Giant aerosols vs turbulent collision enhancement in marine stratocumuli

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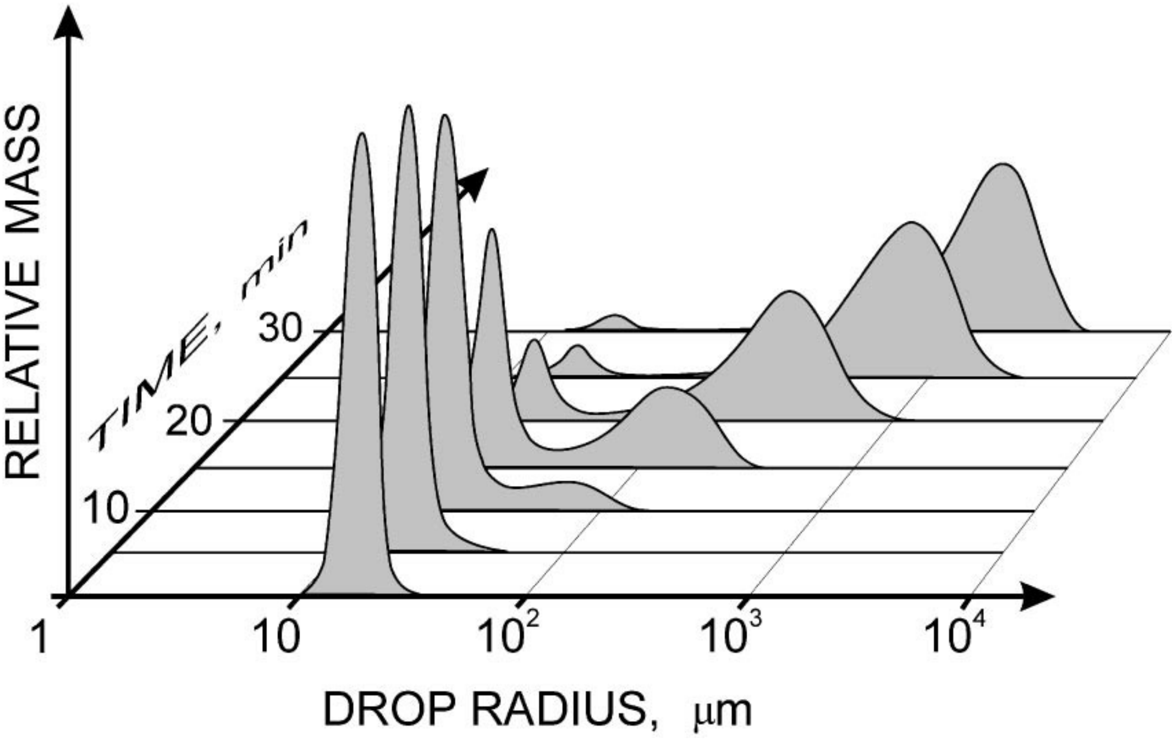
Cloud droplet growth: the size-gap problem

- Shallow convective clouds can develop rain in ~30 min.
- Condensation efficient up to ~15 μm
- Coalescence efficient starting from ~40 μm

