What controls cloud droplet number concentration of trade wind cumuli?

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A. Wiedensohler

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Motivation

Quantification of the sensitivity of the droplet number concentration towards changes in the aerosol microphysical properties

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Airborne Cloud Turbulence Observation System

Aerosol microphysics:

- particle number size distribution,
  (6 nm < D_p < 2.6 µm; SMPS, OPC)
- particle number concentration
  (D_p > 6 nm; CPC, fast CPC)
- CCN concentration
  (0.1% < S < 0.67%; miniature CCNC, G. Roberts)

Cloud microphysics

- liquid water content (PVM)
- cloud droplet size, velocity and number concentration (PDI)
- ..

Meteorology

- 3d wind vector, temperature, humidity, pressure, ..

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Two different approaches

Two different approaches to quantify the sensitivity of the CDNC towards changes in the aerosol properties:

measurements	model results
statistical analysis of almost 700 individual clouds during 10 research flights	comprehensive sensitivity study using a cloud microphysical parcel model

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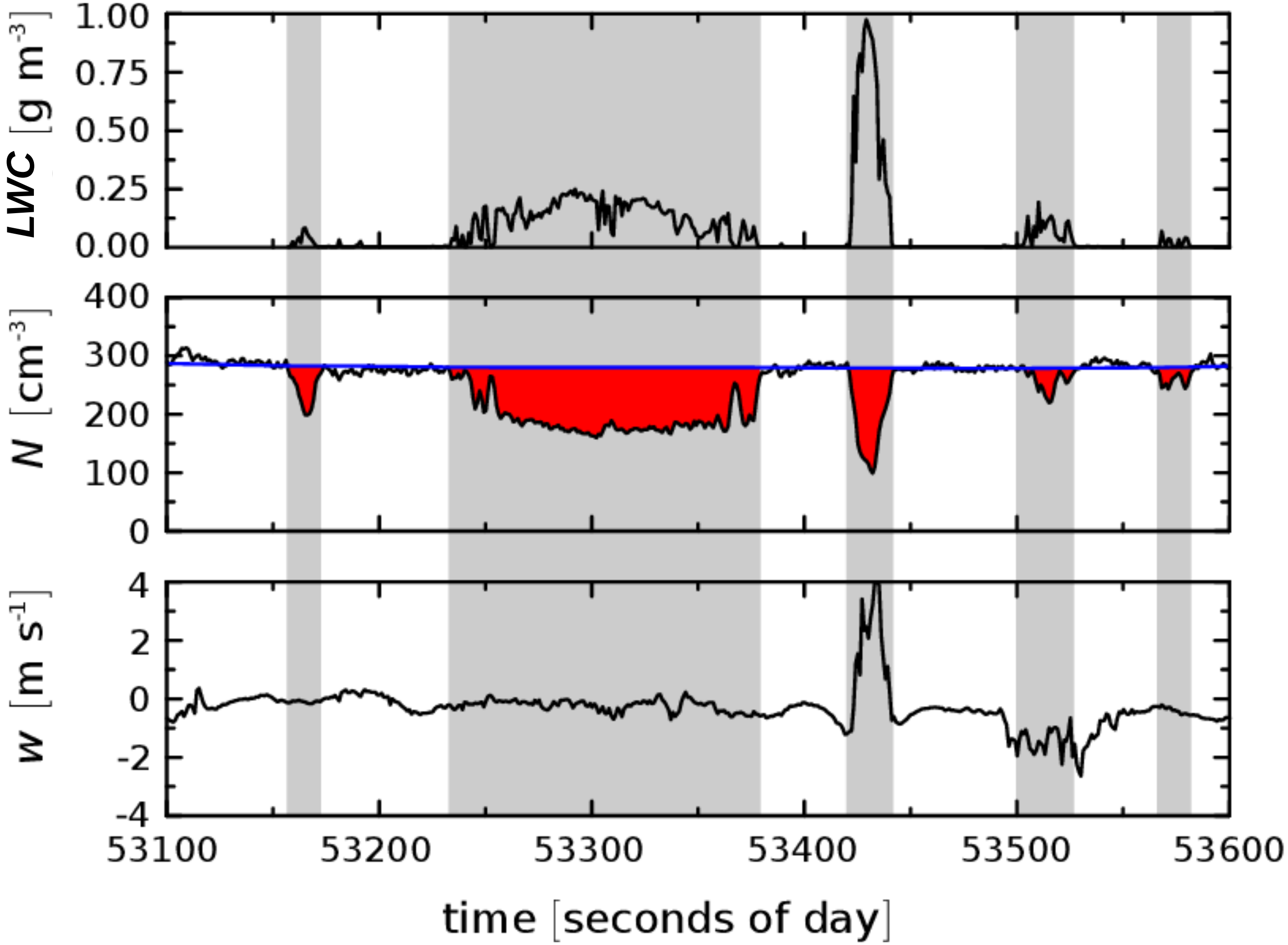
Measurements at cloud level



