Particle-based cloud microphysics: rationale, state of the art and challenges

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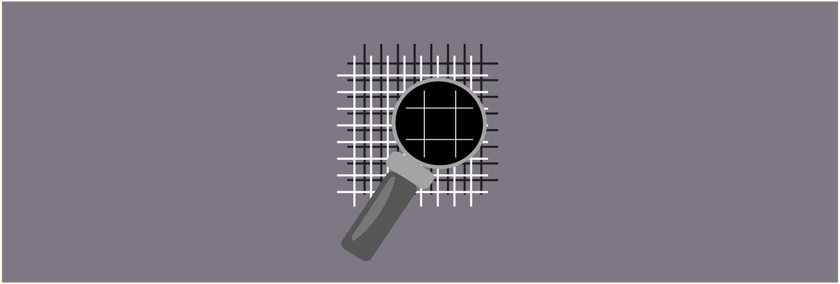
- founded in 1364 (3 years older!)
- ca. 40 000 students, 7000 staff (4000 acad.), 16 faculties
- billateral agreement with U. Pécs signed in 2004

rationale

rationale: aerosol-cloud interactions

"Cloud and ship. Ukraine, Crimea, Black sea, view from Ai-Petri mountain"
(photo: Yevgen Timashov / National Geographic)

rationale: modelling aerosol-cloud interactions



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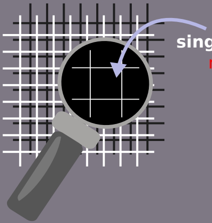
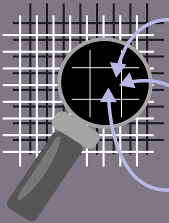


single-moment bulk:

no influence of aerosol on cloud

rationale: modelling aerosol-cloud interactions



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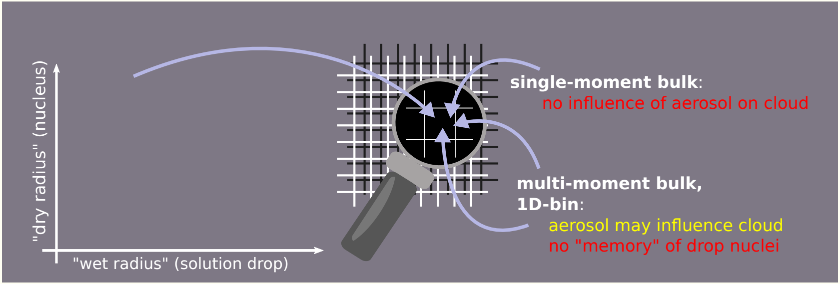

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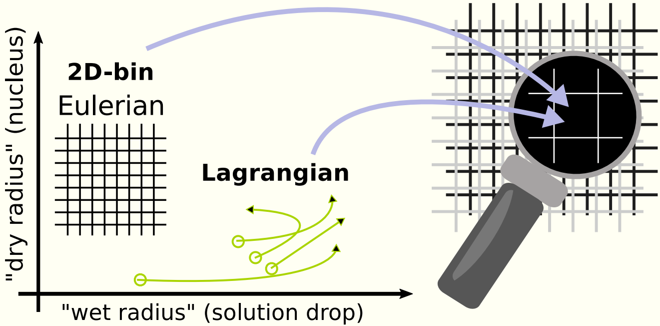

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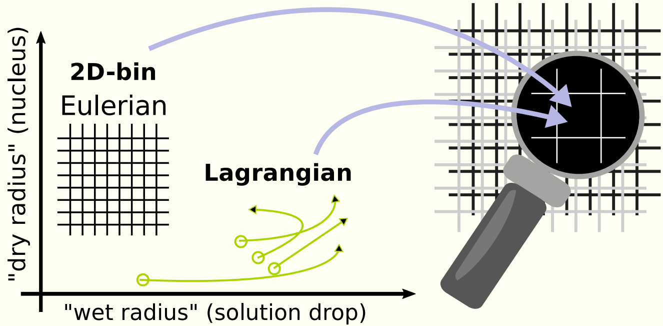

Lagrangian:

- parcel model
  ⇝ moving-sectional/bin schemes (40-ties onwards: Howell, Mordy, ...)

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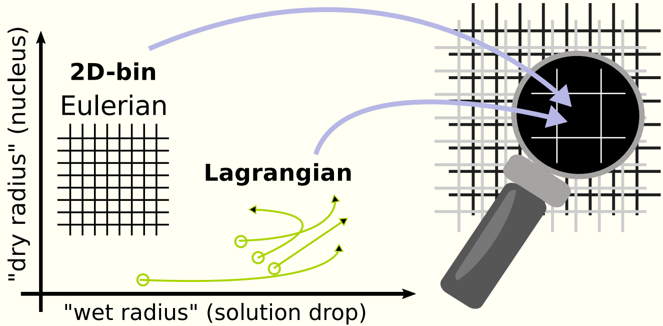
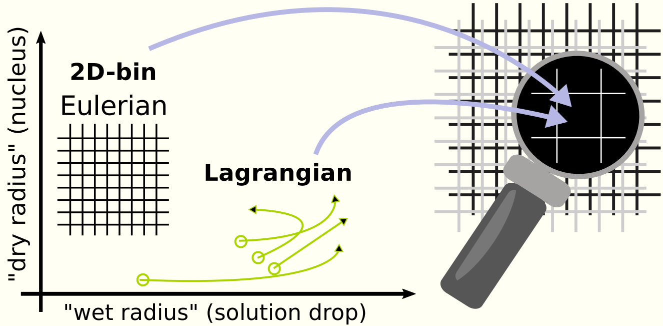


Lagrangian:

- parcel model
  ⇝ moving-sectional/bin schemes (40-ties onwards: Howell, Mordy, . . .)
- LES + Lagrangian-in-space + coalescence
  ⇝ particle-based/super-droplet μ-physics (00-ties onwards: Shima, . . .)

rationale: modelling aerosol-cloud interactions

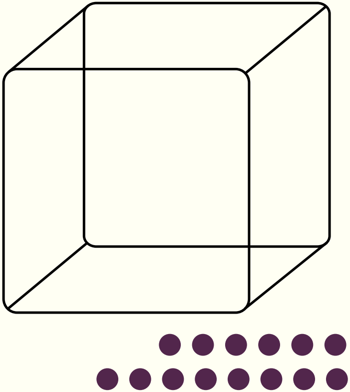


Pioneering warm-rain aerosol-cloud-interaction models:

Andrejczuk et al. 2010	
condensation:	Lagrangian
collisions:	Eulerian

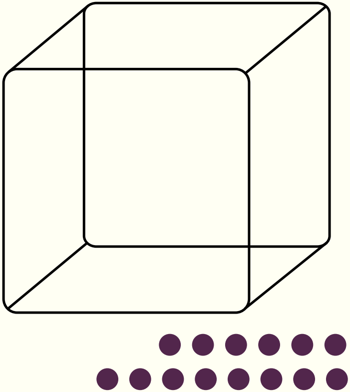
Lebo & Seinfeld 2011	
condensation:	Eulerian
collisions:	Eulerian

