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WAVES TO WEATHER

Aerosol effects on hail storms – large sensitivities and large uncertainties

Andrew Barrett | 20 April 2017
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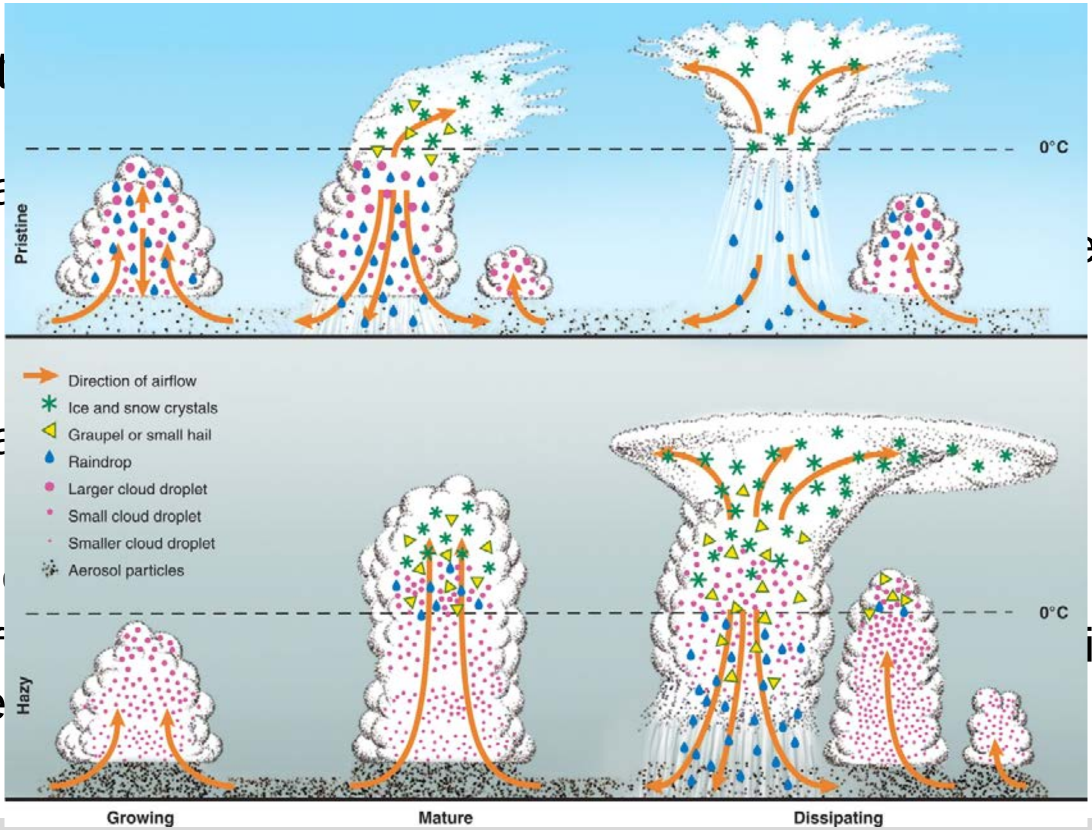
Institute of Meteorology and Climate research – Aerosols, Trace Gases and Climate Processes

Possible aerosol effects on hail

- Convective invigoration (Rosenfeld et al. 2008, Science)
  - More aerosol -> smaller cloud drops -> more likely to freeze -> extra heat released during freezing -> stronger convection
- Changes t
  - More a form rain -> more l er hail
- More, but
  - More a
    AND /
  - More i
  - More f il stone -> smalle



Uncertain aerosol effects on hail

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Simulations of a hailstorm and the impact of CCN using an advanced two-moment cloud microphysical scheme

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ABSTRACT

A hailstorm that caused significant damage in South-West Germany was simulated with the numerical weather prediction model COSMO. To cover hail evolution a sophisticated two-moment cloud microphysical scheme was extended by a particle class representing hail and implemented into COSMO. The horizontal resolution was 1 km. For initialization and boundary values COSMO forecasts with a coarser resolution and the standard one-moment microphysical scheme were used. Running this model system several convective cells develop including a severe hailstorm that resembles the observations qualitatively well and produces realistic amounts of precipitation and hail at the ground. Sensitivity studies were conducted varying the concentration of cloud condensation nuclei (CCN) and the shape of the cloud droplet size distribution (CDSD). Results show that both have a significant impact on hail accumulated at the ground and on the size of the hailstones. For two of the three CDSDs assumed the intensity of the severe storm decreases with increasing CCN concentration. However, this is not true for some of the weaker storms that form as well as for the third CDSD. Two model runs are analyzed and compared in more detail revealing the strong coupling between the numerous microphysical processes and between microphysics and dynamics. The sensitivity studies illustrate that the complexity of such storms makes it difficult to foresee, what will happen, when one microphysical parameter is changed. Thus, general conclusions whether an increase or decrease in CCN concentration invigorates a hailstorm

