University of Warsaw Lagrangian Cloud Model - a modern LES with Lagrangian microphysics[1]

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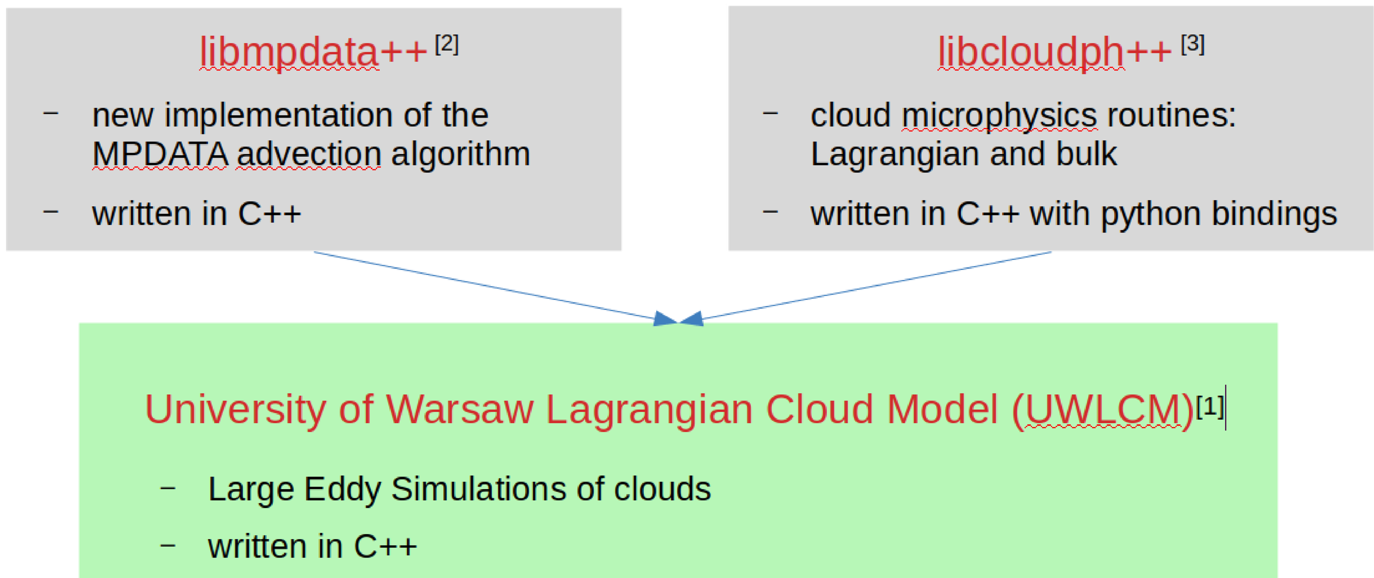
[1] Dziekan, P., Waruszewski, M., and Pawlowska, H. *Geosci. Model Dev. Discuss.* in review, 2019.

Introduction

A new Large Eddy Simulations tool developed at the University of Warsaw.

- Eulerian dynamical core and Lagrangian (Superdroplet) microphysics.
- Anelastic Lipps-Hemler equations.
- Advection solved using MPDATA.
- Generalized conjugate residual solver for the pressure problem.
- Explicitly modeled diffusional growth of droplets.
- Aerosols are explicitly modeled.
- Eulerian bulk microphysics available as reference.
- Makes use of modern hybrid CPU/GPU computing nodes.



[2] A. Jaruga et al. *Geoscientific Model Development* 2015, vol. 8, pp. 1005-1032

[3] S. Arabas et al. *Geoscientific Model Development* 2015, vol. 8, pp. 1677-1707

Spatial coupling between Eulerian and Lagrangian components

- Staggered Arakawa-C grid.
- Eulerian grid cells also used as coalescence cells.
- θ and q_v not interpolated to SD position.
- Courant number interpolated to SD position.

