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Design and applications of the sectional aerosol-cloud model SALSA in a cloud-resolving setup

4/16/19

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Motivation

UCLALES-SALSA (Tonttila et al. 2017 @ GMD):

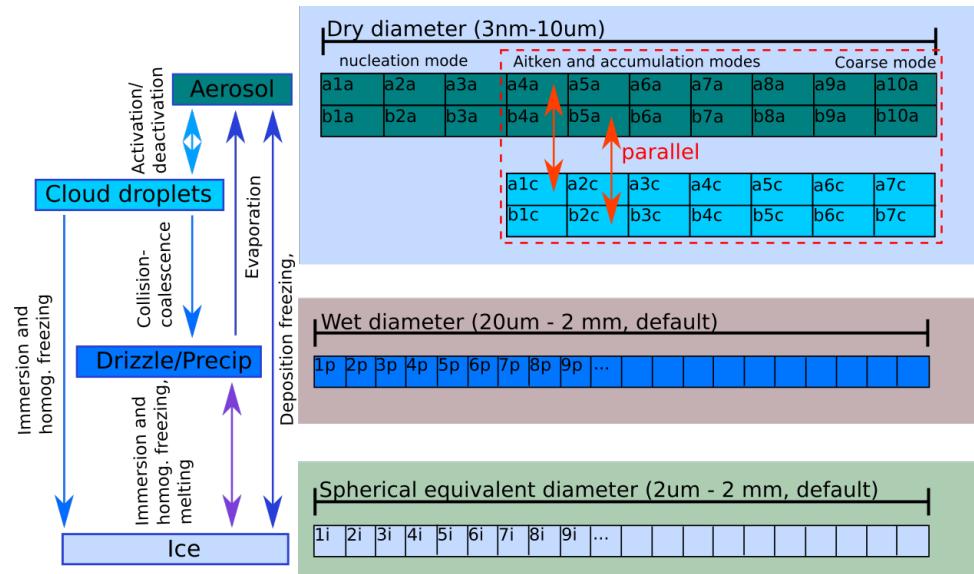
- Aerosol-cloud-precipitation interactions
 - Cloud microphysics coupled with dynamics
 - *Cloud processing of the aerosol*
 - *Wet scavenging effects*
 - Precipitation formation/climate engineering/weather modification



Tools

UCLALES-SALSA

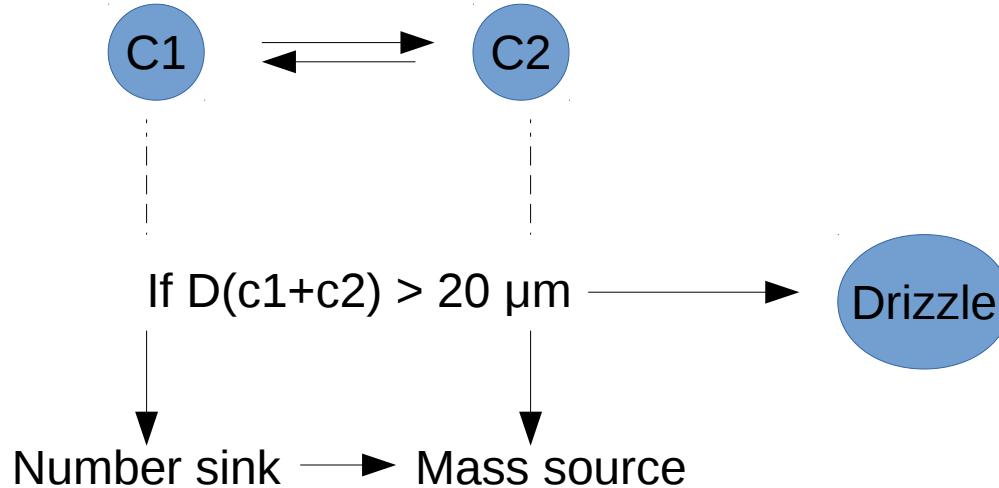
- UCLALES Large-eddy simulator coupled with SALSA aerosol-cloud model
- Size resolved representation for aerosol and cloud microphysical processes
- Condensation, coagulation – based on the semi-implicit method by Jacobson (2005)
- cloud activation deduced directly from aerosol growth
- ice nucleation, immersion, deposition and homogeneous freezing (Khvorostyanov and Curry. 2000)
- SO₄, OC, BC, SS, DU, NO₃, NH₄
- Rimed and unrimed ice ~ P3



