Simulation of convective development with bin scheme: LBA case study to investigate the interaction between dynamics and microphysics

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Outline

- Bin microphysics (UPNB)
- Piggybacking methodology (briefly)
- LBA case setup
- Results
- Conclusions

Bin microphysics scheme (UPNB)

- Four different hydrometeor types
- Each type of the different particles were divided into 36 bins:

	Ice crystal	Water drop		Snowflake	Graupel particle
		Cloud water	Raindrop		
Min. size (m)	$2.06 \cdot 10^{-6}$	$1.56 \cdot 10^{-6}$	$2.50 \cdot 10^{-5}$	$2.06 \cdot 10^{-6}$	$3.37 \cdot 10^{-6}$
Max. size (m)	0.38	$2.50 \cdot 10^{-5}$	$1.02 \cdot 10^{-2}$	$7.85 \cdot 10^{-2}$	$5.08 \cdot 10^{-3}$

- Calculated variables: ~400, mixing ratio, number concentration, melted water on snow and graupel (mixing ratio), rimed water on snow (number and mixing ratio)

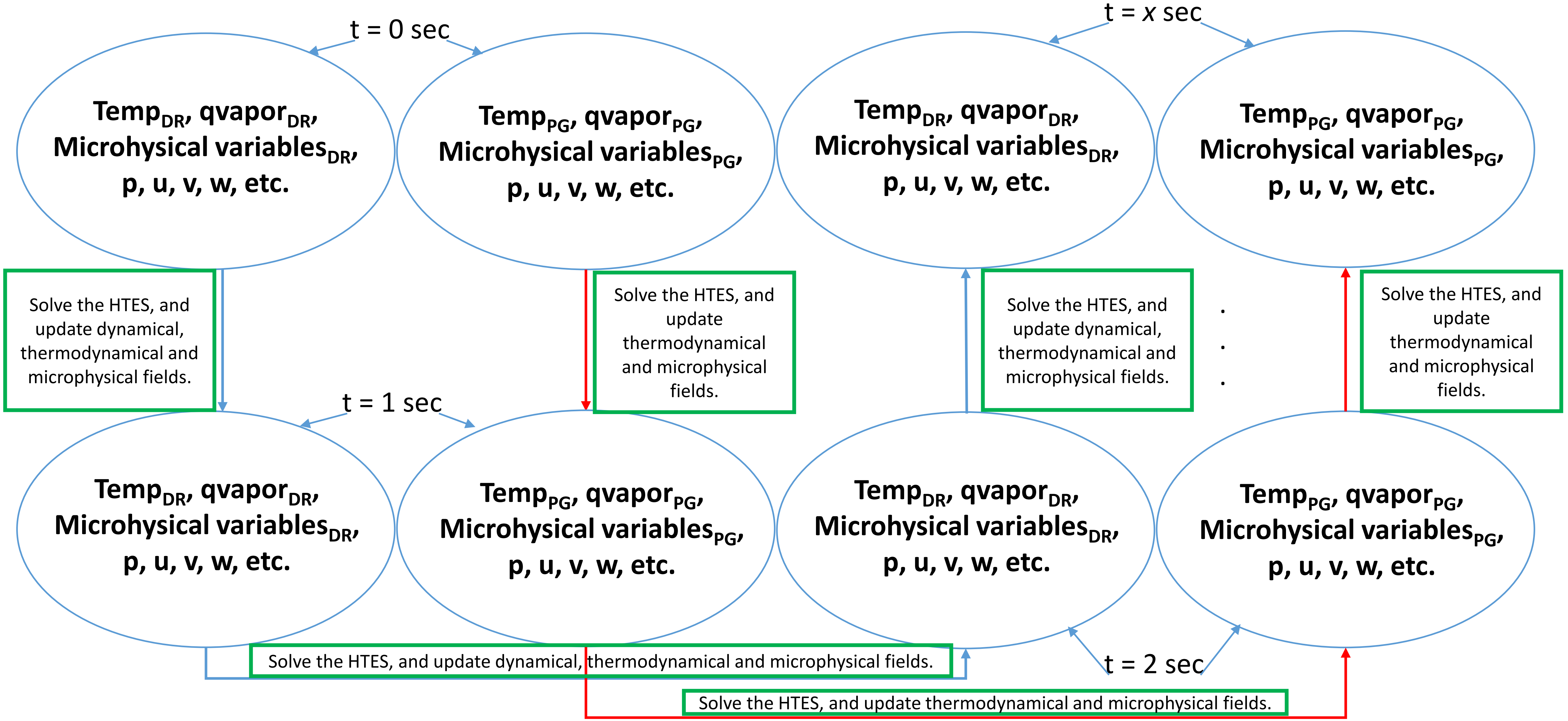
  →melting fraction calculated (0.8)

  →riming fraction calculated (0.5)

Bin microphysics scheme (UPNB)

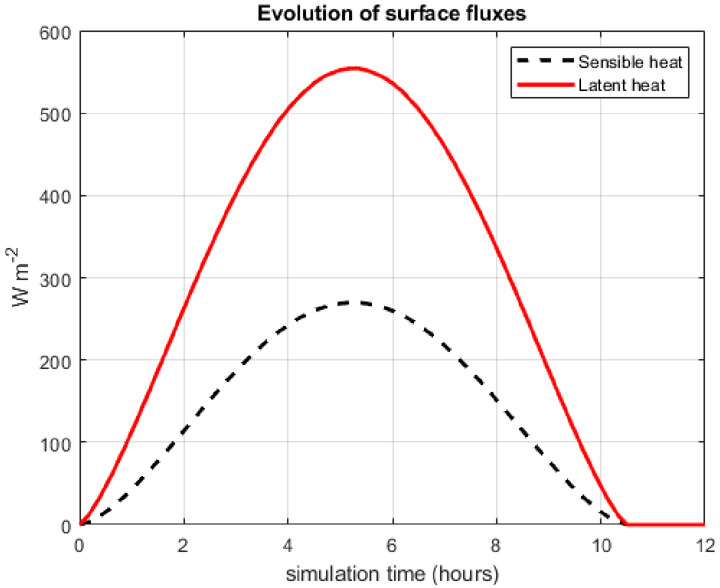
- The following microphysical processes were taken into consideration:
  1) Diffusional growth of different type of hydrometeors;
  2) Melting of solid hydrometeors;
  3) Freezing of supercooled water drops;
  4) Collision and coalescence of water drops;
  5) Self-coagulation of pristine ice crystals results in snowflakes;
  6) Self-coagulation of snowflakes increases the mass of snowflakes;
  7) Riming;
  8) Breakup of water drops;
  9) Formation of pristine ice crystals by deposition nucleation or condensational freezing;
  10) Sedimentation;
  11) Collision-induced shedding

Piggybacking methodology



LBA case setup

- WRF (**W**eather **R**esearch and **F**orecasting) v3.7.1
- Idealized LES simulation
- Prescribed random perturbations on:
    - moisture field
    - temperature field
    - surface heat flux
    - surface moisture flux
- Wind relaxation (60 minutes) (see: http://box.mmm.ucar.edu/gcss-wg4/gcss/case4.html)



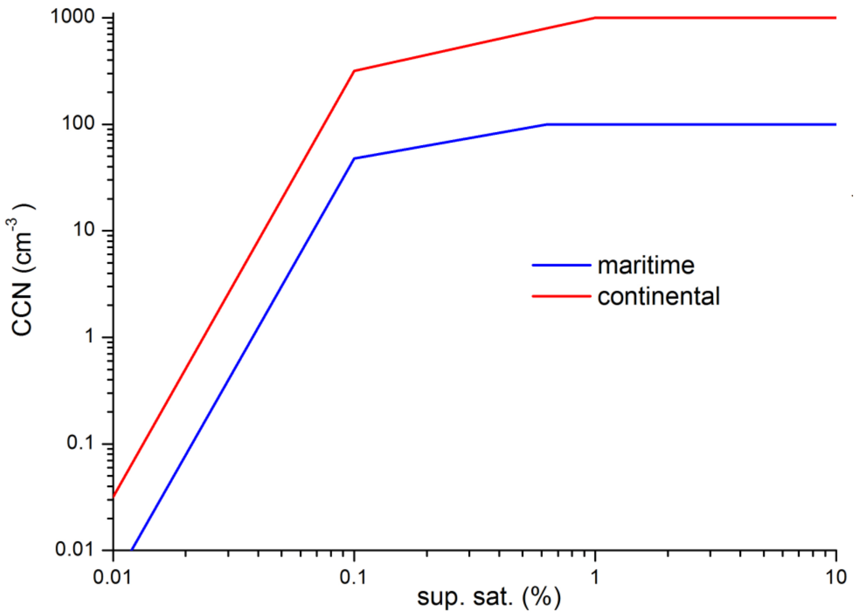
All type was run with D-POL/P-PRI and D-PRI/P-POL