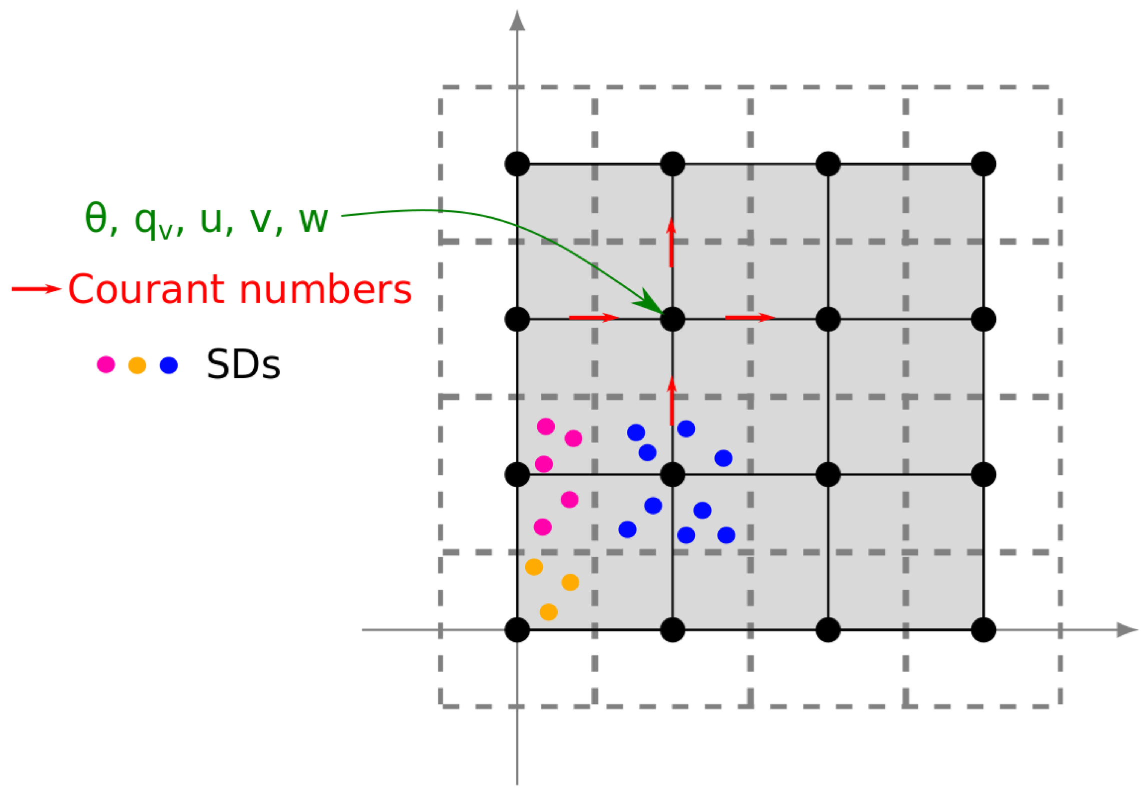


Figure 1: Schematic representation of the spatial discretiation of UWLCM.

Condensation substepping

- LES uses $\Delta t \approx 1$s; activation needs $\Delta t \approx 0.1$s.
- Two types of substepping considered: *per-cell* and *per-particle*.
- *Per-particle* substepping found to be necessary.