Tools

UCLALES-SALSA

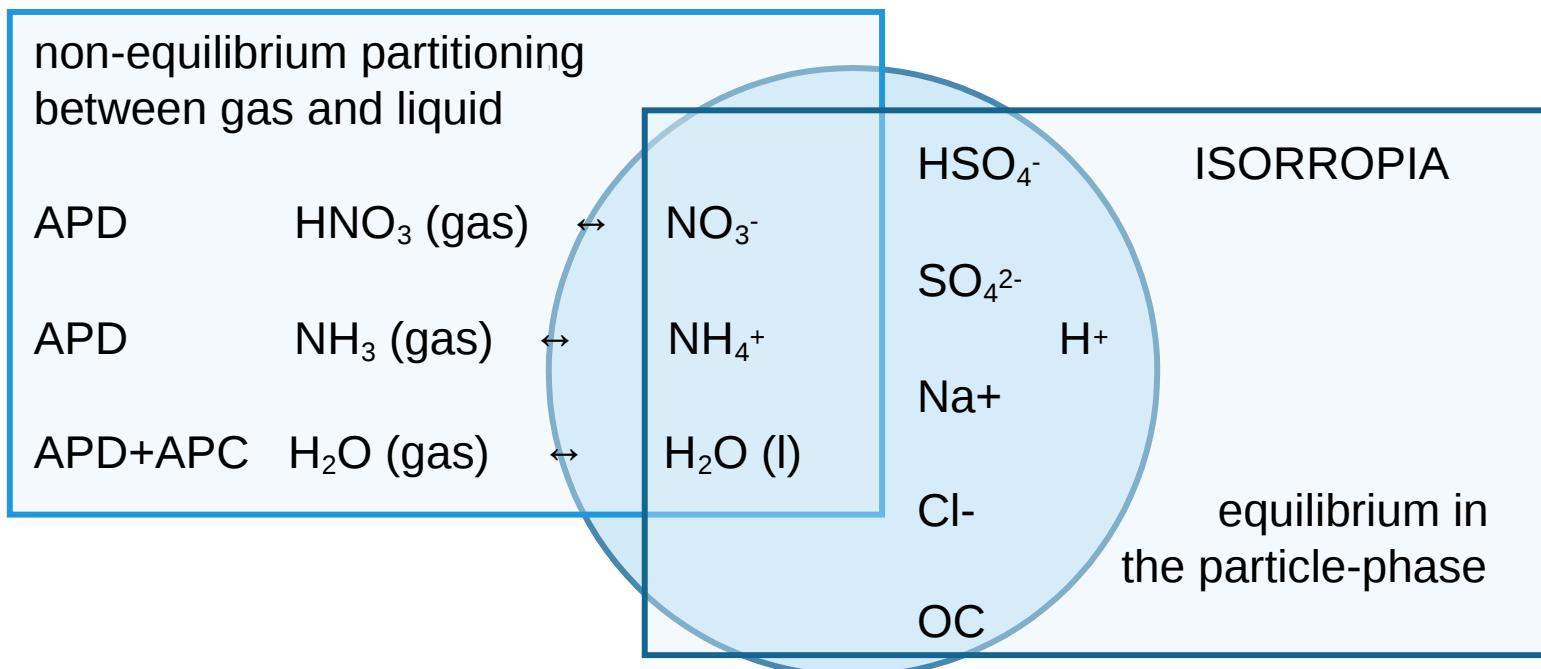
- SALSA precipitation formation
 - "precipitation" bins set to cover drizzle size range between cloud droplets and rain
 - Lower D = 20 μm
 - Transition from cloud droplets to smallest drizzle bin directly from coagulation solver



Semivolatile aerosol partitioning

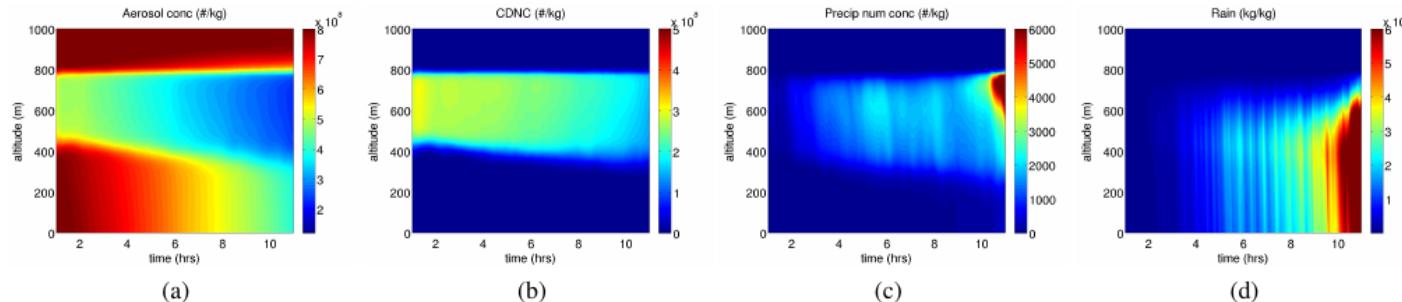
I. Kudzotsa, H. Kokkola

- Highly sensitive process \leftrightarrow computationally very challenging
 - Our solution based on a dissolution scheme (Jacobson 2005) + particle thermodynamics model