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The role of CCN in precipitation and hail in a mid-latitude storm as seen in simulations using a spectral (bin) microphysics model in a 2D dynamic frame

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ABSTRACT

A hail storm at Villingen-Schwenningen, southwest Germany, on 28.06.2006 was simulated using the Hebrew University Cloud Model (HUCM) with spectral (bin) microphysics. The model allows the simulation of hail stones with diameters up to 6.8 cm. To investigate whether the amount of hail is sensitive to atmospheric instabilities, the simulations were performed for two different temperature gradients within the boundary layer. The response of precipitation, the hail mass and hail size distribution to aerosol was investigated in the simulations with cloud condensation nuclei (CCN) concentrations ranging between 100 cm^{-3} and 6000 cm^{-3} (at the supersaturation of 1%). An increase in the surface temperature by one degree leads to an increase in accumulated rain by ~80% and nearly doubles the mass of hail falling to the surface. An increase in CCN concentration from 100 cm^{-3} to 3000 cm^{-3} leads to a certain increase in accumulated rain and to a dramatic increase in the hail mass, as well as to the increase in the hail diameter from a few mm to 1–4 cm. The mechanisms by means of which aerosols affect precipitation and hail stones size are discussed. It is shown that formation of hail increases the precipitation efficiency of deep convective clouds.

"…the intensity of the severe storm **decreases** with increasing CCN concentration."

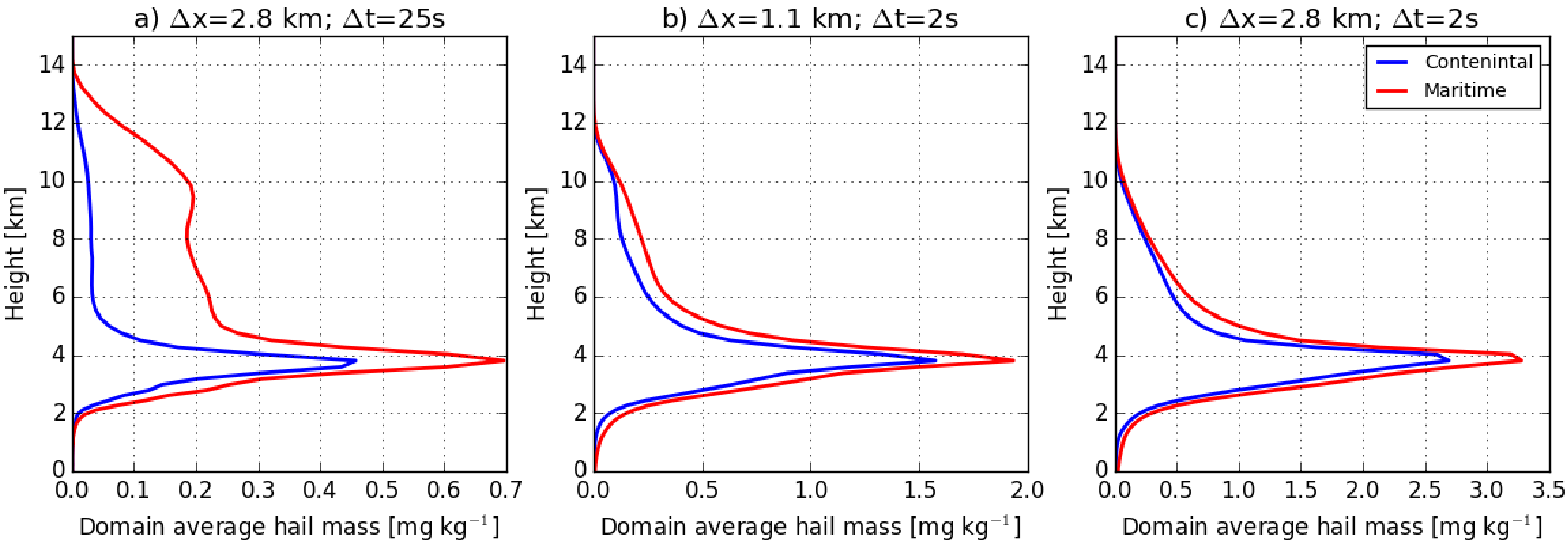
"An increase in CCN … leads to a certain **increase** in accumulated rain and to a dramatic **increase** in the hail mass, as well as to the **increase** in the hail diameter from a few mm to 1-4 cm."