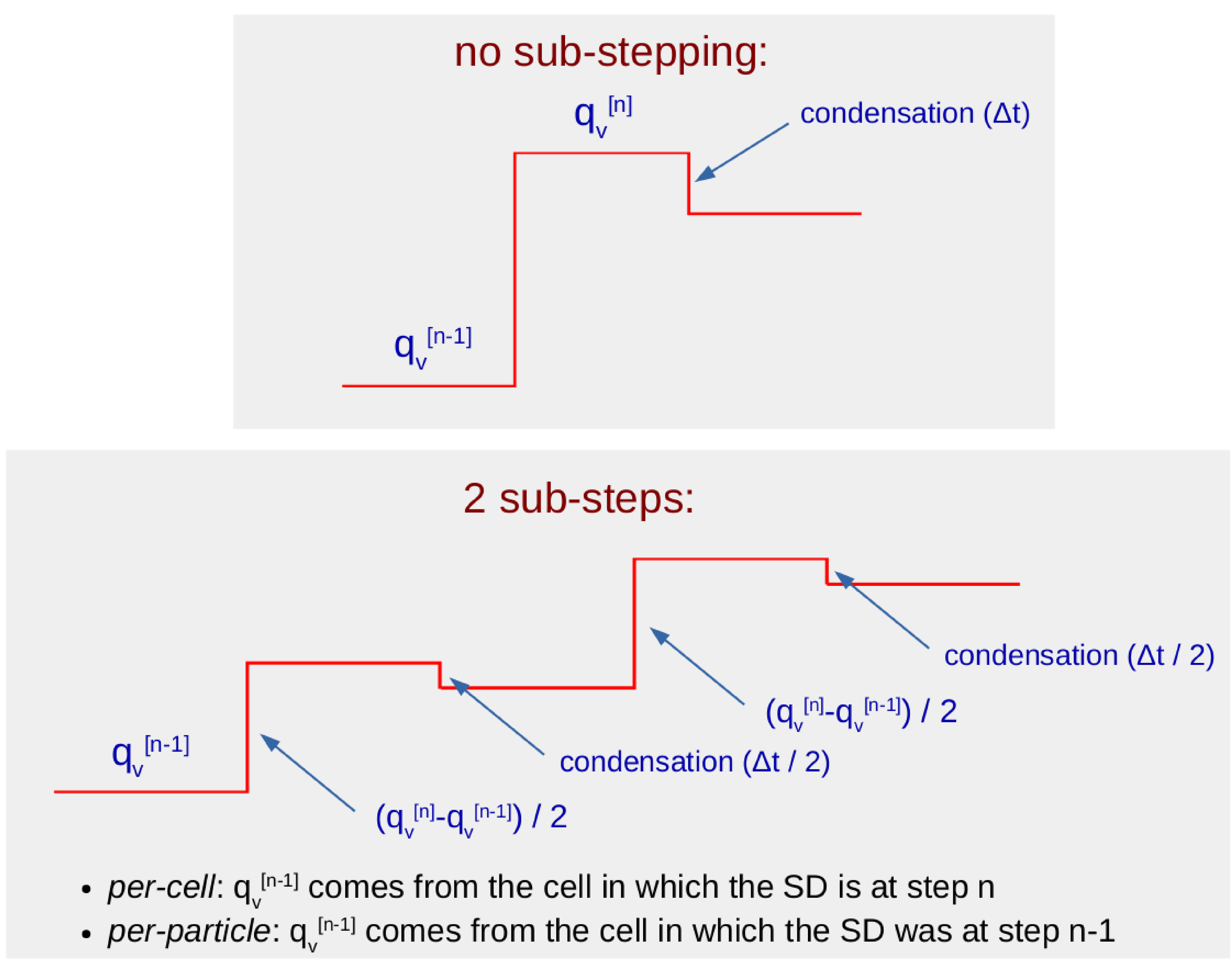


Figure 2: Schematic representation of the substepping algorithm.

Model results - DYCOMS stratocumulus

- Test 2D/3D UWLCM against 11 models from Ackerman et al. 2009[4]
- Other models use bin or bulk, we use Lagrangian microphysics
- Other models use subgrid-scale schemes, we use implicit LES

