On numerical modelling of clouds and precipitation

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Piotr Bartman[1]
Michael Olesik[2]

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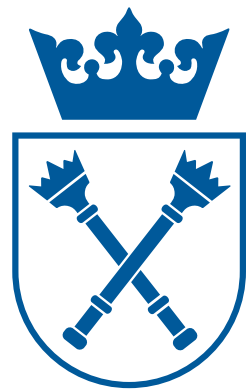
2: Marian Smoluchowski Institute of Physics



2nd Kraków Interdisciplinary Science Seminar (KISS 2020), January 2020

Cloud evolution: conceptual picture

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background image: vitsly.ru / Hokusai

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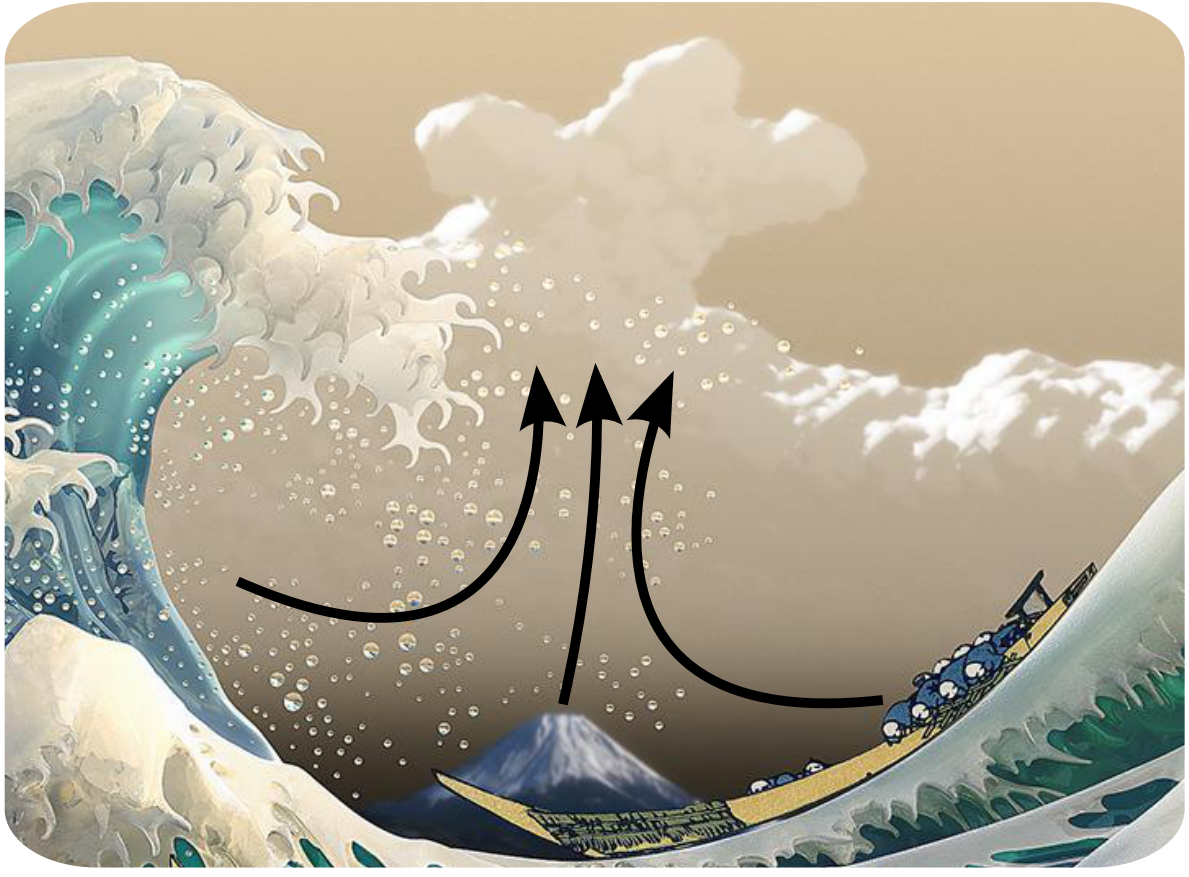
Cloud evolution: conceptual picture

- aerosol particles of natural and anthropogenic origin act as condensation nuclei



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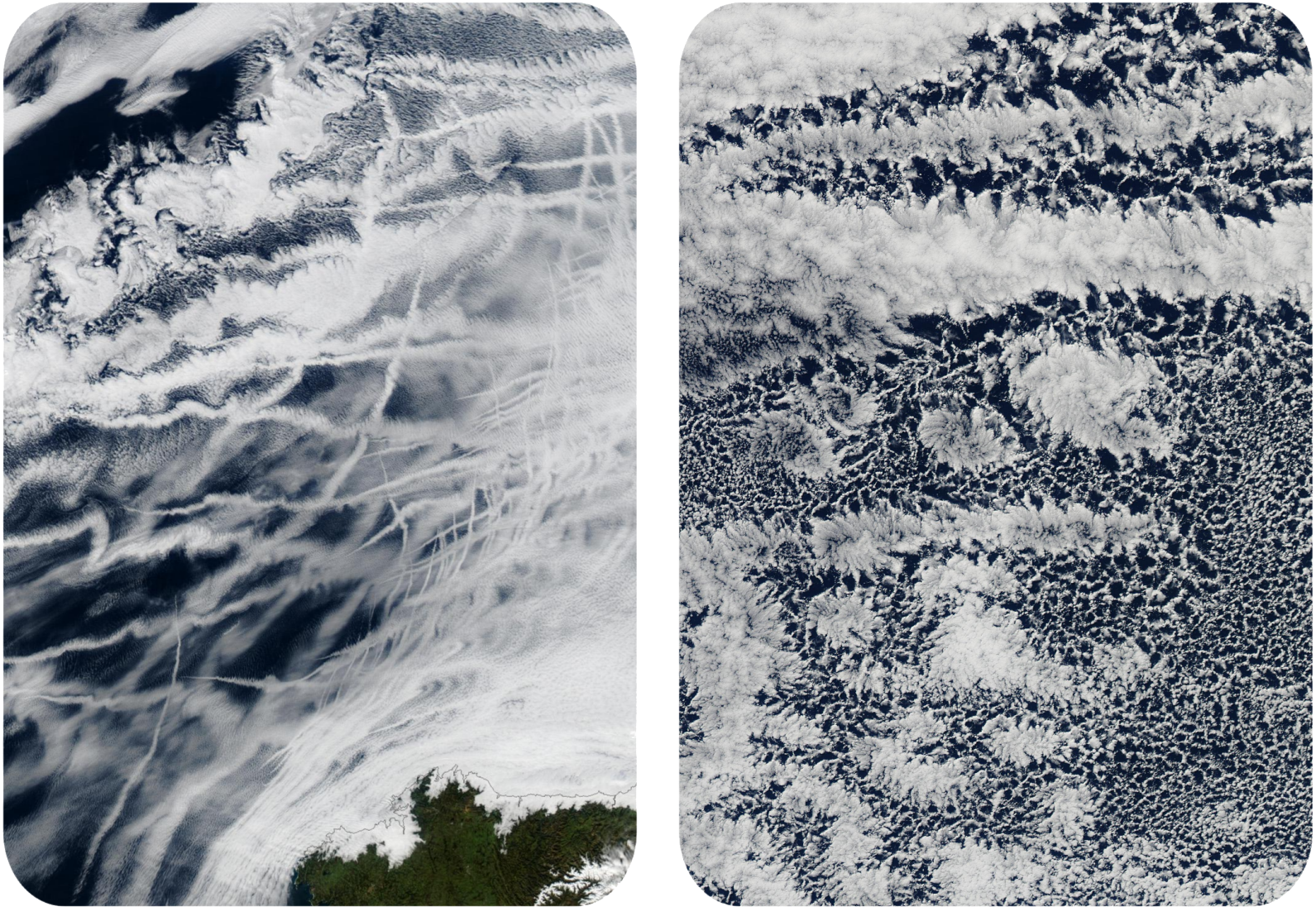
- cloud droplets grow by water vapour condensation
- rain drops form through collisions of cloud droplets
- aqueous chemical reactions irreversibly modify the drop composition
- rain drops precipitate washing out aerosol
- rain drops evaporate into aerosol particles of potentially altered size and/or composition (collisions, chemistry)

background image: vitsly.ru / Hokusai

Cloud evolution: as seen from space



NASA/MODIS (27 Jan 2003 – Bay of Biscay; 17 Apr 2010 – off the coast of Peru)
http://visibleearth.nasa.gov/view.php?id=64992
http://earthobservatory.nasa.gov/IOTD/view.php?id=43795

Cloud evolution: modelling μ-physics

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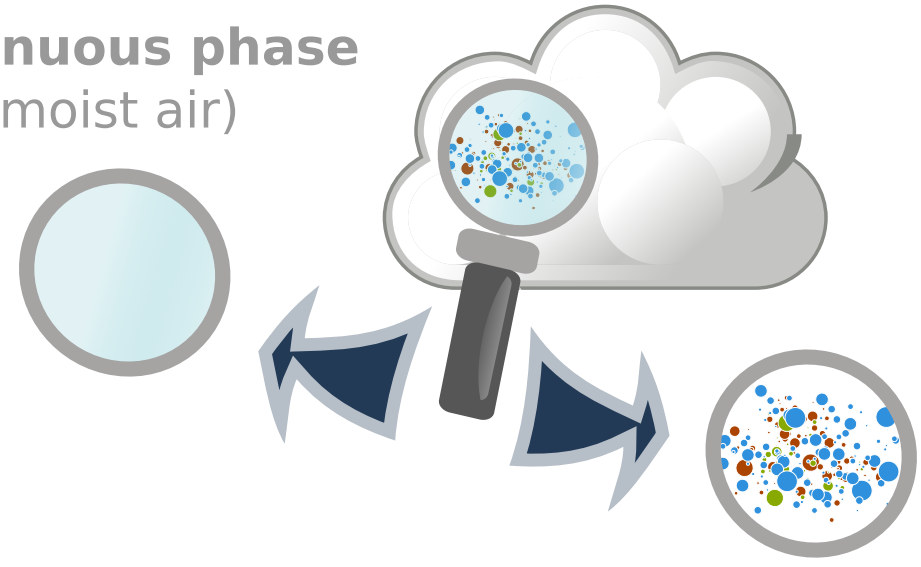

dispersed phase

(aerosol particles, cloud droplets, drizzle, rain, snow, ...)

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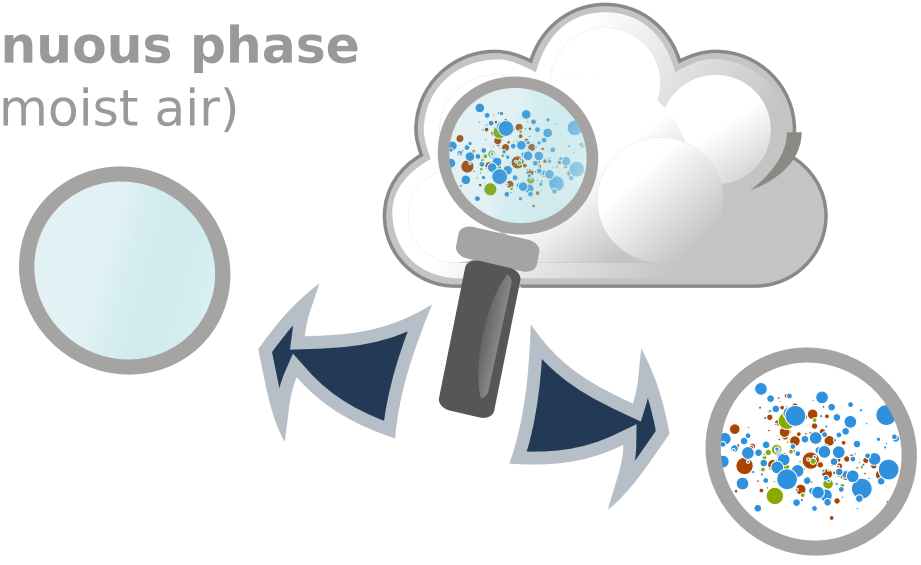

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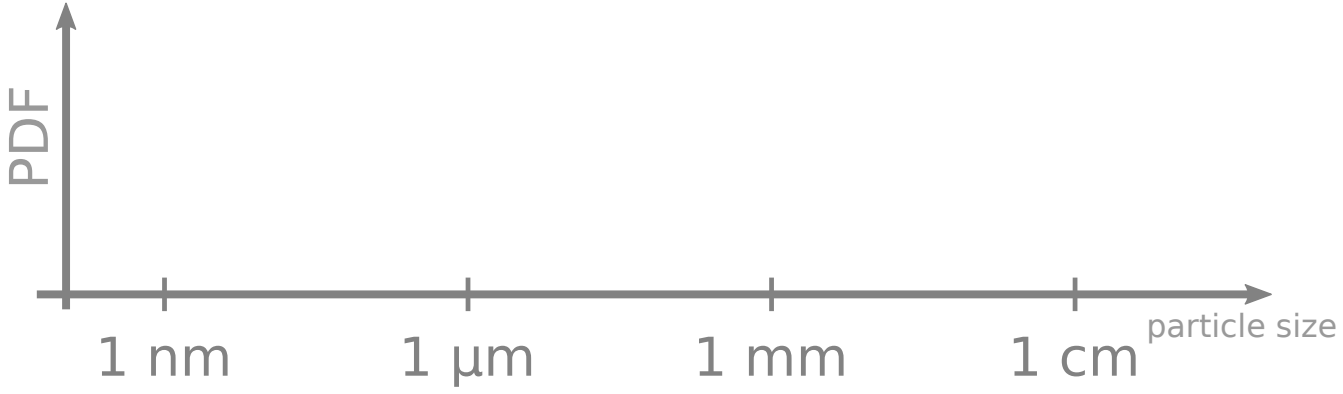

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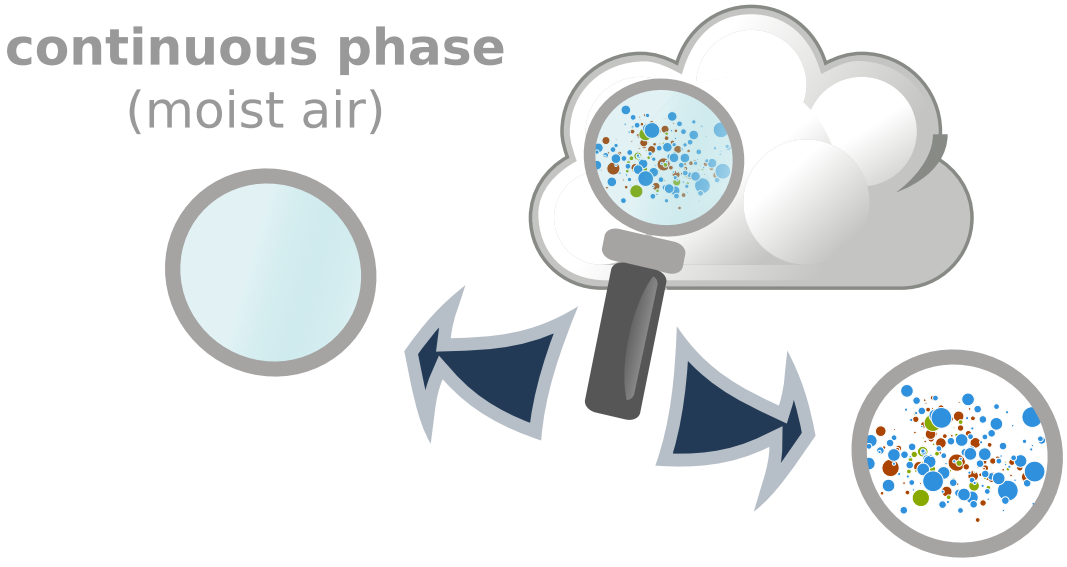

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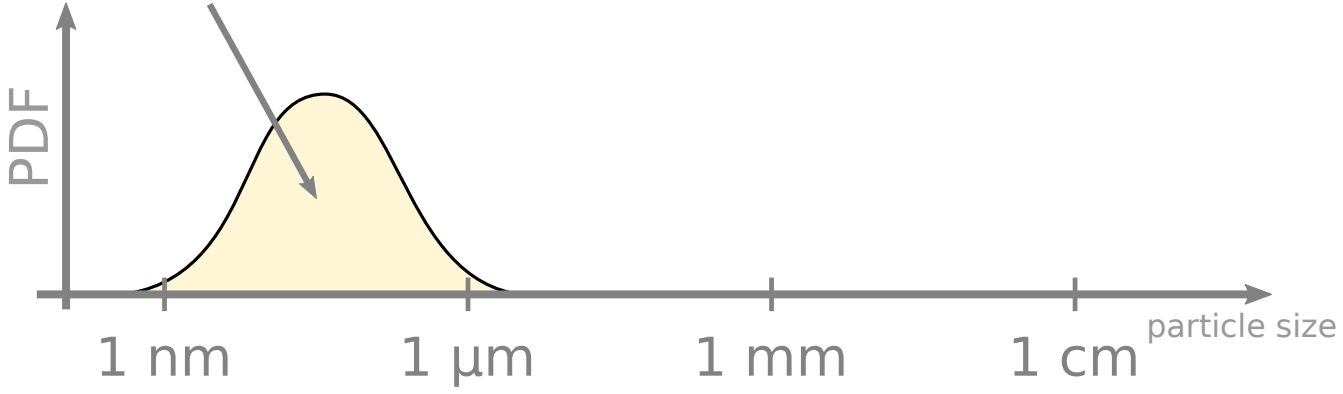

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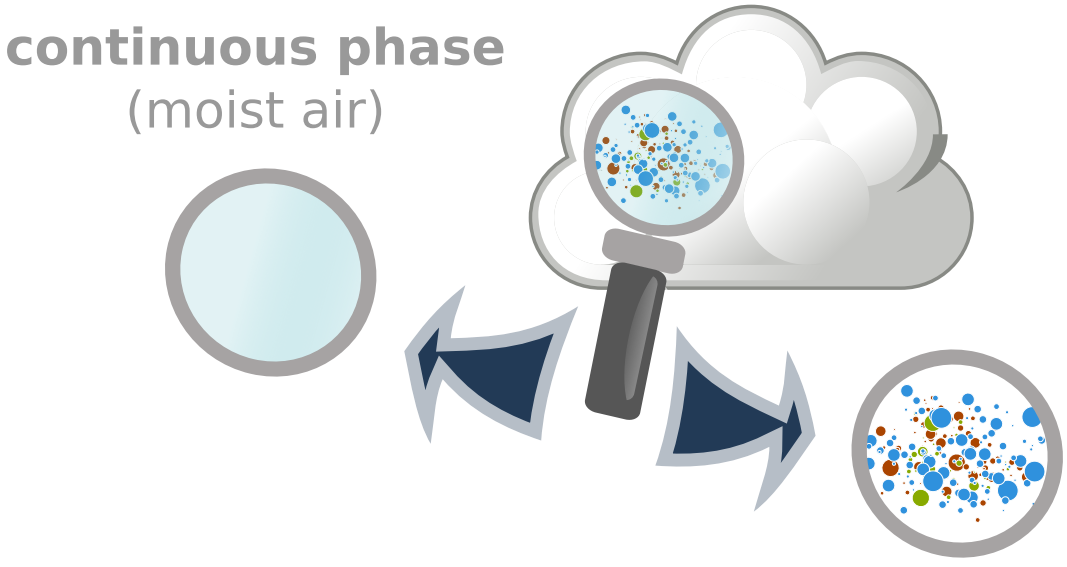

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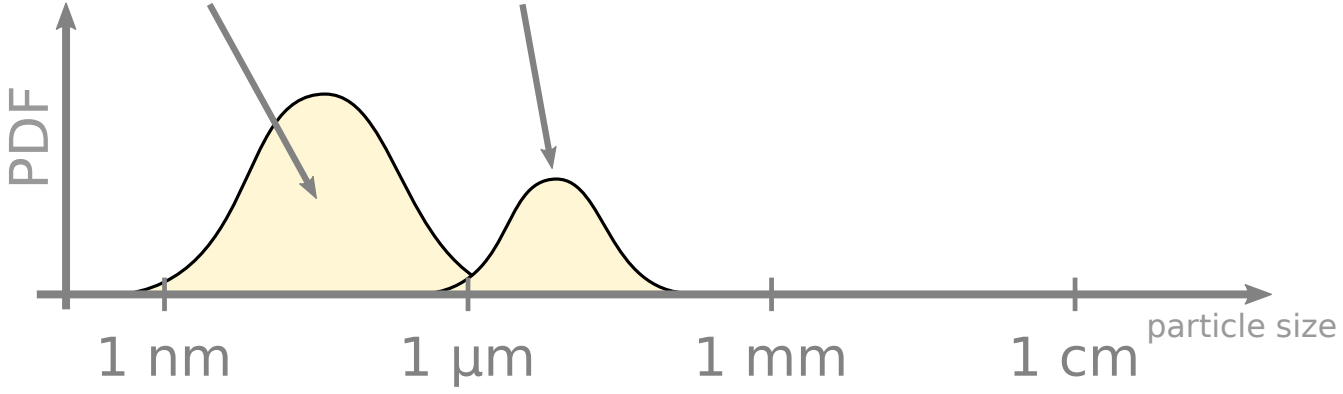

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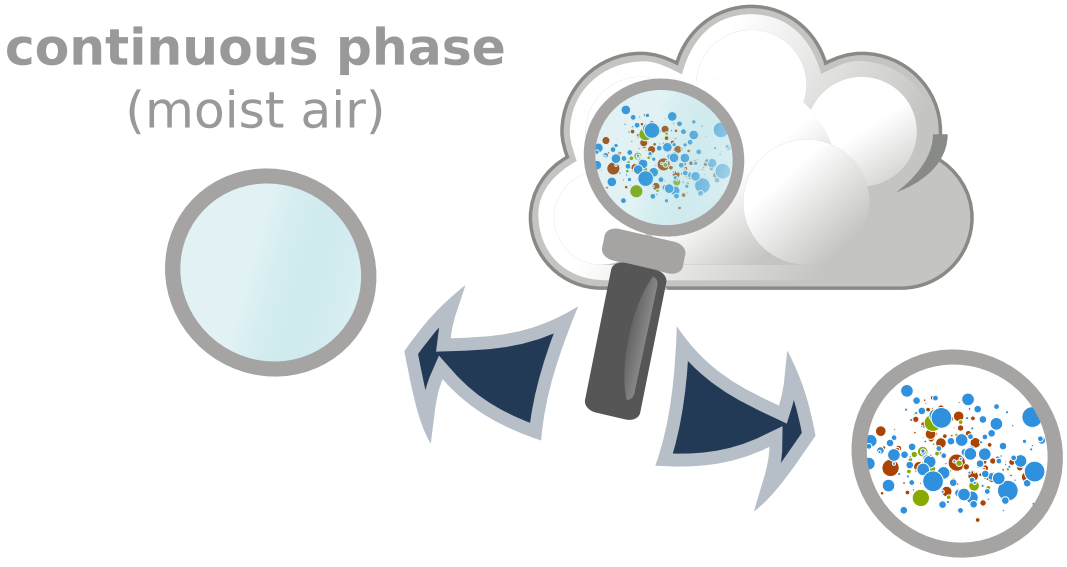

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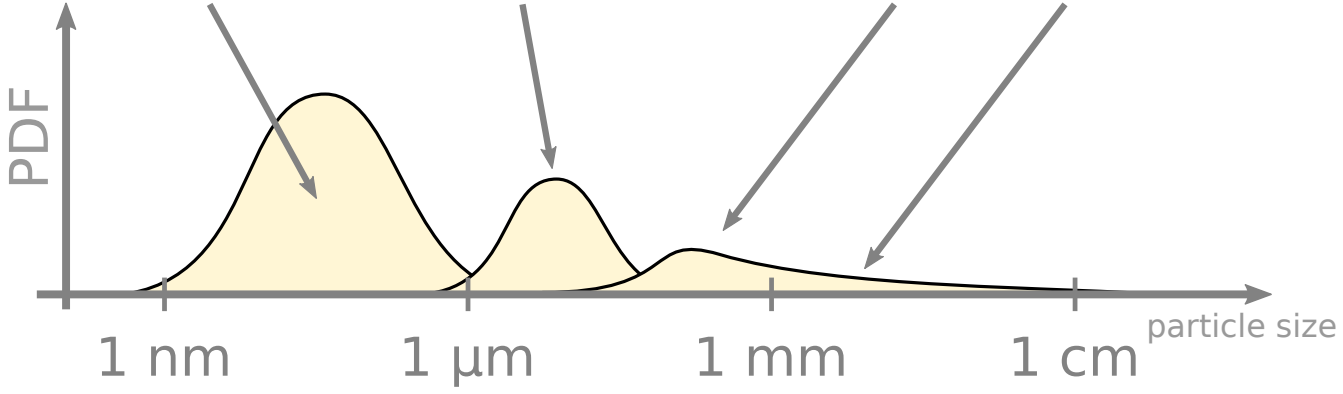

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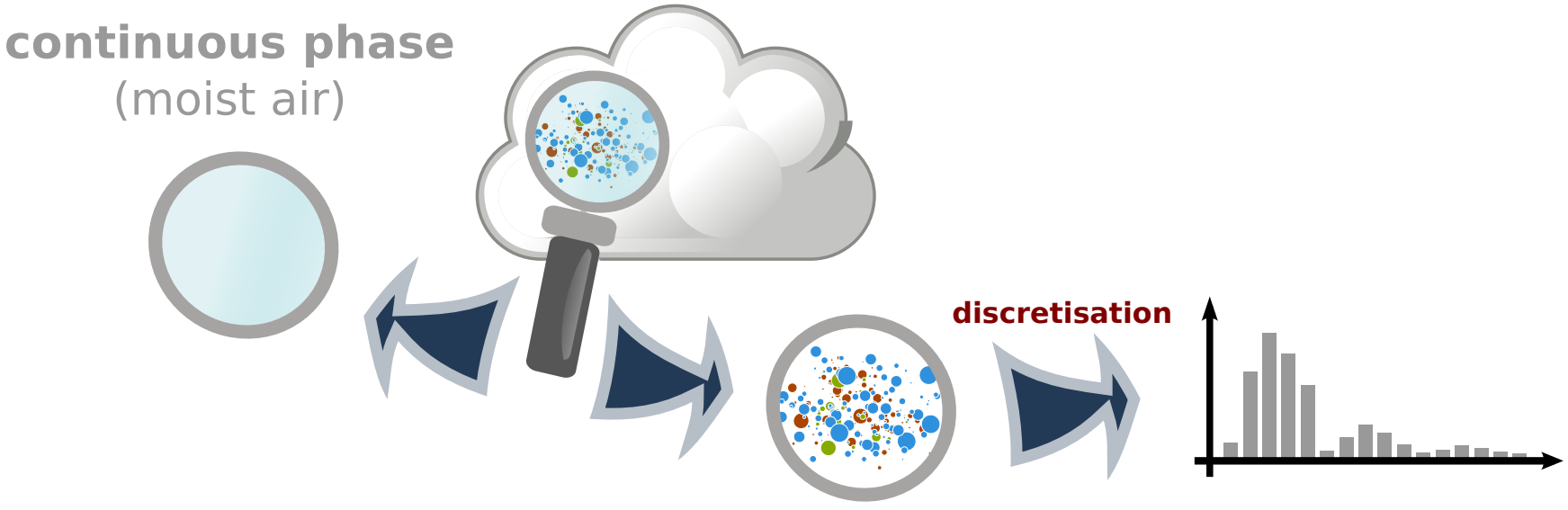

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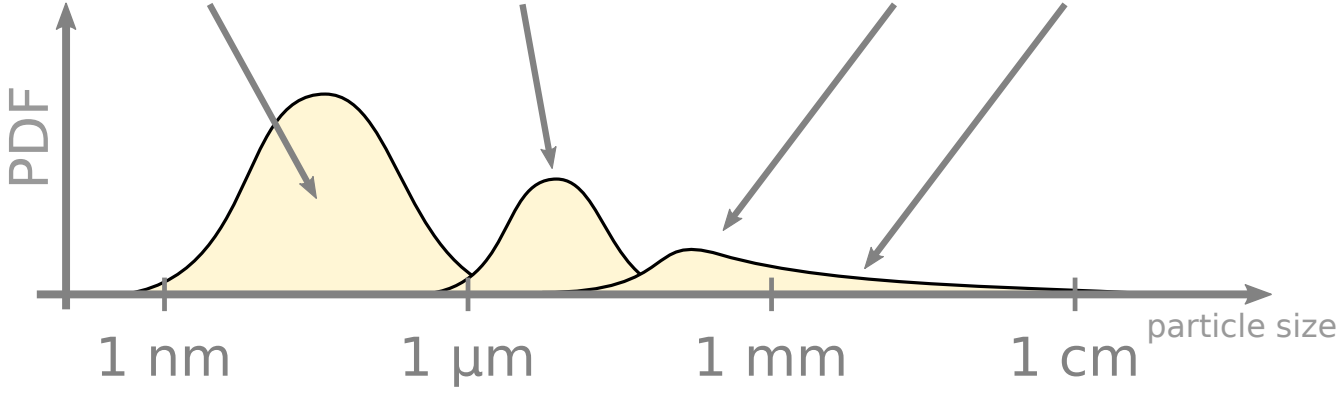

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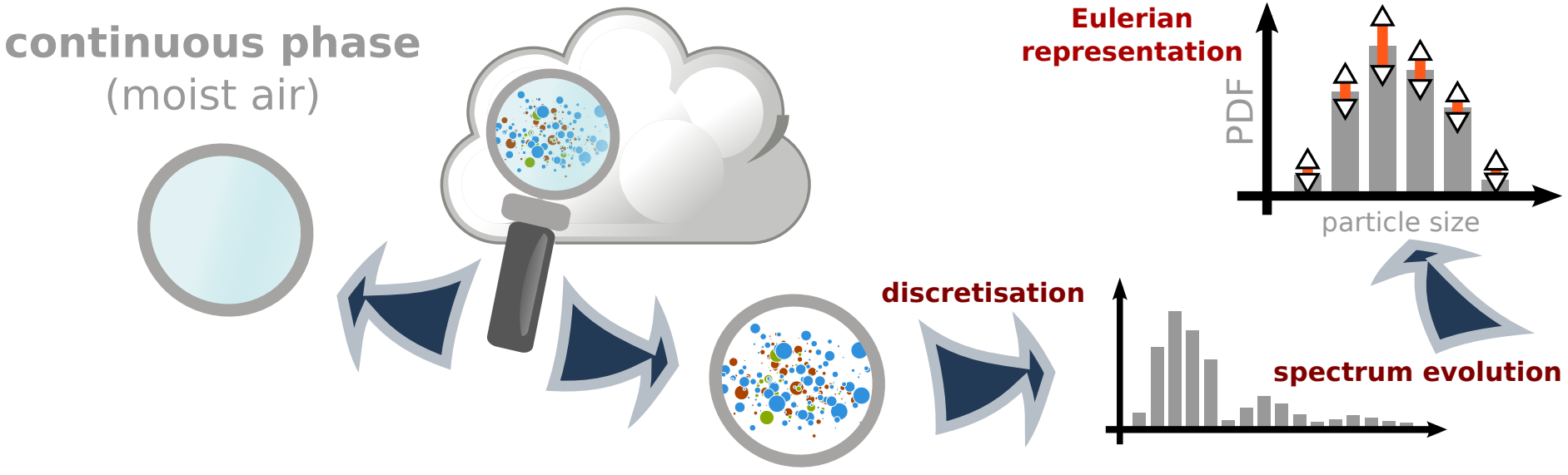