COSMO model setup

- COSMO 5.3
- 1-km resolution; 64 vertical levels
- Idealised simulation
  - Weisman-Klemp thermodynamic profile
  - 2K warm bubble
- 2-hour simulation
- Seifert & Beheng 2-moment microphysics
  - Predicting size and number of hydrometeors
- Two different aerosol settings:
  - 100 CCN cm^{-3} = clean
  - 1700 CCN cm^{-3} = continental

- Future plan to use COSMO-ART, to determine effects of fully interactive aerosol

Aerosol effects on hail in COSMO

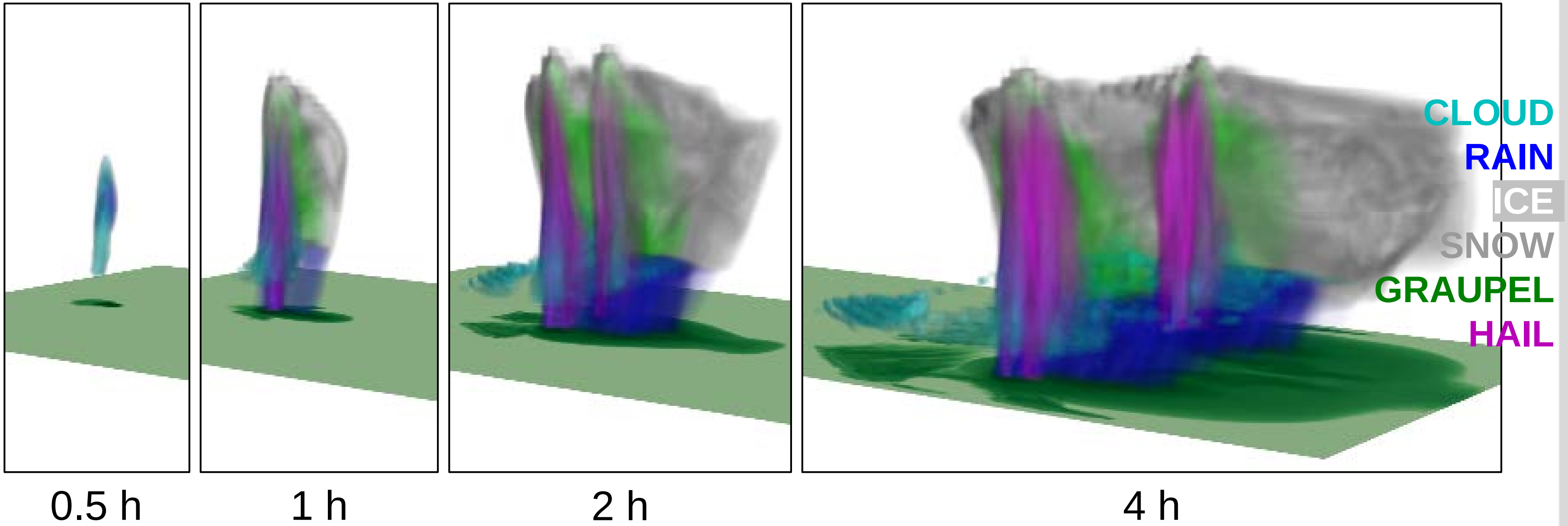


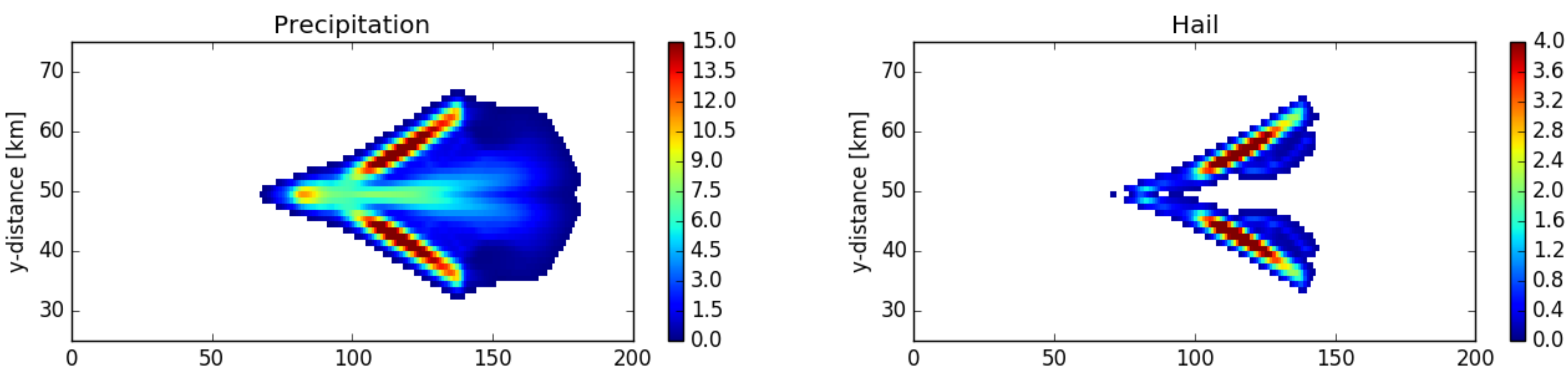
Total mass: low
Sensitivity to aerosol: high