Shima et al. 2009	
condensation:	Lagrangian
collisions:	Lagrangian



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

particle-based μ-physics: key concepts



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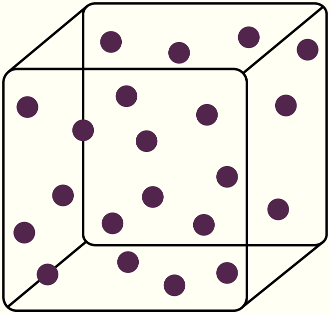

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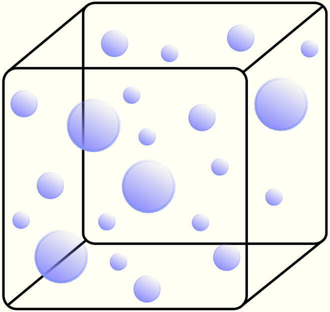

Domain randomly populated with "μ-physics information carriers" (super particles / super droplets)

carrier attributes:

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- wet radius

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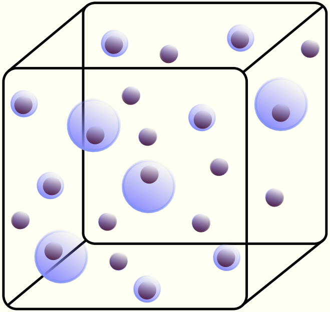

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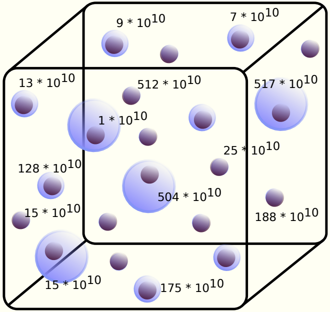

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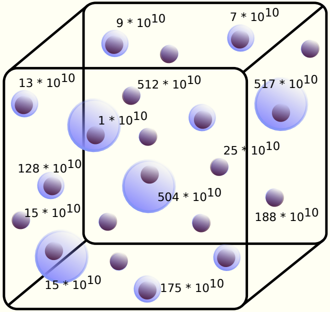

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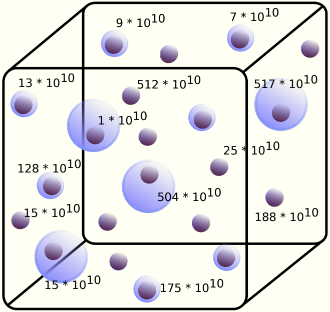

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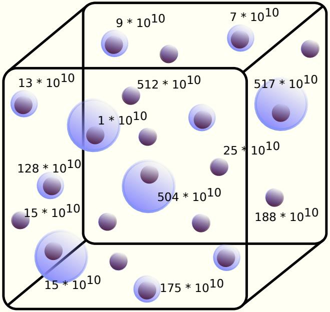

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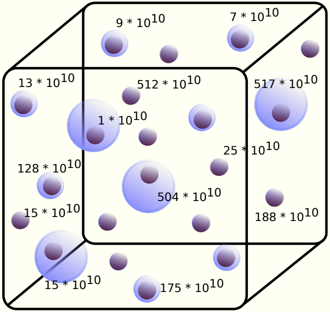

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(ice, chemistry, charge, isotopic composition, ...)

particle-based μ-physics: coupling with the host model

Eulerian / PDE	Lagrangian / ODE

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	sedimentation

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$\partial_t(\rho_d r) + \nabla \cdot (\vec{v}\rho_d r) = \rho_d \dot{r}$	$\dot{r} = \sum_{\text{particles} \in \Delta V} \ldots$
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challenges:

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

example simulation (2D, prescribed flow)

Geosci. Model Dev., 8, 1677-1707, 2015

https://doi.org/10.5194/gmd-8-1677-2015

Model description paper | 09 Jun 2015

libcloudph++ 1.0: a single-moment bulk, double-moment bulk, and particle-based warm-rain microphysics library in C++

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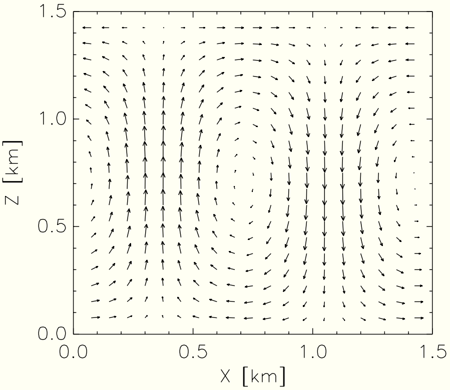

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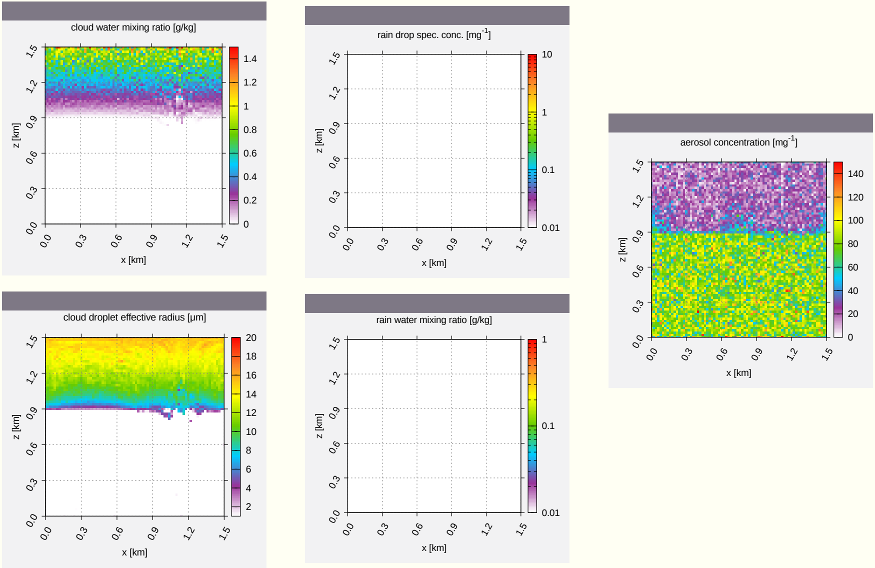

