University of Warsaw Lagrangian Cloud Model (UWLCM)

a modern LES with Lagrangian cloud microphysics

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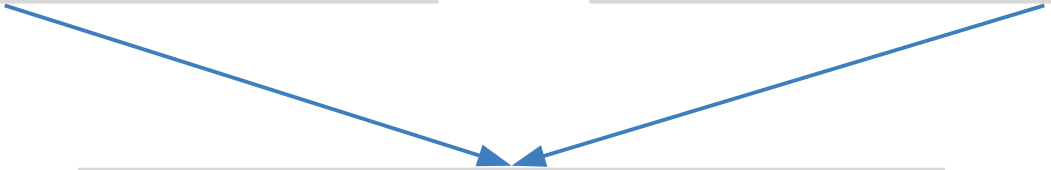
Software developed by our group

libmpdata++

- new implementation of MPDATA
- written in C++
- started ca. 5 years ago

libcloudph++

- cloud microphysics routines
- written in C++ with python bindings
- started ca. 5 years ago



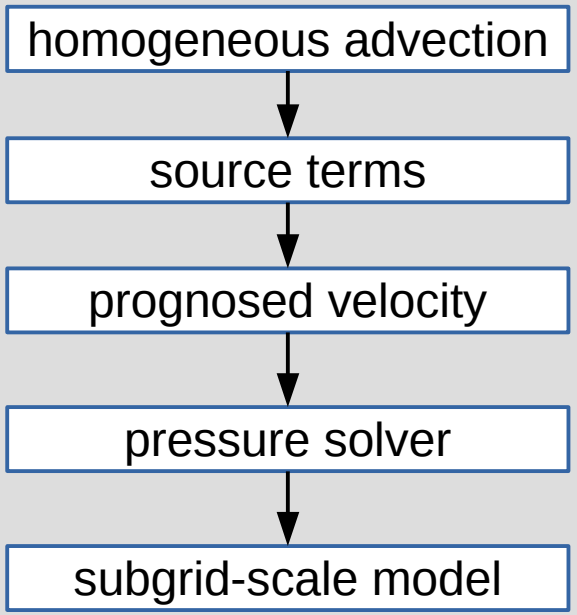
UWLCM

- Large Eddy Simulations of clouds using anelastic approximation
- written in C++
- started ca. 2 years ago

Modern code structure: separation of concerns

libmpdata++

- hierarchy of solvers:

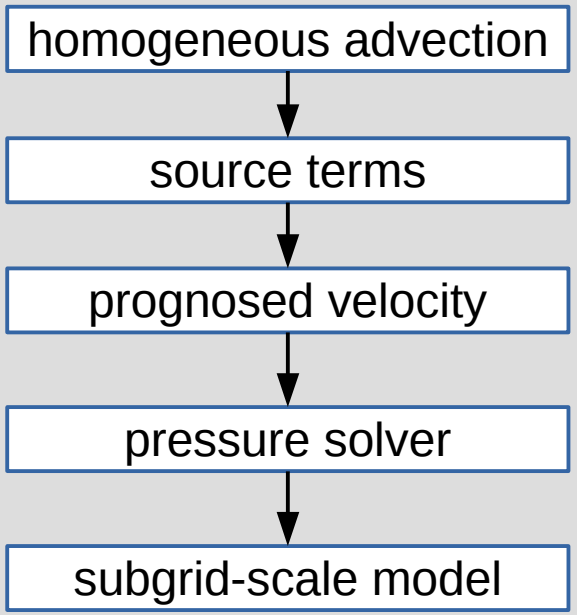


- boundary conditions
- concurrency handlers
- output handlers

Modern code structure: separation of concerns

libmpdata++

- hierarchy of solvers:



- boundary conditions
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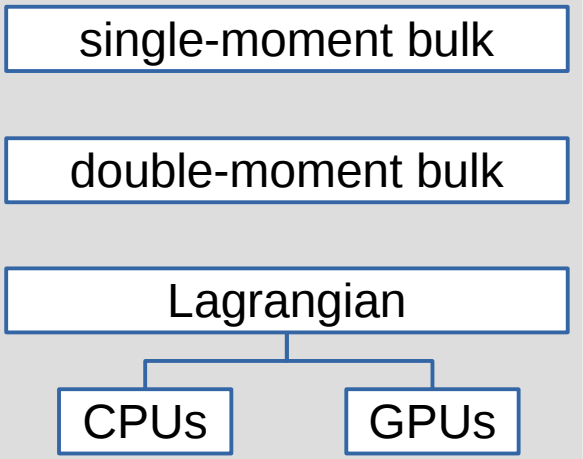
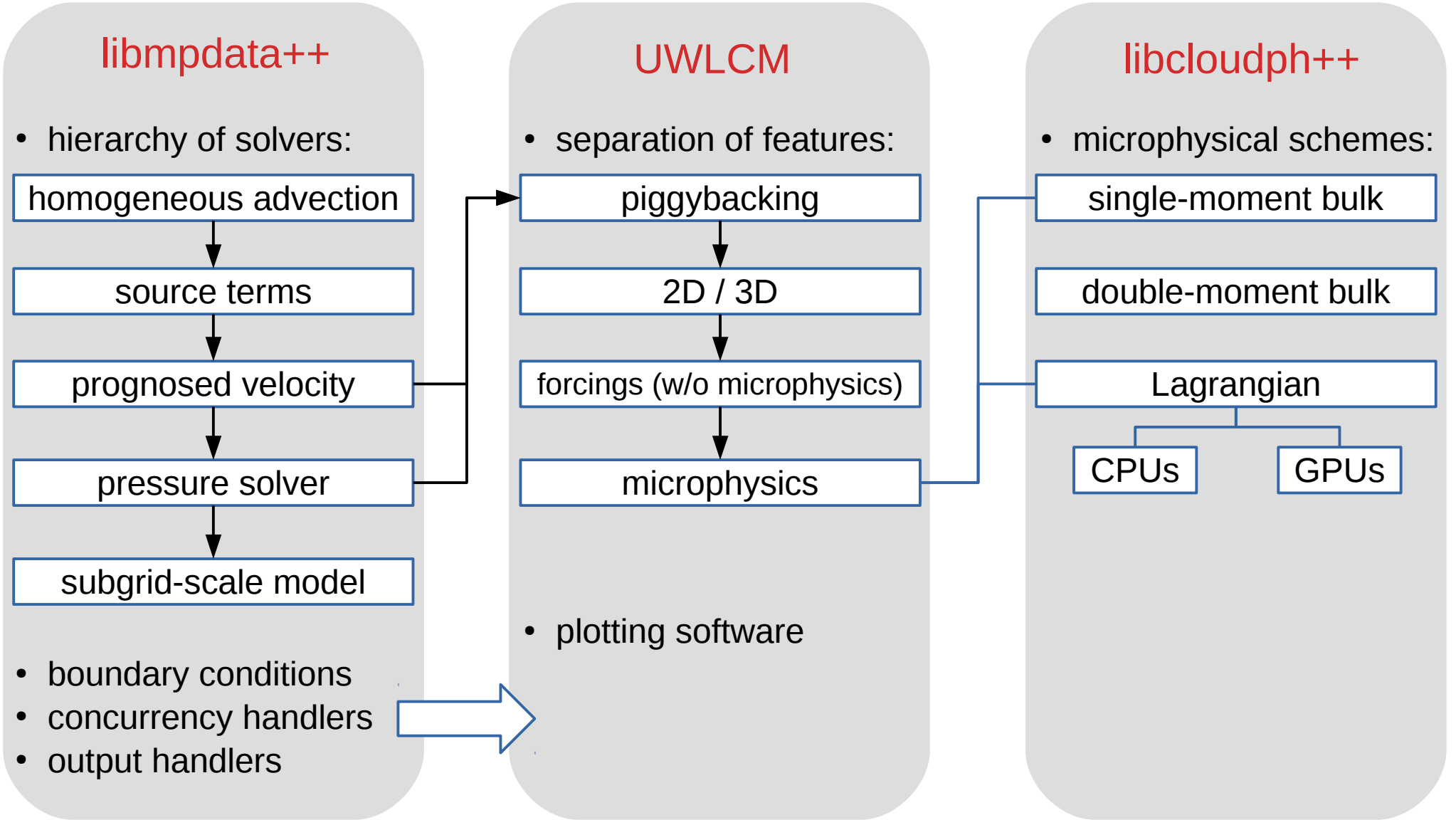
libcloudph++

