University of Warsaw Lagrangian Cloud Model (UWLCM)

SGS turbulent motion, condensation and coalescence

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LES model with Lagrangian microphysics

dynamics

- Eulerian
- Anelastic approximation
- MPDATA advection
- Calculated on CPUs
- Uses libmpdata++

microphysics

- Lagrangian
  - Super-droplet method (SDM) (Shima et al. 2009)
  - Calculated on GPUs
- Eulerian
  - Single-moment bulk
  - Calculated on CPUs
- Uses libcloudph++

Subgrid scale turbulence in UWLCM

Diffusion

- Implicit LES (ILES)
  - No diffusion of liquid water in SDM
- Smagorinsky
  - Random component of SD velocity (Grabowski&Abade 2017)

Microphysics

- Turbulent coalescence kernels
  - Onishi et al. 2015
  - Ayala et al. 2008
  - Pinsky et al. 2008
- Random component of SD supersaturation (Grabowski&Abade 2017)
- Works only with Smagorinsky

Stratocumulus simulations

- A drizzling marine stratocumulus, DYCOMS RF02
- Test UWLCM against 11 LES models from the Ackerman et al. 2009 intercomparison
- Models disagree most in the amount of drizzle
- Microphysical schemes in other models:
  bin, single-moment bulk and double-moment bulk

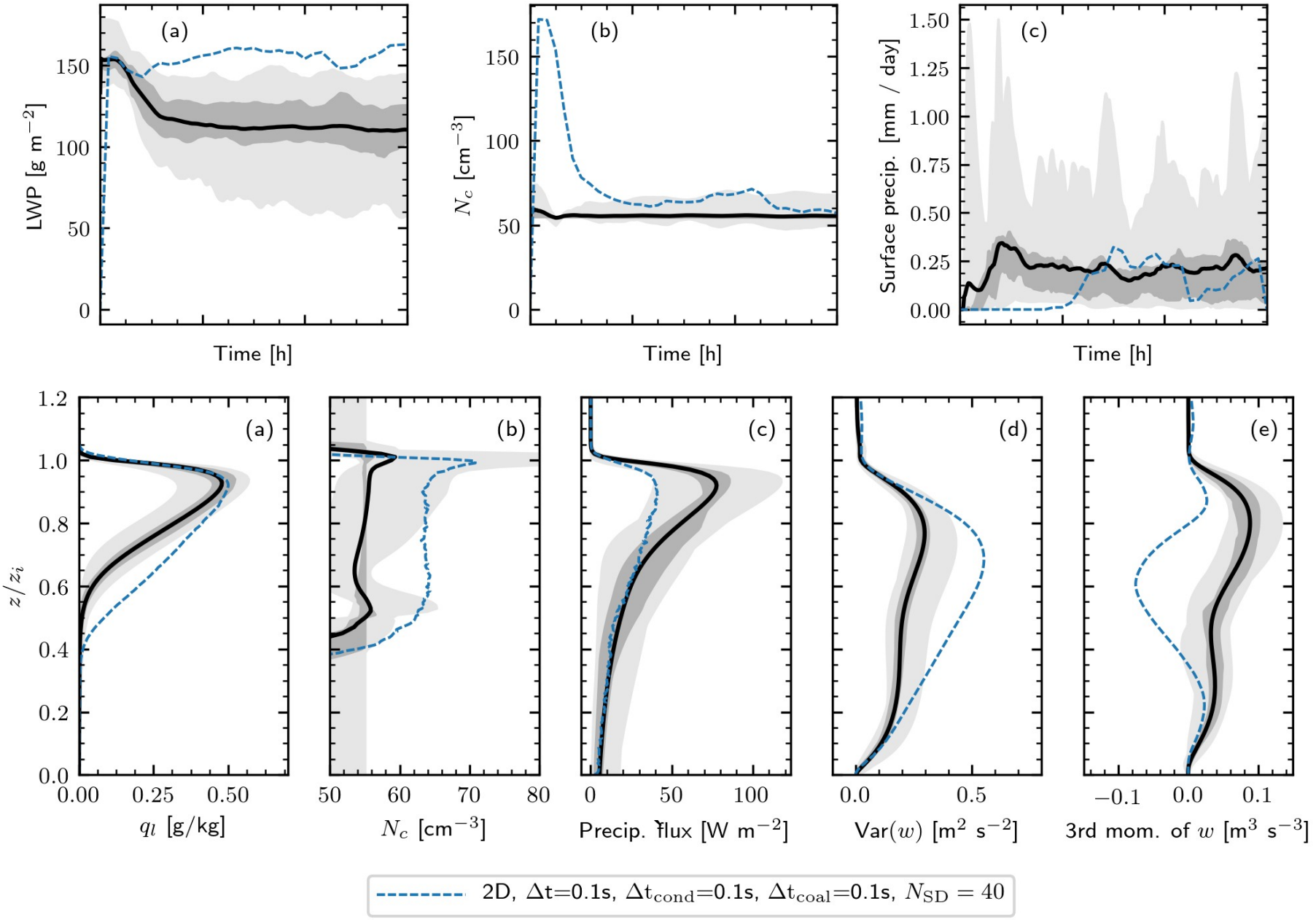
source: Angela Rowe
communitycloudatlas.wordpress.com