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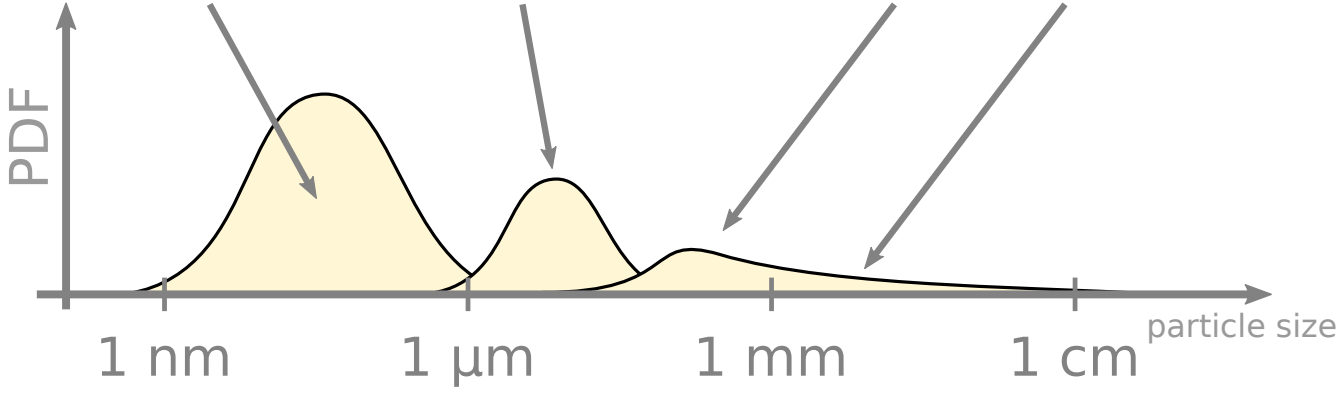

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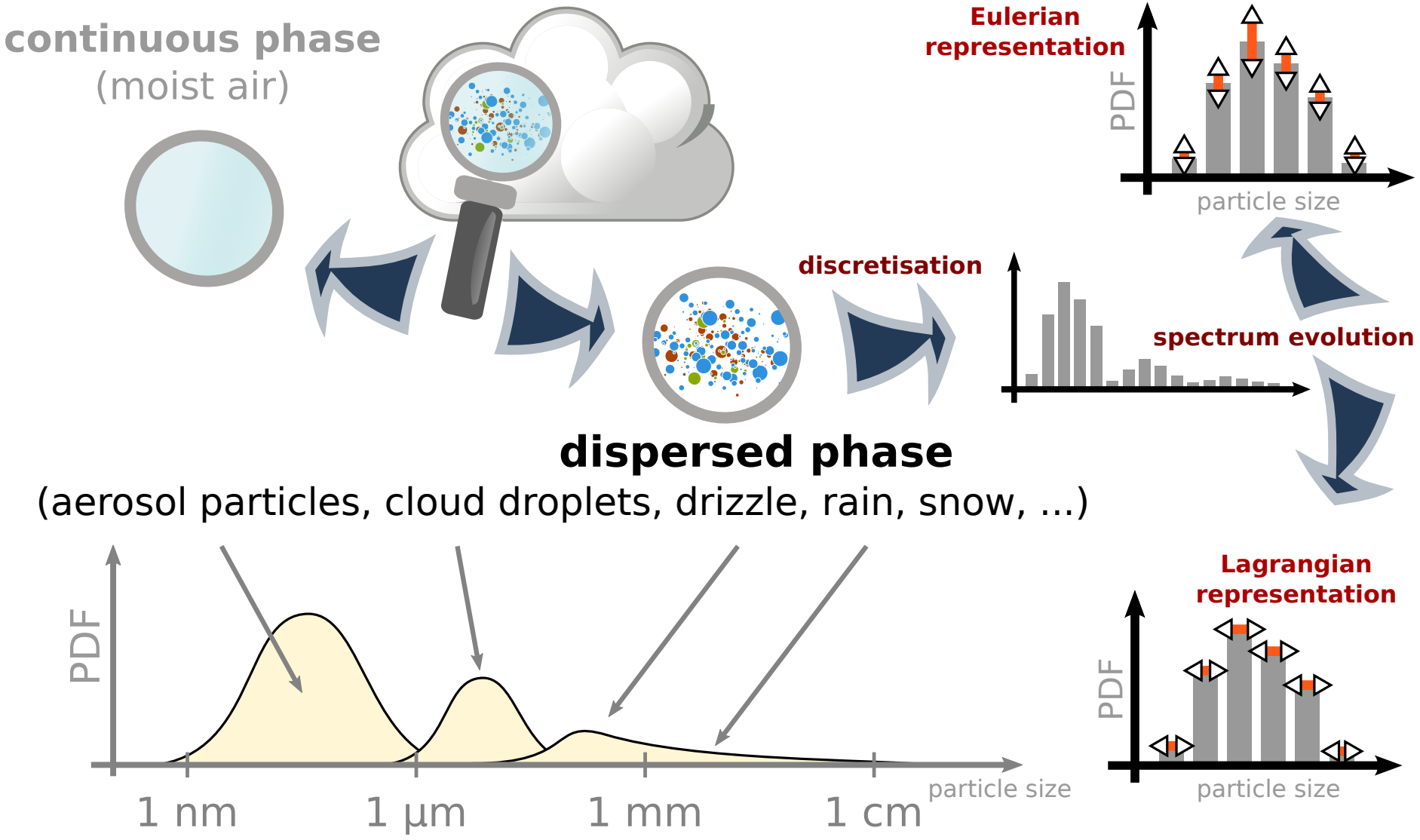
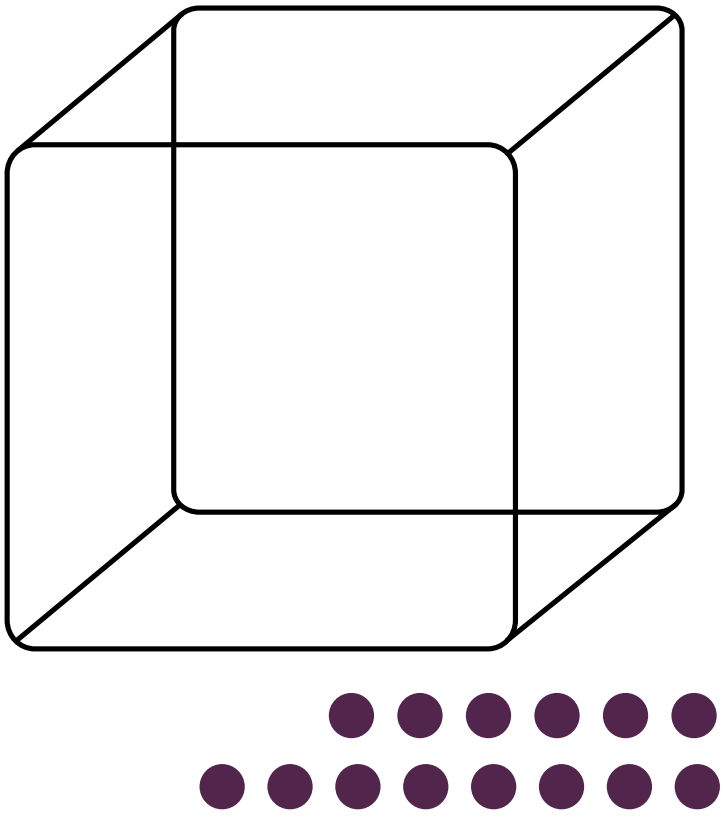


particle-based μ-physics: key concepts



Domain randomly populated with
"μ-physics information carriers"
(super particles / super droplets)

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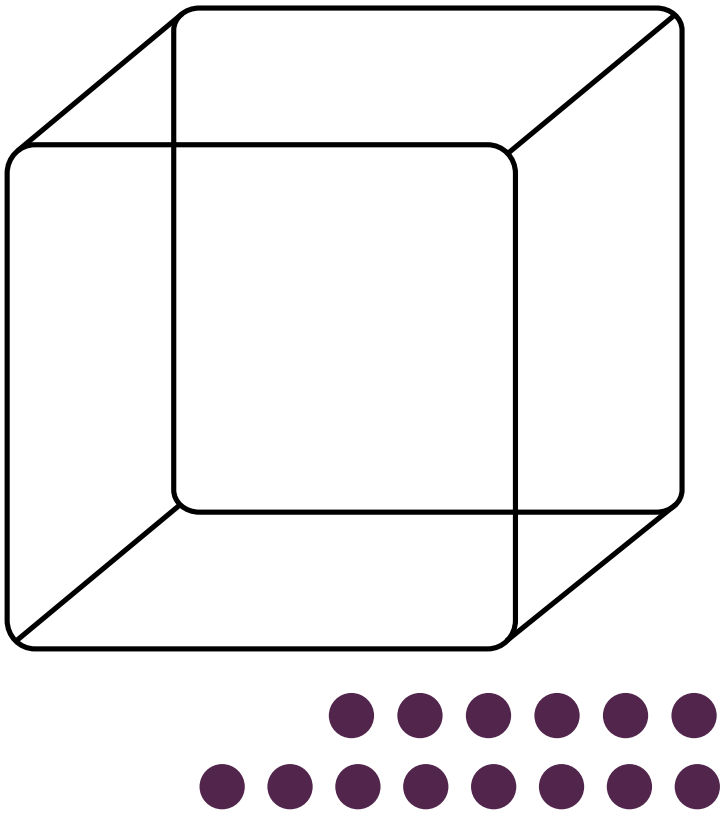

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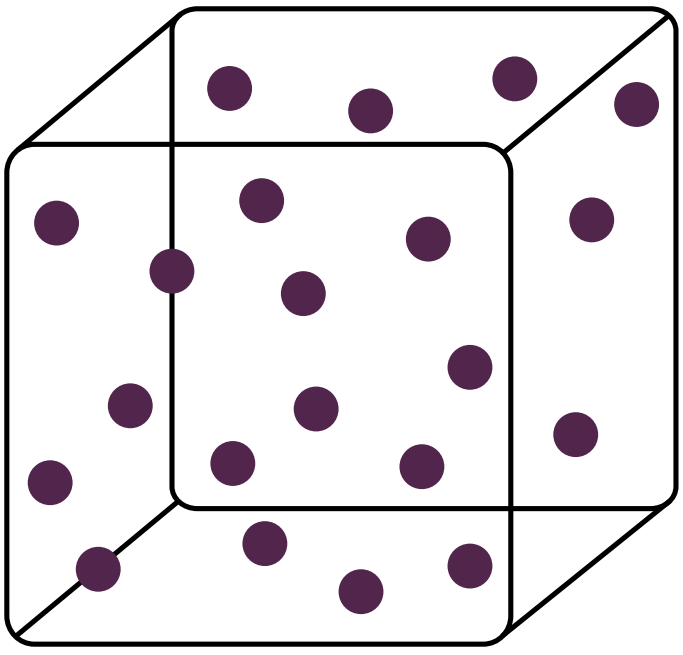

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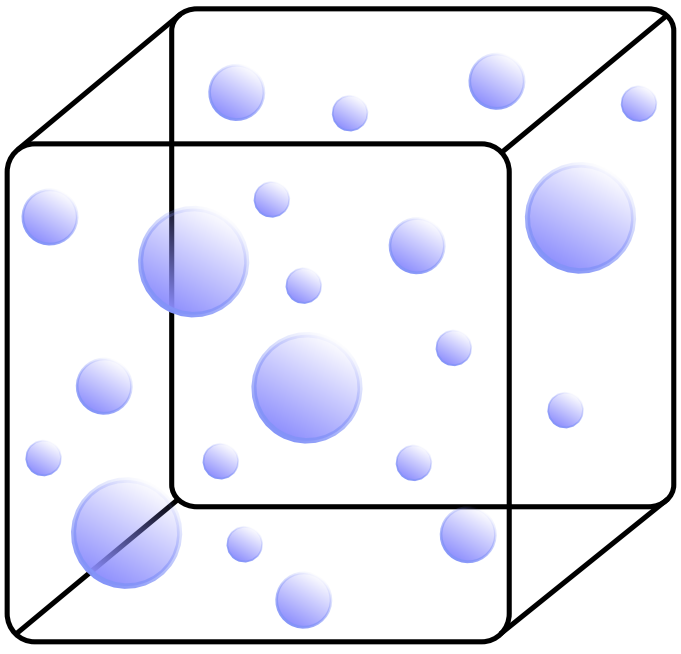

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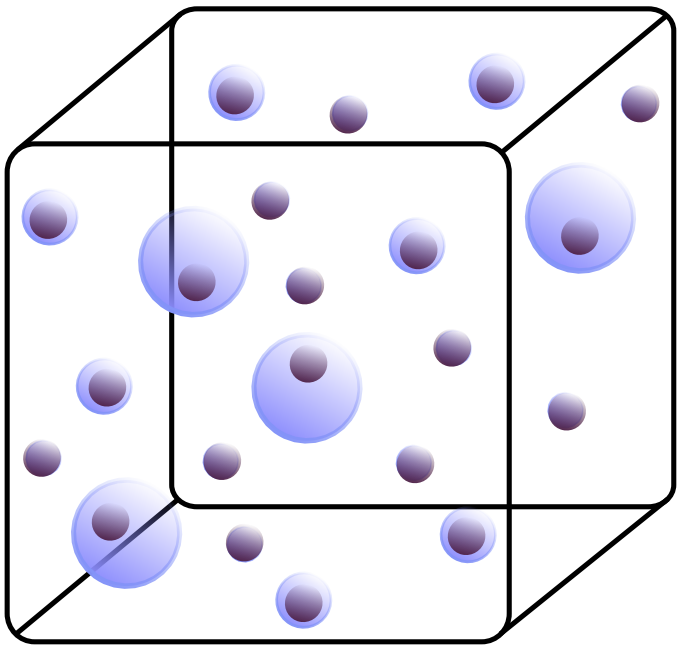

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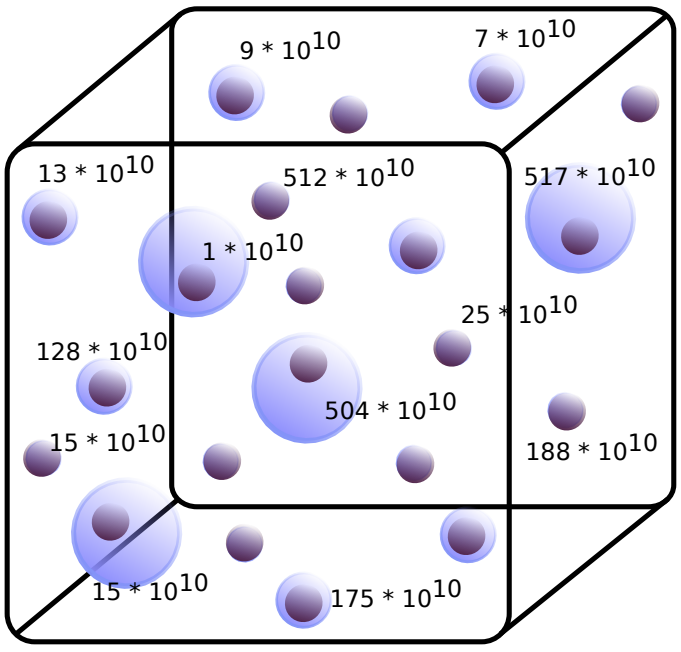

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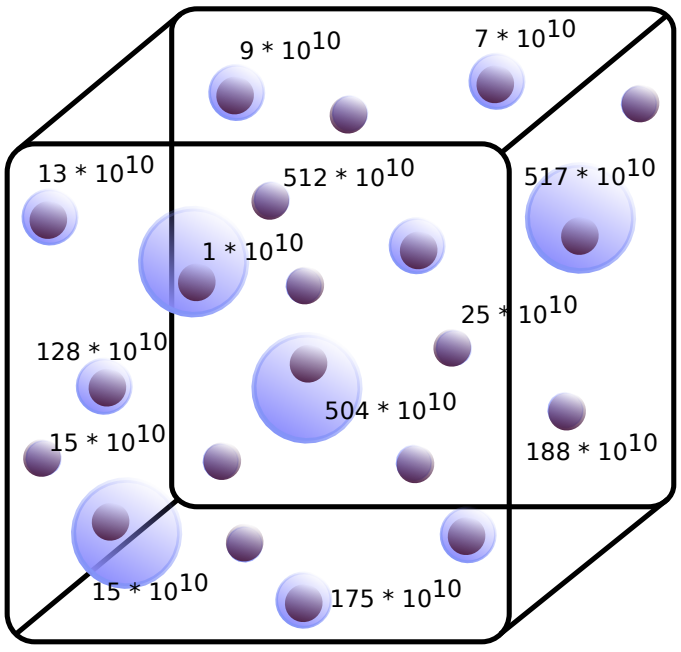

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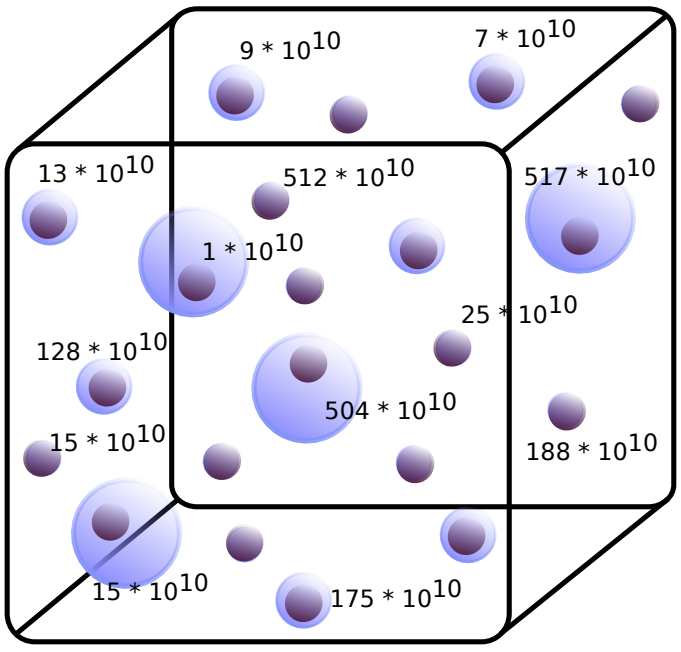

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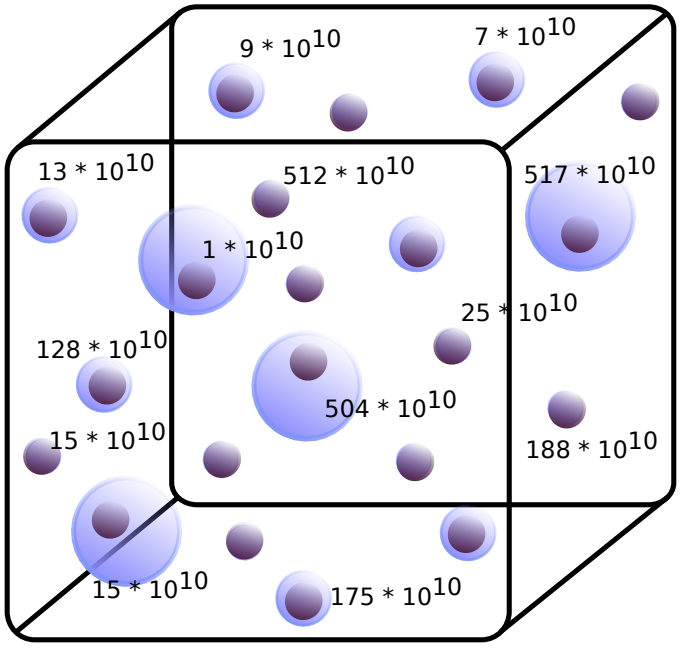

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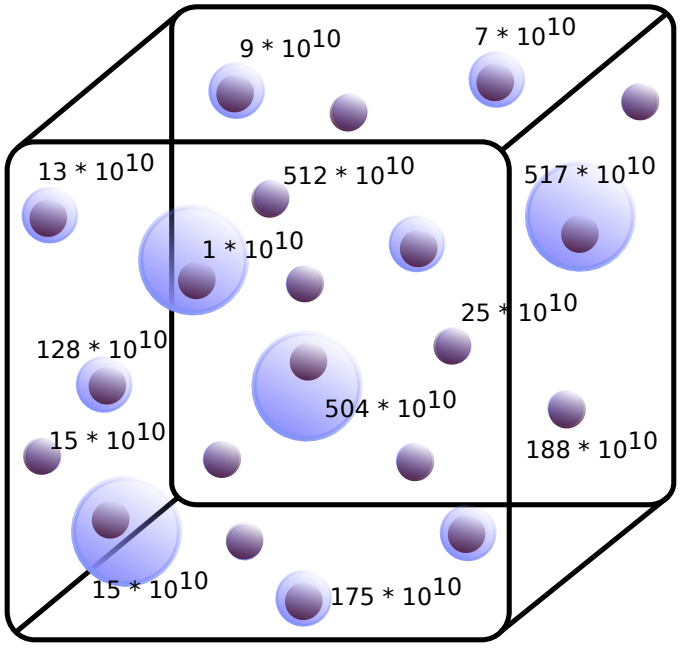

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Eulerian / PDE	Lagrangian / ODE

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challenges:

- scalability (cost vs. number of particles),
- super-particles "conservation" (coalescence!)

example simulation (2D, prescribed flow)

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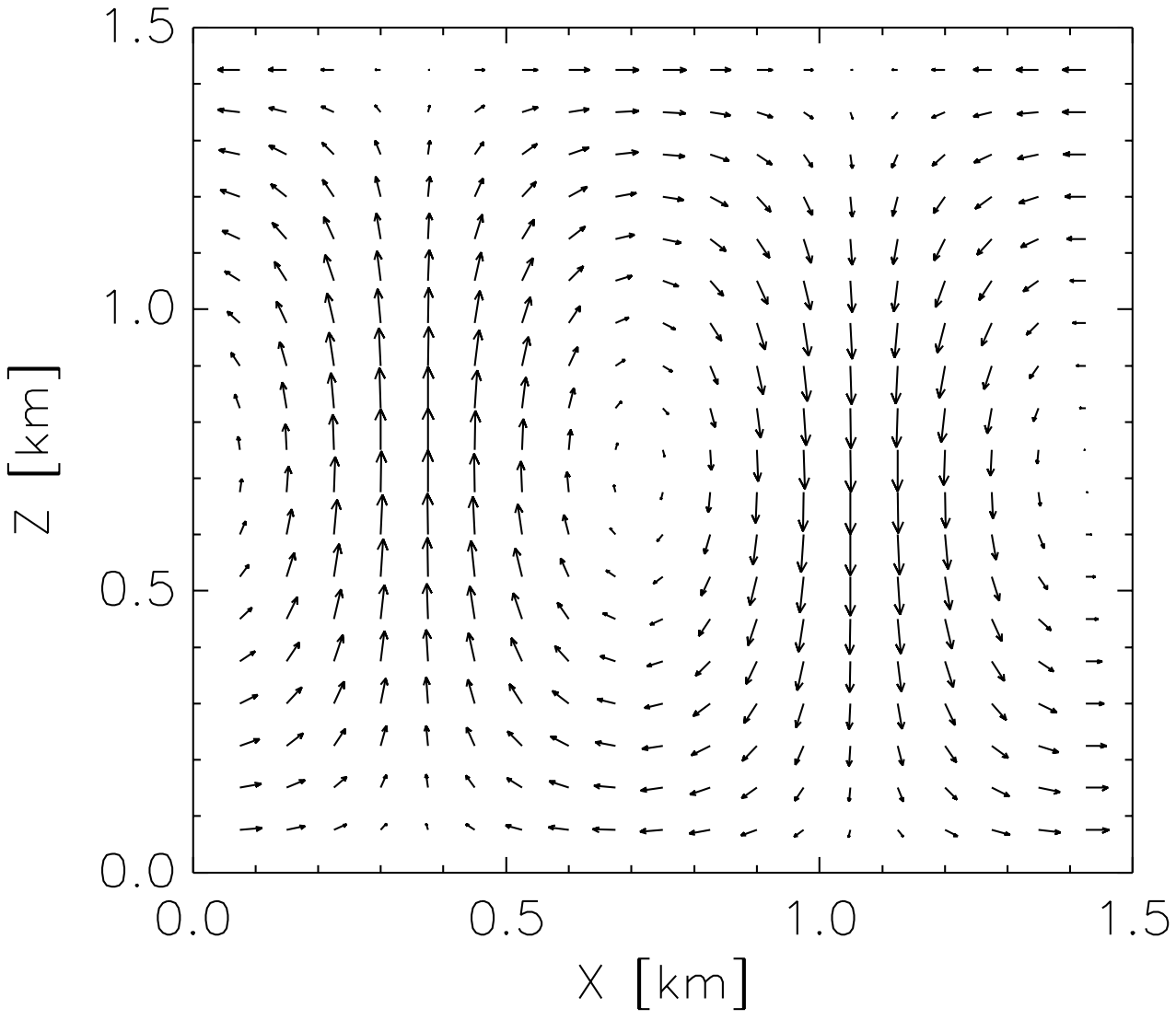

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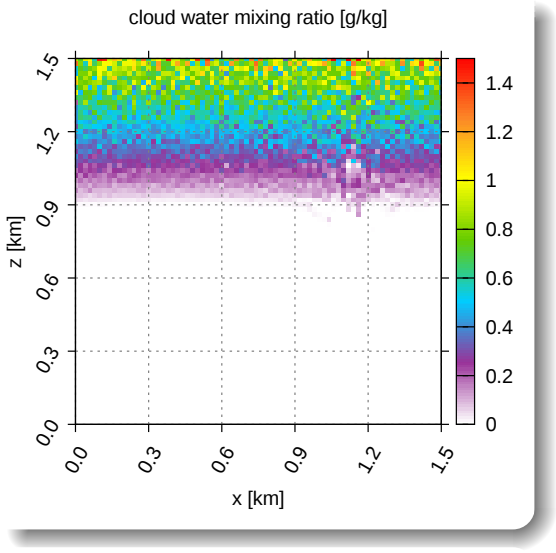

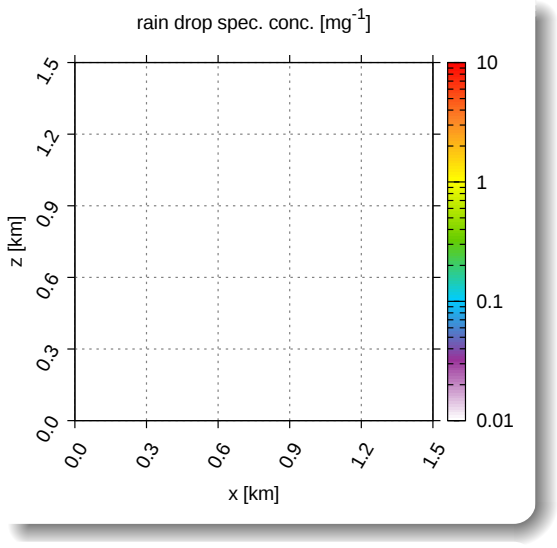

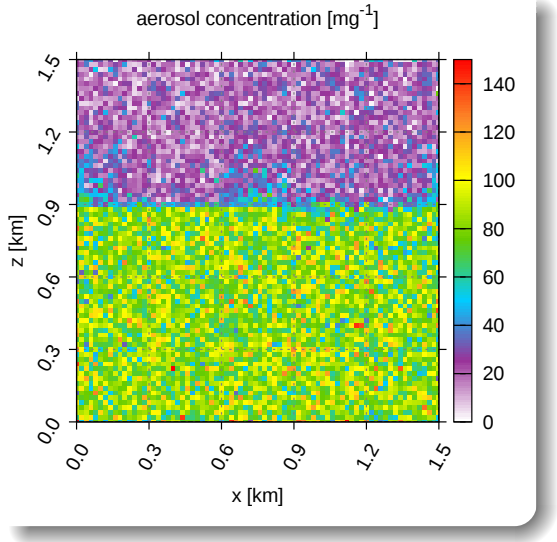

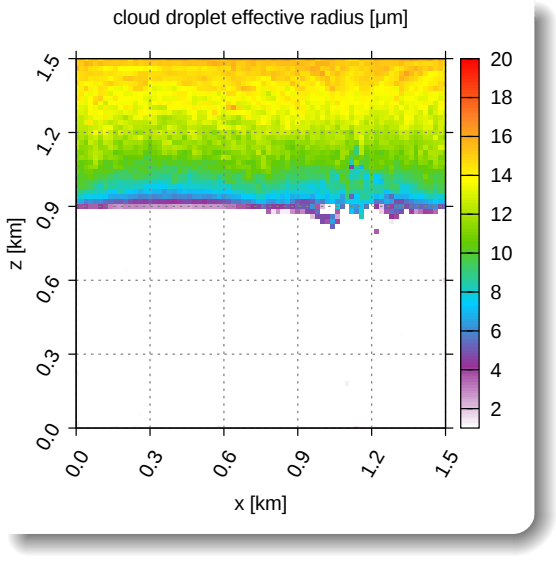

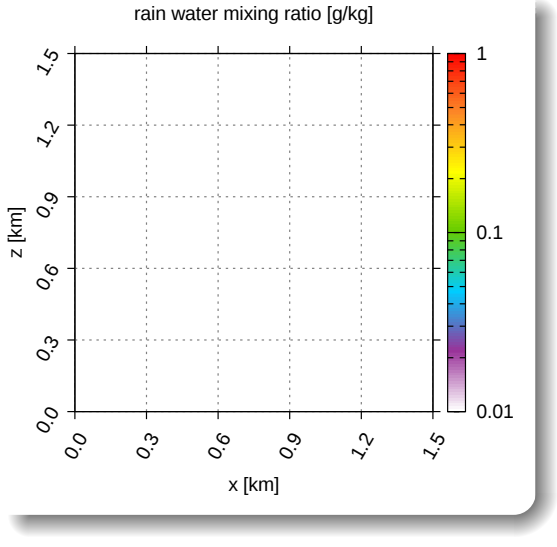

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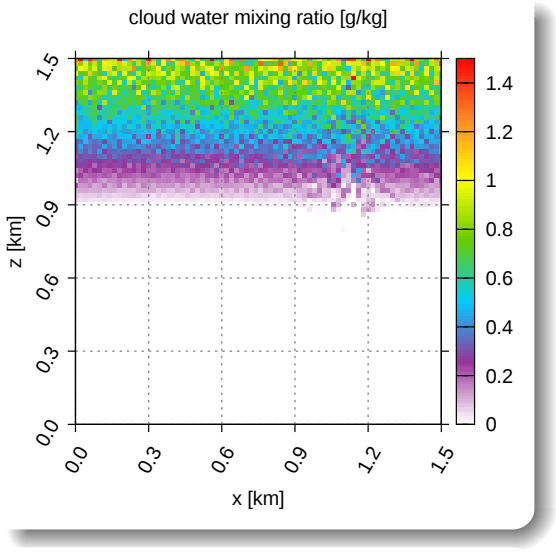

