Aerosol effects on hail storms –
large sensitivities and large uncertainties

Andrew Barrett | 20 April 2017
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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 to liquid water content
  - More aerosol -> smaller cloud drops -> longer required to form rain -> more liquid in cloud -> hail can collect more water -> larger hail

- More, but smaller, hailstones
  - More aerosol -> more cloud drops -> more frozen drops
  - AND/OR
  - More ice nuclei
    - More frozen drops = more hail nuclei
  - More frozen hailstone -> less water per hailstone -> smaller hail

Andrew Barrett (andrew.barrett@kit.edu) – Impact of microphysics and aerosol on hailstorms simulated by COSMO-ART
Uncertain aerosol effects on hail

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

a) $\Delta x=2.8\;\text{km};\;\Delta t=25\text{s}$

- Total mass: low
- Sensitivity to aerosol: high

b) $\Delta x=1.1\;\text{km};\;\Delta t=2\text{s}$

- Total mass: medium
- Sensitivity to aerosol: low

c) $\Delta x=2.8\;\text{km};\;\Delta t=2\text{s}$

- Total mass: high
- Sensitivity to aerosol: low
Simulation overview

0.5 h  1 h  2 h  4 h

Precipitation

Hail

0.5 h  1 h  2 h  4 h

Cloud  Rain  Ice  Snow  Graupel  Hail
Total precipitation: aerosol and timestep effects

Andrew Barrett (andrew.barrett@kit.edu) – Aerosol effects on hail storms – large sensitivities and large uncertainties
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.
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)

Andrew Barrett (andrew.barrett@kit.edu) – Aerosol effects on hail storms – large sensitivities and large uncertainties
Total hail fall: aerosol and timestep effects (with saturation adjustment first)

Andrew Barrett (andrew.barrett@kit.edu) – Aerosol effects on hail storms – large sensitivities and large uncertainties
Aerosol effects after 10 hours

constanze wellmann
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 \( qc \rightarrow qr \))

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