clouds measured
at 1500 m asl,
over ocean

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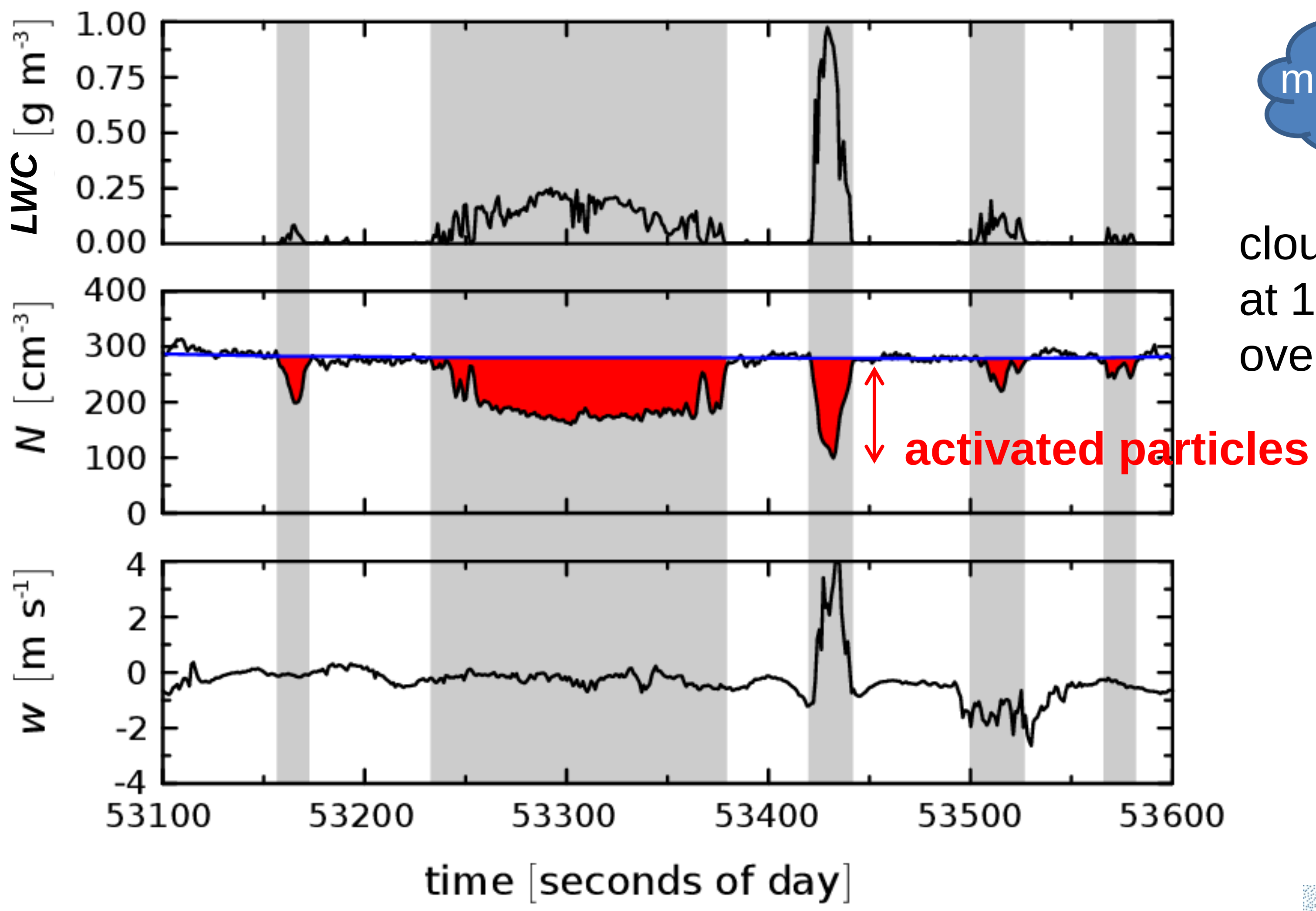
Measurements at cloud level



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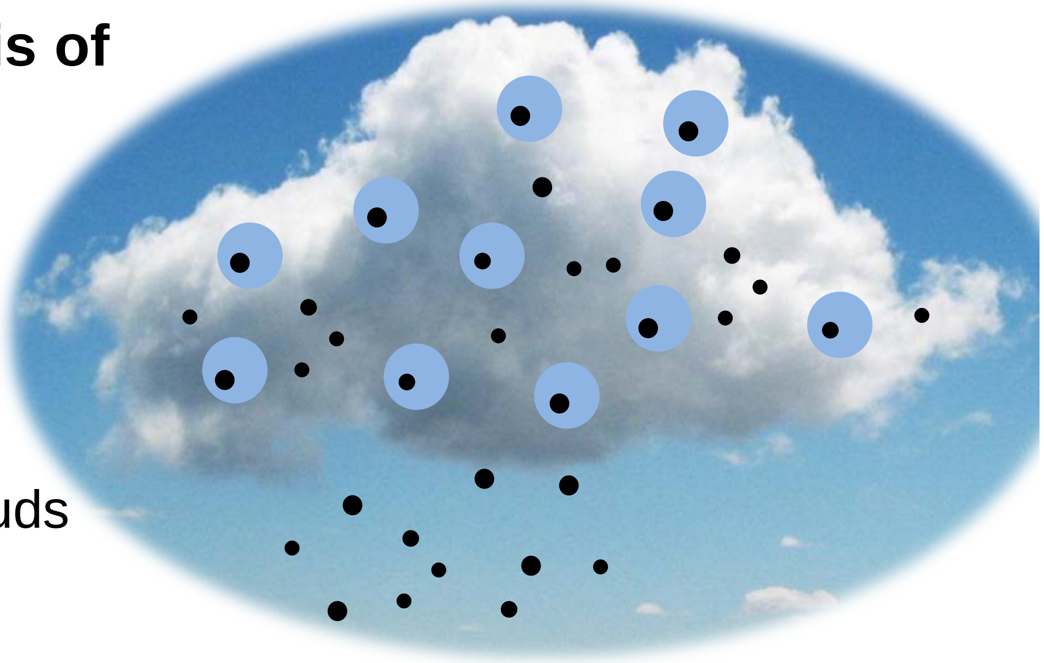
Cloud statistics

Multivariate statistical analysis of 687 individual clouds (10 research flights):



- cloud microphysics
- meteorological parameters
- activated particles inside clouds
- aerosol microphysics below clouds