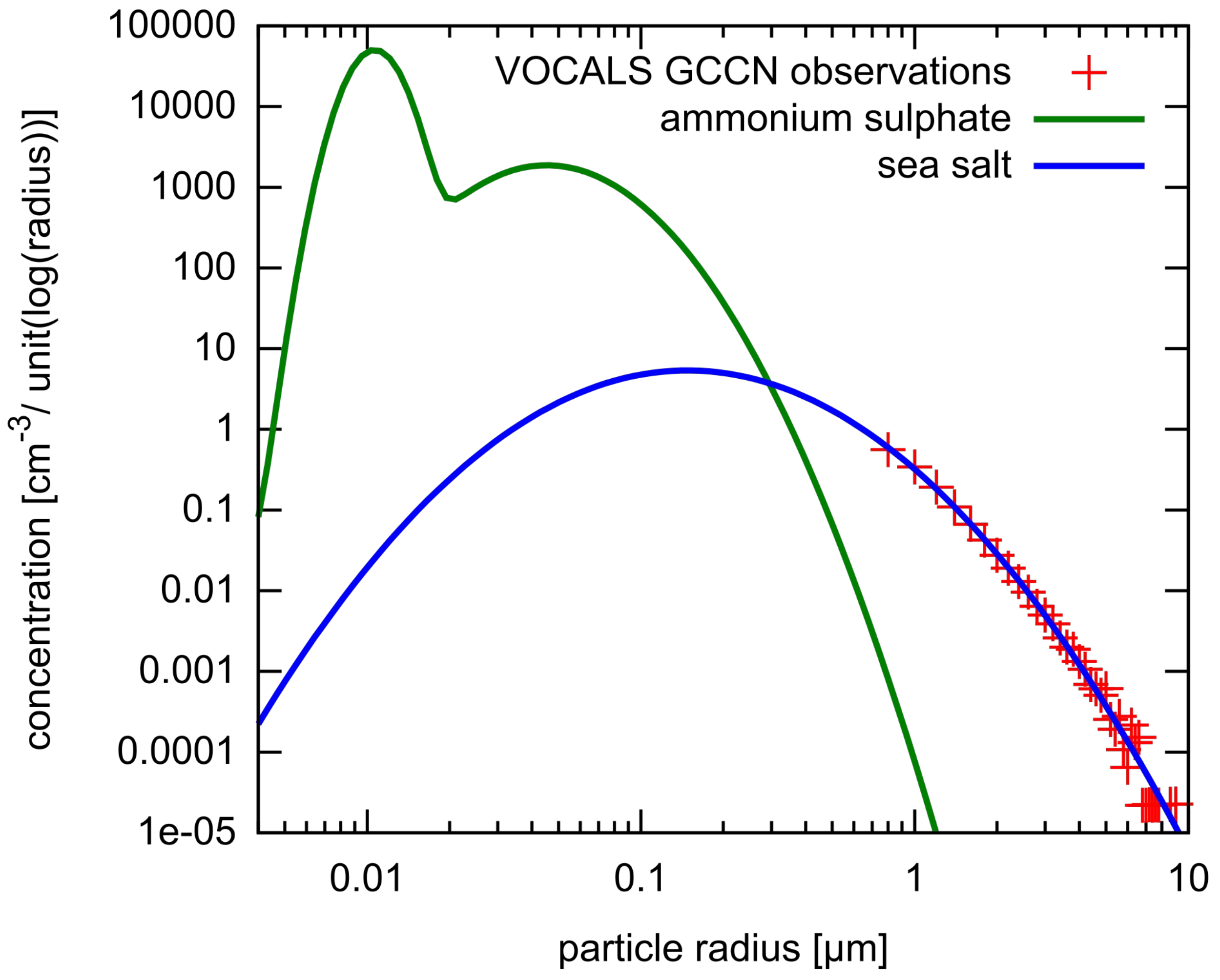


adapted from: Shaw, *Annu. Rev. Fluid Mech.* 2003

Proposed solutions: giant aerosols, turbulence-enhanced coalescence rate, entrainment of dry air, fluctuations in supersaturation

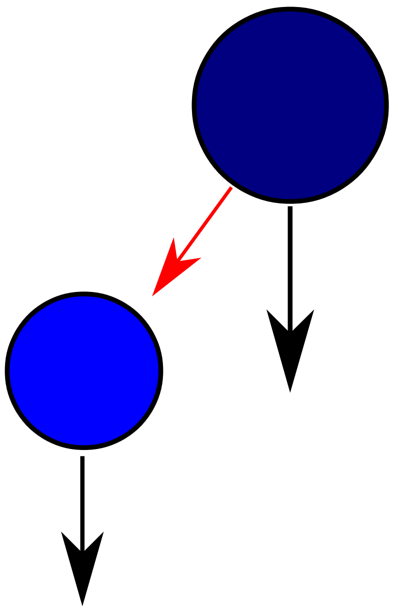
Giant aerosols (GCCN)

- Radius > 1 micron
- Highly hygroscopic
- Cross size-gap by condensation
- Low concentration ~0.3 cm^{-3}
- Can start a cascade of collisions
- Strong solute effects – could grow in downdrafts (Jensen and Nugent in review in *JAS* 2016)