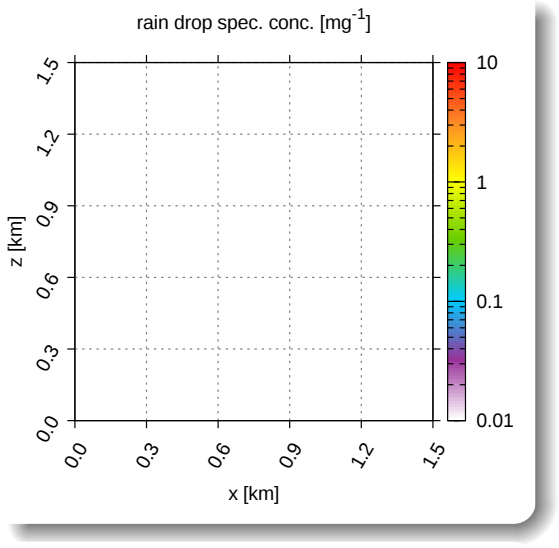

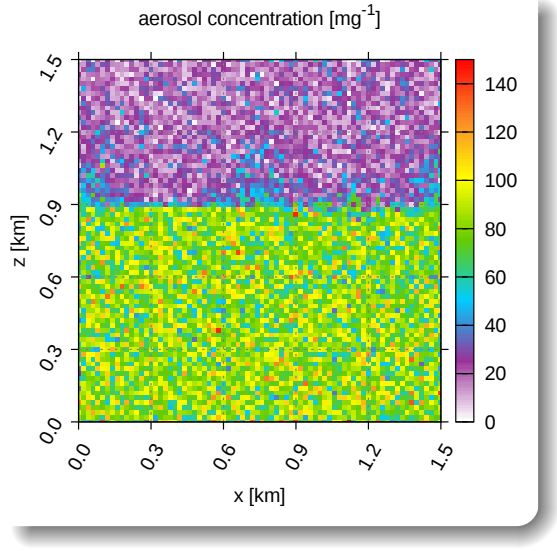

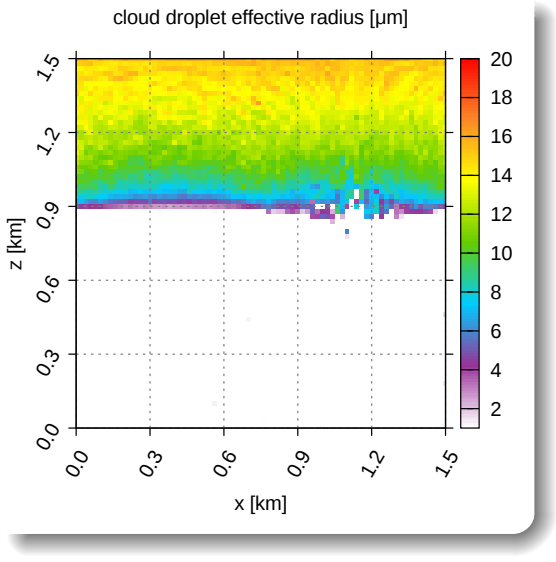

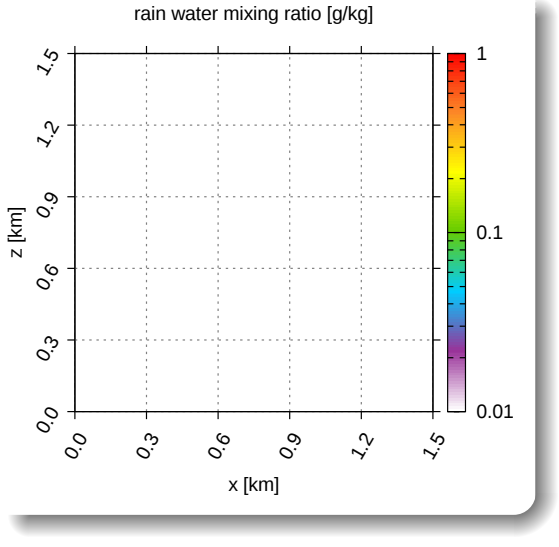

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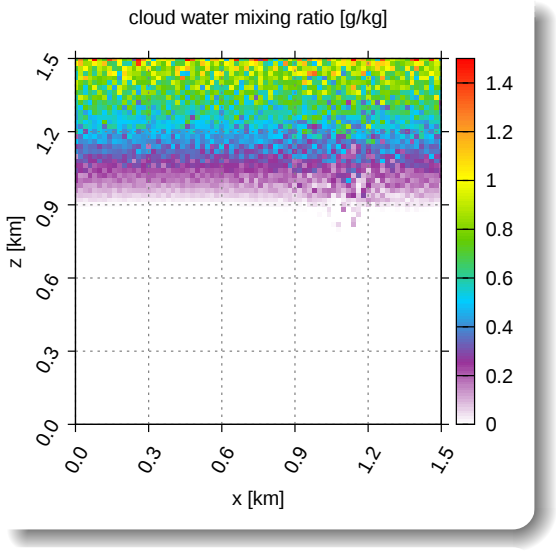

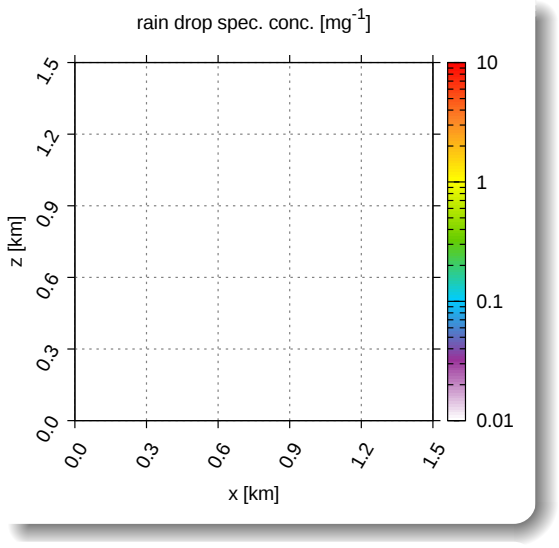

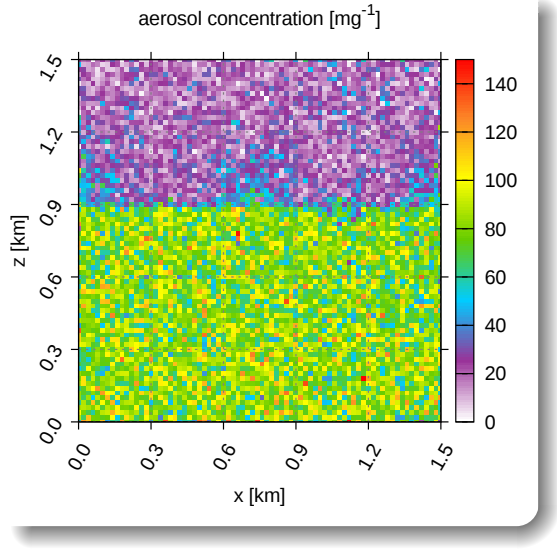

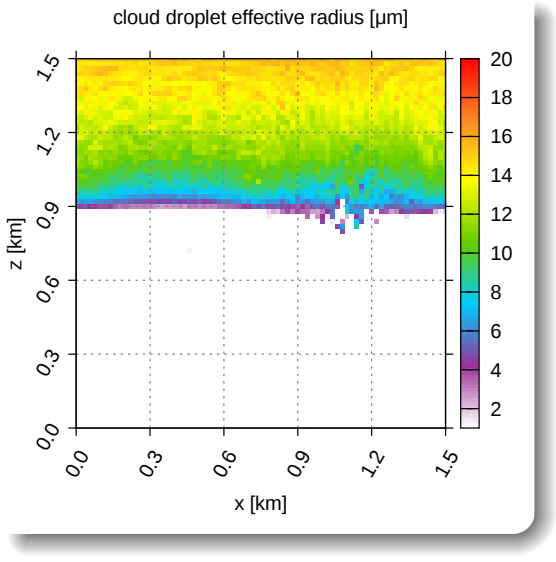

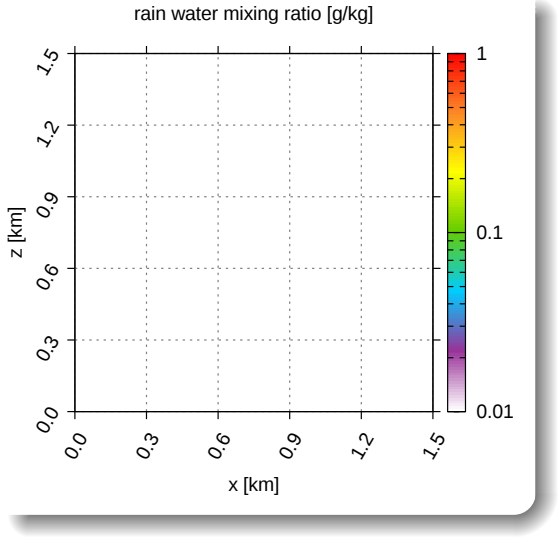

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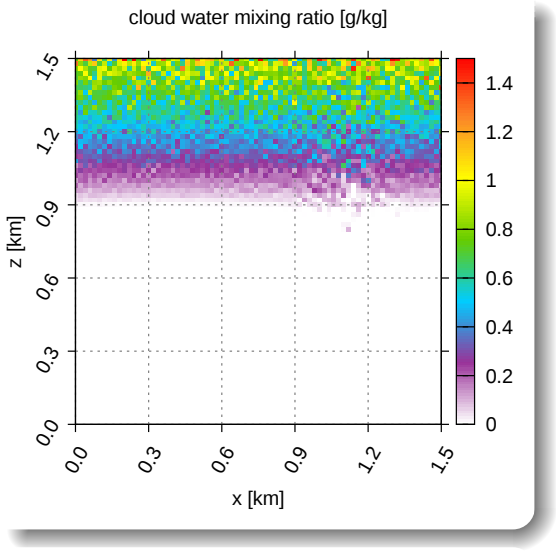

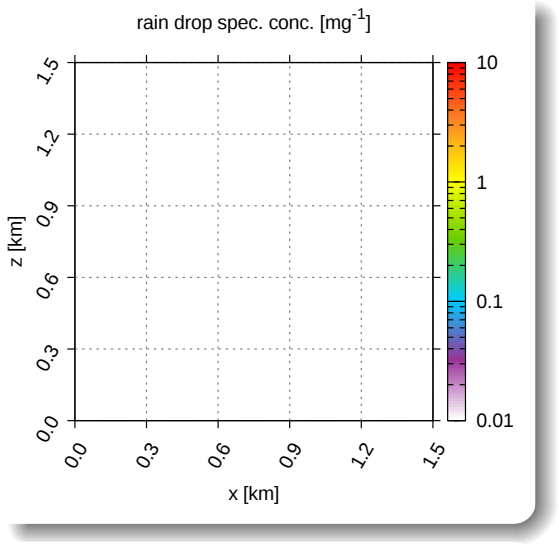

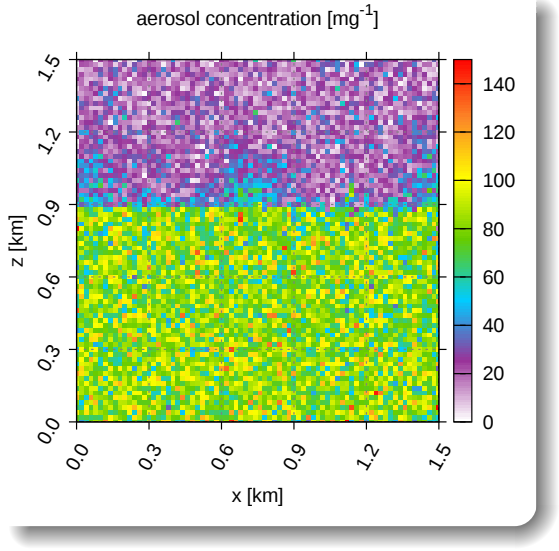

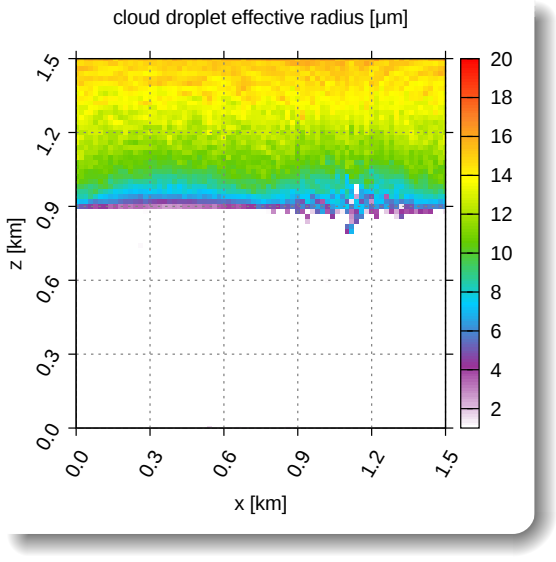

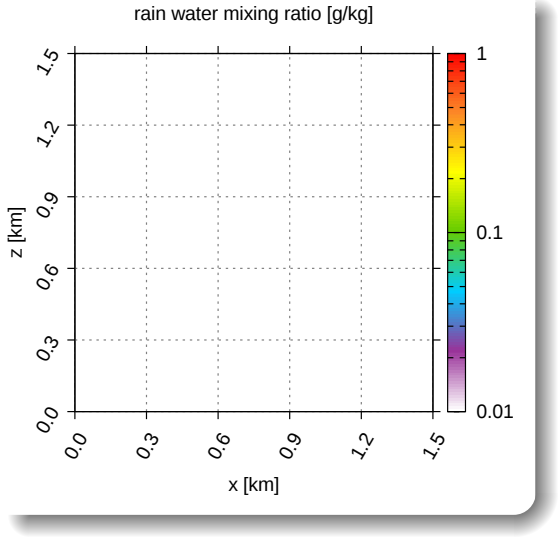

example simulation (2D, prescribed flow)

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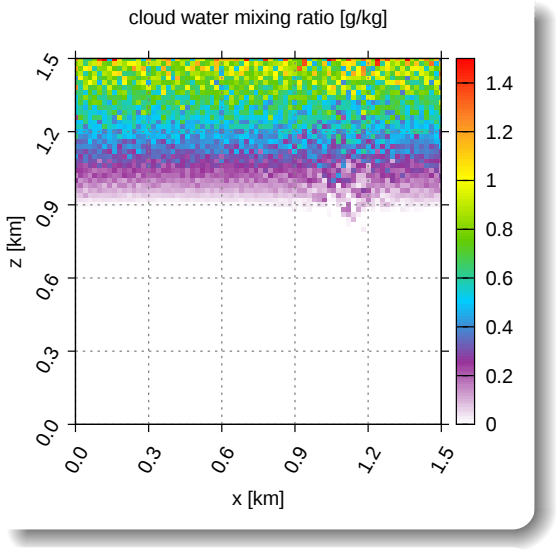

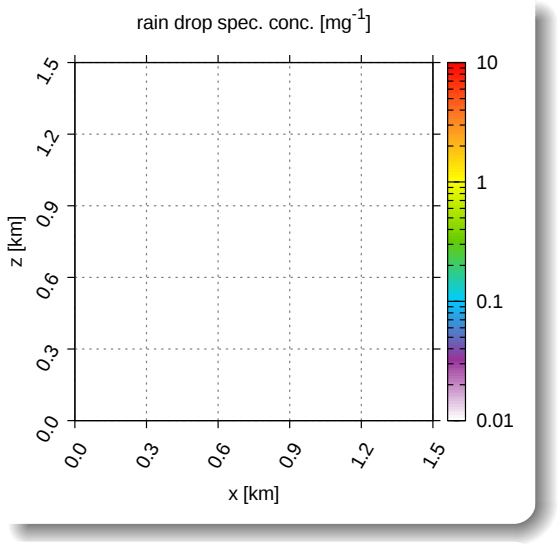

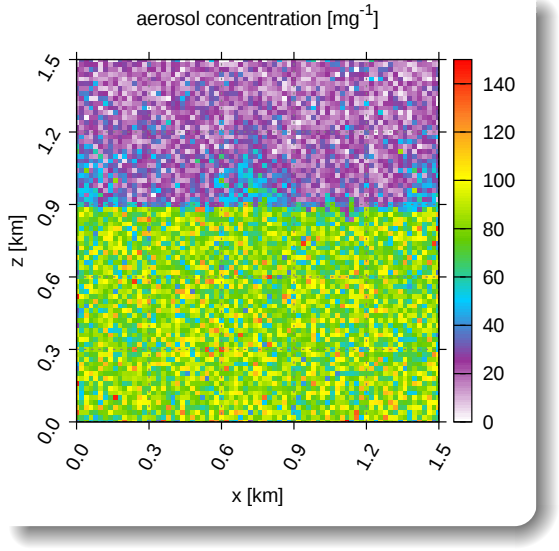

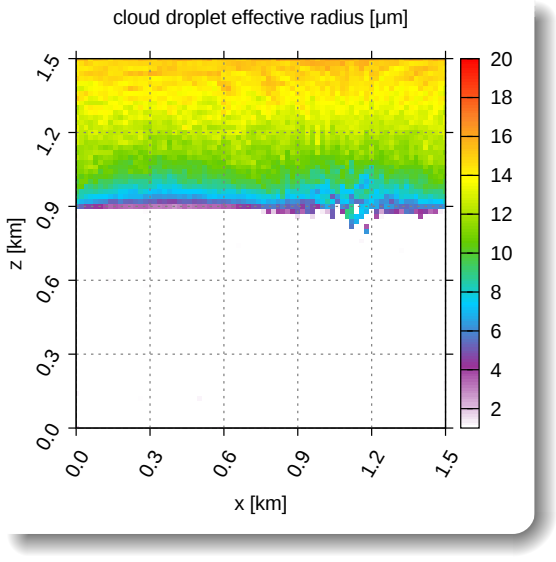

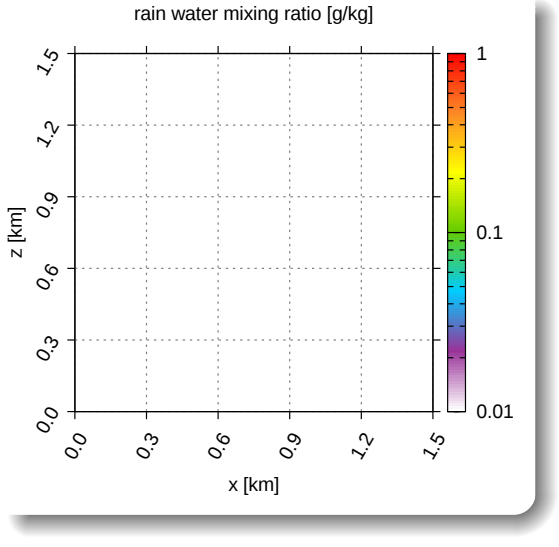

example simulation (2D, prescribed flow)

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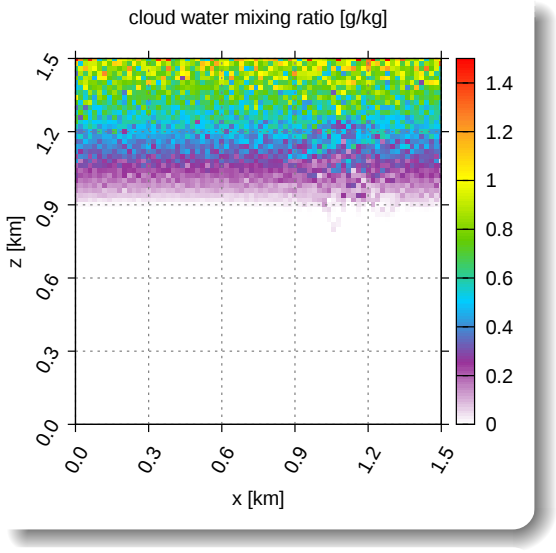

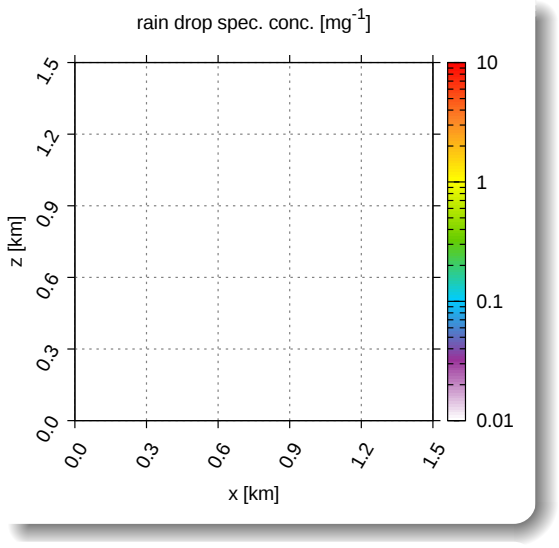

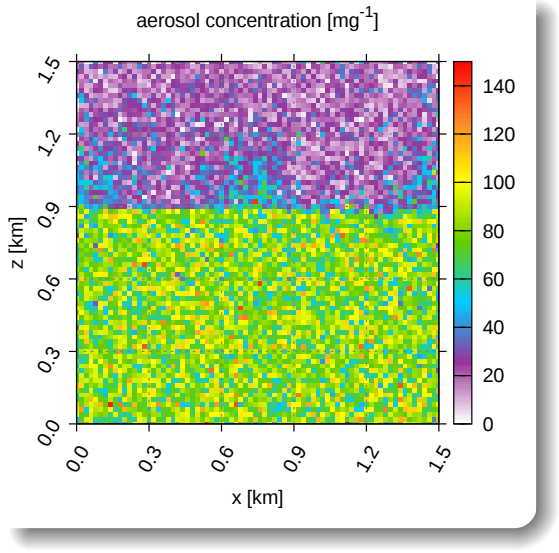

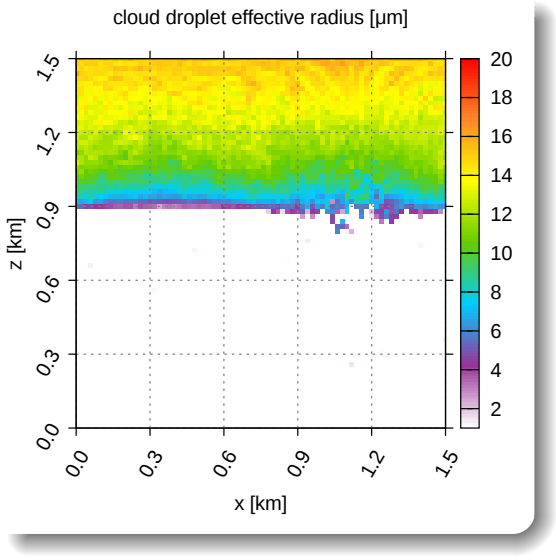

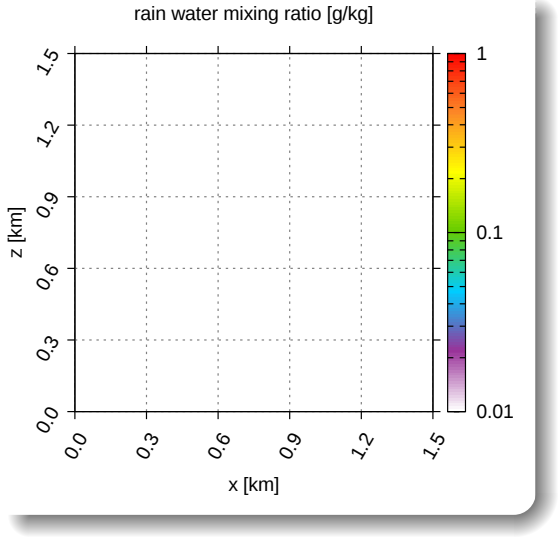

example simulation (2D, prescribed flow)

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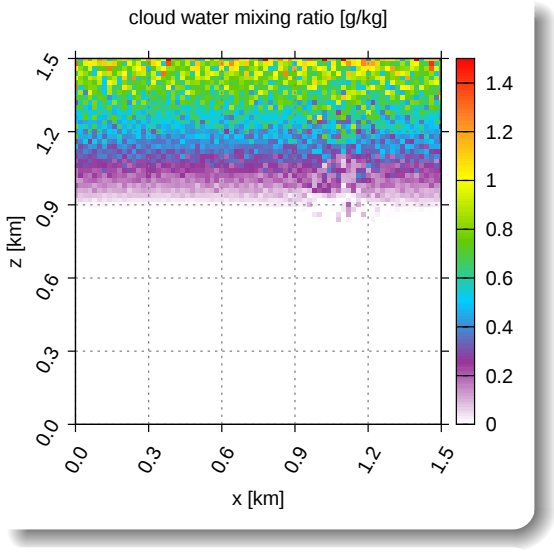

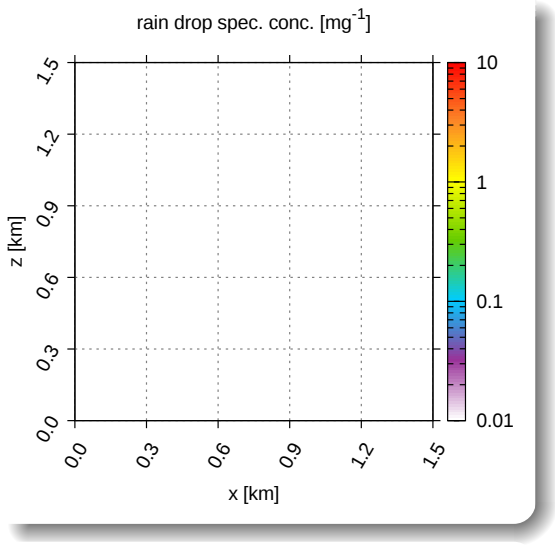

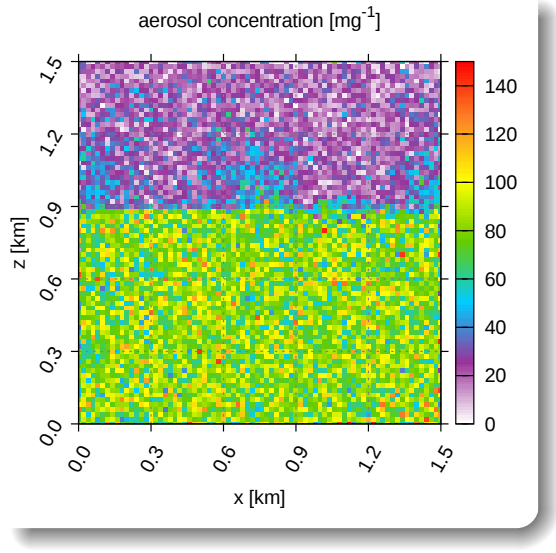

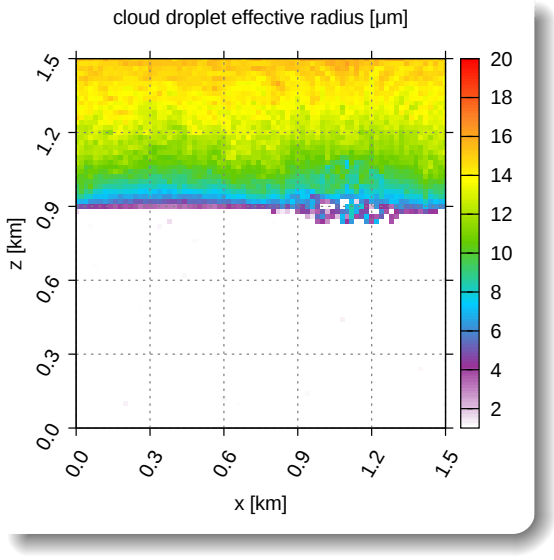

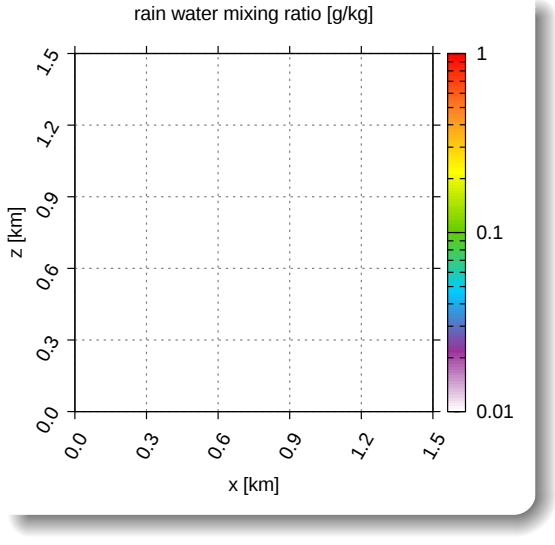

example simulation (2D, prescribed flow)

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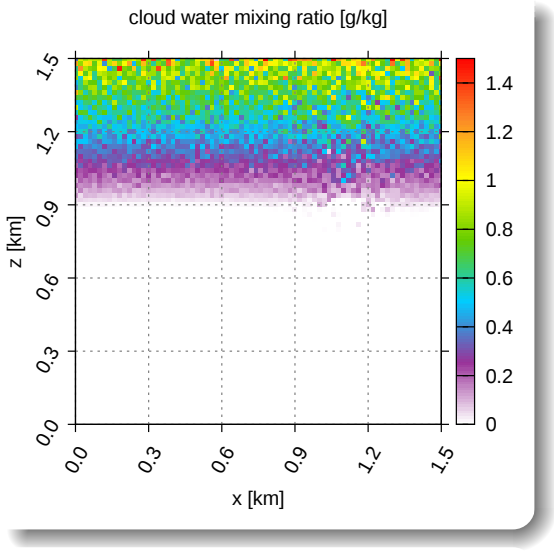

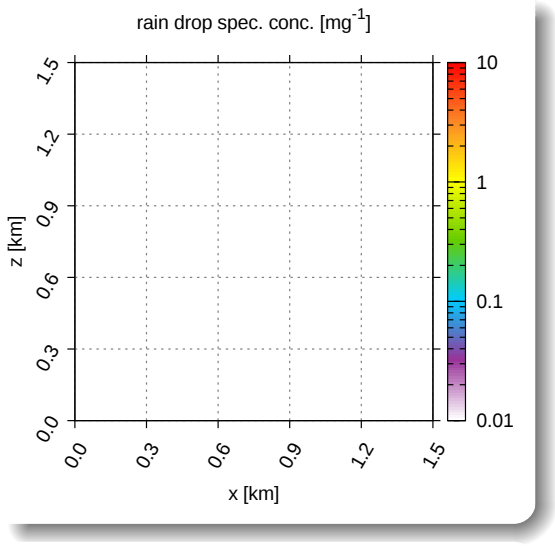

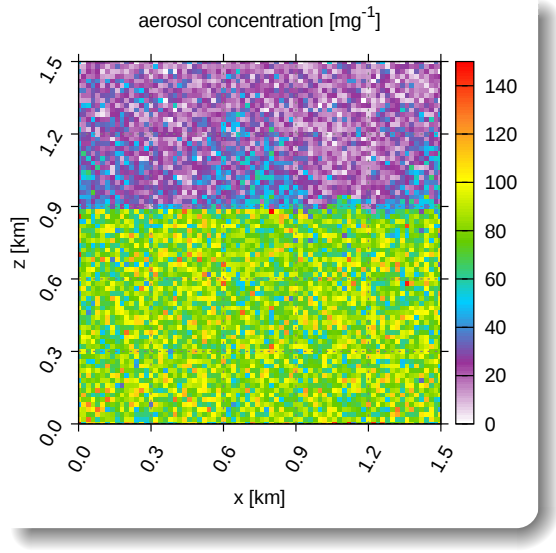

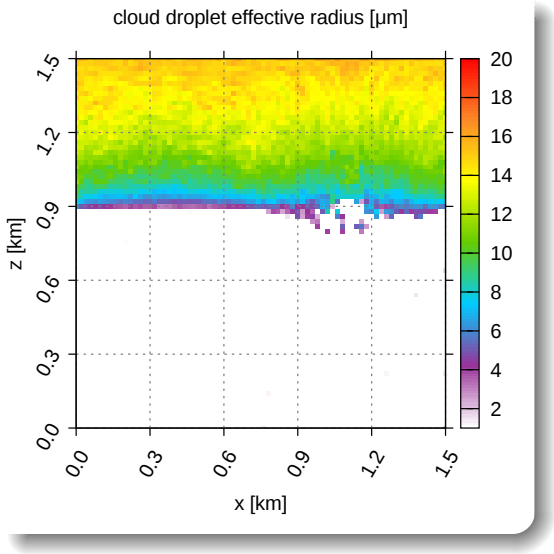

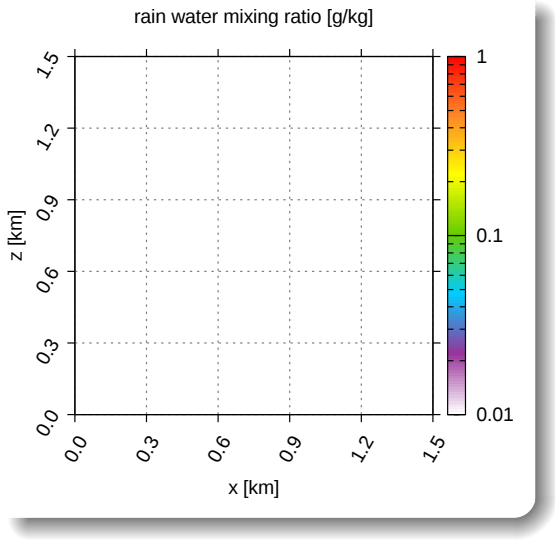

example simulation (2D, prescribed flow)