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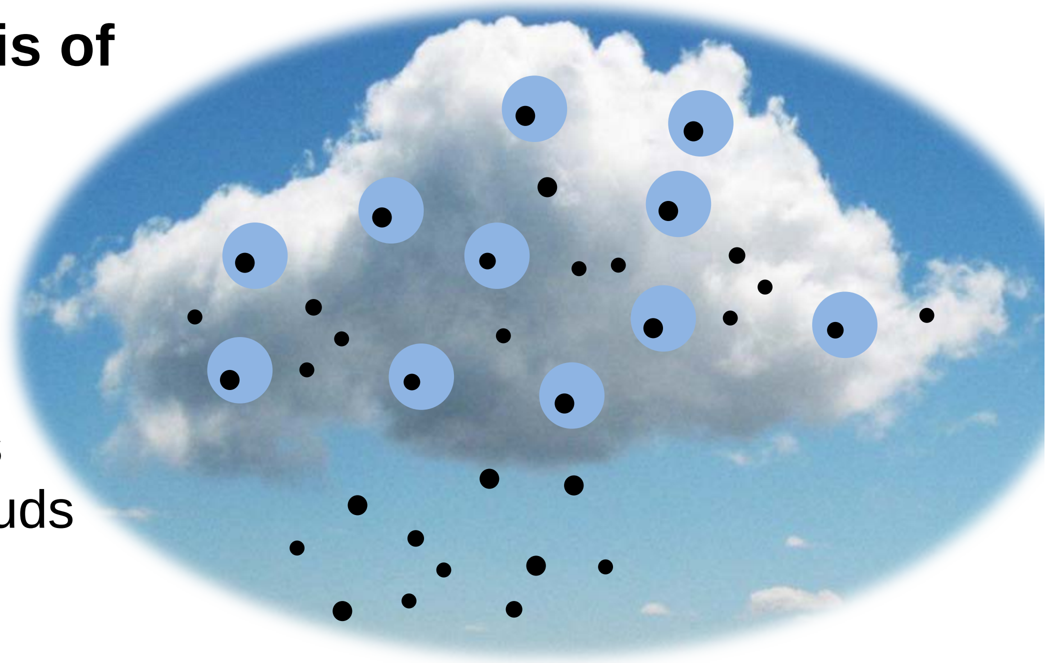

measured clouds at different evolution stages (actively growing, decelerated, dissolving)
→ J. Katzwinkel et. al 2014, JAS, in review

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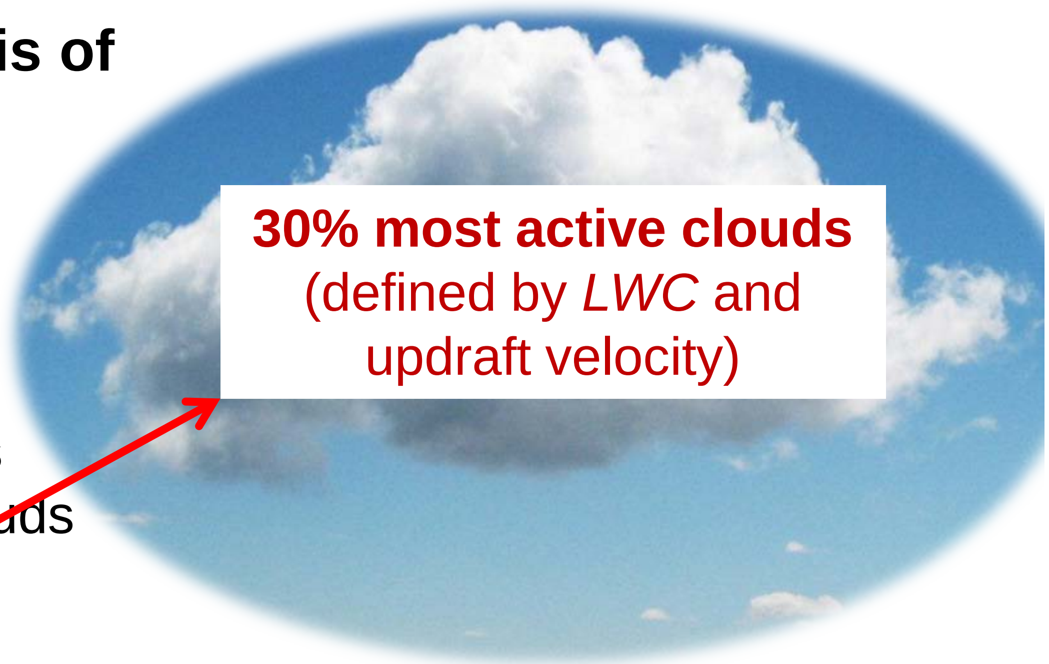

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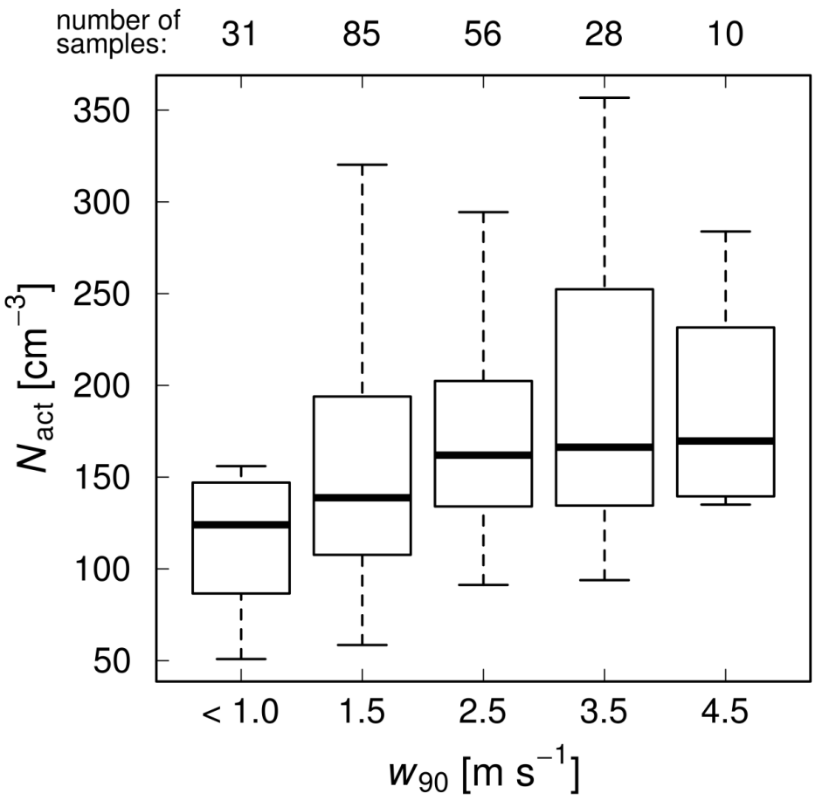
What controls CDNC?

