

Towards a new concept in cloud processes modeling

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and the cloud-aerosol modelling team

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in Warsaw

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- ▶ Piotr Dziekan (postdoc)
- ▶ Anna Jaruga (PhD student)
- ▶ Maciej Waruszewski (PhD student)
- ▶ Anna Zimniak (MSc student)

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- ▶ Dorota Jarecka @ NCAR (postdoc)

Cloud models: challenges

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Stevens & Feingold 2009

[doi:10.1038/nature08281](https://doi.org/10.1038/nature08281)

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Ince et al. 2012

[doi:10.1038/nature10836](https://doi.org/10.1038/nature10836)

„anything less than the release of source programs is intolerable for results that depend on computation”

developing tools for studying aerosol-cloud interactions



- ▶ CCN activation
- ▶ condensational growth



- ▶ collisional growth
- ▶ aqueous chemistry



- ▶ precipitation

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developing tools for studying aerosol-cloud interactions

- ▶ novel cloud/aerosol microphysics models,
 - ▶ state-of-the-art numerical schemes,
 - ▶ modern coding techniques
- ~> priorities: open access & result reproducibility



- ▶ CCN activation
- ▶ condensational growth

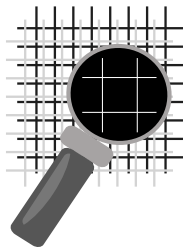


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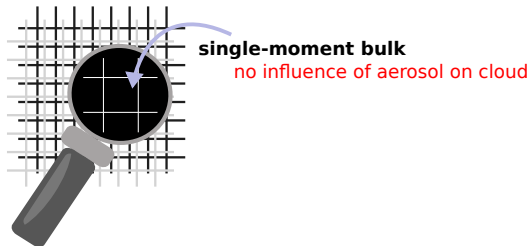


- ▶ precipitation

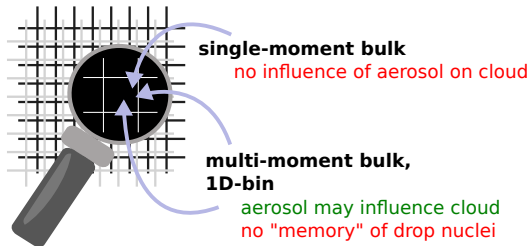
Eulerian vs. Lagrangian μ -physics



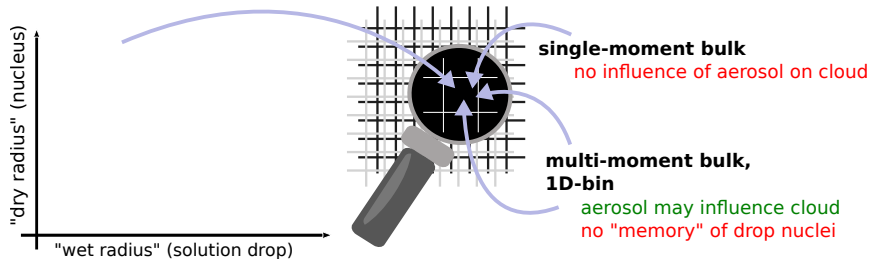
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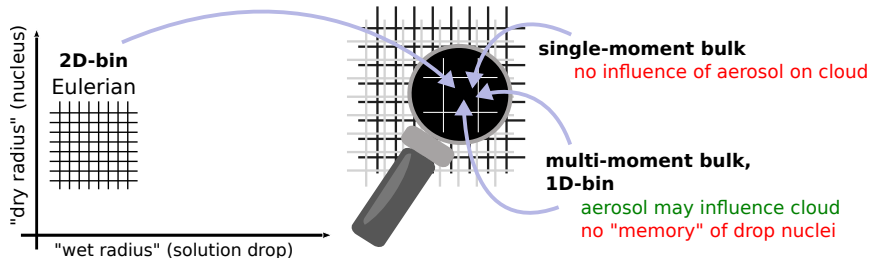
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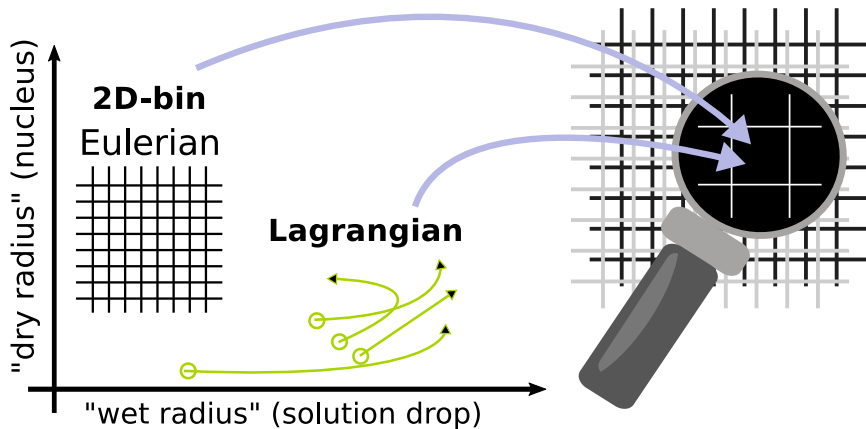
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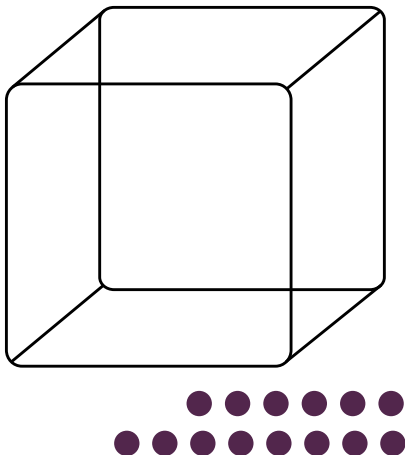