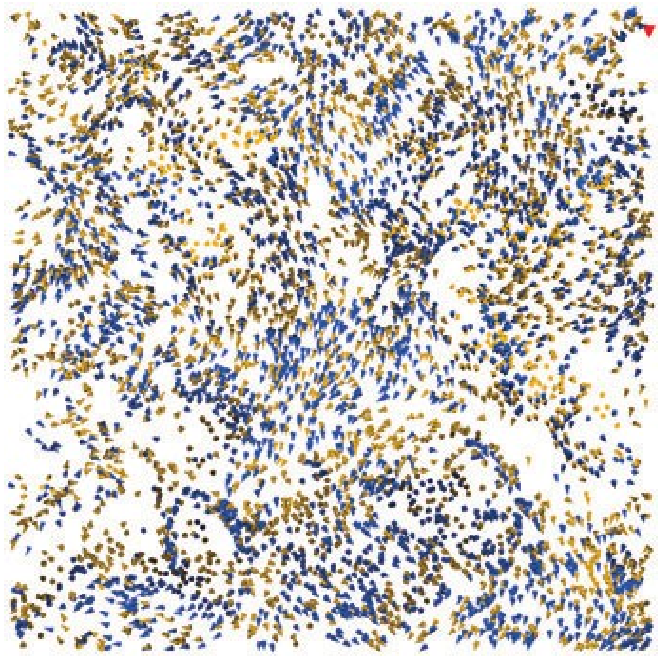


Turbulence-enhanced coalescence rate

Fluctuations in relative velocities



Local increase in concentration of droplets

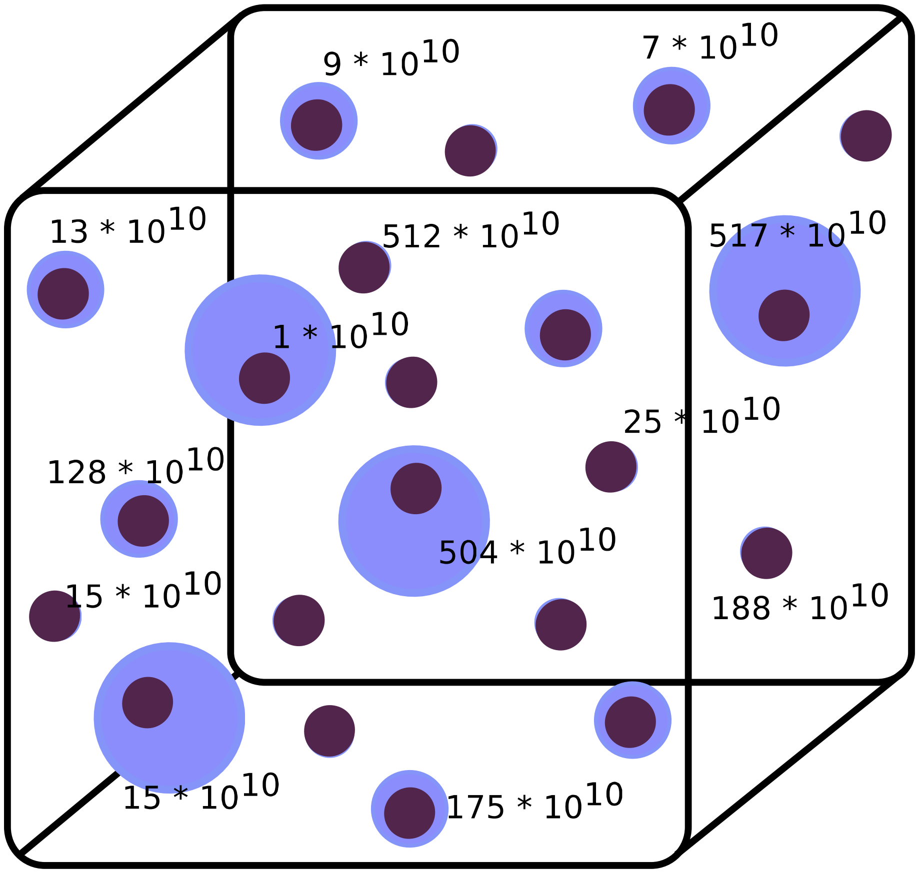


adapted from: Grabowski and Wang, *Annu. Rev. Fluid Mech.* 2013

