Giant cloud condensation nuclei and precipitation in marine clouds

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Giant cloud condensation nuclei (GCCN)

- Aerosols with large dry radii, typically $r_d > 1\mu m$
- Droplets formed on GCCN can grow to $r > 20\mu m$ through condensation, hence they can initiate collision-coalescence
- Over oceans, small concentrations of sea-salt GCCN are released from breaking waves
LES with GCCN

- Marine stratocumulus (Dycoms RF02)
- Marine cumulus (RICO)
- Various GCCN and CCN concentrations

- University of Warsaw Lagrangian Cloud Model (UWLCM)
- Lagrangian microphysics (super-droplet method):
  - solute effect included in growth equation
  - explicitly modeled droplet activation
  - no numerical diffusion in size spectrum
  - CCN and GCCN have different hygroscopicities
Precipitation vs GCCN conc.

**stratocumulus**

![Graph showing precipitation rate vs GCCN concentration for stratocumulus clouds with different cloud droplet concentrations.](image)

**cumulus**

![Graph showing precipitation rate vs GCCN concentration for cumulus clouds with different cloud droplet concentrations.](image)

- Cloud droplet conc. = 30 cm\(^{-3}\)
- Cloud droplet conc. = 45 cm\(^{-3}\)
- Cloud droplet conc. = 105 cm\(^{-3}\)
- Cloud droplet conc. = 35 cm\(^{-3}\)
- Cloud droplet conc. = 55 cm\(^{-3}\)
- Cloud droplet conc. = 75 cm\(^{-3}\)
## Comparison with observations

<table>
<thead>
<tr>
<th>observation</th>
<th>LES without GCCN</th>
<th>LES with GCCN</th>
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</thead>
<tbody>
<tr>
<td>$^1$Sc: 0.04 mm/h cloud base precip. $N_{GCCN} = 1.89/\text{cc}$</td>
<td>0.004 mm/h</td>
<td>0.03 mm/h</td>
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<tr>
<td>$^2$Sc: from 0.24 mm/d to 0.46 mm/d surface precip. Surface wind speed 9.5 m/s</td>
<td>0.01 mm/d</td>
<td>0.22 mm/d $N_{GCCN} = 1.89/\text{cc}$ for this wind speed$^1$</td>
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<td>$^3$Cu: no effect of GCCN on precipitation</td>
<td>Very low sensitivity of precipitation to GCCN</td>
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$^2$ Ackerman et al. *MWR* (2019)

Conclusions

- Wave-released giant sea-salt aerosols:
  - significantly increase precipitation in marine stratocumuli, in particular for moderate CCN concentrations
  - do not have much impact on precipitation in marine cumuli, because marine cumuli produce small concentrations of large droplets even without GCCN