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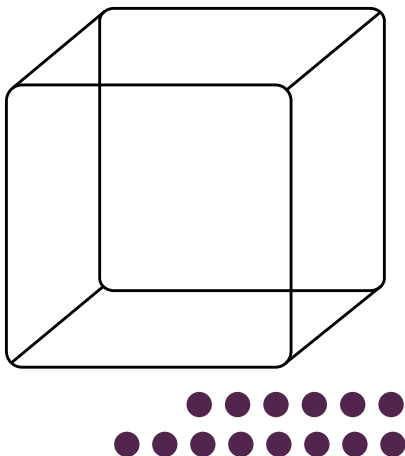
Lagrangian microphysics

super-droplets in the domain

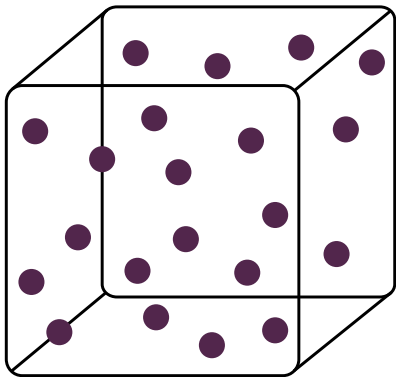


Lagrangian microphysics

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attributes:



Lagrangian microphysics

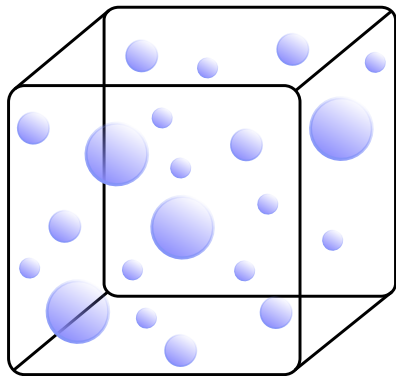


super-droplets in the domain

attributes:

- ▶ location

Lagrangian microphysics

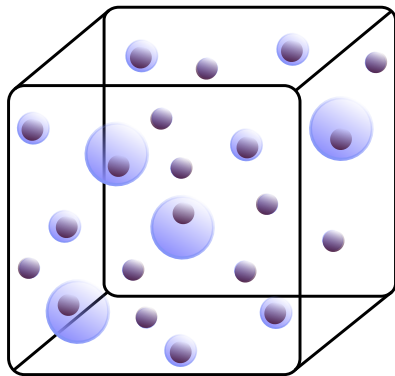


super-droplets in the domain

attributes:

- ▶ location
- ▶ wet radius

Lagrangian microphysics

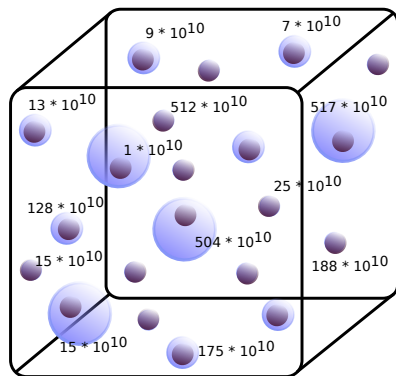


super-droplets in the domain

attributes:

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- ▶ wet radius
- ▶ dry radius

Lagrangian microphysics

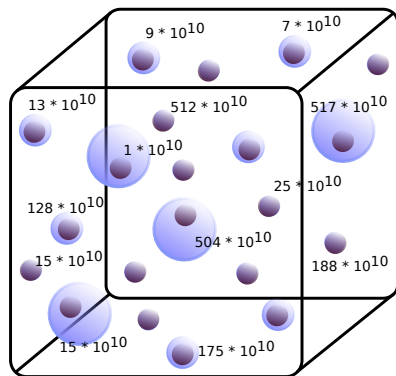


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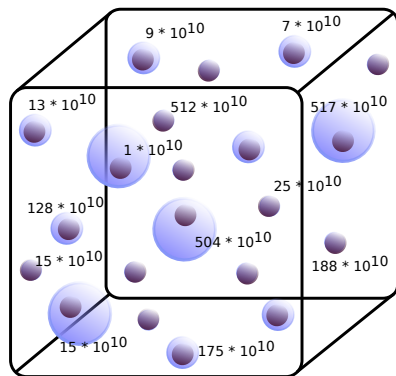


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Lagrangian microphysics



super-droplets in the domain

attributes:

- ▶ location
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- ▶ multiplicity
- ▶ ...
- ▶ mass of chemical compounds within droplets

Cloud microphysics

- ▶ Maxwell-Mason equation of condensational growth for each super-droplet using κ -Koehler parametrisation of hygroscopicity (Petters & Kreidenweis, 2007)



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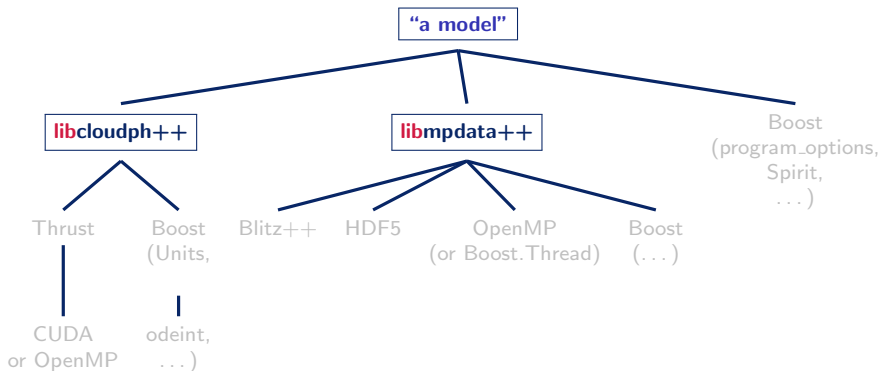
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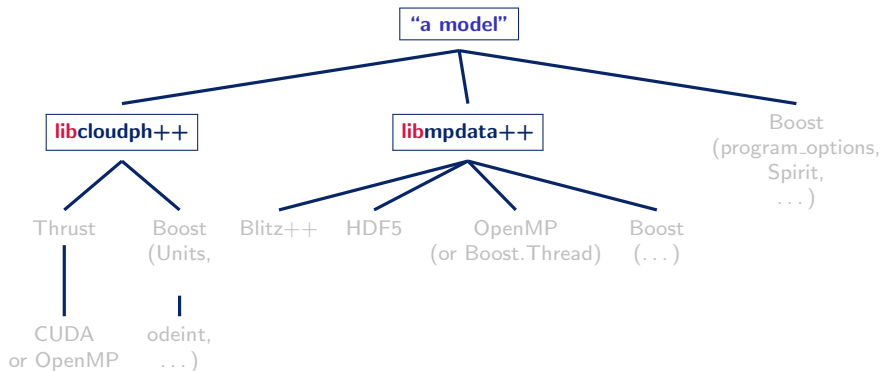
design choices