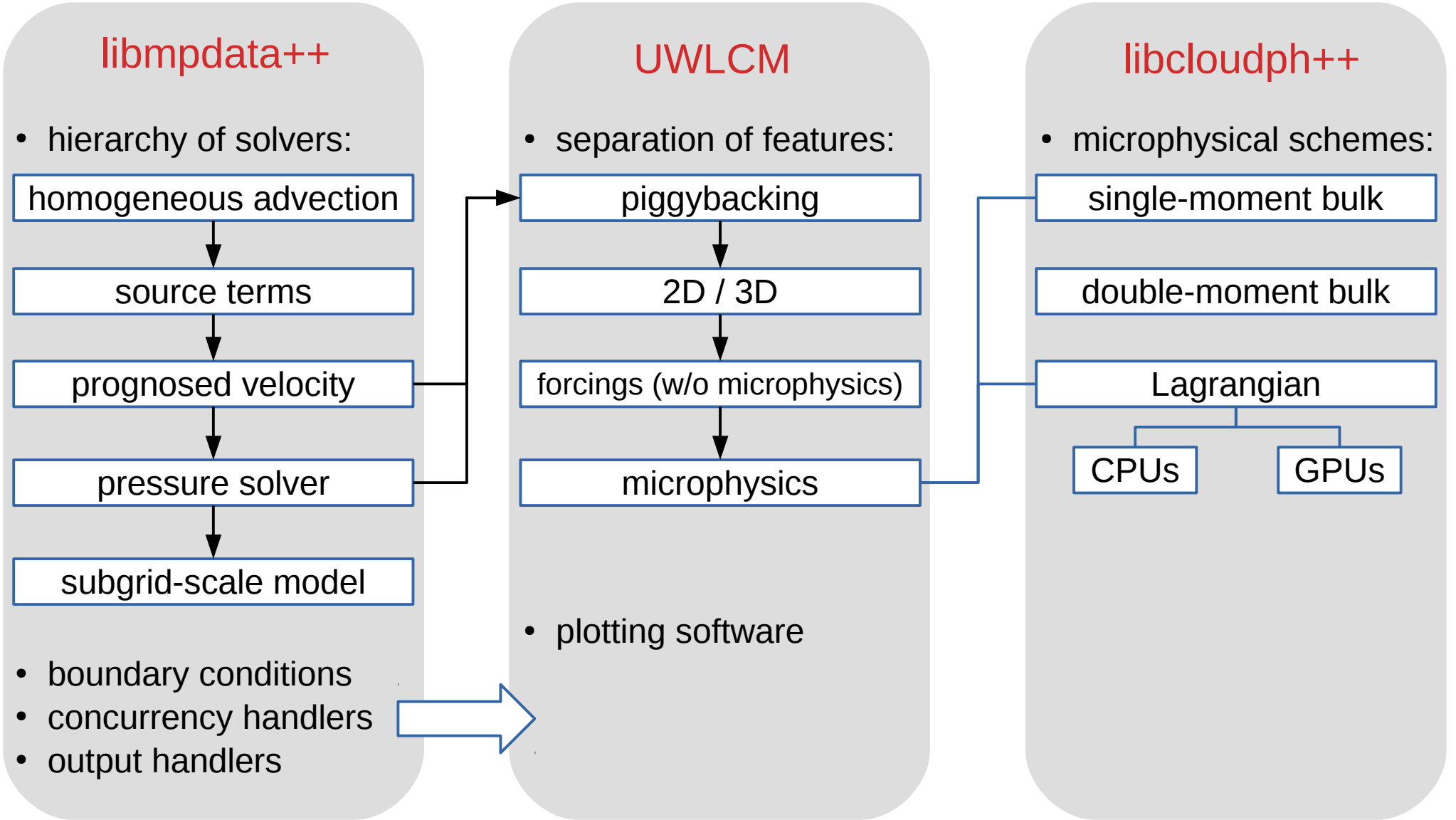
- microphysical schemes:



Modern code structure: separation of concerns



Modern code structure: separation of concerns



- Code sections can be developed independently.
- Code are sections ready to be reused.

- version control system
- automated tests
- open-source code hosted on github

Benefits of the modern code structure: one code, many models

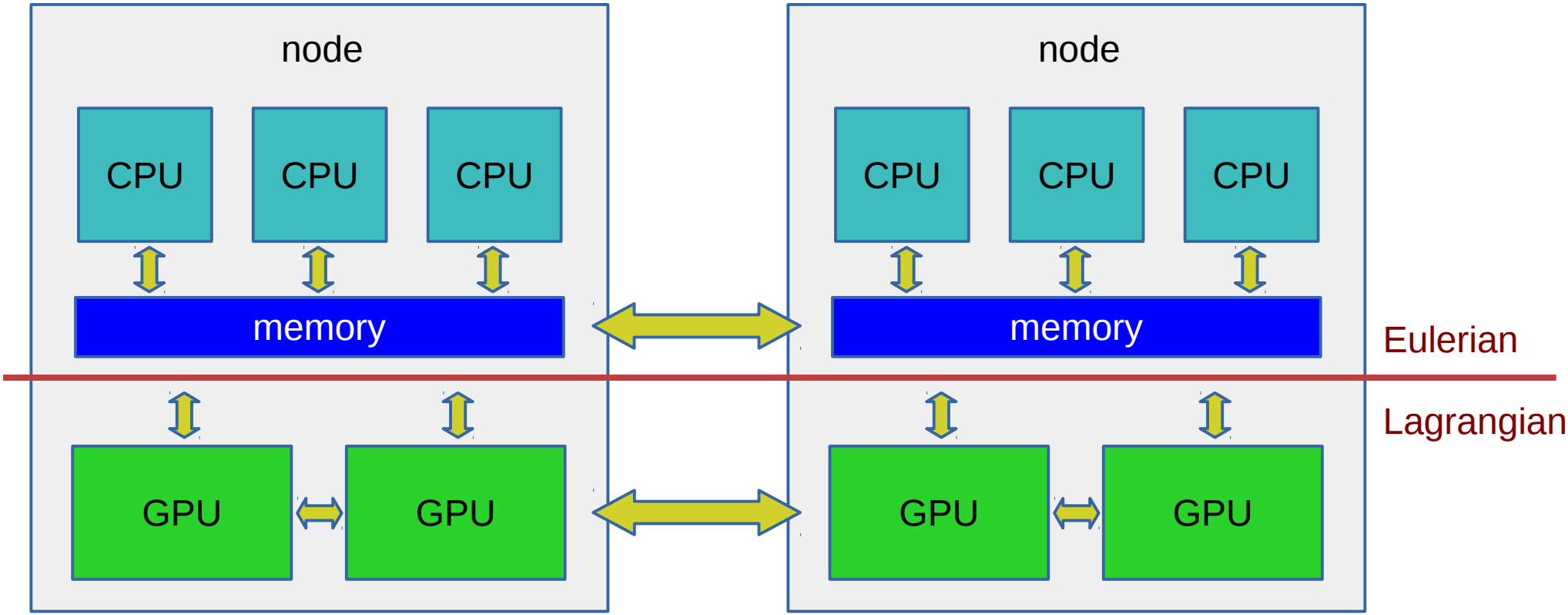
runtime options:

- number of dimensions:
  ./bicycles --ny=[0, X]
- type of microphysics:
  ./bicycles --micro=[blk_1m, lgrngn]
- where to calculate Lagrangian microphysics:
  ./bicycles --backend=[serial, OpenMP, CUDA, multi_CUDA]
- model setup:
  ./bicycles --case=[dycoms, bomex, ...]
- piggybacking:
  ./bicycles --piggy=1 --vel_in=file
- number of CPU threads for dynamics:
  OMP_NUM_THREADS=X ./bicycles
- distributed memory runs:
  mpiexec -np X ./bicycles
- advection, coalescence, condensation timesteps
- number of super-droplets
- ...

compile time options:

- MPDATA options
  - variable-sign option:
    opts = [opts::iga, opts::abs]
  - non-oscillatory option:
    opts = [opts::fct]
  - third-order terms:
    opts = [opts::tot]
  - ...
- microphysics options
  - coalescence kernel
  - terminal velocity
  - ....
- numerical precision
  real_t = [float, double]

Modern HPC architecture



- Domain decomposition between nodes
- Separate intra-node domain decomposition for CPU threads and GPUs
- Bulk microphysics computed on CPUs
- Lagrangian microphysics computed on CPUs or GPUs
- Simultaneous computations of fluid flow on CPUs and microphysics on GPUs synchronized only during condensation

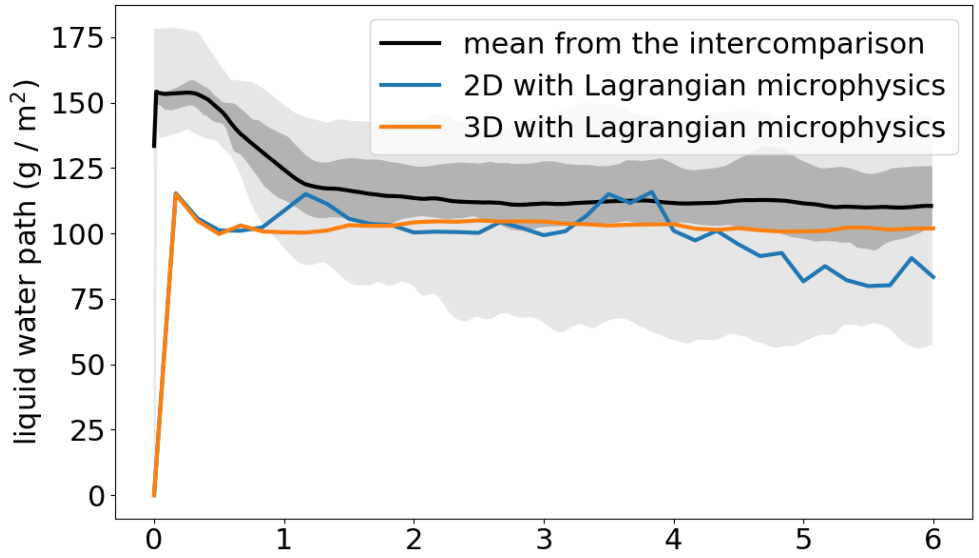
Model validation - stratocumulus

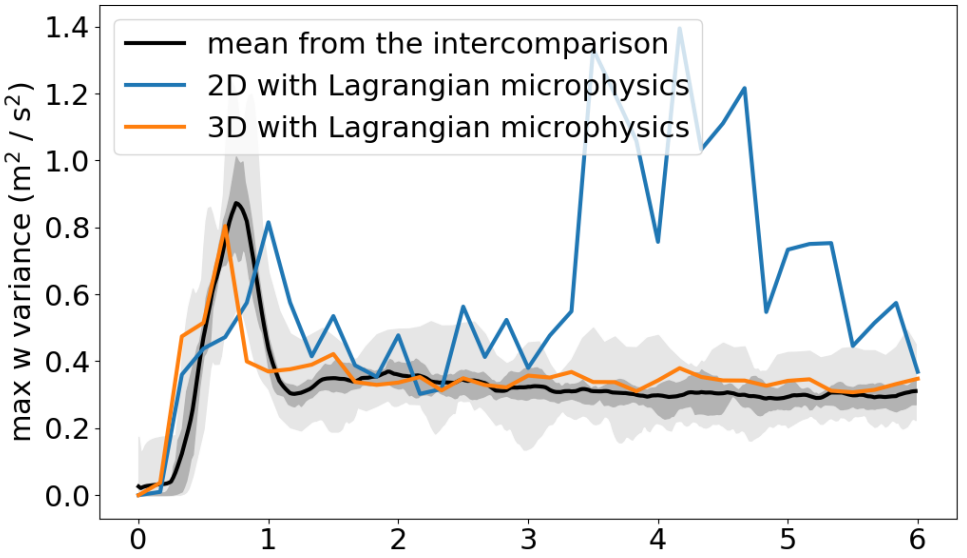
- Test UWLCM against 14 models from the Ackerman et al. 2009 intercomparison
- Microphysical schemes in other models:
  bin, single-moment bulk and double-moment bulk
- implicit LES in UWLCM, other models with subgrid-scale schemes