	CTRL	**Temperure (T)**	**Moisture (Q)**	**Member$_1$ ($E_{0.25}$)**	**Member$_2$ ($E_{0.5}$)**
Domain size (horizontal)	126×126	126×126	126×126	126×126	126×126
Horizontal resolution	400 m	400 m	400 m	400 m	400 m
Domain size (vertical)	81 (stretched grid)	81 (stretched grid)	81 (stretched grid)	81 (stretched grid)	81 (stretched grid)
Vertical resolution	<1 km ~ 100m, > ~ 200 m	<1 km ~ 100m, > ~ 200 m	<1 km ~ 100m, > ~ 200 m	<1 km ~ 100m, > ~ 200 m	<1 km ~ 100m, > ~ 200 m
Simulation time	12 h	12 h	12 h	12 h	12 h
Time step	3 sec.	3 sec.	3 sec.	3 sec.	3 sec.
Microphysics	Bin with modified surface heat and moisture fluxes	Bin with modified surface heat and moisture fluxes	Bin with modified surface heat and moisture fluxes	Bin with modified surface heat and moisture fluxes	Bin with modified surface heat and moisture fluxes
Order of perturbation	Initial temperture: **± 0.1 K** random perturbation Initial moisture: **± 0.1 g/kg** random pert. In every ***15 min***utes: temperature and moisture: **± 0.1 K** and **± 0.1 g/kg** random pert. Heat and moisture flux: **± 10%** random pert.	Initial temperture: **± 1 K** random perturbation Initial moisture: **± 0.1 g/kg** random pert. In every ***15 min***utes: temperature and moisture: **± 0.1 K** and **± 0.1 g/kg** random pert. Heat and moisture flux: **± 10%** random pert.	Initial temperture: **± 0.1 K** random perturbation Initial moisture: **± 1 g/kg** random pert. In every ***15 min***utes: temperature and moisture: **± 0.1 K** and **± 0.1 g/kg** random pert. Heat and moisture flux: **± 10%** random pert.	Initial temperture: **± 0.25 K** random perturbation Initial moisture: **± 0.25 g/kg** random pert. In every ***15 min***utes: temperature and moisture: **± 0.1 K** and **± 0.1 g/kg** random pert. Heat and moisture flux: **± 10%** random pert.	Initial temperture: **± 0.5 K** random perturbation Initial moisture: **± 0.5 g/kg** random pert. In every ***15 min***utes: temperature and moisture: **± 0.1 K** and **± 0.1 g/kg** random pert. Heat and moisture flux: **± 10%** random pert.

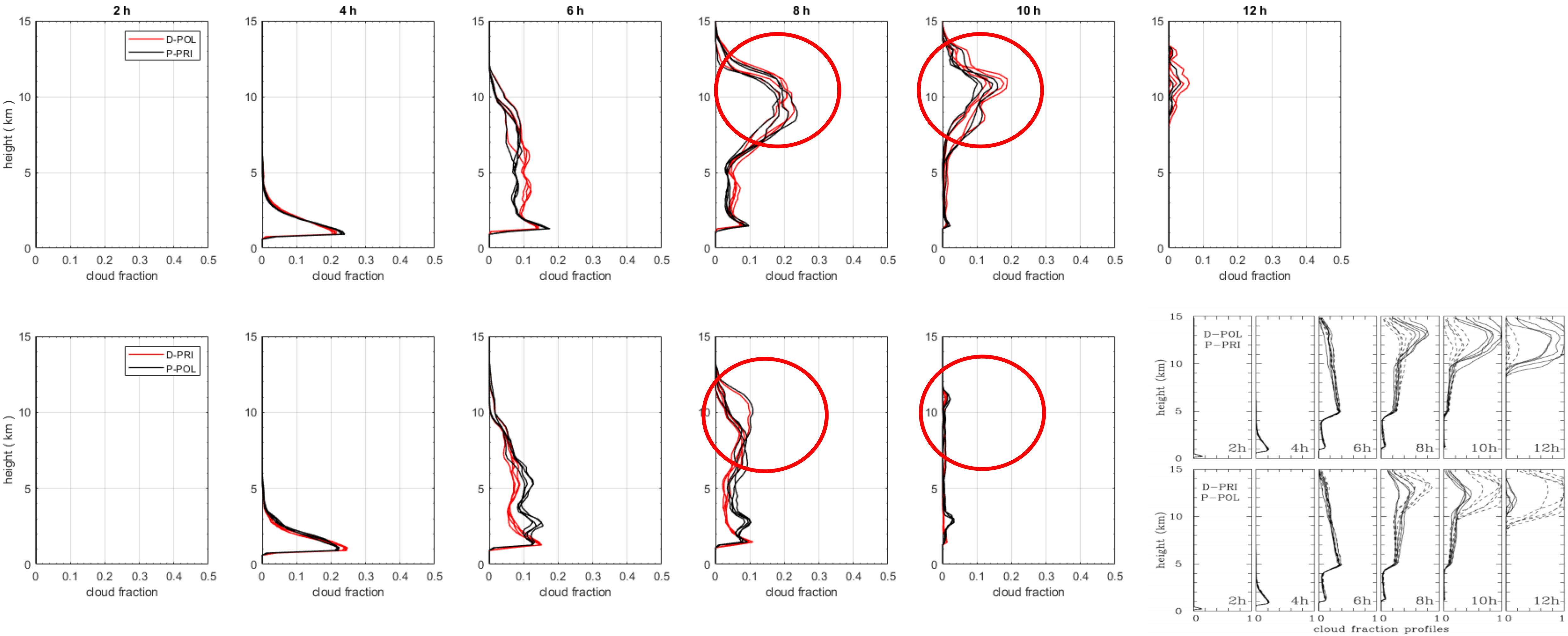
Bin microphysics scheme (UPNB) – CCN

- CCN concentrations for POL and PRI cases:

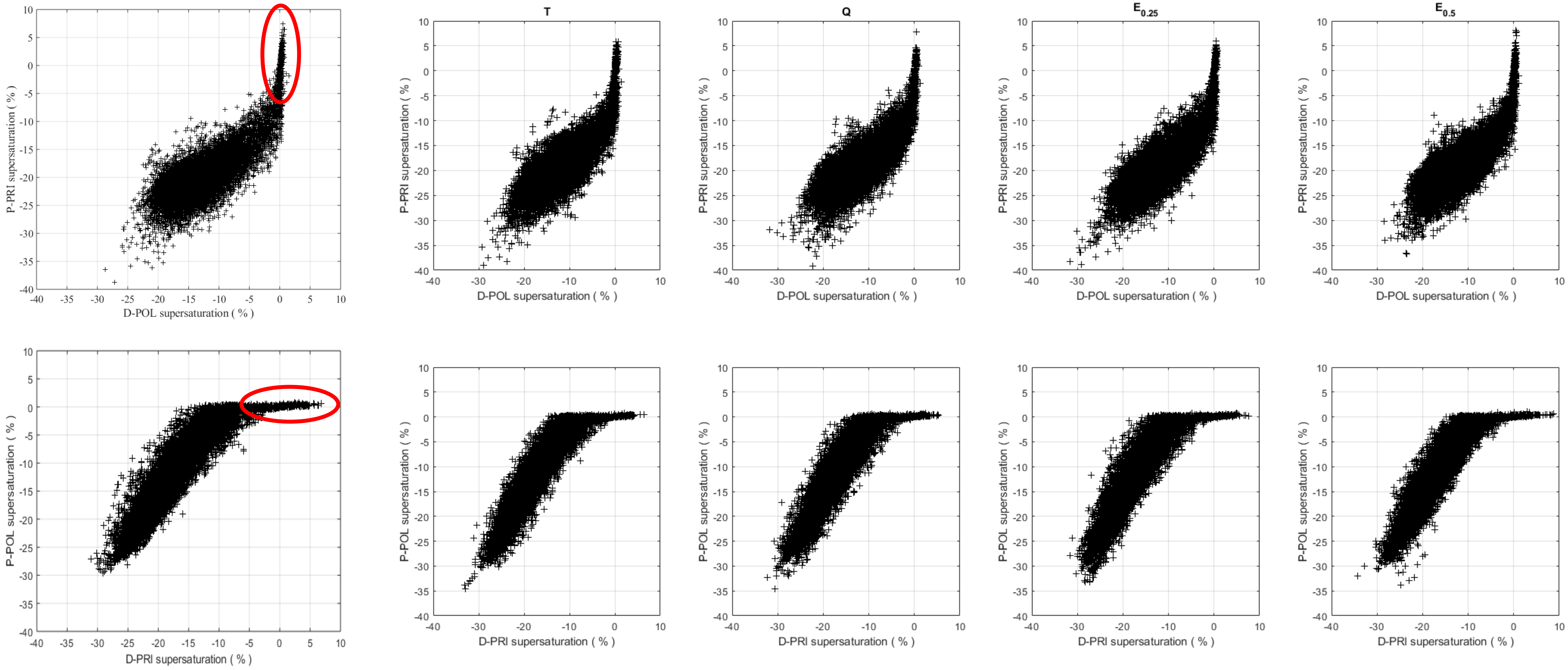
POL (continental) ~ 1000 cc	**Supersaturation**		**PRI (maritime) ~ 100 cc**
NCCN = 316.e4*SS$^{4.0}$*1.e6	SS < 0.1	SS < 0.1	NCCN = 4.78e5*SS$^{0.4}$*1.e6
NCCN = SQRT(SS)*1.e9	SS >= 0.1 & SS < 1.0	SS >= 0.1 & SS < 0.63	NCCN = 120.0*SS$^{0.4}$*1.e6
NCCN = 1.e9	SS >= 1.0	SS >= 0.63	NCCN = 1.e8



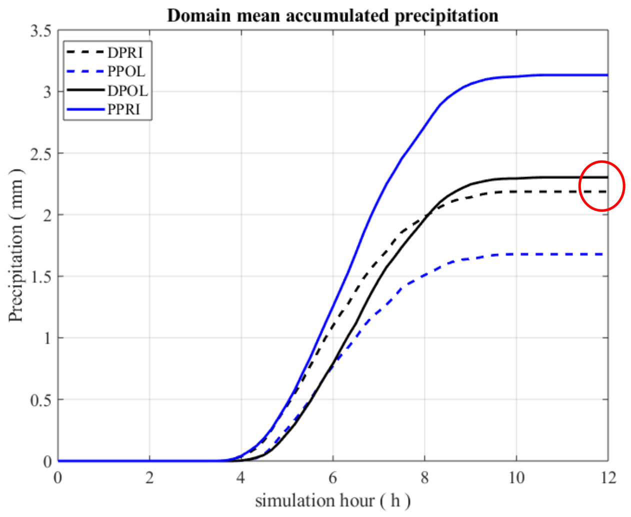
Cloud fraction



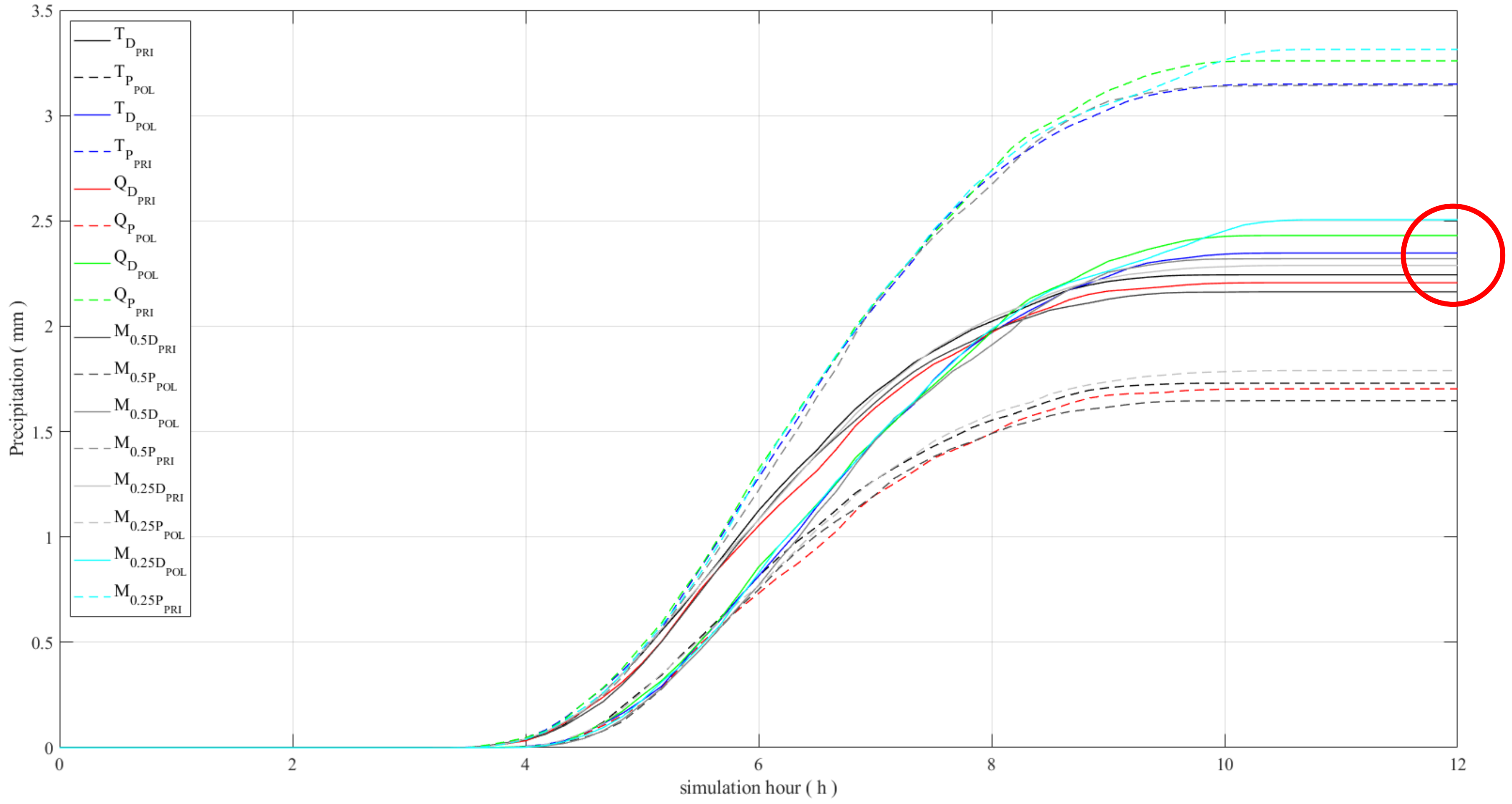
Supersaturation



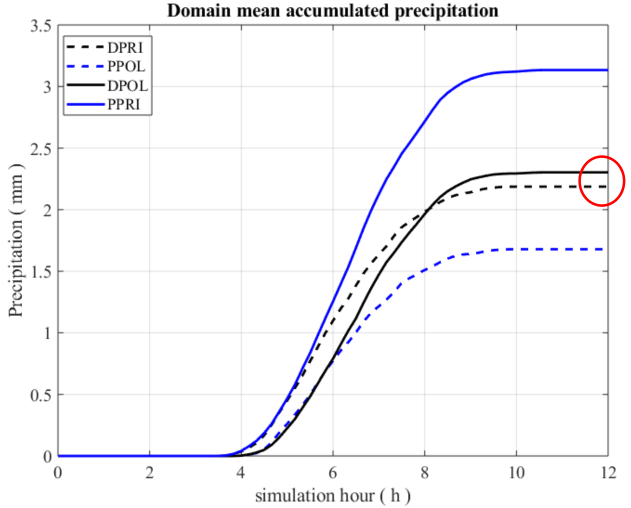
Precipitation (domain mean)