- ▶ structure the code into “standalone” libraries



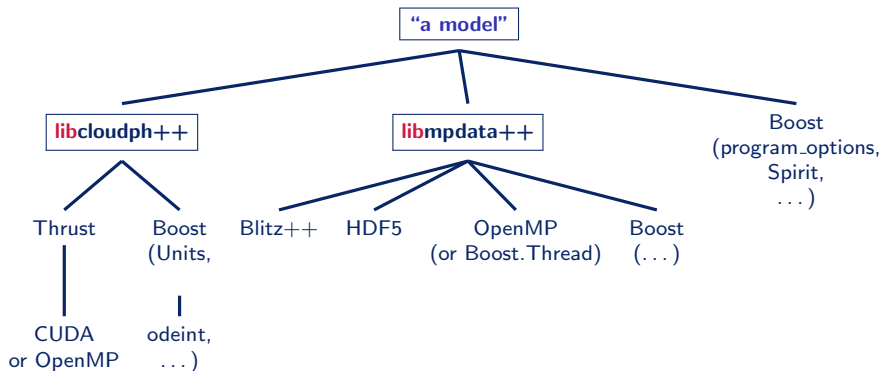
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 - ↪ `libmpdata++` : library `mpdata` C++
 - ↪ `libcloudph++` : library `cloud physics` C++



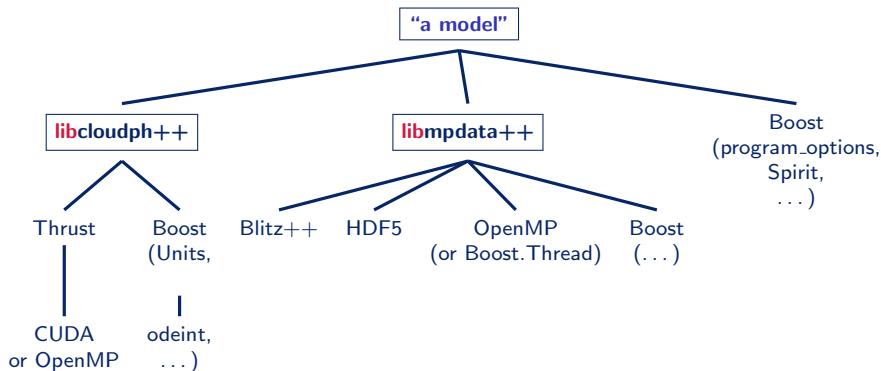
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- ▶ structure the code into “standalone” **libraries**
 - ↪ **libmpdata++** : **library** **mpdata** C++
 - ↪ **libcloudph++** : **library** **cloud physics** C++
- ▶ leverage existing **reusable** software



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 - ↪ `libmpdata++` : library `mpdata` C++
 - ↪ `libcloudph++` : library `cloud physics` C++
- ▶ leverage existing **reusable** software
 - ↪ save time, benefit from state-of-the-art components



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In our project it will serve as a dynamical core for our LES model

components

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current “products” – C++ libraries

libmpdata++ parallel solvers for systems of transport equations

- ▶ <http://libmpdataxx.igf.fuw.edu.pl/>
- ▶ [doi:10.5194/gmd-8-1005-2015](https://doi.org/10.5194/gmd-8-1005-2015)

libcloudph++ aerosol/cloud μ -physics algorithm collection

- ▶ <http://libcloudphxx.igf.fuw.edu.pl/>
- ▶ [doi:10.5194/gmd-8-1677-2015](https://doi.org/10.5194/gmd-8-1677-2015)

LIBCLOUDPH++

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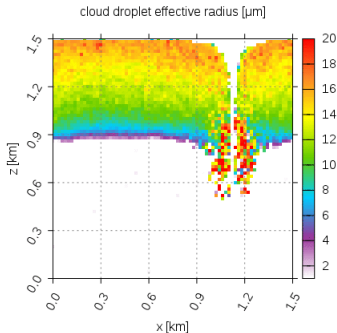
libcloudph++

SYNOPSIS

C++ library of algorithms for representing cloud microphysics in numerical models. A 1.0 version was released in June 2015 and the library is still in active development.

