Sensitivity study of physical parameters in SCAM5 using RACORO cases

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Motivations

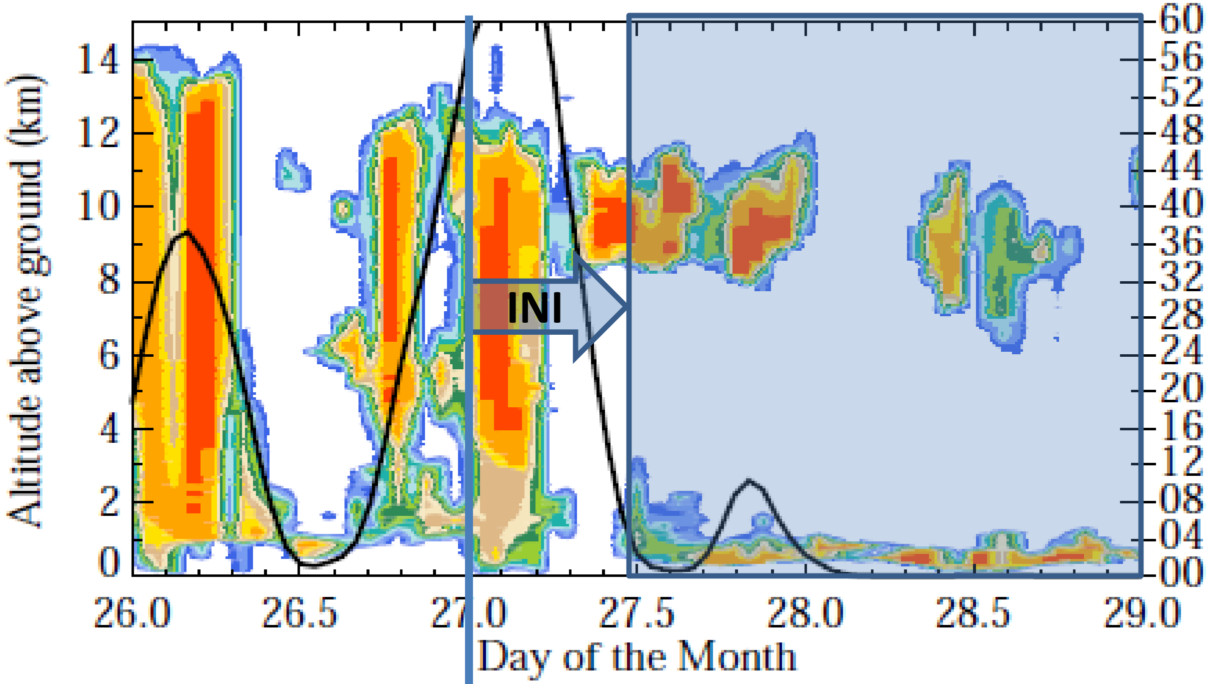
- Sensitivity to physical parameters in the models well recognized

  development stage: model calibration
  production stage: uncertainty quantification

- Multiple critical process components involve a significant number of parameters that are tunable to a varying extent
- Robust parameter sensitivity study commonly requires highly intensive computation.
- Given the efficiency of SCMs, can the SCM framework be used to aggressively explore the parameter space to at least narrow down the likely parameter ranges for further investigation?
- Feasible pathways to make SCM-based sensitivity results translatable to full-scale model?

RACORO case: 04/27 – 04/29, Observed Cloud & Precipitation.

