Special Thanks To My Colleagues and Co-authors:

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Separating dynamical and microphysical impacts on cloud processes

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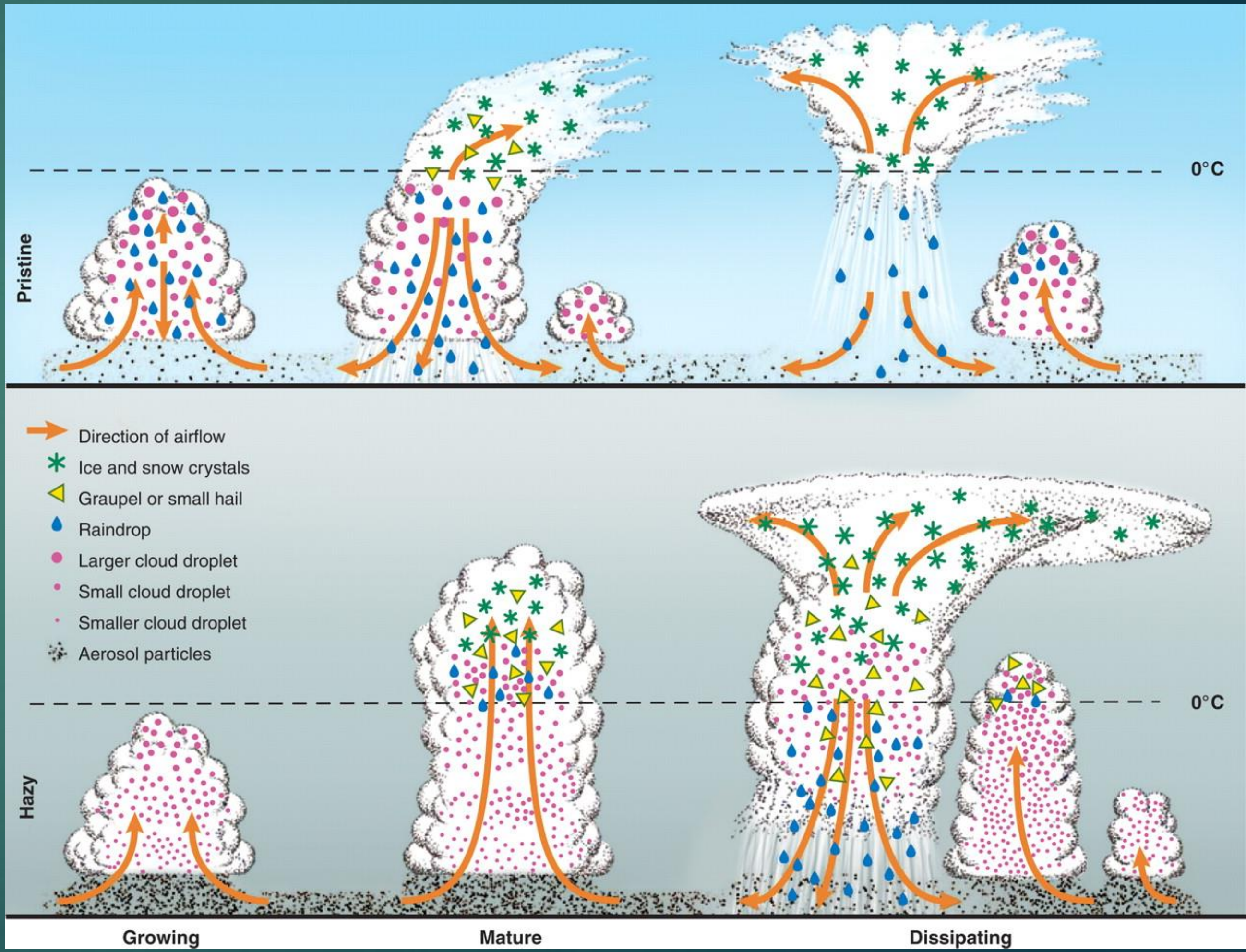
Outline

- Motivation
- Piggybacking method
- Results and findings
- Further plans

Motivation

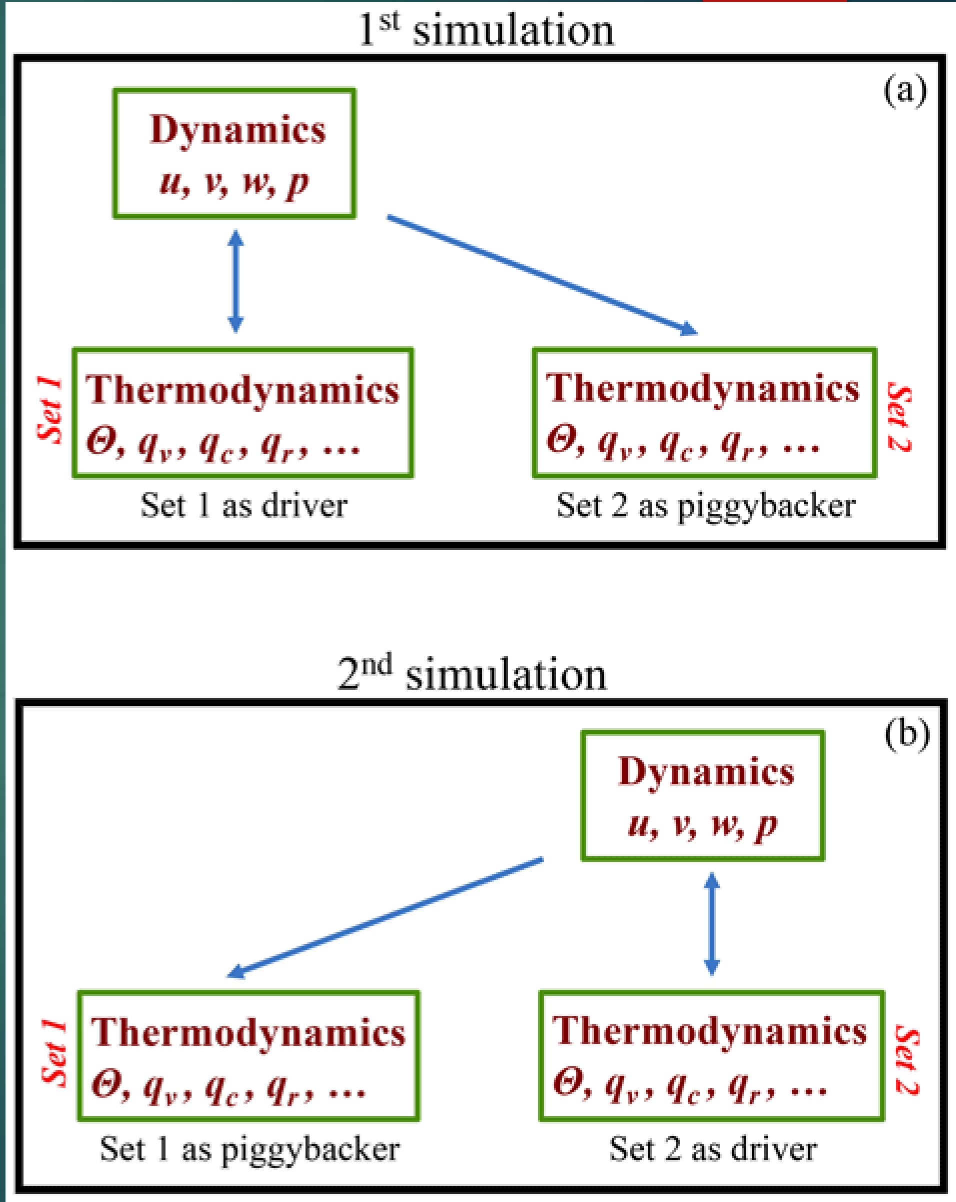
- **Aerosol direct and indirect effects**
- „Convective invigoration”: increasing CCN concentration result higher amount of precipitation (Cold-phase invigoration)
- Low CCN → larger water drops (less ice, supercooled water). High CCN → smaller water drops (reach below 0°C in larger concentration) → freezing (latent heat release) + melting (cooling) → temperature difference → strengthen updrafts, formation new clouds. (Rosenfeld et al., 2008)
- „Convective enervation”: latent heat release during freezing slow down condensation, either can initiate evaporation. In polluted air it can cause that the buoyancy not increase as intense as can bounce this release. As a result the convection enervate (especially with warm cloud base). (Igel & van den Heever, 2021).

Source: Rosenfeld *et al.*, *Science*, 2008.