Movie

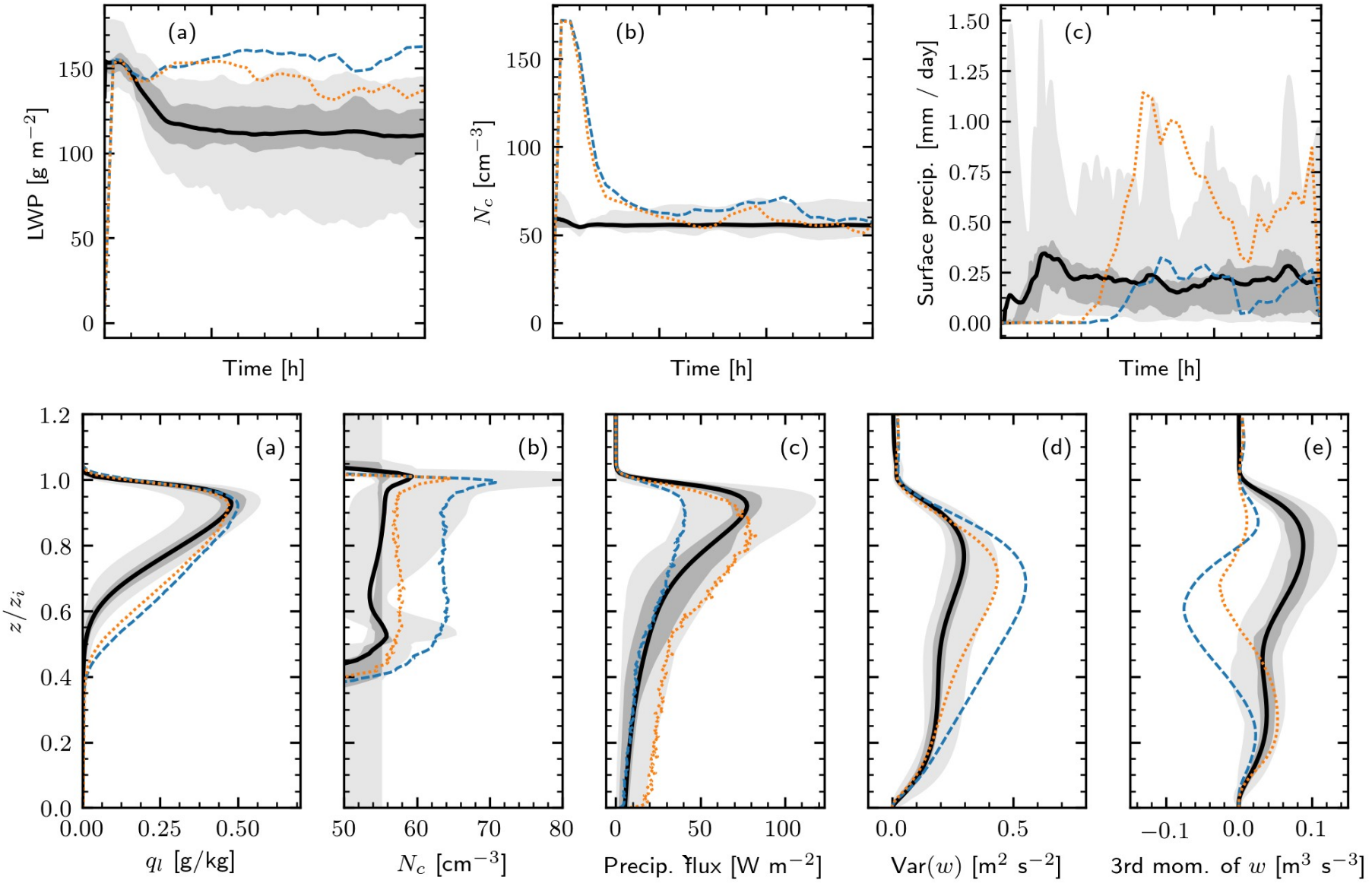
2D – SDM sensitivity

- Test different timestep lengths
  - for condensation
  - for coalescence
- Test different numbers of SDs,
  N_{SD} - initial number of SDs per cell
- Focus on precipitation
- Implicit LES

2D – SDM sensitivity



2D – SDM sensitivity



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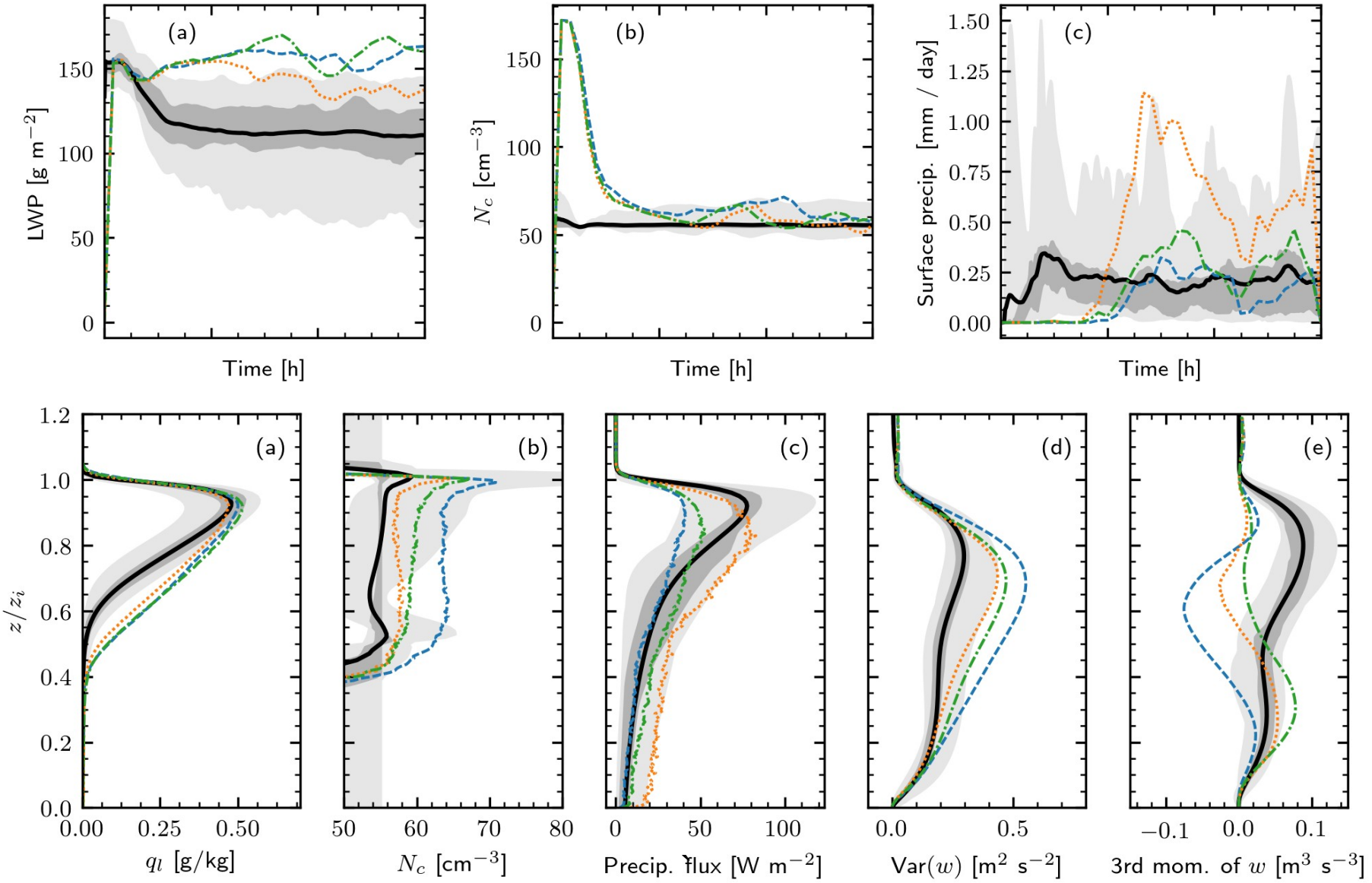