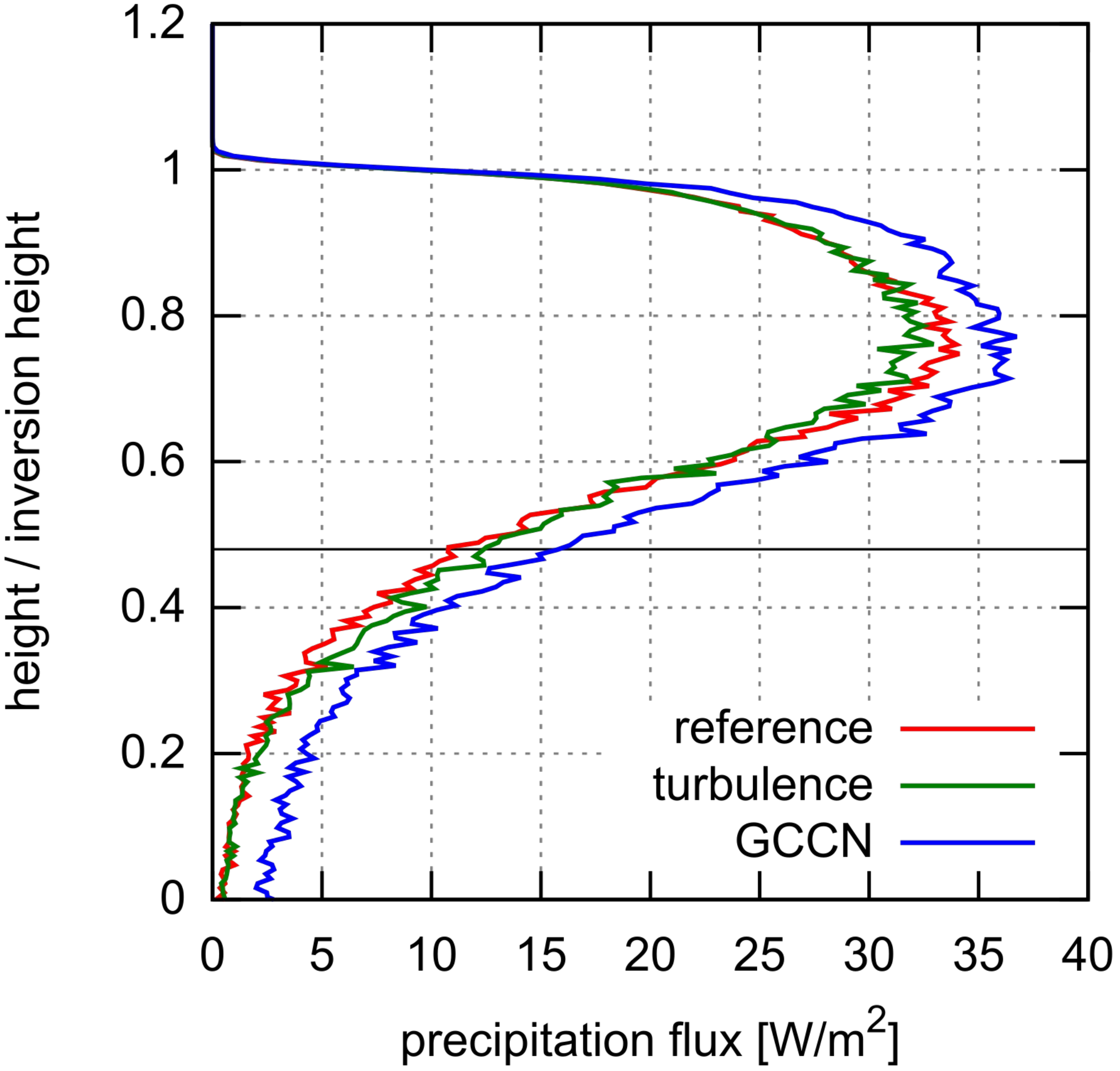
- Coalescence kernel proposed by Onishi (Onishi et al. *JAS* 2015)
- TKE dissipation rate = 10 cm^2 / s^3 and Taylor-microscale Reynolds number = 5000 (Jen-La Plante et al. *Atmos. Chem. Phys. Discuss.* 2016)

