Untangling microphysical impacts on deep convection applying a novel modeling methodology

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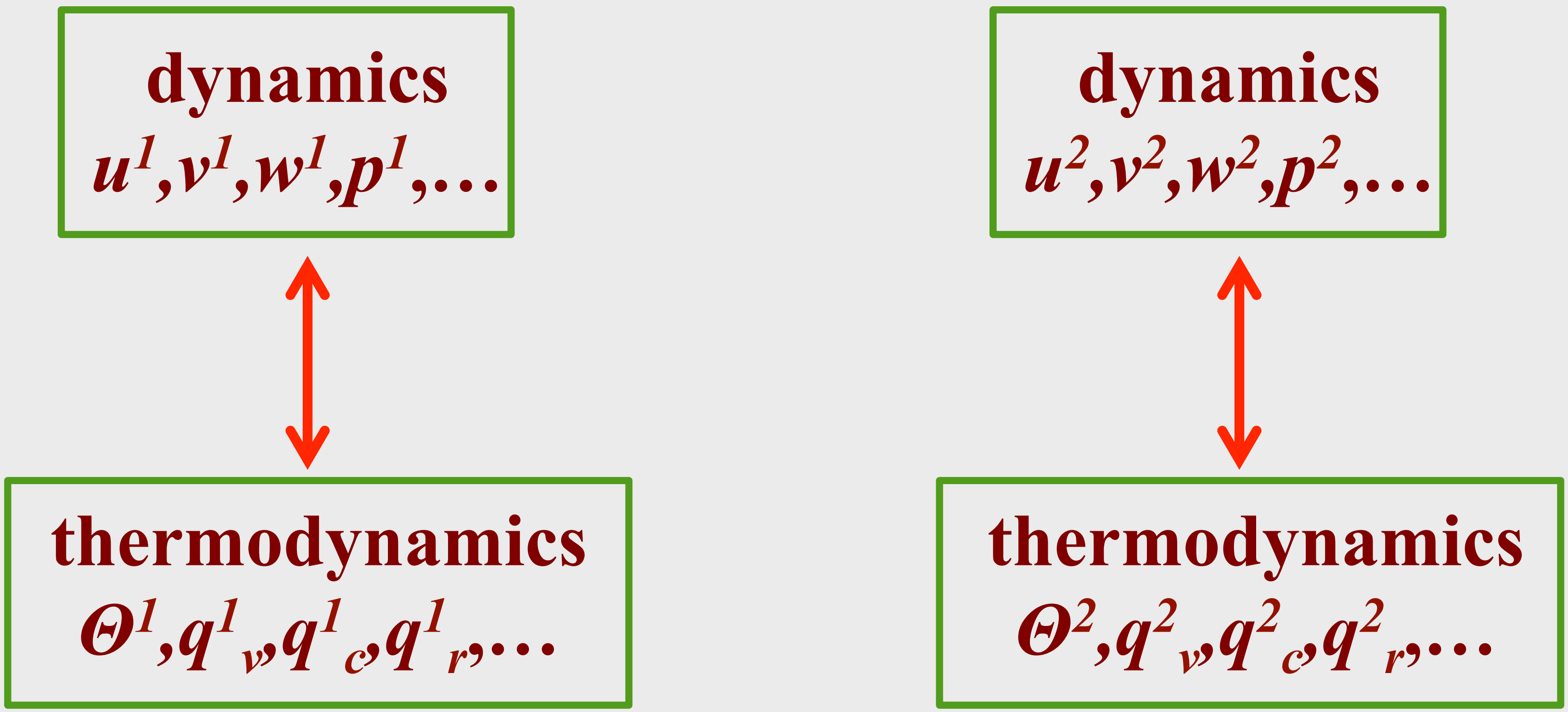
Microphysical piggybacking…

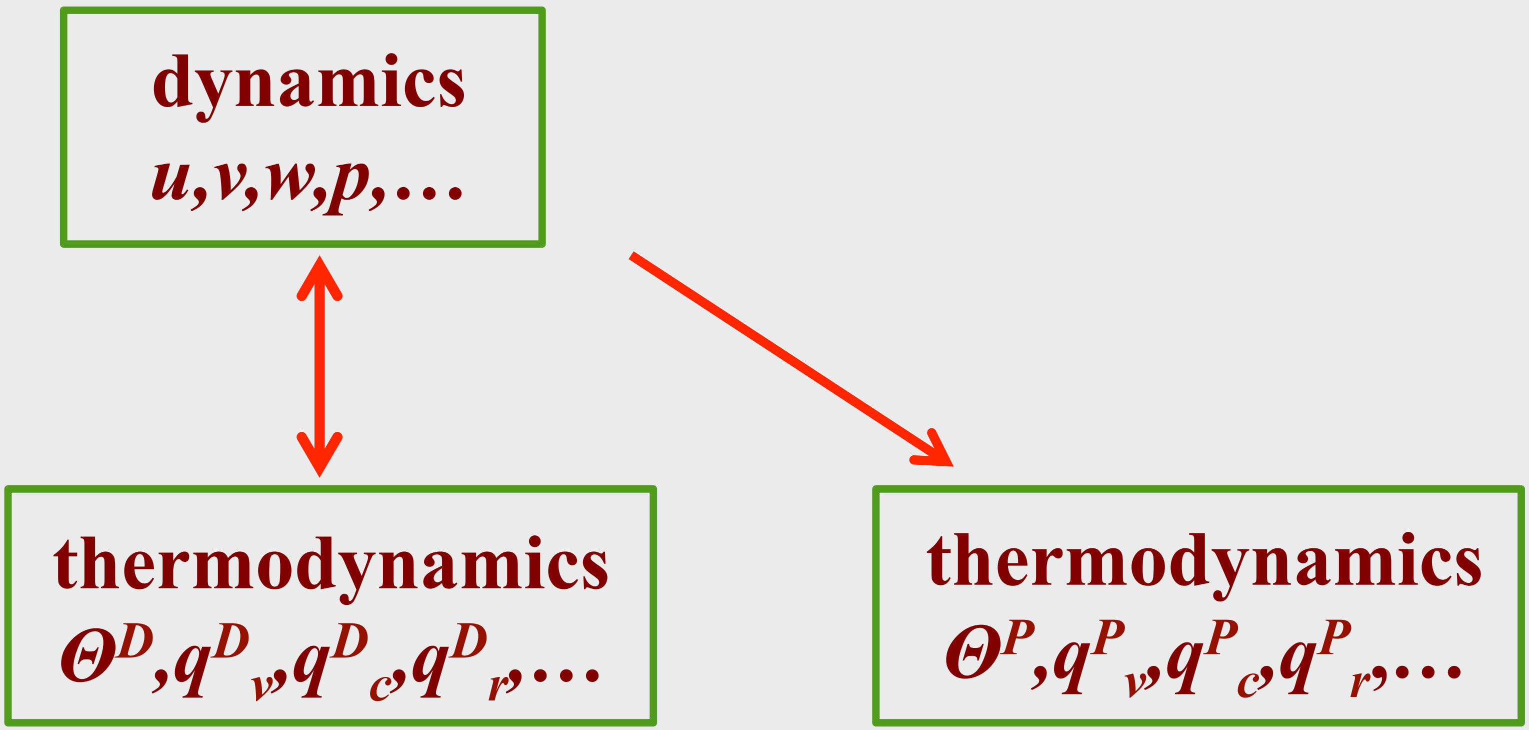
Grabowski, W. W., 2014: Extracting microphysical impacts in large-eddy simulations of shallow convection. *J. Atmos. Sci*. **71**, 4493-4499.