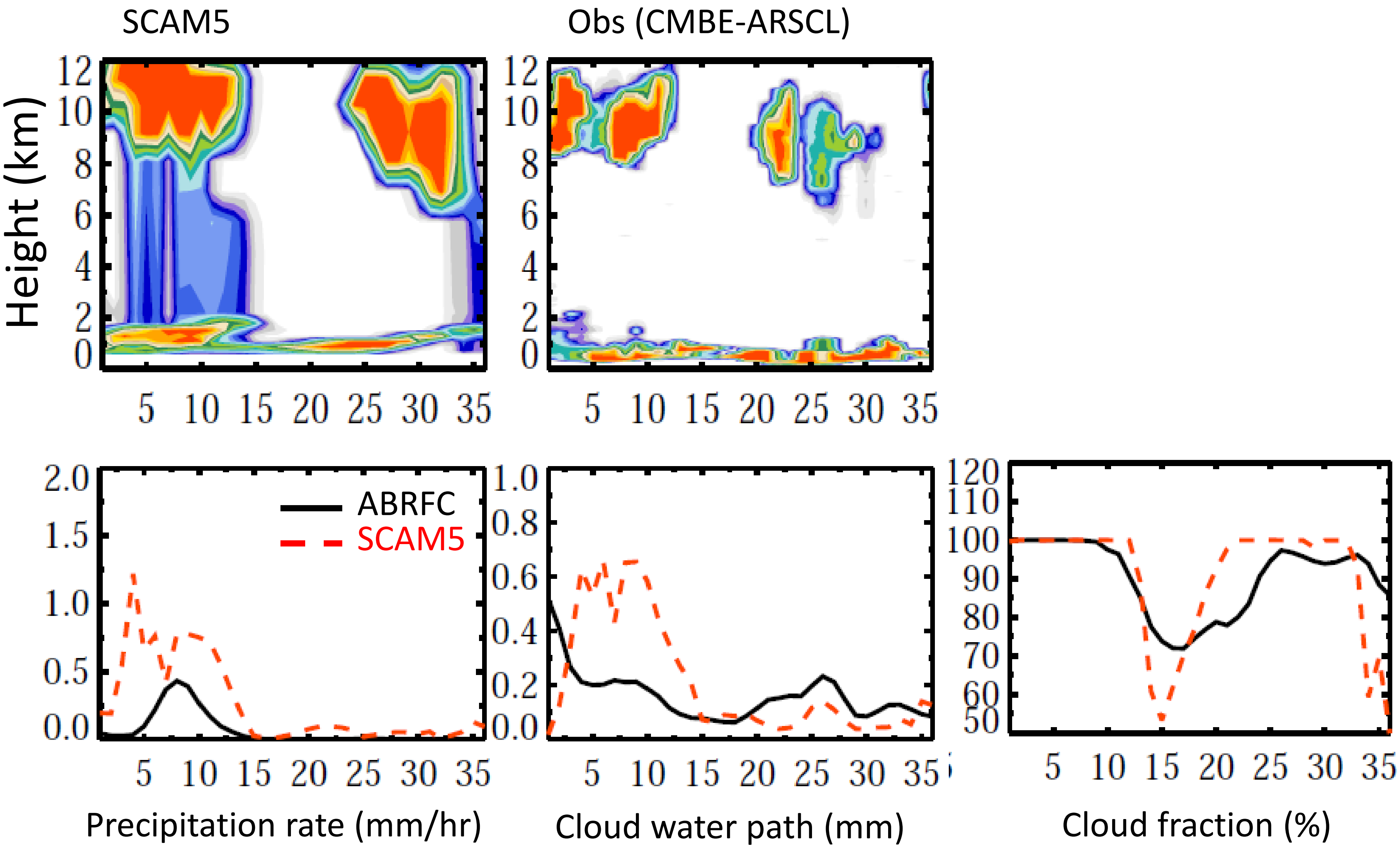
precipitation/drizzle, lasting & wide spread stratus/stratocumulus



(April, 2009)

SCAM5 driven by ARM continuous foricng (*Xie. et al 2004*)