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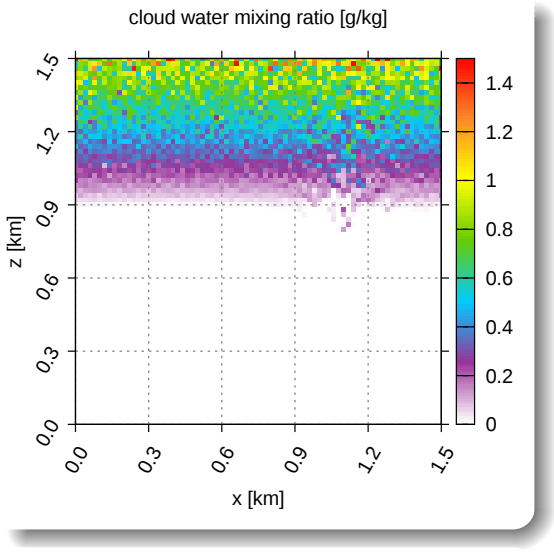

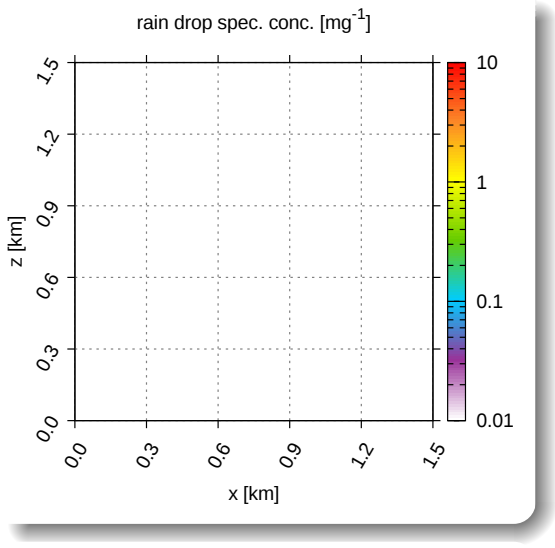

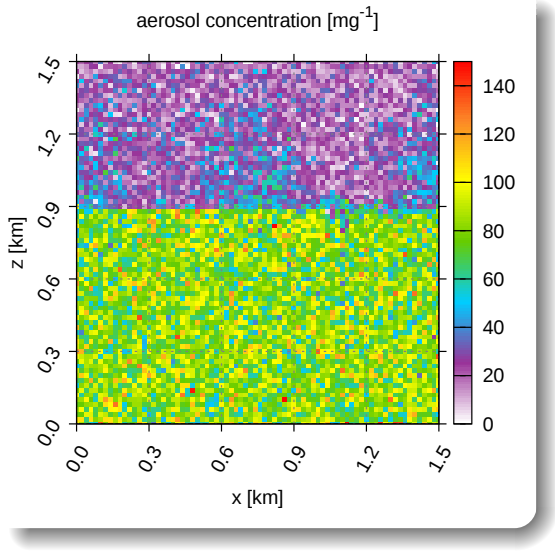

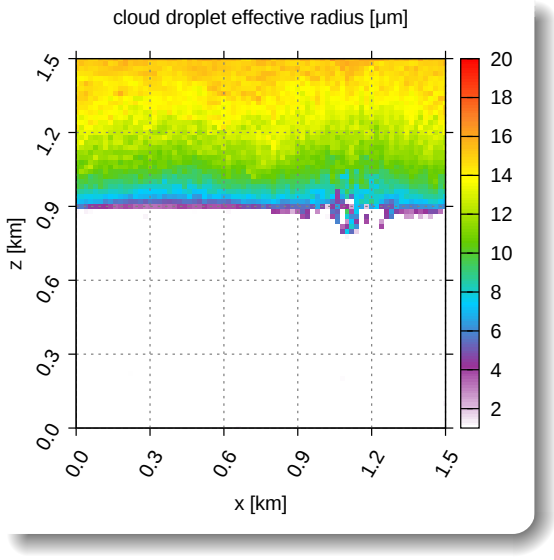

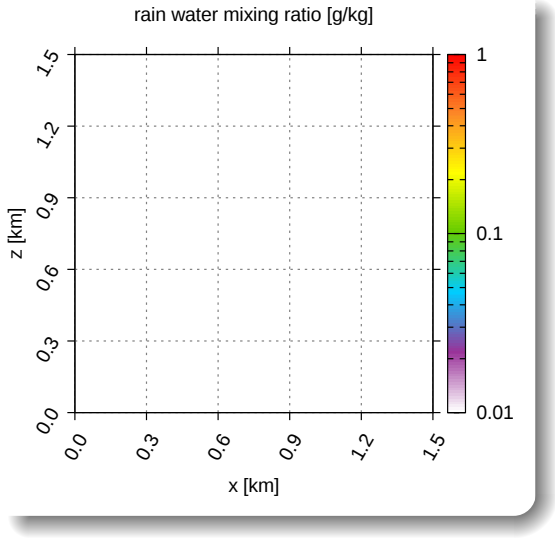

example simulation (2D, prescribed flow)

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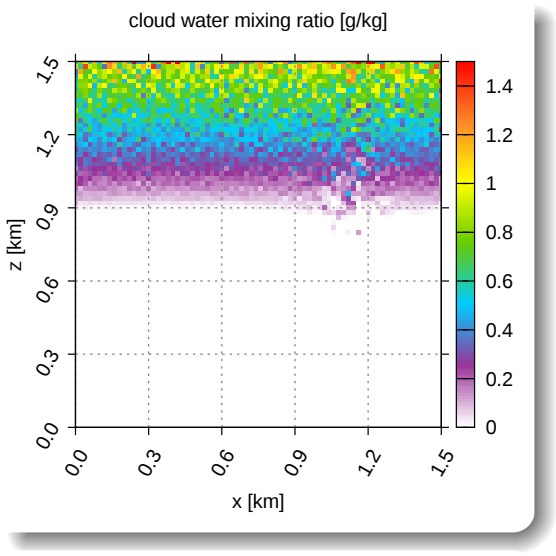

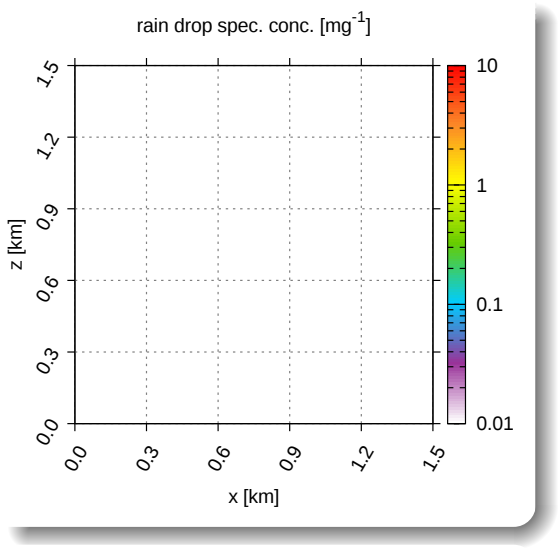

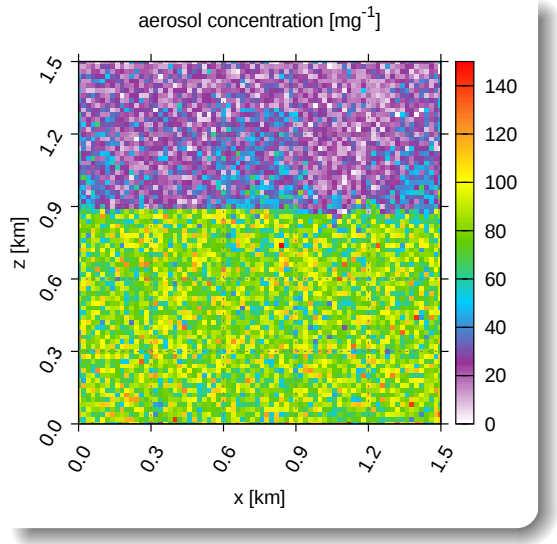

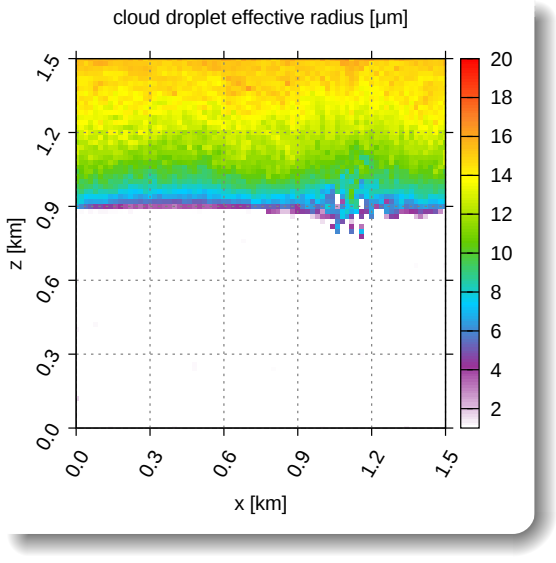

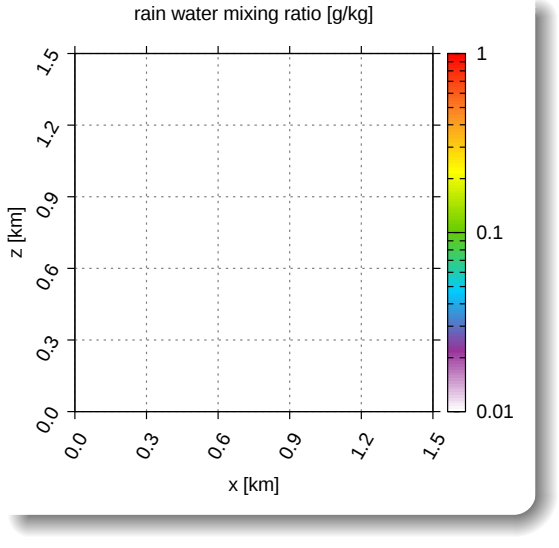

example simulation (2D, prescribed flow)

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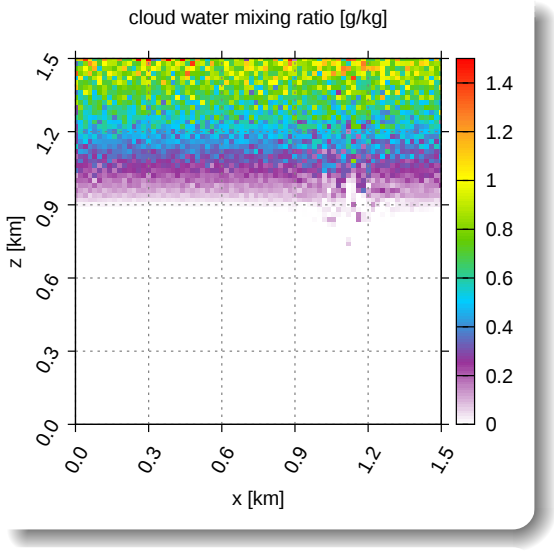

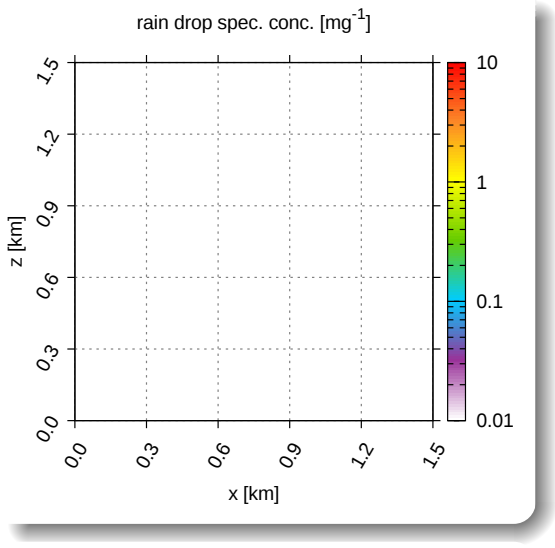

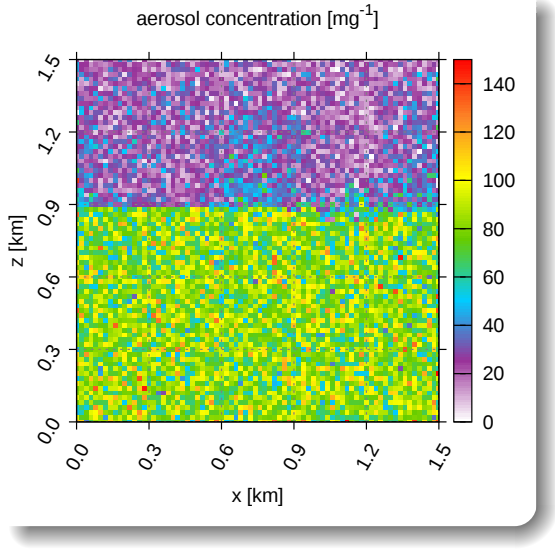

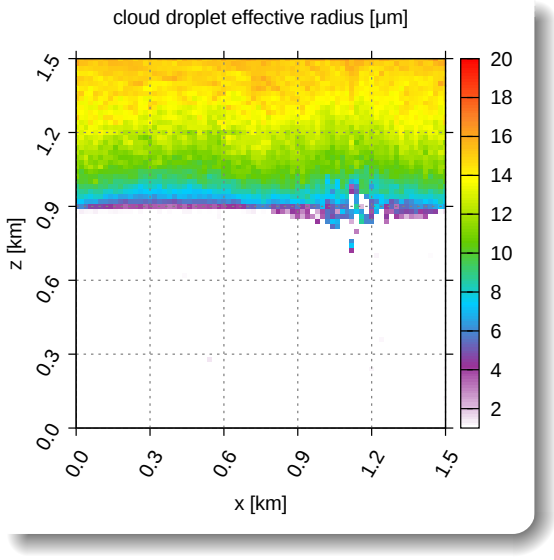

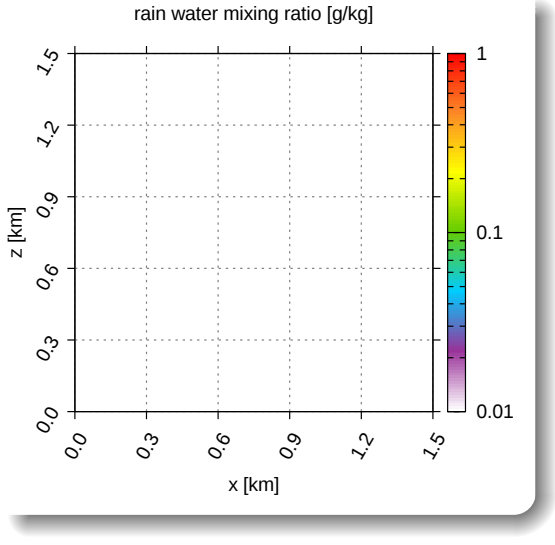

example simulation (2D, prescribed flow)

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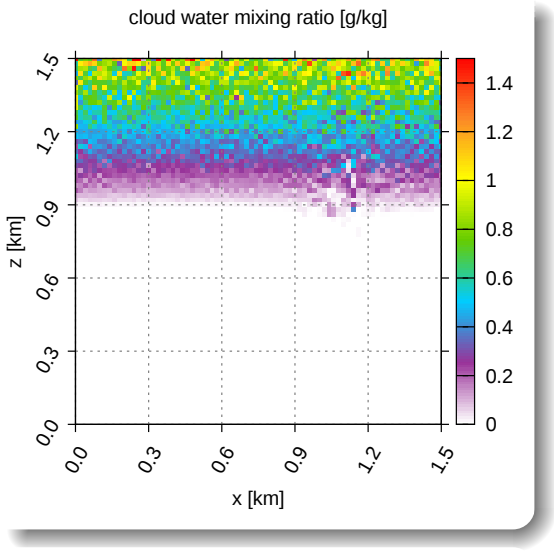

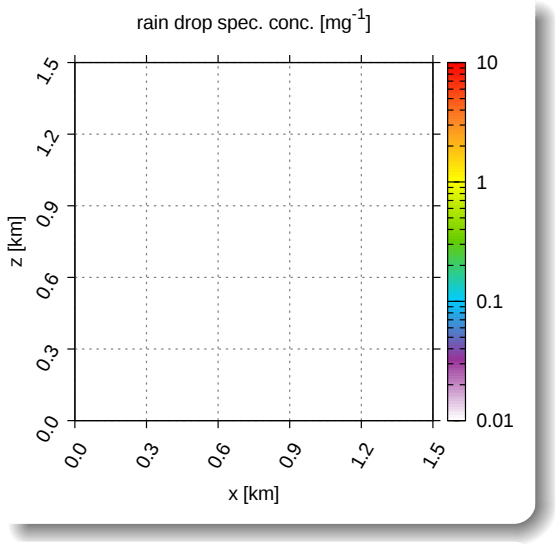

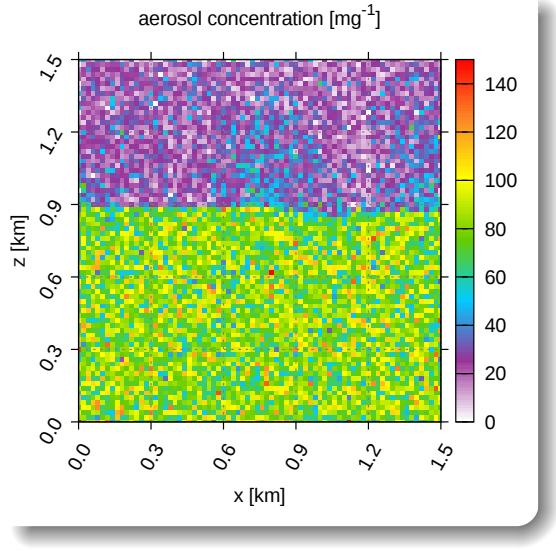

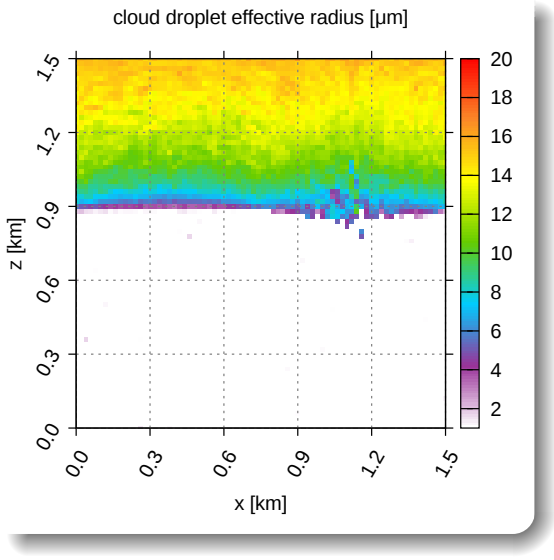

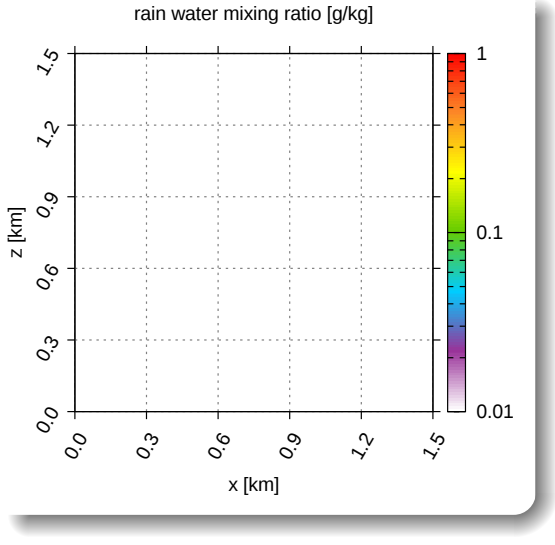

example simulation (2D, prescribed flow)

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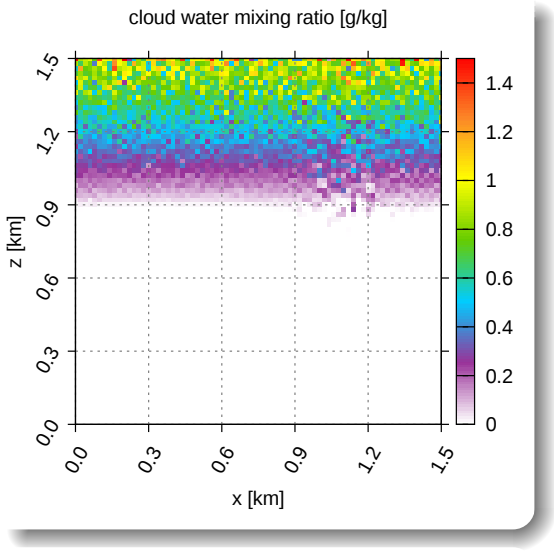

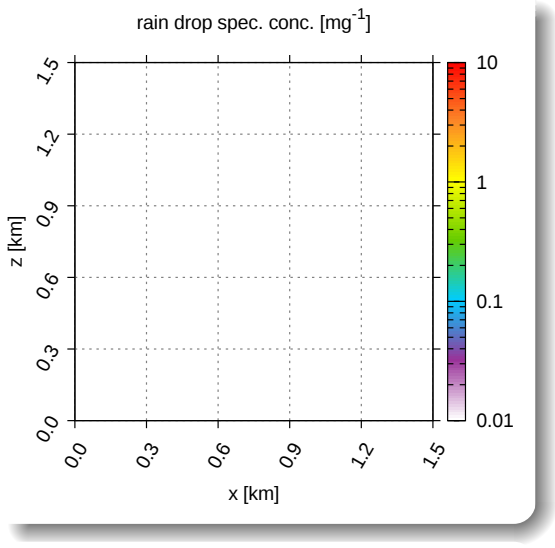

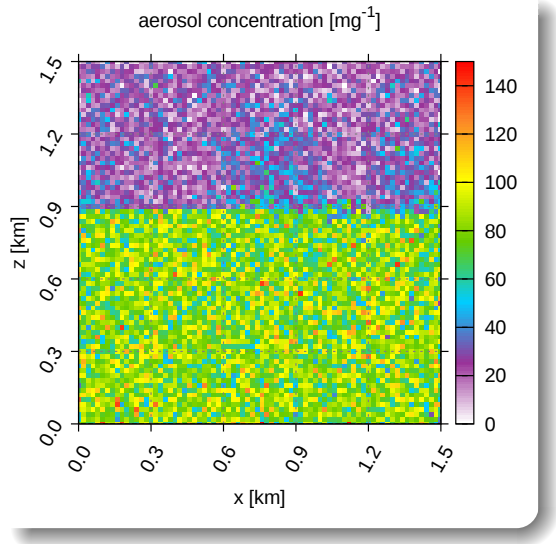

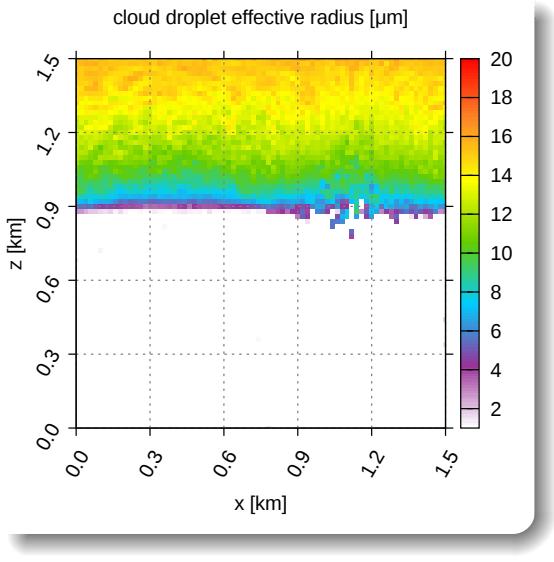

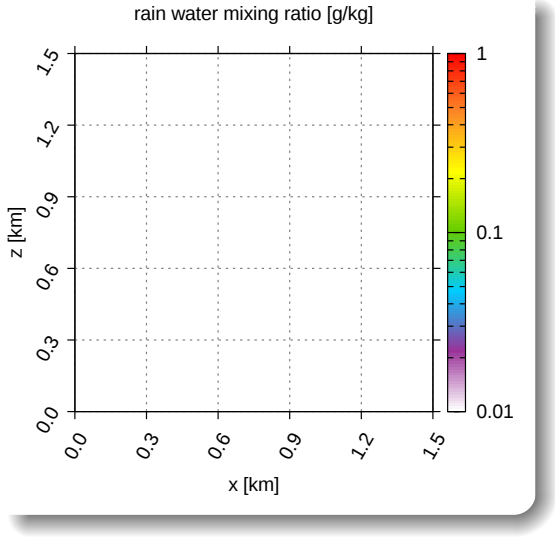

example simulation (2D, prescribed flow)

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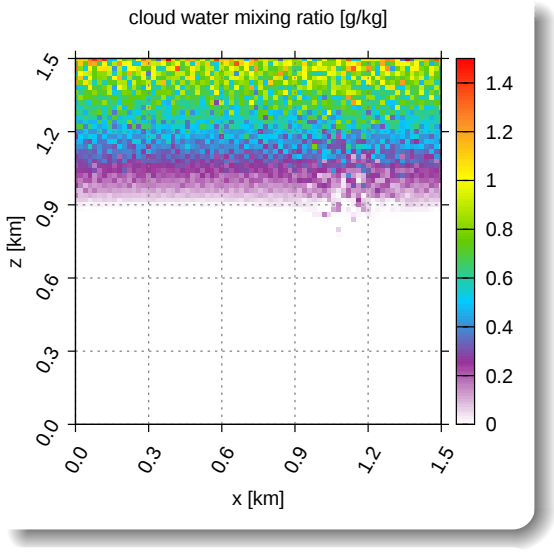

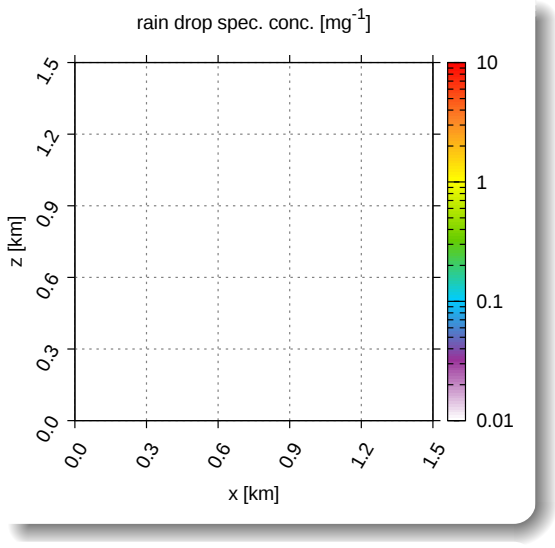

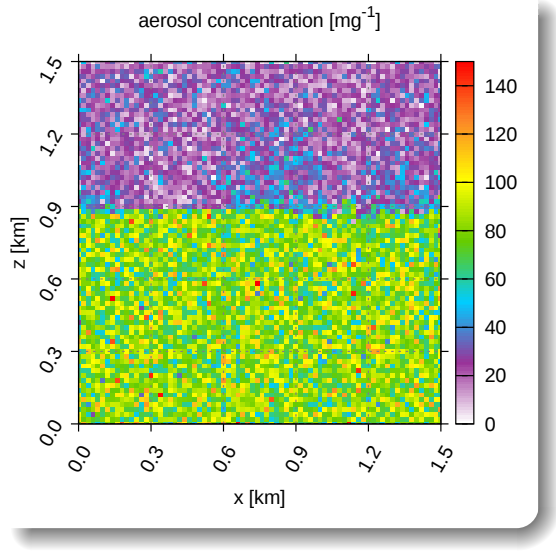

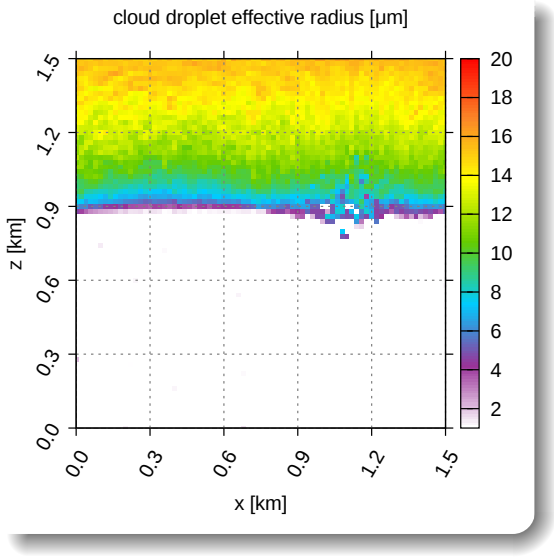

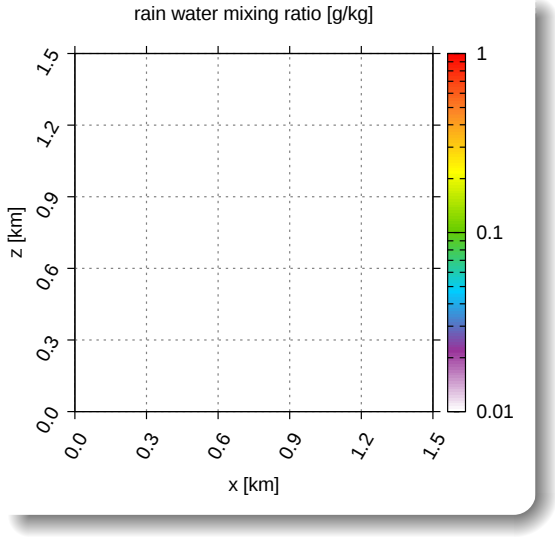

example simulation (2D, prescribed flow)

