Small-scale cloud variability from ARM observations and its implications for parameterizations

Dong Huang

Brookhaven National Laboratory

Stochastic parameterizations based on subgrid-scale variation

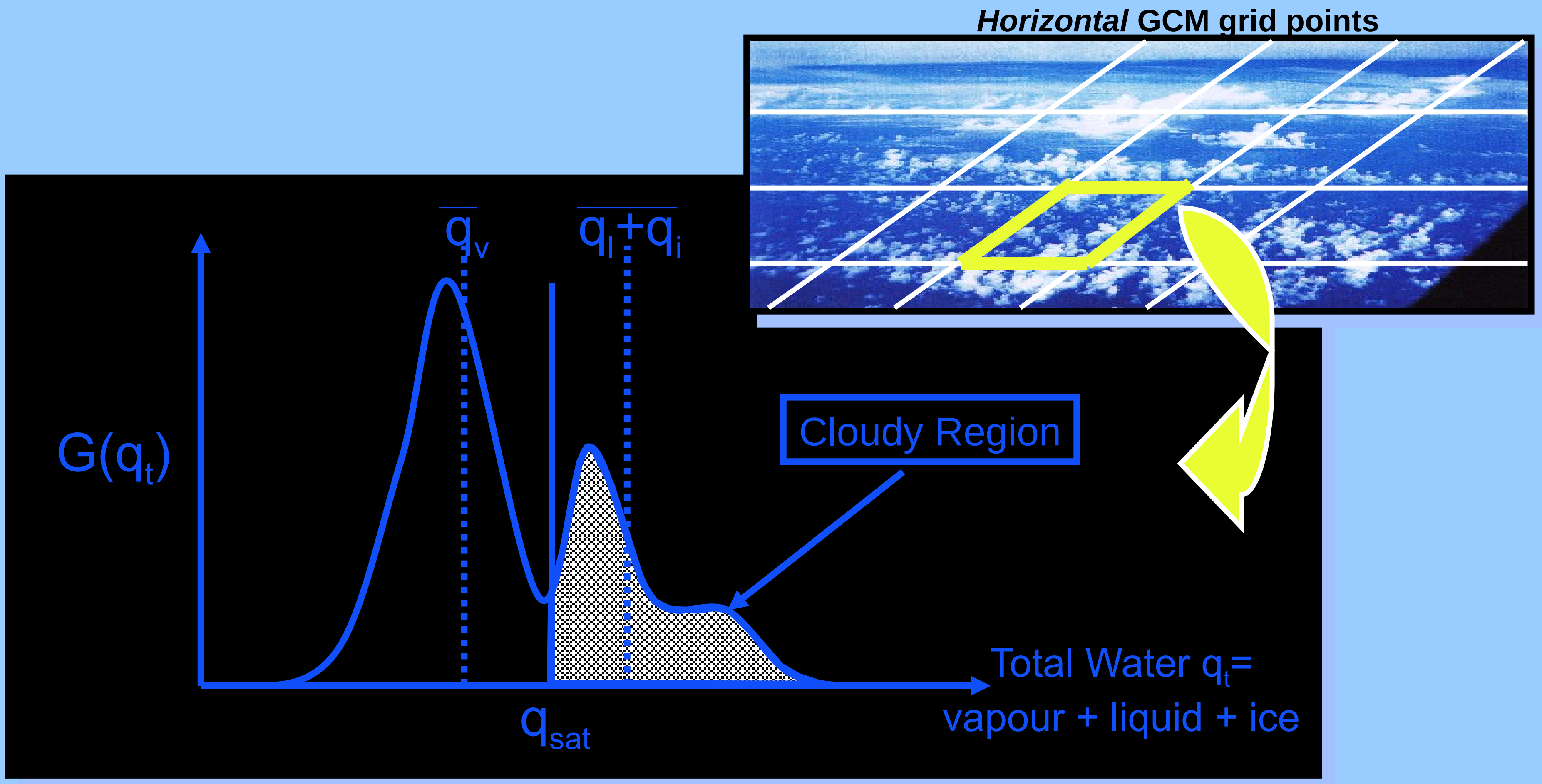
Small-scale fields of clouds and other relevant properties are not predictable at climate scales.

One can use finer grids and try to "resolve" more processes (e.g., deep convection) instead of parameterizing them (each run gets one realization of the stochastic system).