Grabowski W. W., 2014: Untangling microphysical impacts on deep convection applying a novel modeling methodology *J. Atmos. Sci*. (in review).

The traditional approach: two (or many) simulations…



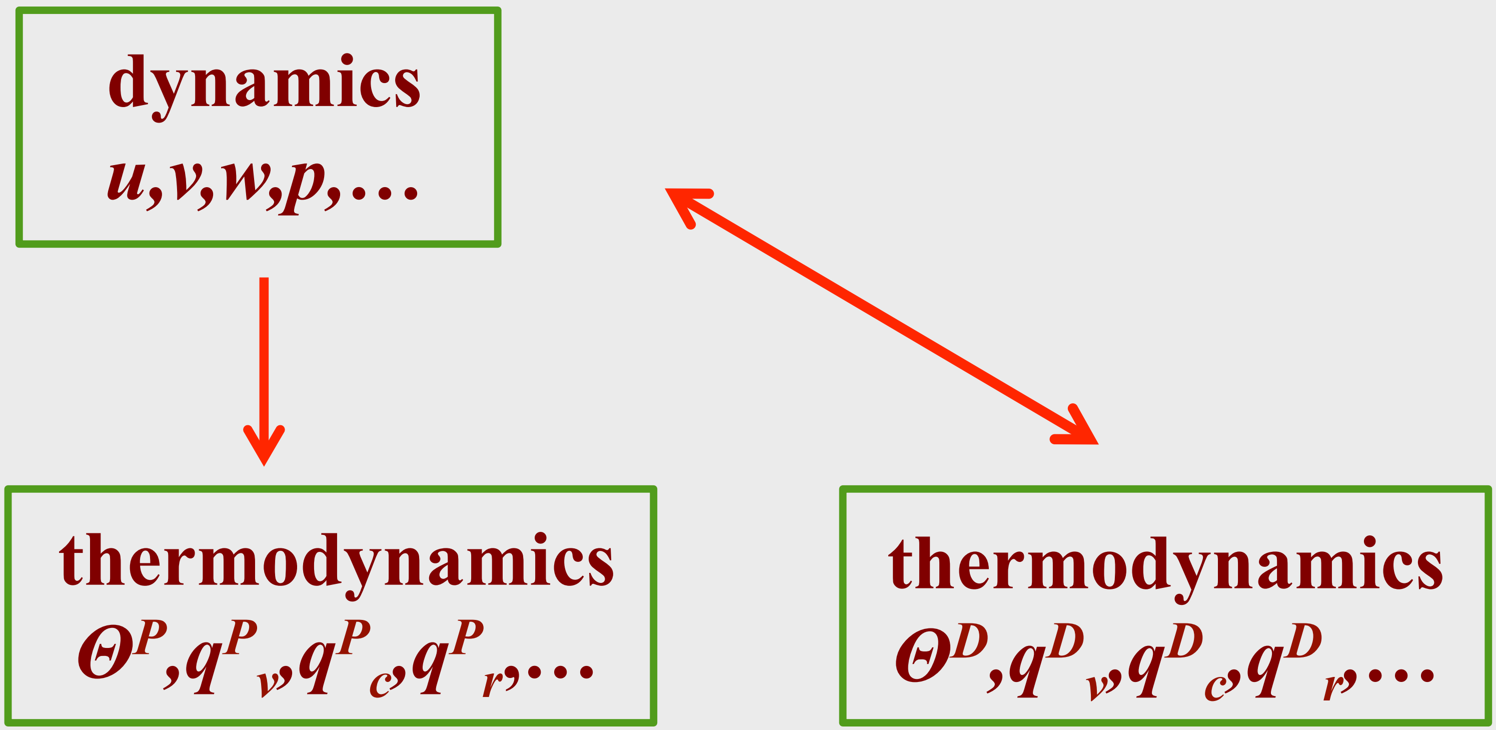
The new methodology:



"D" for driving
the dynamics

"P" for piggybacking
the simulated flow

The new methodology:

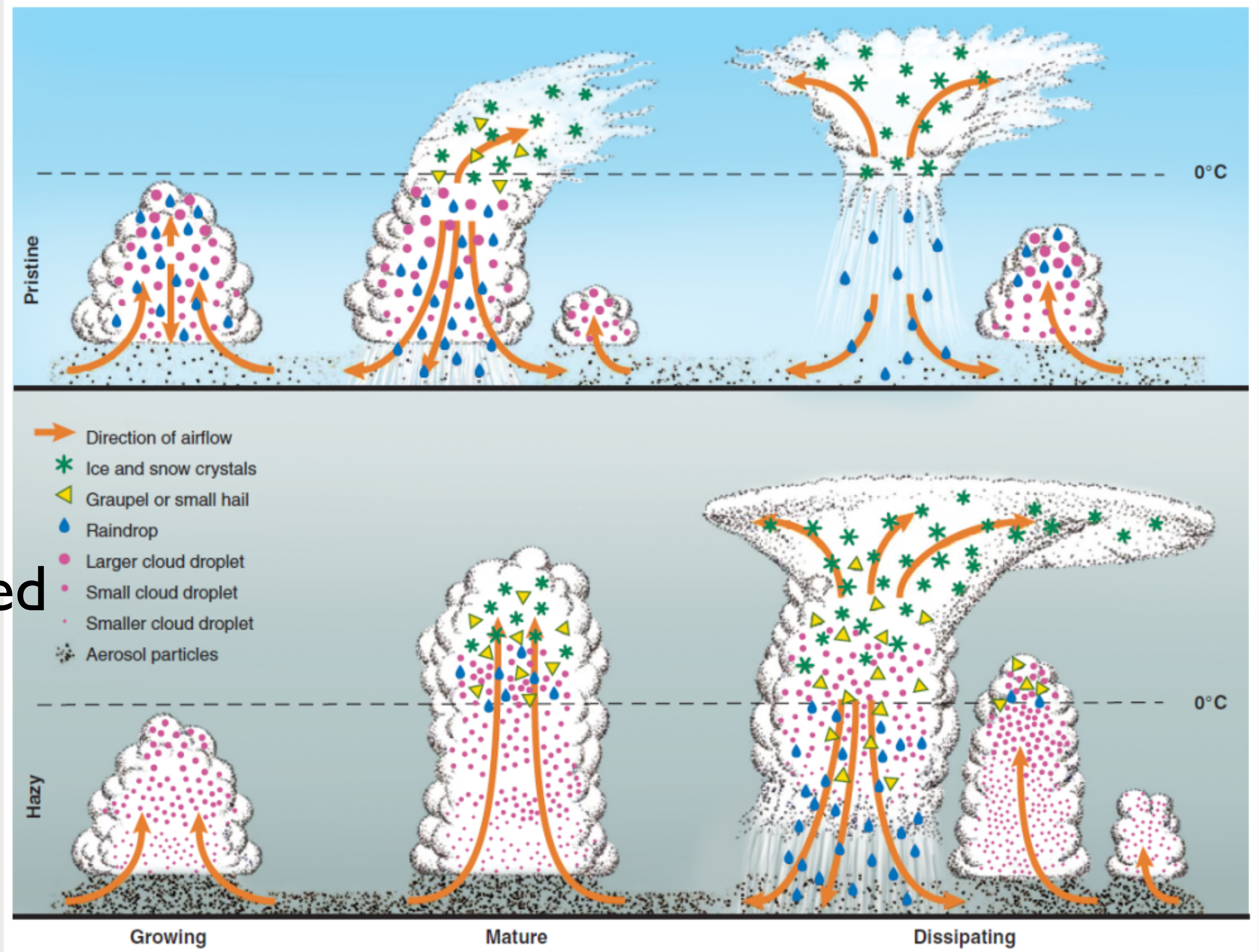


"P" for piggybacking
the simulated flow

"D" for driving
the dynamics

clean

polluted

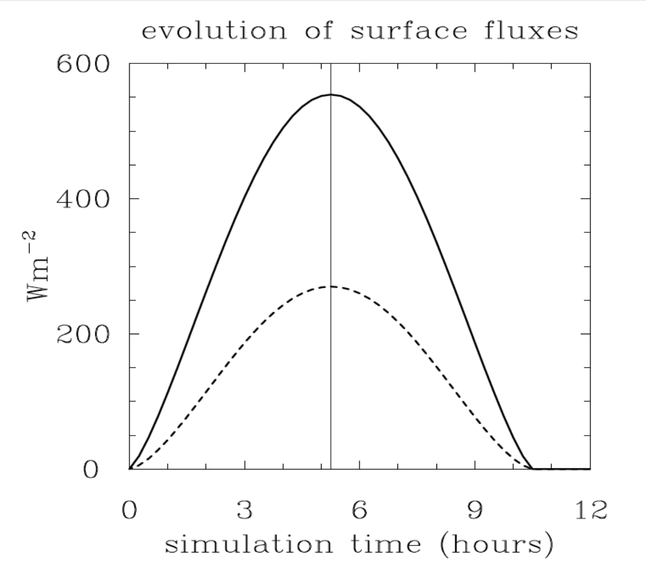


Rosenfeld et al. *Science*, 2008
"Flood or Drought: How Do Aerosols Affect Precipitation?"

Q. J. R. Meteorol. Soc. (2006), **132**, pp. 317–344 doi: 10.1256/qj.04.147

Daytime convective development over land: A model intercomparison based on LBA observations

By W. W. GRABOWSKI[1]*, P. BECHTOLD[2], A. CHENG[3], R. FORBES[4], C. HALLIWELL[4], M. KHAIROUTDINOV[5], S. LANG[6], T. NASUNO[7], J. PETCH[8], W.-K. TAO[6], R. WONG[8], X. WU[9] and K.-M. XU[3]



Current simulations:

Extended to 12 hrs
50 x 50 km^2 horizontal domain, 400 m gridlength
24 km deep domain, 81 levels, stretched grid

1. Contrasting simulations applying different microphysical schemes: separating dynamical and microphysical effects.

2. Contrasting simulations assuming clean and polluted conditions (with droplet concentration of 100/1,000 per cc for clean/polluted): exploring dynamical basis of deep convection invigoration in polluted environments.

Two microphysics schemes:

Grabowski 1998 (G98) – simple ice: SIM

Grabowski 1999 (G99) – more complex ice: IAB

Two collection of simulations:

C1: 12 simulations piggybacking with SIM and IAB:

3 pristine ensemble members for D-SIM/P-IAB and 3 for D-IAB/P-SIM

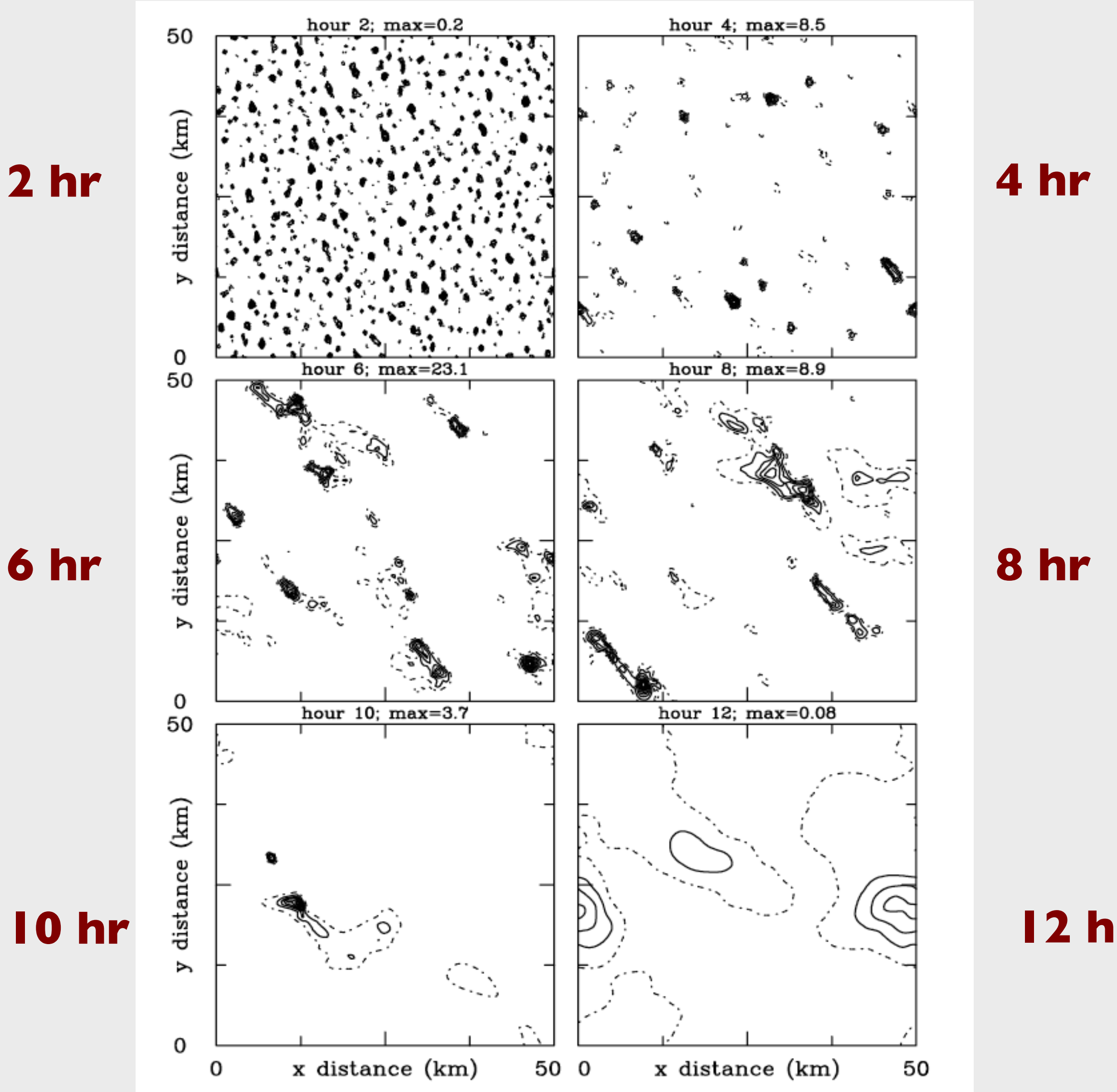
3 polluted ensemble members for D-SIM/P-IAB and 3 for D-IAB/P-SIM