Currently, the library covers three warm-rain schemes: the single- and double-moment bulk schemes, and the particle-based scheme with Monte-Carlo coalescence.

EXAMPLE SIMULATION



[SYNOPSIS](#)

[EXAMPLE SIMULATION](#)

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libcloudphysics++ - a library of algorithms for representing cloud microphysics in numerical models <http://libcloudphxx.igf.fuw.edu.pl/>

1,228 commits 1 branch 1 release 4 contributors

Branch: master New pull request New file Find file HTTPS https://github.com/igfuw/ Download ZIP

 **pdziekan** Merge pull request #205 from trontrytel/parcel_travis

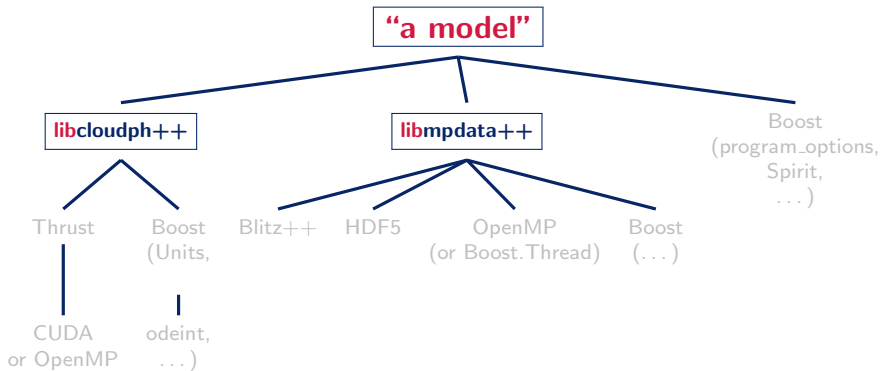
Latest commit 10ca421 on Dec 29, 2015

 bindings	Merge branch 'master' of https://github.com/igfuw/libcloudphxx into v...	2 months ago
 include	Merge branch 'master' of https://github.com/igfuw/libcloudphxx into v...	2 months ago
 src	Merge branch 'master' of https://github.com/igfuw/libcloudphxx into v...	2 months ago
 tests	Merge pull request #195 from pdziekan/vt_beard_fast	a month ago
 .travis.yml	...	a month ago
 CMakeLists.txt	turn back on CUDA	2 months ago
 COPYING	adding copying file	2 years ago
 CREDITS	adding CREDITS file	8 months ago
 Readme.md	Merge branch 'master' of https://github.com/pdziekan/libcloudphxx	2 months ago
 libcloudph++-config.cmake	moving BZDEBUG from from libcloudph++-config.cmake to bindings/python...	6 months ago

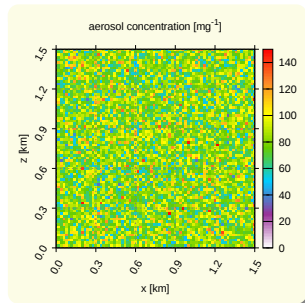
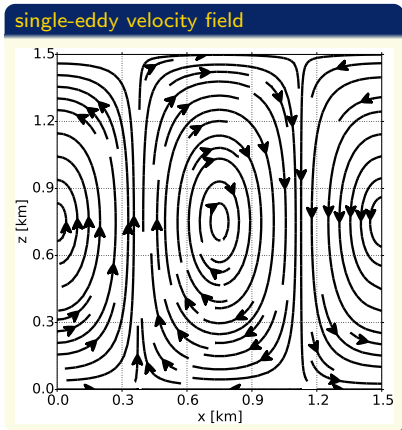
 **Readme.md**