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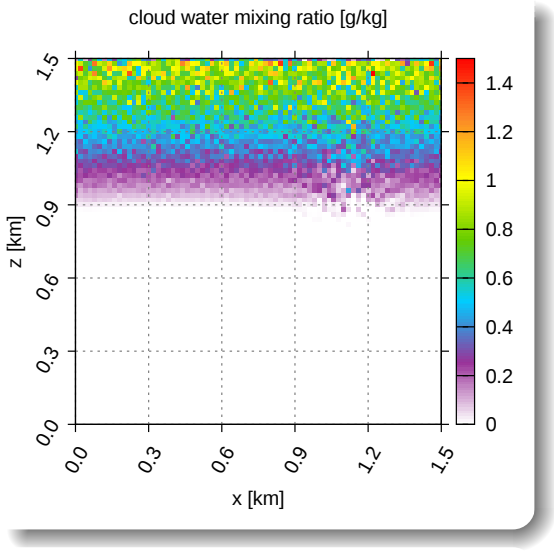
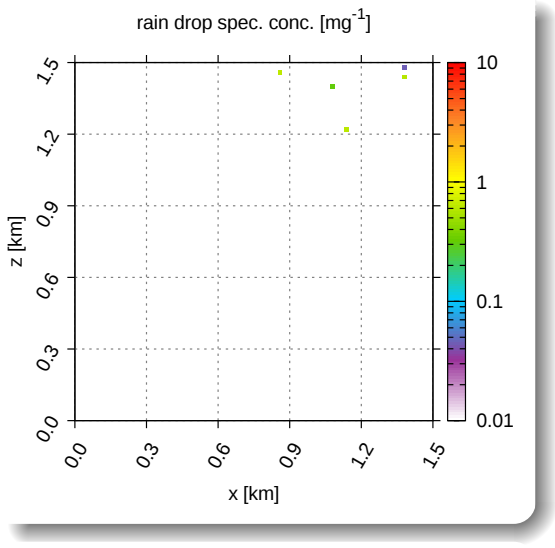
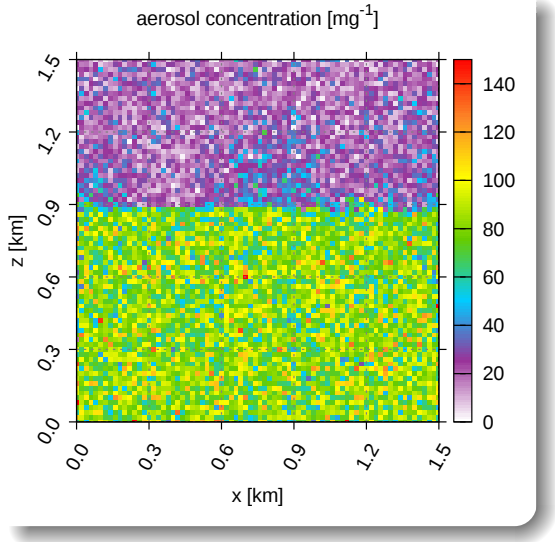
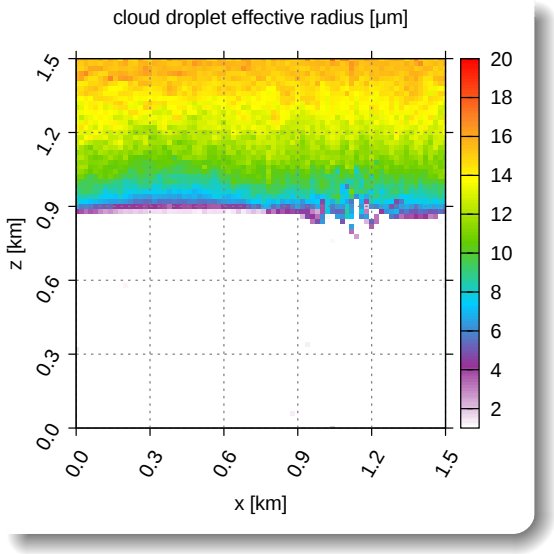
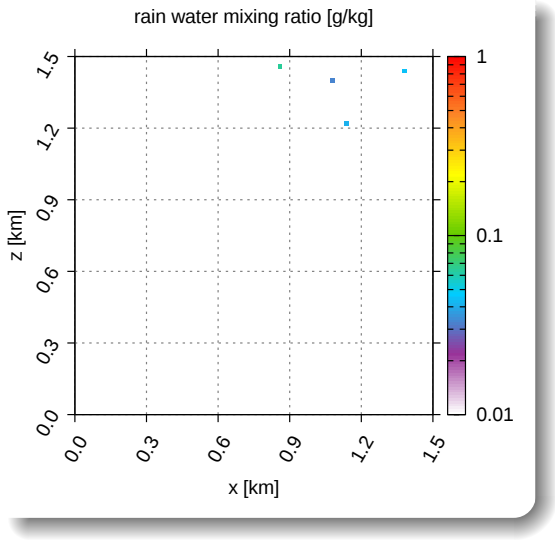


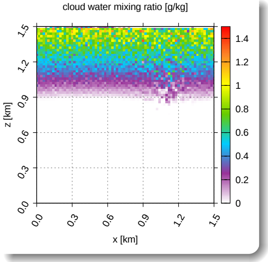


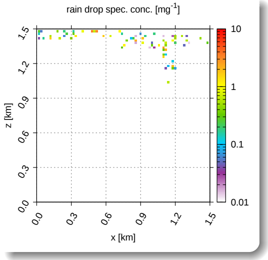


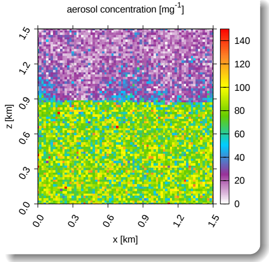


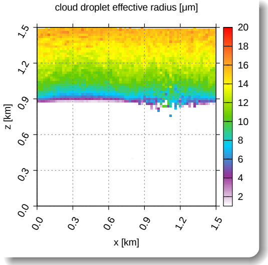


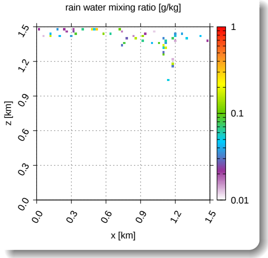
example simulation (2D, prescribed flow)



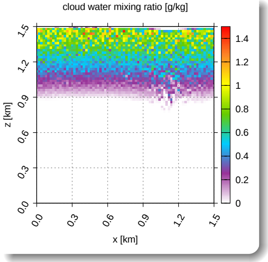


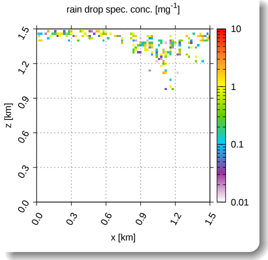


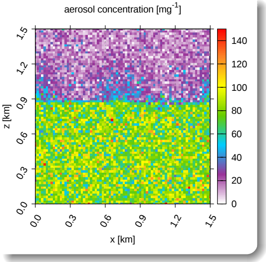


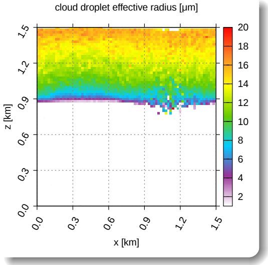


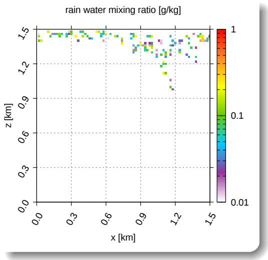
example simulation (2D, prescribed flow)











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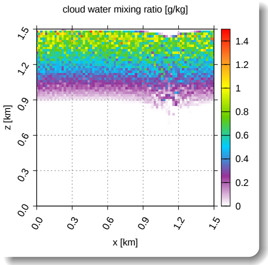

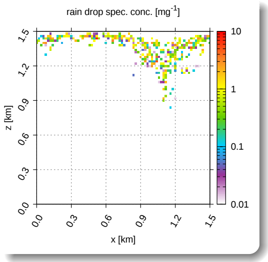

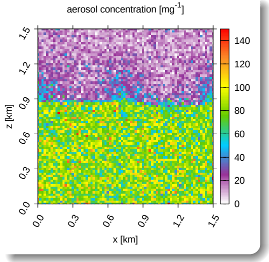

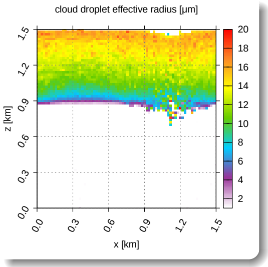

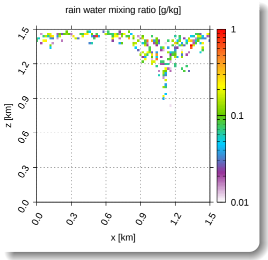

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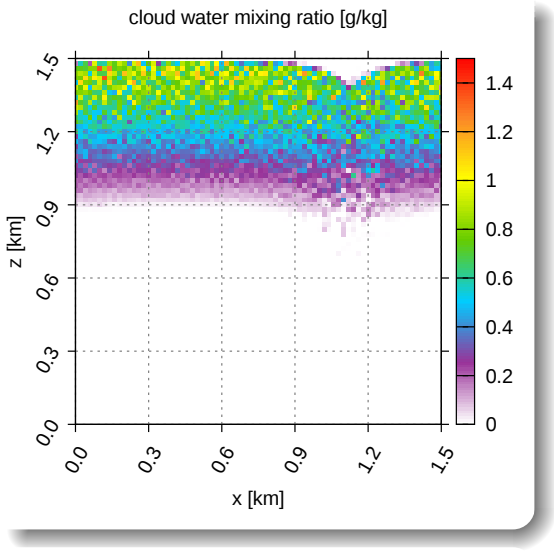

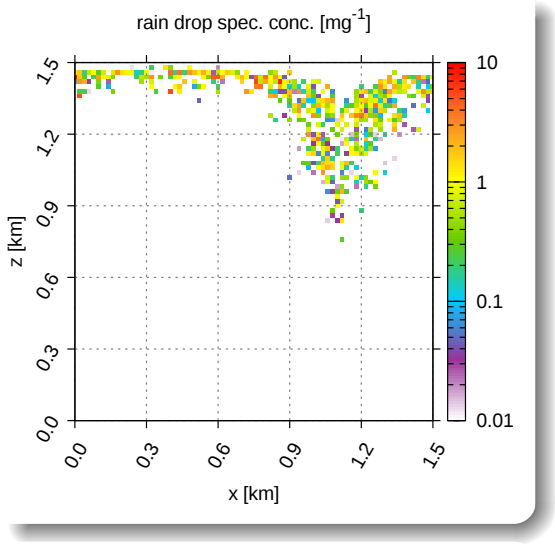

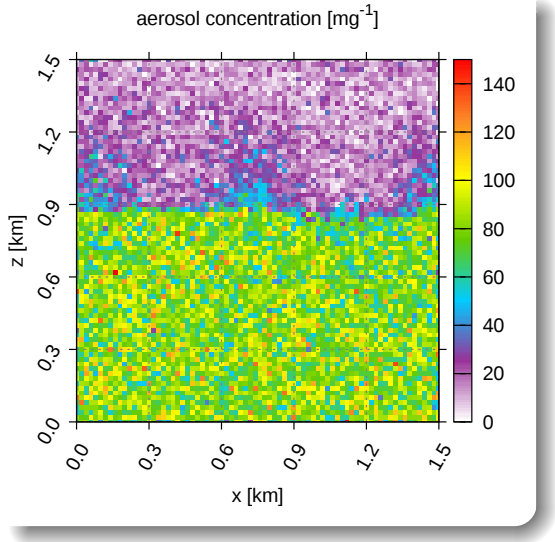

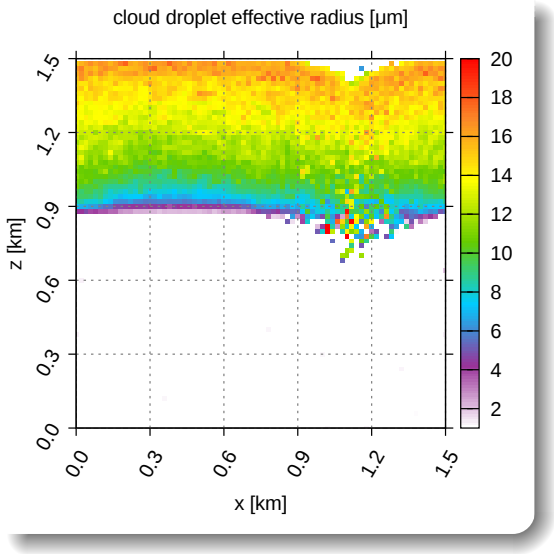

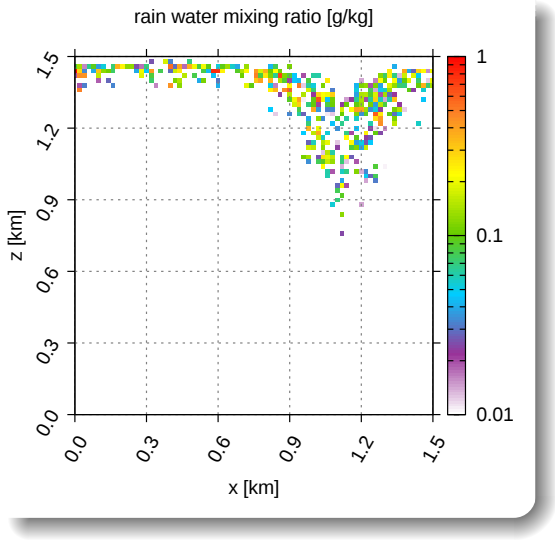

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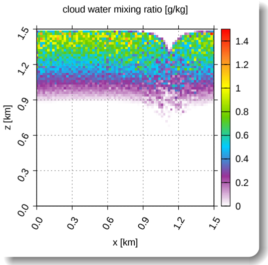

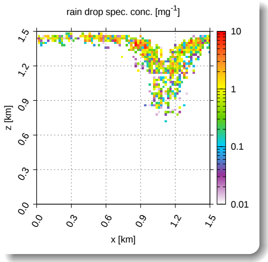

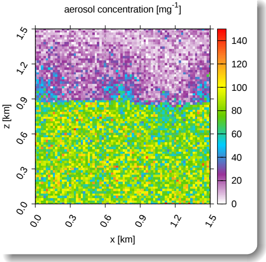

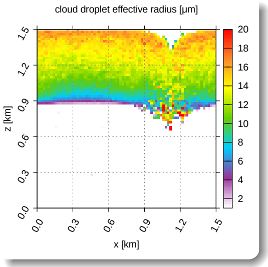

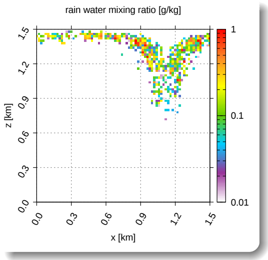

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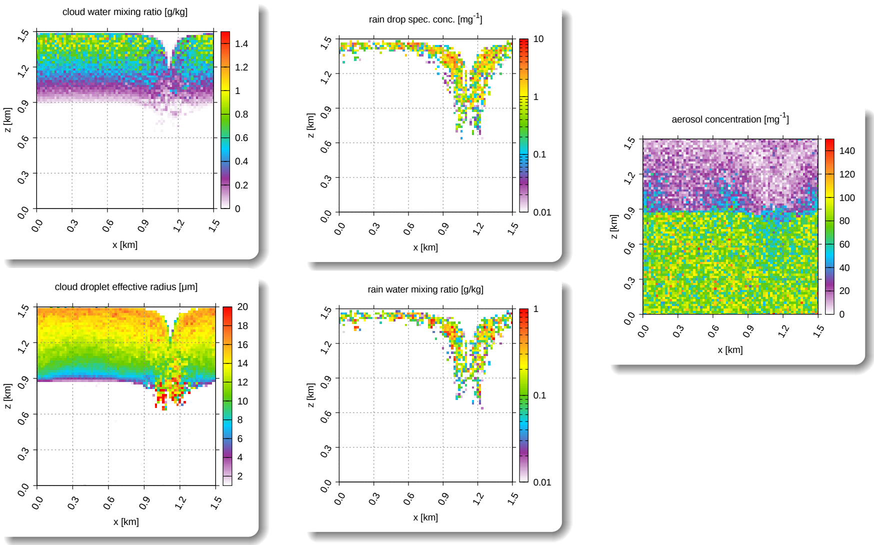

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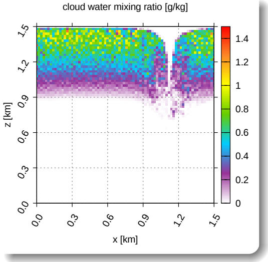

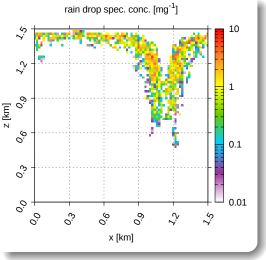

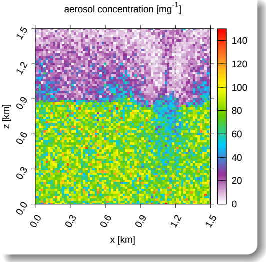

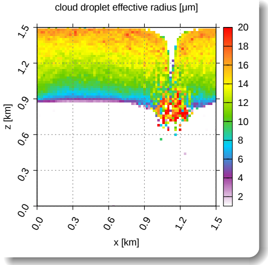

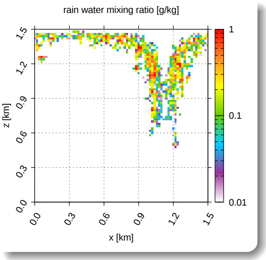

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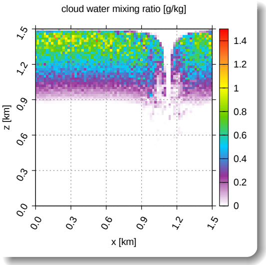
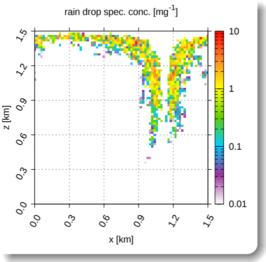
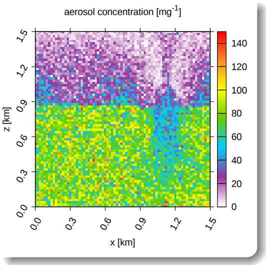
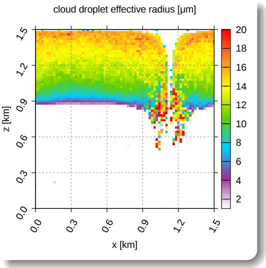
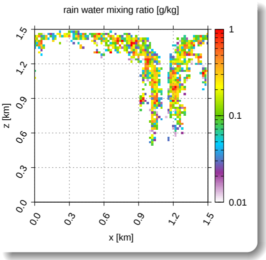




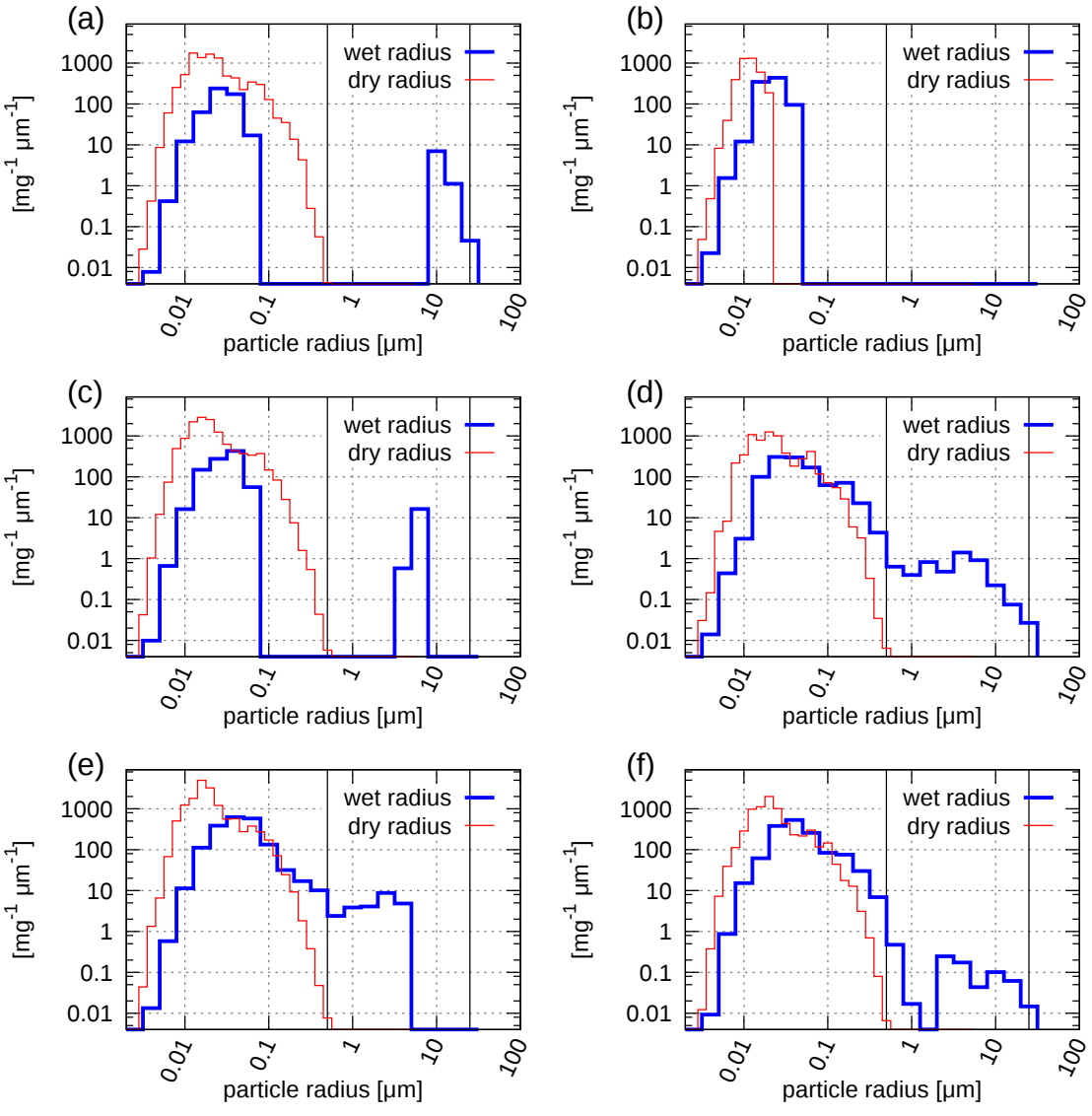


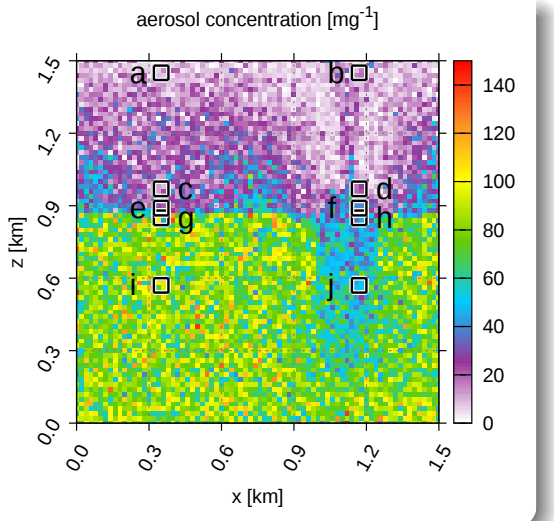




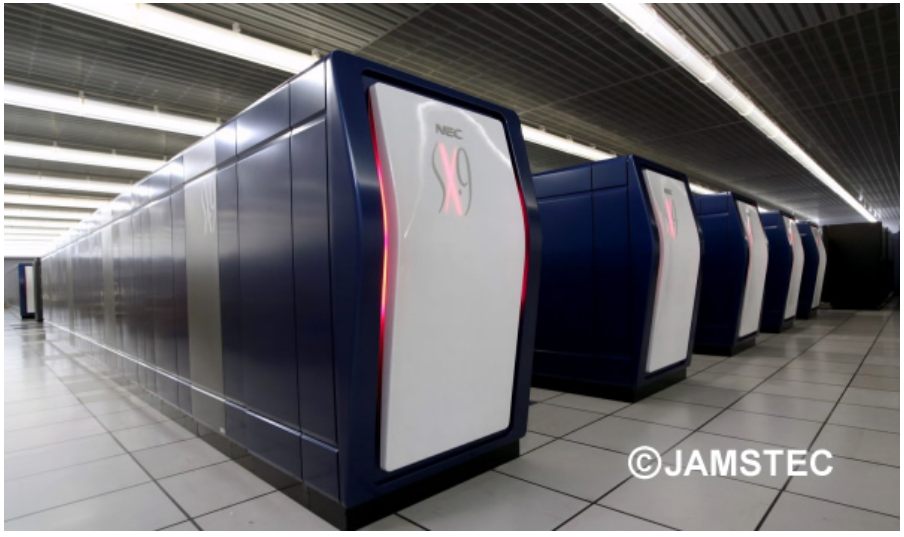
example simulation (2D, prescribed flow)

particle size spectra



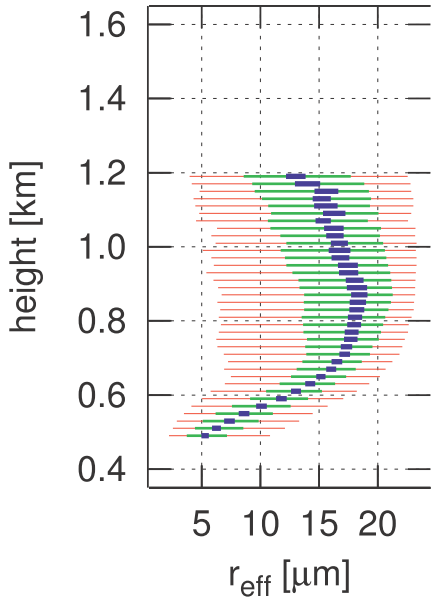


Lagrangian μ-physics in 3D: simulations vs. aircraft data



Lagrangian μ-physics in 3D: simulations vs. aircraft data

Arabas & Shima 2013, JAS



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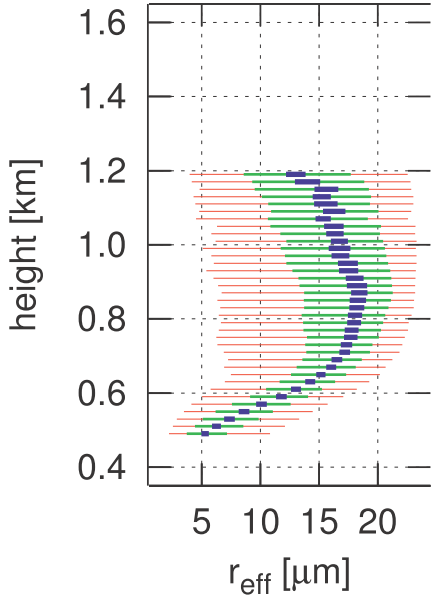
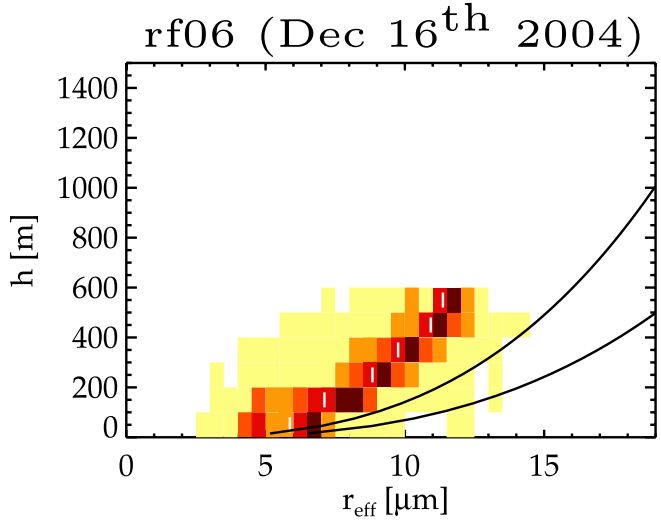


Arabas, Pawlowska, Grabowski 2009, GRL



(h = height - 550 m)

a detour...

a detour...

