The Effect of Long-range Transportation of Aerosols on Cloud and Precipitation

Yan Yin, Qian Chen, Lian-ji Jin, Yan-min Rong, Hui Xiao, Shi-chao Zhu
CMA Key Laboratory for Atmospheric Physics and Environment
Nanjing University of Information Science and Technology
Outline

- Introduction
- Description of Model and Numerical Experiments
- Results
- Conclusions
Seasonal variations of east Asia outflow and North America inflow of pollution aerosol. [Yu, H., et al., 2008]

Aerosol characteristics changed with long range transportation. [Brock, C. A., et al. 2004]


Motivation and Goal

- How would the long range transported aerosols influence cloud and precipitation?
- What are the dominant microphysical mechanisms that control the cloud development and precipitation in response to the aerosols from distant area?
Description of Model and Numerical Experiments

- The model dynamics and bin-resolved microphysics are based on the axisymmetric nonhydrostatic cloud model of Reisin et al. [1996], which is an updated version of the one put forth by Tzivion et al. [1994], and improved by Yin et al. [2005].

- The model domain is 12 km in the vertical and 6 km in the radial. The grid size is 100 m, both in the vertical and radial directions. A time step of 1.5 s is used for condensation/evaporation of drops or deposition/sublimation of ice particles, and 3 s for all other processes.
Initial vertical profiles of temperature (solid line) and dew point temperature (dashed line) .

Initial aerosol number concentration [Roberts, G., et al. 2006]
The effect of distant aerosol to continental air mass

- **Sensitive test:**
  - **C-case:** Background continental aerosol
  - **CL-case:** Background continental aerosol, with long-range transported particles at 2-5 km asl
Updraft and liquid drop properties

Graphs showing:
- Maximum updraft (m/s) over time (min) for C-case and CL-case.
- Maximum number concentration of drops (# cm$^{-3}$) over time (min) for C-case and CL-case.
- Maximum mass concentration of drops (g kg$^{-1}$) over time (min) for C-case and CL-case.
- Rainfall rate (liquid) (mm/h) over time (min).
Spatial and spectral distributions of specific mass and number concentration of drop after 35 min of simulation

**MASS (Drops)**
Unit: g kg$^{-1}$ µm$^{-1}$ Time: 35min

**NUMBER (Drops)**
Unit: cm$^3$ µm$^{-1}$ Time: 35min
Characteristics of ice crystal and graupel

- Maximum Mass Concentration of Graupel (g/kg)
  - C-case
  - CL-case

- Maximum Number Concentration of Graupel (#/litre⁻¹)
  - C-case
  - CL-case

- Maximum Mass Concentration of Ice (g/kg)
  - C-case
  - CL-case

Graphs show the variation over time (in minutes) of the concentration of ice crystals and graupel under different cases.
The maximum rate for ice and graupel formation via various microphysical processes at selected times

**For number concentration of ice crystal**

<table>
<thead>
<tr>
<th></th>
<th>C-case</th>
<th>CL-case</th>
</tr>
</thead>
<tbody>
<tr>
<td>drop frozen</td>
<td>180.5</td>
<td>278.8</td>
</tr>
<tr>
<td>deposition</td>
<td>161.9</td>
<td>141.7</td>
</tr>
<tr>
<td>ice multiplication</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Bergeron process</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>collision-coalescence</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**For number concentration of graupel**

<table>
<thead>
<tr>
<th></th>
<th>C-case</th>
<th>CL-case</th>
</tr>
</thead>
<tbody>
<tr>
<td>drop frozen</td>
<td>37.7</td>
<td>11.87</td>
</tr>
<tr>
<td>Bergeron process</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>collision-coalescence</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**For mass concentration of ice crystal**

<table>
<thead>
<tr>
<th></th>
<th>40min</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ice crystal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-case</td>
<td>1.17E-04</td>
<td>1.05E-04</td>
</tr>
<tr>
<td>CL-case</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bergeron process</td>
<td>0.0008264</td>
<td>0.000905</td>
</tr>
<tr>
<td>collision-coalescence</td>
<td>2.51E-05</td>
<td>7.15E-05</td>
</tr>
</tbody>
</table>

**For mass concentration of graupel**

<table>
<thead>
<tr>
<th></th>
<th>35min</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ice crystal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C-case</td>
<td>0.002562</td>
<td>5.06E-04</td>
</tr>
<tr>
<td>CL-case</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bergeron process</td>
<td>3.82E-04</td>
<td>8.99E-05</td>
</tr>
<tr>
<td>collision-coalescence</td>
<td>0.007698</td>
<td>0.001693</td>
</tr>
</tbody>
</table>
Spatial and spectral distributions of specific mass and number concentration of graupel after 35 min of simulation

**MASS (Graupel)**
Unit: g kg$^{-1}$ µm$^{-1}$ Time: 35min

**NUMBER (Graupel)**
Unit: l$^{-1}$ µm$^{-1}$ Time: 35min
The solid and total rainfall rate
Conclusions

- For the typical continental case, the number concentration of drop increased with the enhanced aerosol loading at higher supersaturation area.
- With the adding of distant aerosol, both the number and mass of ice crystals increased with the frozen of droplet in the development stage of cloud, and the number of ice crystals decreased with weak deposition in mature stage.
- The efficiency of drop frozen depressed with smaller drop size, as a result, both of the number and mass concentration of grauple reduced, and the solid precipitation are delayed and suppressed.
Thank you for your attention!