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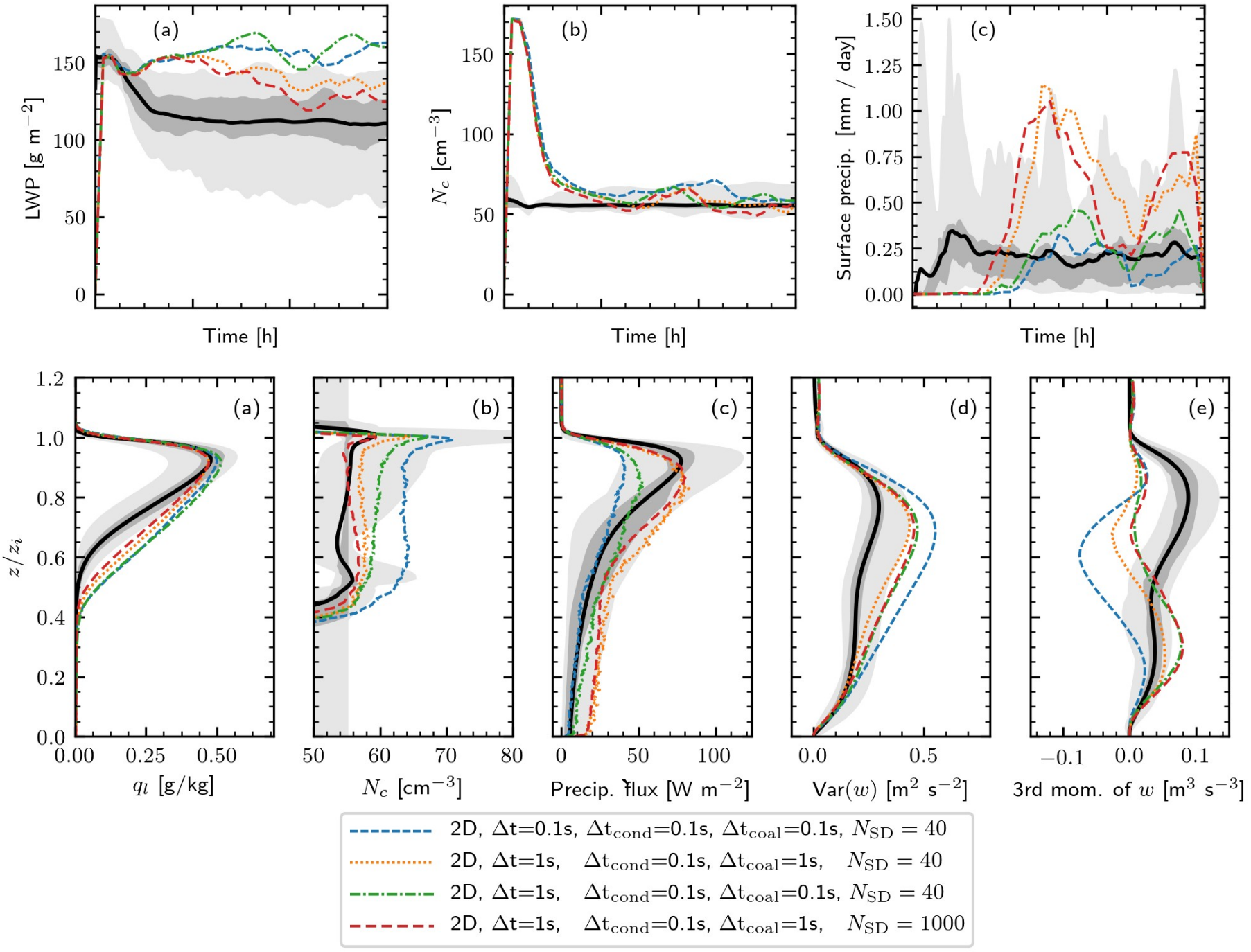