libcloudph++ - a cloud (micro)physics library

Model



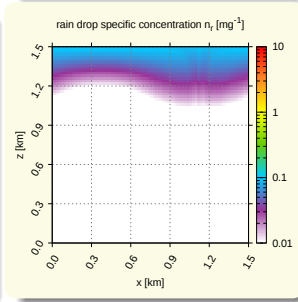
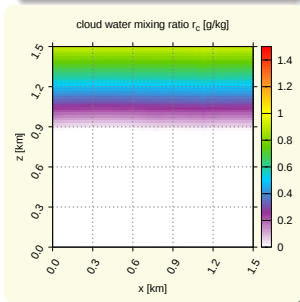
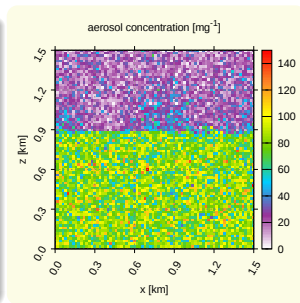
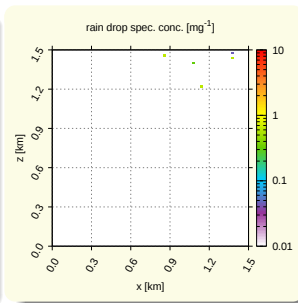
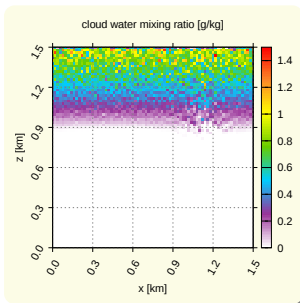
2D kinematic set-up (example results with collisions)



- ▶ set-up: Grabowski & Lebo (ICMW 2012)
- ▶ 2D prescribed flow
- ▶ advection: `libmpdata++` (2-pass FCT)
- ▶ μ -physics: `libcloudph++`

2D kinematic set-up (example results with collisions)

x

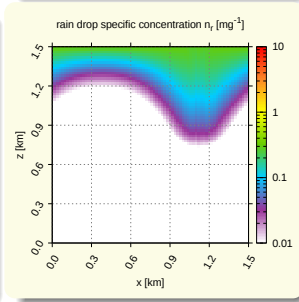
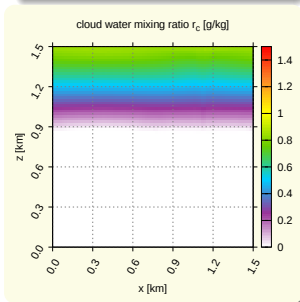
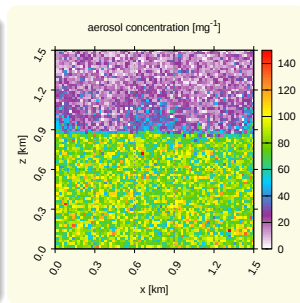
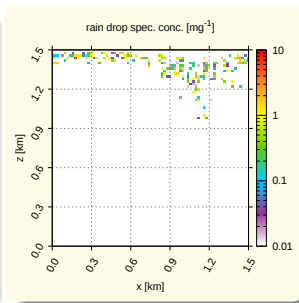
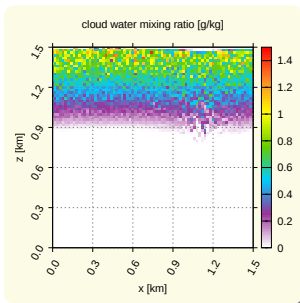


Lagrangian/Monte-Carlo scheme
(Shima et al. 2009)

2-moment bulk scheme
(Morrison & Grabowski 2007)

