Untangling microphysics-dynamics interactions in simulations of moist convection

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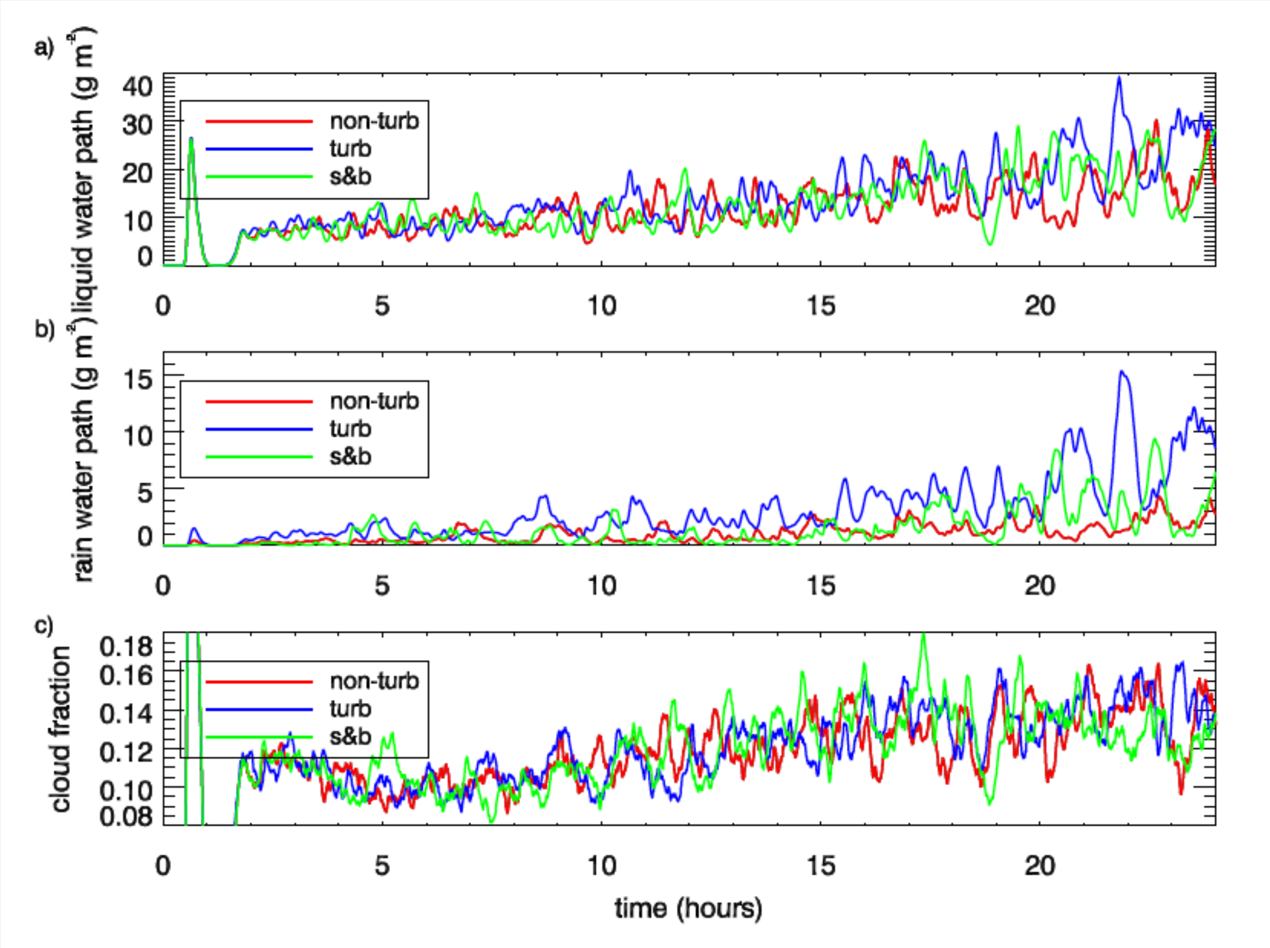