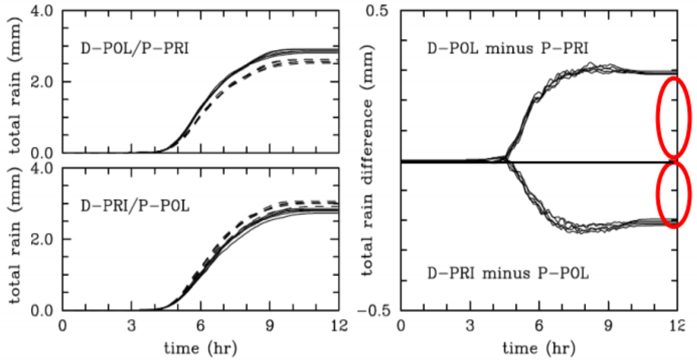


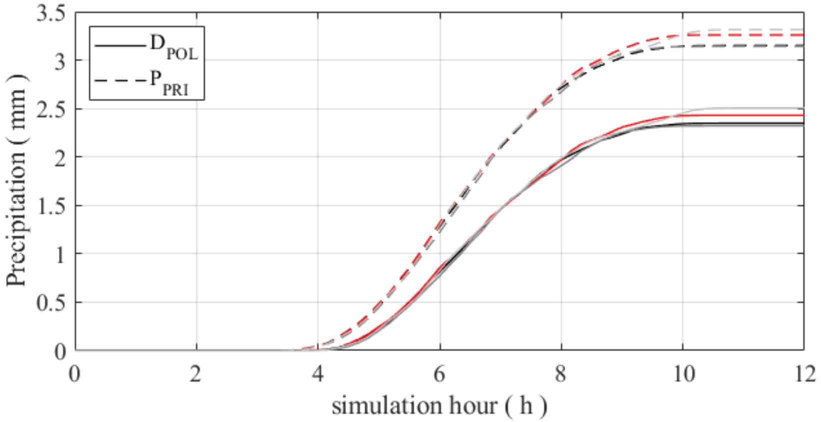
$D_{POL} - D_{PRI} < 0.5$ mm

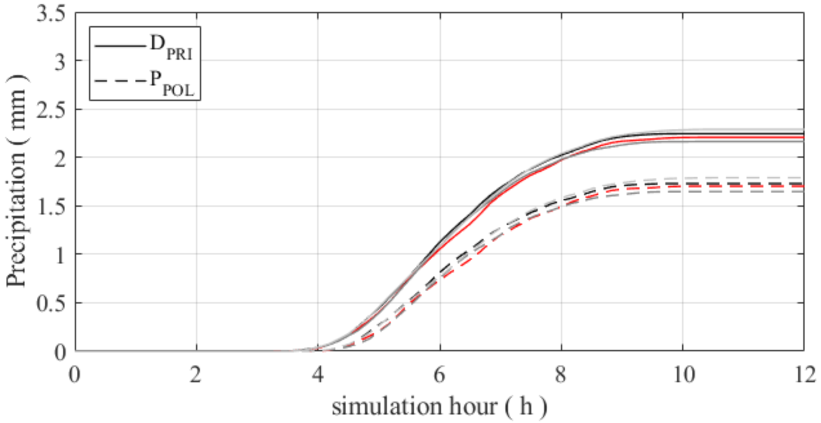


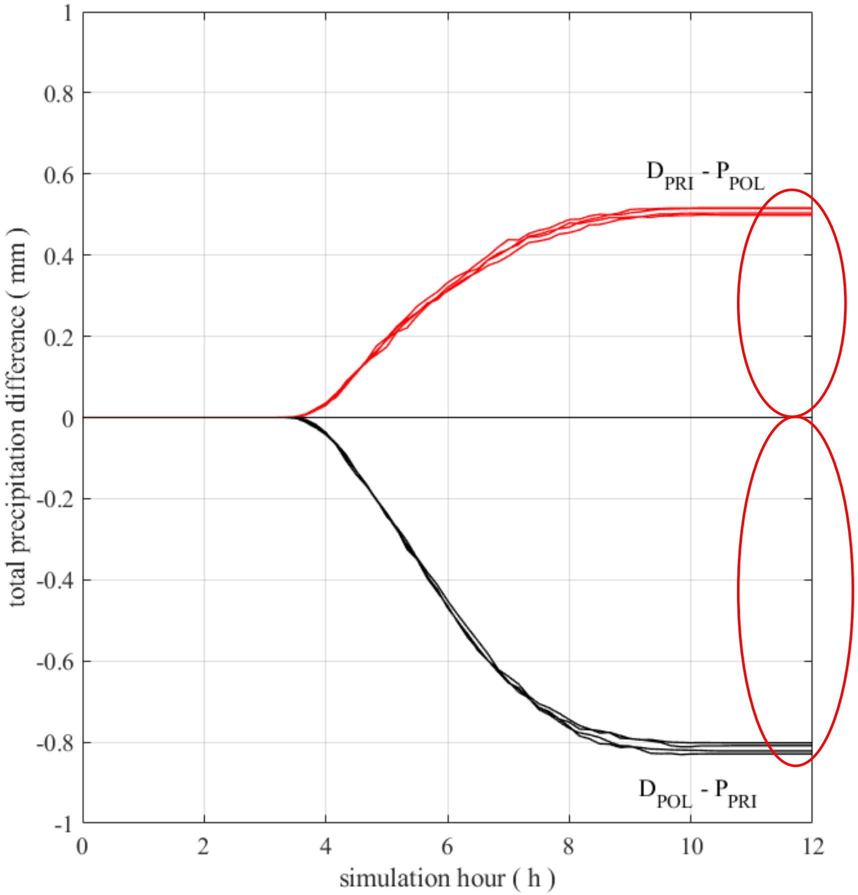
Precipitation (domain mean)