C2: 12 simulations piggybacking with polluted and pristine:

3 SIM ensemble members for D100/P1000 and 3 for D1000/P100

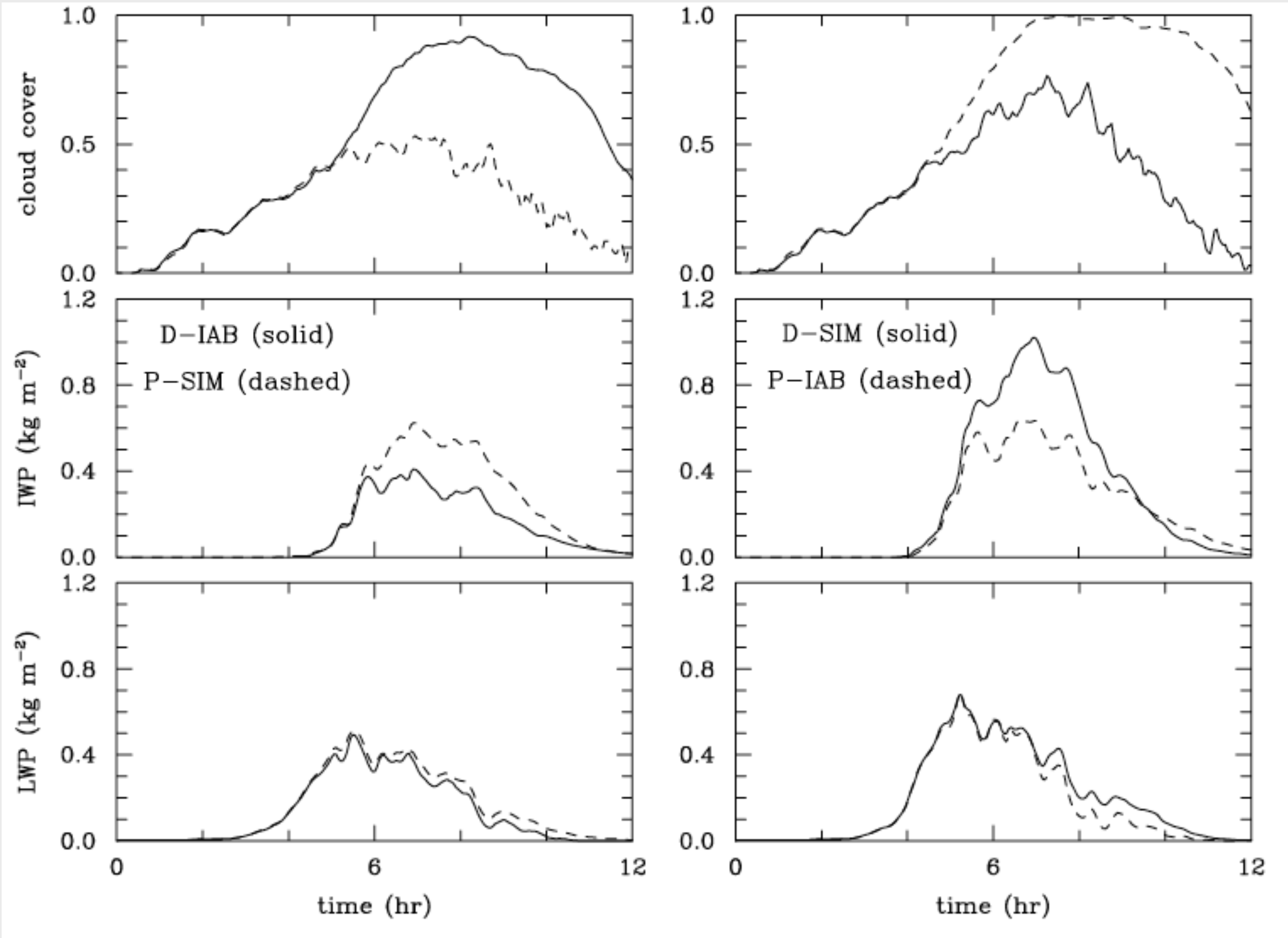
3 IAB ensemble members for D100/P1000 and 3 for D1000/P100

Example of model results: maps of the total water path (liquid plus ice) from a single simulation from IAB ensemble