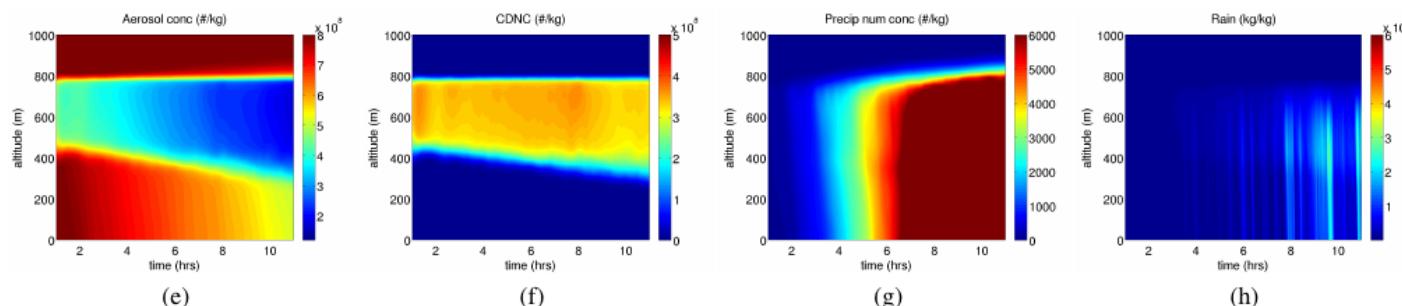


Semivolatile aerosol partitioning

I. Kudzotsa, H. Kokkola



CTRL



+3ppb
NH₃,HNO₃



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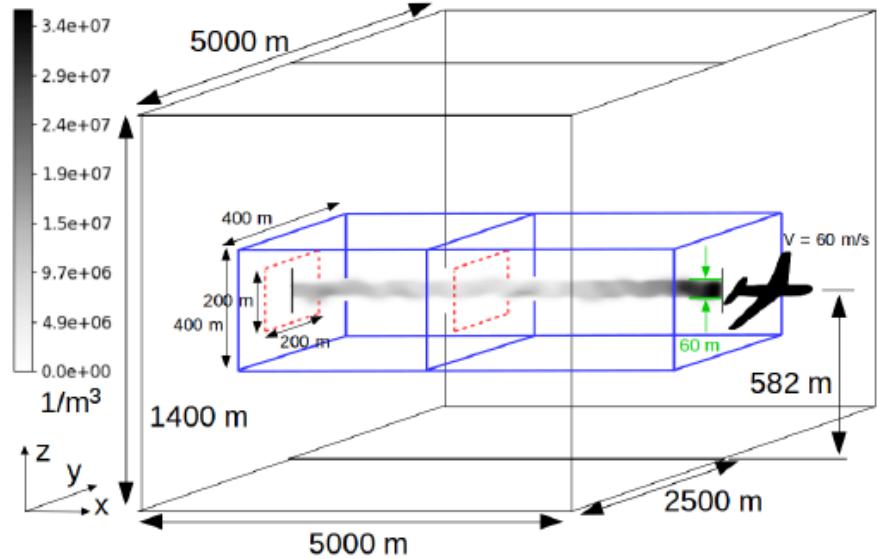
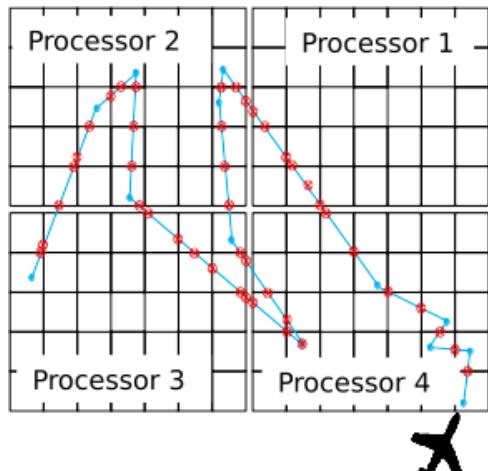
Precipitation enhancement

- Precipitation enhancement by cloud seeding to improve water security
- Lots of field experiments
- Scientific confidence relatively low
- Use a cloud resolving platform with state-of-the-art aerosol-cloud microphysical package to identify the key factors influencing seeding efficiency
- Focus primarily on microphysical processes and feedbacks with cloud dynamics
- Evaluation in a marine Sc scenario
- Work in progress for convective cloud cases based on data from the UAE

Precipitation enhancement

A. Afzalifar

- Moving point source aerosol emissions
 - Aerosol seeding from an aircraft
 - Velocity
 - emission rate
 - type
 - size distribution



Precipitation enhancement

A stratocumulus case study

- Field experiment with hygroscopic seeding in marine Sc

Atmos. Chem. Phys., 15, 5645–5658, 2015
www.atmos-chem-phys.net/15/5645/2015/
doi:10.5194/acp-15-5645-2015
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Precipitation effects of giant cloud condensation nuclei artificially introduced into stratocumulus clouds

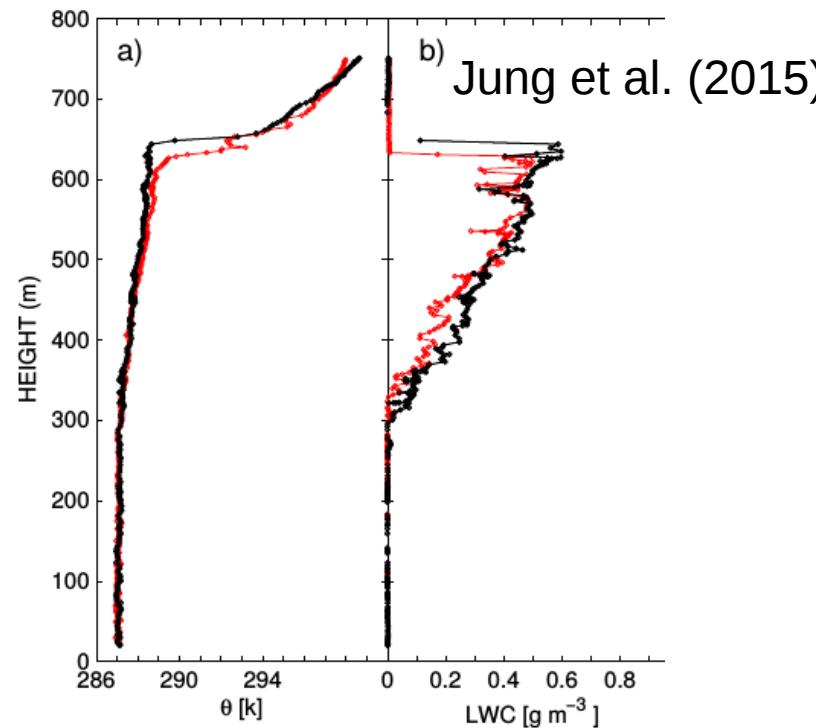
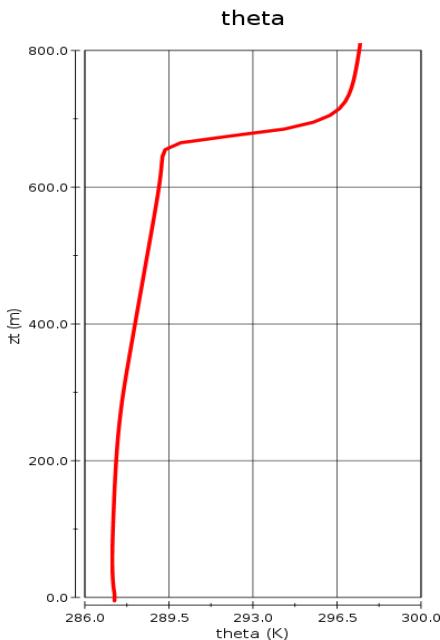
E. Jung¹, B. A. Albrecht¹, H. H. Jonsson², Y.-C. Chen^{3,4}, J. H. Seinfeld³, A. Sorooshian⁵, A. R. Metcalf^{3,*}, S. Song¹, M. Fang¹, and L. M. Russell⁶