Morin et al. 2012 doi:10.1126/science.1218263

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Easterbrook 2014 doi:10.1038/ngeo2283

„Poor code quality is endemic..."
„Significant improvements in the sharing of software tools and in making computationally-based research reproducible require much more than merely making the code available"

detour: new 2019 GMD journal policy

doi:10.5194/gmd-12-2215-2019

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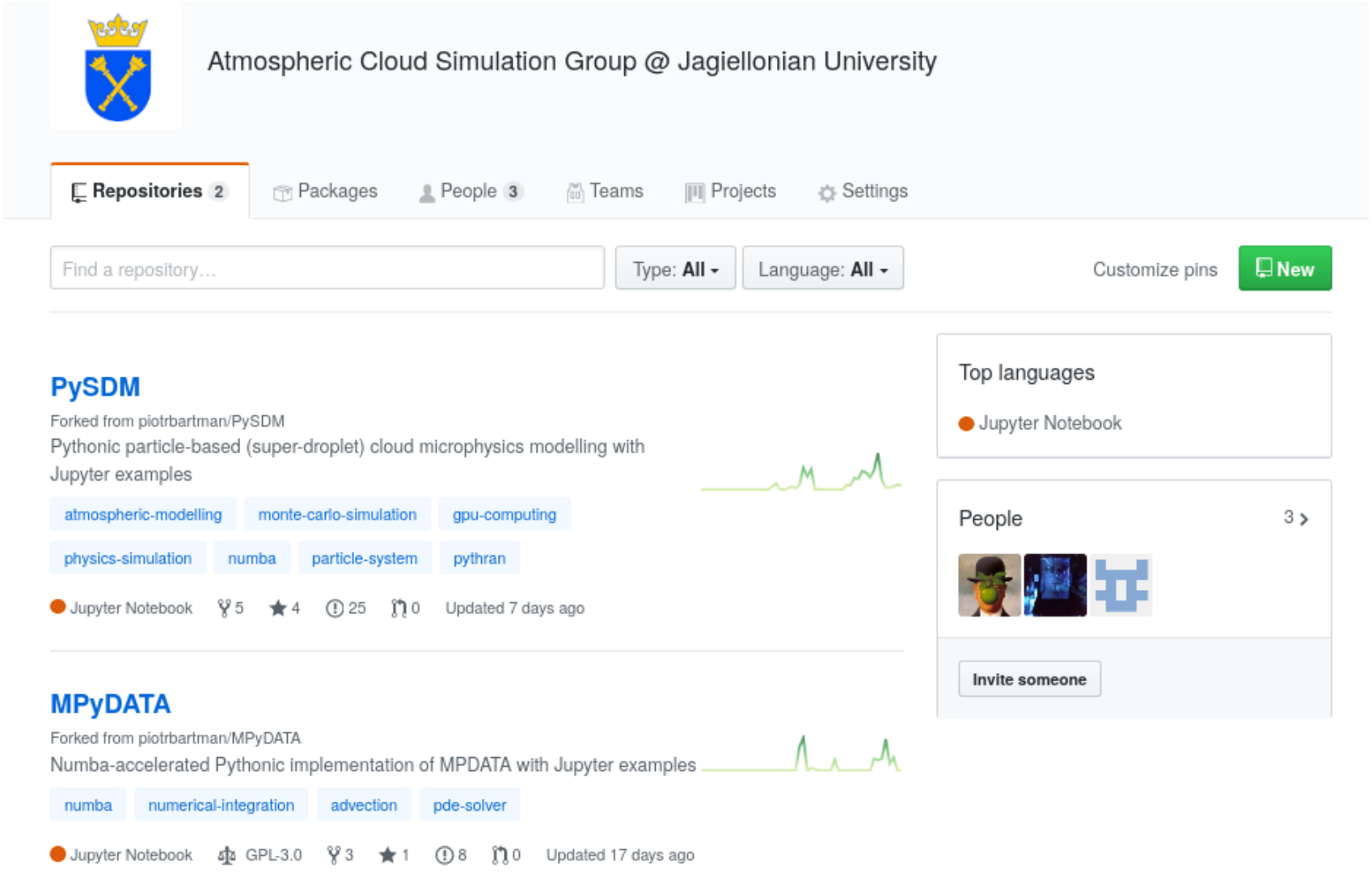
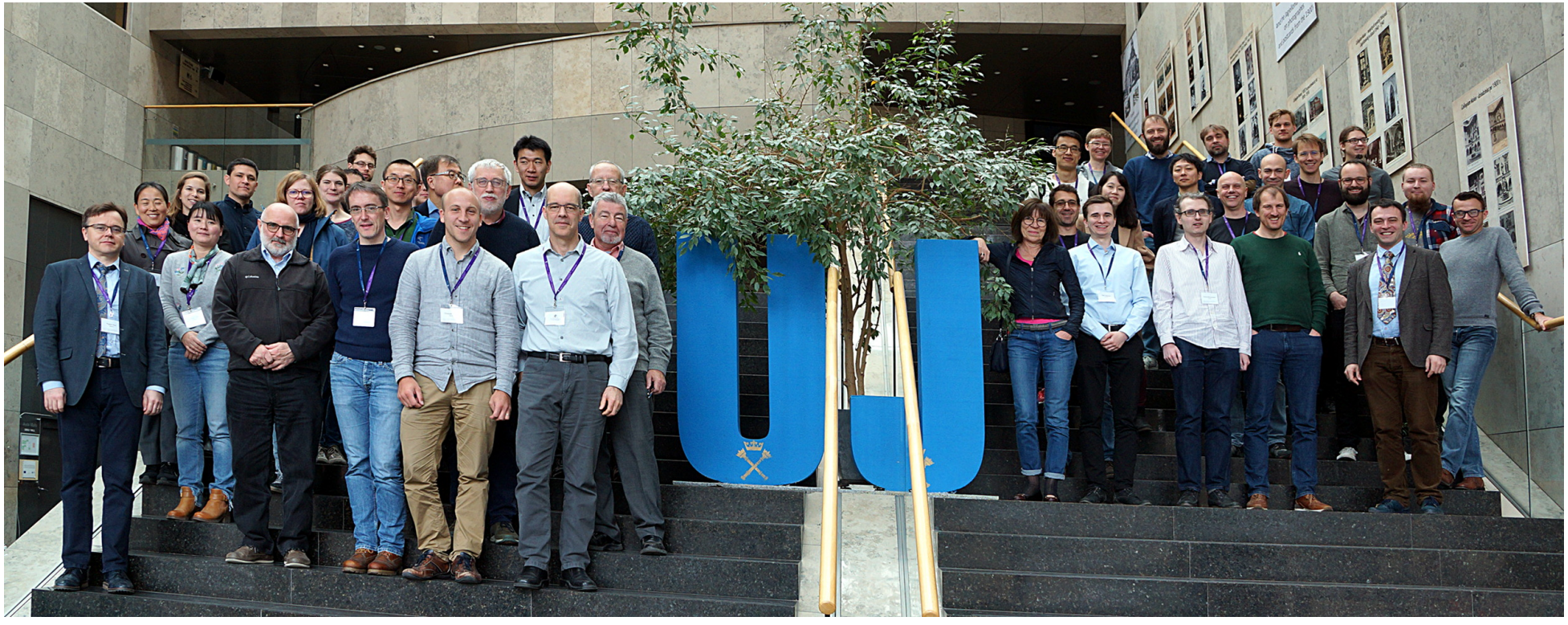
- *„During the review process, the ease of model download, compilation, and running of test cases may be assessed"*

open-source software developed at UJ with FNP funding



particle-based cloud modelling workshop at UJ (April '19)



44 researchers from 28 institutions from 11 countries

http://www.ii.uj.edu.pl/~arabas/workshop_2019/

Thank you!

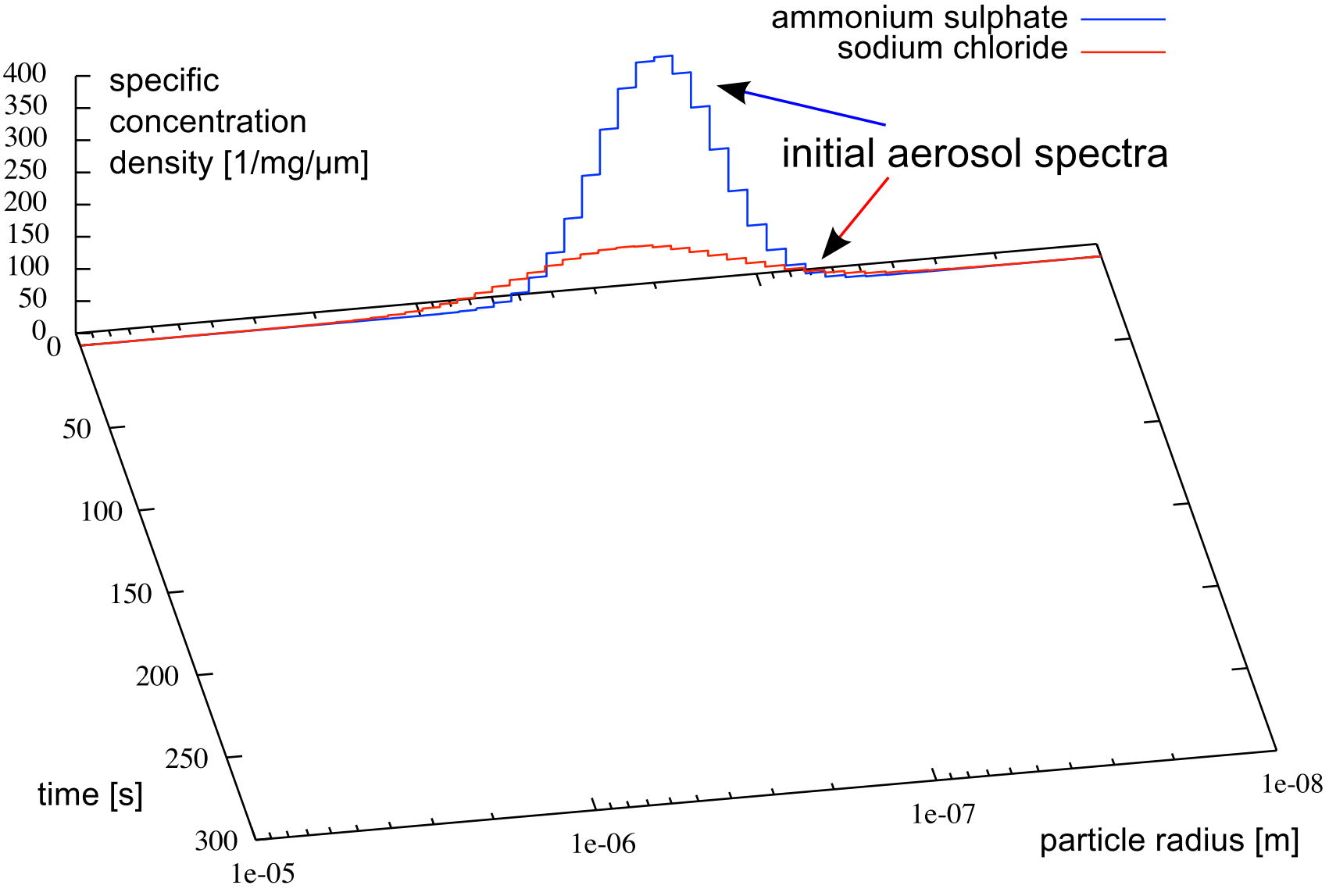

European Funds
Smart Growth


Republic of Poland


Foundation for Polish Science

European Union
European Regional Development Fund

Lagrangian μ-physics in 0D (parcel model)



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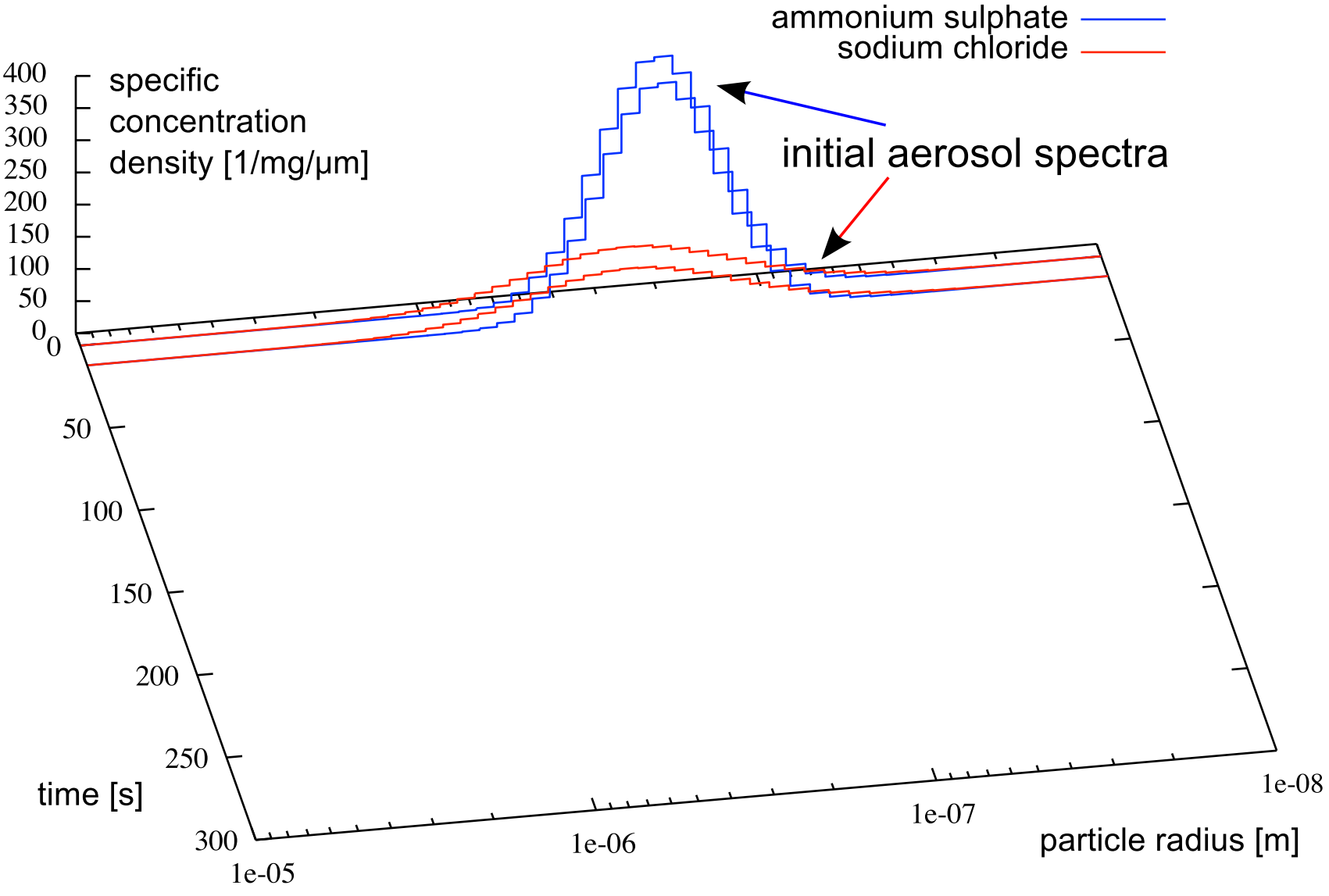

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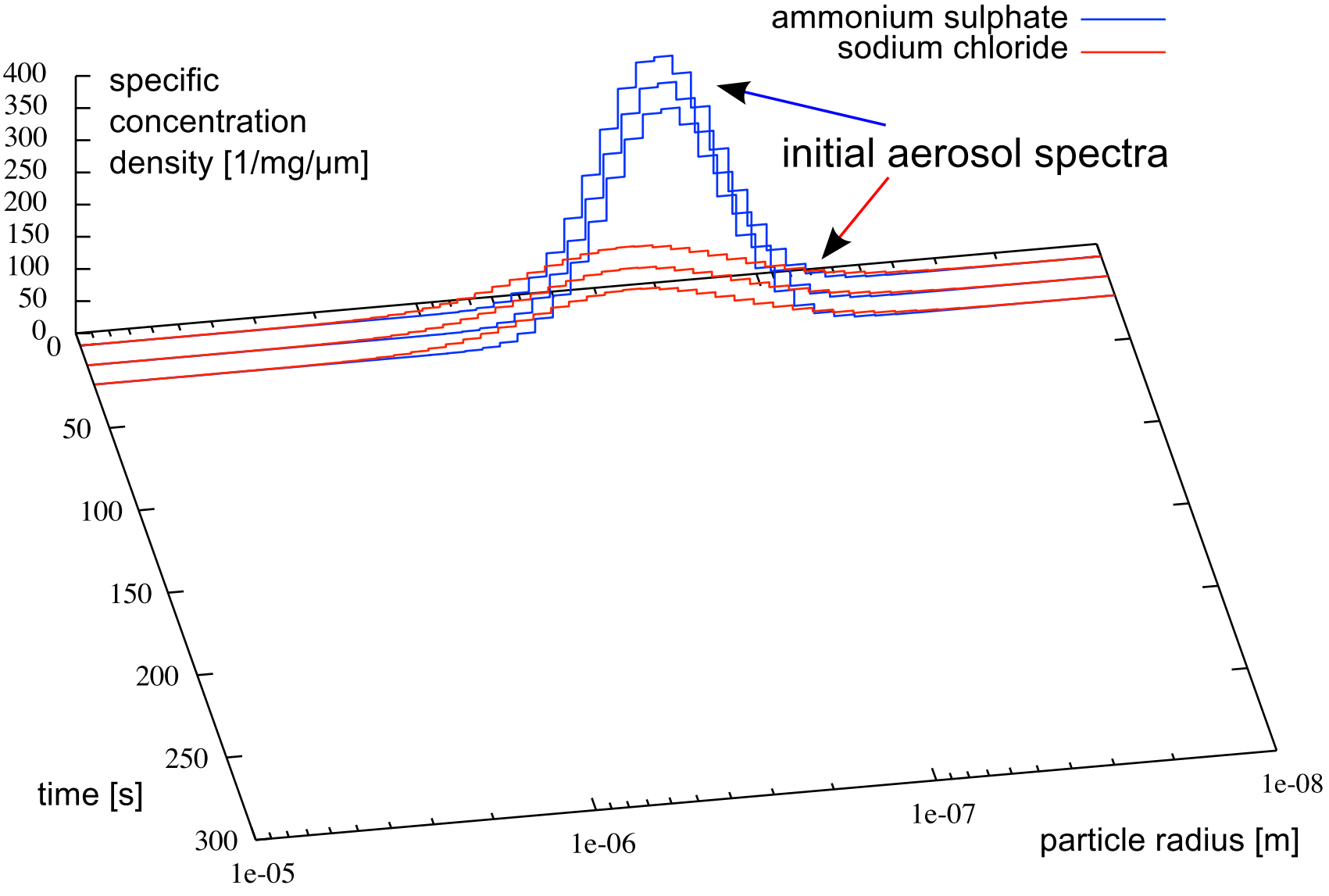

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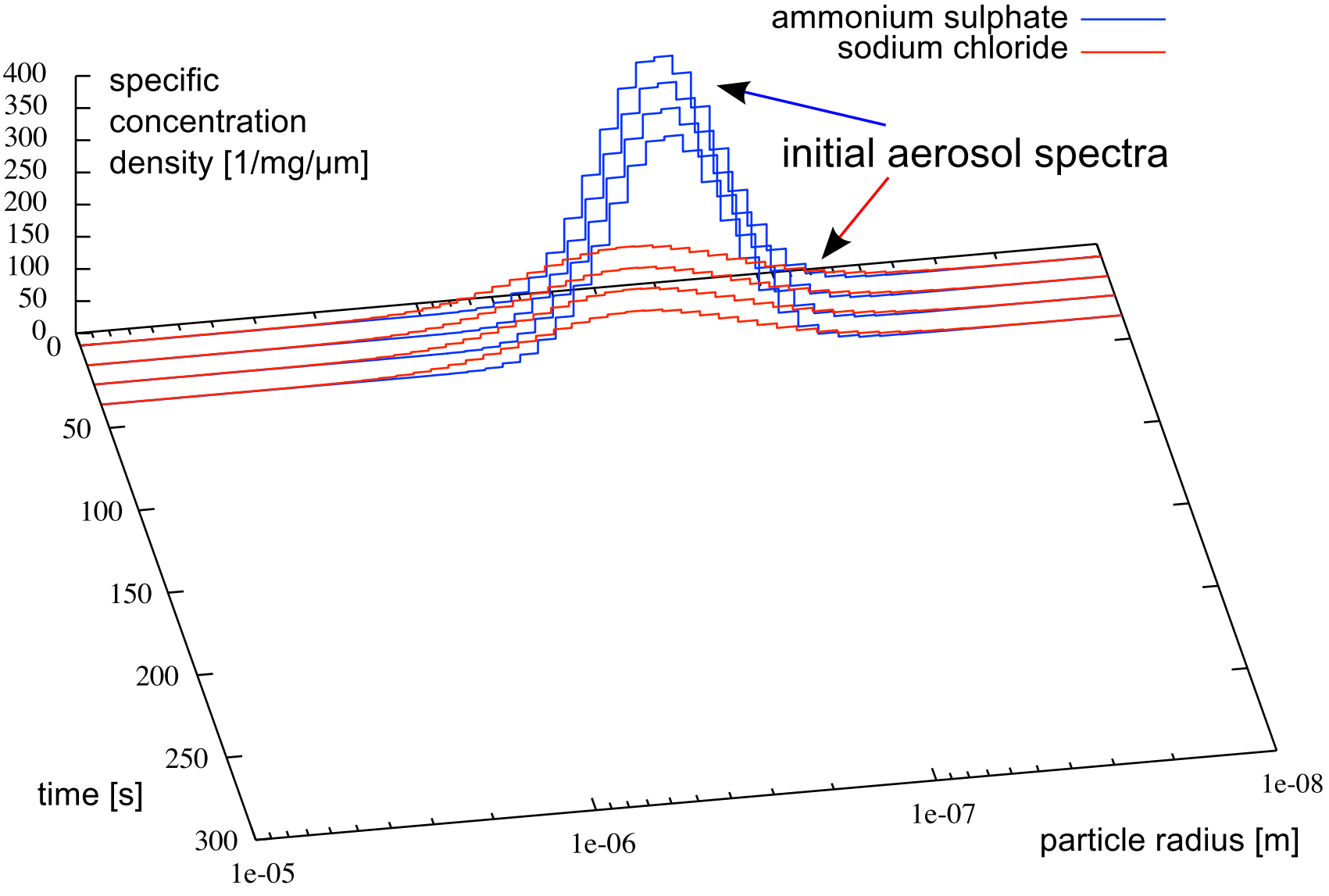

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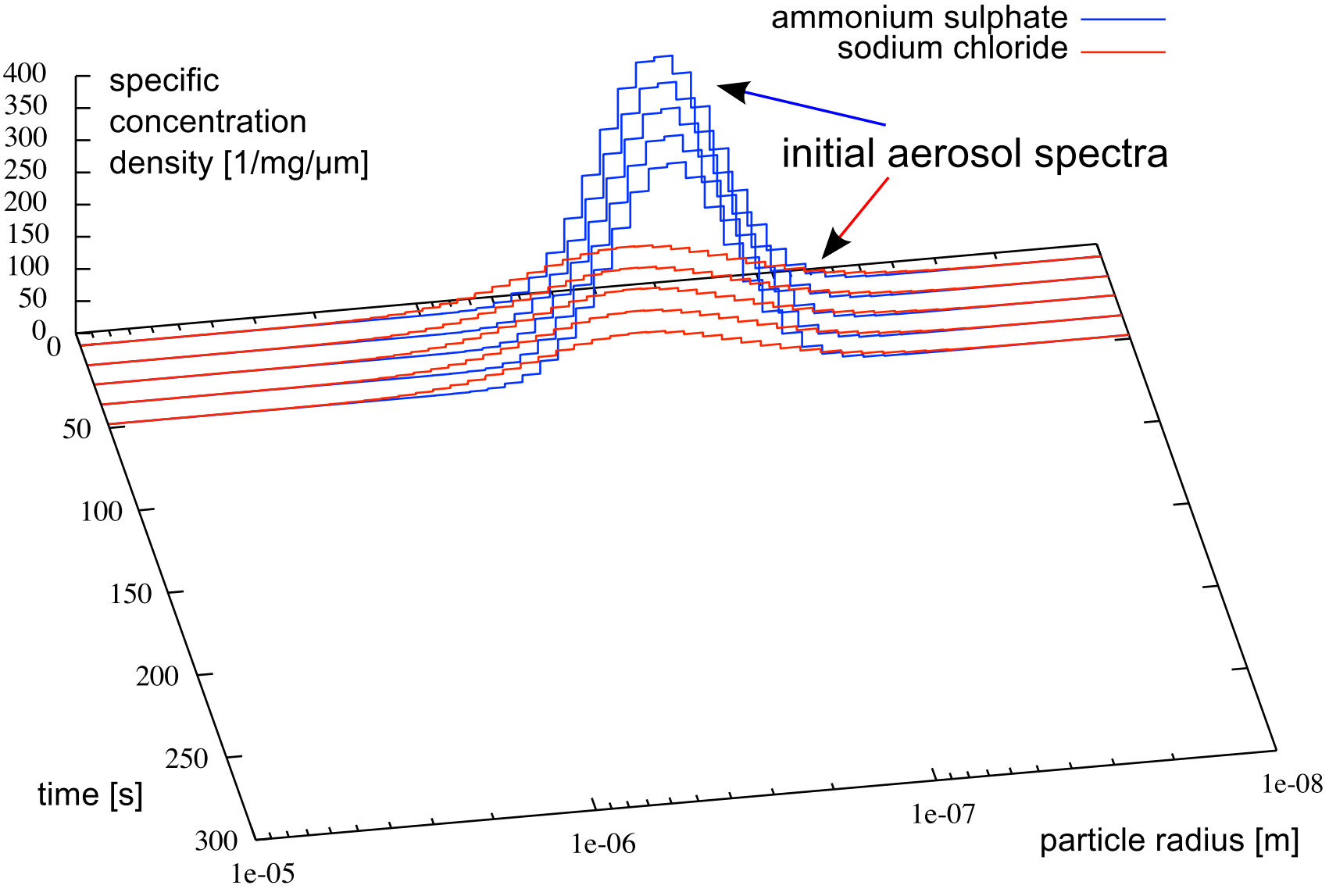

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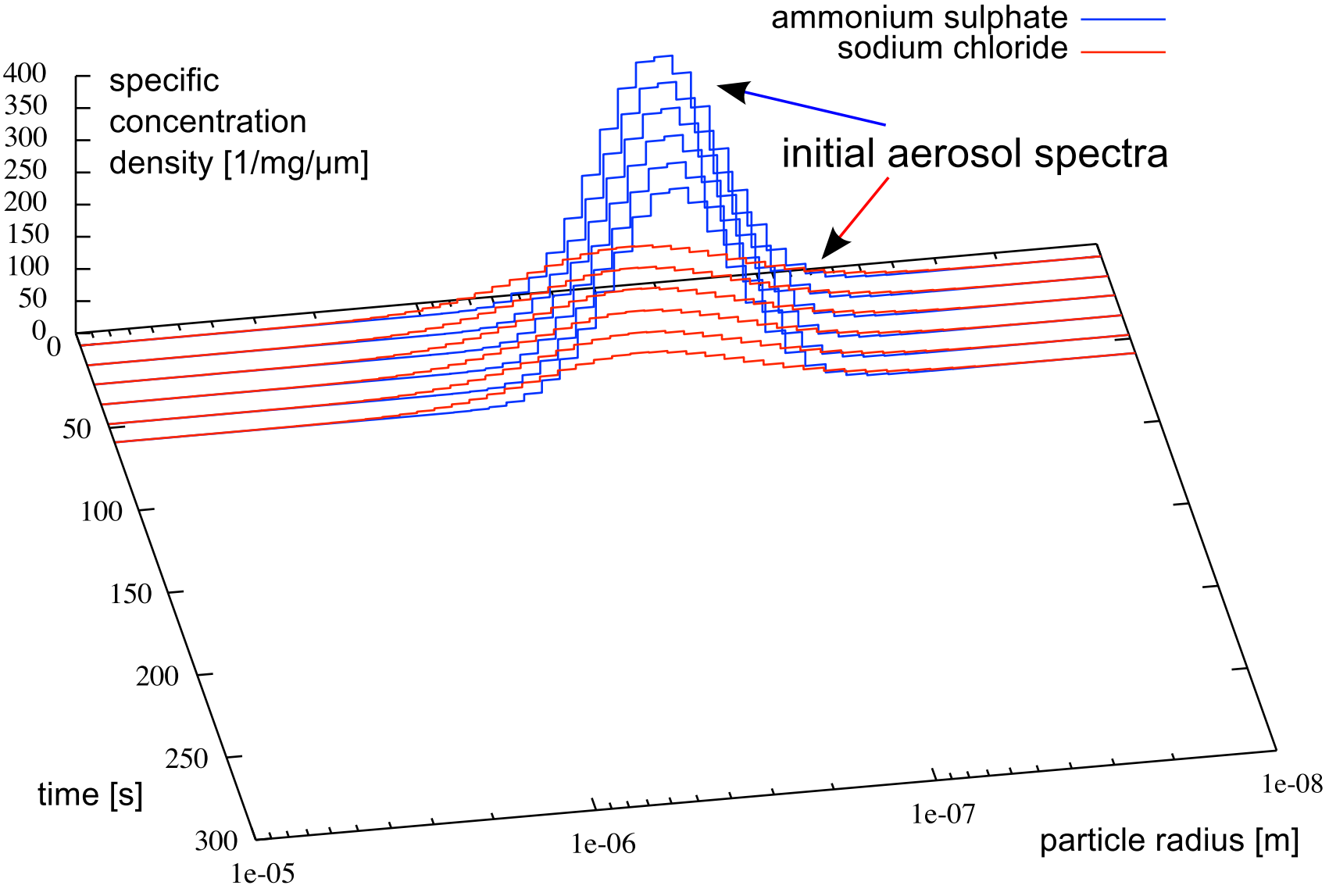

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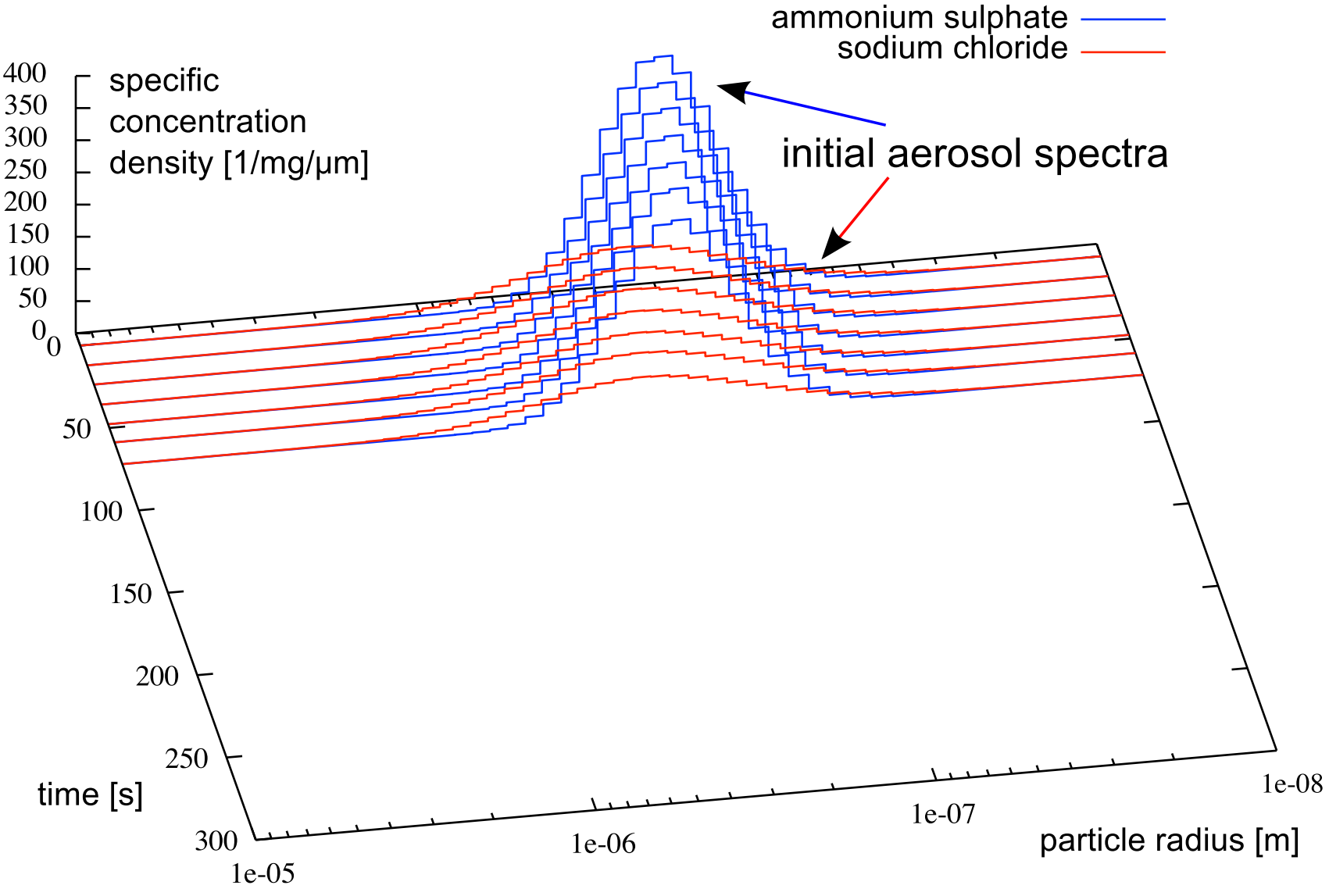