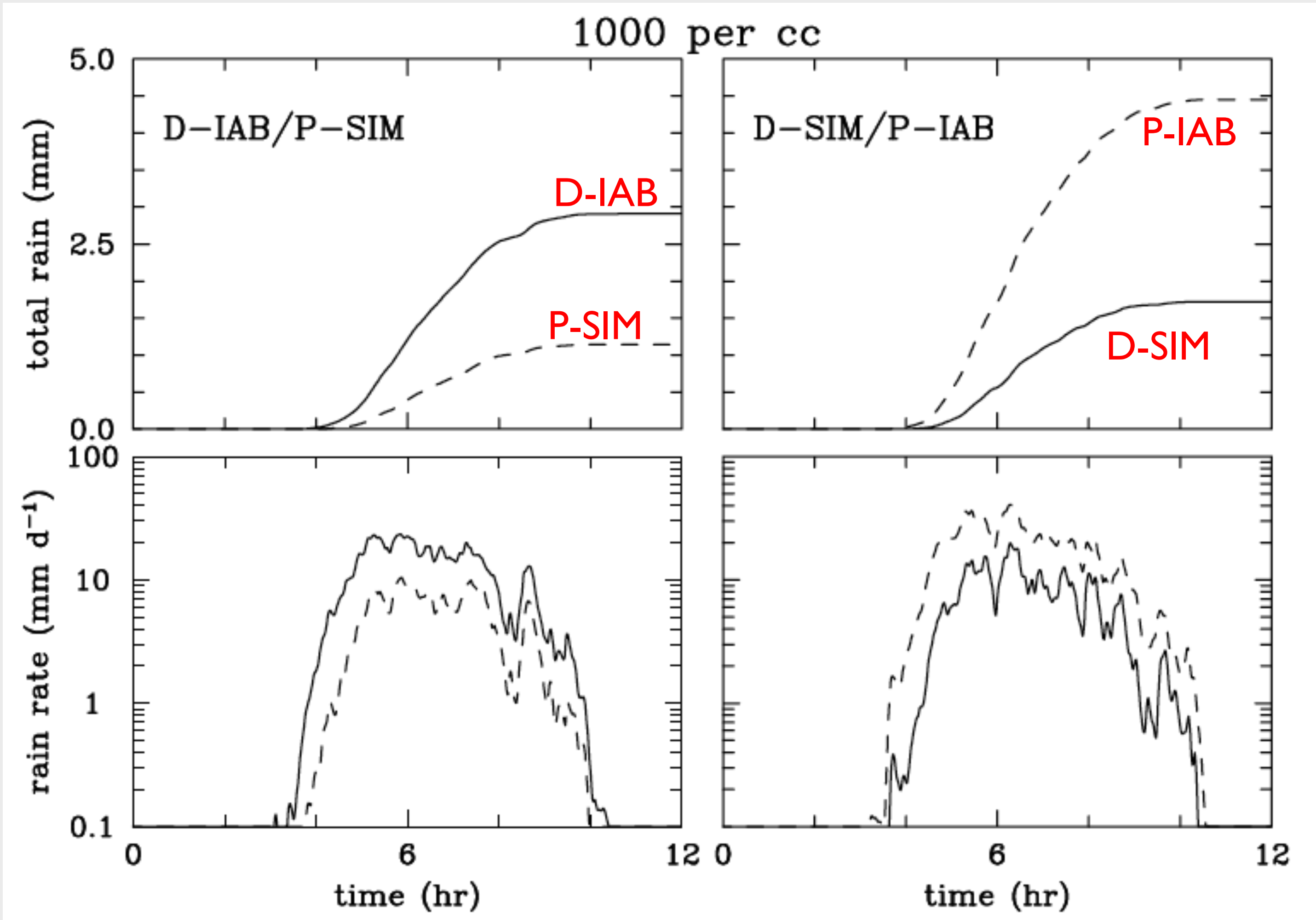


contour interval: 0.1 x maximum

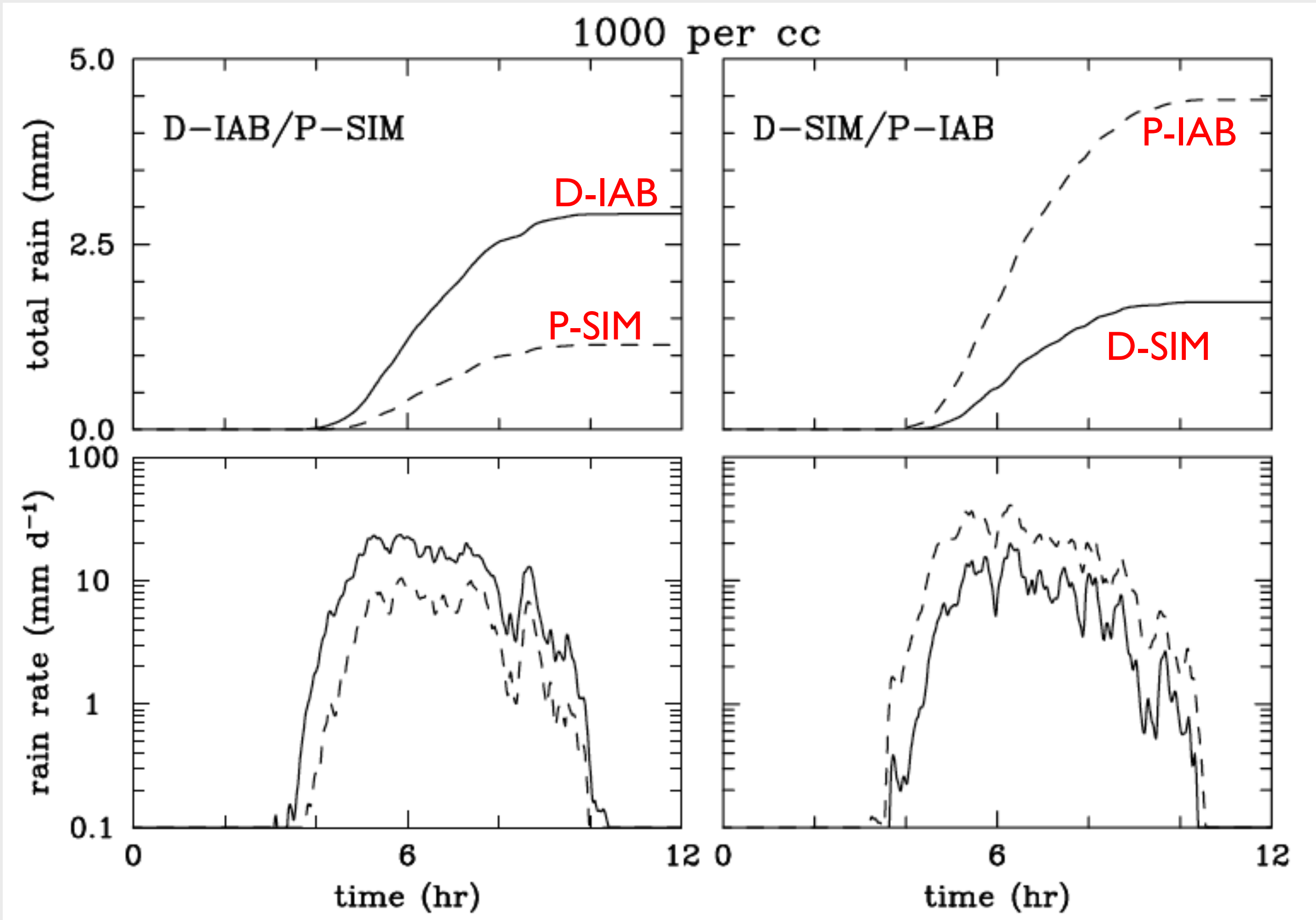
Piggybacking with different schemes: D-IAB/P-SIM versus D-SIM/P-IAB