Total mass: medium
Sensitivity to aerosol: low

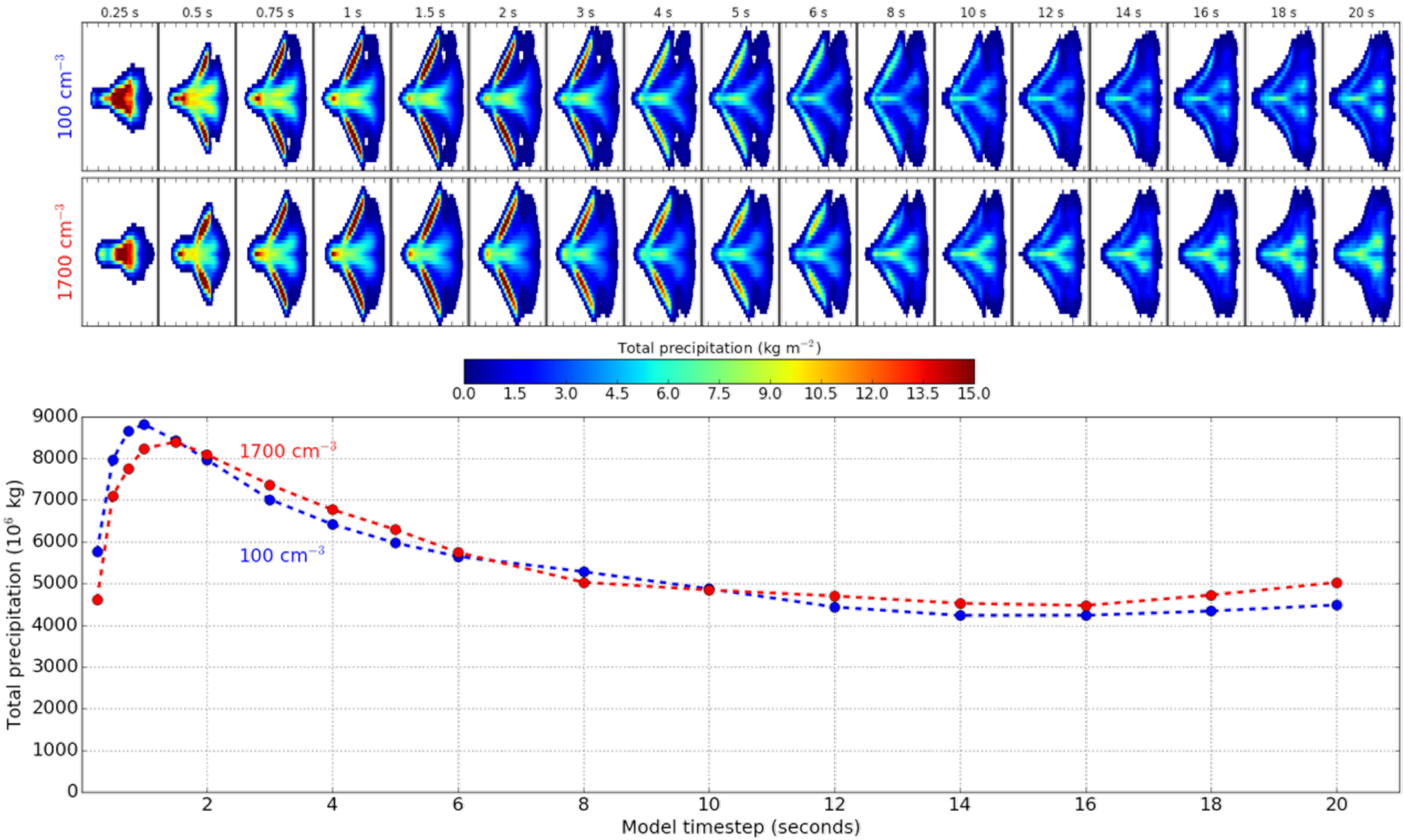
Total mass: high
Sensitivity to aerosol: low