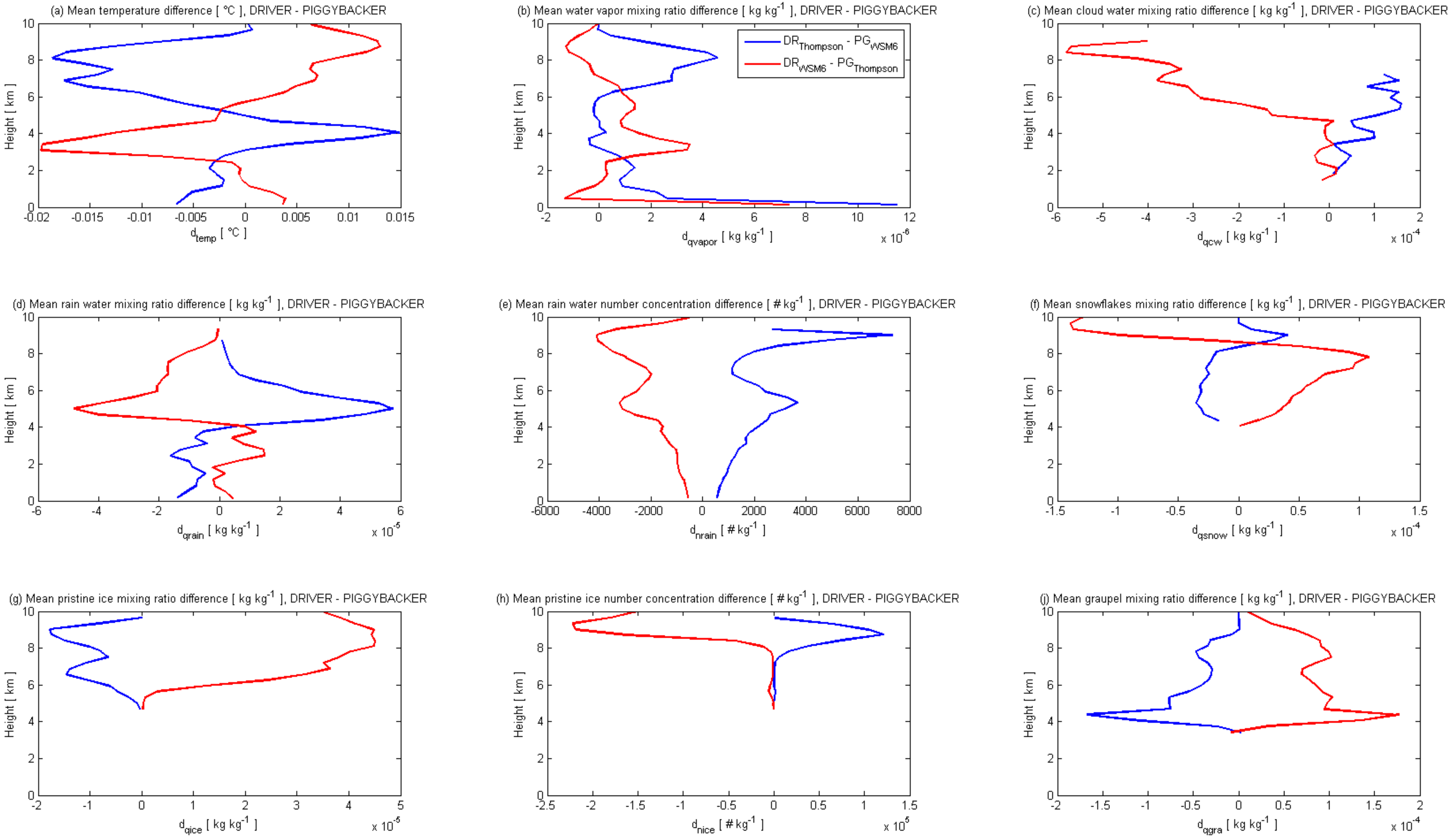
Piggybacking method

Source: W.W.Grabowski, *Adv. Geosci.*, 2019.



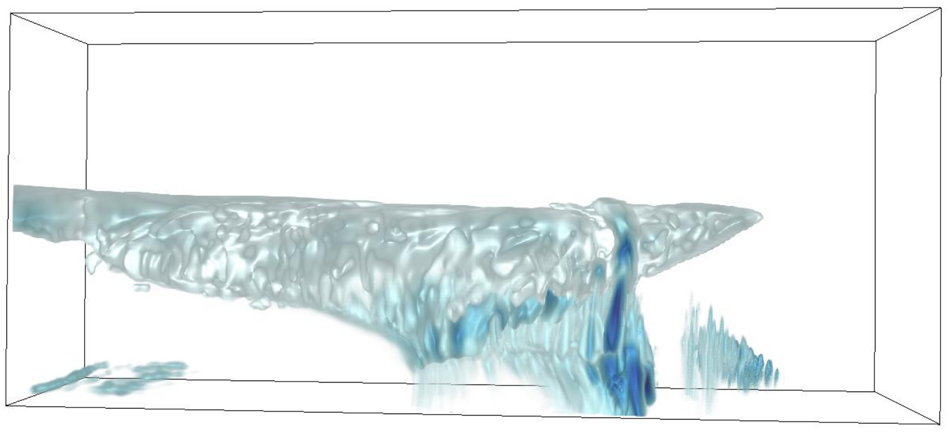
- Piggybacking – master-slave technique
  - 1 set of dynamics
  - 2 sets of thermodynamics/microphysics
  - 2 simulations (switch thermodynamics/ microphysics)
- Difference between driver and piggybacker caused by microphysics (the dynamical parameters are the same in the simulation)
- Difference between the drivers caused microhysical-dynamical interactions.

Example: Thompson vs. WSM6 piggybacking in idealized squall line case with WRF, domain averaged values.



Results I – Squall line

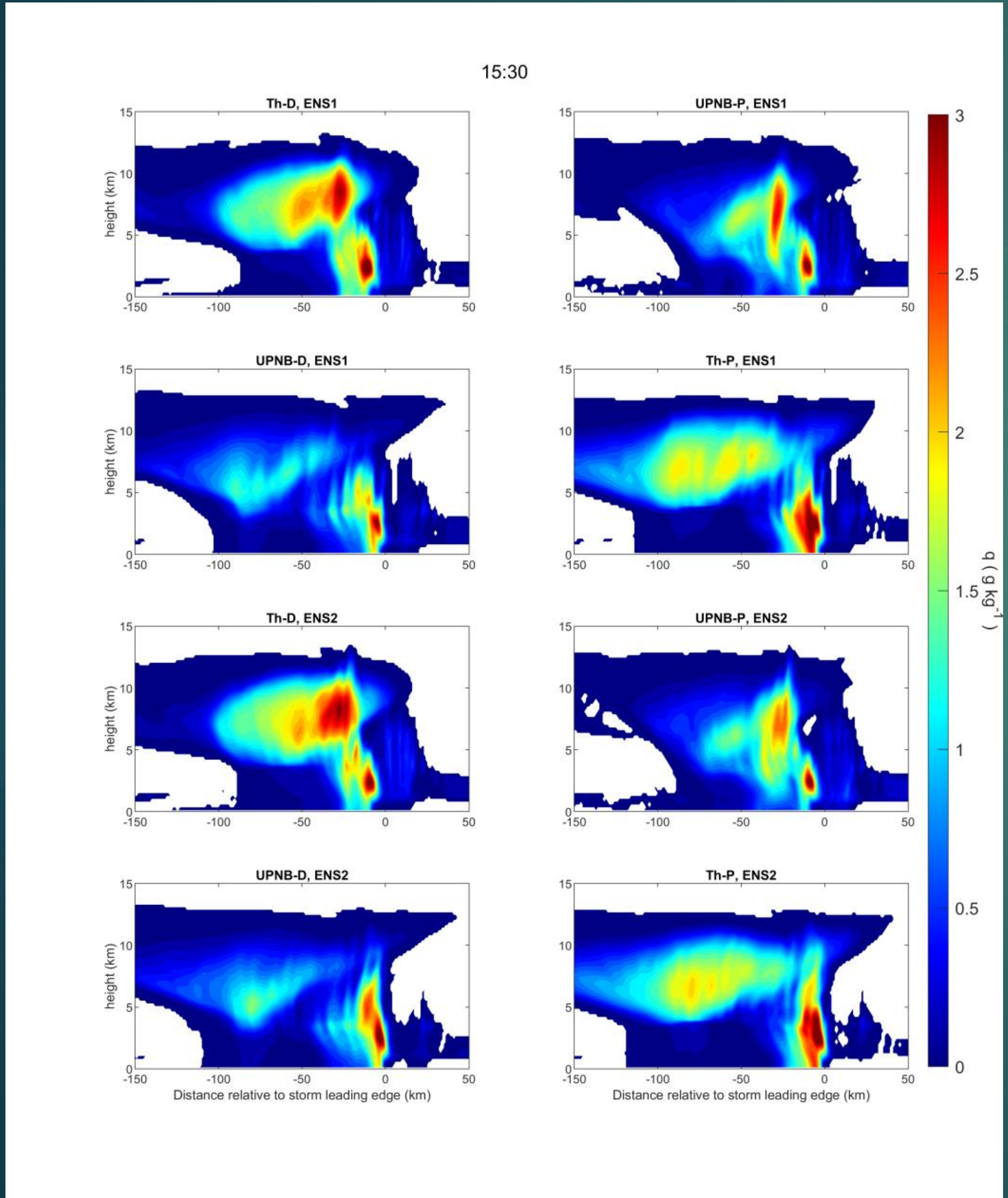
- MC3E (Mid-latitude Continental Convective Clouds Experiment; Jensen et al., 2016)
- Microphysical piggybacking