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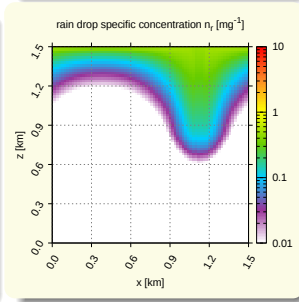
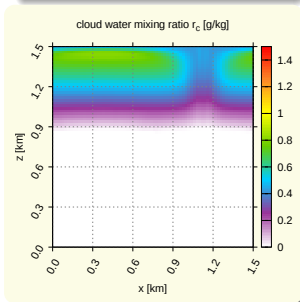
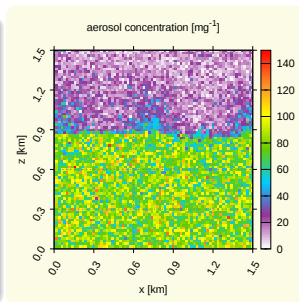
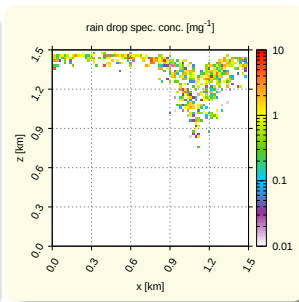
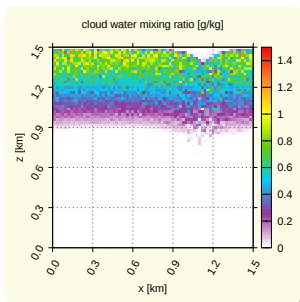


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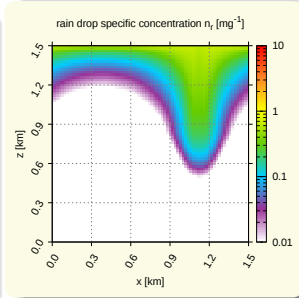
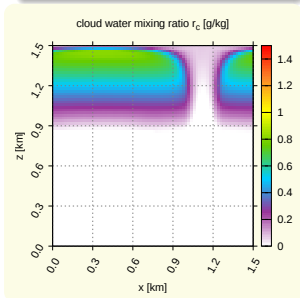
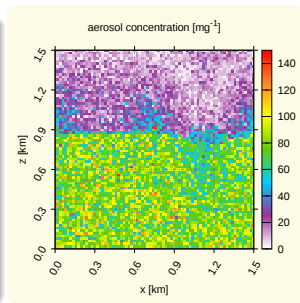
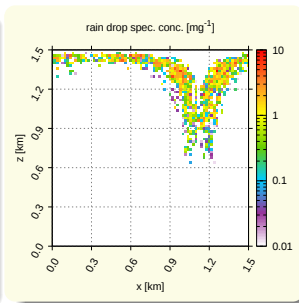
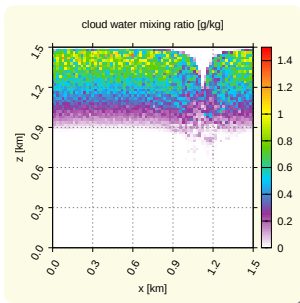


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xooo

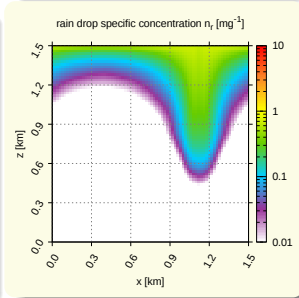
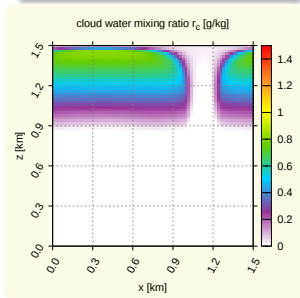
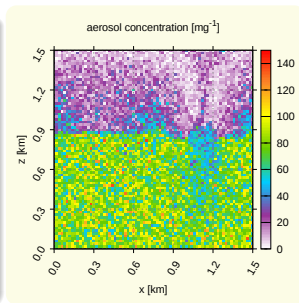
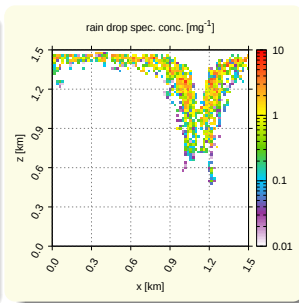
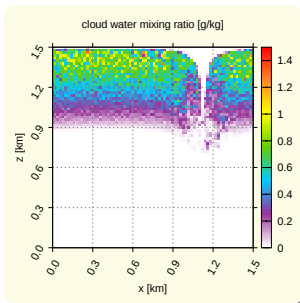