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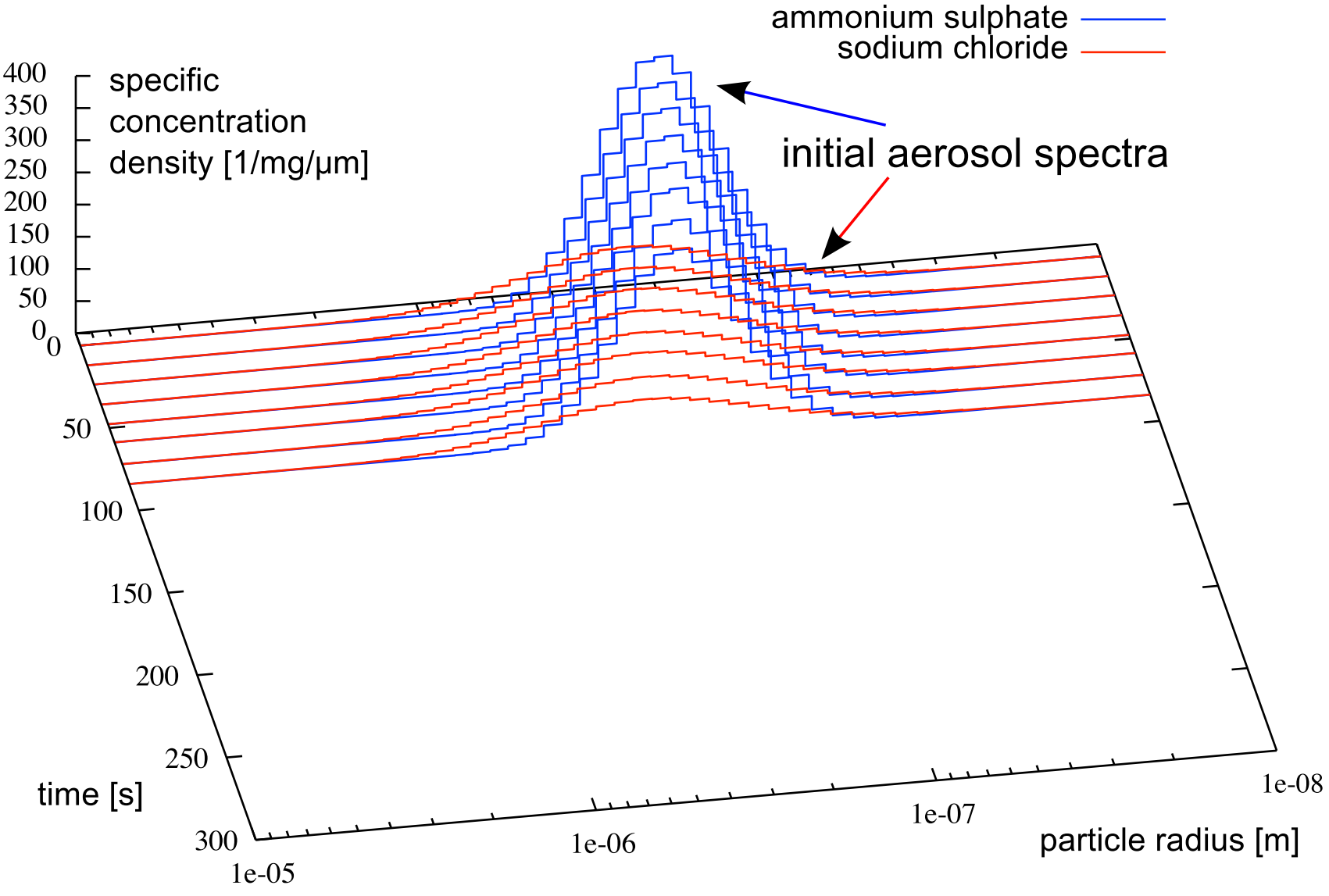

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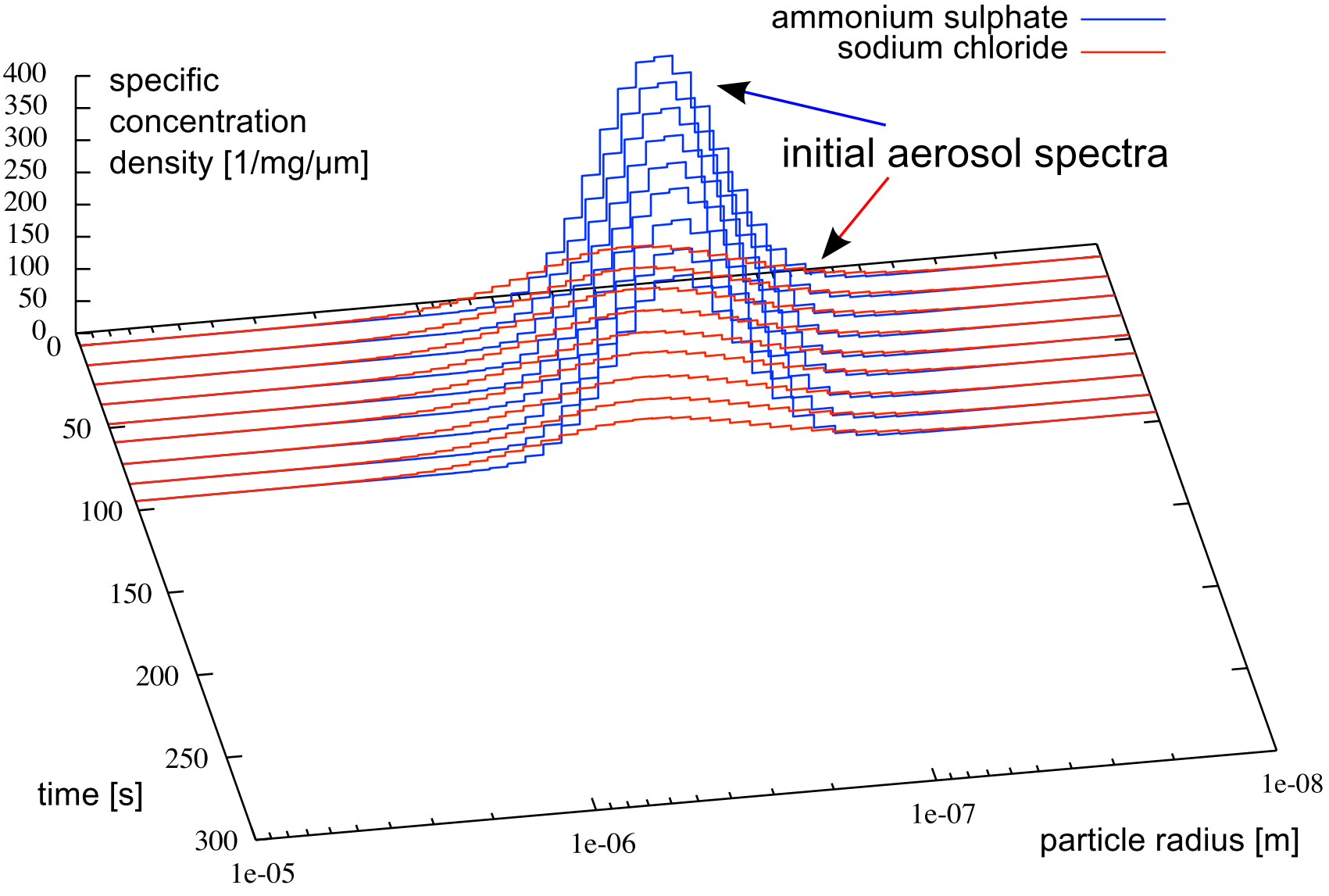

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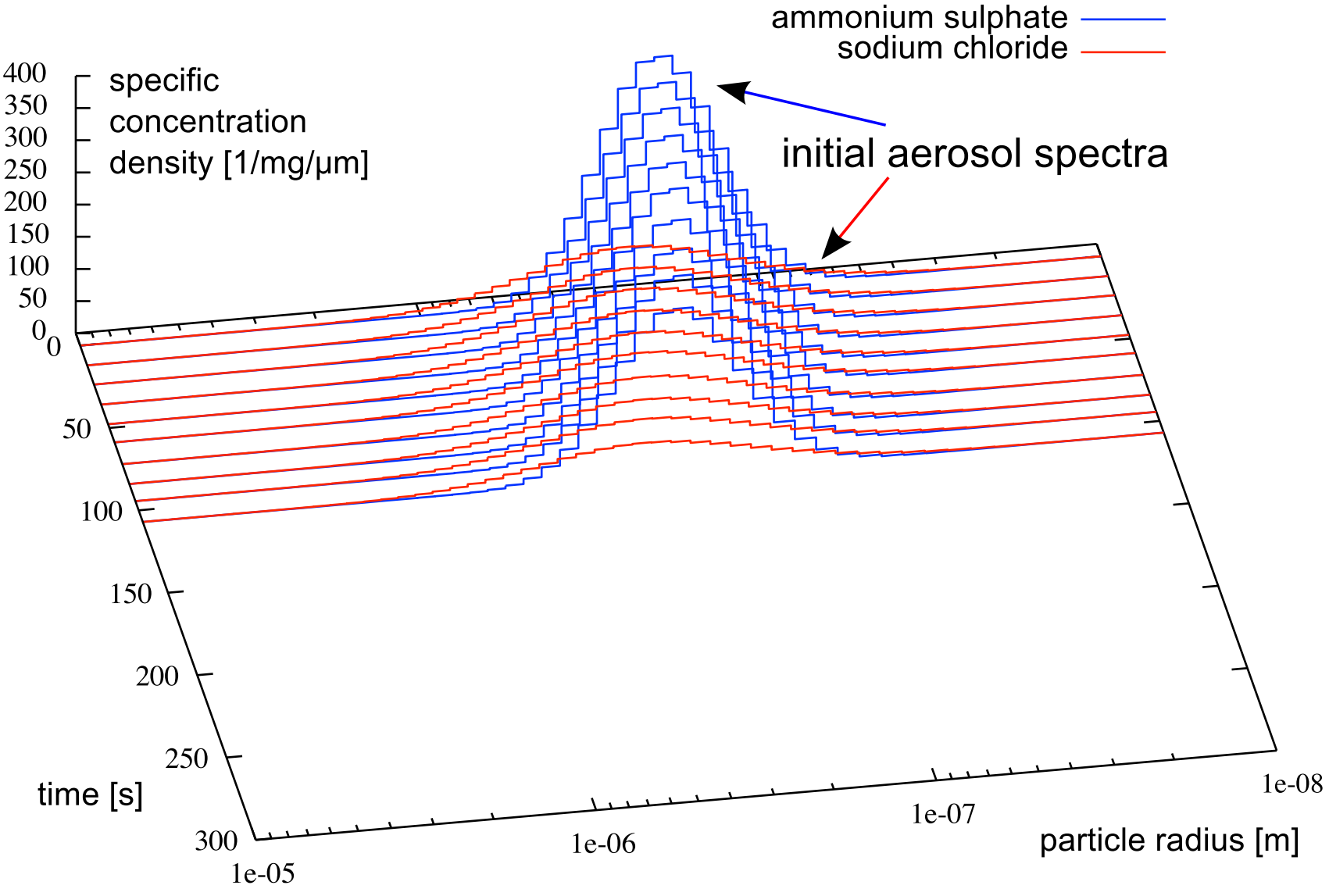

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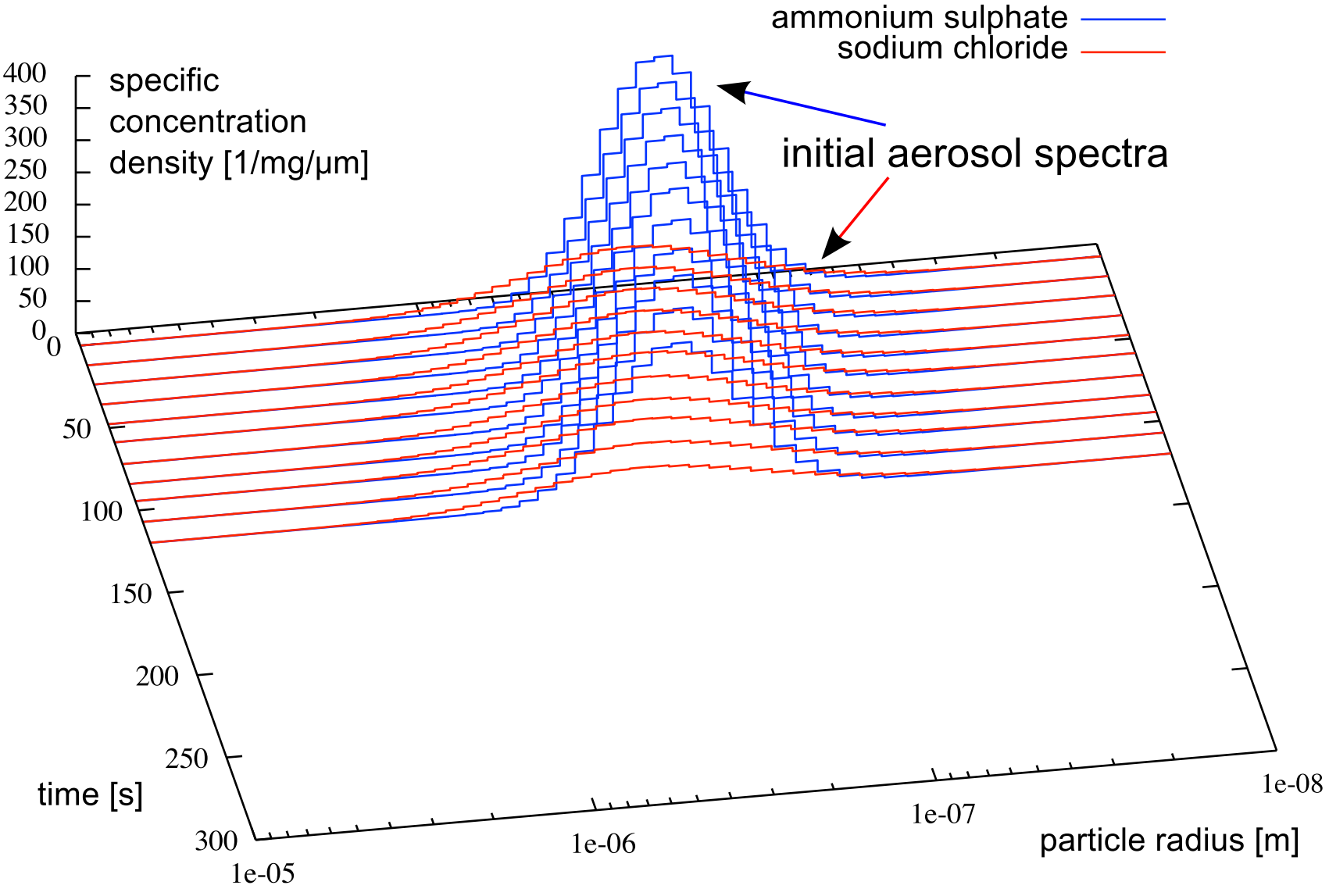

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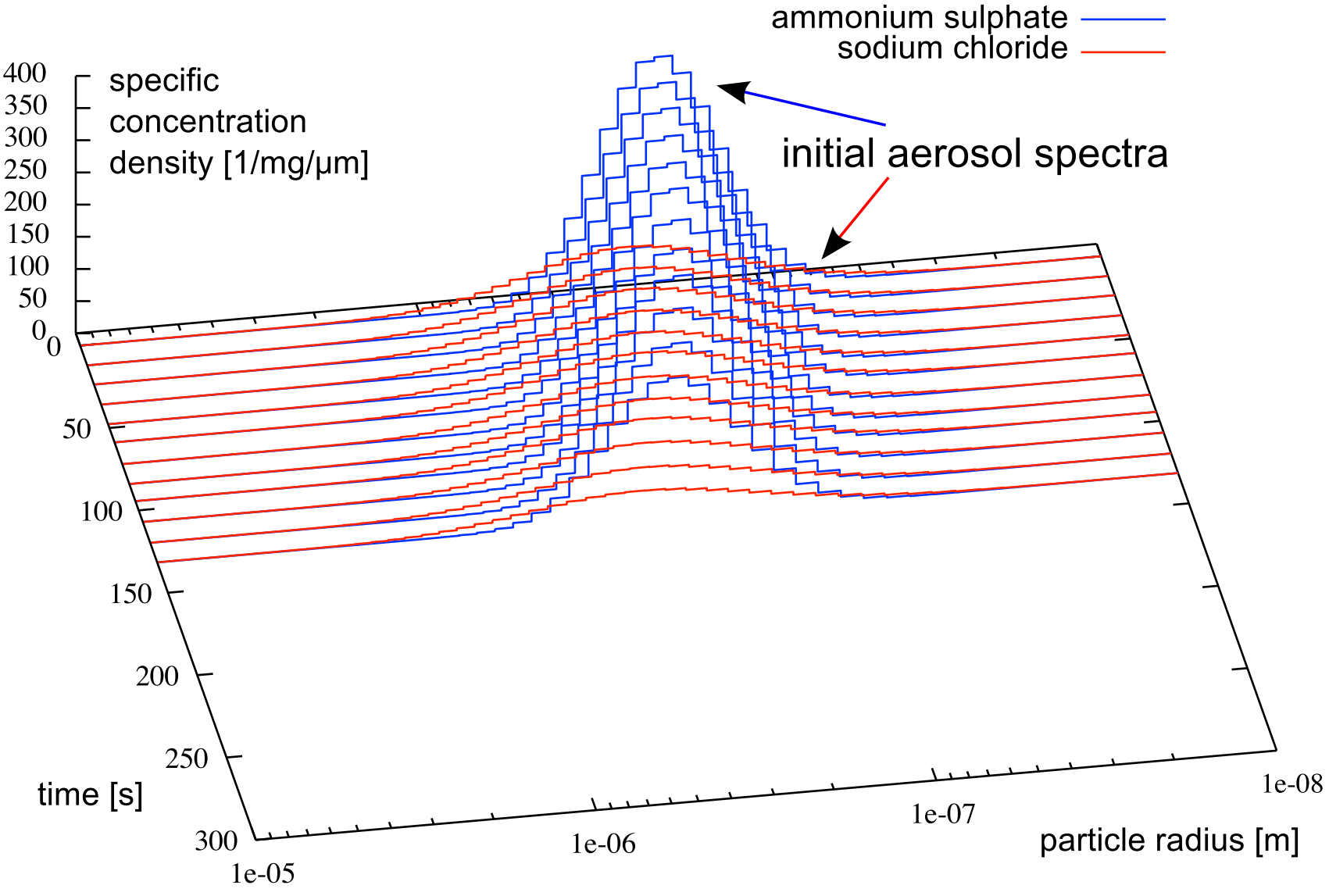

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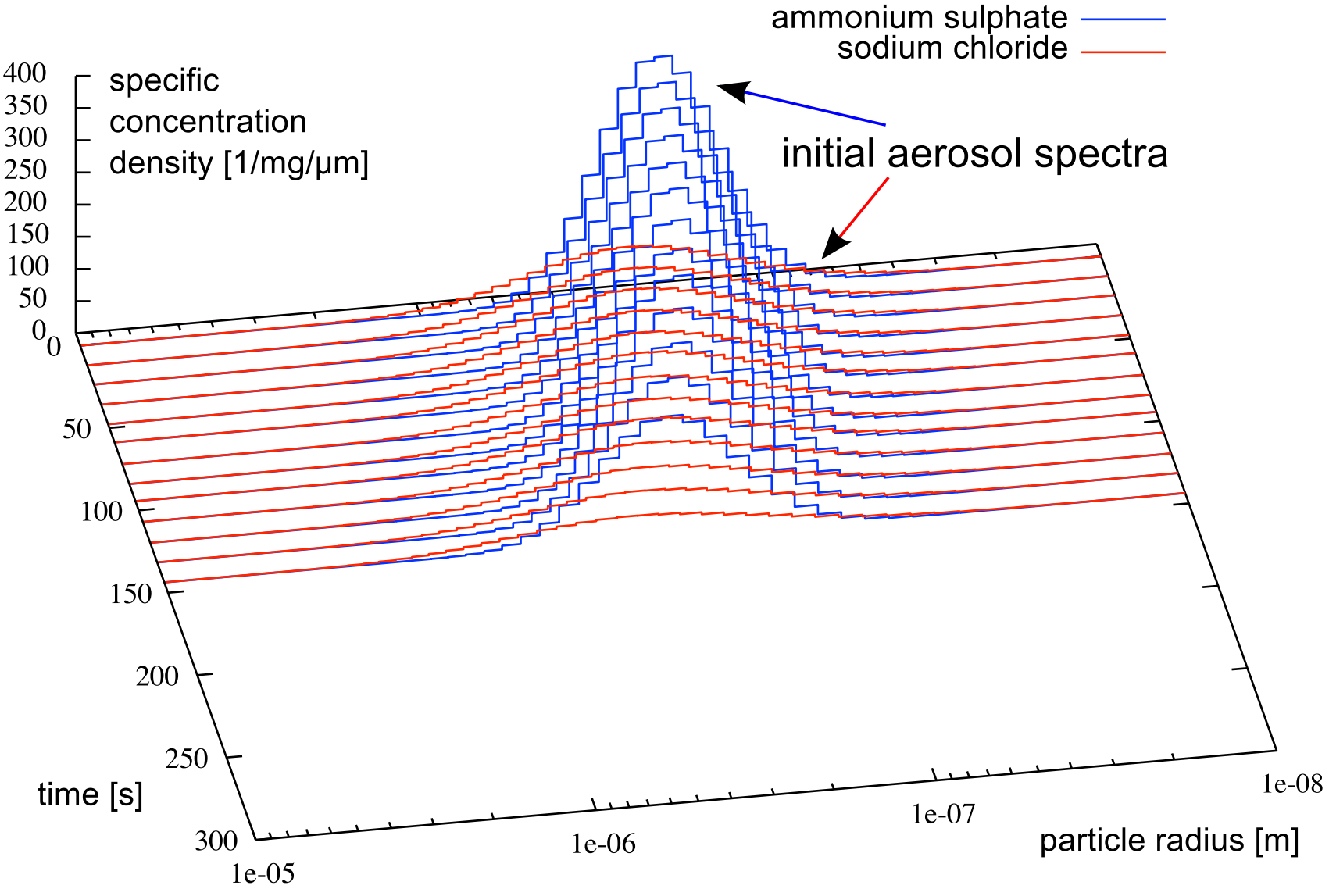

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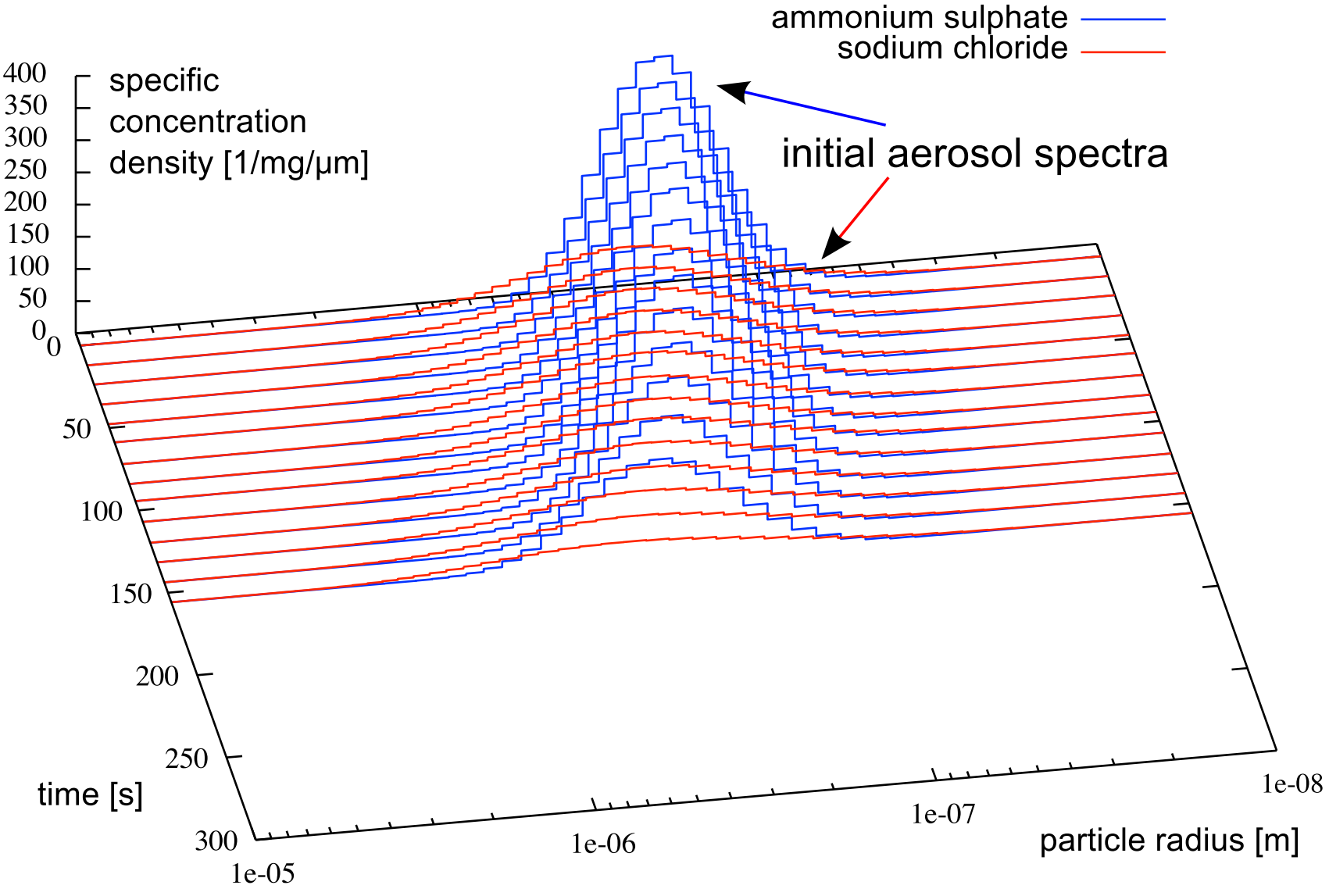
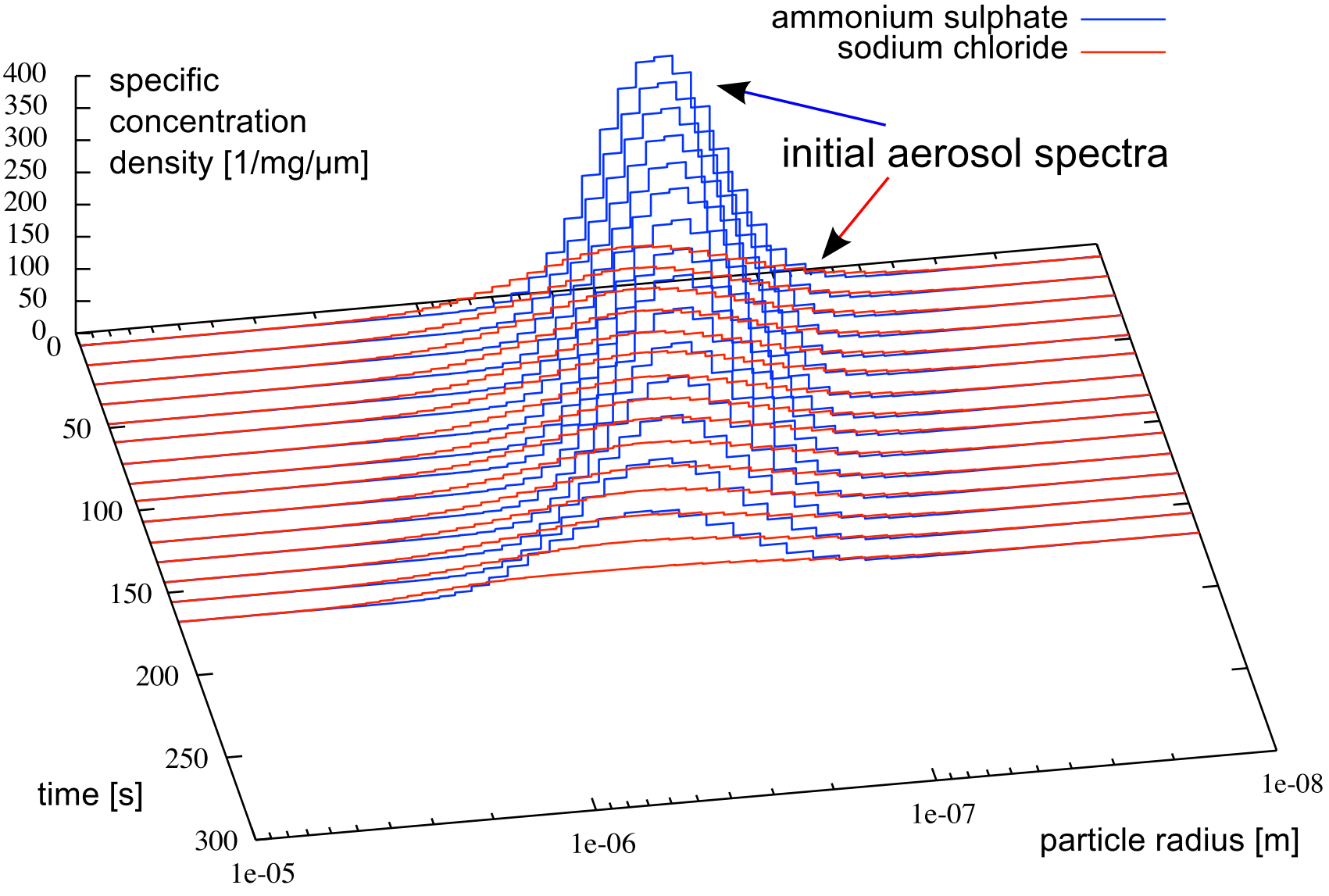
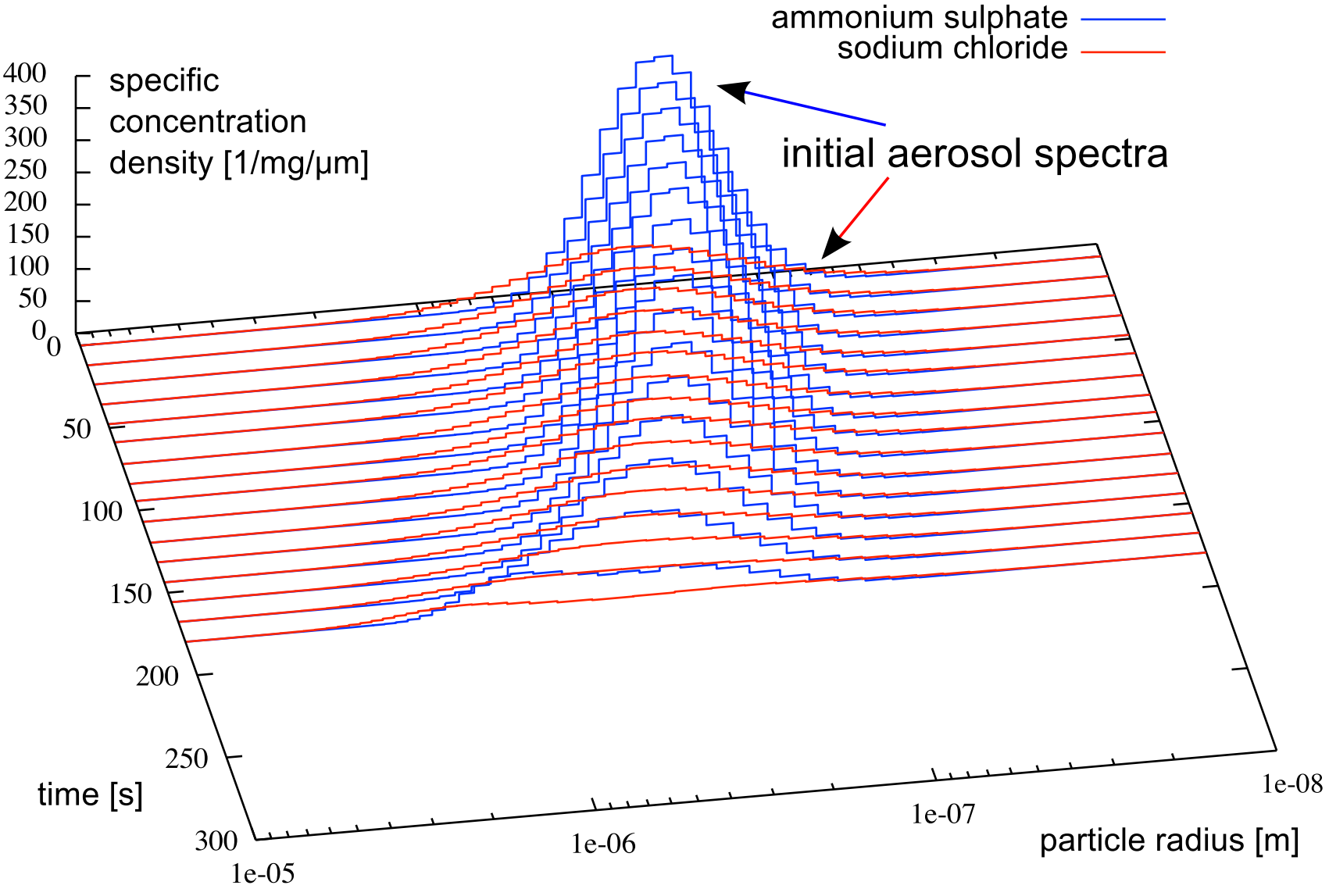