- Evaluate the simulated microphysical response
- Sea salt aerosol as proxy for seeding aerosol
- 50 m resolution (10 m in the vertical), 1 s timestep, 5 km domain

Precipitation enhancement

A stratocumulus case study

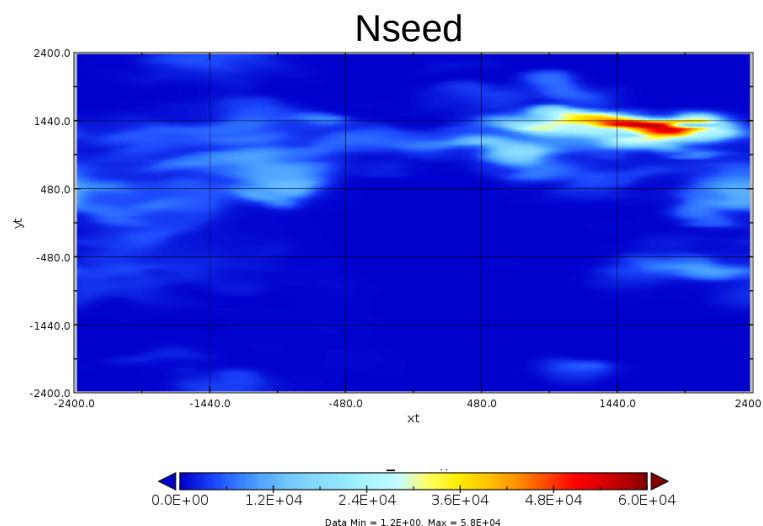
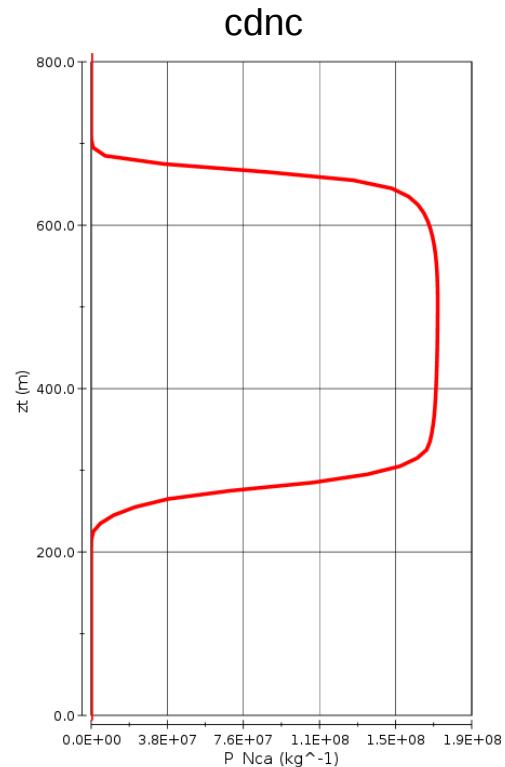
- Pre-seeding mean state



Precipitation enhancement

A stratocumulus case study

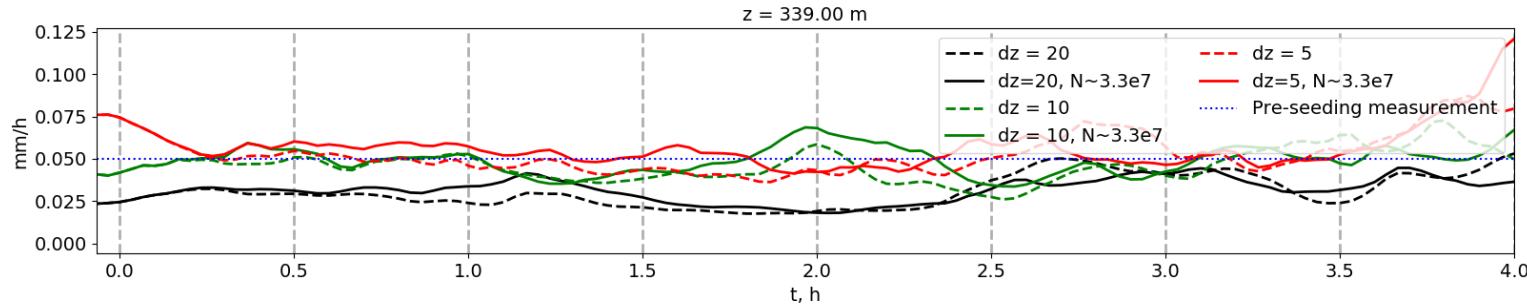
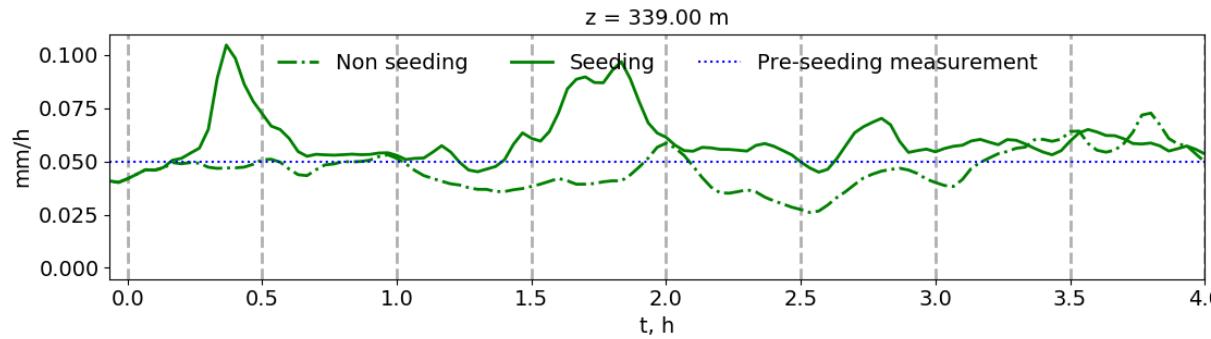
- Reported pre-seeding CDNC $\sim 150\text{-}200 \text{ cm}^{-3}$
- Model initial conditions
 - Background: Acc 200 cm^{-3} ,
GCCN 1 cm^{-3}
- Reported seeding aerosol
 - Expected $10^{-3} \text{ -- } 10^{-2} \text{ cm}^{-3}$, $5 \mu\text{m}$