Lagrangian/Monte-Carlo scheme
(Shima et al. 2009)

2-moment bulk scheme
(Morrison & Grabowski 2007)

2D kinematic set-up (example results with collisions)

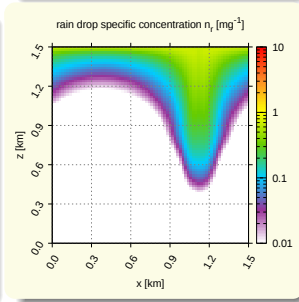
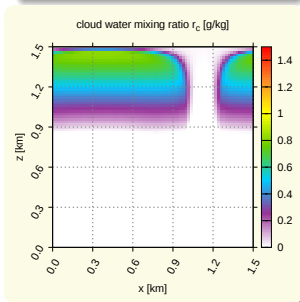
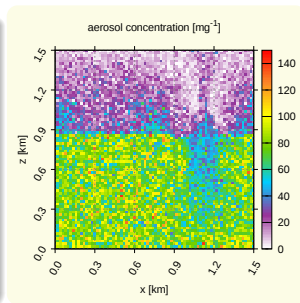
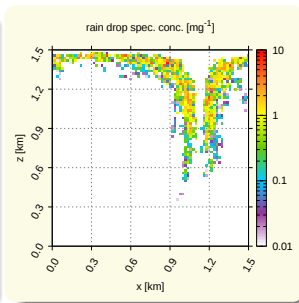
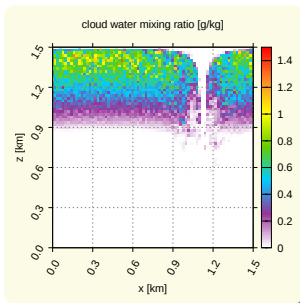
xoooo



Lagrangian/Monte-Carlo scheme
(Shima et al. 2009)

2-moment bulk scheme
(Morrison & Grabowski 2007)

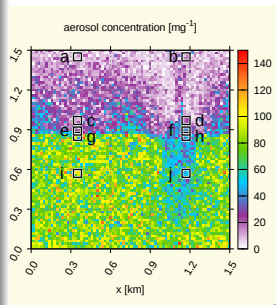
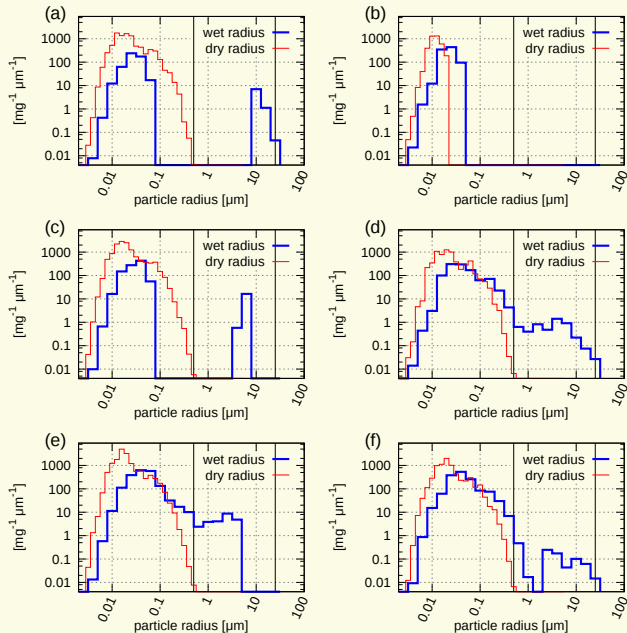
X O O O O O



Lagrangian/Monte-Carlo scheme
(Shima et al. 2009)

2-moment bulk scheme
(Morrison & Grabowski 2007)

2x2 cell particle-derived spectra



L

ES-type tool featuring:

- ▶ robust numerics (MPDATA)
- ▶ particle-based aerosol/warm-rain μ -physics (super-droplet)



- ▶ CCN activation
- ▶ condensational growth



- ▶ collisional growth
- ▶ aqueous chemistry



- ▶ precipitation
- ▶ wet deposition
- ▶ droplet deactivation