The super-droplet method (SDM) is a particle-based and probabilistic numerical scheme, which enables accurate simulations of cloud microphysics with less demand on computation (Shima et al. 2009). In this study, the SDM is applied to mixed-phase cloud microphysics. Following Chen and Lamb (1994), ice particles are represented by porous spheroids. The model is evaluated through a 2D LES simulation of an isolated cumulonimbus. It is confirmed that the result is in reasonable agreement with the known mass-dimension relationships of ice particles. (to be submitted to GMDD)

Application of SDM to Mixed-Phase Cloud Microphysics

<table>
<thead>
<tr>
<th>Attribute variables of a particle</th>
<th>Cloud microphysical processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equatorial radius of ice</td>
<td>Ice formation (condensation/immersion/ homogeneous freezing)</td>
</tr>
<tr>
<td>Polar radius of ice</td>
<td>Melting</td>
</tr>
<tr>
<td>Apparent density of ice</td>
<td>Deposition/sublimation</td>
</tr>
<tr>
<td>Rime mass</td>
<td>Condensation/evaporation (incl. CCN act.)</td>
</tr>
<tr>
<td>Number of monomers (primary ice crystals)</td>
<td>Sedimentation of ice/droplets</td>
</tr>
<tr>
<td>Freezing temperature of particle</td>
<td>Droplet-ice coalescence (riming)</td>
</tr>
<tr>
<td>Equivalent radius of droplet</td>
<td>Ice-ice coalescence (aggregation)</td>
</tr>
<tr>
<td>Mass of soluble materials</td>
<td>Droplet-droplet coalescence</td>
</tr>
</tbody>
</table>

Shape and structure of ice particles (T=2400 s)

Results of 2D LES simulation of an isolated cumulonimbus

Mixing ratio of hydrometeors

- Snow: T=1620 s
- Ice: T=1800 s
- All: T=2040 s
- Graupel: T=2220 s
- Mixed phase: T=2400 s

Domain averaged water path

- T=2400 s
- T=2760 s
- T=5400 s

Domain averaged precipitation

- T=2400 s
- T=2580 s
- T=5000 s

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Conclusion

SDM was applied to mixed-phase cloud microphysics

2D LES simulation of a cumulonimbus was carried out for model evaluation

The model reproduced mass-dimension relationships reasonably well

More detailed validation and sophistication of the model is needed:

Reliable aggregation efficiency and outcome; Breakup (spontaneous, collisional, rime splintering); Partial melting and shedding

Numerical Setup

- Aerosol: Pure (NH4)2SO4: 105/cc
- Grid size: SDM (256x5x5-grid)
- LES solver: SCALE (Nishizawa et al. 2015; Sato et al. 2015)

Application of the Super-Droplet Method to Mixed-Phase Clouds

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Optimization Support Program of the HPCI system.

Research Institute, Tsukuba, Japan, 5National Research Institute for Earth Science and Disaster Resilience, Tsukuba, Japan
Supplement: Polluted Case (105/cc → 10500/cc)

Sounding

Aerosol
- Pure (NH₄)₂SO₄: 105/cc → 10500/cc
- Mineral dust internally mixed with (NH₄)₂SO₄: d=1μm, 10/cc

Grid size
Δx=Δy=Δz=125m

Cloud microphysics
SDM (256SD/grid)

LES solver
SCALE (Nishizawa et al. 2015; Sato et al. 2015)

Results of 2D LES simulation of an isolated cumulonimbus

Mixing ratio of hydrometeors
- T=1620 s
- T=1800 s
- T=2040 s
- T=2220 s
- T=2400 s
- T=2580 s
- T=2760 s
- T=5400 s

Shape and structure of ice particles (T=2400 s)

Shape and structure of ice particles (T=5400 s)

Domain averaged water path

Domain averaged precipitation

Numerical Setup

- Mass–Dimension (Mass Density log([kg/unit_log10(D)/unit_log10(m)]))
- Terminal velocity
- Density–Dimension (Density log([kg/m³]))
- Shape (Mass Density log([kg/unit_log10(a)/unit_log10(c)])
- Density–Dimension (Density log([kg/m³]))
- Shape (Mass Density log([kg/unit_log10(a)/unit_log10(c)]))