Simulation overview

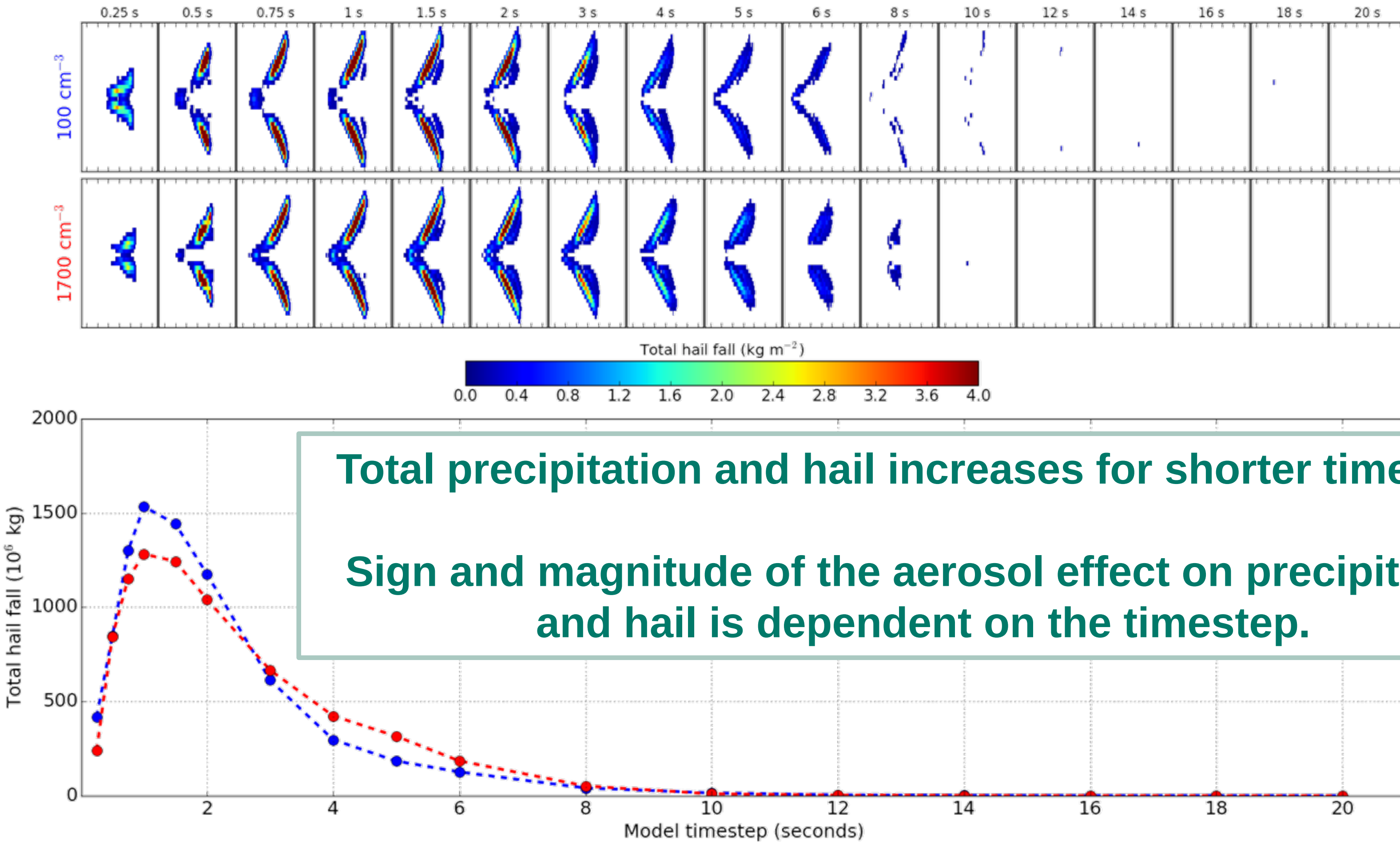




Total precipitation: aerosol and timestep effects