04/27 – 04/29 with standard SCAM5/MAM3



Parameters	Low	Default	High	Description	Physics
rhminh	0.65	0.80	0.85	Threshold RH for fraction high stable clouds	Cloud frac
rhminl	0.80	0.91	0.99	Threshold RH for fraction low stable clouds	
cc	0.0	0.1	1.0	For newly formed/dissipated in-stratus CWC	Cloud macro-p
qist_min	1.0e-8	1.0e-7	1.0e-6	Minimum in-stratus IWC constraint	
qlst_min	0.00001	0.00002	0.00004	Minimum in-stratus LWC constraint	
ai	350.0	700.0	1400.0	Fall speed parameter for cloud ice	Cloud micro-p
as	5.86	11.72	23.44	Fall speed parameter for snow	
bimm	10.0	100.0	100.0	Immersion freezing parameter	
cdnl	0.0	0.0	10.0e+6	Cloud droplet number limiter	
dcs	100.0e-6	400.0e-6	500.0e-6	Autoconversion size threshold for ice to snow	
eii	0.001	0.1	1.0	Collection efficiency aggregation of ice	
qcvar	0.5	2.0	5.0	Inverse relative variance of sub-grid cloud water	
rhoi	100.0	500.0	900.0	Bulk density cloud ice	
rhos	20.0	250.0	500.0	Bulk density snow	
a2l	10.0	30.0	50.0	Moist entrainment enhancement parameter	PBL
criqc	0.5e-3	0.7e-3	1.5e-3	Maximum updraft condensate	Shallow convec
kevp	1.0e-6	2.0e-6	20.0e-6	Evaporative efficiency	
rkm	8.0	14.0	16.0	Fractional updraft mixing efficiency	
rmaxfrac	0.05	0.10	0.15	Maximum core updraft fraction	
rpen	1.0	5.0	10.0	Penetrative updraft entrainment efficiency	
alfa	0.05	0.10	0.60	Initial cloud downdraft mass flux	Deep convec
c0_lnd	1.0e-3	3.5e-3	6.0e-3	Deep convection precipitation efficiency over land	
capelmt	20.0	70.0	200.0	Threshold value for CAPE for deep convection	
ke	0.5e-6	1.0e-6	10.0e-6	Evaporation efficiency parameter	
tau	1800.0	3600.0	28800.0	Convective time scale	

The Metric: Relative Euclidean Distance

Wu et al. 2012, JGR

$$\mathrm{D_i} = \sqrt{\left[\frac{\left(\overline{X_{im}} - \overline{X_{io}}\right)}{\overline{X_{io}}}\right]^2 + \left[\frac{(\sigma_{im} - \sigma_{io})}{\sigma_{io}}\right]^2 + (1 - r_i)^2}$$