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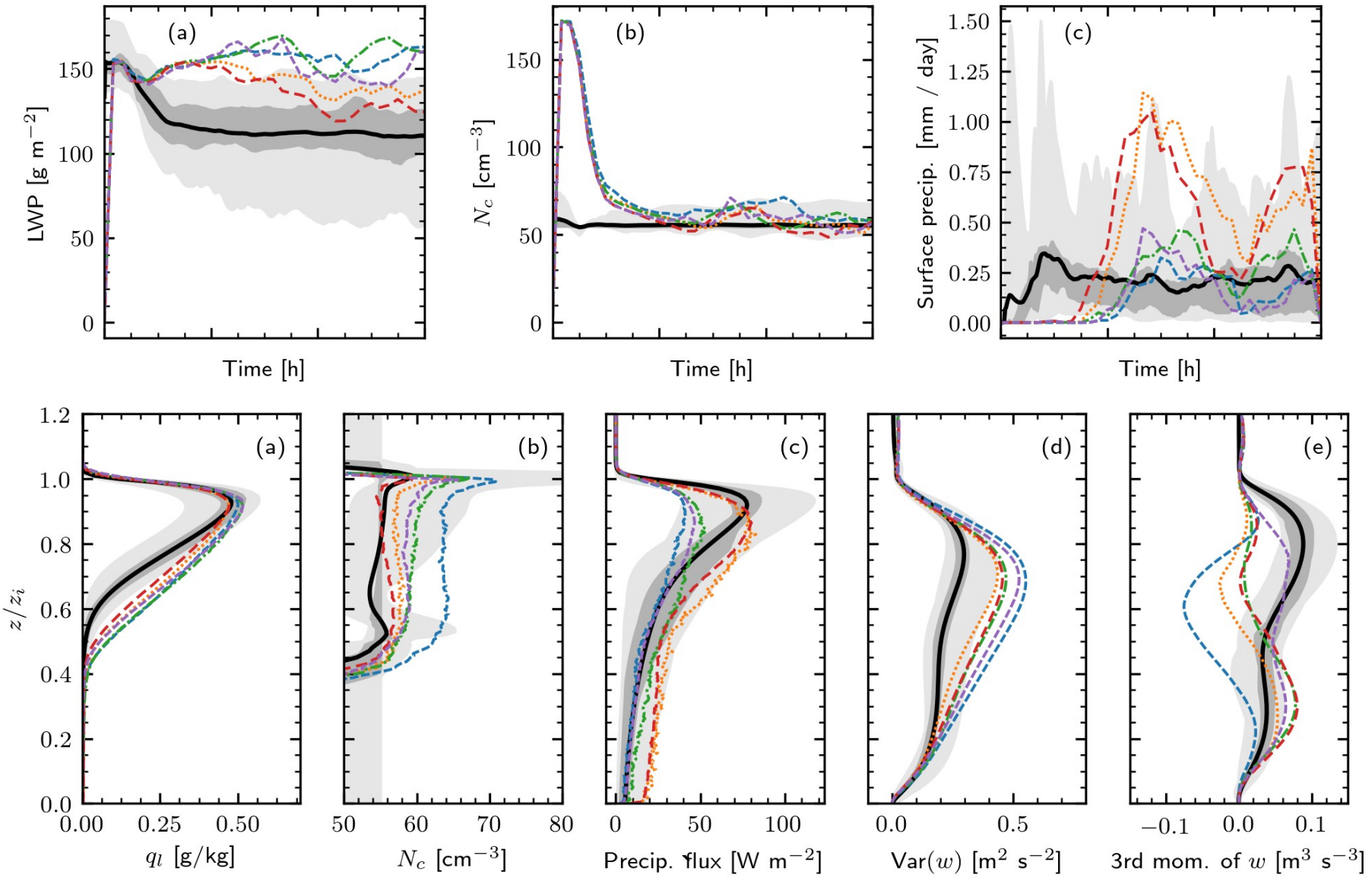
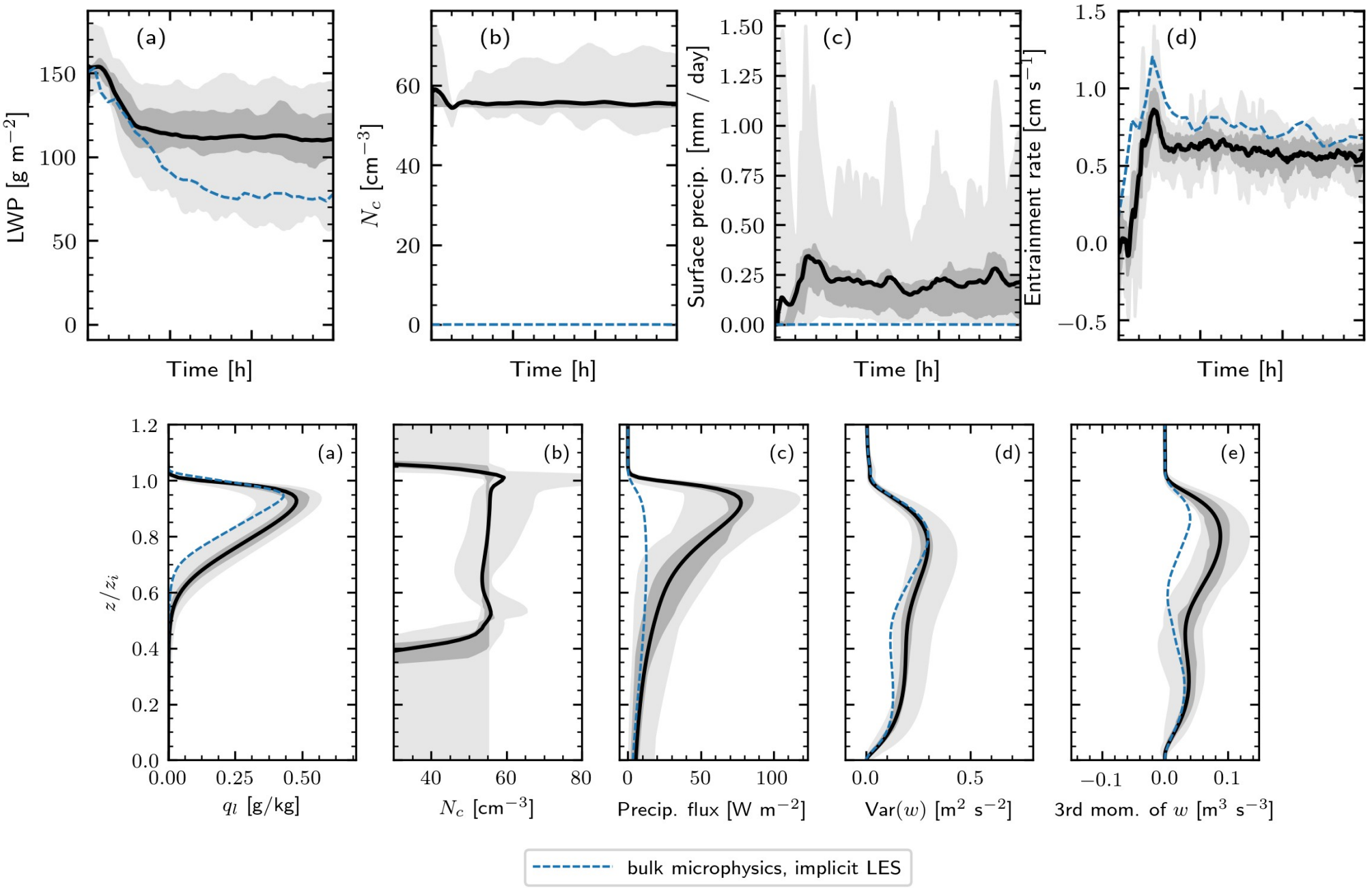