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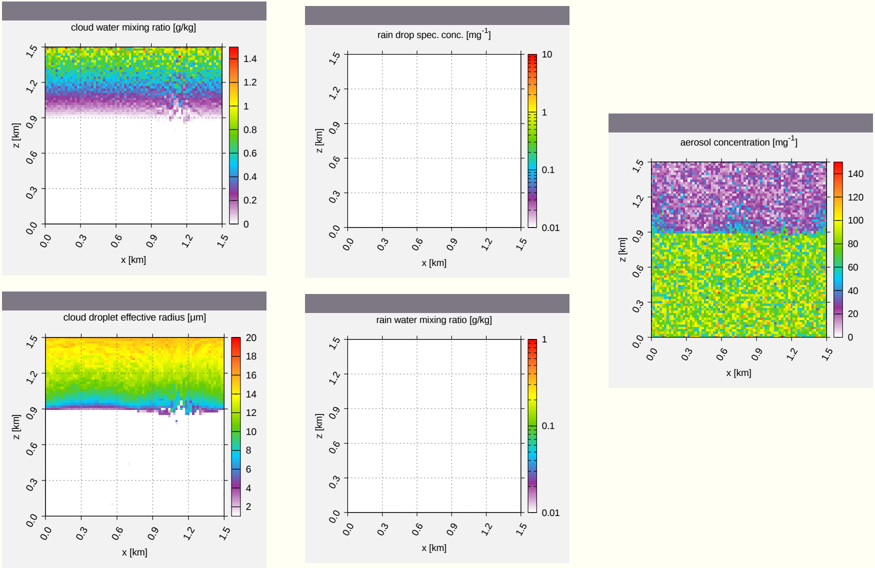

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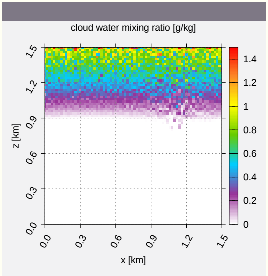

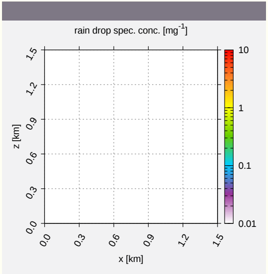

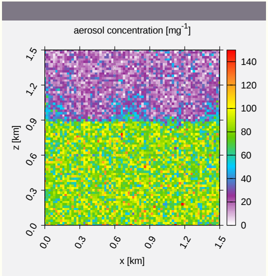

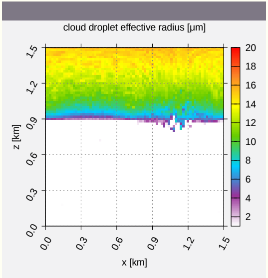

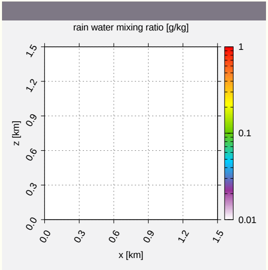

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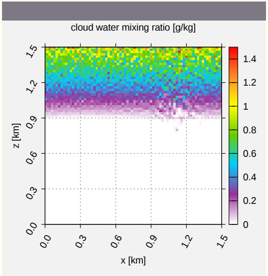

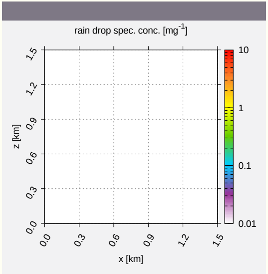

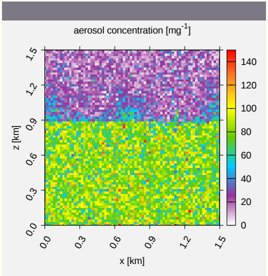

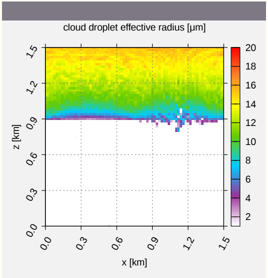

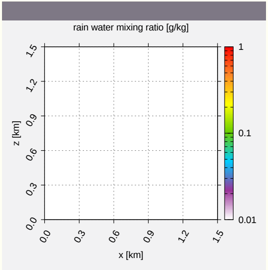

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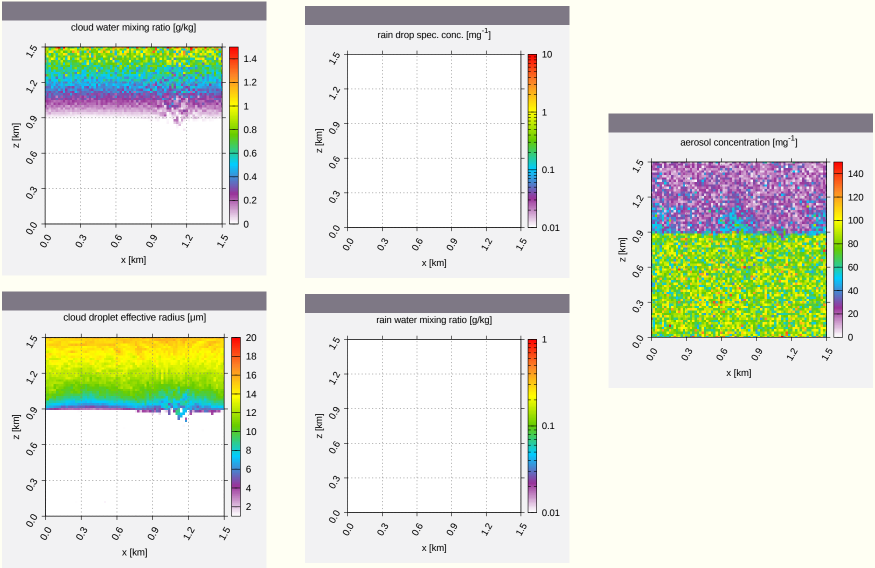

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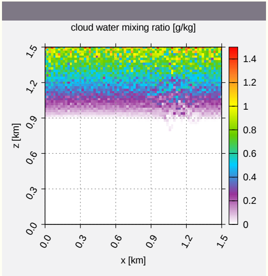

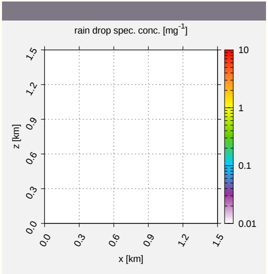

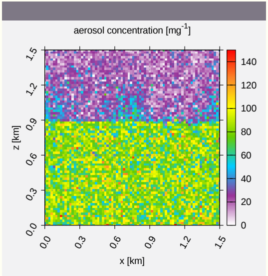

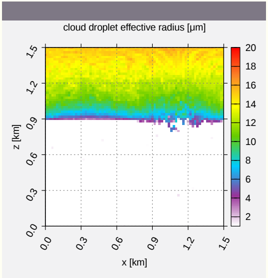

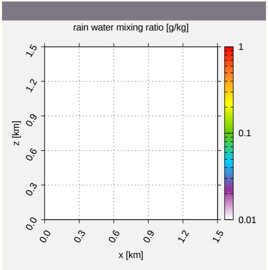

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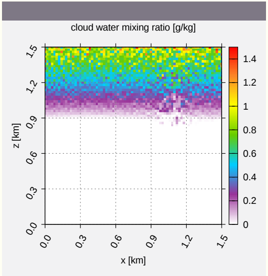