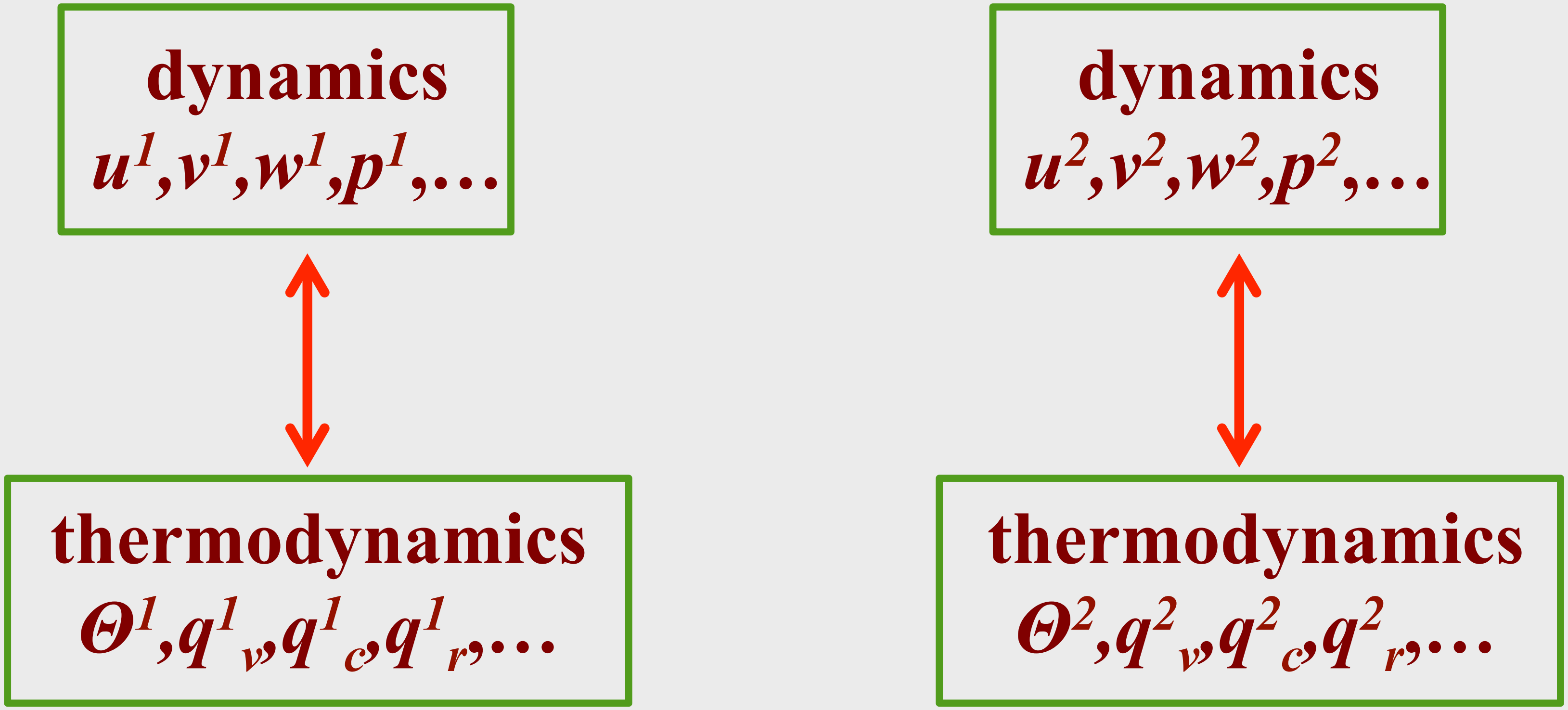
The problem: how to asses the impact of modifications in cloud microphysics on cloud field simulations?