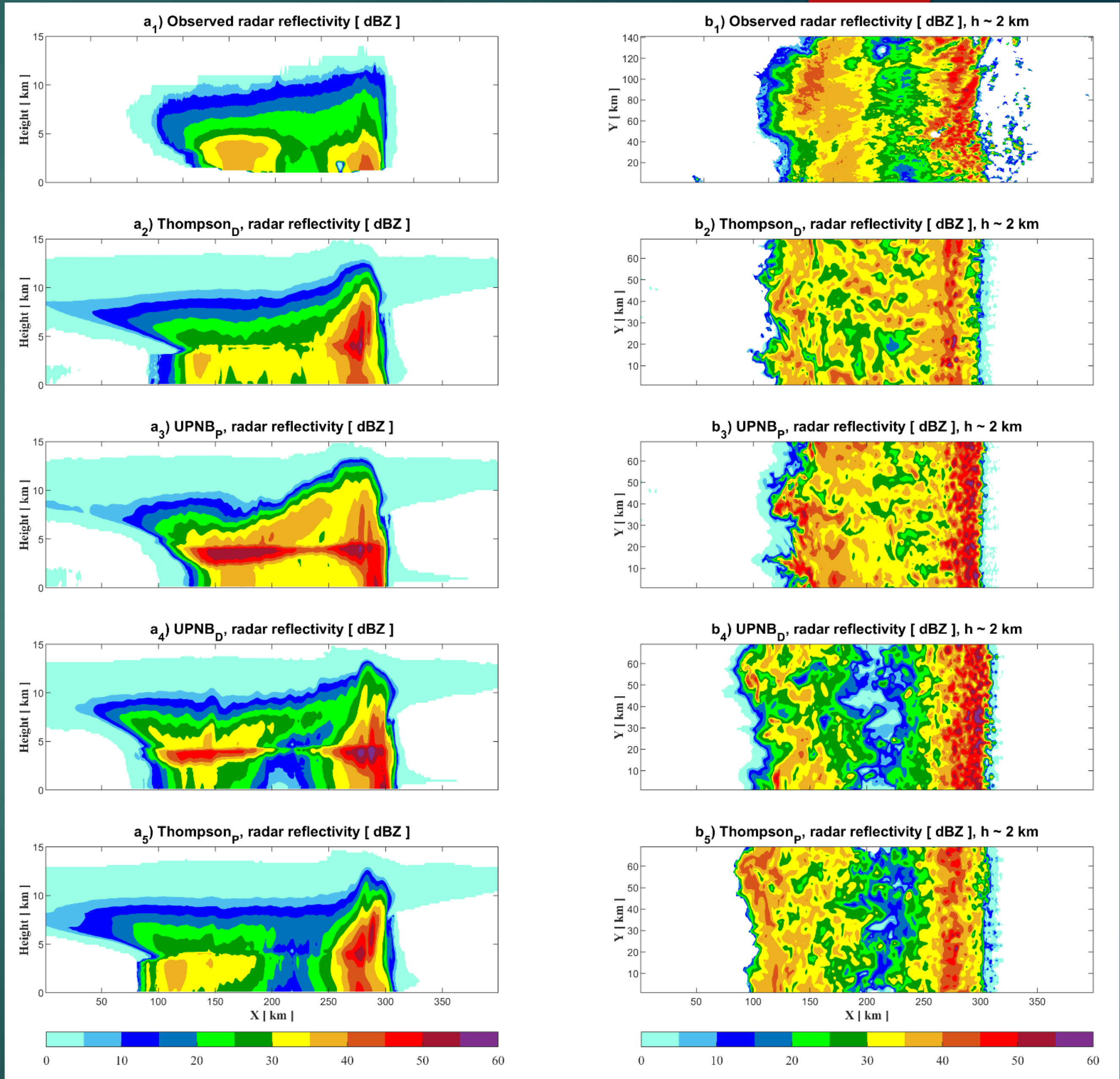


Horizontal domain size/horizontal grid length	**400 gridpoints × 70 gridpoints/1 km**
Vertical domain size/vertical grid length	101 levels /semi-uniform grid (up to 25 km)
Dynamical time step	2 sec.
CCN concentration	~250 cm^{-3}
Simulated time period (integration time)	2011. 05. 20. 12:00 – 18:00 (6 h)
Initial conditions/case study	Initialization with random temperature perturbation (pairs of ensemble members shared the same perturbation) and u-convergence in the middle of the domain.
Microphysics	Two ensembles (3 members) of simulations were completed and analyzed: (1) bulk scheme (Thompson, namelist option: 8) drives and bin scheme (UPNB) piggybacks; (2) bin drives and bulk piggybacks.
Planetary boundary layer	no boundary-layer (namelist option: 0)
Cumulus parameterization	no cumulus (namelist option: 0)
Radiation physics	no shortwave and longwave radiation (namelist option: 0)
Surface layer physics	no surface-layer (namelist option: 0)
Land-surface physics	no surface temperature prediction (namelist option: 0)

Results I – Squall line

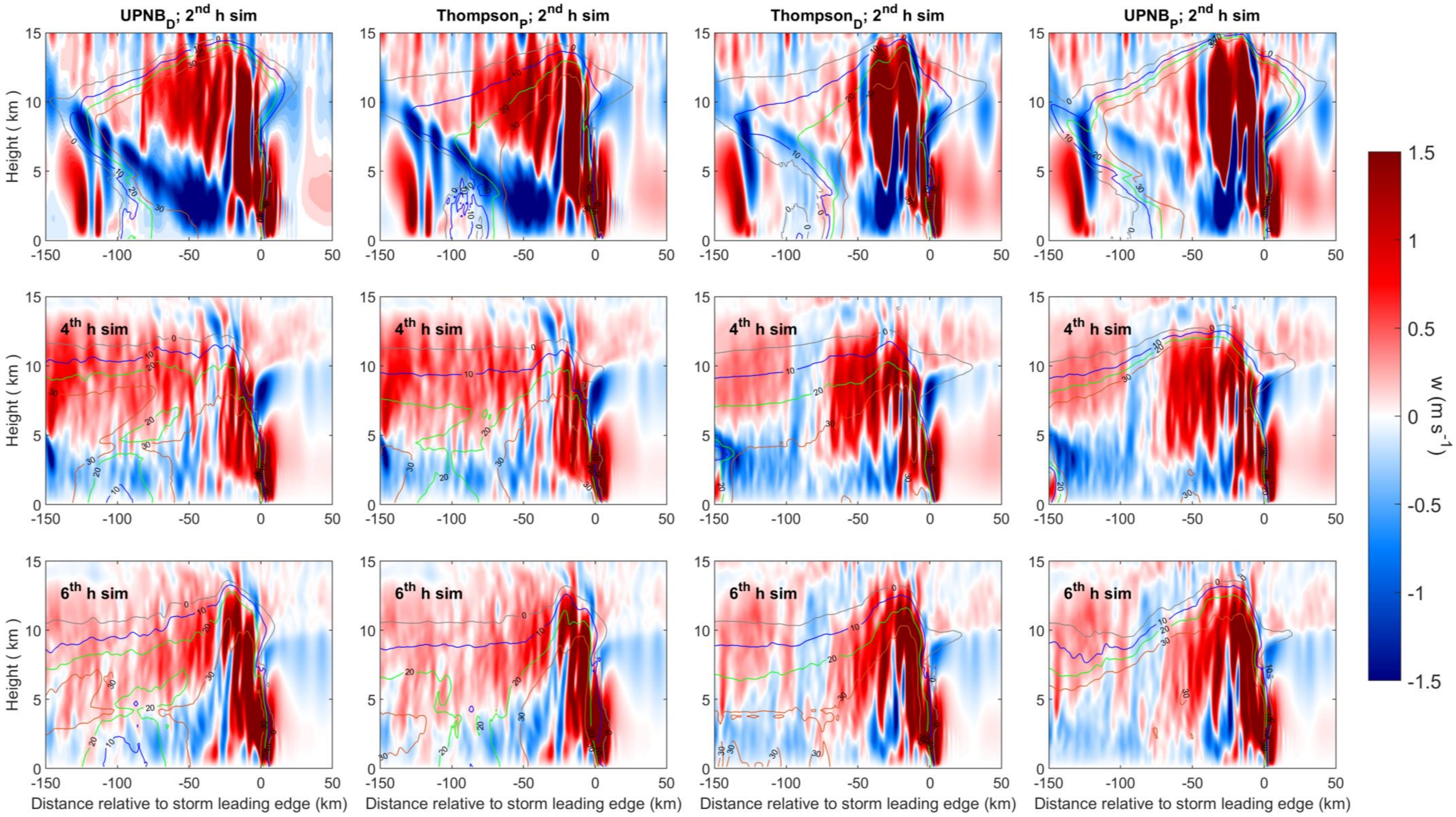
Source: Sarkadi et al., *JAMES*, 2022.