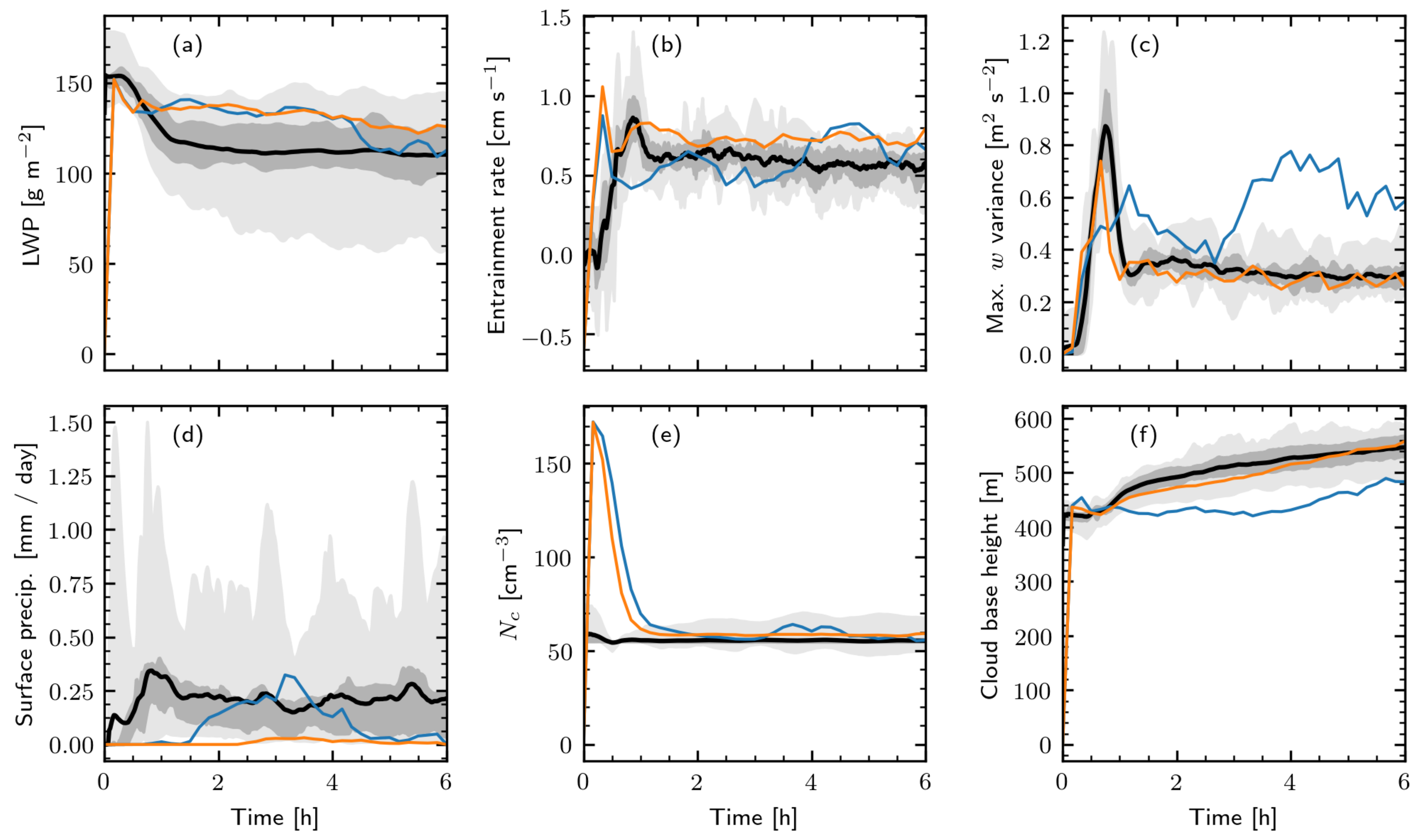


Figure 3: Time series from 2D (blue line) and 3D (orange line) UWLCM with Lagrangian microphysics and from the DYCOMS RF02 intercomparison. Dark (light) shaded region depicts middle two quartiles (whole range) of the ensemble of simulations from the intercomparison. Only selected time series that differ most are shown. 2D results are averages from 10 runs.