Since microphysics feed back on the cloud dynamics, simulations diverge after a relatively short time and separating physical effects from natural variability is difficult…

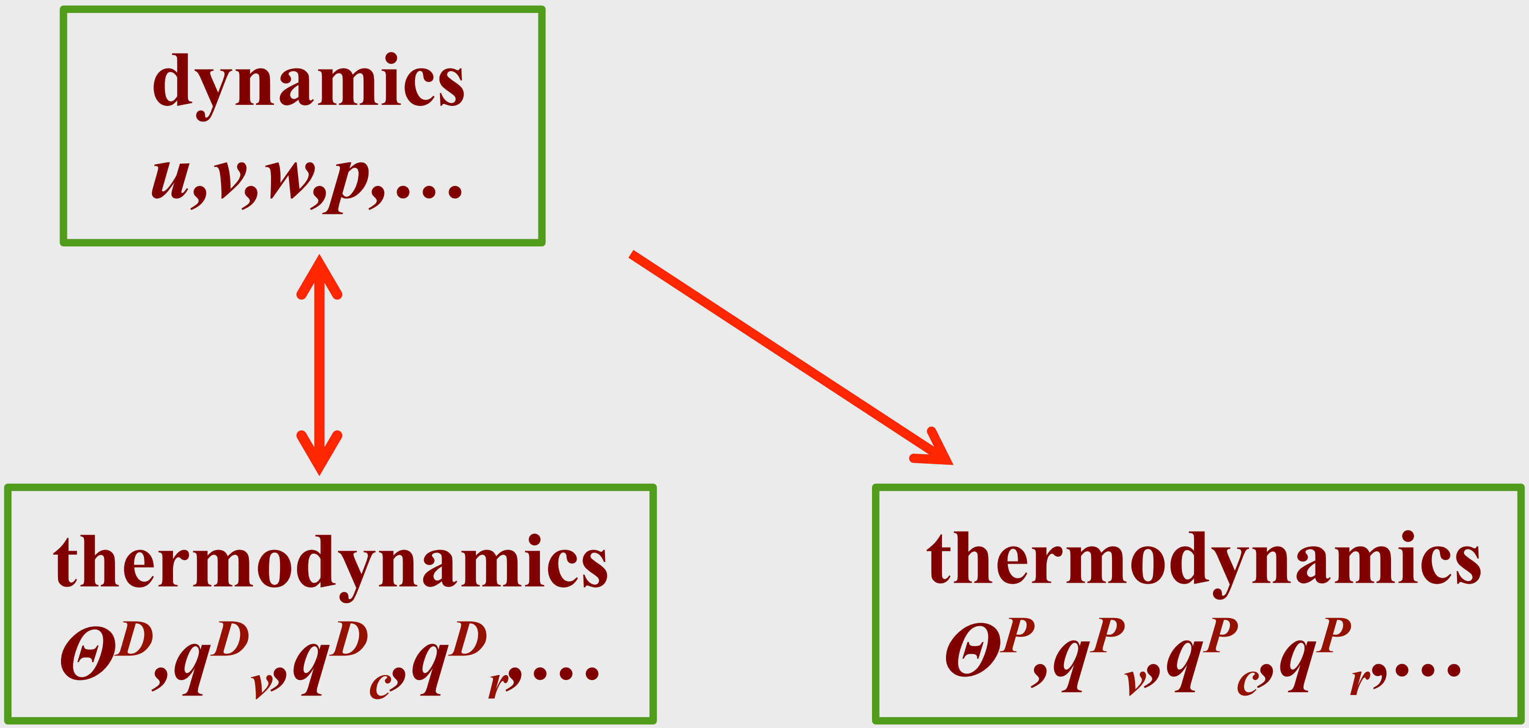


Franklin *ACP* 2014

The traditional approach: two (many?) simulations…



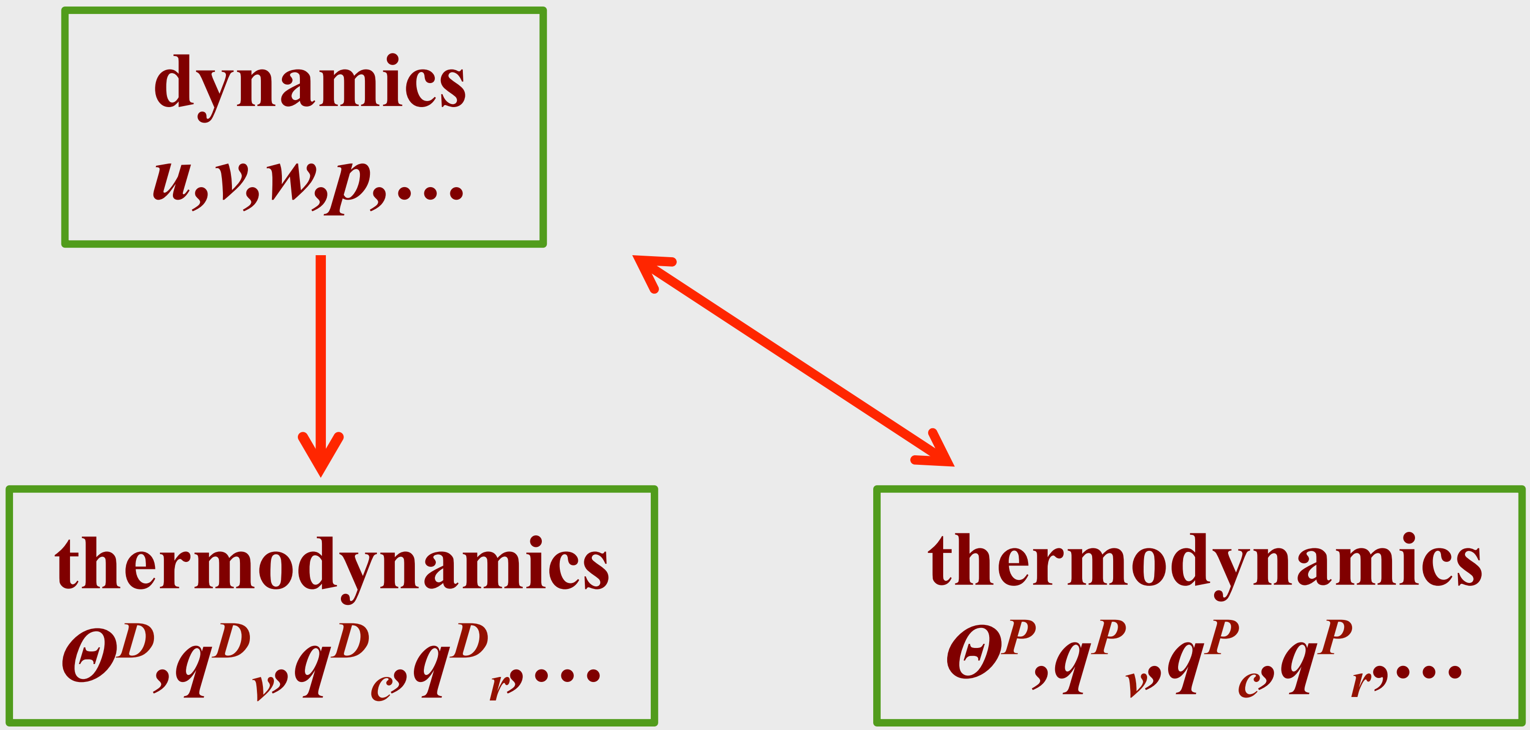
The new methodology:



“D” for driving
the dynamics

“P” for piggybacking
the dynamics

The new methodology:



"D" for driving
the dynamics

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Example of application: effect of cloud droplet concentration on drizzle/rain from shallow cumulus field

bulk microphysics (Grabowski 1998) with autoconversion depending on the cloud droplet concentration: 70 versus 100 per cc

A Large Eddy Simulation Intercomparison Study of Shallow Cumulus Convection

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JAS 2003

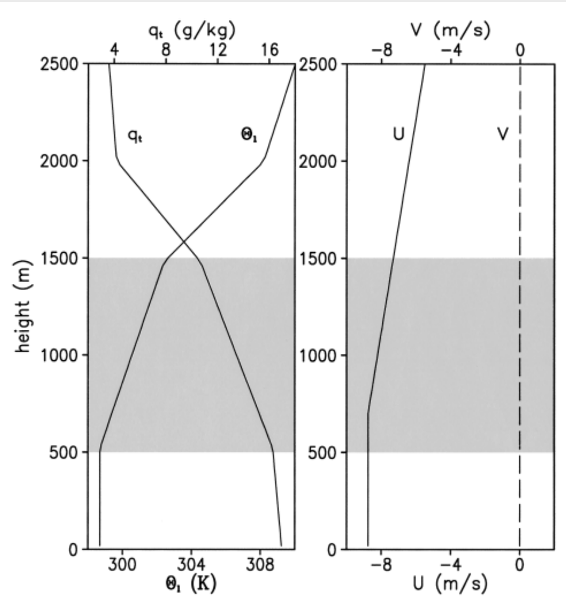
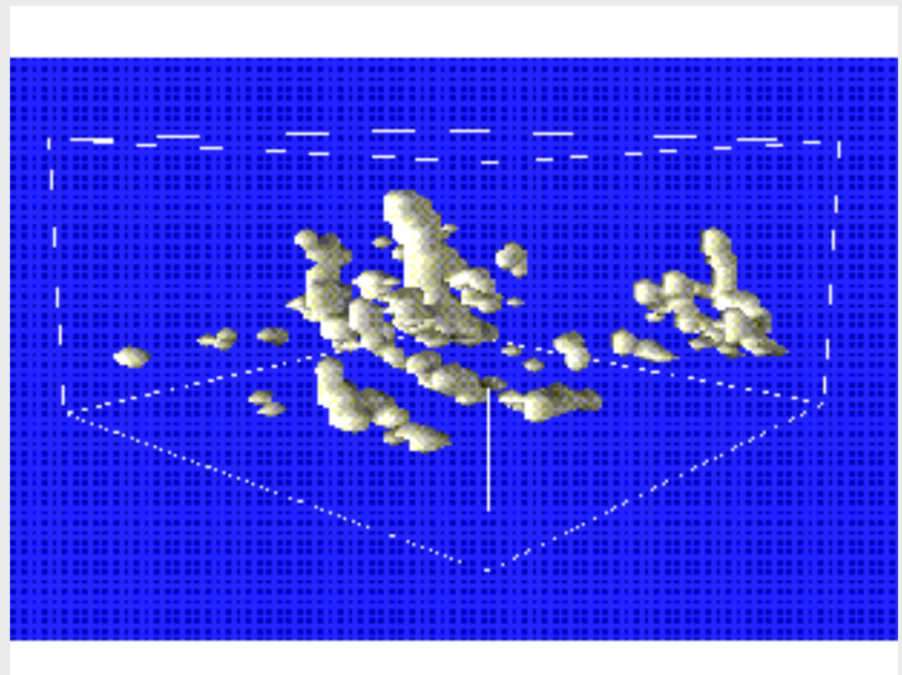


