Giant cloud condensation nuclei and precipitation in marine clouds

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Giant cloud condensation nuclei (GCCN)

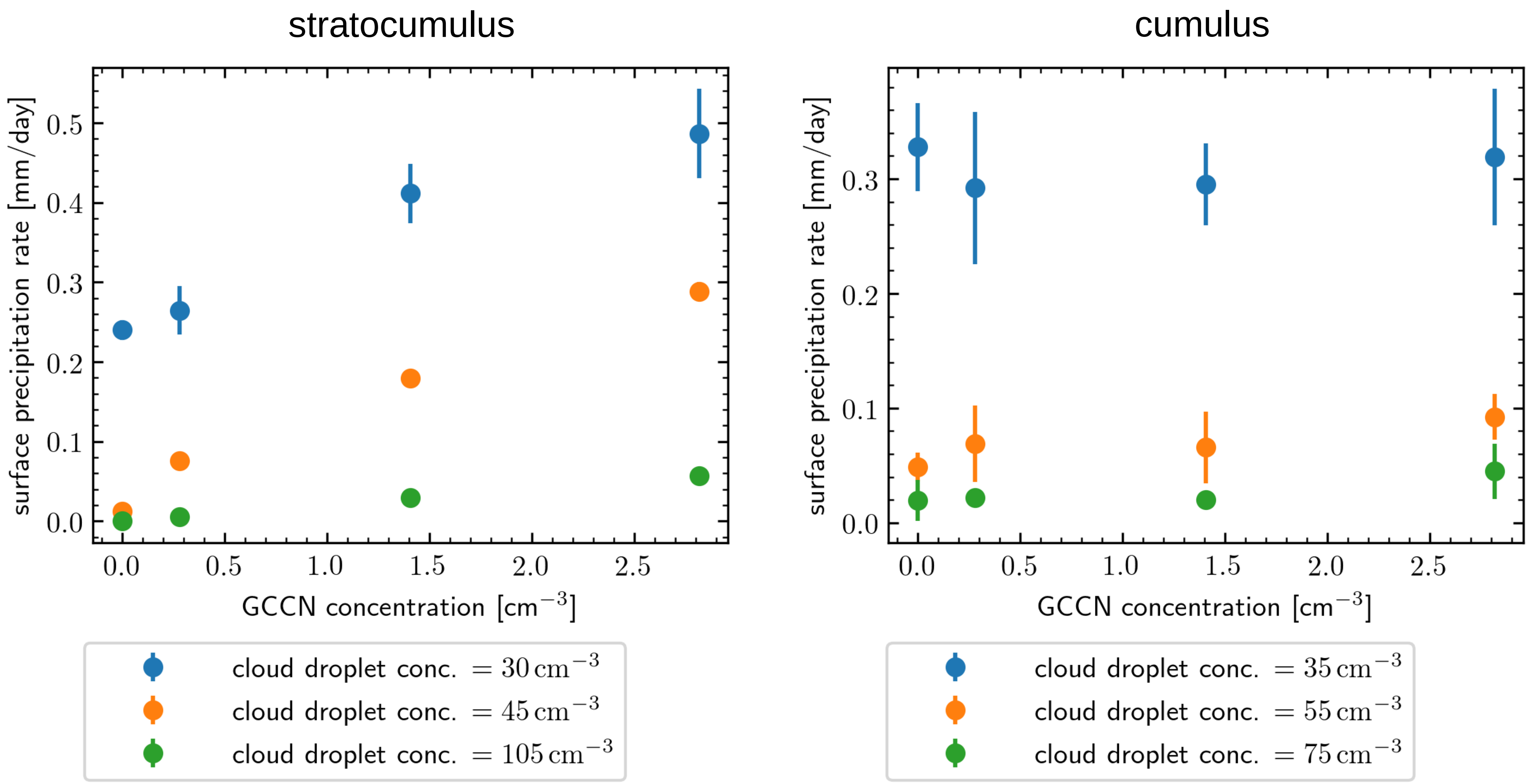
- Aerosols with large dry radii, typically $r_d > 1\mu m$
- Droplets formed on GCCN can easily grow to $r > 20\mu m$ through condensation, hence they can initiate collision-coalescence
- Over oceans, small concentrations of sea-salt GCCN, of the order of 1/cc, are released from breaking waves