measurements

30% most active clouds



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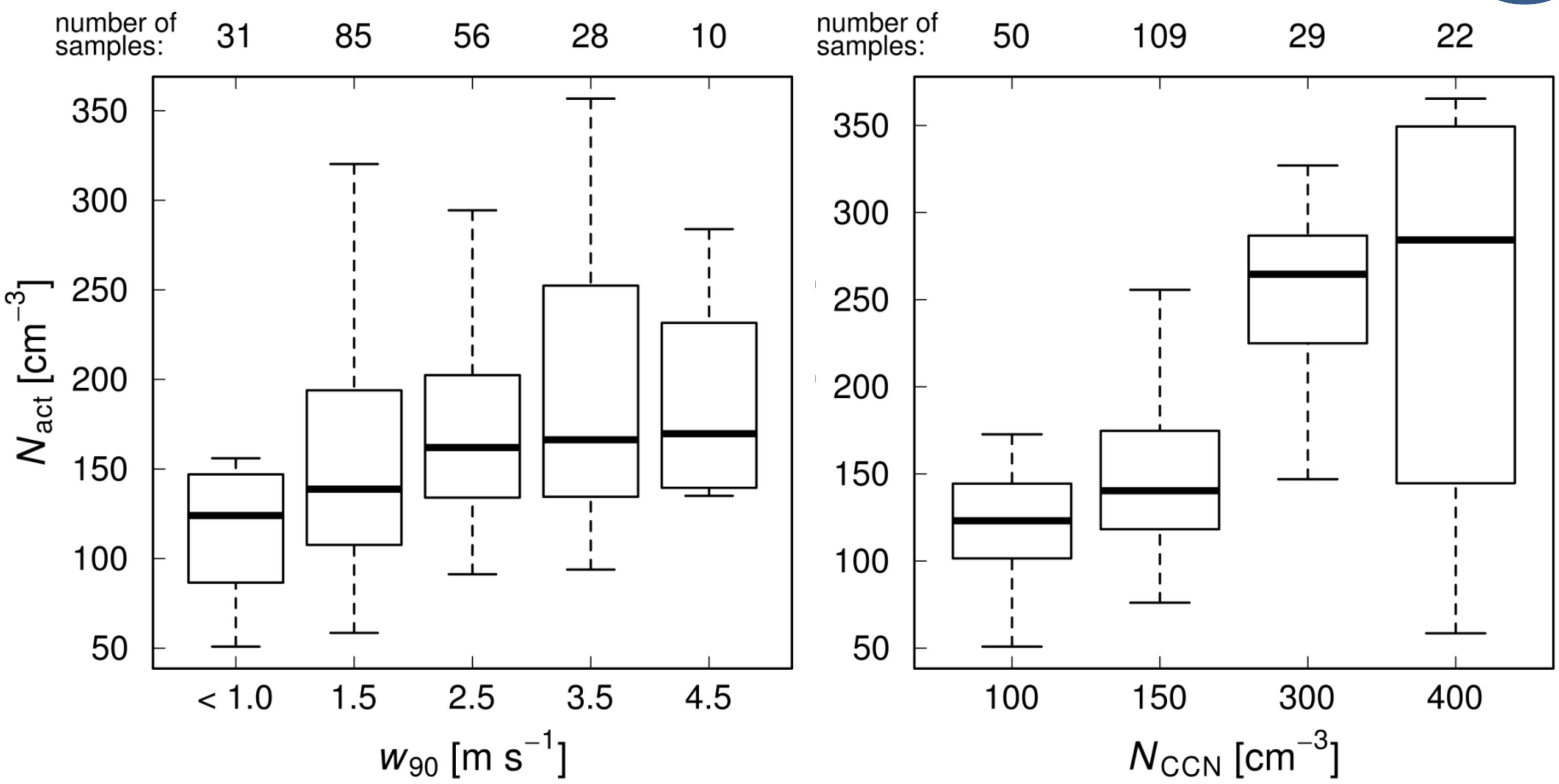

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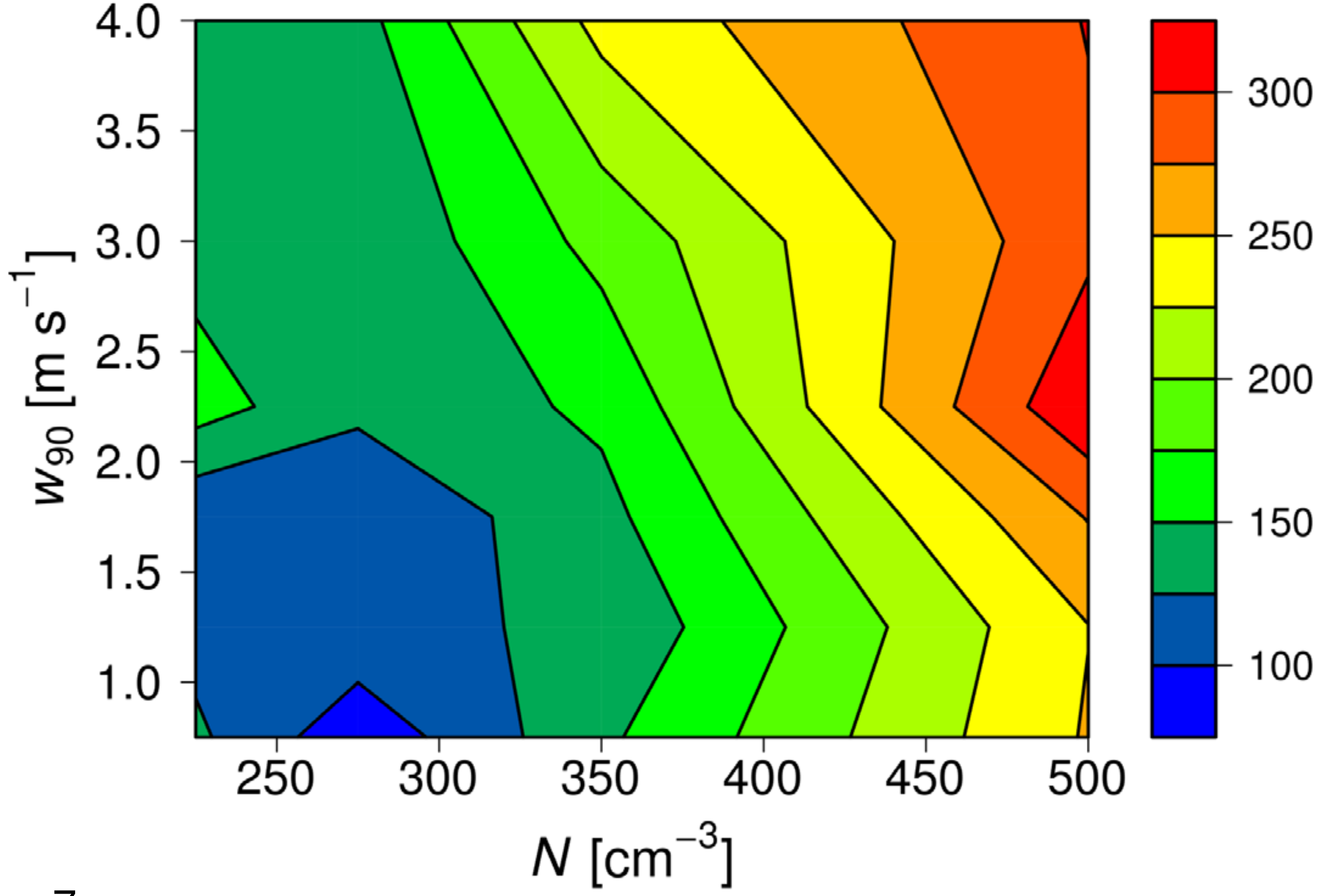
What dominates? *w* or *N*?