FIG. 1. Initial profiles of the total water specific humidity q_t, the liquid water potential temperature θ_ℓ, and the horizontal wind components u and v. The shaded area denotes the conditionally unstable cloud layer.

$\Delta x = \Delta y = 100$m;
$\Delta z = 40$m



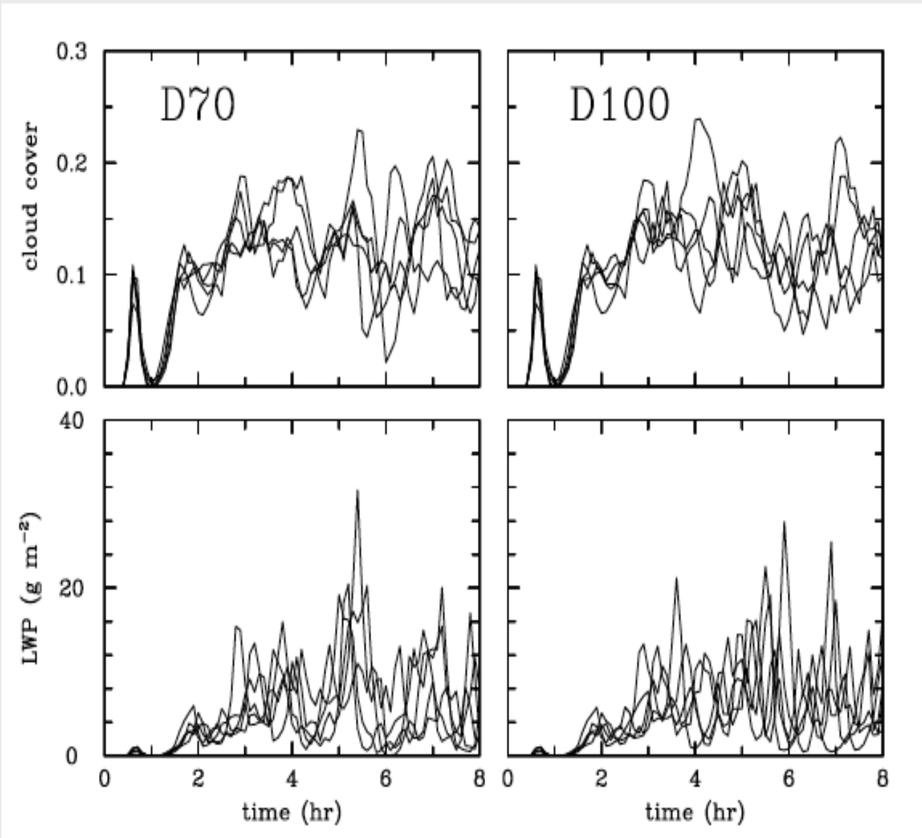
The Barbados Oceanographic and Meteorological Experiment (BOMEX) case (Holland and Rasmusson 1973)

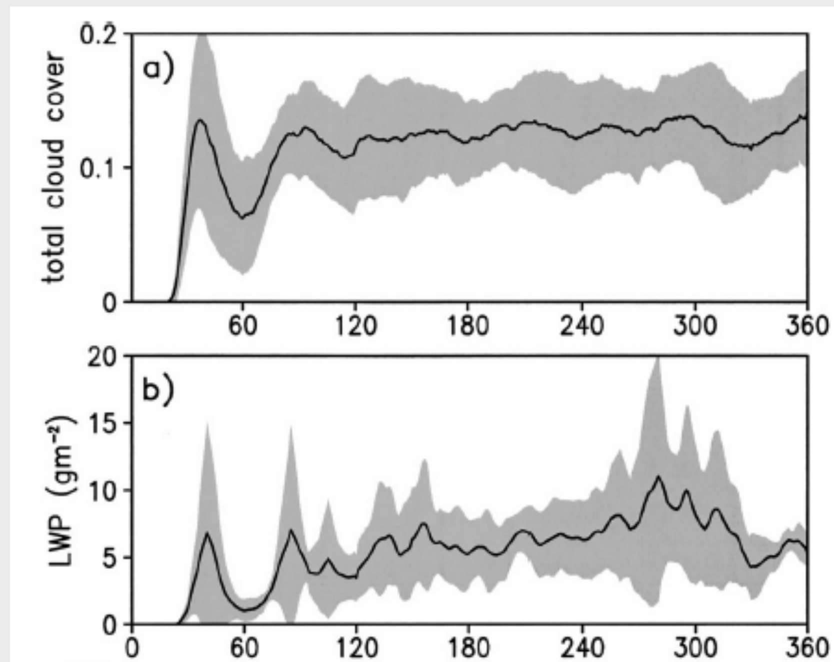
Simulations:

ensemble of 5 simulations with 70 per cc – D70, P100
ensemble of 5 simulations with 100 per cc – D100, P70

- look at D simulations only (traditional approach)
- look at D/P simulations (the new methodology)

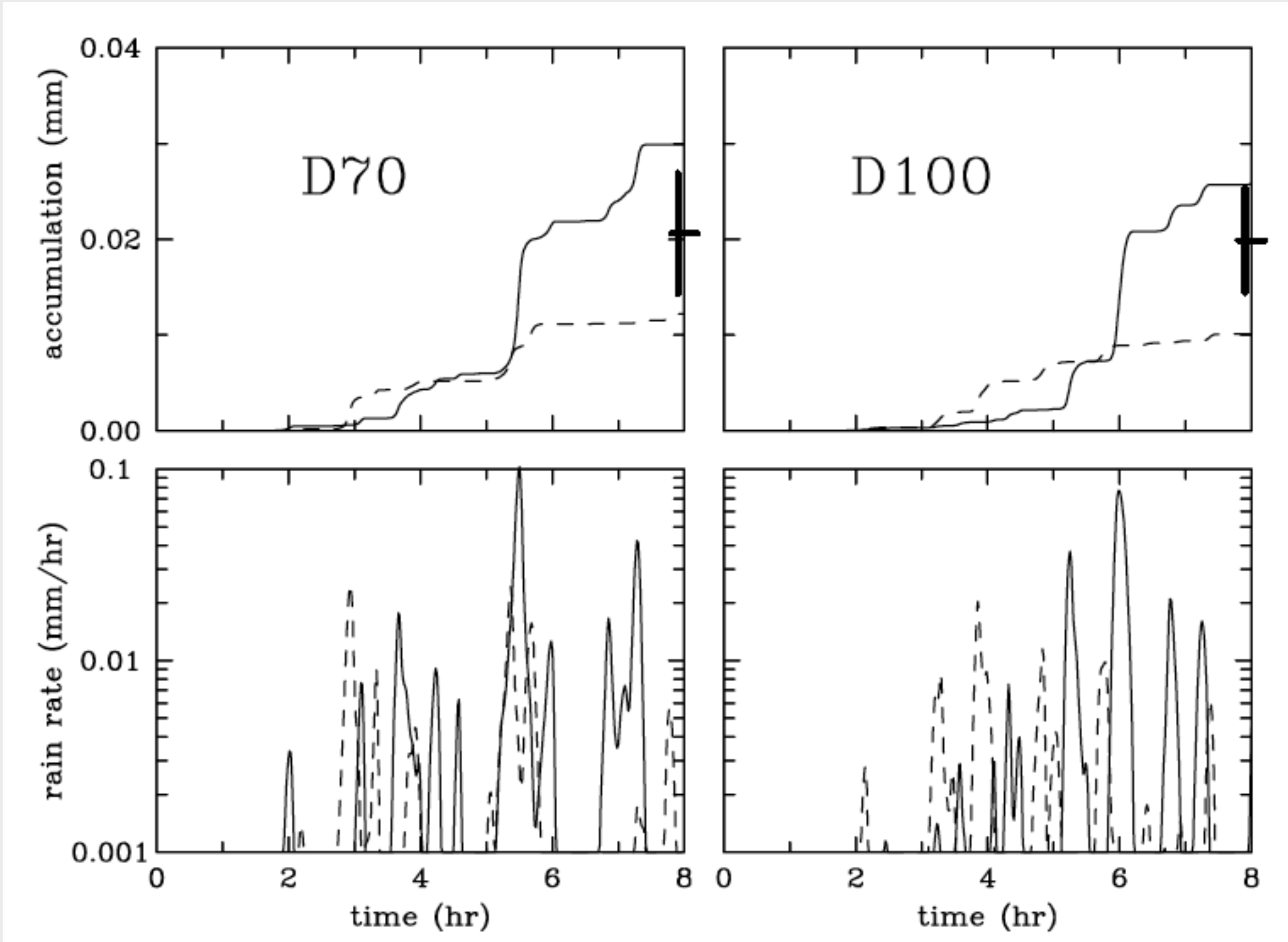
Comparison of two D simulation ensembles (5 members):