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

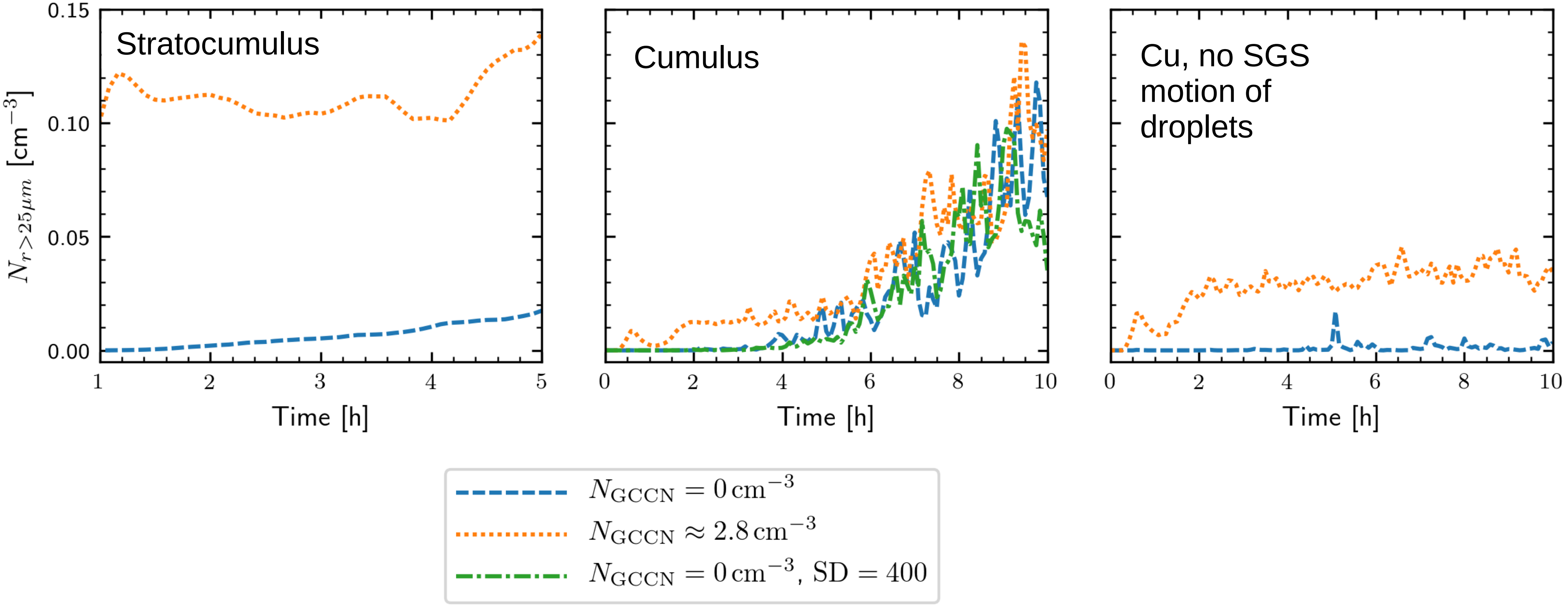
Precipitation vs GCCN conc.



Cumulus – why rain is not sensitive to GCCN?

- GCCN affect rain, because they are seeds for large droplets that collide efficiently with smaller droplets
- Maybe in cumuli large droplets are formed even without GCCN?
- We test this by comparing concentrations of droplets with r>25um in Sc and Cu that have similar cloud base precipitation

Sc vs Cu – concentration of large droplets



Comparison with observations

observation	LES without GCCN	LES with GCCN
[1]Sc: 0.04 mm/h cloud base precip. N_{GCCN}=1.89/cc	0.004 mm/h	0.03 mm/h
[2]Sc: from 0.24 mm/d to 0.46 mm/d surface precip. Surface wind speed 9.5m/s	0.01 mm/d	a) 0.22 mm/d N_{GCCN} = 1.89/cc[1] b) 0.13 mm/d N_{GCCN} = 0.82/cc[4]
[3]Cu: no effect of GCCN on precipitation	Very low sensitivity of precipitation to GCCN	

[1] Jung et al. *Atmos. Chem. Phys.* (2015)

[2] Ackerman et al. *MWR (2019)*

[3] Reiche & Lasher-Trapp *Atmos. Res.* (2010), Minor et al. *J. Atmos. Sci.* (2011)

[4] O’Dowd et al. *Atmospheric Environment* (1997)

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
  - production of large droplets in cumuli depends on SGS motion of droplets; Is this a physical or numerical effect? Any benchmark on SGS motion of Lagrangian particles?