Piggybacking with different schemes: D-IAB/P-SIM versus D-SIM/P-IAB



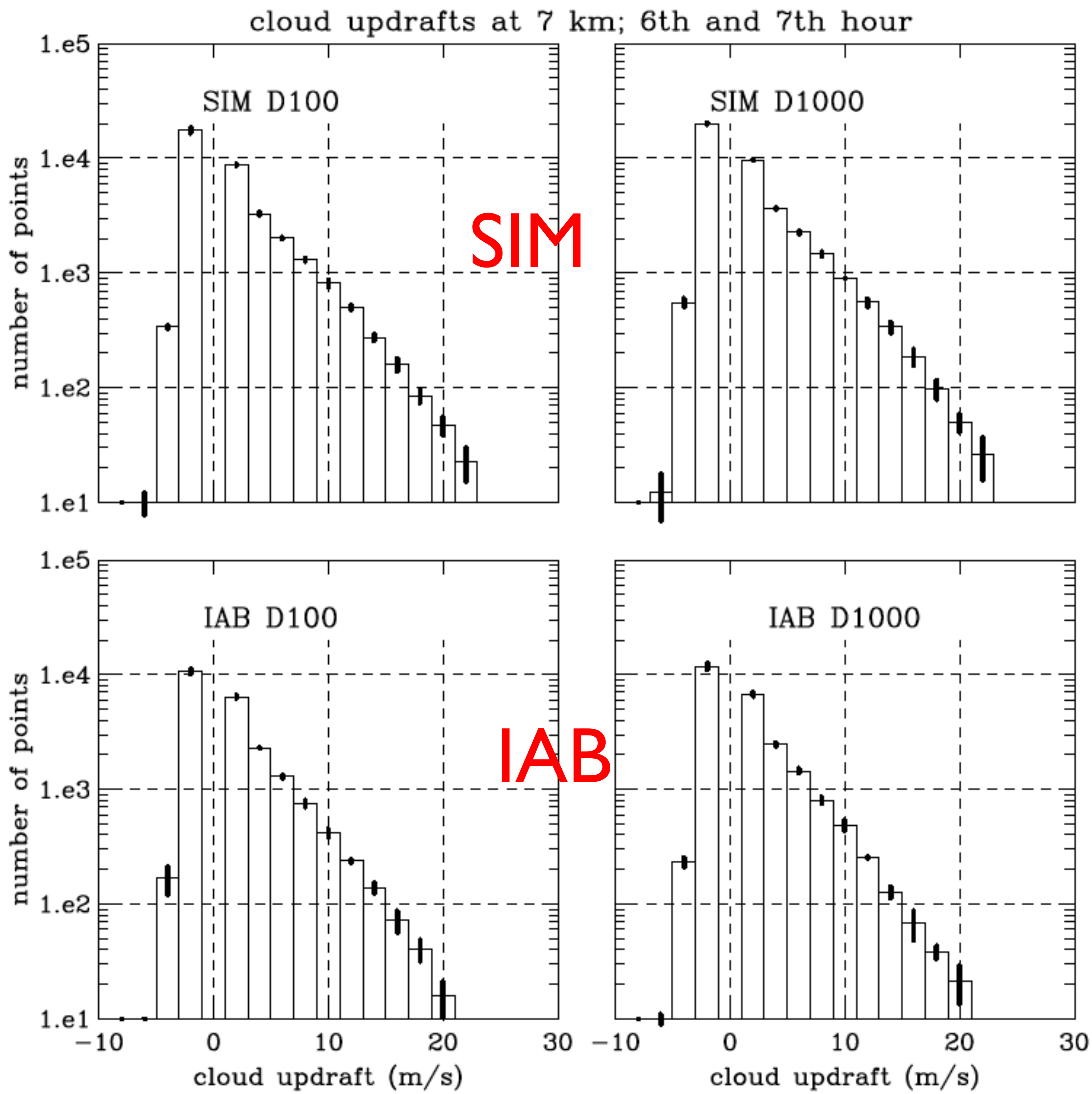
Piggybacking with different schemes: D-IAB/P-SIM versus D-SIM/P-IAB



Differences between left and right panel suggest modified dynamics between SIM and IAB driving…

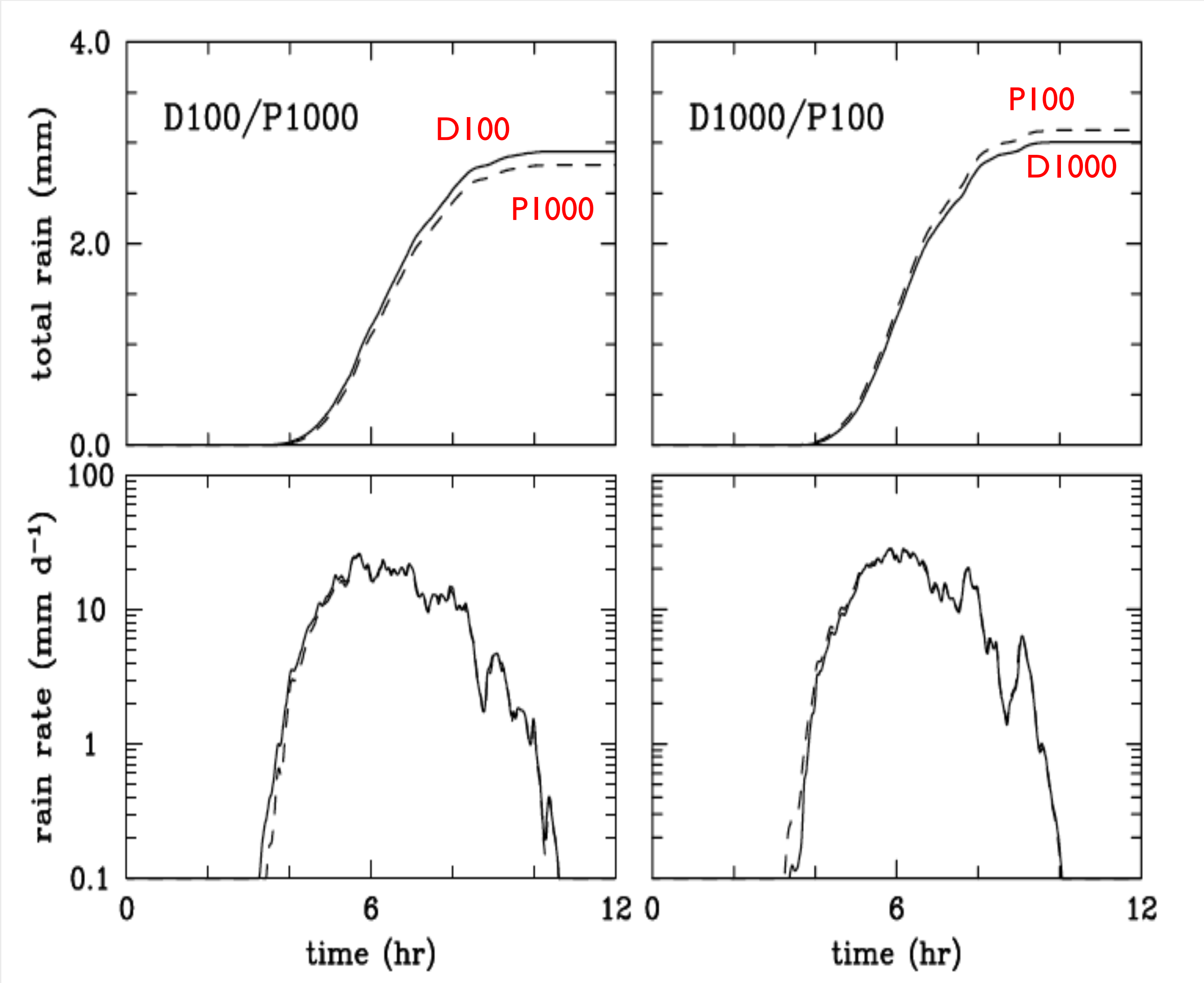
Piggybacking with different schemes: D-IAB/P-SIM versus D-SIM/P-IAB

set	accumulation for each member (in mm)	ensemble mean, st. dev.	D-P mean, st. dev.
pristine simulations:			
D-SIM	1.76, 1.81, 1.73	1.77, 0.06	-2.35, 0.09
D-IAB	2.91, 3.04, 2.79	2.91, 0.12	1.65, 0.05
P-IAB	4.06, 4.22, 4.08		
P-SIM	1.24, 1.34, 1.20		
polluted simulations:			
D-SIM	1.65, 1.72, 1.60	1.66, 0.05	-2.65, 0.13
D-IAB	2.85, 2.91, 2.78	2.85, 0.05	1.75, 0.06
P-IAB	4.31, 4.45, 4.15		
P-SIM	1.08, 1.14, 1.08		