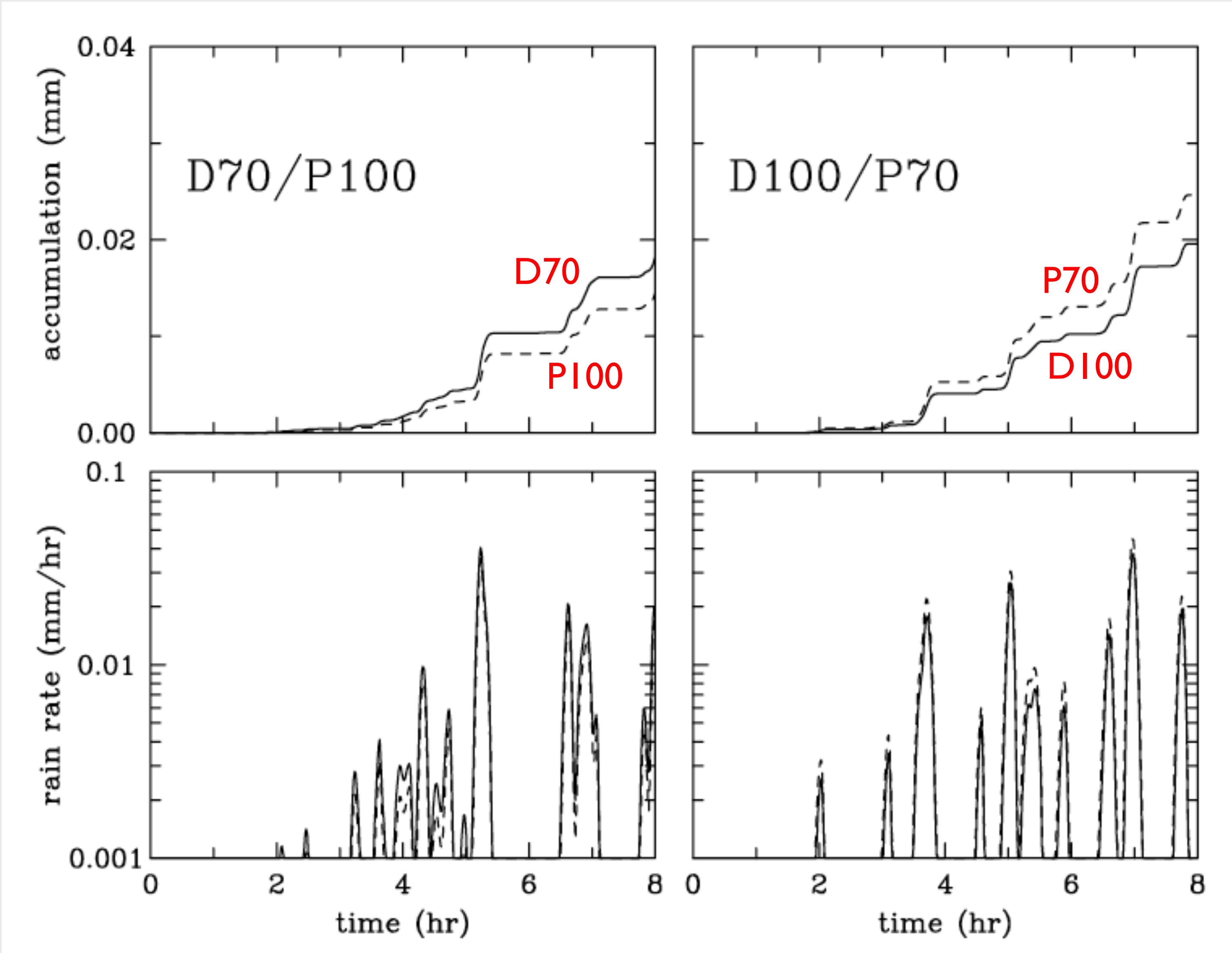
Siebesma et al. *JAS* 2003

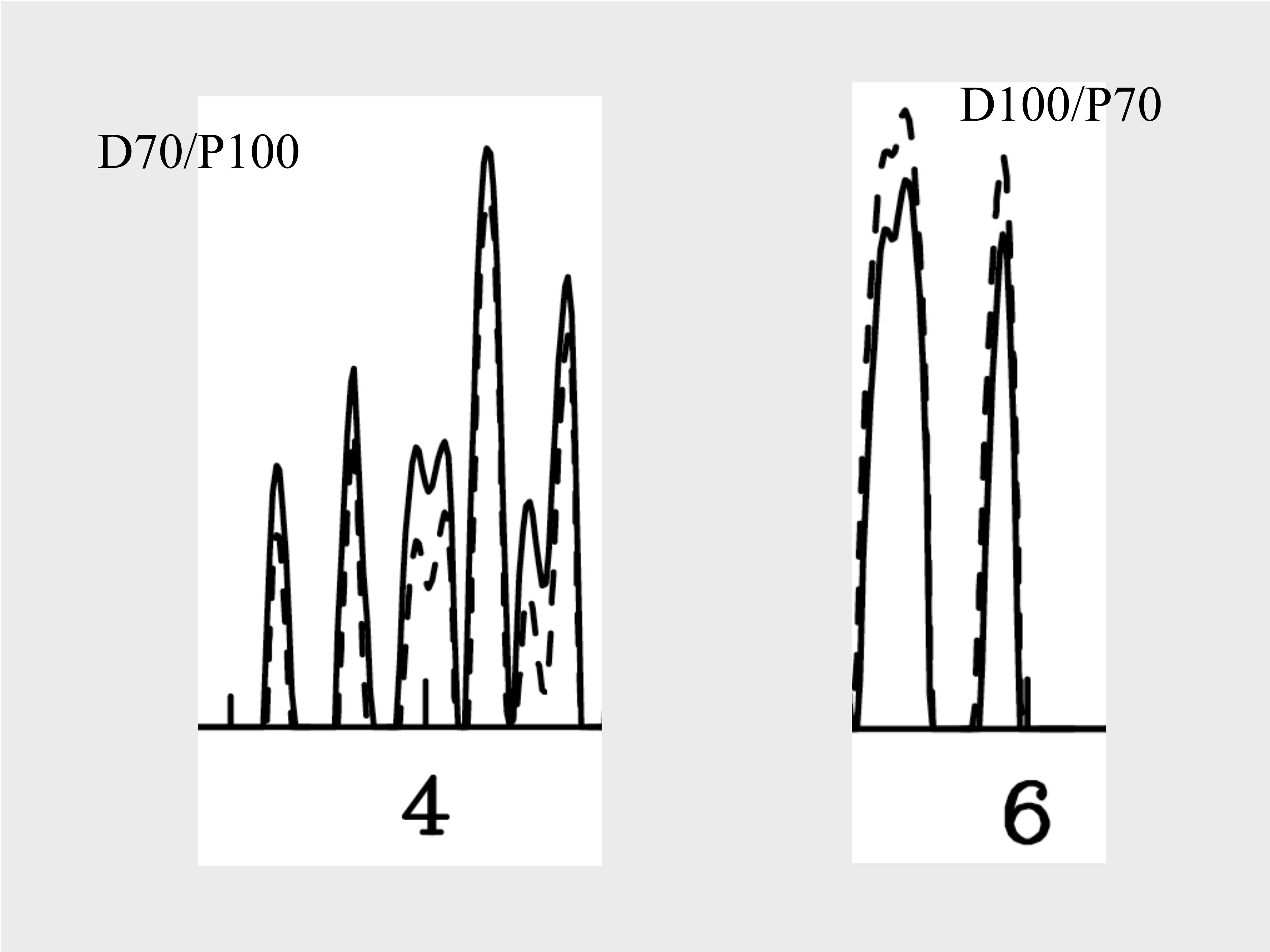
Comparison of two D simulation ensembles (5 members):



	8-hr rain accumulations (in units of 0.01 mm)	ensemble mean, st. dev.
D70	2.54, 1.72, 2.99, 1.81, 1.22	2.06, 0.63
D100	1.01, 1.97, 1.96, 2.58, 2.43	1.99, 0.55

Comparison of two D/P simulation ensembles:




D70/P100
D100/P70
4
6

	8-hr rain accumulations (in units of 0.01 mm)	ensemble mean, st. dev.	D-P mean, st. dev.
D70	2.54, 1.72, 2.99, 1.81, 1.22	2.06, 0.63	0.41, 0.08
D100	1.01, 1.97, 1.96, 2.58, 2.43	1.99, 0.55	-0.43, 0.07
P100	2.06, 1.33, 2.48, 1.44, 0.94	1.65, 0.55	
P70	1.32, 2.38, 2.46, 3.04, 2.91	2.42, 0.60	

Conclusions:

1. The new 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.

3. The method can be applied (is being applied?) to other modeling problems/parameterizations.