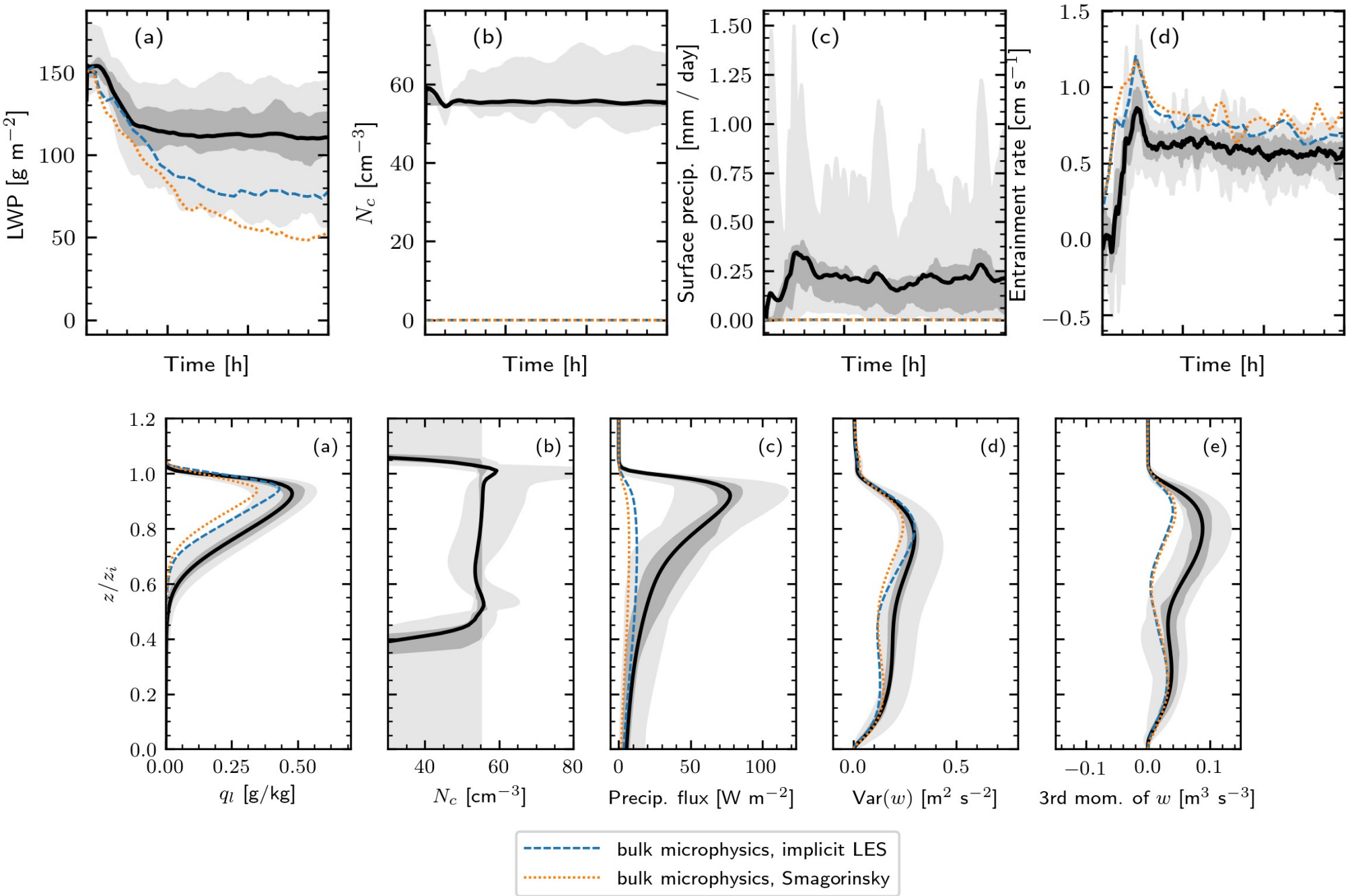
Lessons for SDM from the sensitivity test