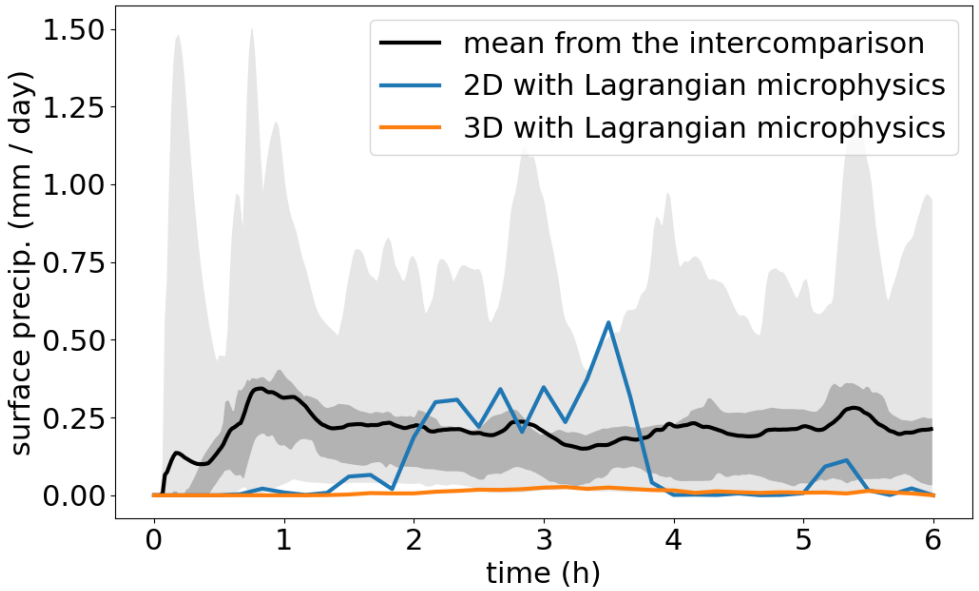
source: Angela Rowe
communitycloudatlas.wordpress.com