Climate models need only a few statistical moments of these small-scale fields.

Their impacts on large-scale can and should be treated stochastically.

PDF Schemes for Cloud Parameterization



Courtesy of Tompkins

CLUBB (Cloud Layers Unified By Binormals)
Unified parameterizations of convection, turbulence transport, etc.

PDFs can serve as the basis for other relevant parameterizations.

For local processes (e.g., some cloud microphysical processes), grid average can be obtained by a simple integration:

$$\overline{A(q_l)} = \int P(q_l) A(q_l)\, dq_l$$

Grid average autoconversion

PDF

"Local" autoconversion rate

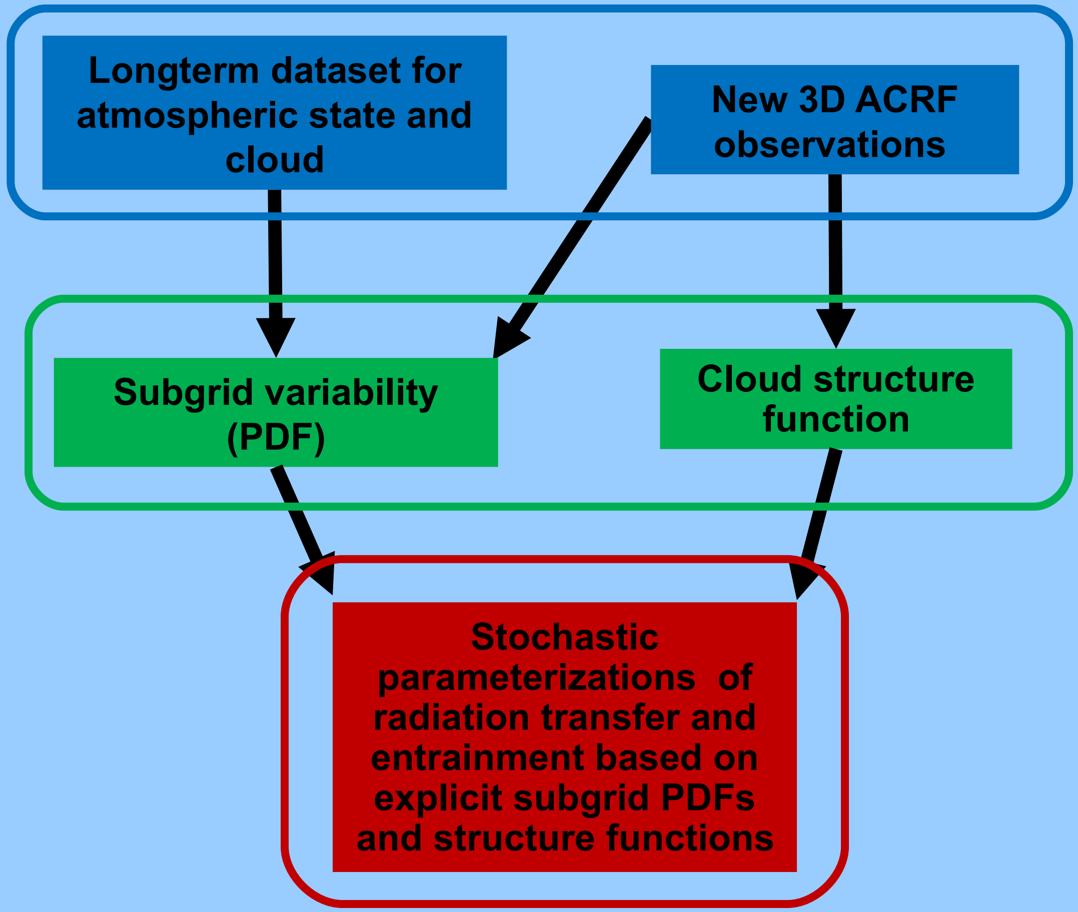
Larson et al. (2002)

Sometimes structure (two-point or multi-point statistics) also matters.