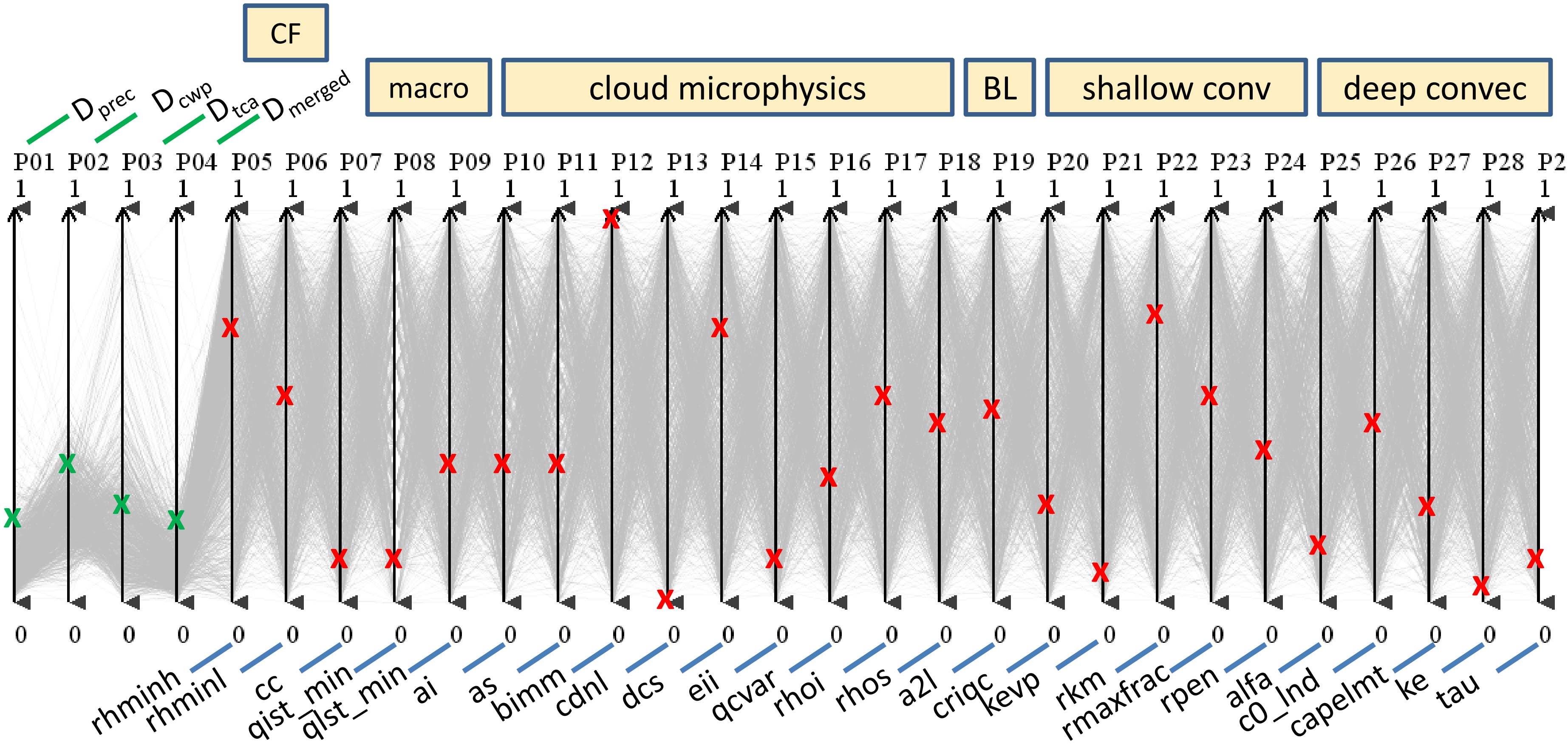
The mean, the variation, and co-variation in a single scalar.

$D = \sqrt{\sum_i D_i^2}$, when multiple quantities considered in a metric.

Assuming independence between model and observed,
and between different quantities.

