, larger changes in the liquid water content (not shown).

Summary and Conclusions

Differences between the Thompson and Morrison microphysics schemes are greater than the differences due to varying the aerosol load by +/- 20%. However, aerosol variations of this magnitude are sufficient to lead to differences in microphysical properties and precipitation amount.

Differences between schemes are largely due to the different size-dependent process parameterizations and assumptions of hydrometeor size distributions.

The response of each scheme to change in aerosol load is case-dependent (shallow convection vs. 2D squall line).

In the case of shallow convection, with the Thompson scheme, more aerosols led to less total precipitation. With the Morrison scheme, the opposite occurred.