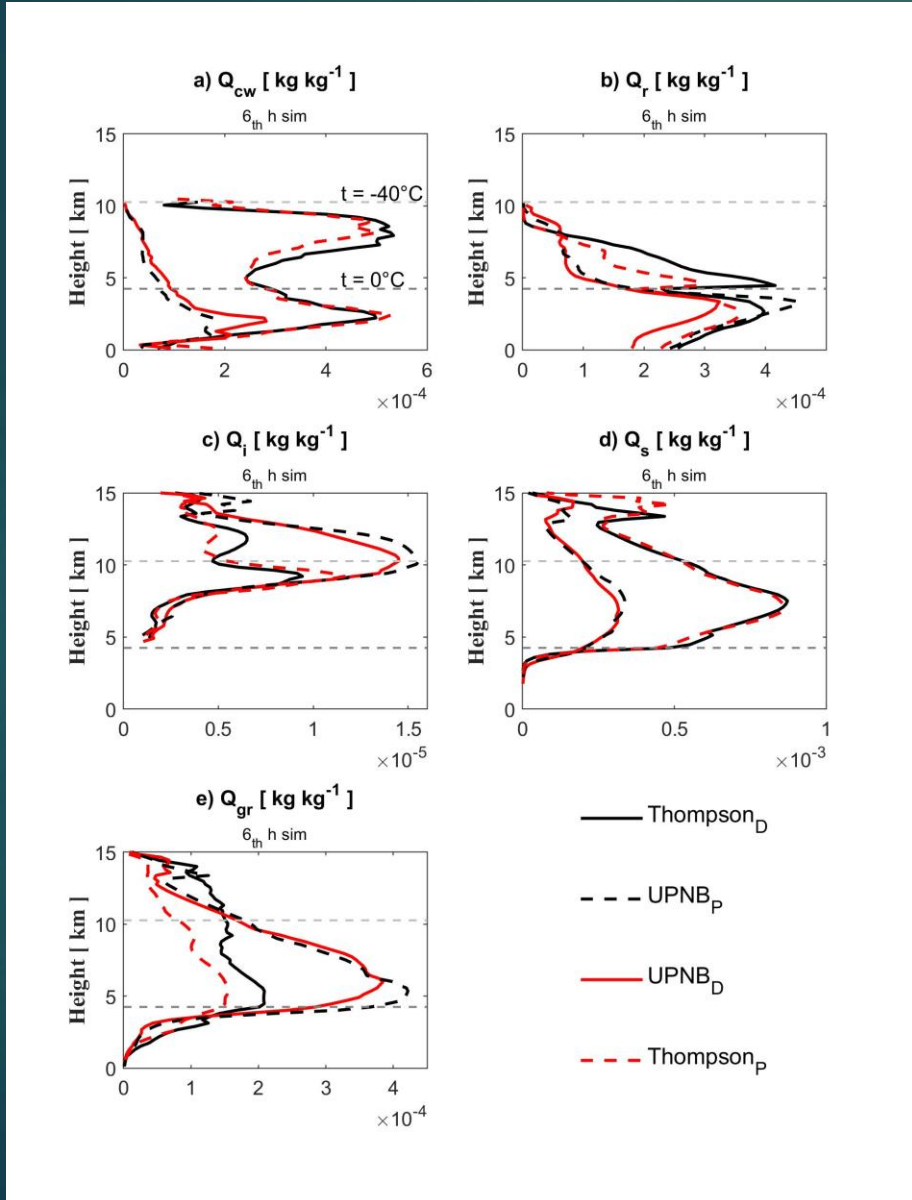
Results I – Squall line

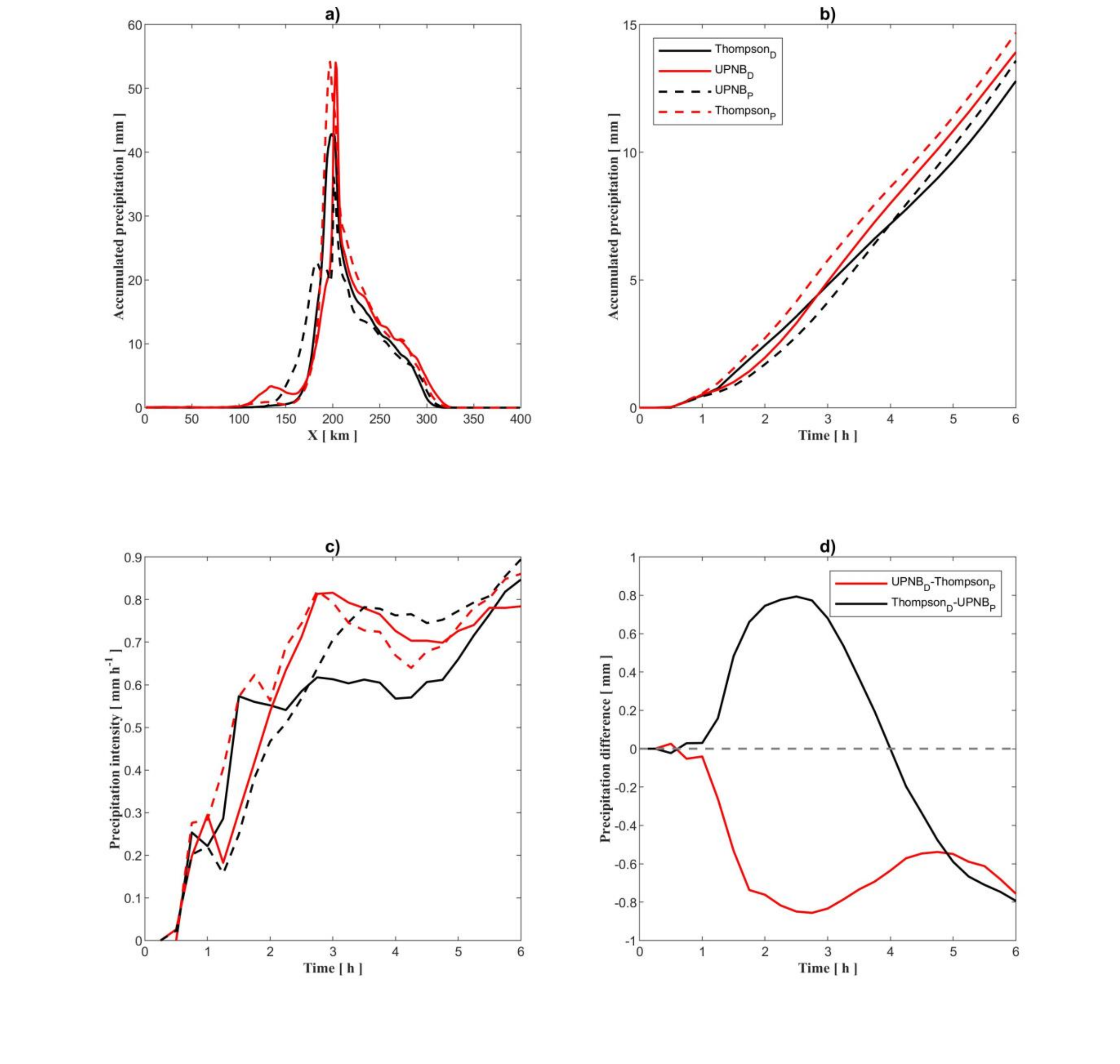
Source: Sarkadi et al., *JAMES*, 2022.



Source: Sarkadi et al., *JAMES,* 2022.