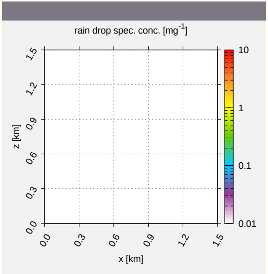

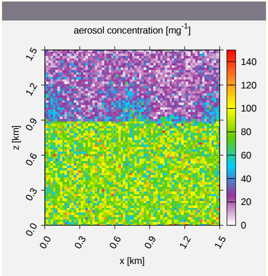

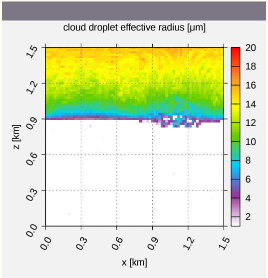

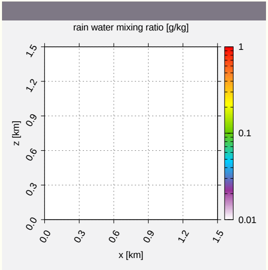

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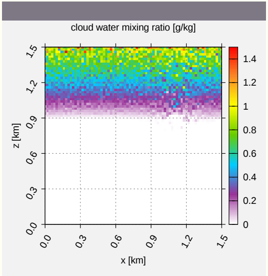

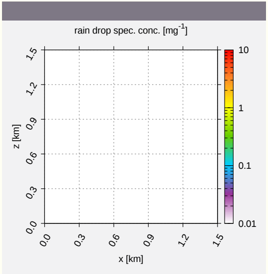

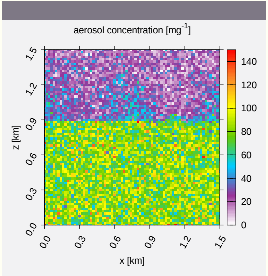

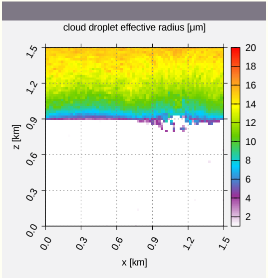

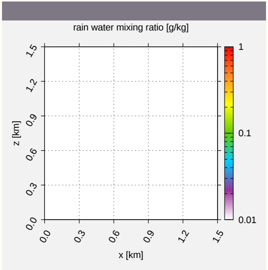

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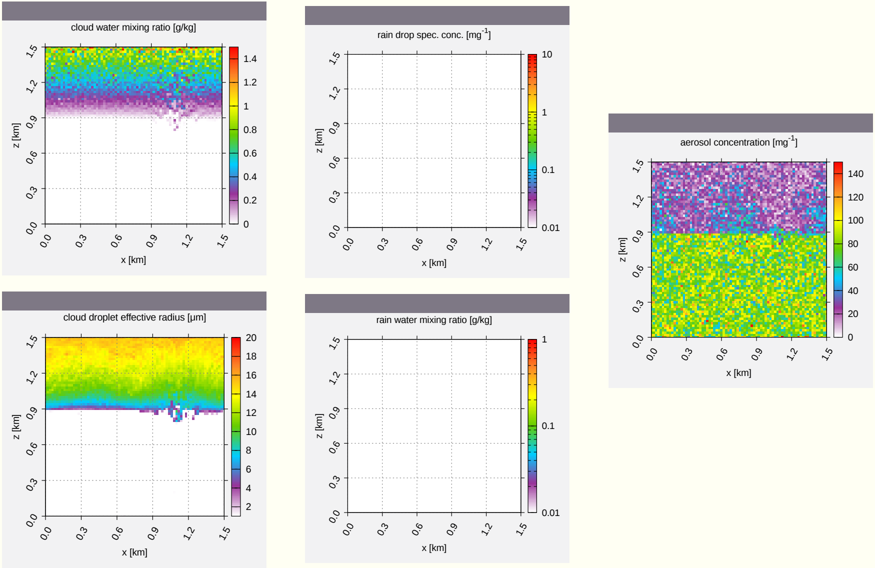

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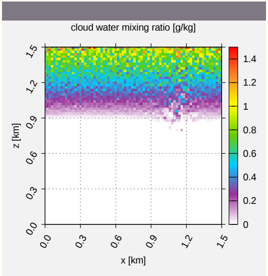

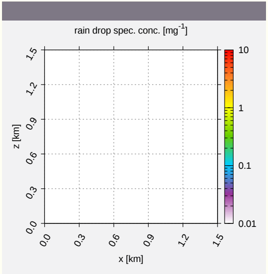

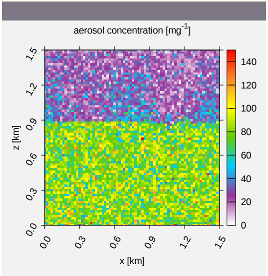

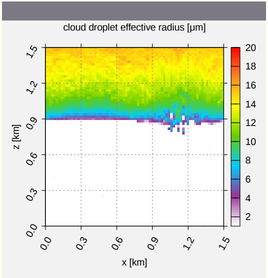

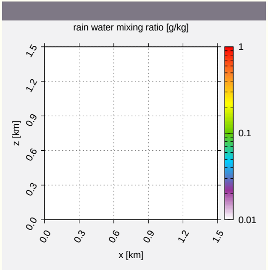

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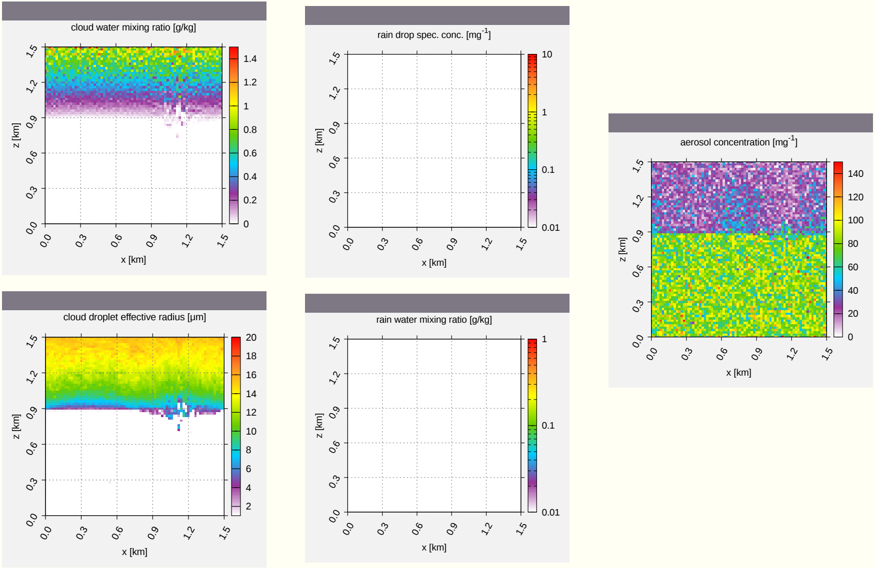