Method

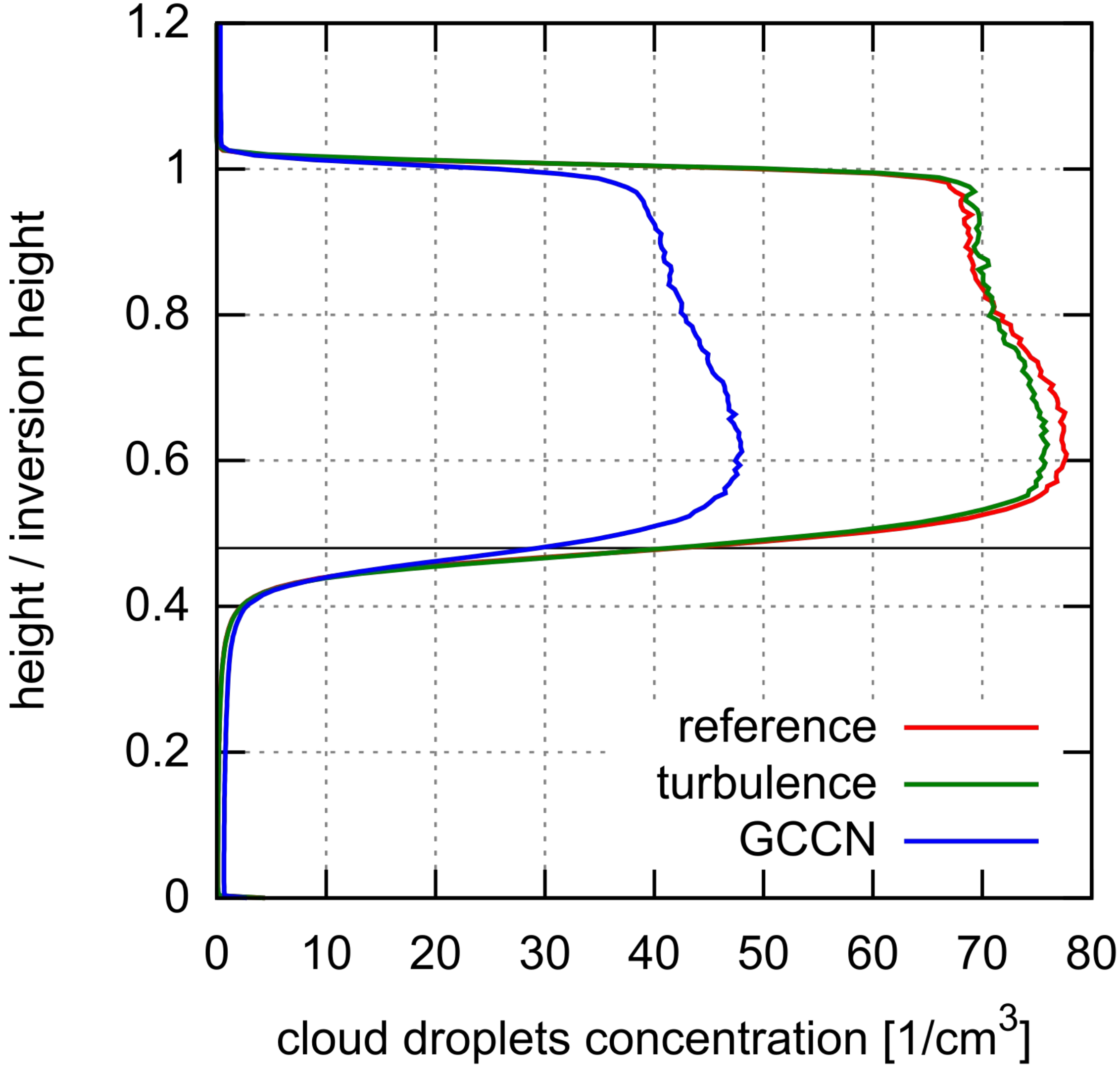
- 2D eddy-resolving model
  (Jaruga et al. *Geosci. Model Dev.* 2015)
- Super-droplet microphysics of Shima
  (Arabas et al. *Geosci. Model Dev.* 2015)
- Condensation: Maxwell-Mason equation with the κ-Köhler approximation
- Dycoms setup of a drizzling stratocumulus, but with two times higher aerosol concentration
  (Ackerman et al. *Monthly Weather Review* 2009)