Results I – Squall line





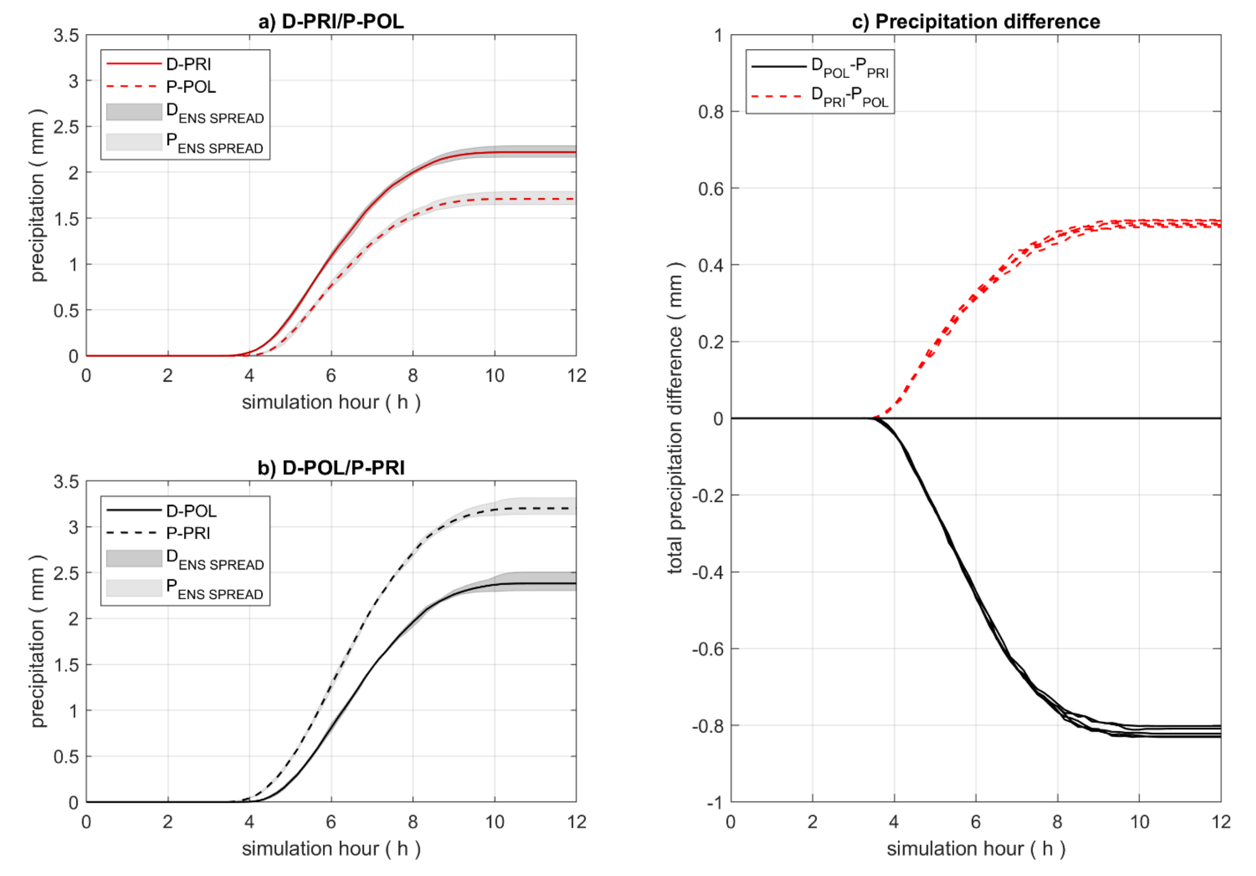
Results II – Daytime convection

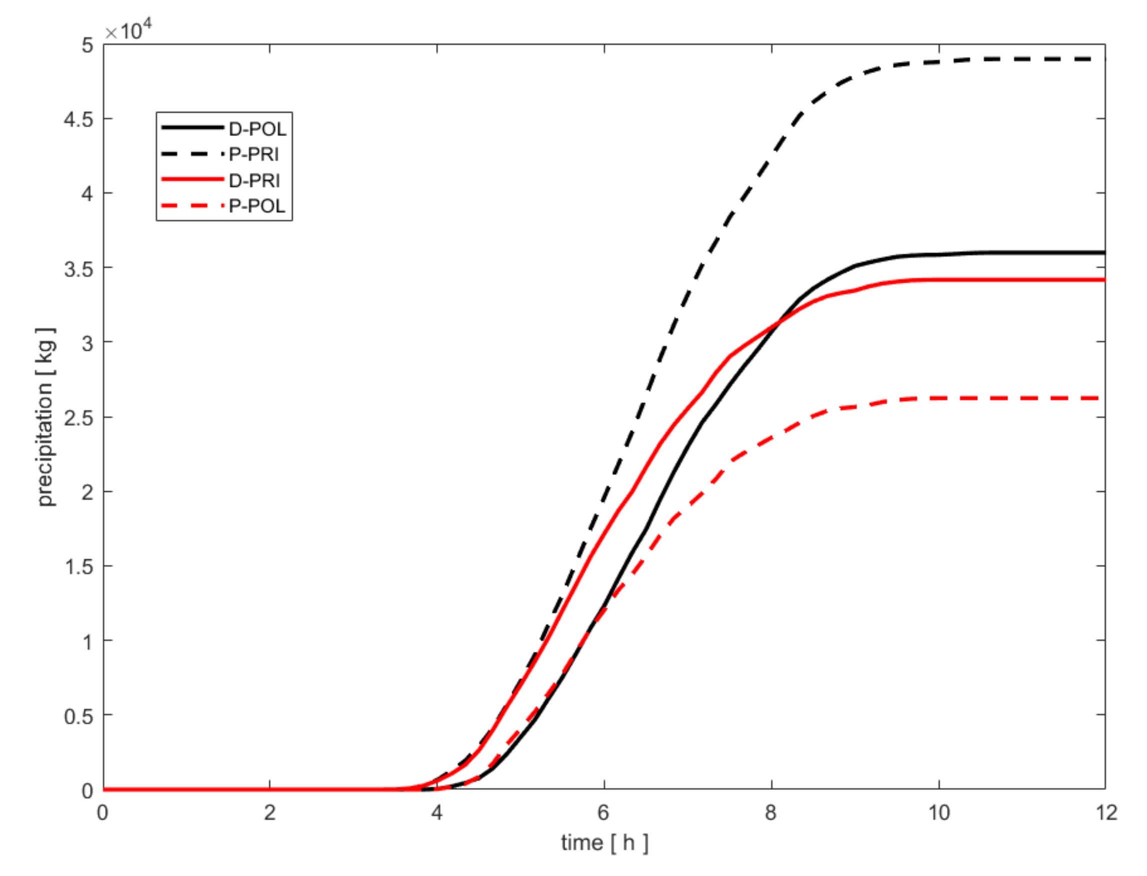
- Daytime convection: shallow – to – deep
- Large-Scale Biosphere–Atmosphere (LBA) field project in Amazonia (Rondonia, Brazil)
- Same microphysics, with different initial CCN concentrations:
  - effect of CCN conc. on surface precipitation and cloud evolution

Horizontal domain size/horizontal grid length	125 gridpoints ×125 gridpoints / 400 m
Vertical domain size/vertical grid	20 km /81 levels with stretched grid
Dynamical time step	3 sec.
CCN concentration	Pristine (PRI; ~ 100 cm^{-3}); Polluted (POL; ~ 1000 cm^{-3})
Simulated time period (integration time)	12 hours
Initial conditions/case study	As in Grabowski et al. (2006)
Microphysics	Two ensembles (5 members) of simulations were completed and analyzed with UPNB microphysics: (1) PRI drives and POL piggybacks; (2) POL drives and PRI piggybacks.
Planetary boundary layer	no boundary-layer (namelist option: 0)
Cumulus parameterization	no cumulus (namelist option: 0)
Radiation physics	no shortwave and longwave radiation (namelist option: 0)
Surface layer physics	Old MM5 scheme (namelist option: 91), prescribed surface temperature and moisture fluxes (as in Grabowski et al., 2006)
Land-surface physics	no surface temperature prediction (namelist option: 0)

Results II – Daytime convection

Source: Sarkadi et al., *JAMES*, 2022.