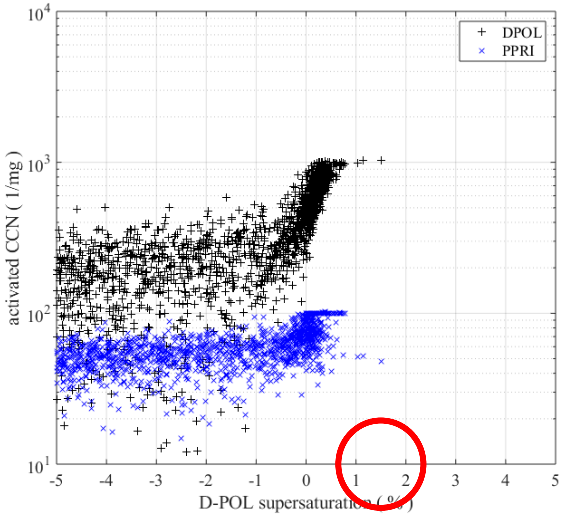


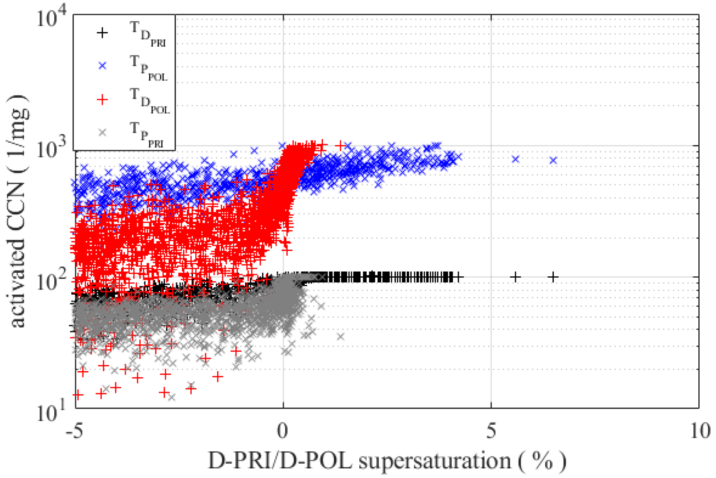


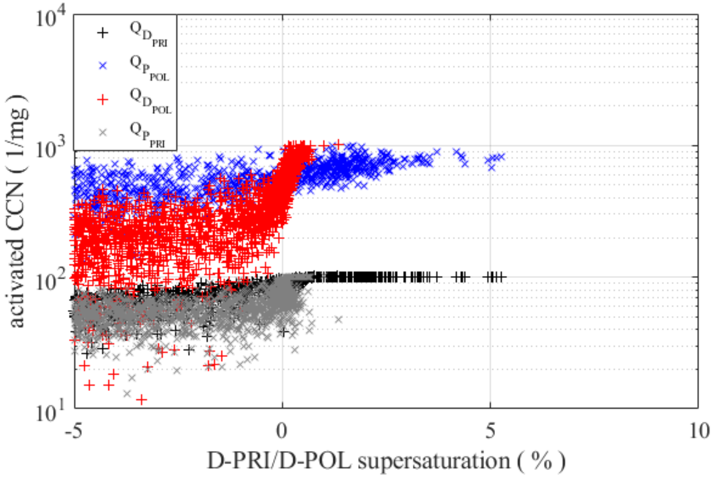


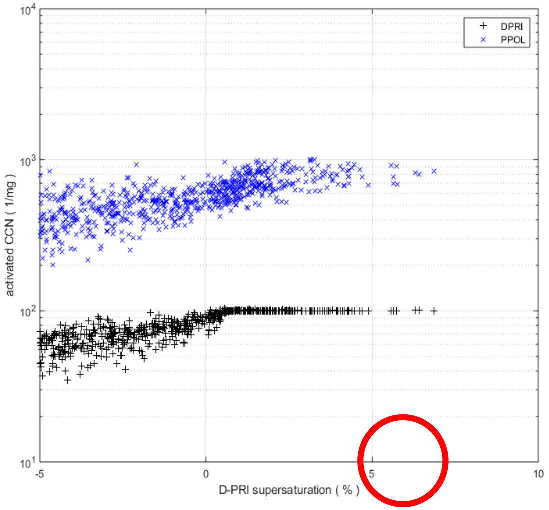
D_{POL}-P_{PRI} > D_{PRI}-P_{POL}

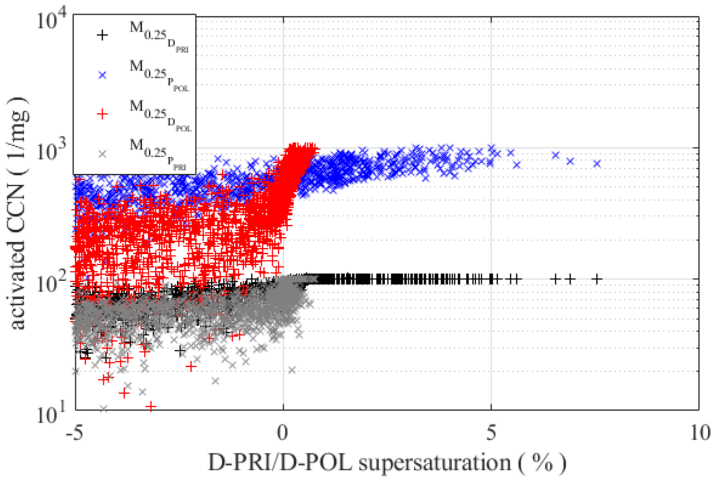
CCN activation vs. supersaturation

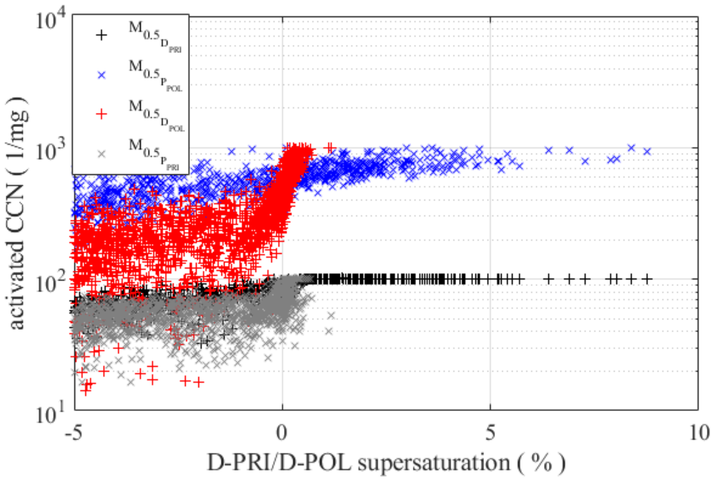




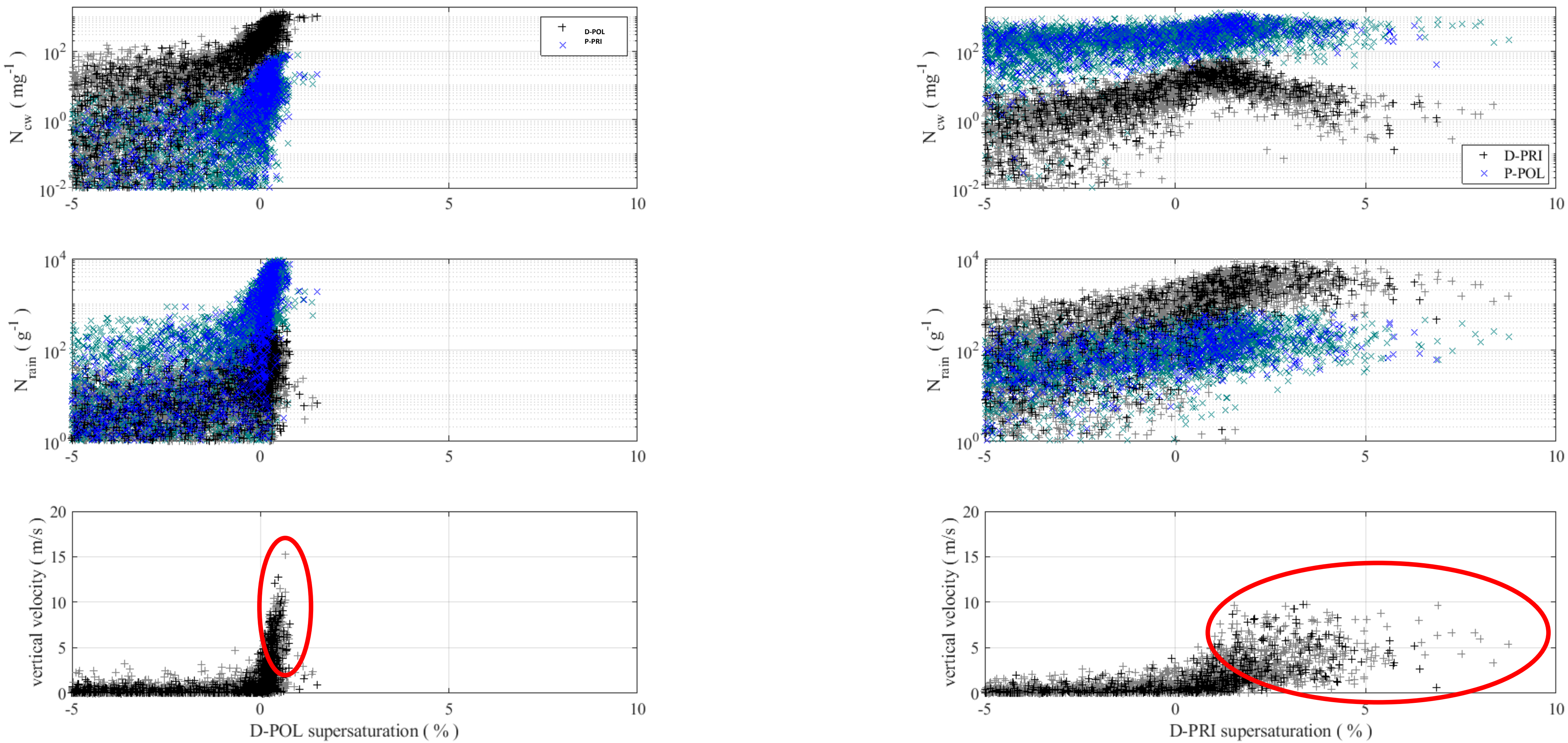




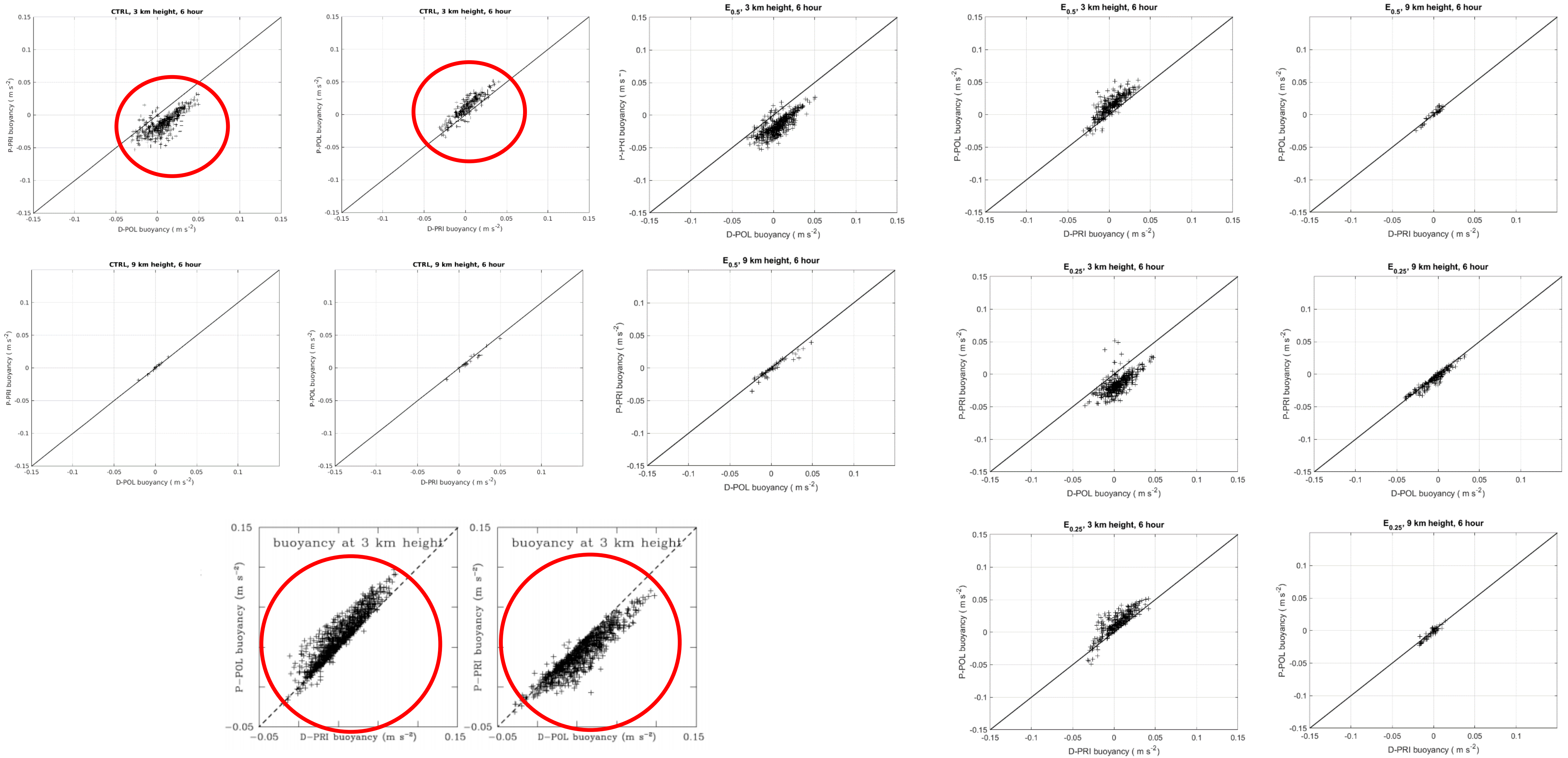




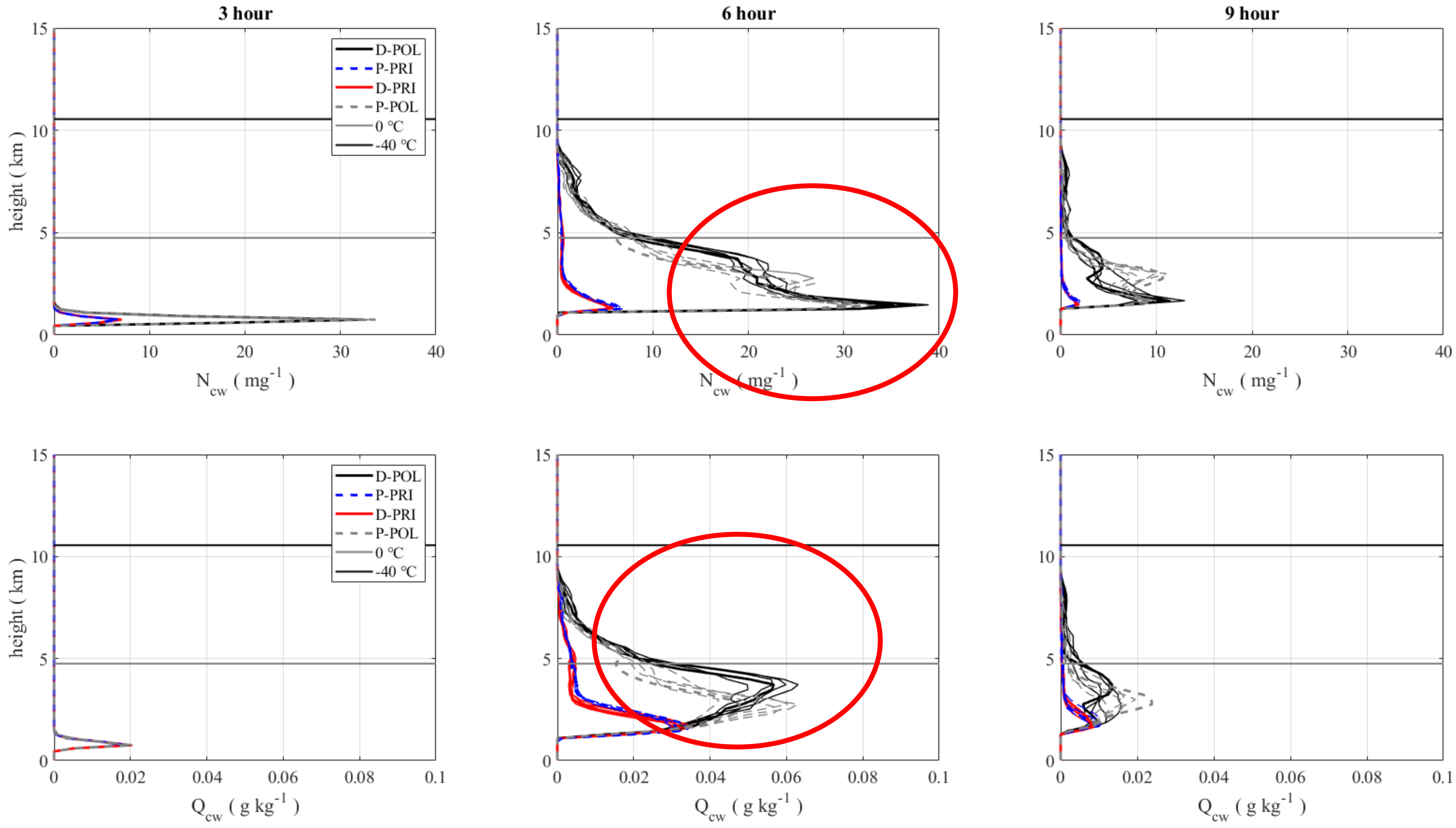
Cloud water/rain and vertical velocity



Bouyancy

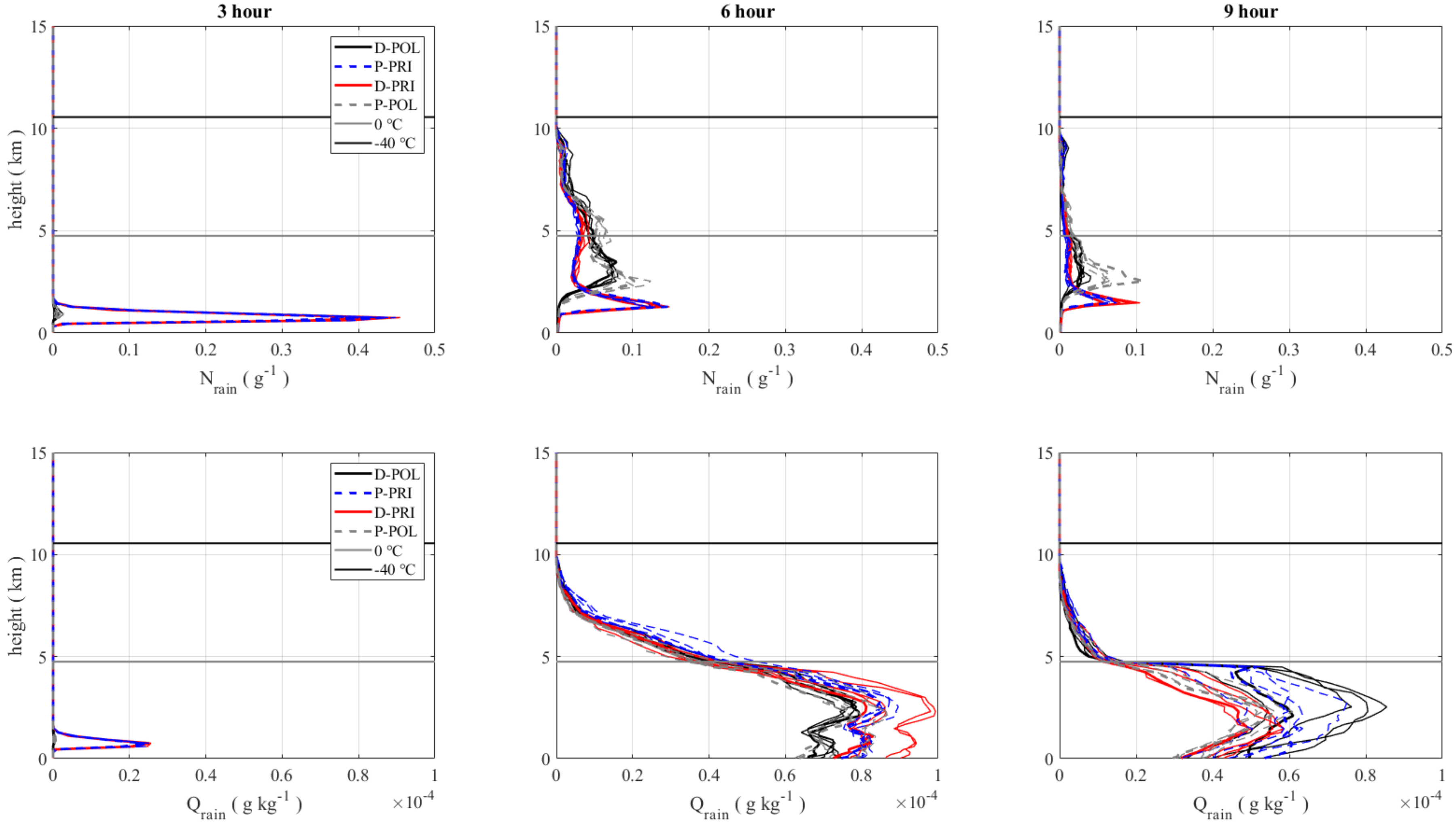

CTRL, 3 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
CTRL, 3 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
$E_{0.5}$, 3 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
$E_{0.5}$, 3 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-PRI buoyancy (m s^{-2})
$E_{0.5}$, 9 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-PRI buoyancy (m s^{-2})
CTRL, 9 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
CTRL, 9 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-PRI buoyancy (m s^{-2})
$E_{0.5}$, 9 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
$E_{0.25}$, 3 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
$E_{0.25}$, 9 km height, 6 hour
P-PRI buoyancy (m s^{-2})
D-POL buoyancy (m s^{-2})
buoyancy at 3 km height
P−POL buoyancy (m s^{-2})
D−PRI buoyancy (m s^{-2})
buoyancy at 3 km height
P−PRI buoyancy (m s^{-2})
D−POL buoyancy (m s^{-2})
$E_{0.25}$, 3 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-PRI buoyancy (m s^{-2})
$E_{0.25}$, 9 km height, 6 hour
P-POL buoyancy (m s^{-2})
D-PRI buoyancy (m s^{-2})