30% most active clouds



measurements

contours: **median number of activated particles**

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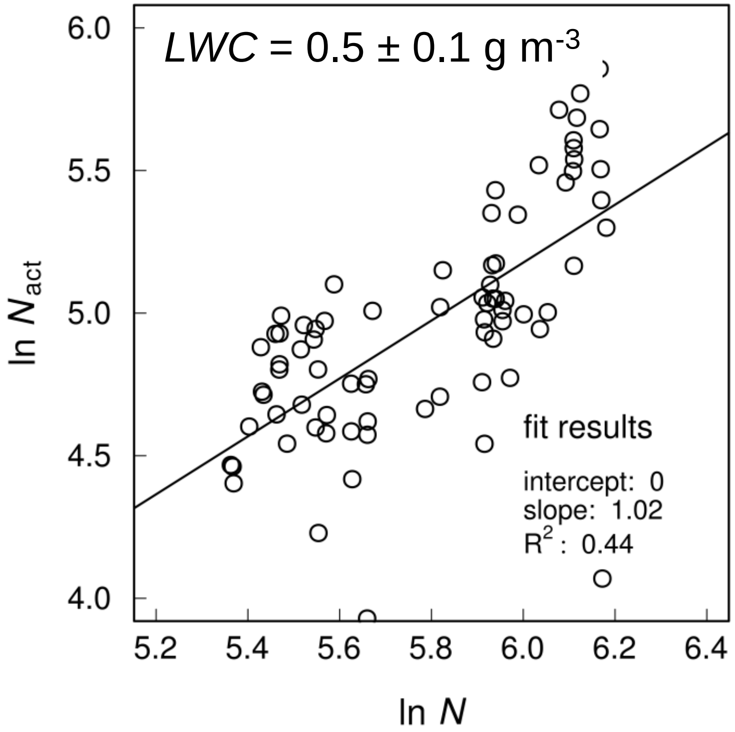
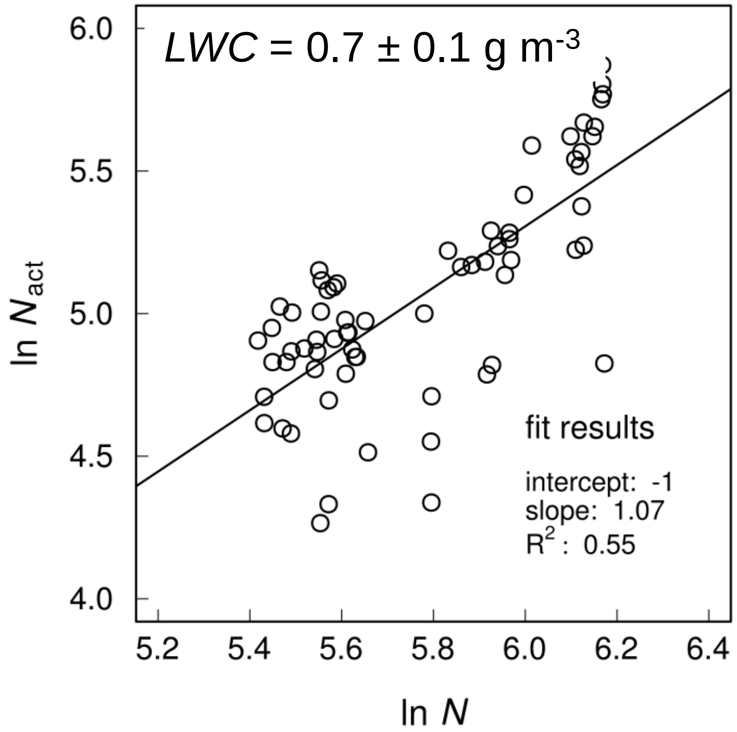
Aerosol cloud interaction metric

ACI = d ln N_{act} / d ln N (Feingold, 2001, JGR):

for different *LWC* bins

30% most active clouds





ACI ≈ 0.8 ... 1

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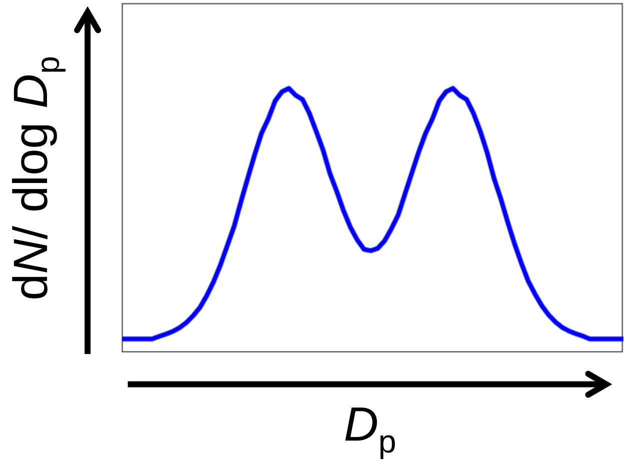
Sensitivity study

Sensitivity study for trade wind conditions:

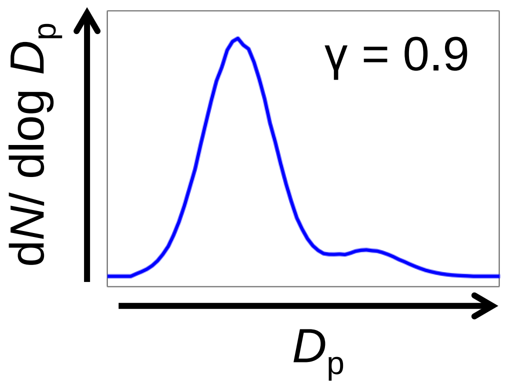
sensitivity study using cloud parcel model (Simmel and Wurzler, 2006, Atmos. Res.)