Results II – Daytime convection

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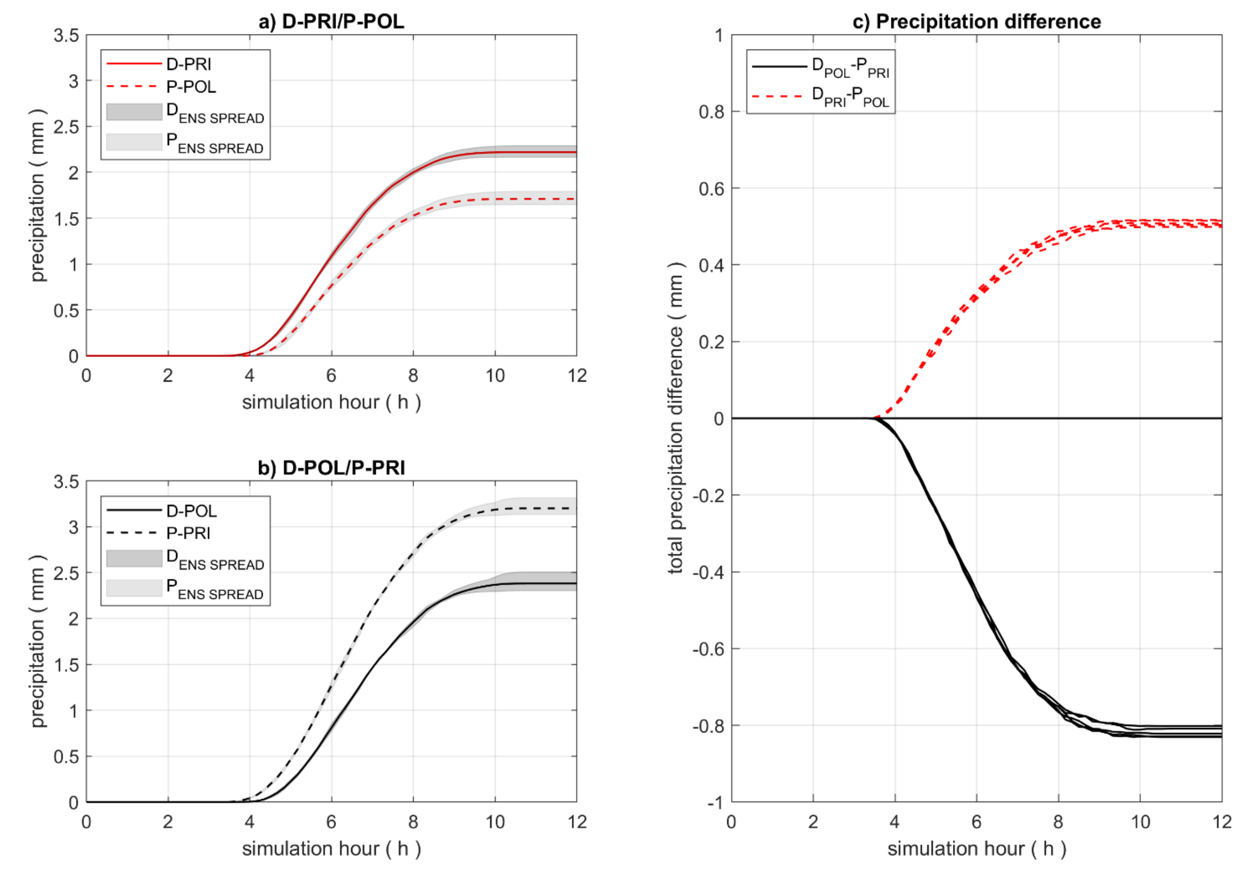
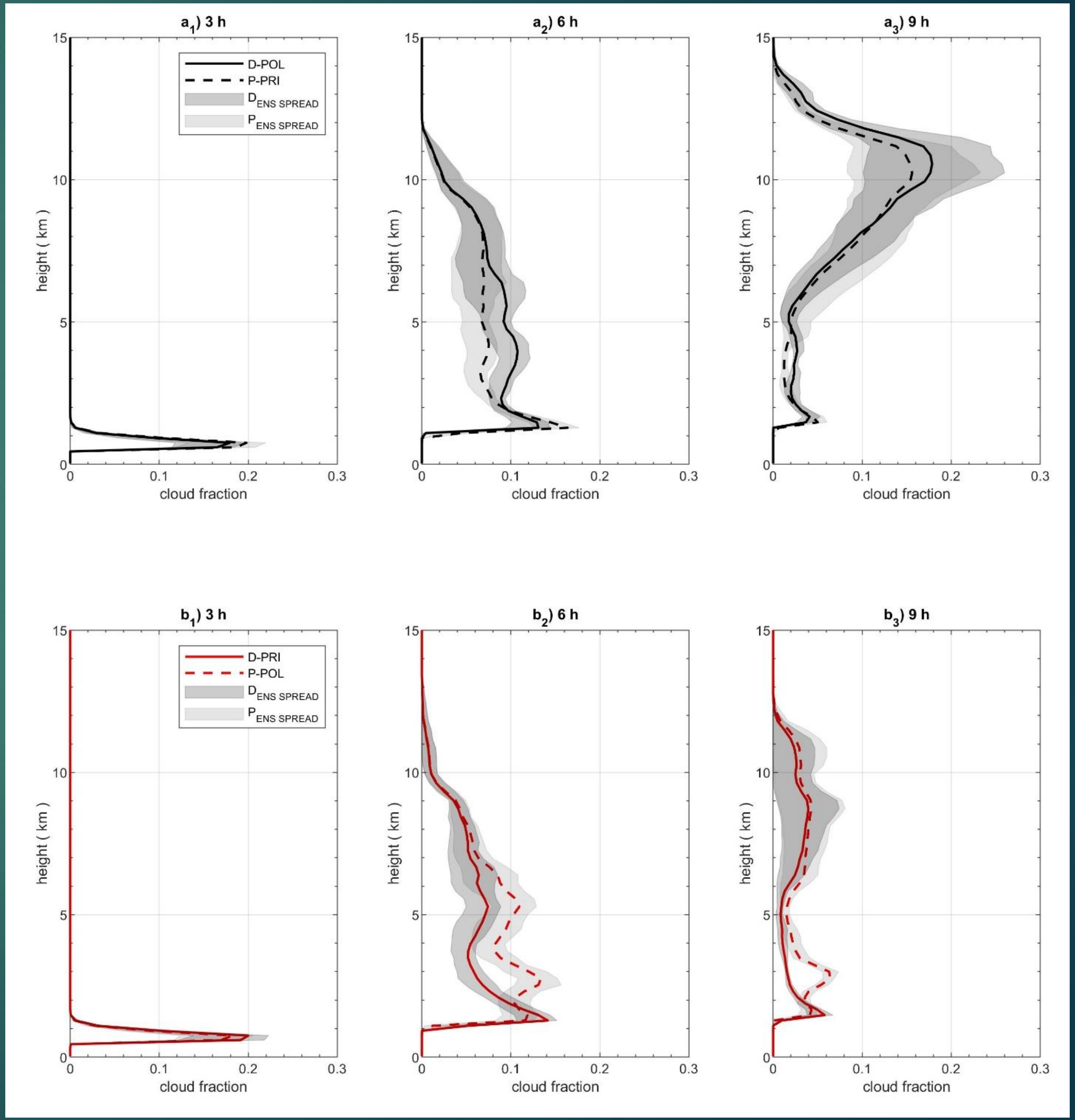
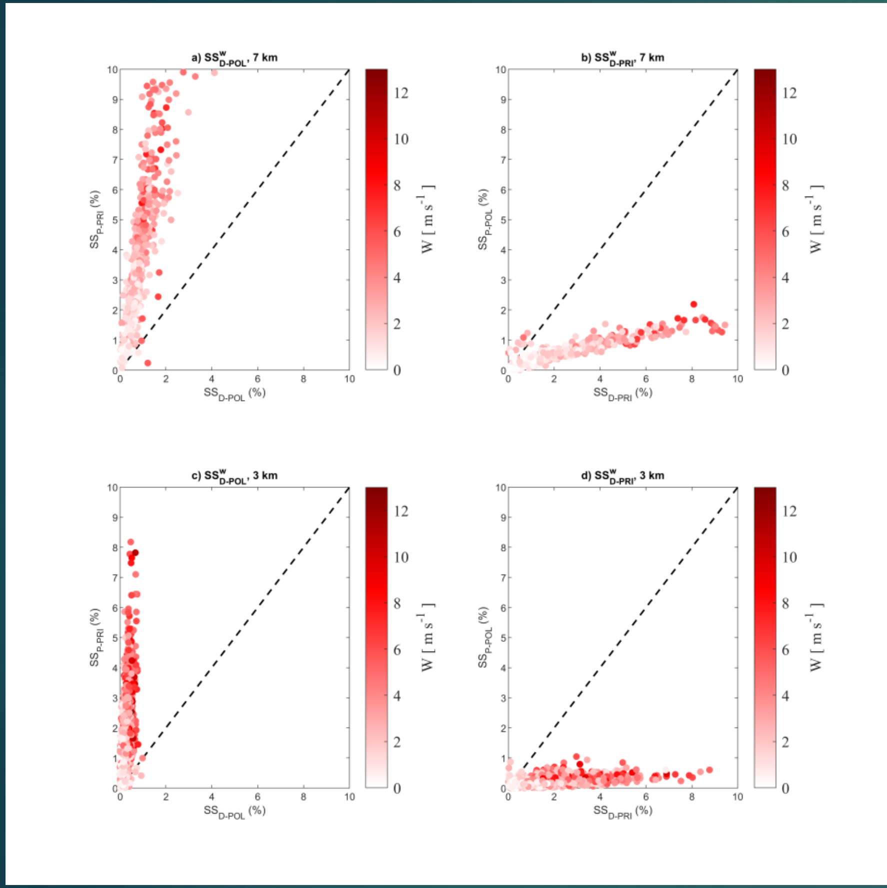
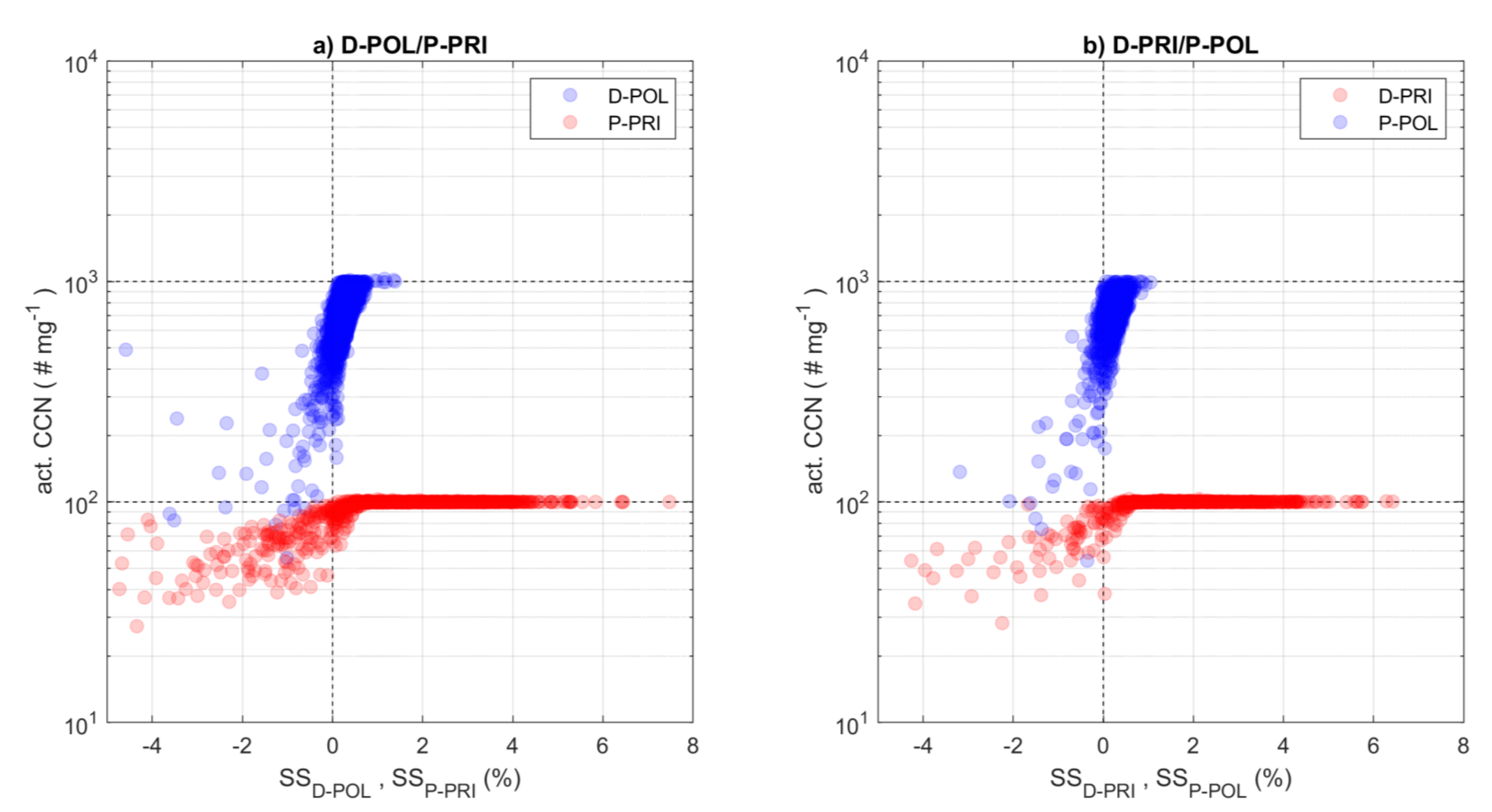