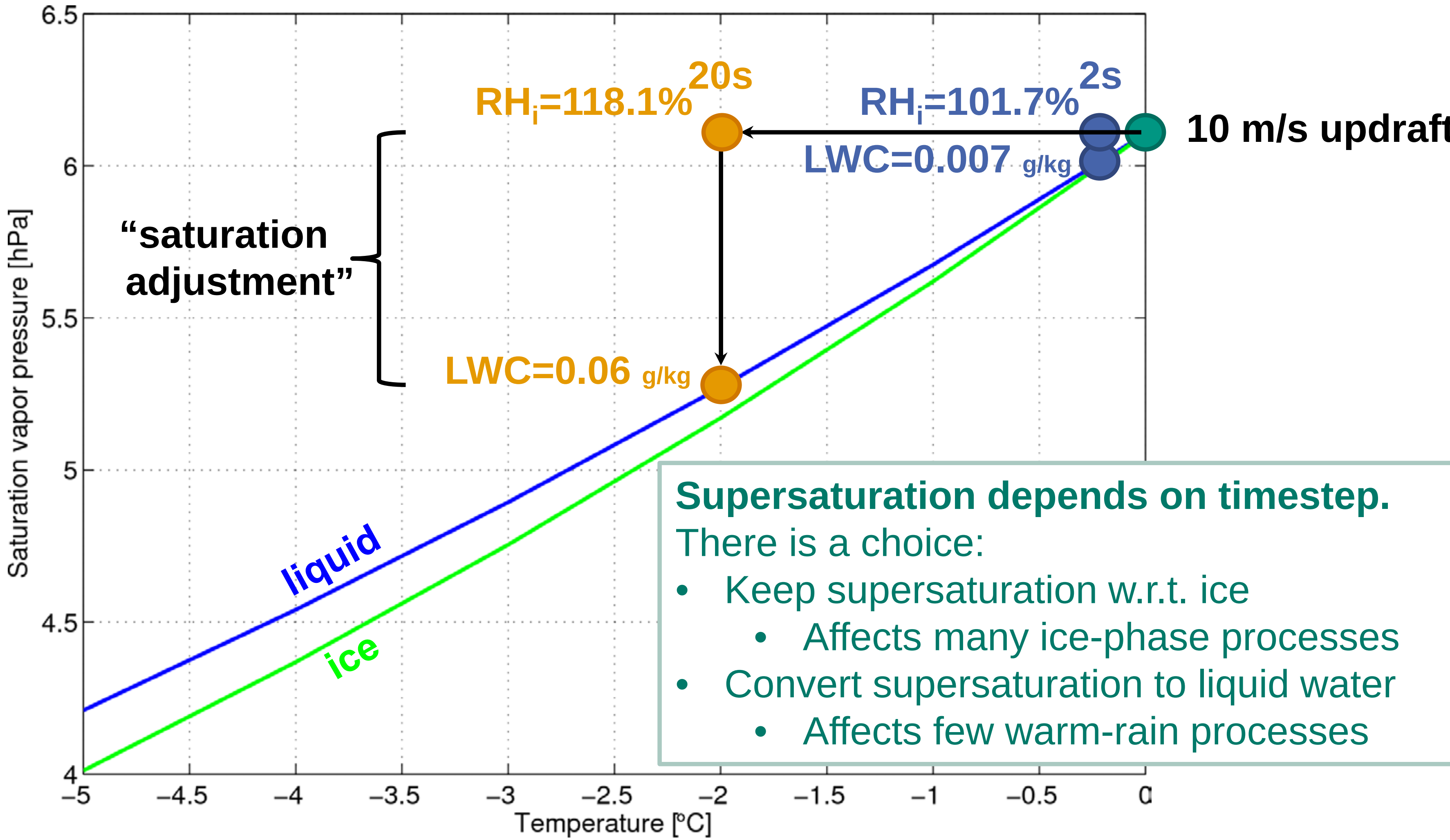
Total hail fall: aerosol and timestep effects