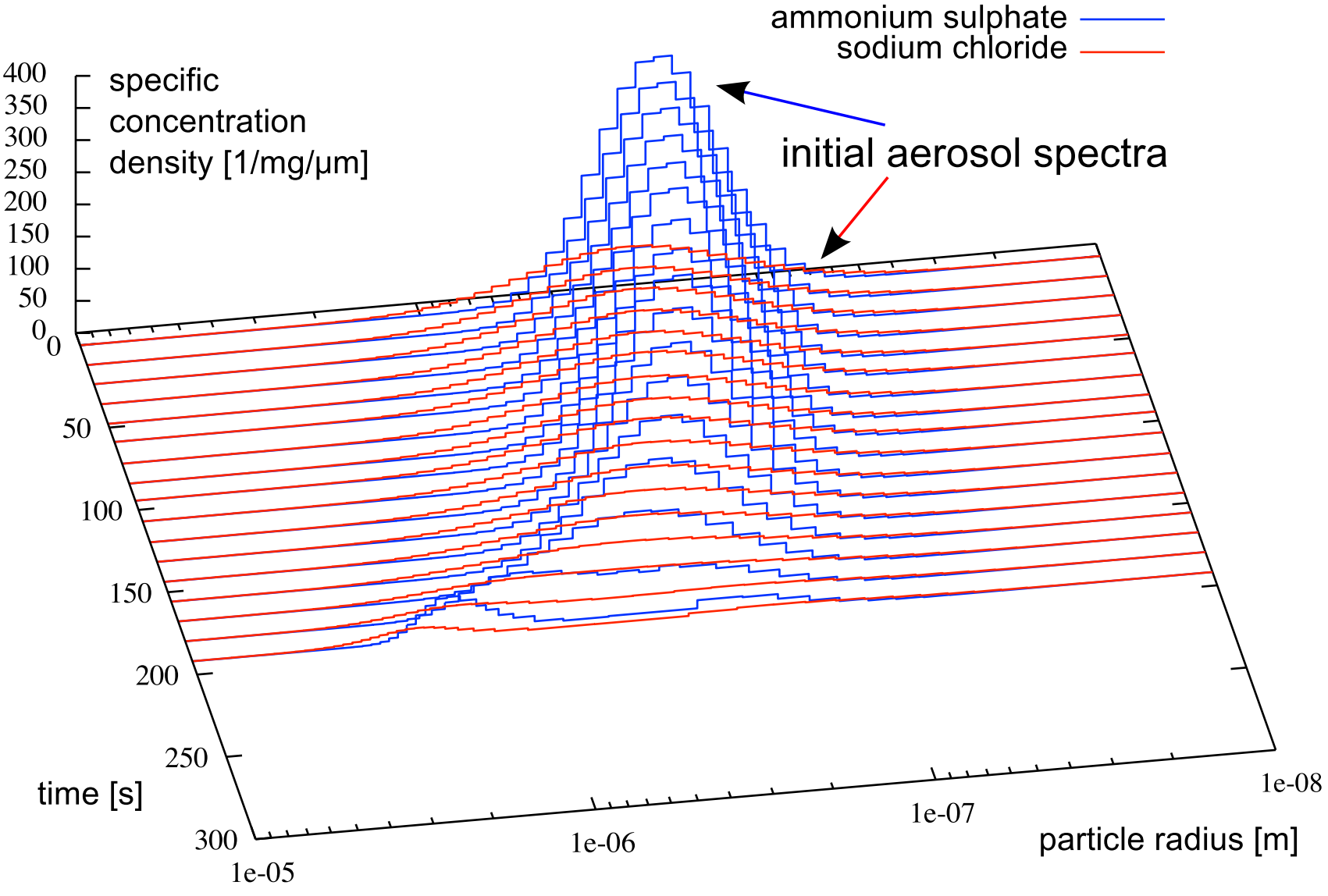
Lagrangian μ-physics in 0D (parcel model)



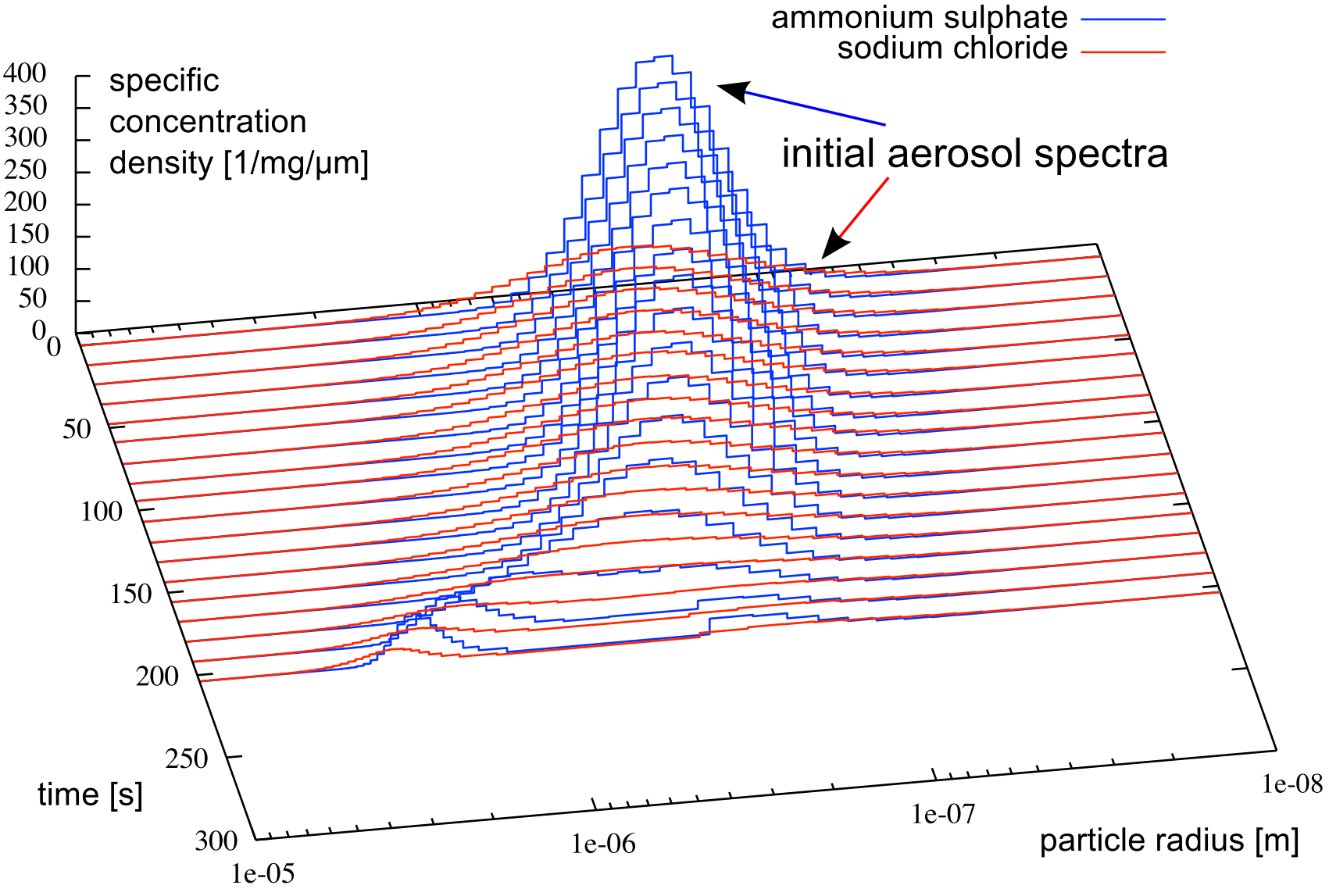
Lagrangian μ-physics in 0D (parcel model)



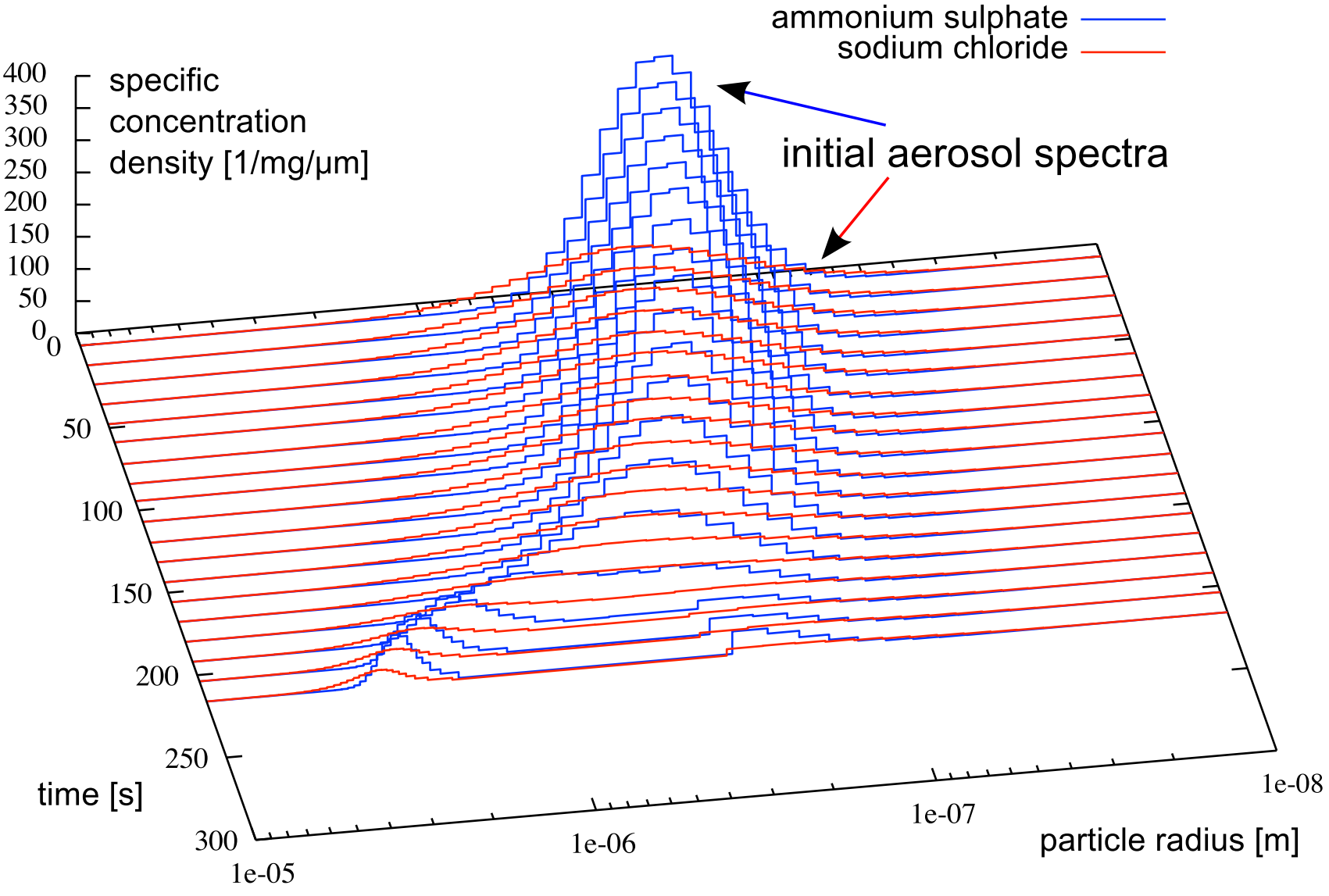
Lagrangian μ-physics in 0D (parcel model)



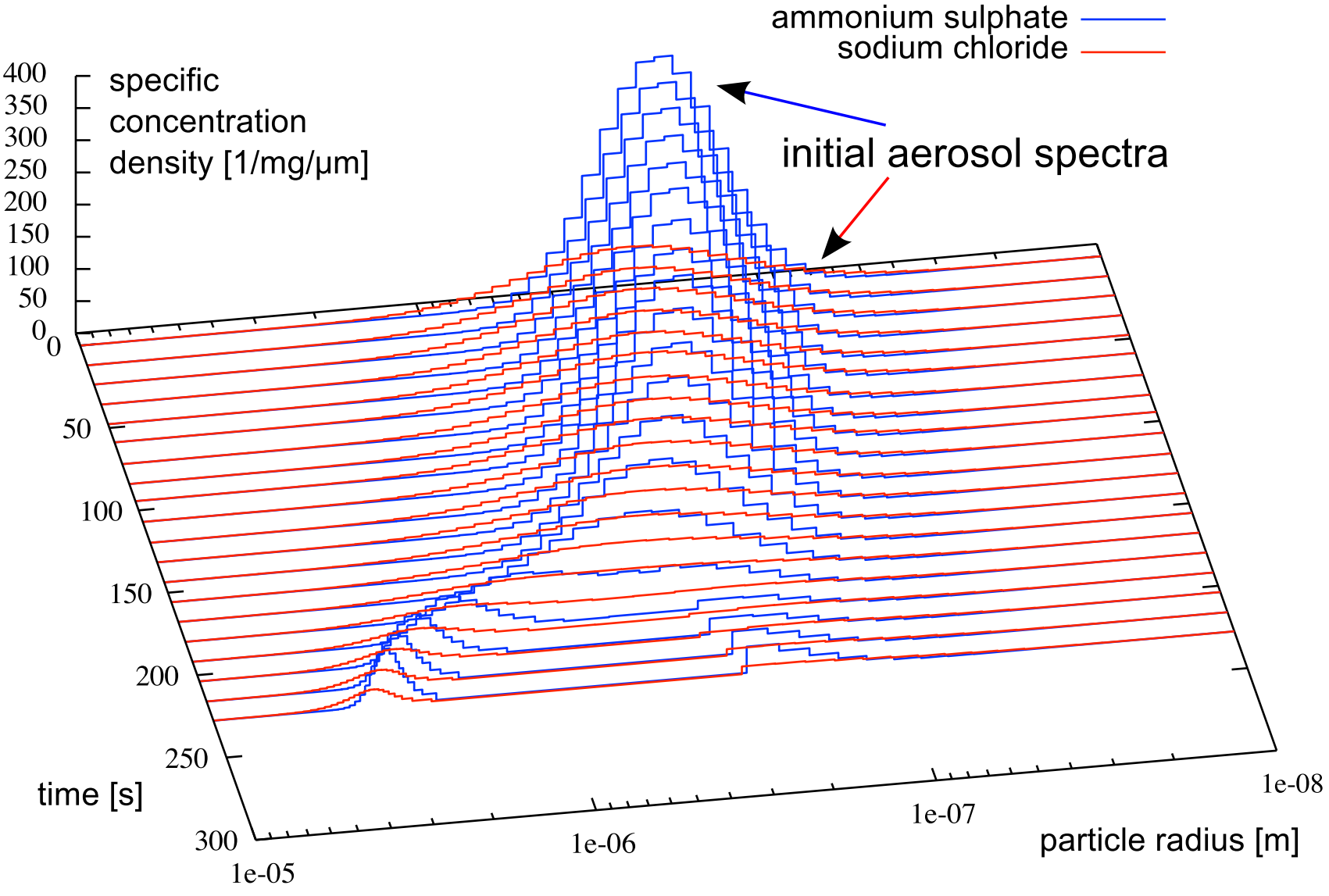
Lagrangian μ-physics in 0D (parcel model)



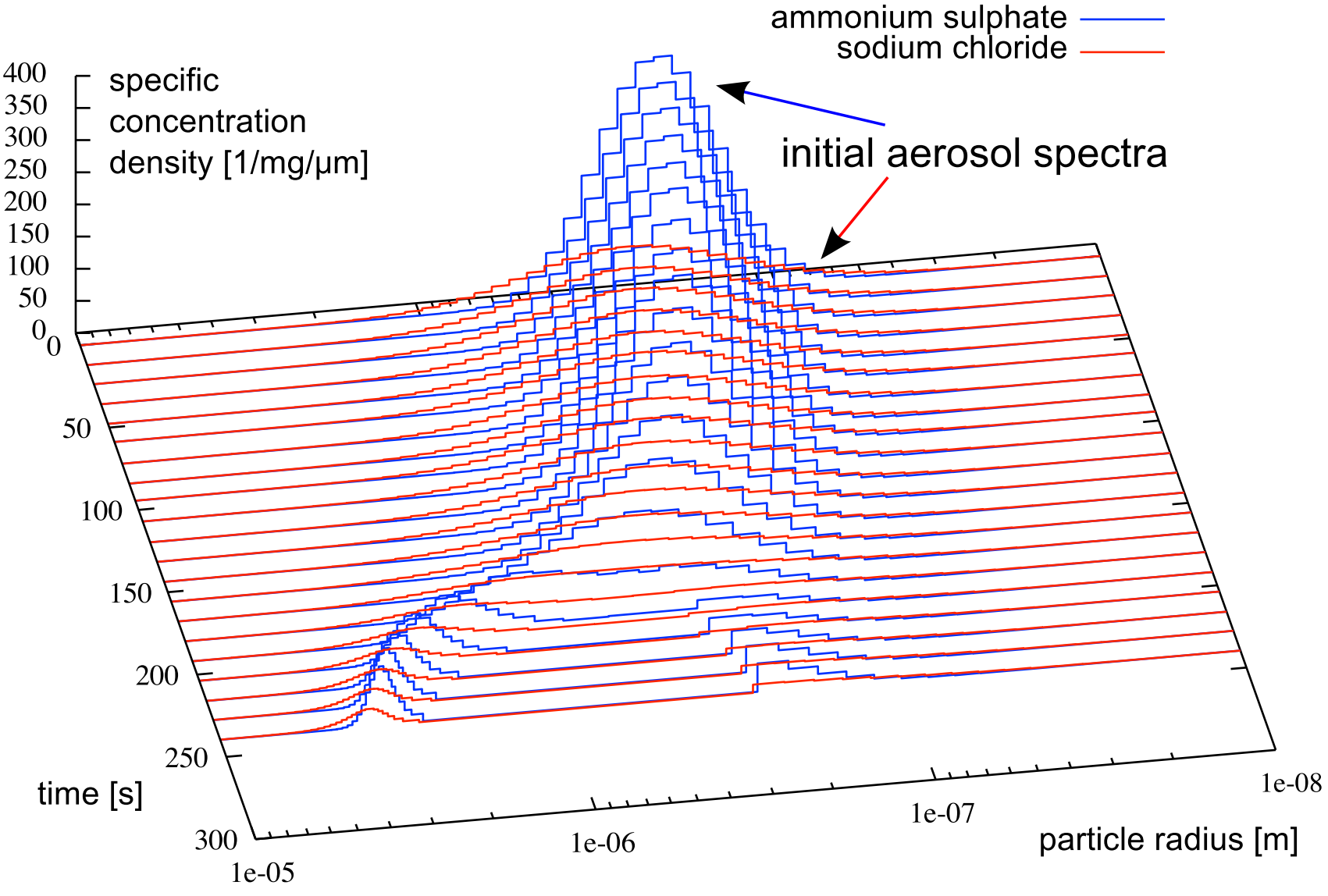
Lagrangian μ-physics in 0D (parcel model)



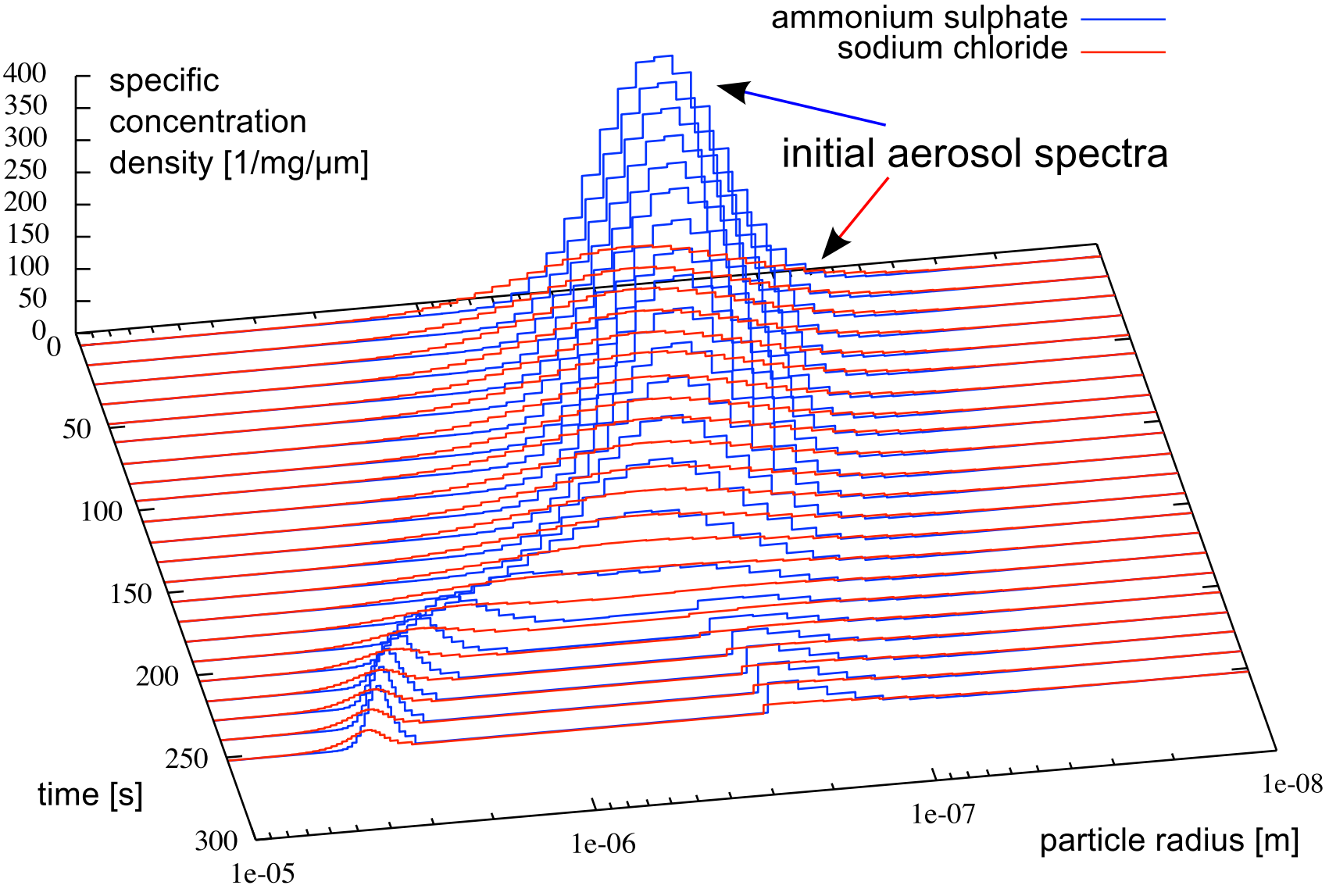
Lagrangian μ-physics in 0D (parcel model)



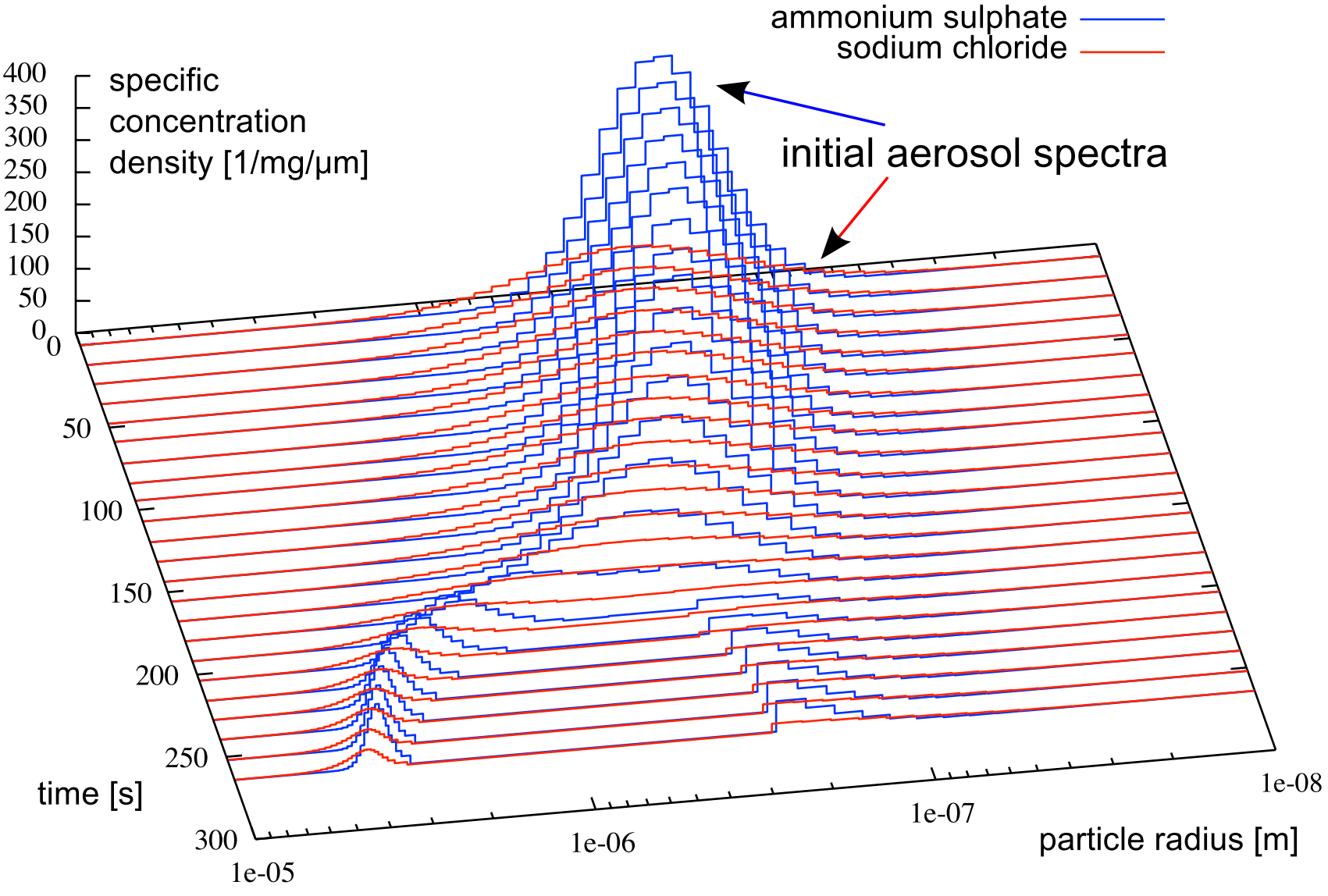
Lagrangian μ-physics in 0D (parcel model)



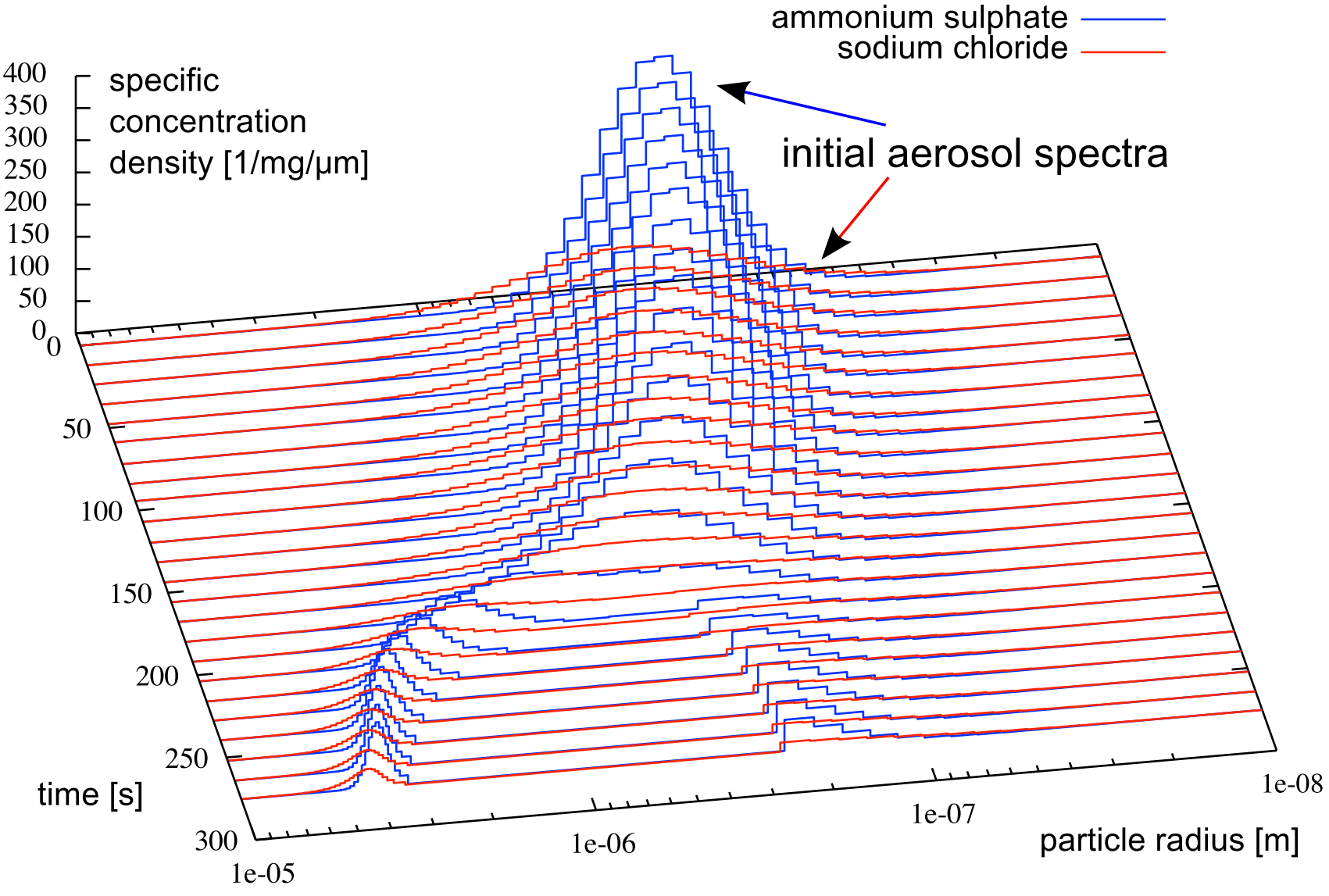
Lagrangian μ-physics in 0D (parcel model)



Lagrangian μ-physics in 0D (parcel model)



Lagrangian μ-physics in 0D (parcel model)



Lagrangian μ-physics in 0D (parcel model)