Results II – Daytime convection





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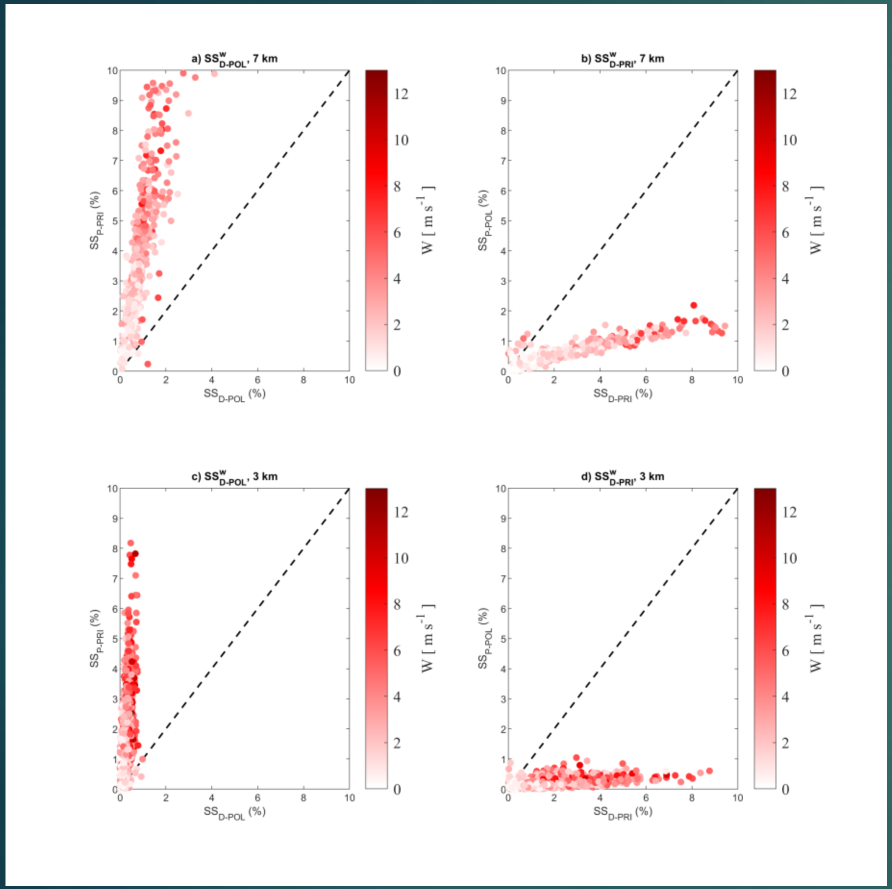
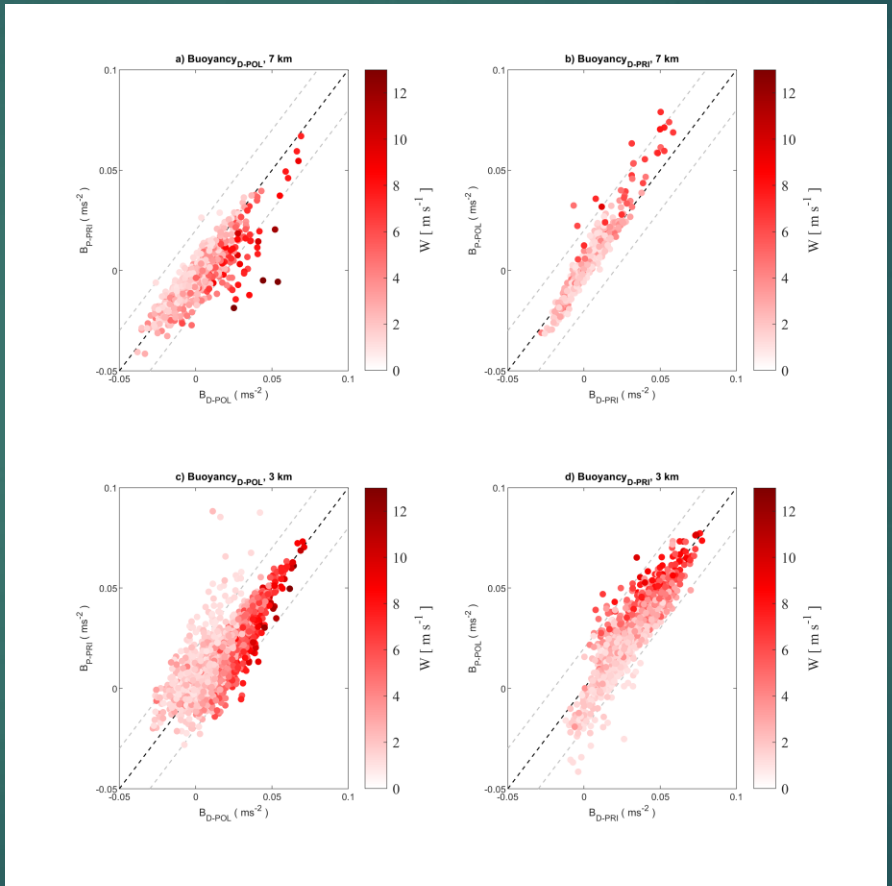
Results II – Daytime convection





Source: Sarkadi et al., *JAMES*, 2022.