Precipitation enhancement

A stratocumulus case study

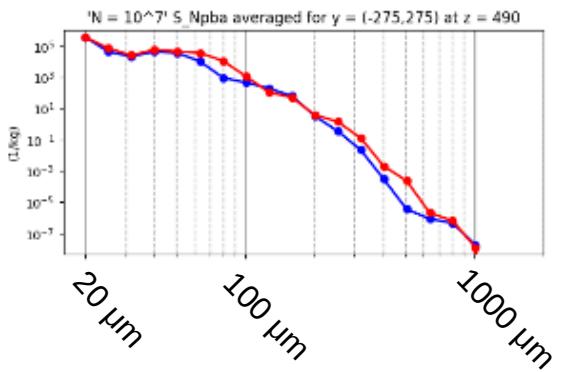
- Overall precipitation rate close to reported
- Periodical increase of precipitation from seeding, up to 2-fold
- Effect of (vertical) resolution
- Measured seeding efficiency stronger



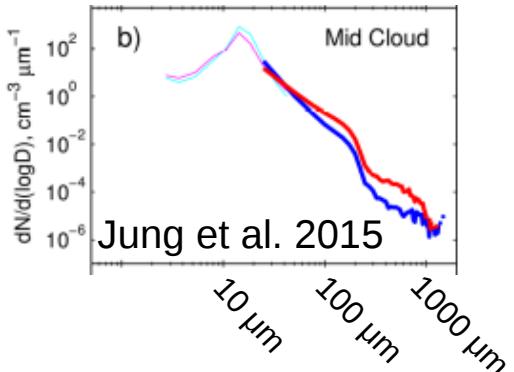
Precipitation enhancement