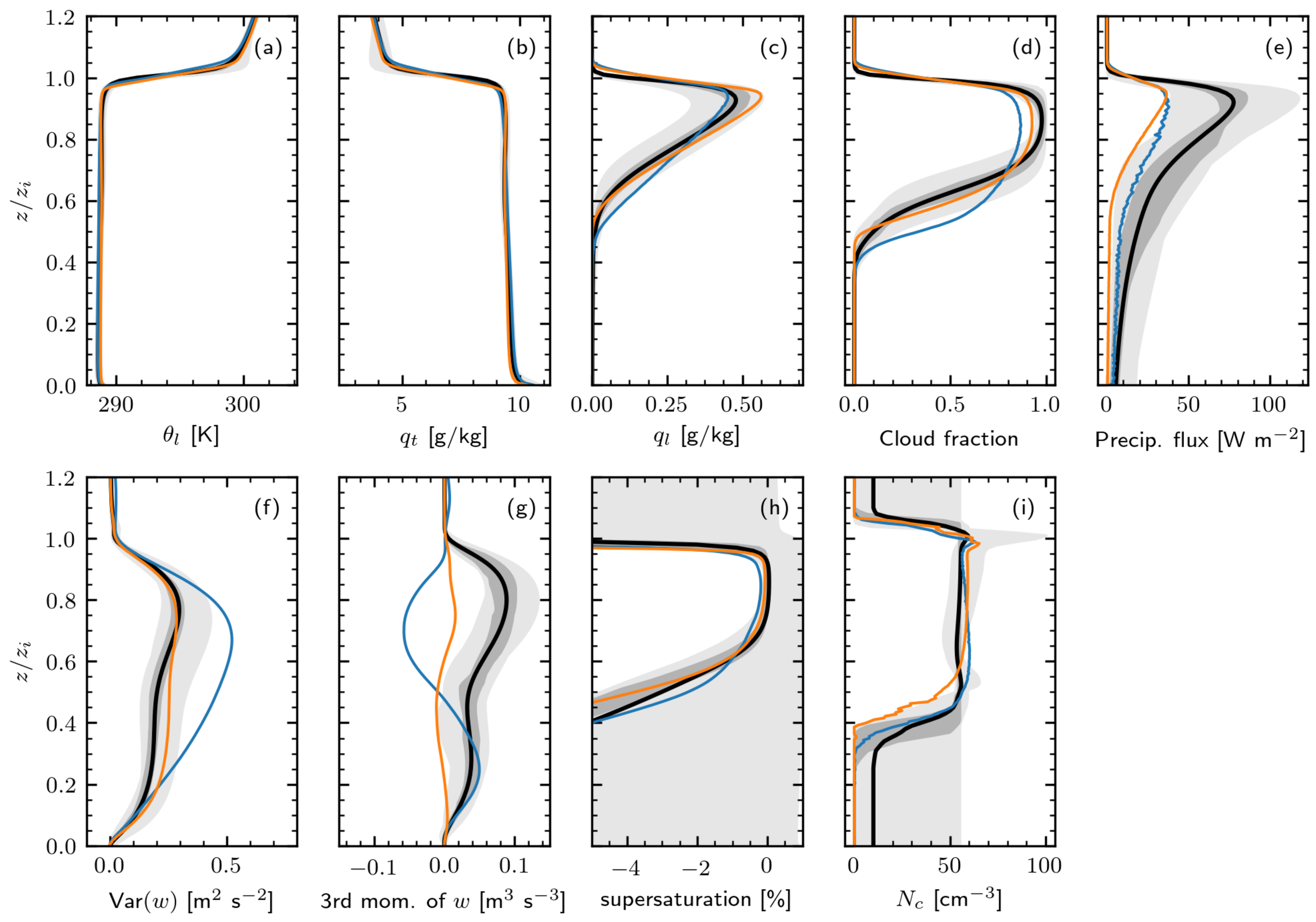


Figure 4: As in Fig.4, but for averaged vertical profiles.