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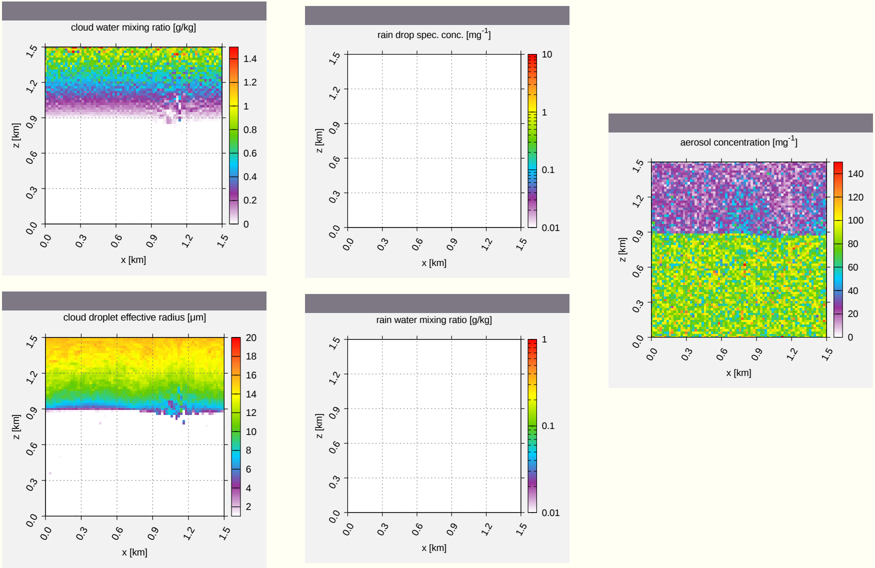

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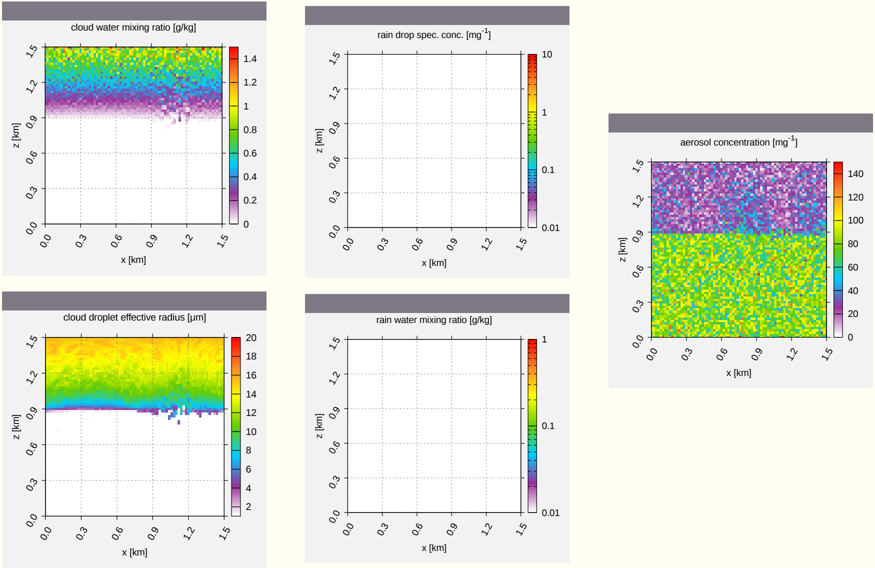

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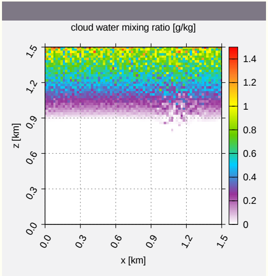

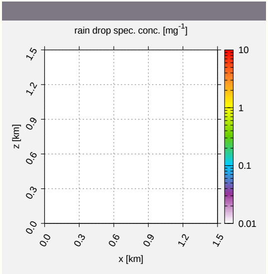

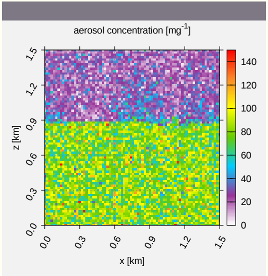

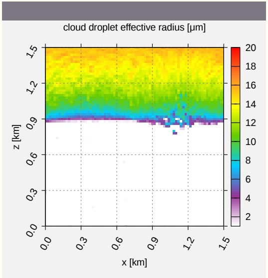

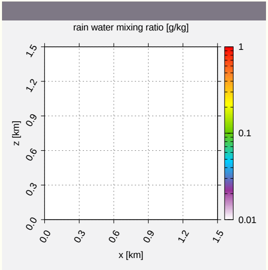

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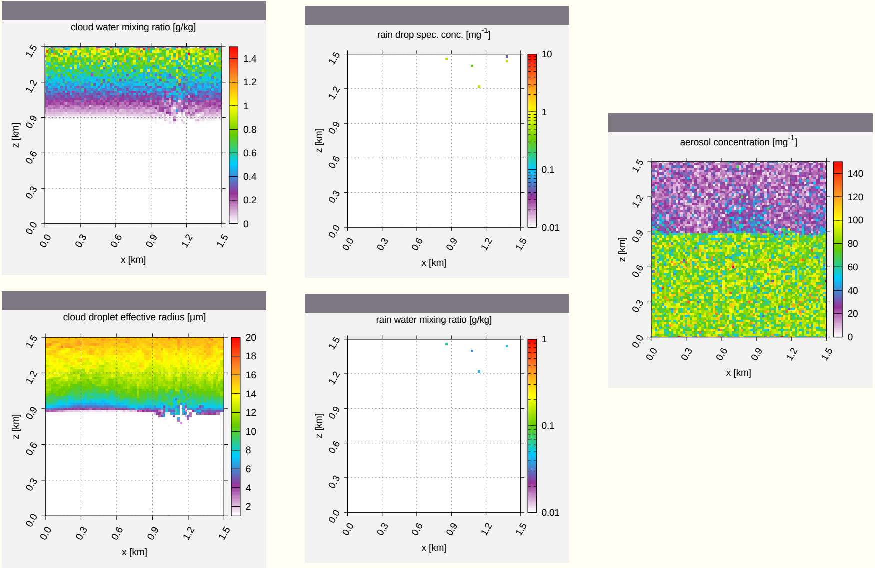