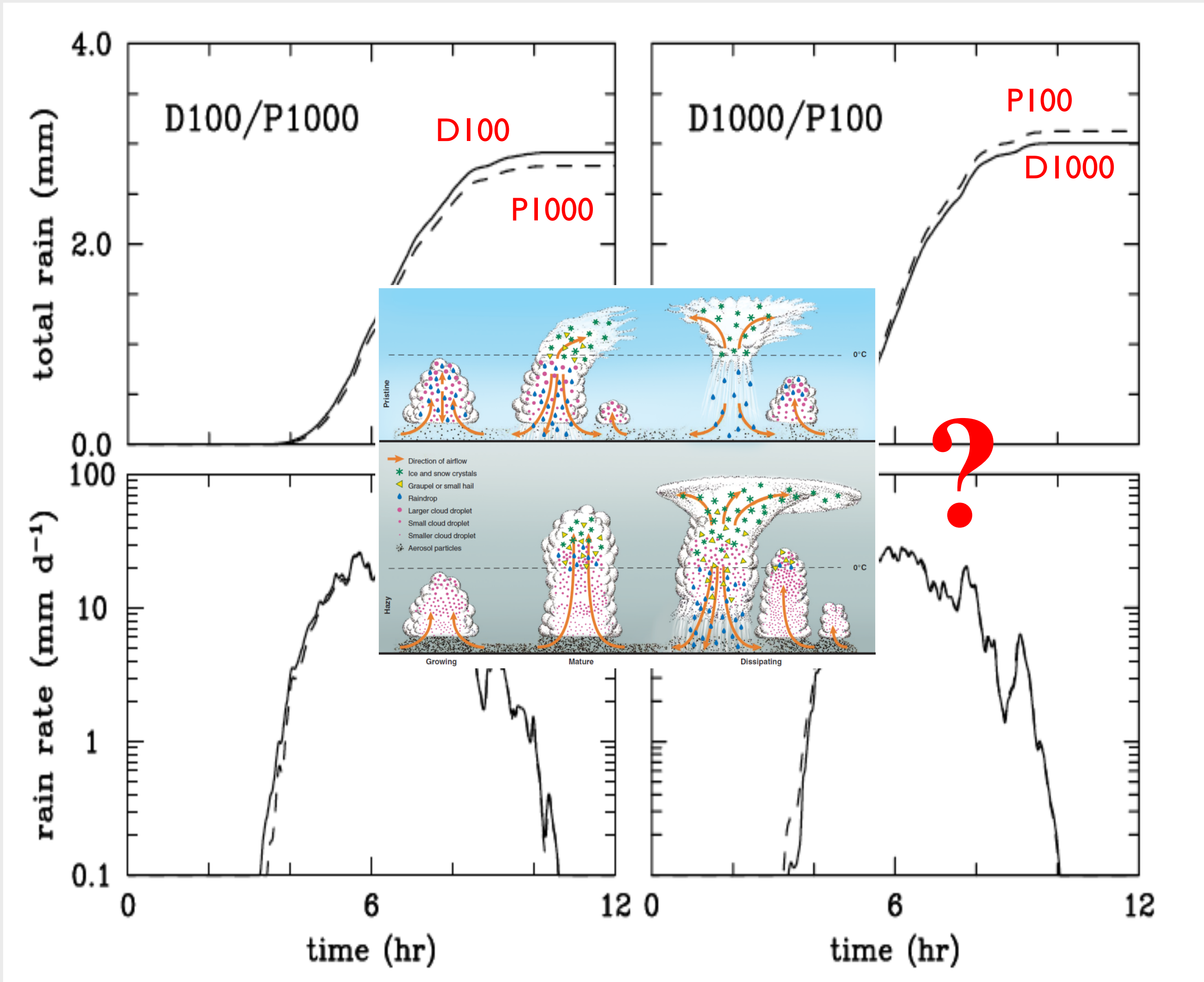
cloud updrafts at 7 km; 6th and 7th hour
SIM D100
SIM D1000
IAB D100
IAB D1000
SIM
IAB
number of points
1.e5
1.e4
1.e3
1.e2
1.e1
−10
0
10
20
30
cloud updraft (m/s)

Piggybacking with the same scheme: D100/P1000 versus D1000/P100



Pristine simulations produce more rain…

Piggybacking with the same scheme: D100/P1000 versus D1000/P100



Pristine simulations produce more rain…

IAB

	12-hr rain accumulations (mm)	D ensemble mean, st. dev.
D100	2.91, 3.03, 2.79	2.91, 0.10
D1000	3.01, 2.90, 2.91	2.94, 0.09

IAB

	12-hr rain accumulations (mm)	D ensemble mean, st. dev.
D100	2.91, 3.03, 2.79	2.91, 0.10
D1000	3.01, 2.90, 2.91	2.94, 0.09

?

IAB

	12-hr rain accumulations (mm)	D ensemble mean, st. dev.	D-P ensemble mean, st. dev.
D100	2.91, 3.03, 2.79	2.91, 0.10	0.12, 0.01
D1000	3.01, 2.90, 2.91	2.94, 0.09	-0.12, 0.01
P1000	2.78, 2.92, 2.67		
P100	3.12, 3.02, 3.03		