Microphysics – Cloud water

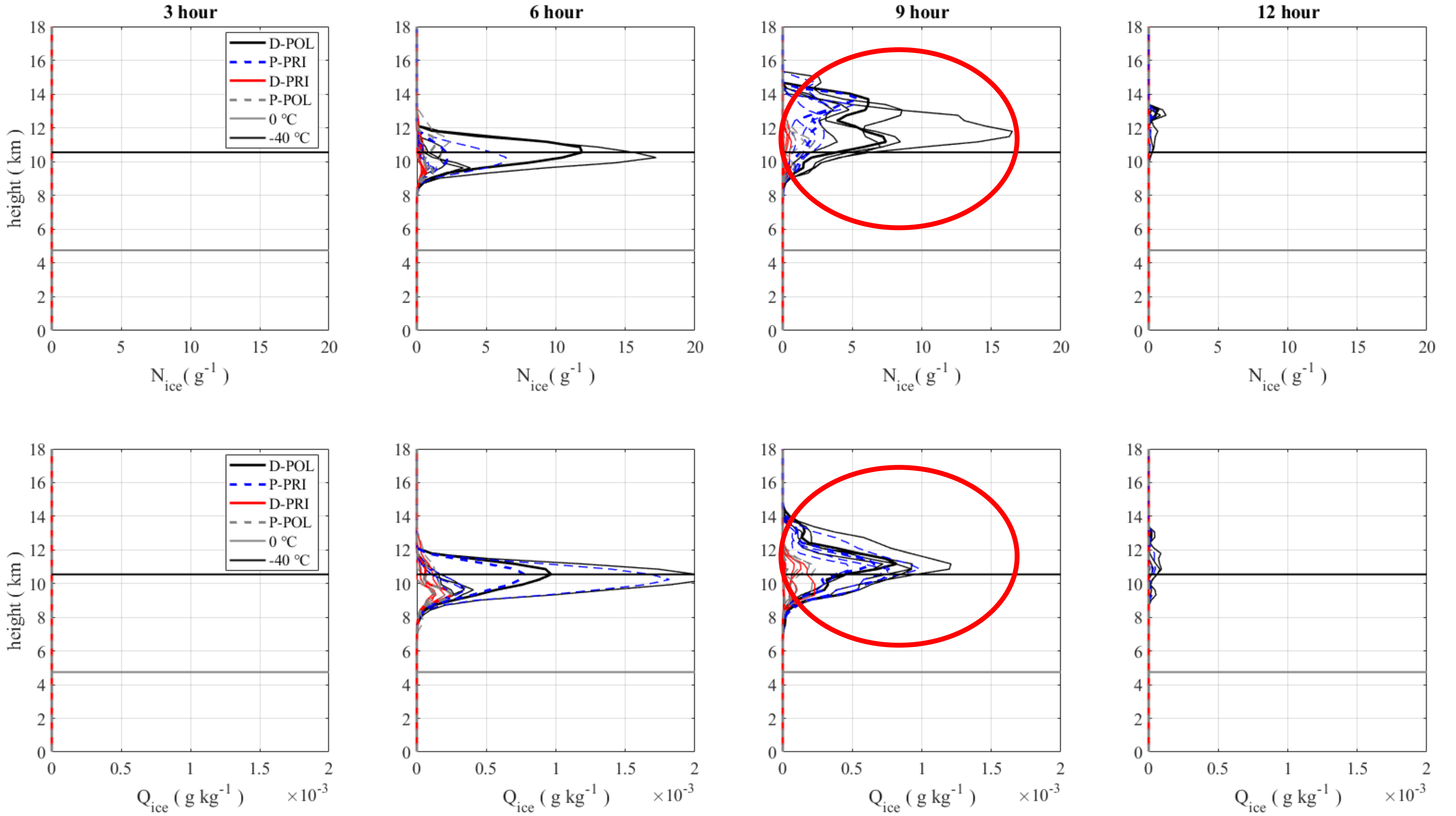


POL case: more cloud water

Microphysics – Rain

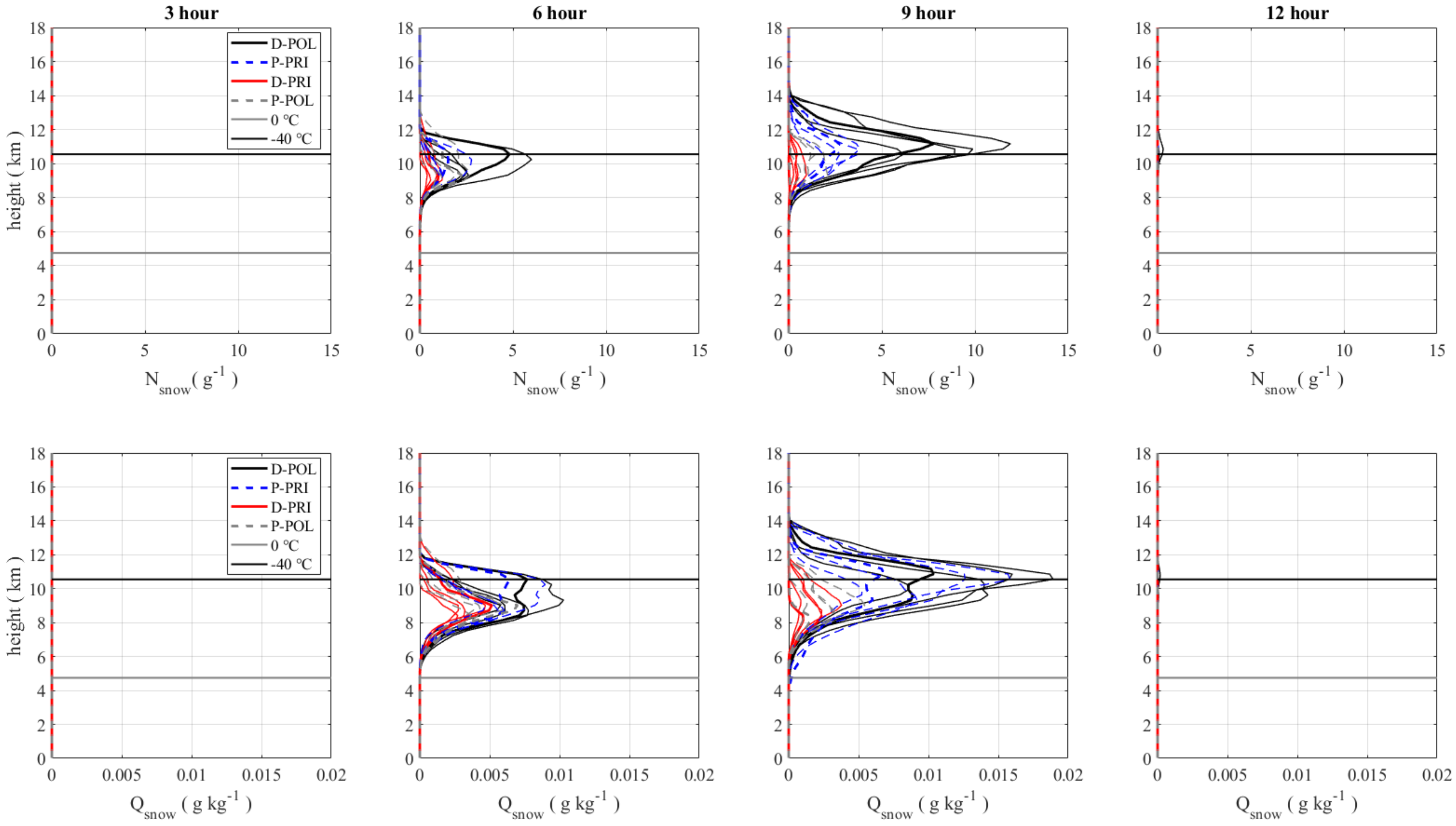


Microphysics – Pristine ice

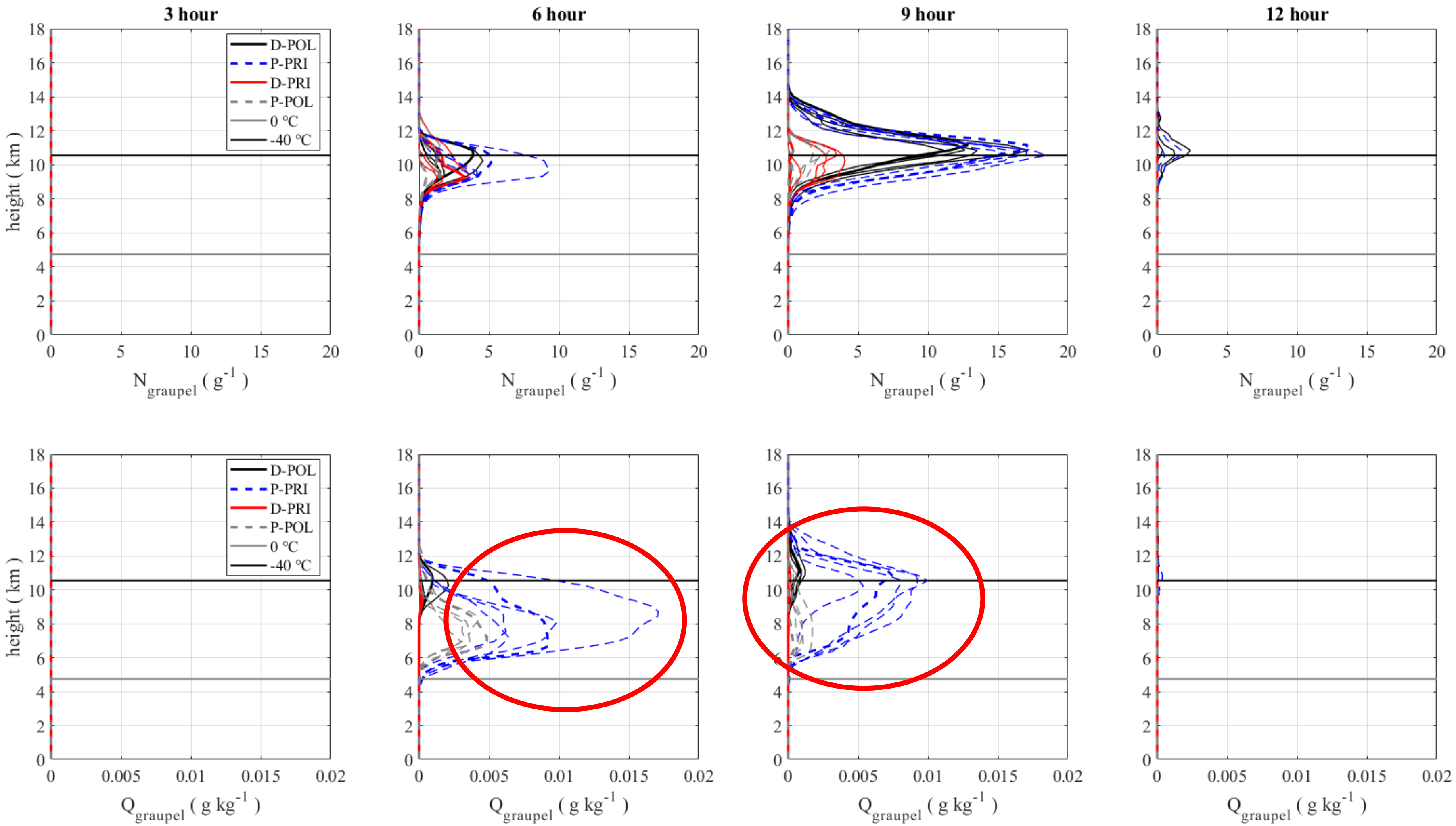


POL/PRI in ice: affect the driver (dynamics); not the microphysics

Microphysics – Snow



Microphysics – Graupel



Same number, higher mass → larger graupel particles (P set)

Conclusions

- Similar difference in precipitation like in GM16*, but opposite sign.
- No significant effect on microphysicsal, dynamical fields of the perturbations of the initial field.
- Pristine supersaturation > polluted supersaturation.
- CCN concentration impact cloud water, dynamics (driver) affects ice microphysics
- **Further plans:**
  - investigation of the size distributions
  - different model (differences caused due to microphysics or due to different representation of dynamics?)
  - updated version of bin scheme (different description of CCN activation and cloud water formation)

GM16: Grabowski-Morrison, JAS, 2016

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Thank you for your attention!

Questions?