Parallel coordinate view of 1024 realizations,

with quasi Monte Carlo parameter sampling

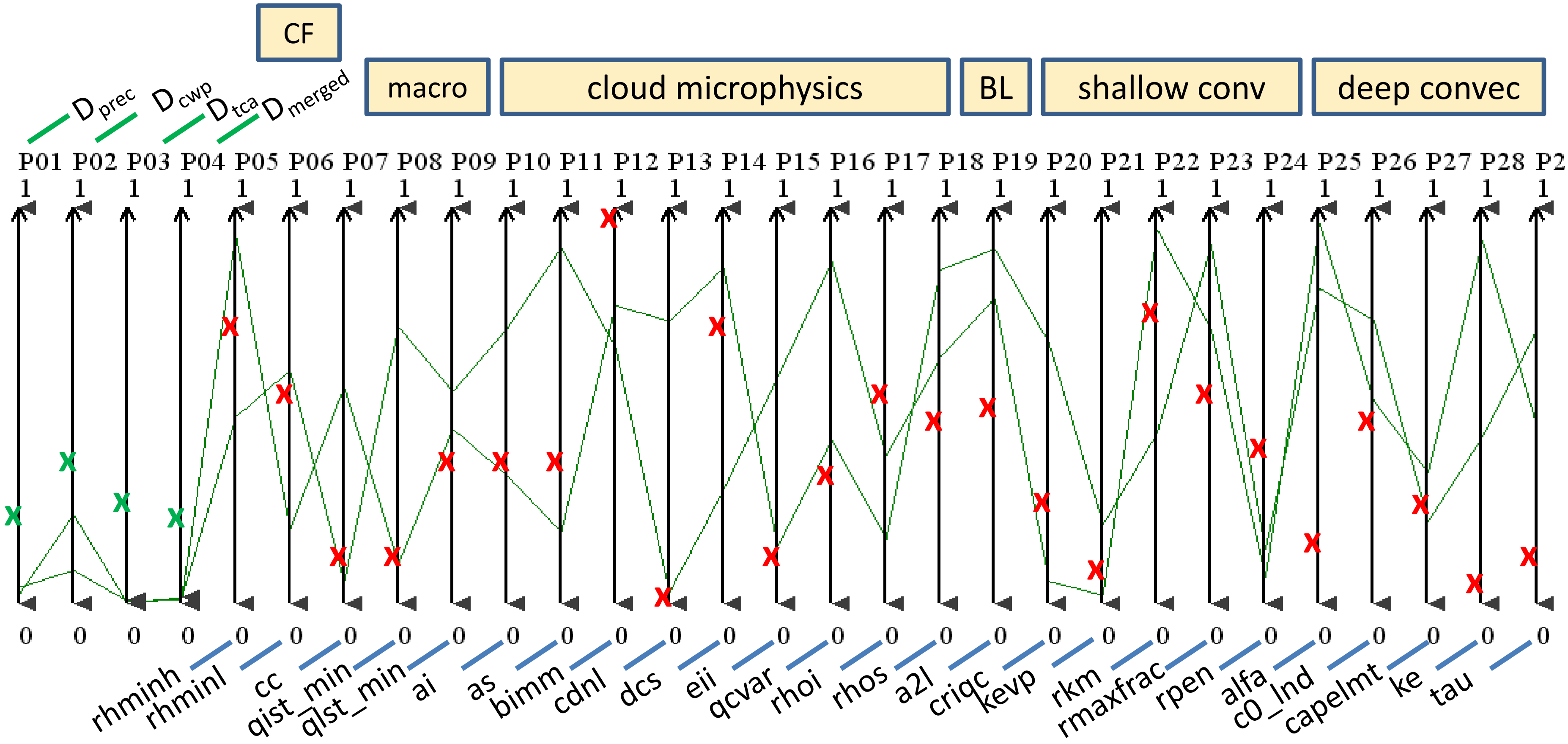


X The default values

Parallel coordinate, Müller, Zhang, and FASTER, for analysis & visualization of high-dimensional data space