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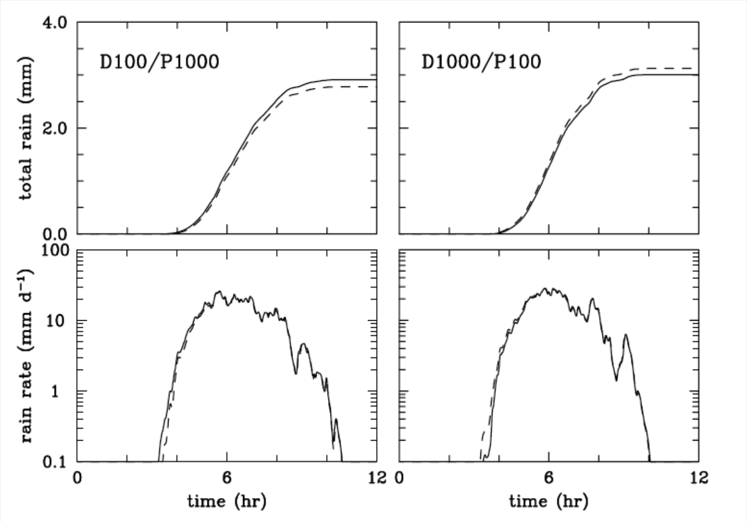
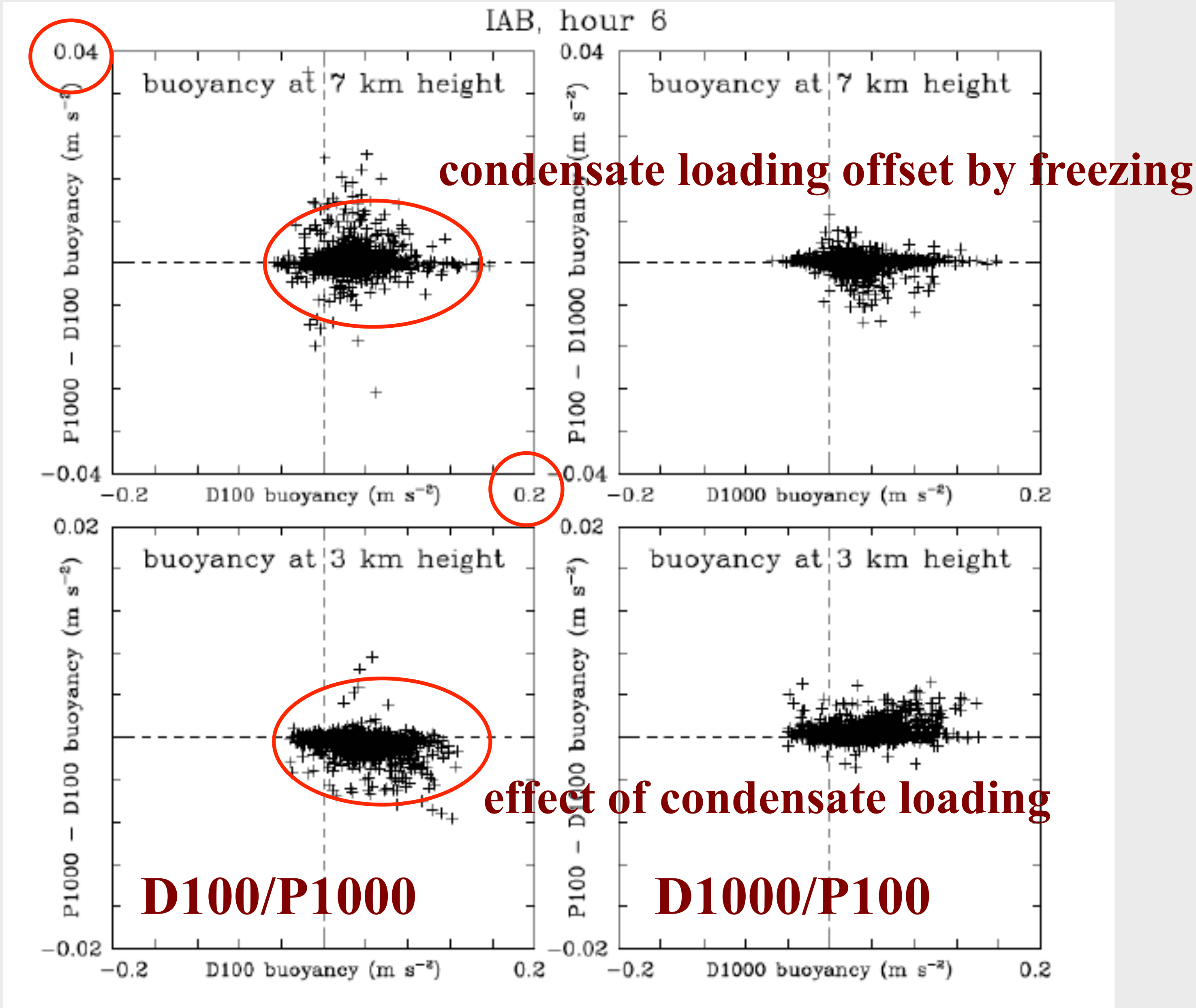
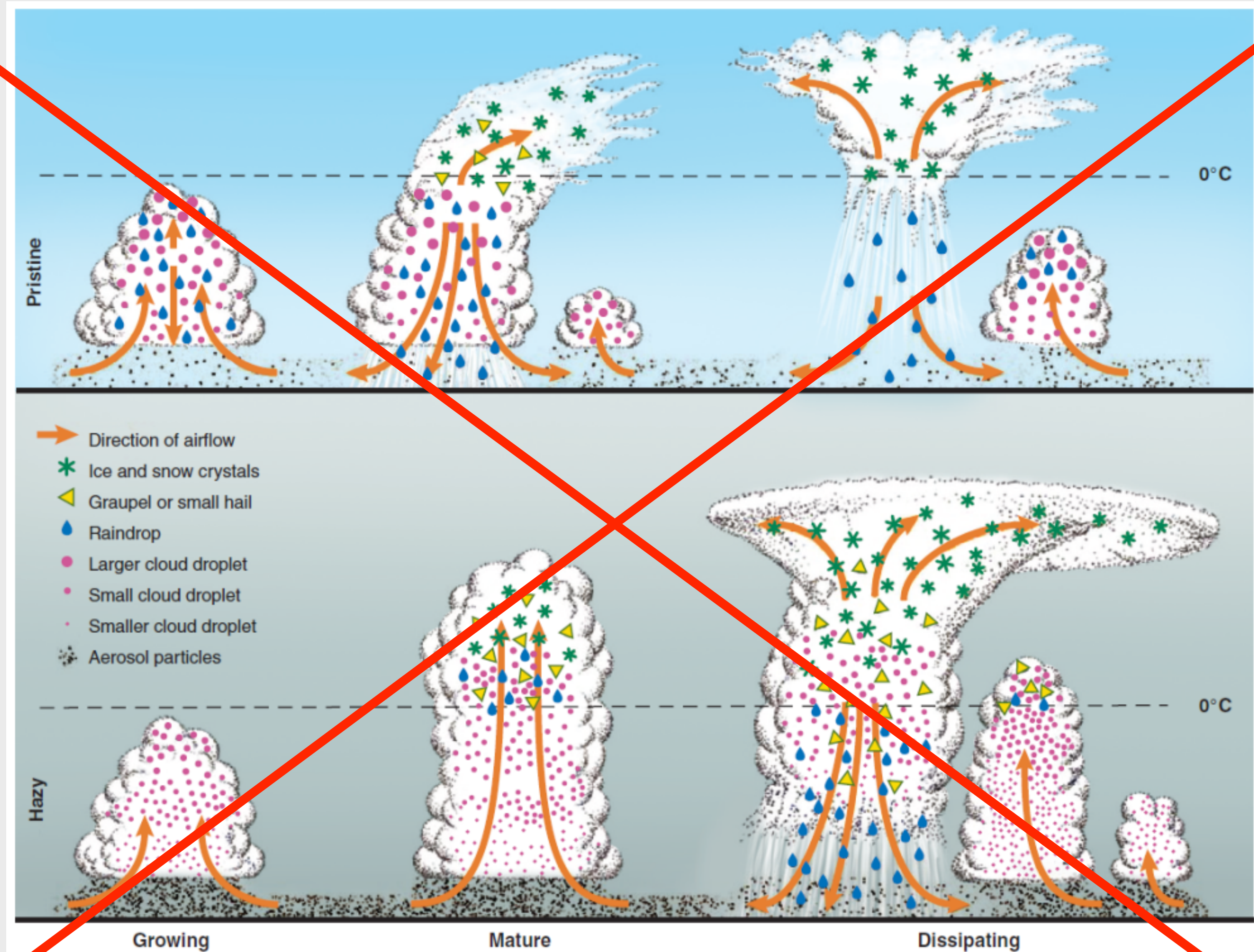


Comparing cloud updraft buoyancies in IAB D/P simulation:

7 km;
-12 degC

3 km;
9 degC





Rosenfeld et al. *Science*, 2008
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Conclusions:

1. **The piggybacking methodology allows confident assessment of impacts of cloud microphysical parameterizations. It decouples their effect from the impact on the cloud dynamics.**

2. **Contrasting D/P and P/D simulations allows investigating the impact on the dynamics. The fact that the D-P differences are similar (modulo the sign) between D/P and P/D implies small impact on the cloud dynamics. Large differences imply significant impact, like in the set C1.**

3. **The simulations call into question the dynamic basis of convective invigoration in polluted environments.**