- 0.1 s timestep for condensation to get activation right
- 1s timestep for coalescence gives too much precipitation
- 40 super-droplets per cell is fine

3D simulations

- $\Delta t = 1s$, $\Delta t_{cond} = 0.1s$, $\Delta t_{coal} = 0.1s$, $N_{SD} = 40$
- Bulk vs SDM microphysics
- SGS turbulence effects


(a)
LWP [g m^{-2}]
Time [h]
(b)
N_c [cm^{-3}]
Time [h]
(c)
Surface precip. [mm / day]
Entrainment rate [cm s^{-1}]
Time [h]
(d)
Time [h]
(a)
z/z_i
q_l [g/kg]
(b)
N_c [cm^{-3}]
(c)
Precip. flux [W m^{-2}]
(d)
Var(w) [m^2 s^{-2}]
(e)
3rd mom. of w [m^3 s^{-3}]
bulk microphysics, implicit LES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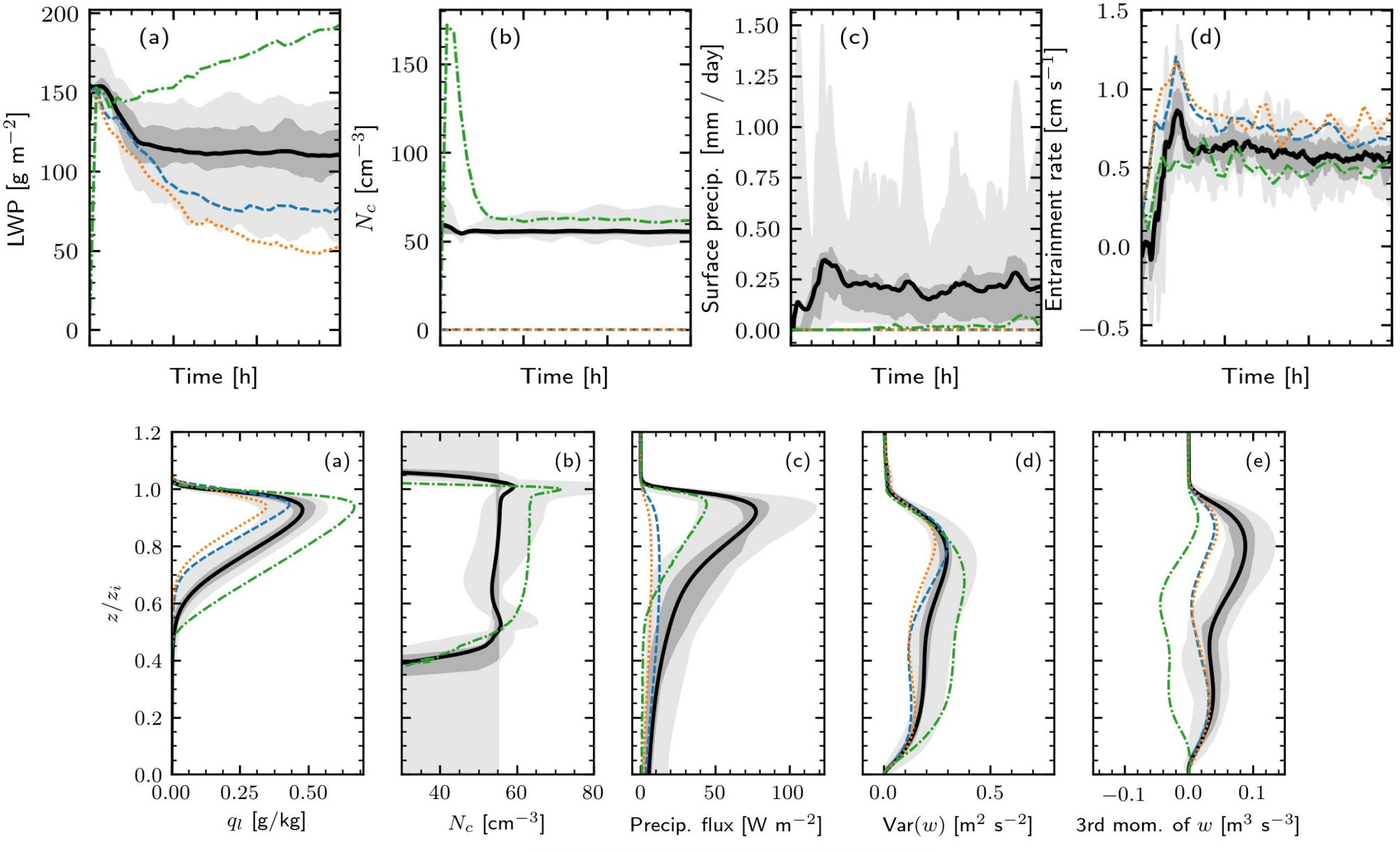
bulk microphysics, Smagorinsky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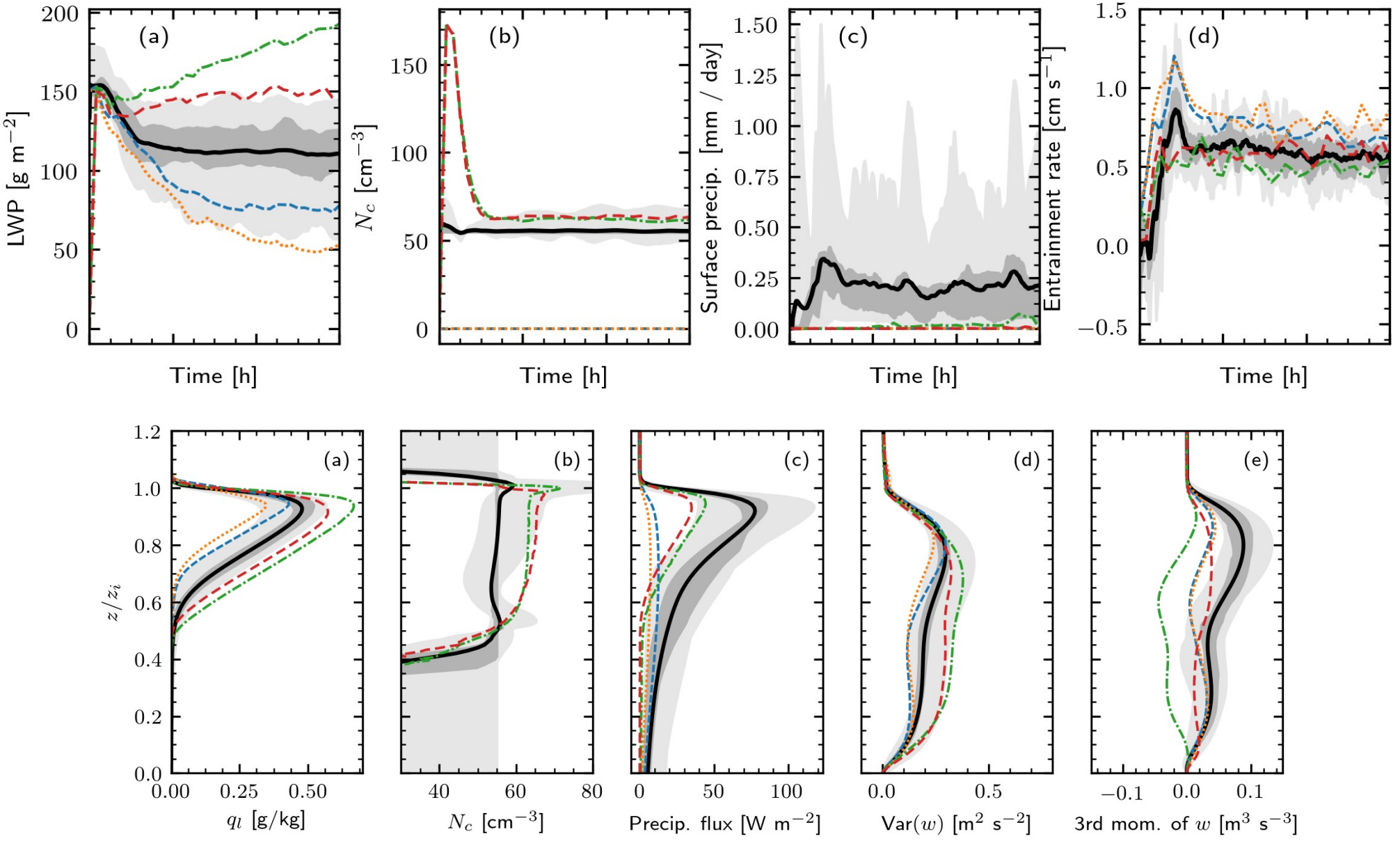
bulk microphysics, Smagorinsky
SDM, implicit LES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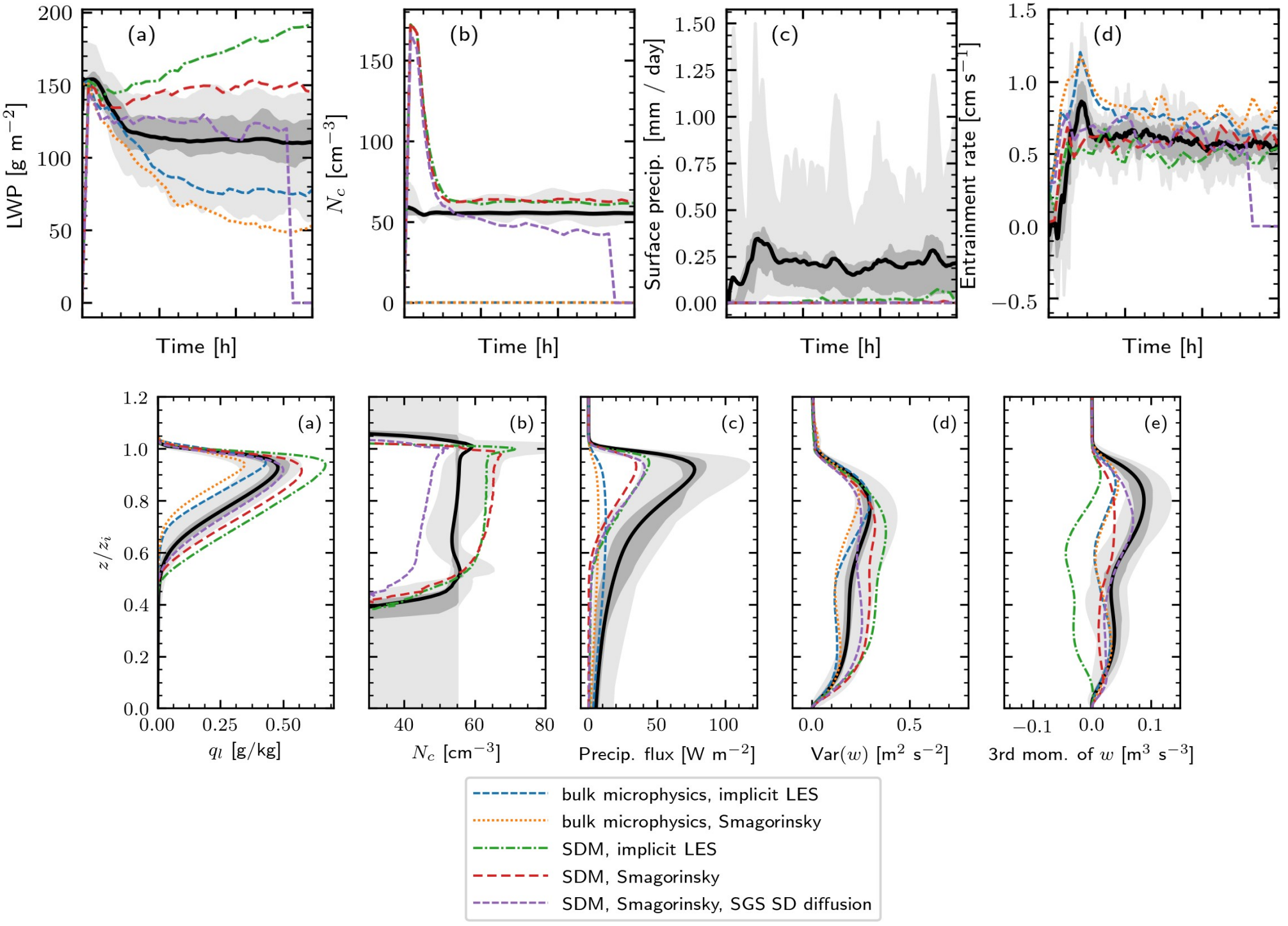