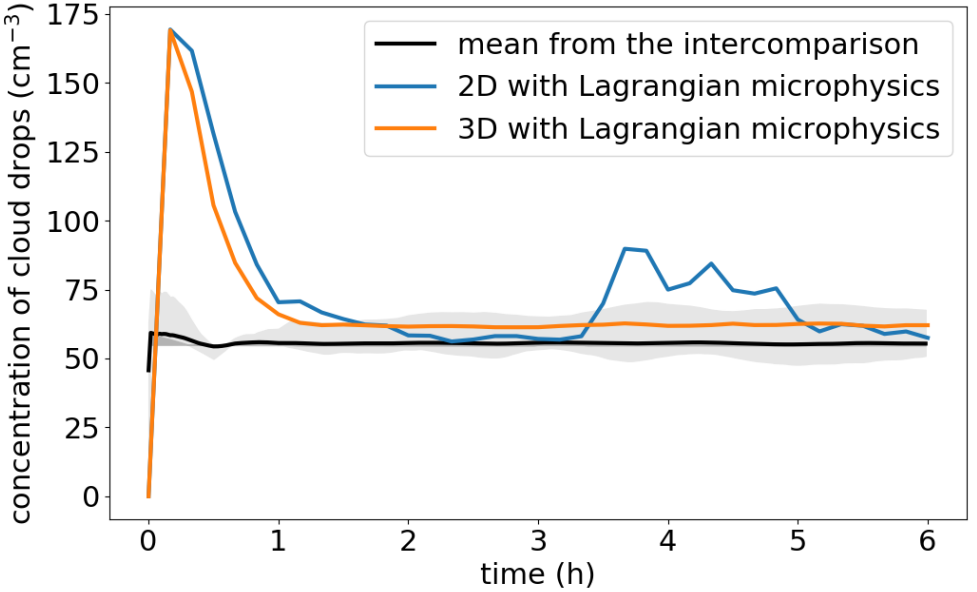
ANIMATION

Stratocumulus time series

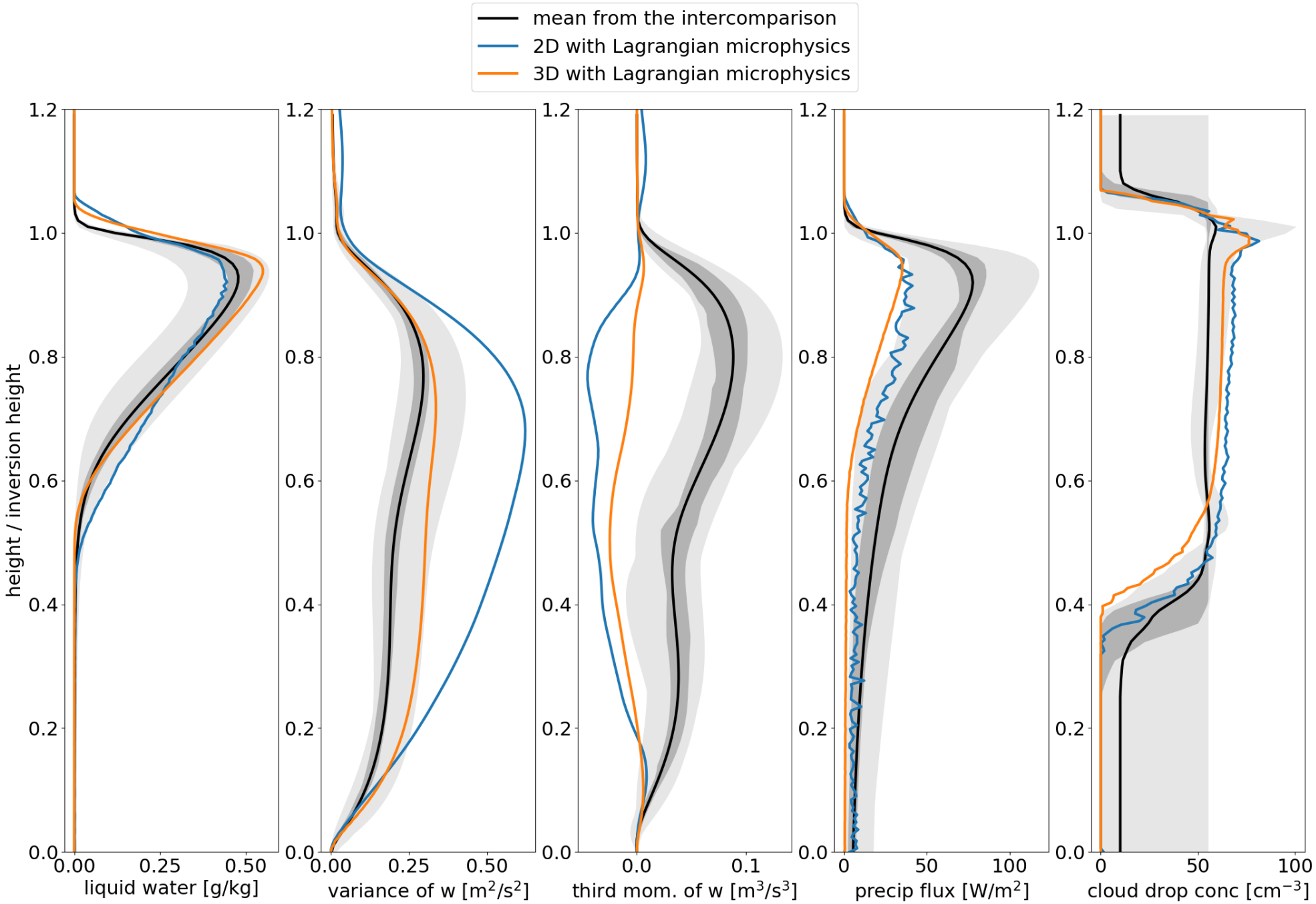




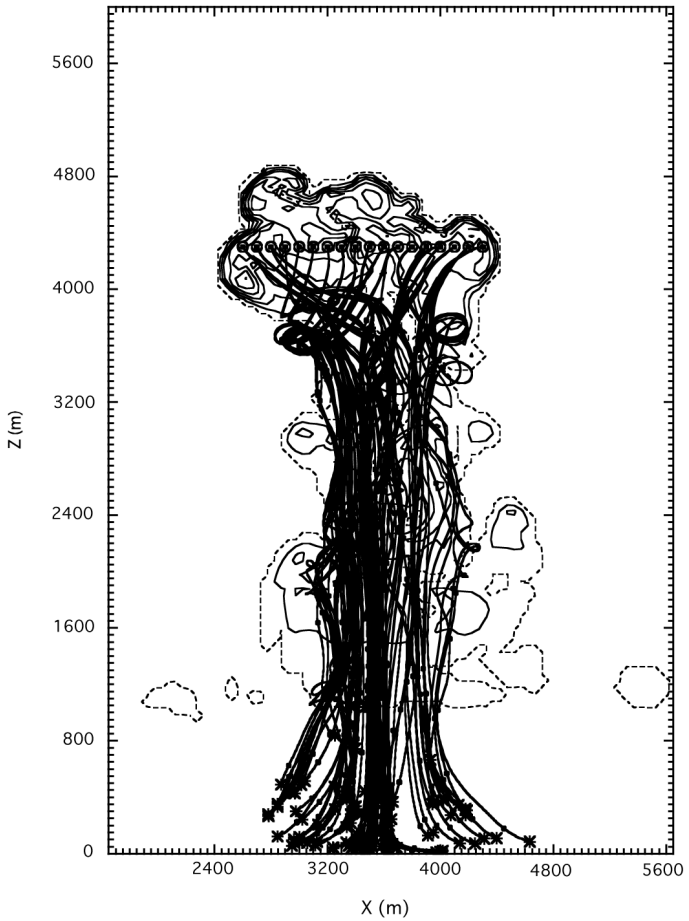