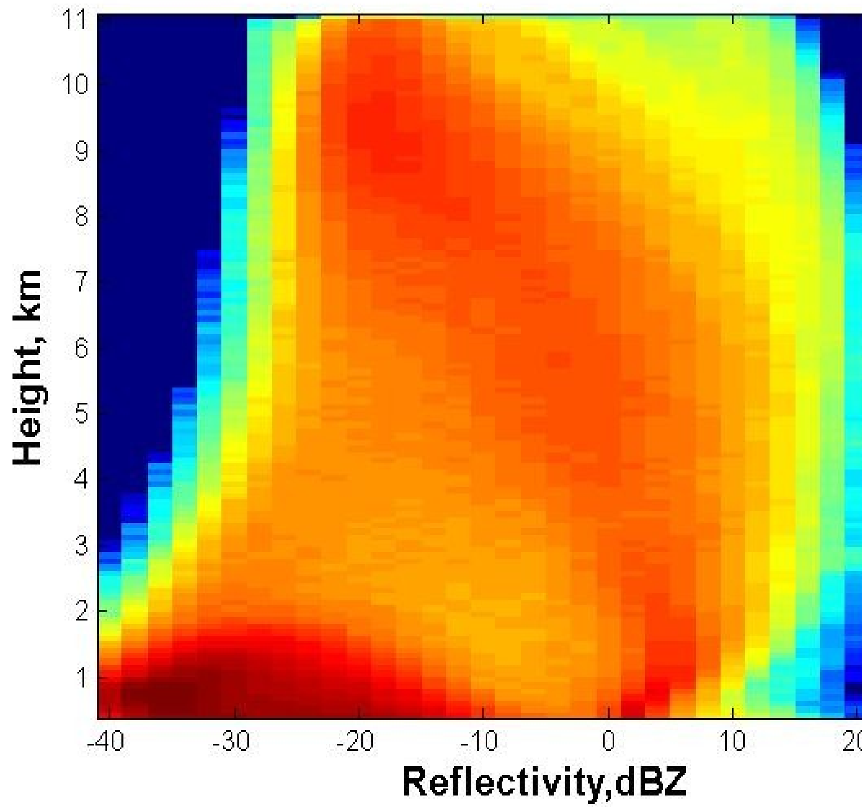
Radiative transfer

entrainment

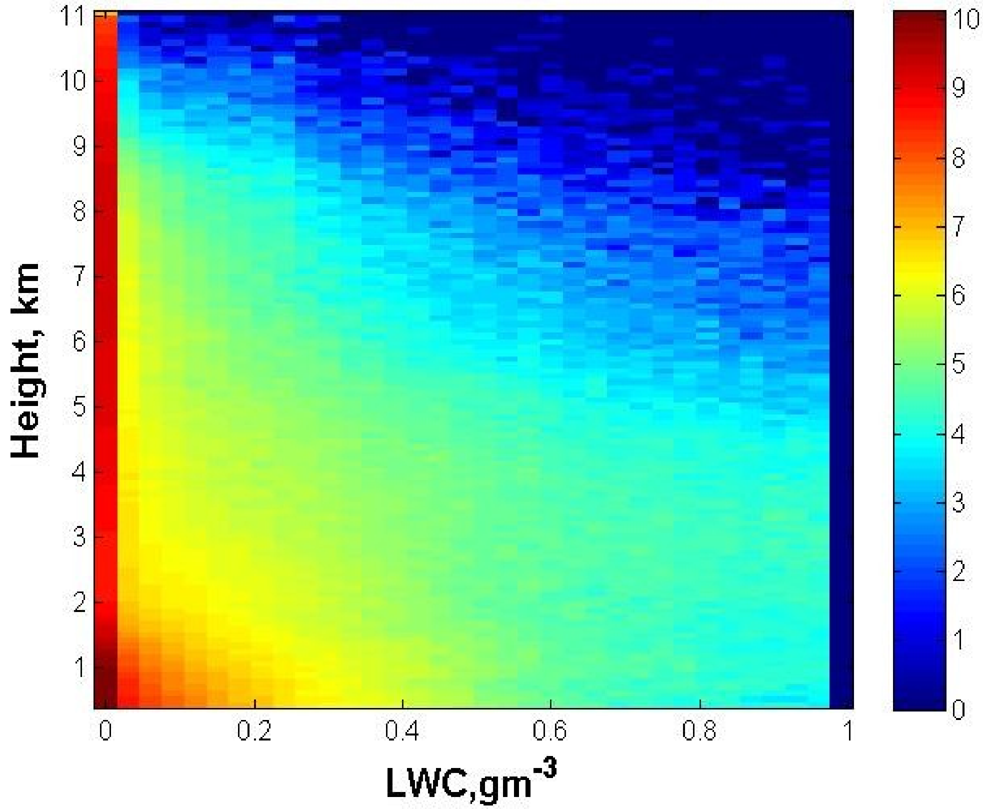
precipitation



PDFs

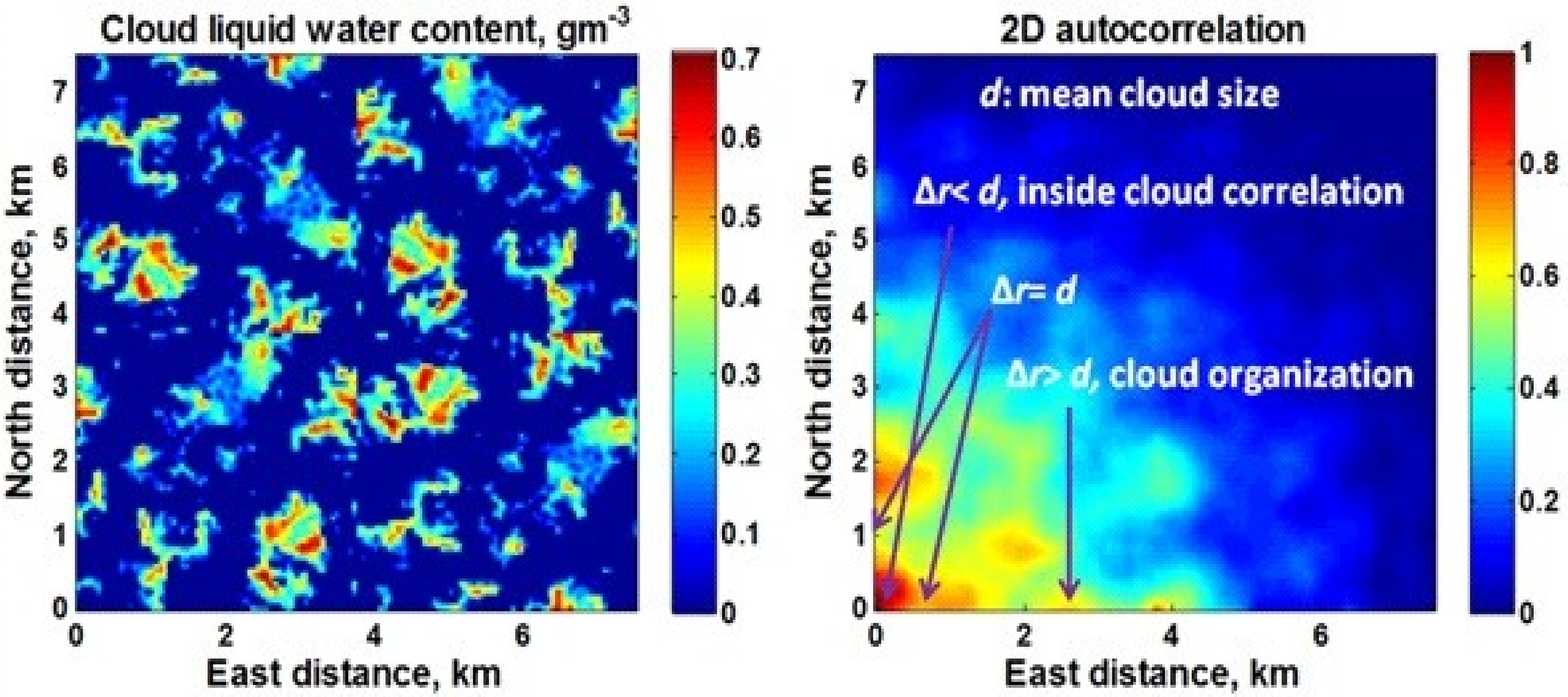


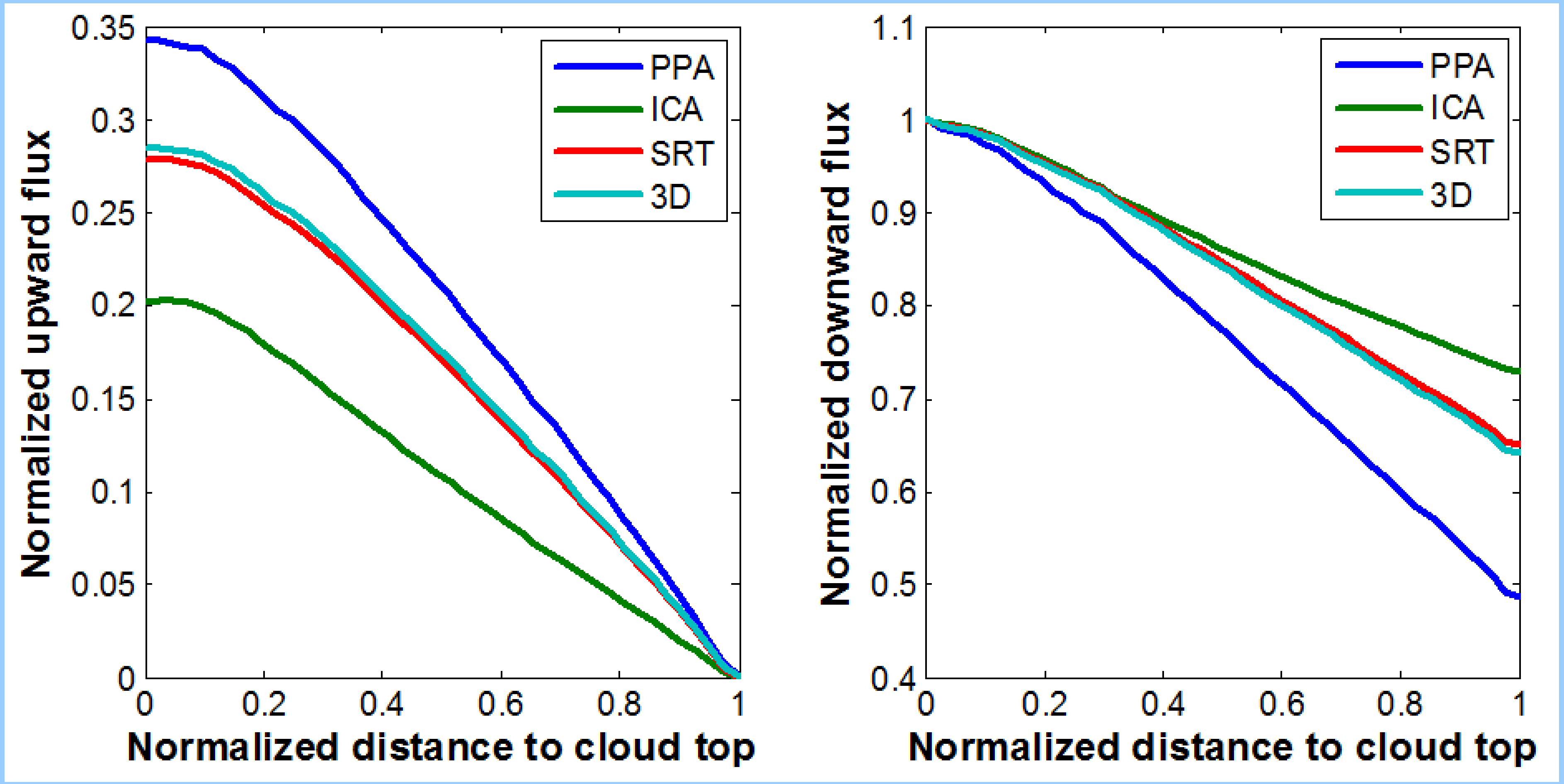
Height, km
Reflectivity,dBZ
11
10
9
8
7
6
5
4
3
2
1
-40
-30
-20
-10
0
10
20



Height, km
LWC,gm^{-3}
11
10
9
8
7
6
5
4
3
2
1
0
0.2
0.4
0.6
0.8
1
10
9
8
7
6
5
4
3
2
1
0

An example of structural function (two-point correlation)





PPA: Plane-parallel approximation

ICA: Independent column approximation (use PDF)

SRT: Stochastic RT (use PDF and structural function)

3D: Monte Carlo RT (use full 3D clouds)

"Improved physical description does not necessarily immediately provide a better concordance between model results and available observations. This is nevertheless an improvement of the basis for further development of both models and theory. That is why you can accept that a new model version performs somewhat worse than the old version, at least as an intermediate stage in the development process, if the changes in the model are justified by a physical reasoning."