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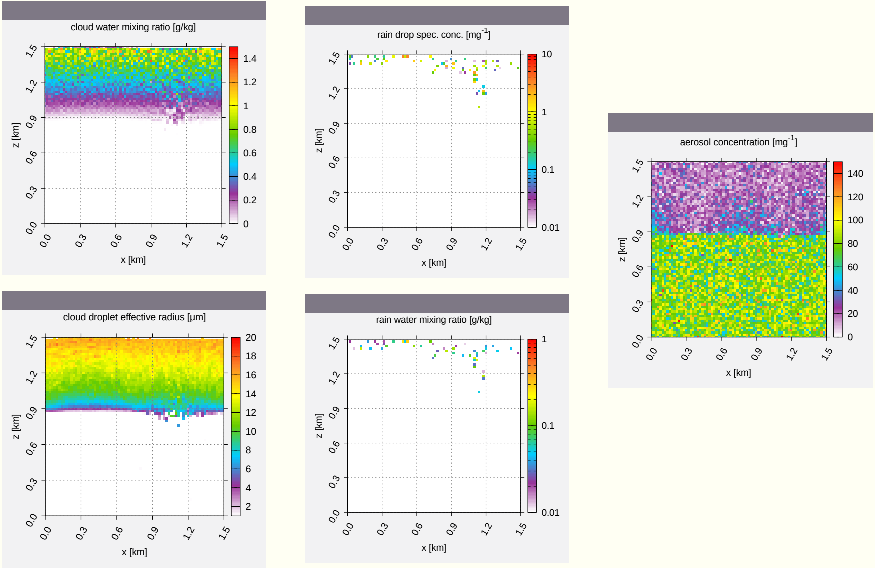

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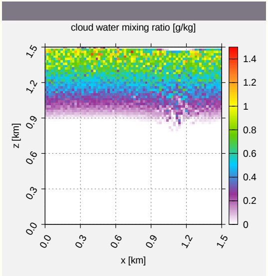

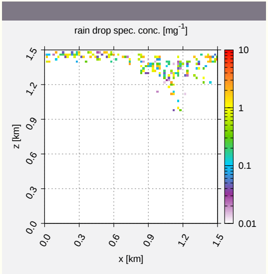

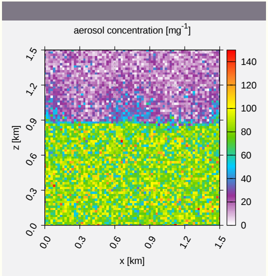

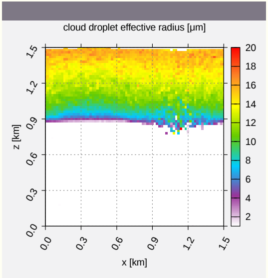

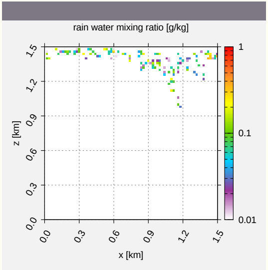

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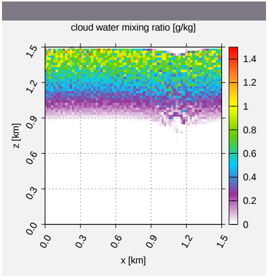

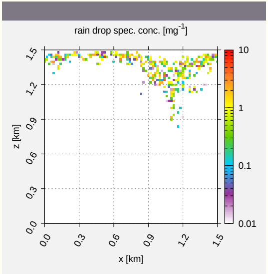

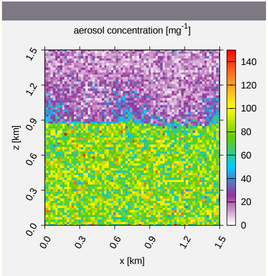

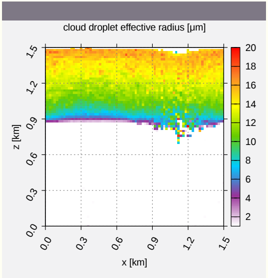

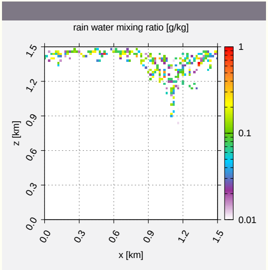

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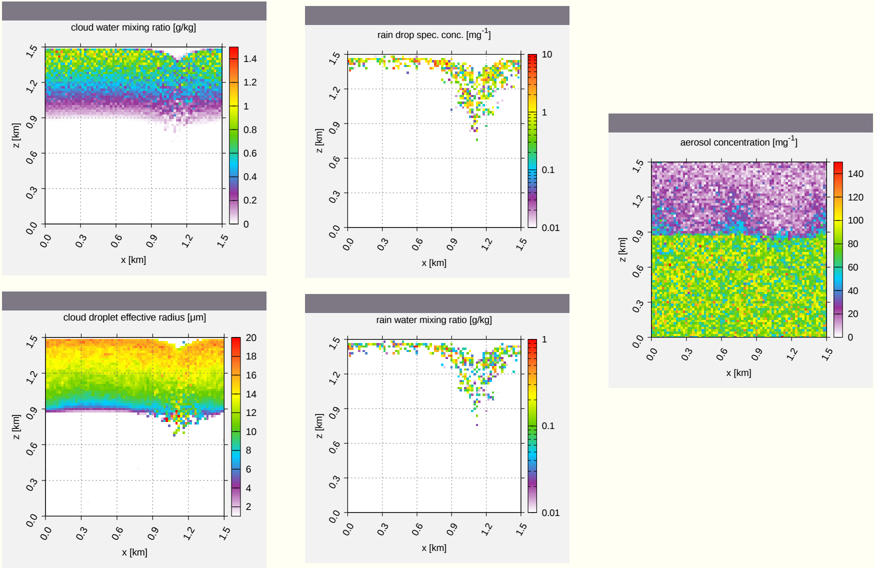

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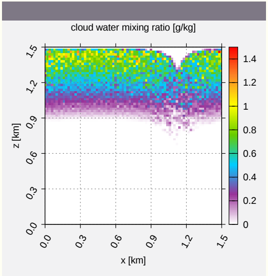