Total precipitation and hail increases for shorter timestep.

Sign and magnitude of the aerosol effect on precipitation and hail is dependent on the timestep.

Timestep sensitivity explained

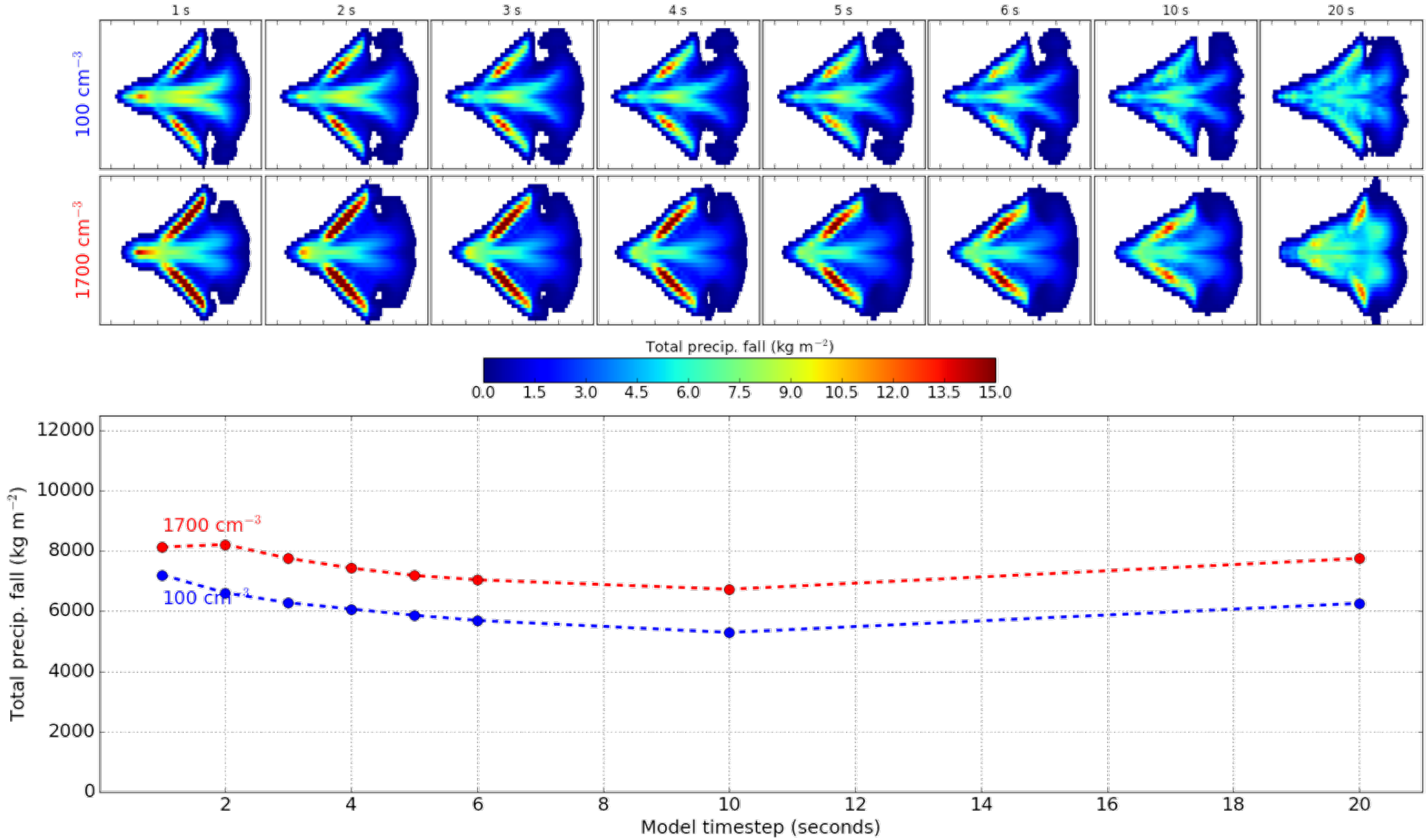


Supersaturation depends on timestep.

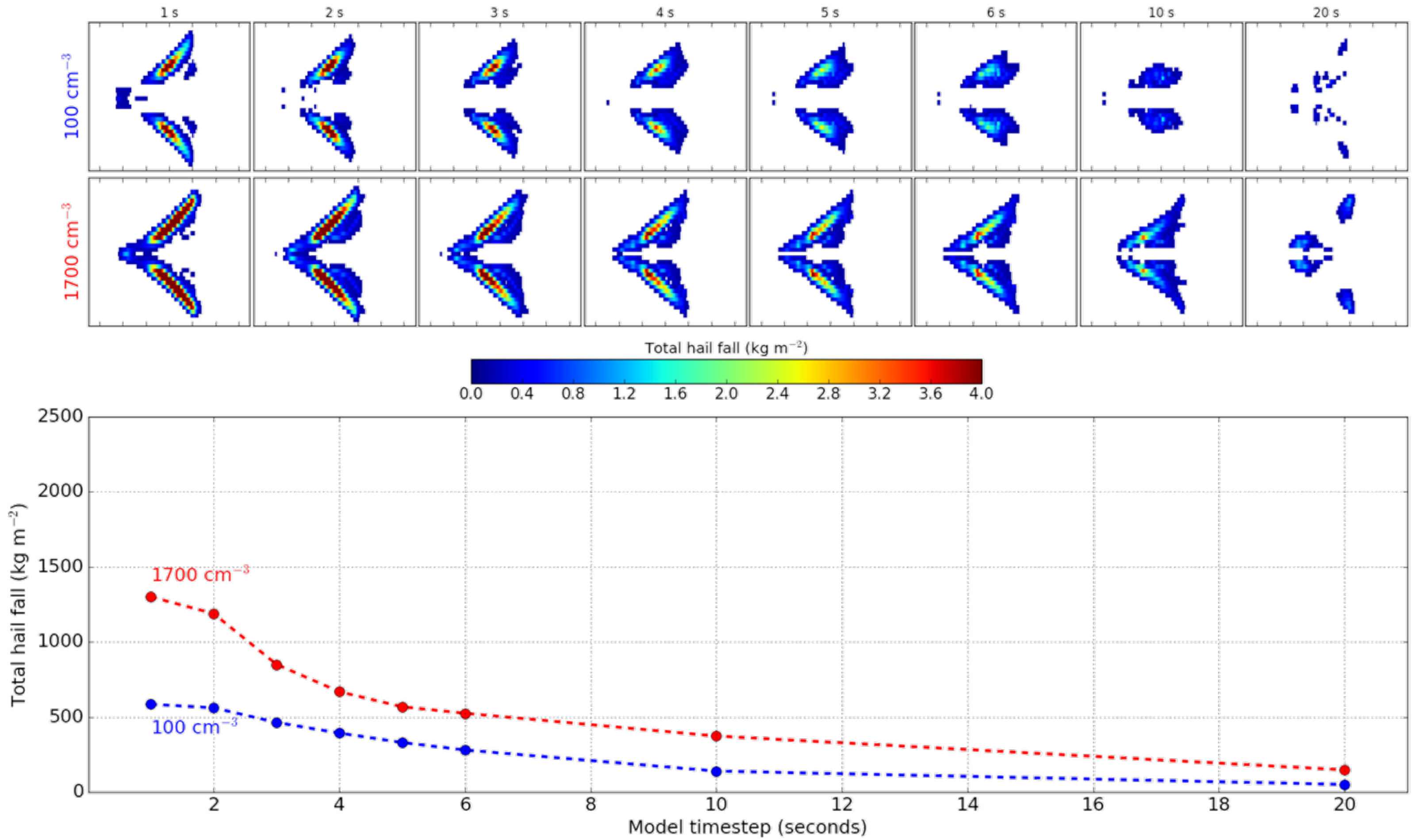
There is a choice:

- Keep supersaturation w.r.t. ice
  - Affects many ice-phase processes
- Convert supersaturation to liquid water
  - Affects few warm-rain processes

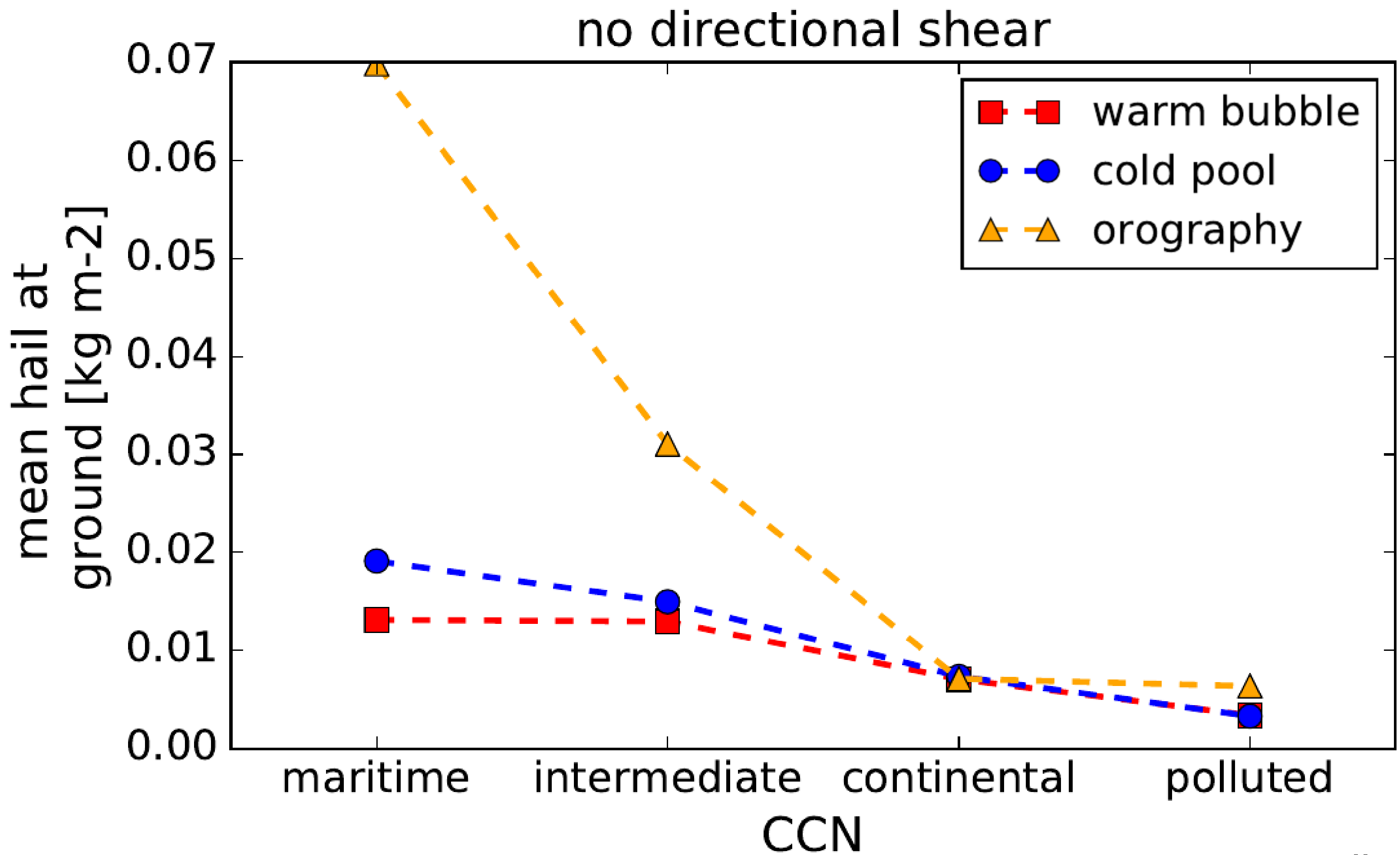
Total precipitation: aerosol and timestep effects (with saturation adjustment first)



Total hail fall: aerosol and timestep effects (with saturation adjustment first)



Aerosol effects after 10 hours



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Summary

- Aerosol effects are potentially large BUT they depend on microphysics implementation (and timestep) (and simulation length)
  - T=2hrs: 2x more hail in polluted (more CCN) simulations
  - T=10hrs: 2x more hail in clean (fewer CCN) simulations

- Difference in microphysics implementation between models/schemes could explain current uncertainty of aerosol-convection interaction

- Timestep sensitivity arises because of a choice regarding supersaturation:
  - Leave as ice supersaturation (long dt = large Si ; affects many processes)
  - Convert to cloud water (long dt = large qc ; affects autoconversion qc→qr)

- Results here from COSMO model / Seifert&Beheng 2-moment scheme
  - Similar effects in other models and microphysics schemes?