A stratocumulus case study

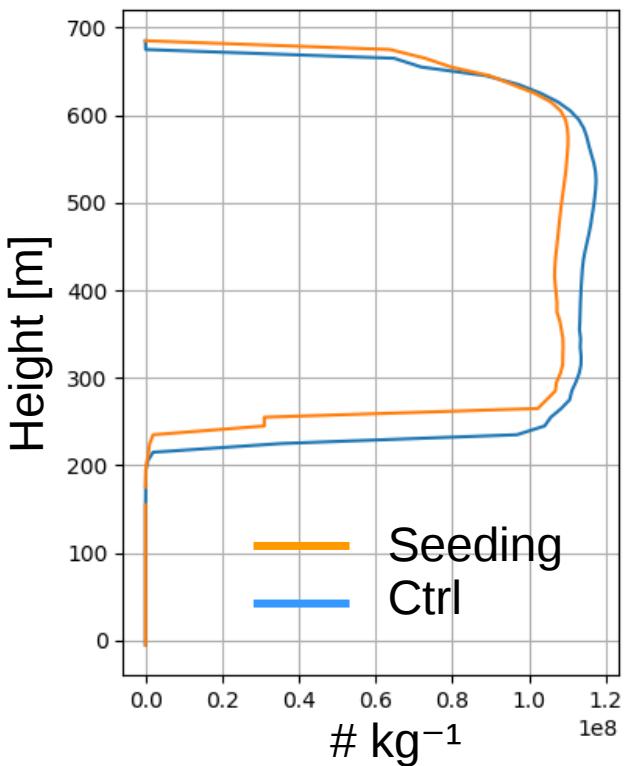
model



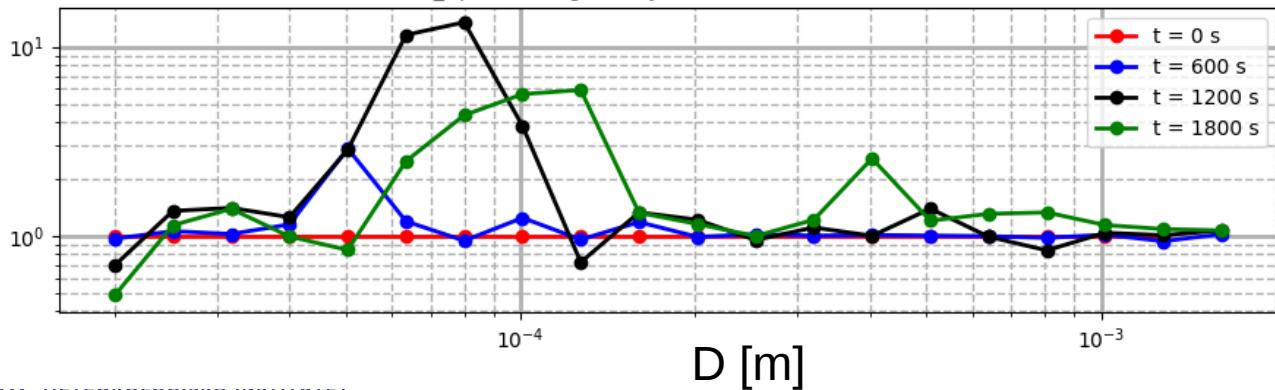
observed



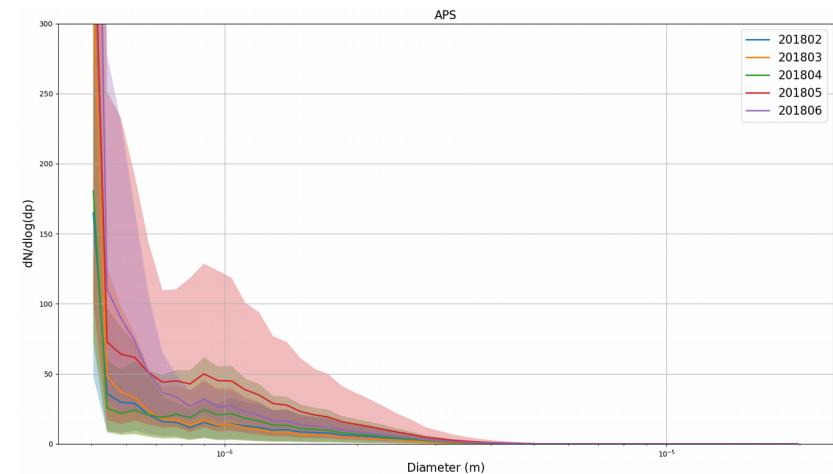
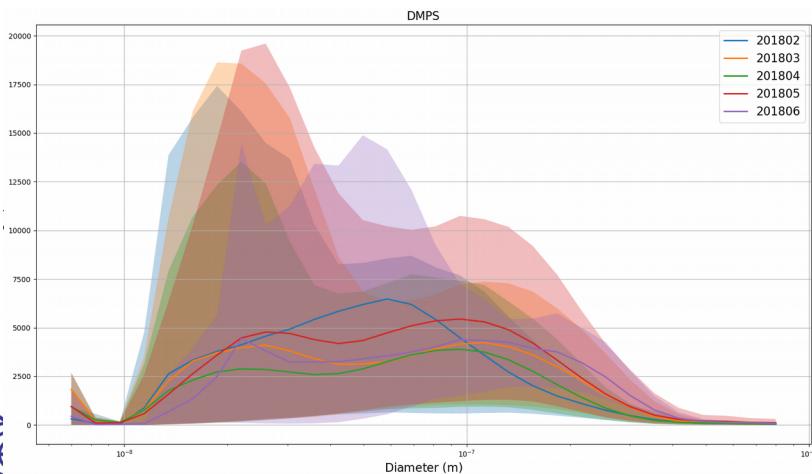
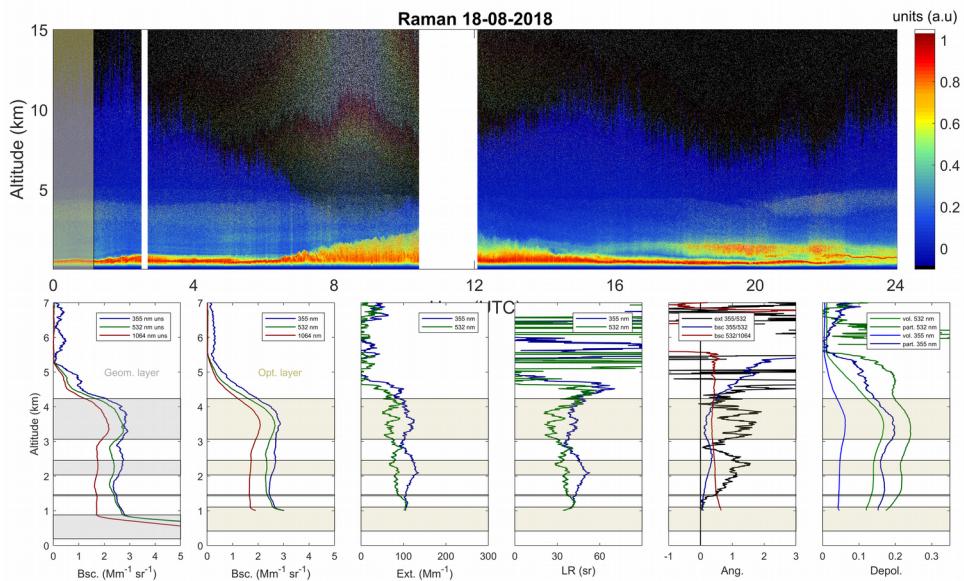
CDNC



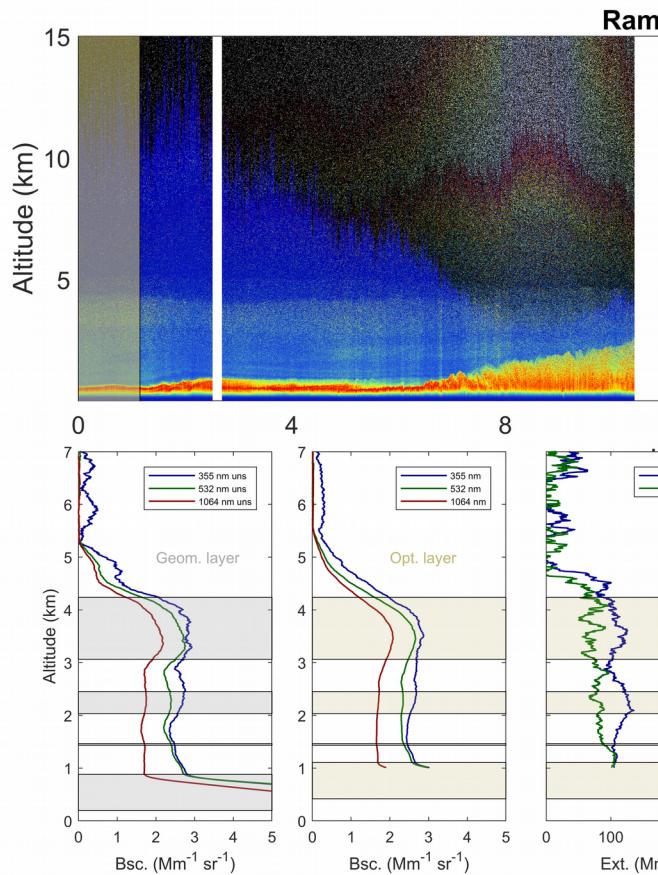
Relative S_Npba , averaged for $y = (-225.00, 225.00)$ at $z = 339.00$