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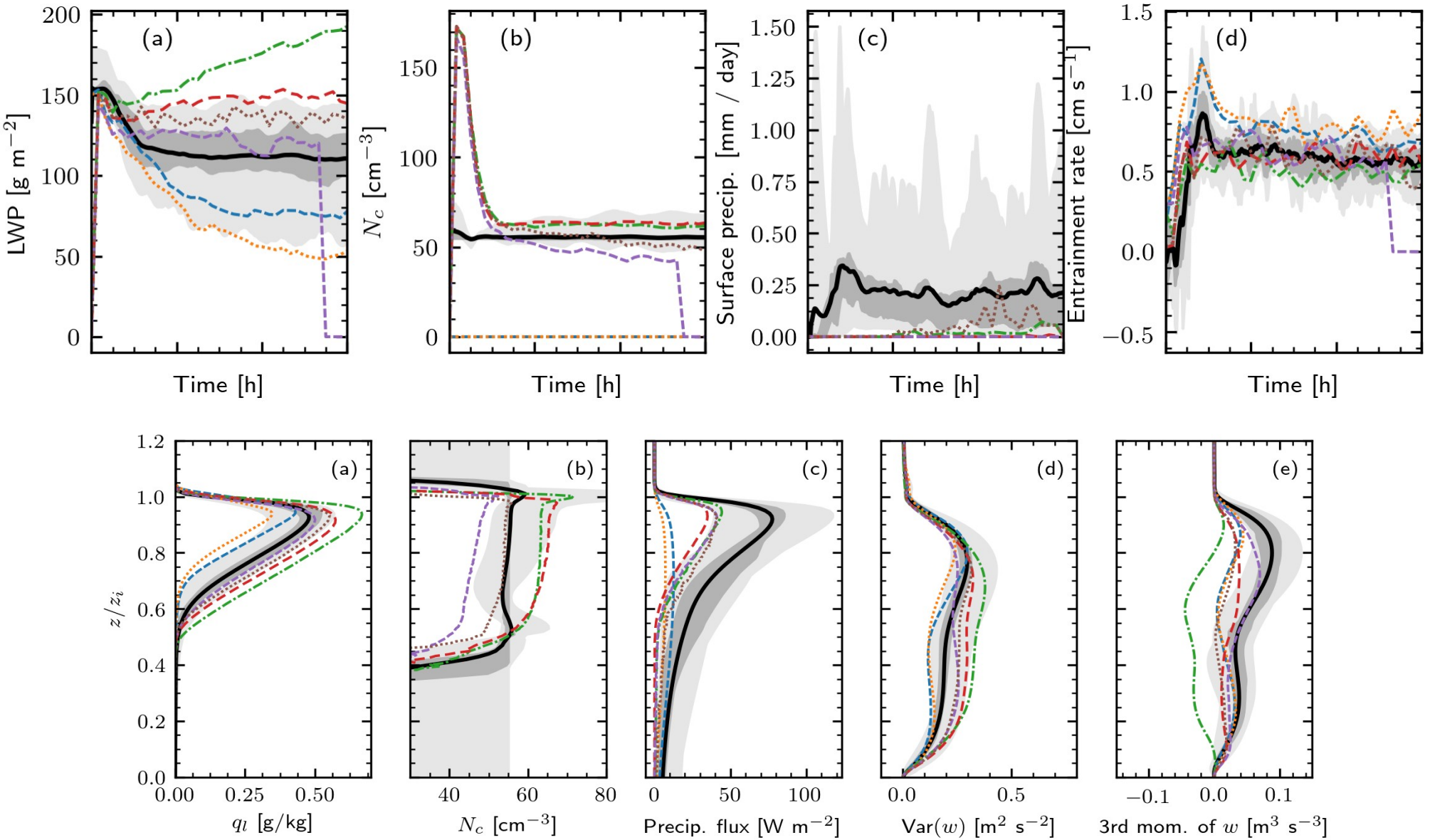
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SDM, implicit LES
SDM, Smagorinsky
SDM, Smagorinsky, SGS SD diffusion
SDM, Smagorinsky, SGS SD coalescence

Conclusions

- Stratocumulus:
  - Turbulent enhancement of collision-coalescence rate is important
- Lagrangian microphysics:
  - Subgrid scale diffusion is needed
- SDM:
  - Condensation and coalescence timestep of 0.1 s
  - 40 Super-droplets per cell is good enough
- Paper in GMDD