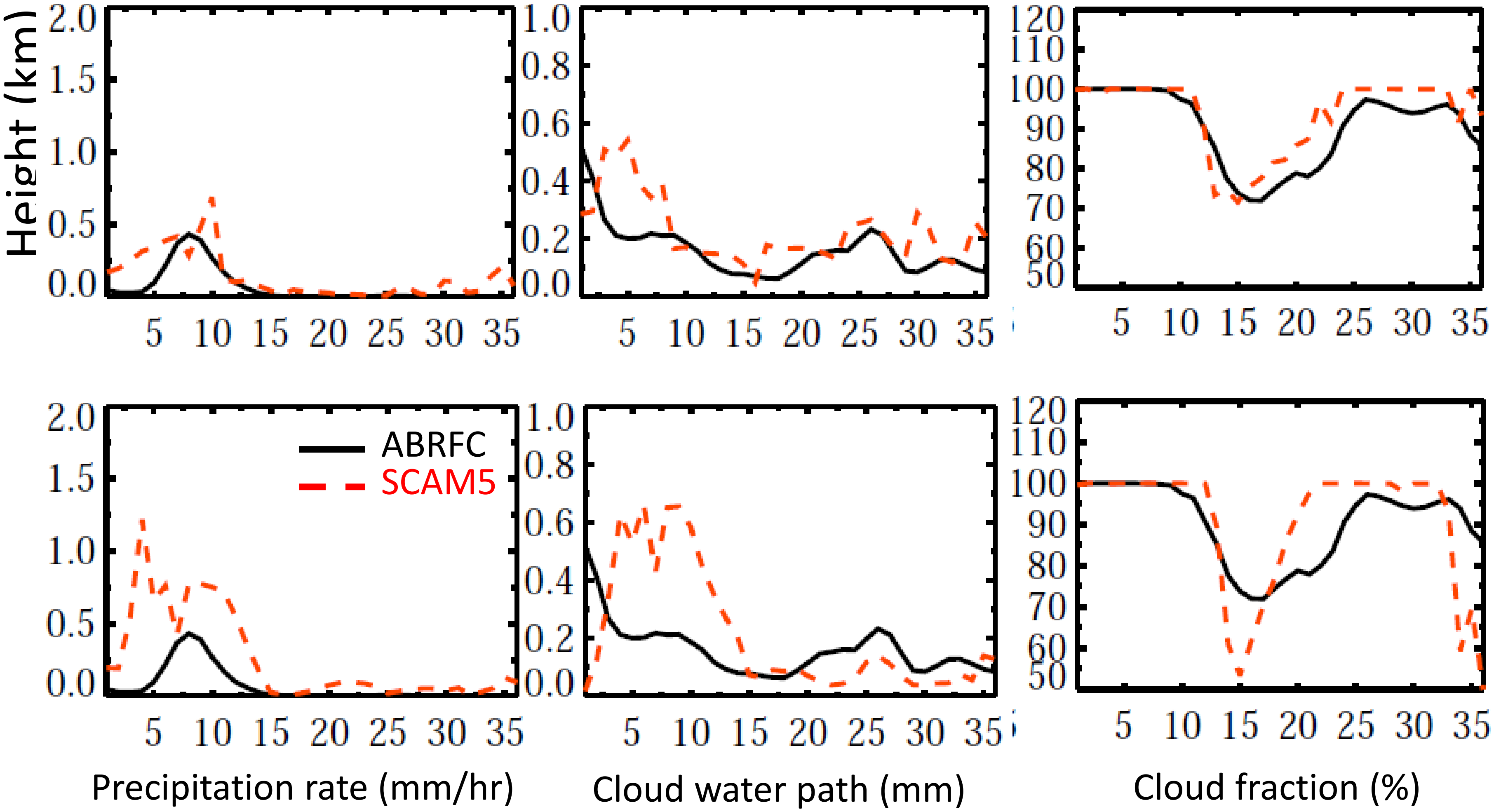
When the relative Euclidean distances are minimized,

(presumably would lead to improved simulations in terms of the specified metric)