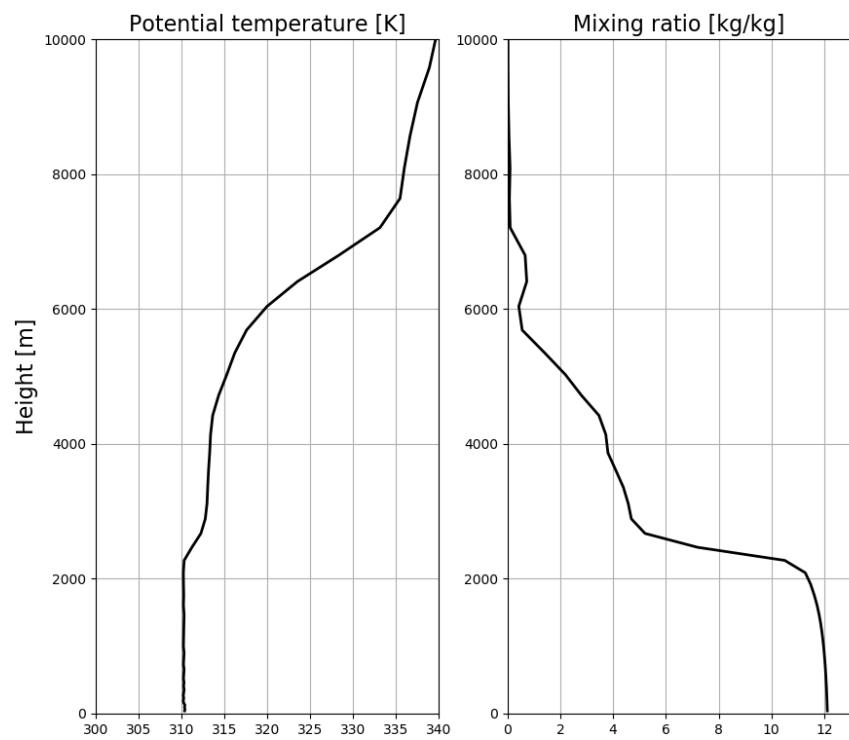
Cloud seeding in moderate convective clouds over the UAE