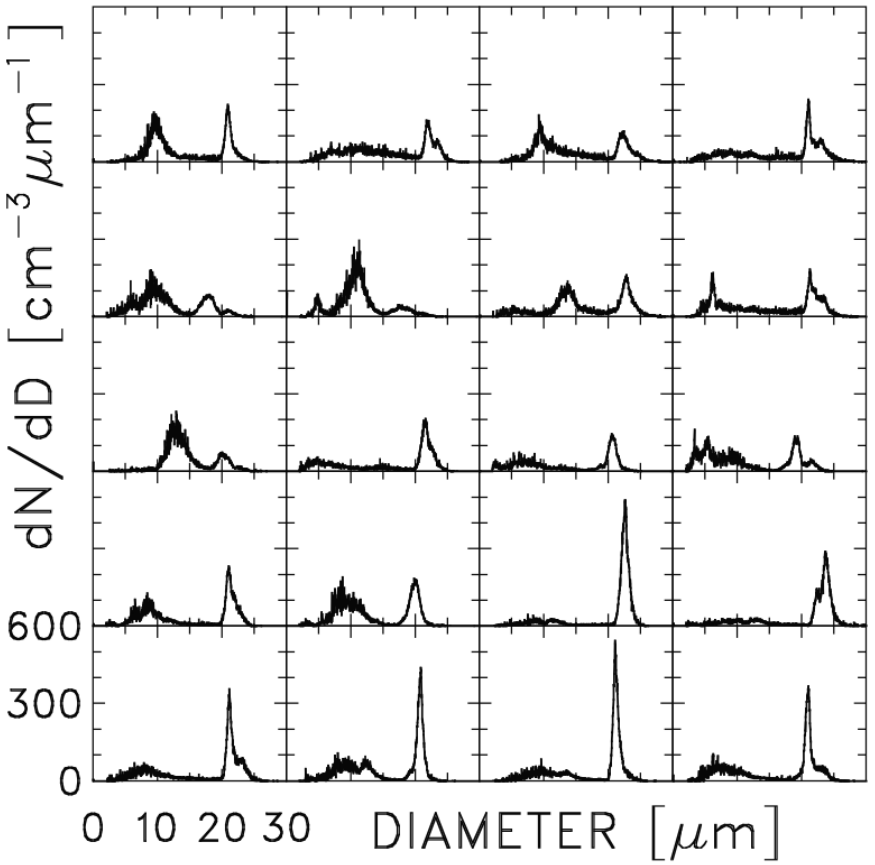


Stratocumulus vertical profiles



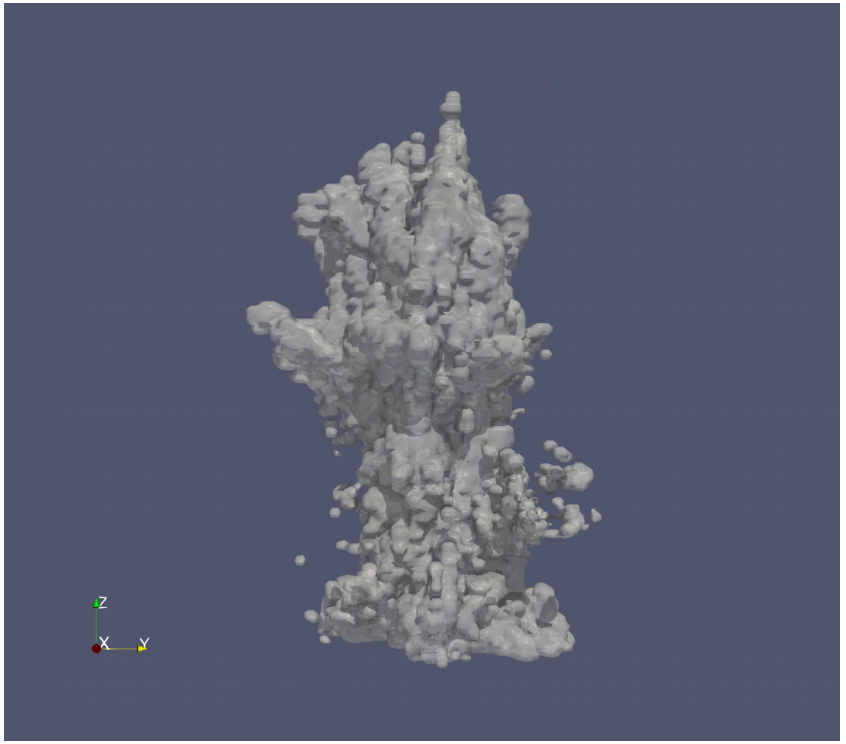
Advantages of particle-based microphysics: Cumulus simulations