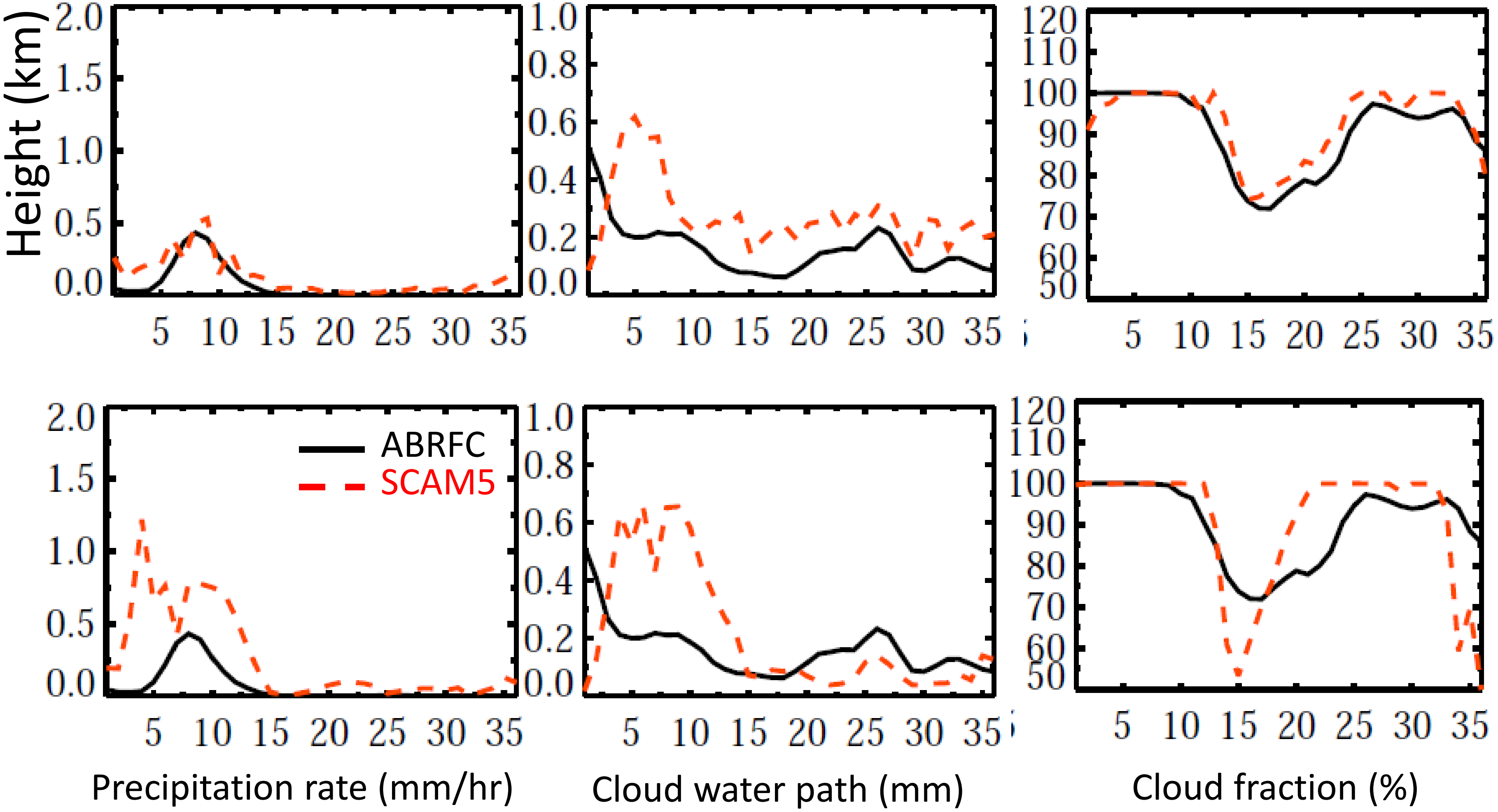


The more the range is reduced, the more sensitive the simulation is to the parameter.