Cloud seeding in moderate convective clouds over the UAE



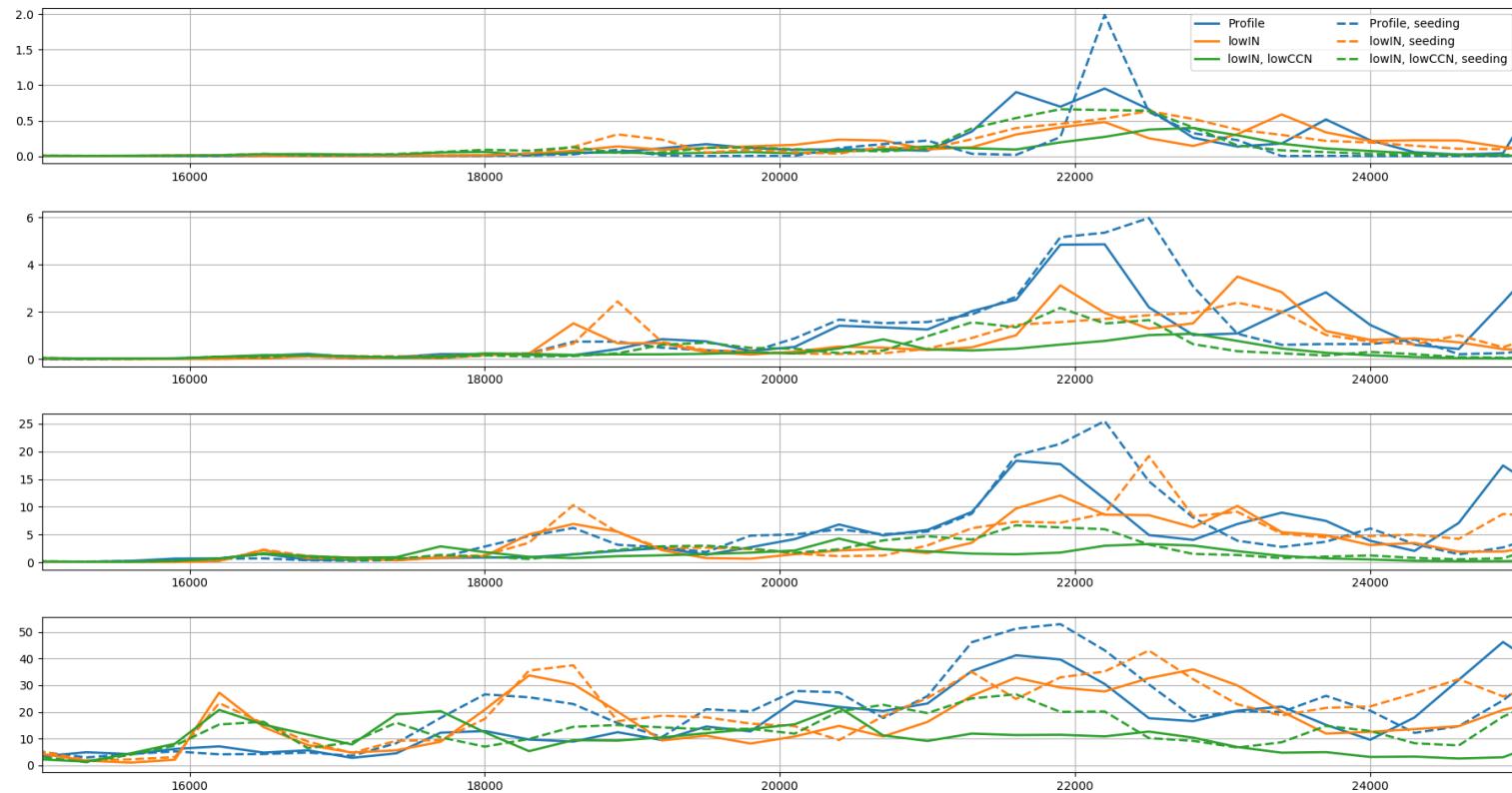
On-site measurements



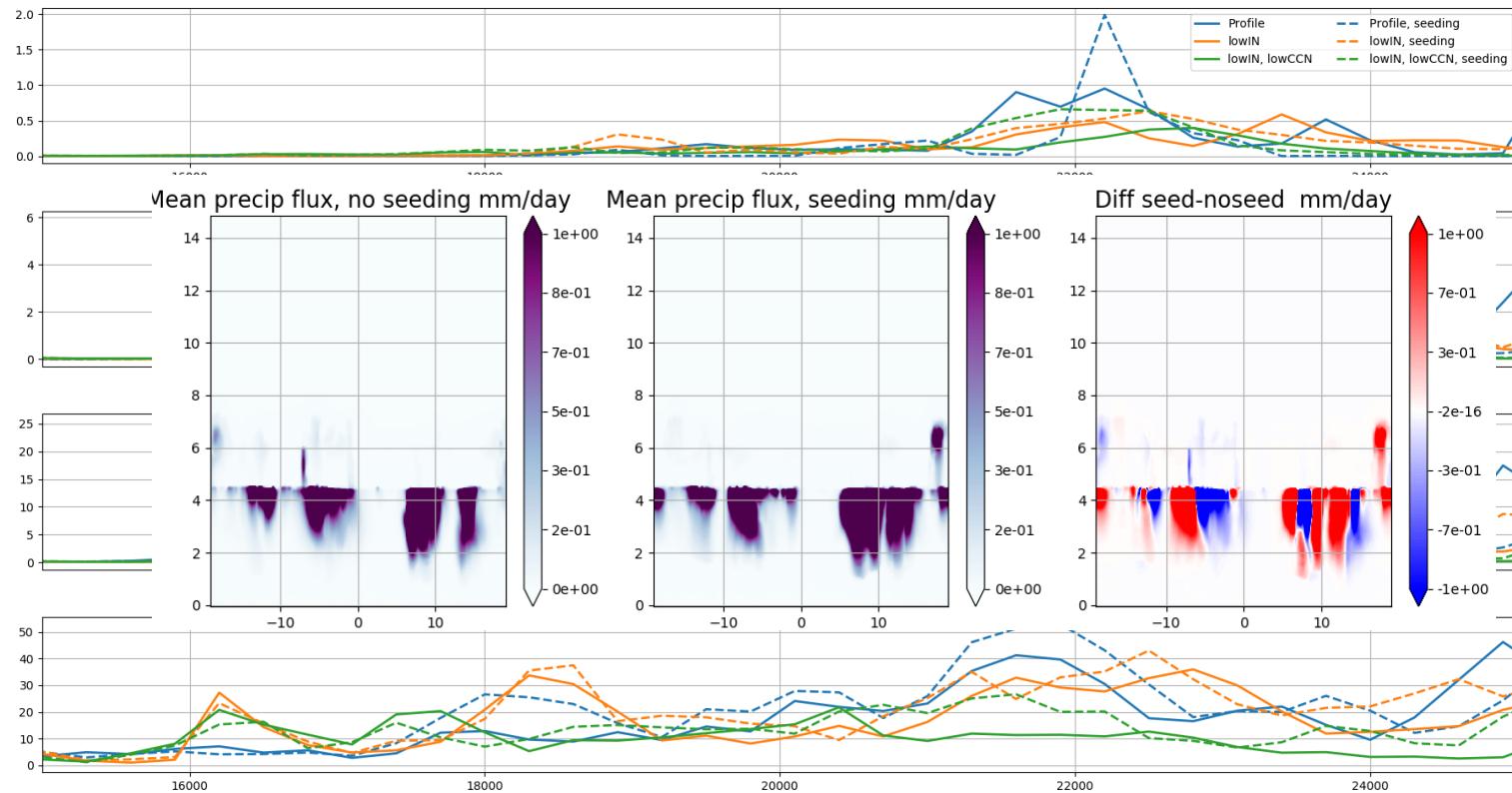
HARMONIE simulation



Cloud seeding in moderate convective clouds over the UAE



Cloud seeding in moderate convective clouds over the UAE



Summary

- UCLALES-SALSA cloud resolving bin microphysics model for aerosol-cloud studies
- Several aerosol species in all particle and hydrometeor categories
 - Including dynamic partitioning of semivolatile aerosol
- Rain enhancement studies
 - Evaluation of the model in a marine Sc setup
 - Good agreement with pre-seeding conditions vs field experiment data
 - Effect of seeding captured, albeit weaker than observed
 - Work ongoing with convective clouds over UAE
 - Hygroscopic seeding vs ice phase in mixed phase clouds?
 - Aerosol layering vs inversion heights