[4] AS Ackerman et al. *Monthly Weather Review* 2009, vol. 137.3, pp. 1083-1110

Comparison with models with bin microphysics

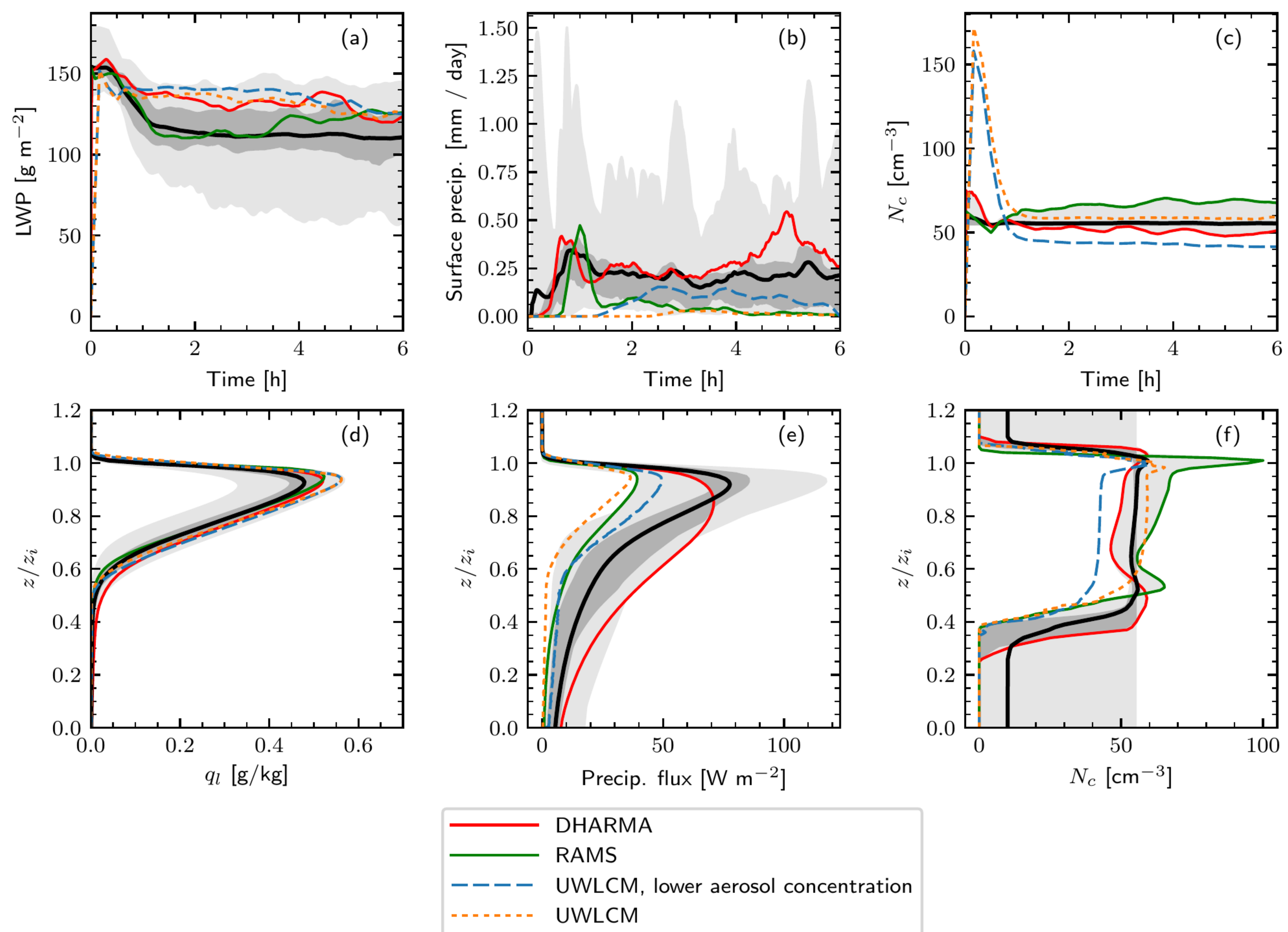


Figure 5: Selected time series and profiles from 3D UWLCM and models that use bin microphysics.

- Better resolved activation than in bin schemes.
- Precipitation in agreement with RAMS (2-moment bin scheme).
- DHARMA (1-moment bin scheme) gives significantly more precipitation.

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