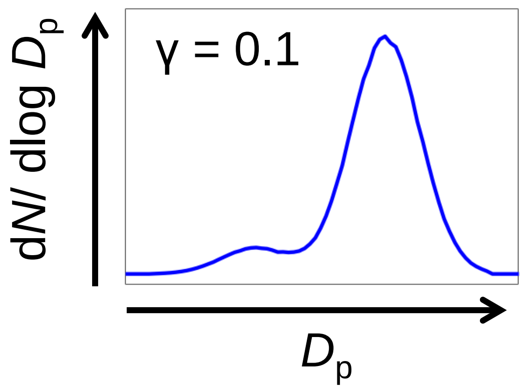
Input: bimodal particle NSD



variable parameters:

- updraft velocity (0.5 ... 5 m/s)
- total particle number concentration (100 ... 1000 cm^{-3})
- ratio between Aitken mode particles and total particle concentration (γ)
- hygroscopicity parameter κ (0.1 ... 0.9)



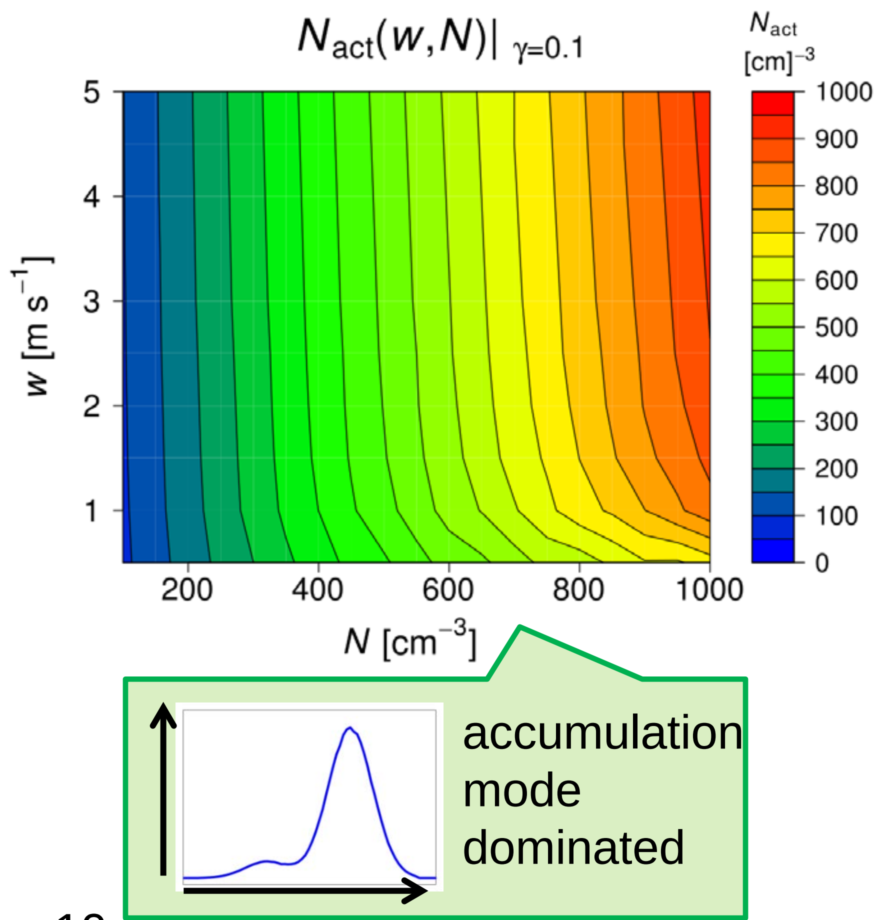


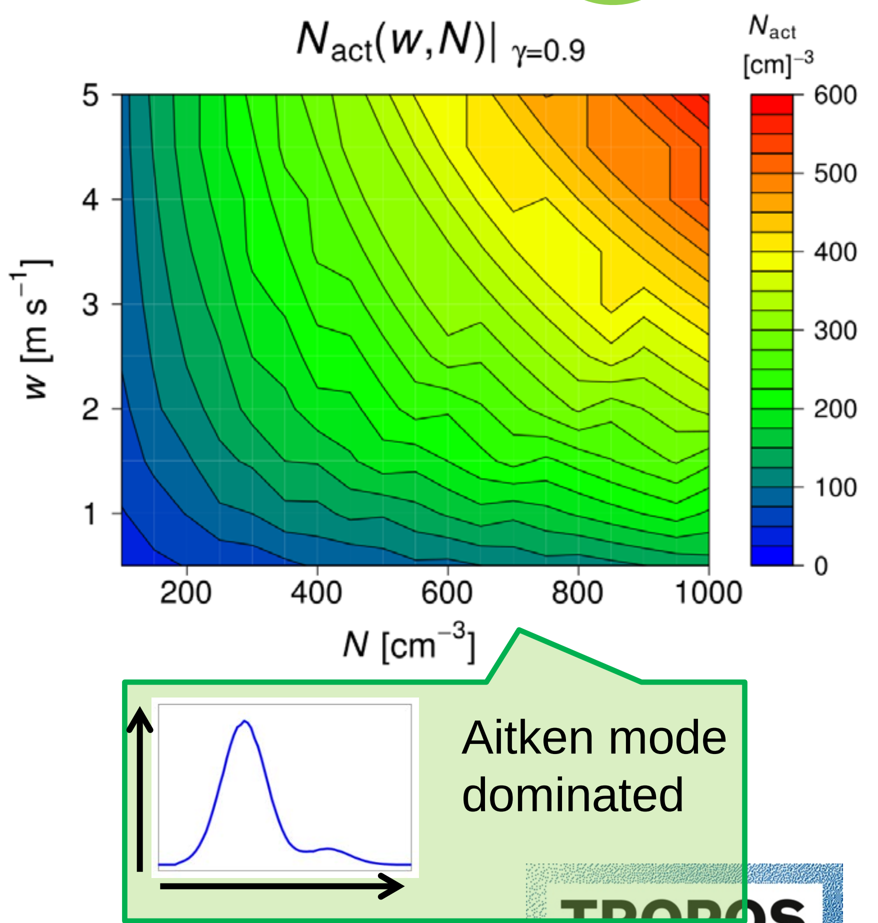
comparable to Reutter et. al, 2009, ACP

Sensitivity study

Sensitivity study using parcel model:

model results





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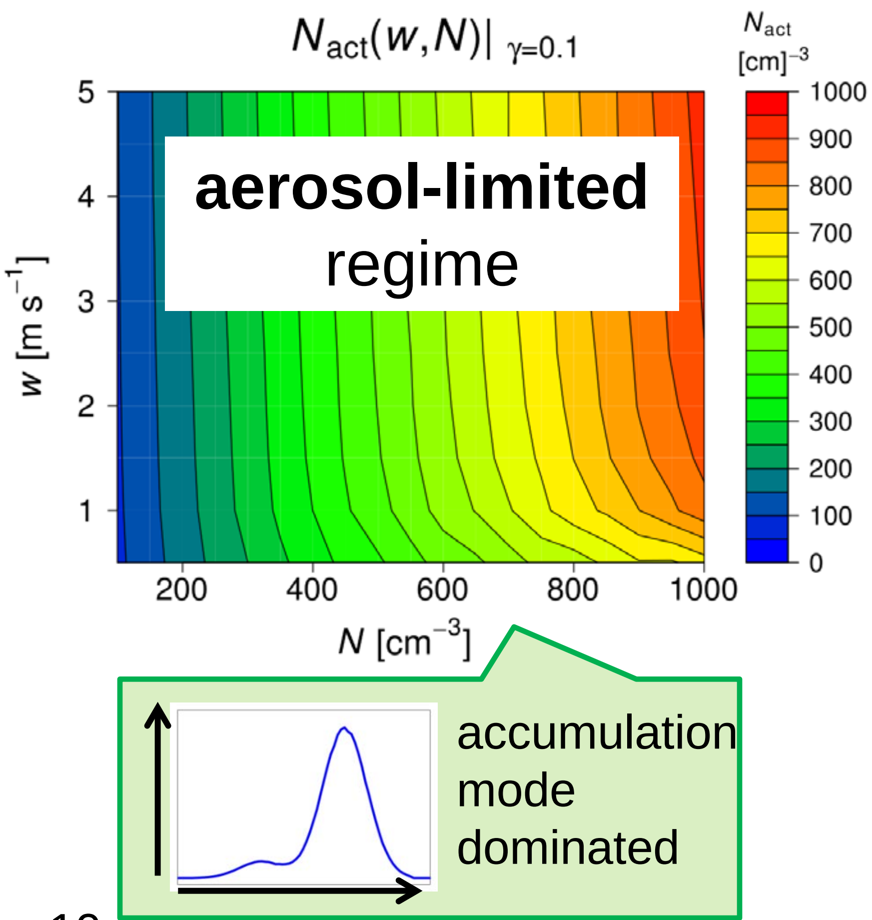