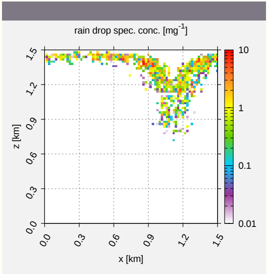

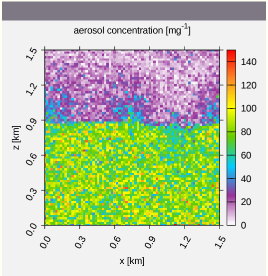

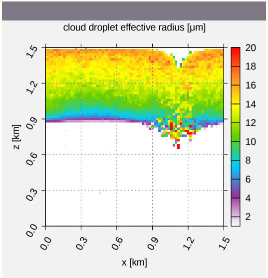

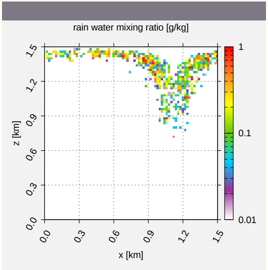

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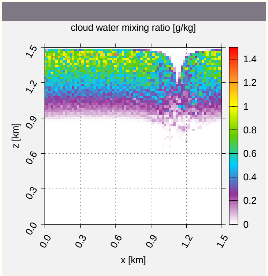

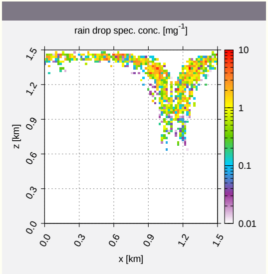

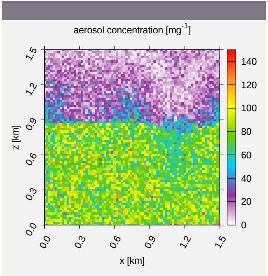

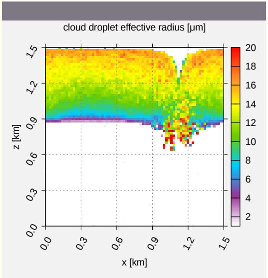

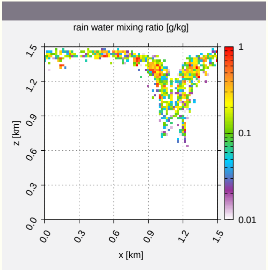

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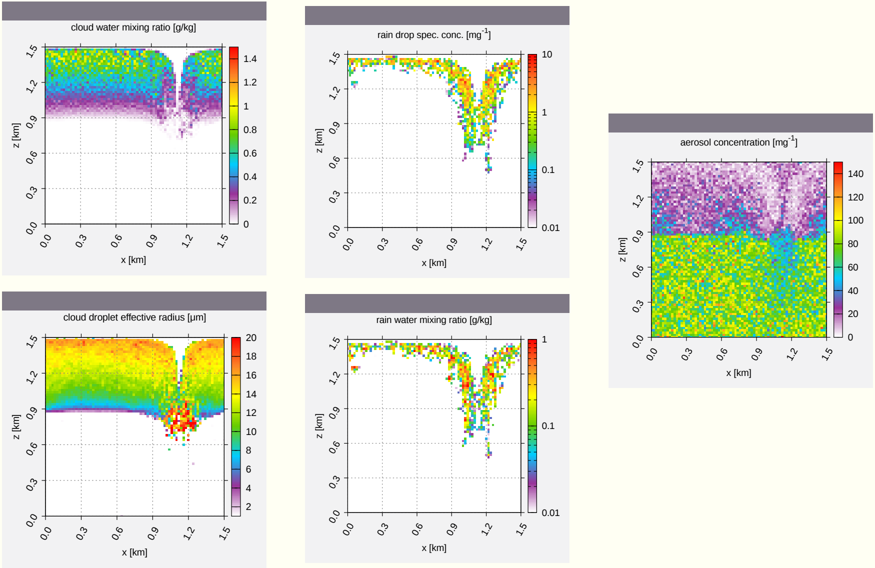

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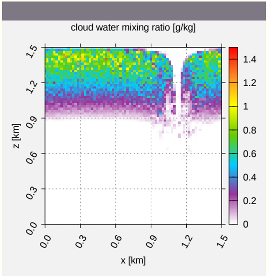

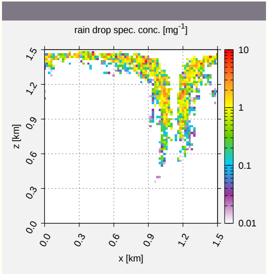

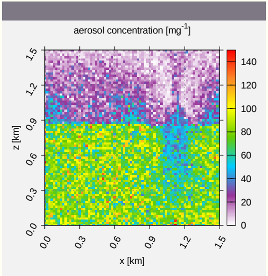

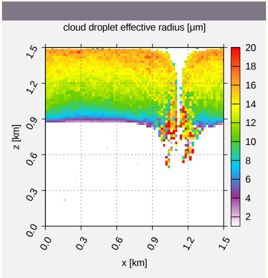

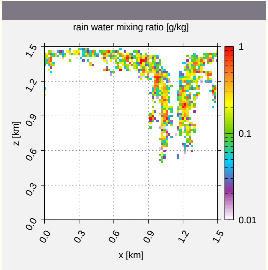

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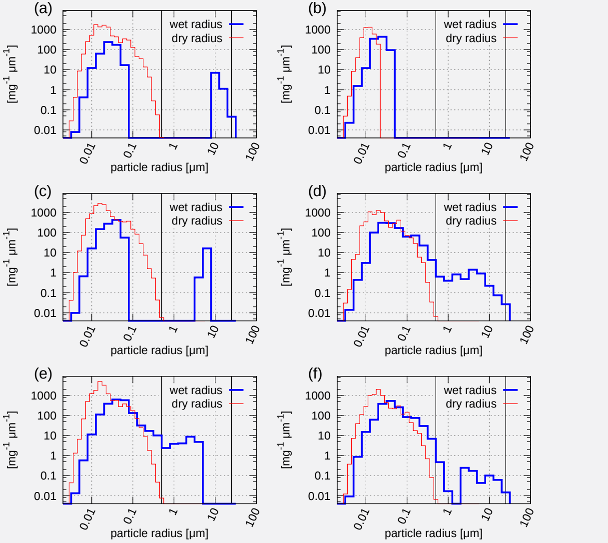
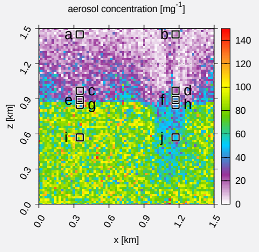
particle size spectra





recent particle-based μ-physics software developments

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- UWLCM (http://github.com/igfuw/UWLCM) from Univ. Warsaw.