Precipitation flux

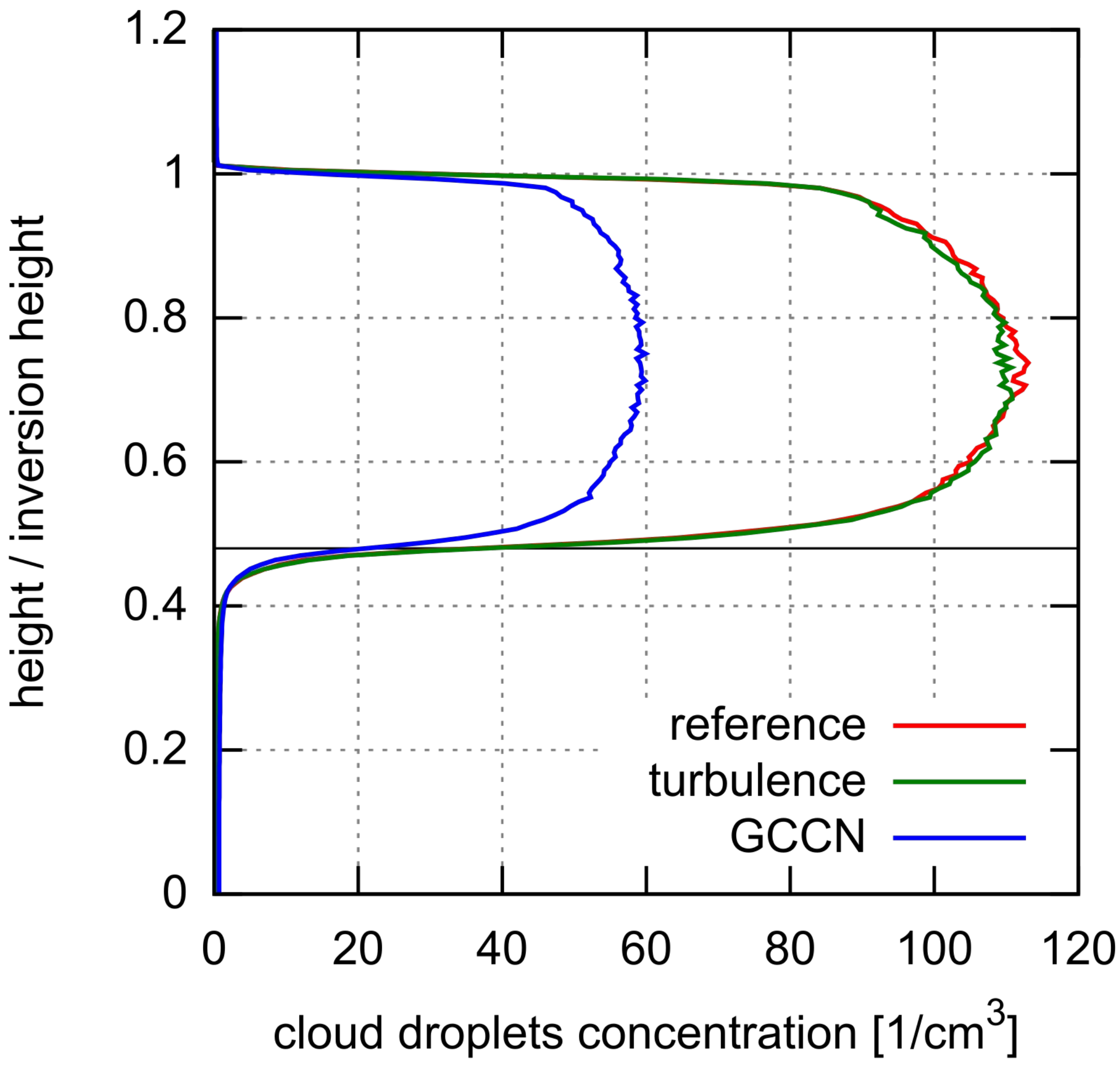


Cloud droplets concentration



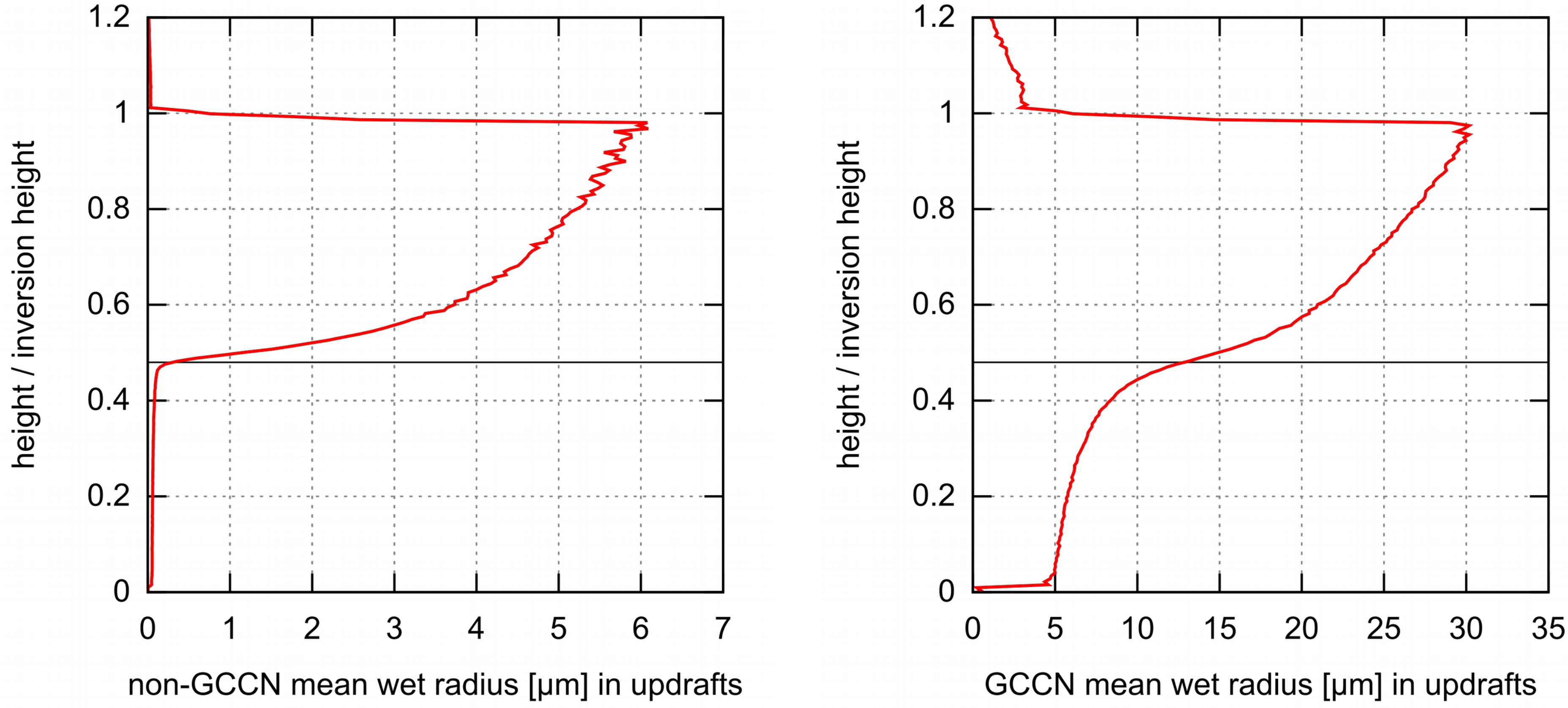
- Significantly lower number of cloud droplets
- Caused by coalescence?