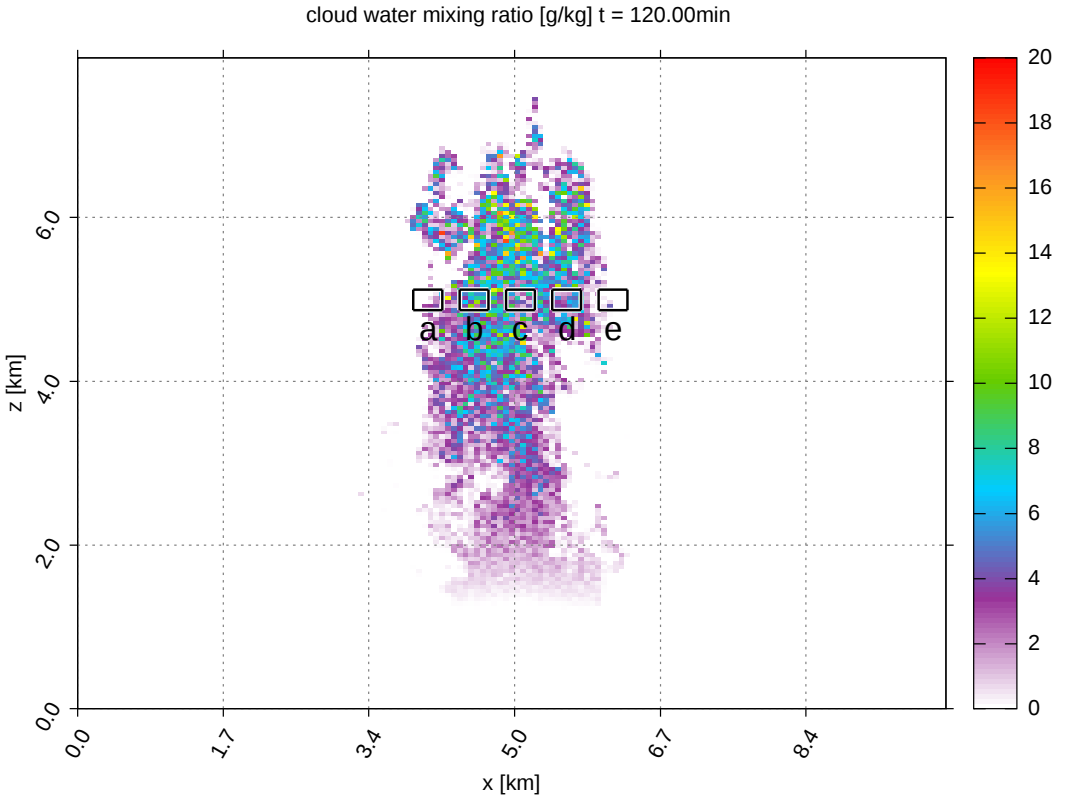


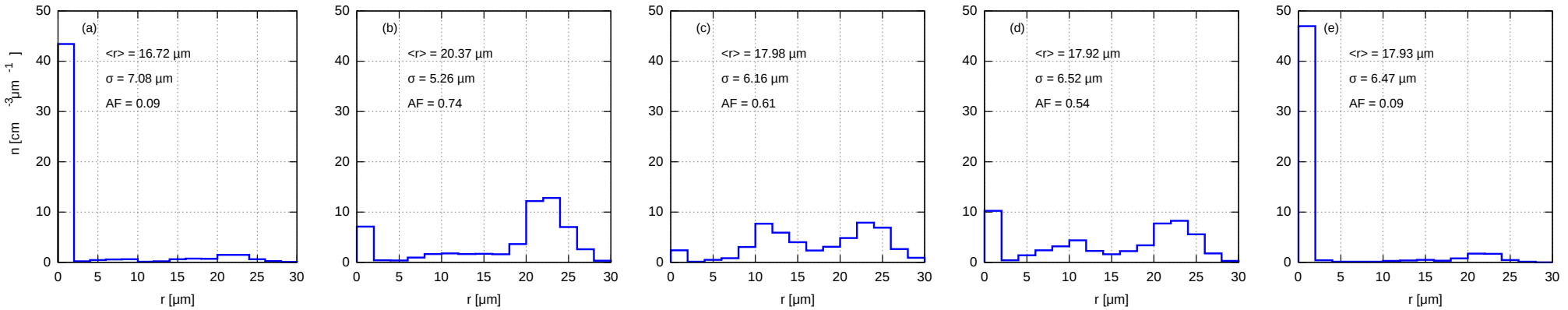


reproduced from Lasher-Trapp et al. *Q. J. R. Met. Soc.* 2005

UWLCM cumulus results







Conclusions

- Particle-based Lagrangian microphysics used in LES give stratocumulus results in agreement with bulk and bin microphysics, except for lower precipitation.
- Implicit LES is in agreement with LES with subgrid-scale models, with the exception of skewness of the vertical velocity distribution.
- Thanks to the use of GPUs, sophisticated microphysics do not slow down simulations.
- LES code available for everyone: https://github.com/igfuw/UWLCM

We have open PhD student positions!