CReSS

highlights

- particle-based microphysics vs. praticle-based measurements
- new particle formation studies

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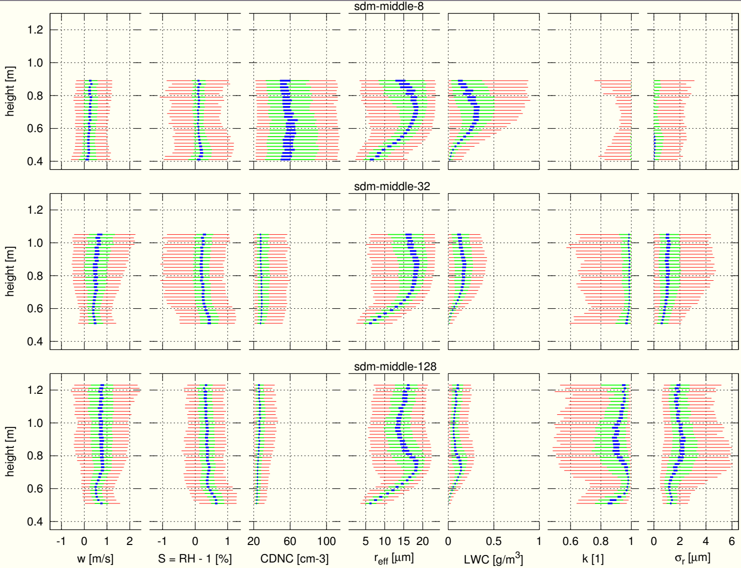
references

- **Arabas & Shima 2013** (JAS): *"Large Eddy Simulations of Trade-Wind Cumuli using Particle-Based Microphysics with Monte-Carlo Coalescence"*
- **Shima, Hasegawa & Kusano 2015** (EGU Vienna): *"Preliminary numerical study on the cumulus-stratus transition induced by the increase of formation rate of aerosols"*

CReSS - RICO 24h LES of cumulus cloud field



(Arabas & Shima 2013, JAS)

UWLCM

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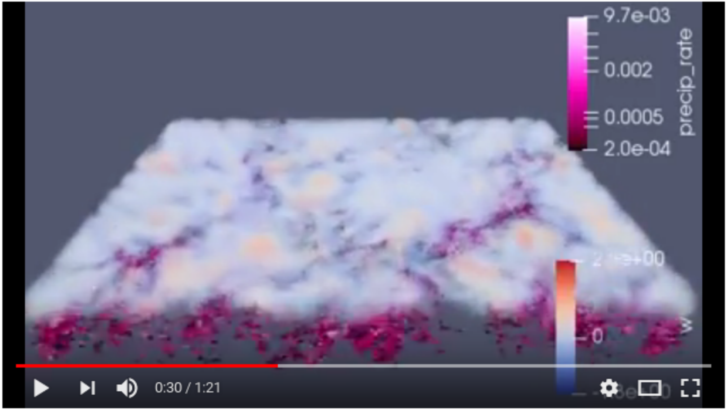
- **Arabas, Jaruga, Pawlowska & Grabowski 2015** (GMD): *"libcloudph++ 1.0: single-moment bulk, double-moment bulk, and particle-based warm-rain microphysics..."*
- **Jaruga & Pawlowska 2018** (GMD): *"libcloudph++ 1.1: aqueous phase chemistry extension of the Lagrangian cloud microphysics scheme"*
- **Dziekan & Pawlowska 2017** (ACP): *"Stochastic coalescence in Lagrangian cloud microphysics"*
- **Grabowski & Abade 2017** (JAS): *"Broadening of cloud droplet spectra through eddy hopping: Turbulent adiabatic parcel simulations"*
- **Grabowski, Dziekan & Pawlowska 2018** (GMD): *"Lagrangian condensation microphysics with Twomey CCN activation"*
- **Dziekan, Waruszewski & Pawlowska 2019** (GMD): *"University of Warsaw Lagrangian Cloud Model (UWLCM)..."*

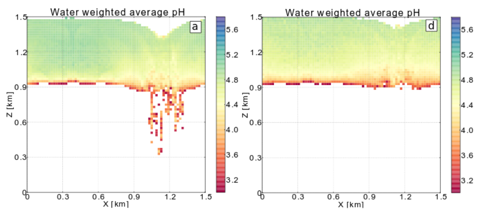
UWLCM - DYCOMS example



https://www.youtube.com/watch?v=BEidkhpw-MA

UWLCM: Hoppel-gap resolving particle-based μ-physics

Jaruga and Pawlowska 2018 (doi: 10.5194/gmd-11-3623-2018)



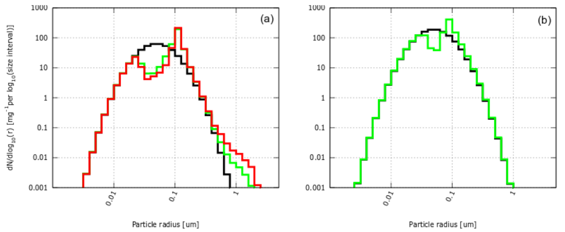


Figure 6. The size distributions of dry radii for the base case **(a)** and case3 **(b)**. The initial dry radius size distribution is marked in black, the final dry radius size distribution from grid cells with $r_c > 0.01\,\mathrm{g\,kg^{-1}}$ in green, and from grid cells with $r_r > 0.01\,\mathrm{g\,kg^{-1}}$ in red. See Tables 2 and 3 for a definition of simulation set-ups.

challenges ($\rightsquigarrow$ opportunities)

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- **charge, isotopic ratio, ...**

news: BAMS super-droplet review (Grabowski et al. '19)

MODELING OF CLOUD MICROPHYSICS

Can We Do Better?

WOJCIECH W. GRABOWSKI, HUGH MORRISON, SHIN-ICHIRO SHIMA, GUSTAVO C. ABADE, PIOTR DZIEKAN, AND HANNA PAWLOWSKA

The Lagrangian particle-based approach is an emerging technique to model cloud microphysics and its coupling with dynamics, offering significant advantages over Eulerian approaches typically used in cloud models.

doi:10.1175/BAMS-D-18-0005.1

news: postdoc offer @ University of Warsaw (UWLCM)

met-jobs@lists.reading.ac.uk
August 2019
Message 15

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[Met-jobs] Postdoc position at the Institute of Geophysics, University of Warsaw

From	Gustavo Abade <Gustavo.Abade@fuw.edu.pl>
To	Met Jobs <met-jobs@lists.reading.ac.uk>
Date	Tue, 06 Aug 2019 16:03:32 +0200

Dear colleagues,

The cloud-modeling group at the Institute of Geophysics, Faculty of Physics, University of Warsaw, invites applications for a full-time postdoctoral position. The post holder is expected to join our team for 24 months. The successful candidate will work on the project entitled "Turbulent dynamics and microphysics in a Stochastic Lagrangian Cloud Model" funded by the Polish National Science Centre. The project investigates by numerical simulations the role of turbulence in the microphysical processes that shape the droplet spectrum in convective clouds. The candidate should be ready to start not later than January 2020.

Applications are due on 30 September 2019.

For further details visit:

https://www.igf.fuw.edu.pl/en/articles/oferty-pracy-i-stypendia-f/oferta-pracy-post-doc-w-insty-q2019-08-06/

Köszönöm!

Thank you for your attention!

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