Cloud droplets concentration

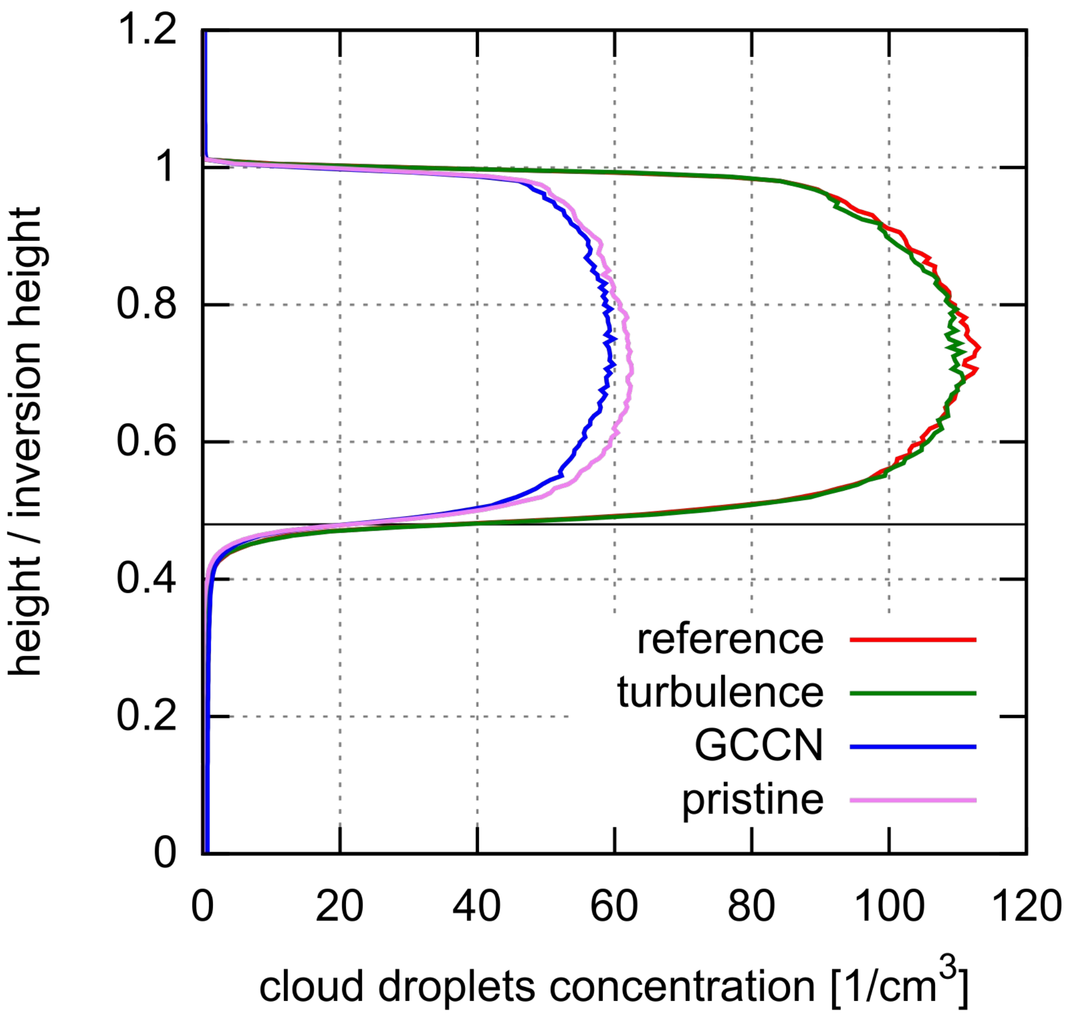


- Significantly lower number of cloud droplets
- Caused by coalescence?
- No, without coalescence it is also much lower