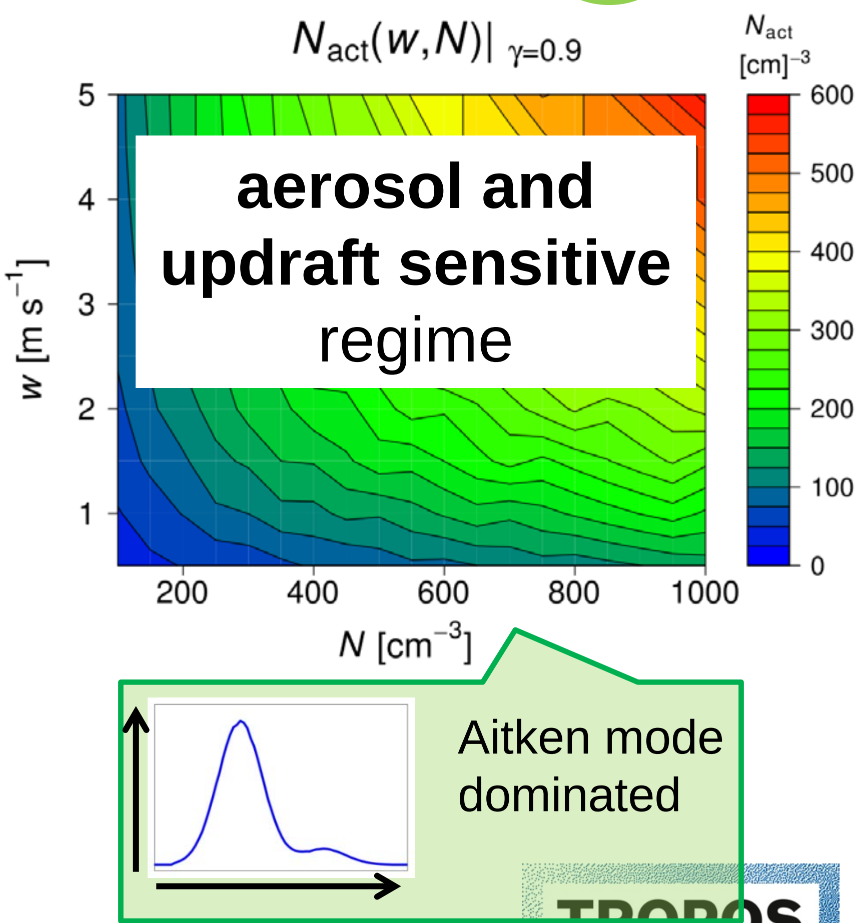

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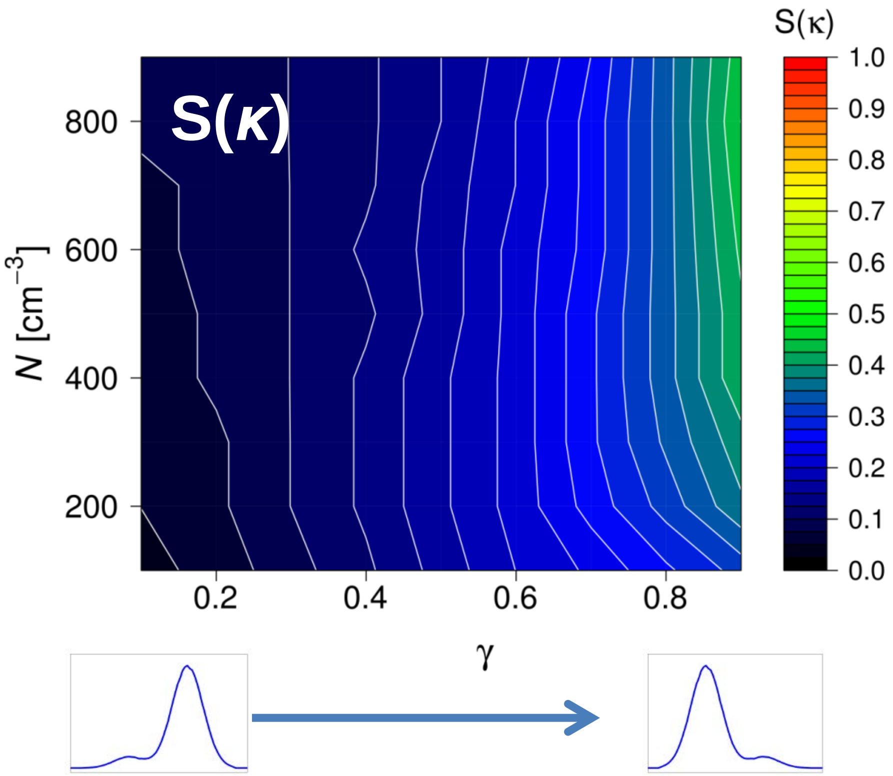
Influence of particle hygroscopicity (κ)

model results

Susceptibility of N_{drops} towards changes in κ,

$$S(\kappa) = d \ln N_{drops} / d \ln \kappa$$



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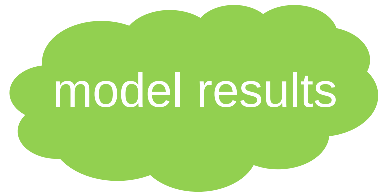

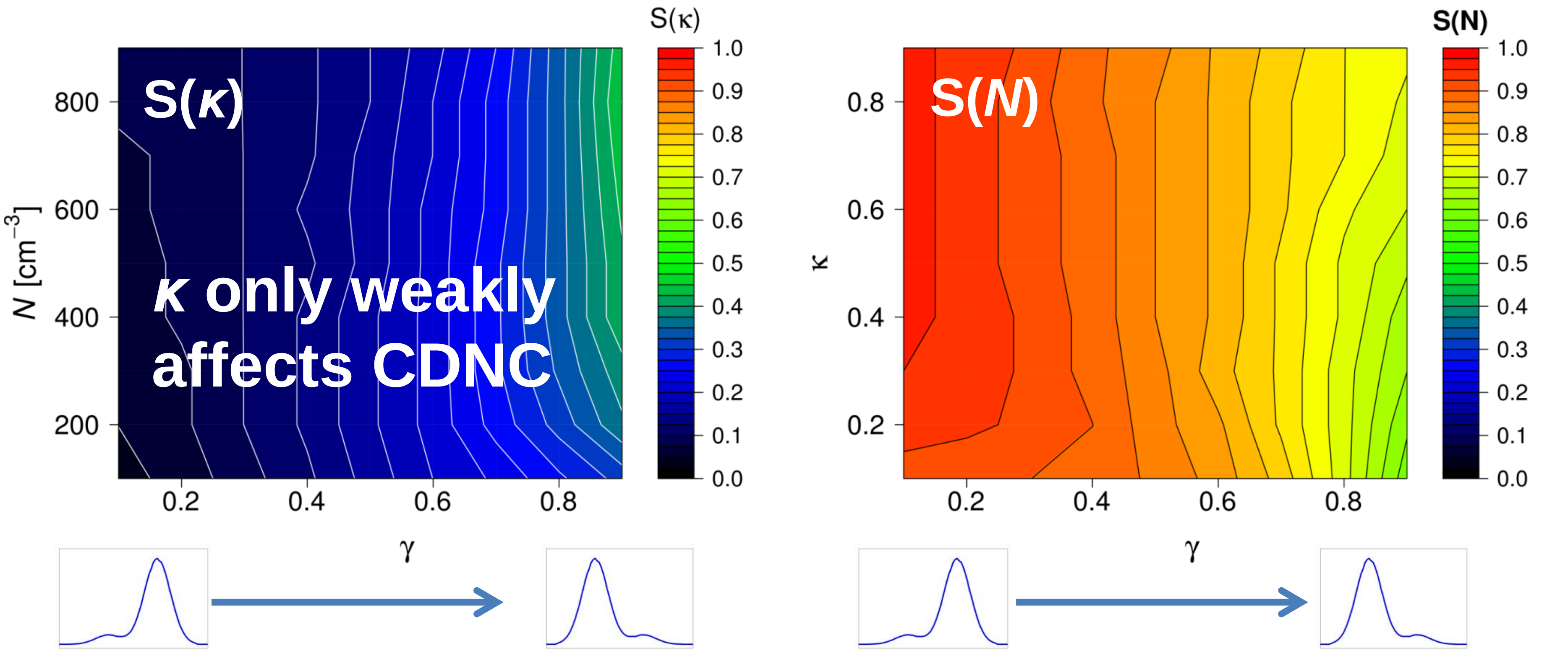

Conclusions

in the trade wind regime:

- CCN concentration defines CDNC (aerosol-limited regime)
- ACI metrics close to 1 (physically meaningful maximum)
- cloud base updraft becomes important for
  - large total particle number concentration (e.g., $N > 1000\ cm^{-3}$)
  - Aitken mode dominated particle number size distributions
- κ weakly affects CDNC

Thank you

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