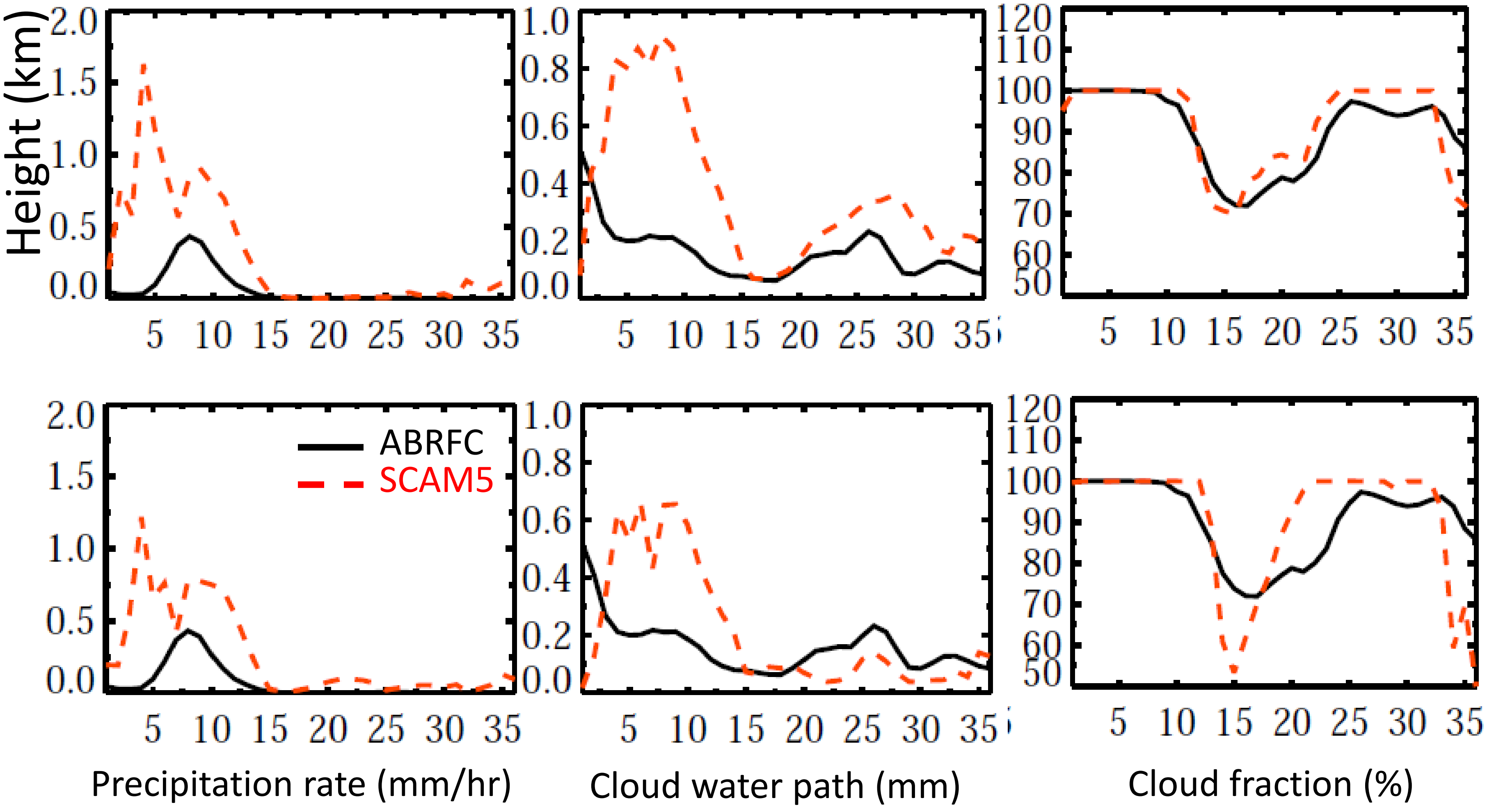
optimized parameters (top) vs. standard



optimized parameters (top) vs standard



BAM (top) vs MAM3 -- implication of aerosol impact



Summary and Further works

- SCM framework coupled with exhaustive parameter space sampling is demonstrated to deliver improved cloud simulation. This may be an efficient and promising approach for developing and evaluation of physical parameterizations.

- To be effective, the metrics used must be sufficiently representative of the target subject.
- Use metrics to adaptive guide the parameter sampling then optimization
- To translate SCM-based results to full model scale, diversified cloud and dynamical regimes must be included. This is doable with the ARM’s long-term and distributed measurement network, and FASTER’s establishment of cloud regimes.