GCCN activate below cloud base

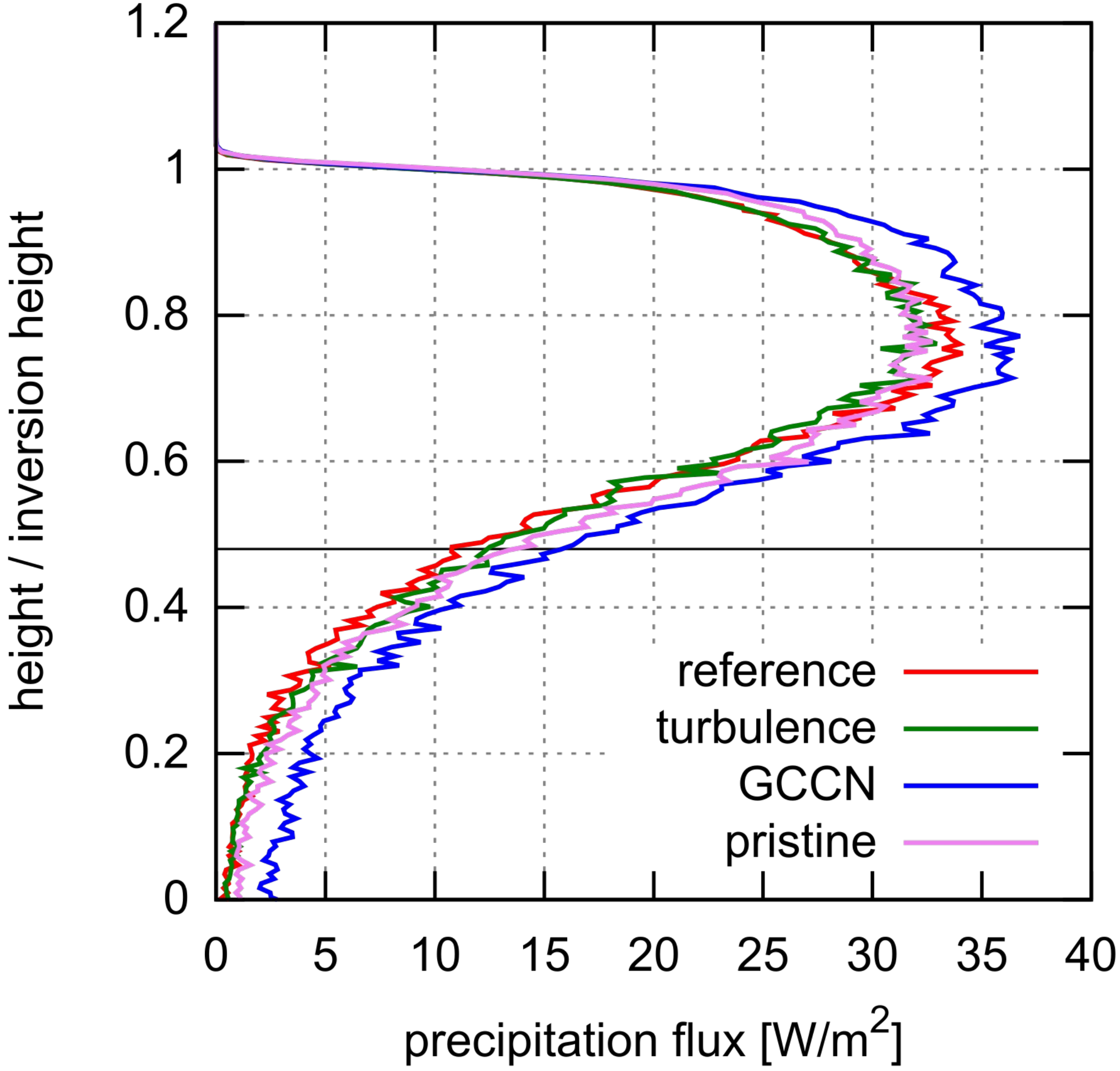


Pristine conditions

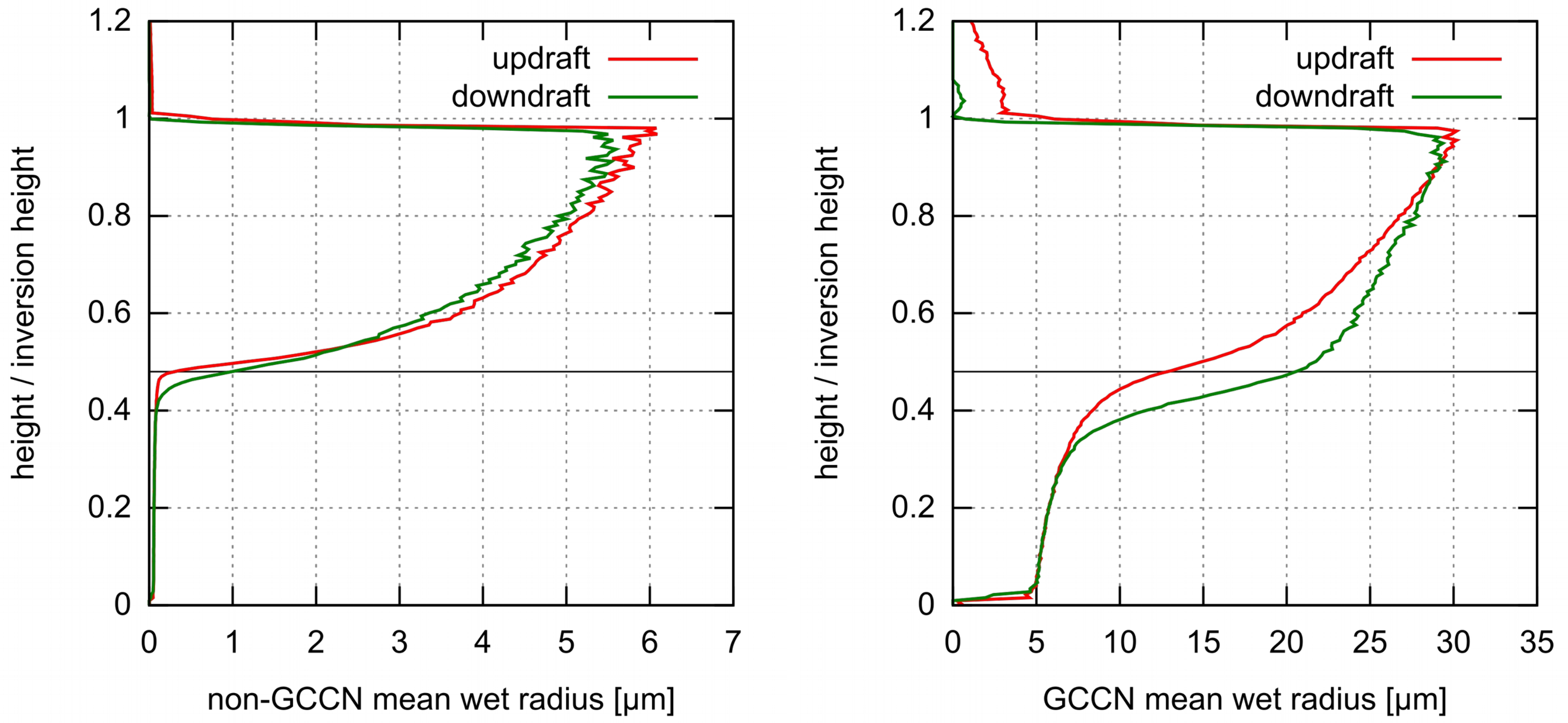


- Aerosol concentration from reference decreased by 50%, no GCCN
- Same cloud droplet concentration as in GCCN case

Pristine conditions - precipitation



Do GCCN grow in downdrafts?



Conclusions

- Highly hygroscopic giant aerosols decrease the number of cloud droplets
- Giant aerosols increase precipitation flux not only by decreasing cloud droplet number, but also by increasing coalescence rate
- Coalescence rate enhancement due to turbulence is insignificant in stratocumuli