Results II – Daytime convection

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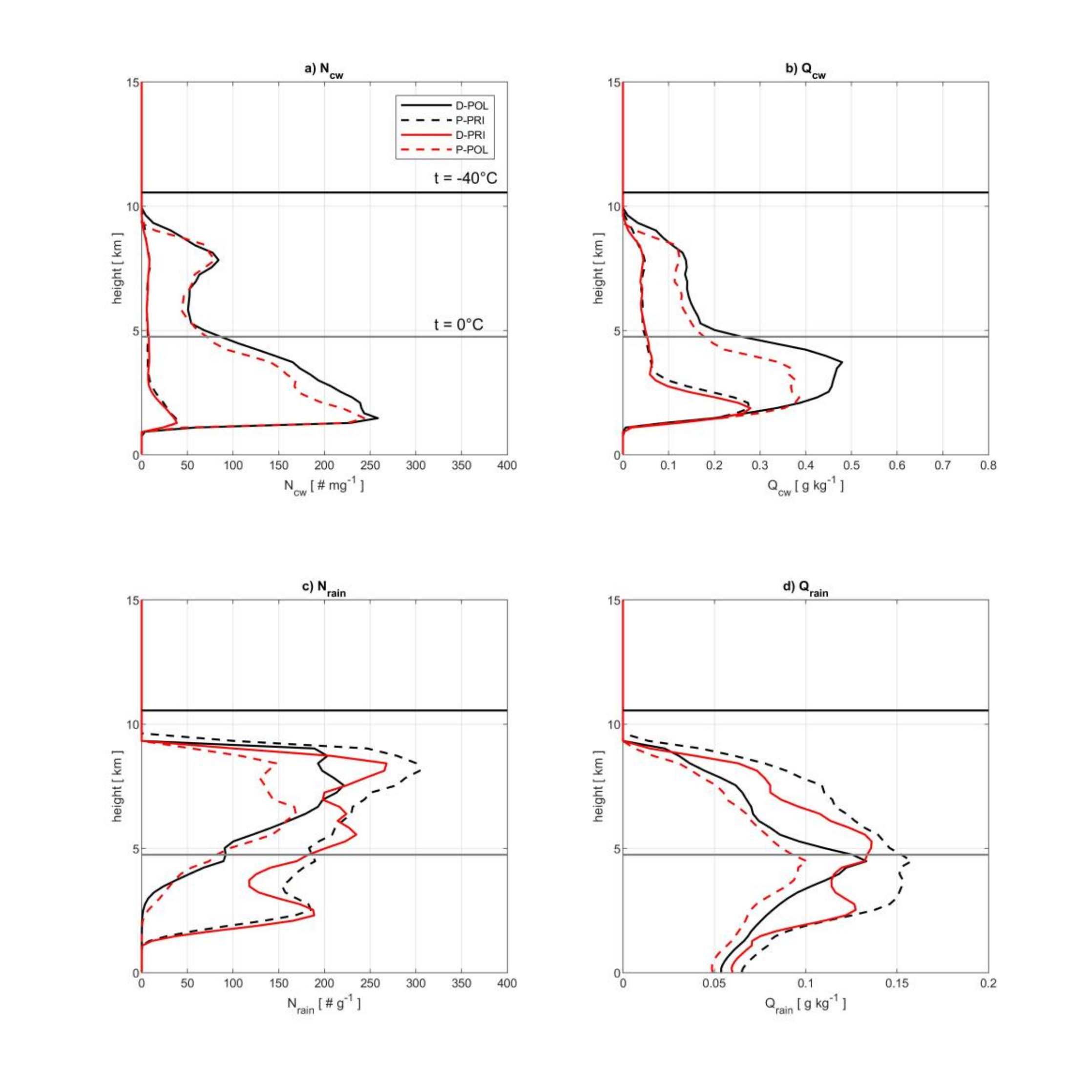

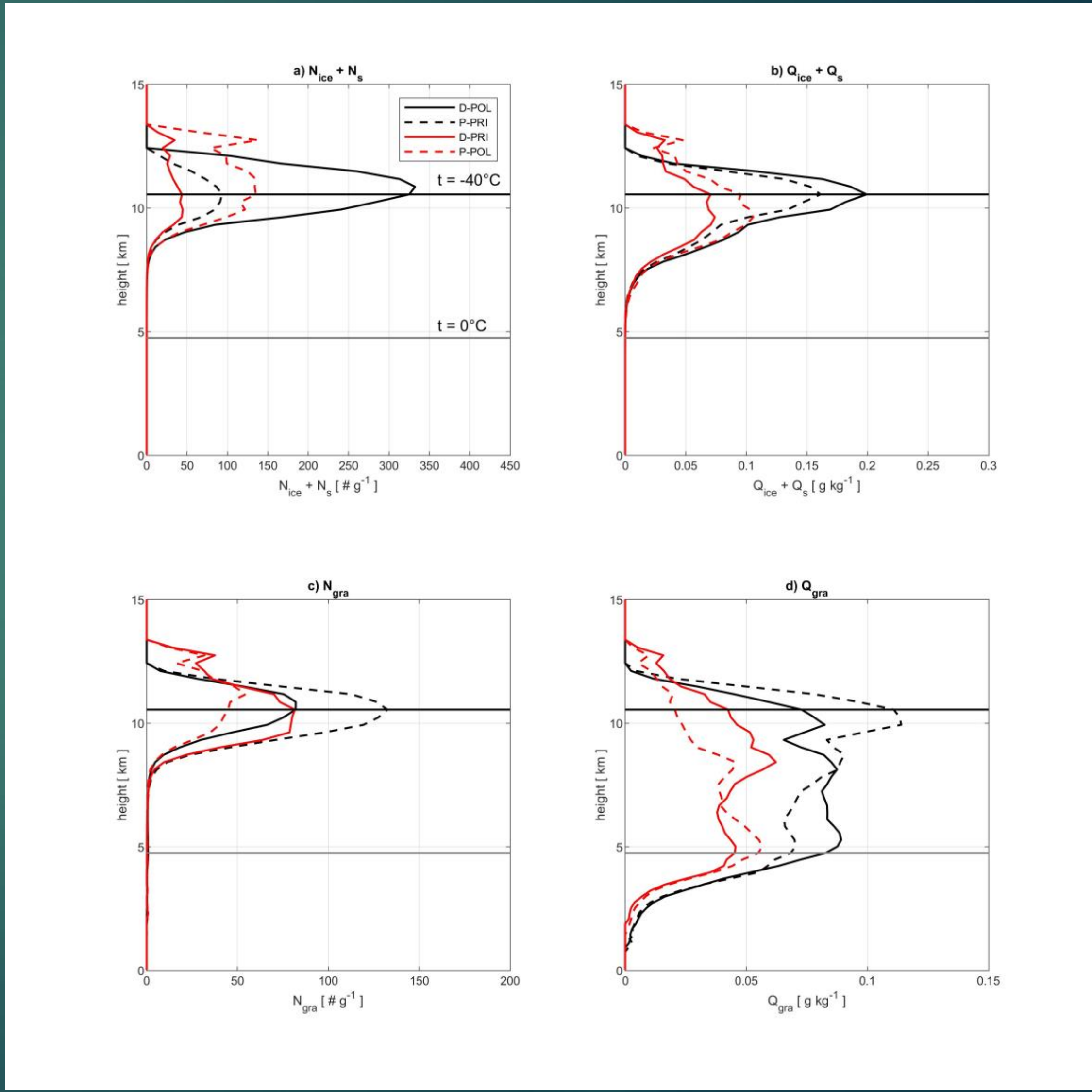

Take home message…

- Understanding the behavior and effects of aerosol particles is essential when modeling atmospheric processes (aerosol – cloud – atmosphere interactions):
  - latent heat release → dynamic effects
  - weather forecast, as well as climatological impacts
- Presented results were accepted (and published online) in Journal of Advances in Modeling Earth Systems – Sarkadi et al., JAMES (2022): *Microphysical Piggybacking in the Weather Research and Forecasting Model*, **doi: 10.1029/2021MS002890**
- Real case piggybacking (including radiation, pbl, etc. processes) will be present at

  103rd AMS, *15th Symposium on Aerosol-Cloud-Climate Interactions*

  09. 01. 2023. Session 4b.3: „*Application of the Piggybacking Methodology to Real Convective Cases*"

"*I agree it works in practice. But how can be certain that it will work in theory?*"

From plaque of Dévényi Dezső Award

Thank you for your attention!