A PDF based parameterization of microphysical variability in cumulus convective clouds

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Support by the US Office of Naval Research is greatly appreciated

16th EMS Annual Meeting

12–16 September 2016 | Trieste, Italy

conversion rates are local

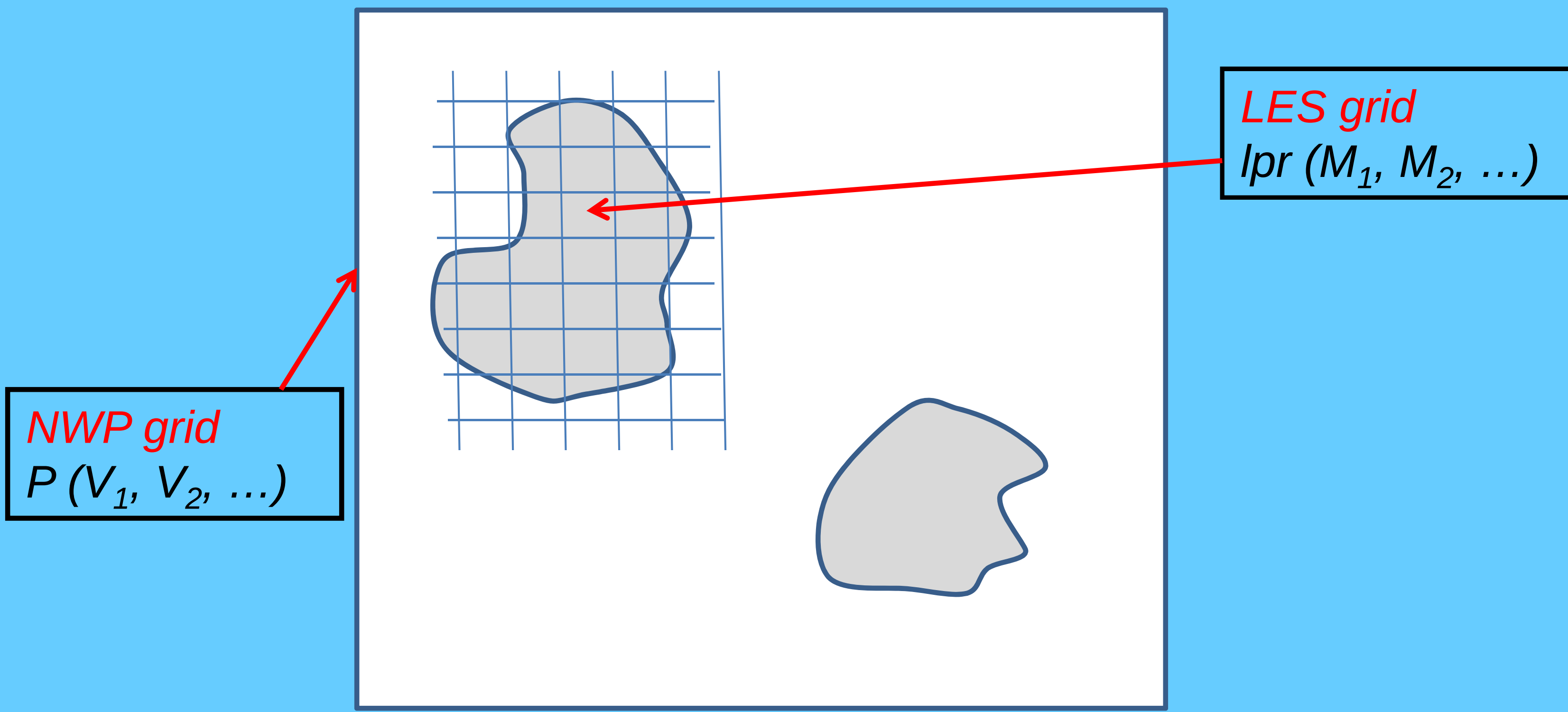
Parameterization of microphysics in <u>mesoscale models</u> needs to account for sub-grid variability

$$\frac{\partial q_r}{\partial t} = -\frac{\partial u_i q_r}{\partial x_i} + \frac{\partial V_{q_r} q_r}{\partial z} + \left(\frac{\partial q_r}{\partial t}\right)_{cond} + \left(\frac{\partial q_r}{\partial t}\right)_{auto} + \left(\frac{\partial q_r}{\partial t}\right)_{accr} + \frac{\partial}{\partial x_i} K \frac{\partial q_r}{\partial x_i}$$

Autoconversion $$\left(\frac{\partial q_r}{\partial t}\right)_{auto} = 7.98 \times 10^{10} q_c^{4.22} N_c^{-3.01}$$

Accretion $$\left(\frac{\partial q_r}{\partial t}\right)_{accr} = 8.53 q_c^{1.05} q_r^{0.98}$$

Kogan Y. L., 2013: A Cumulus Cloud Microphysics Parameterization for Cloud-Resolving Models. *J. Atmos. Sci.*, **70**, 1423-1436.



$$P(V_1,V_2,\ldots)=\int lpr(M_1,M_2,\ldots)\,pdf_k(V_1,V_2,\ldots)\,cf\,(V_1,V_2,\ldots)\,dM_1 dM_2\ldots$$

Model and Simulations

SAM-BM: SAM-EX, but bulk microphysics

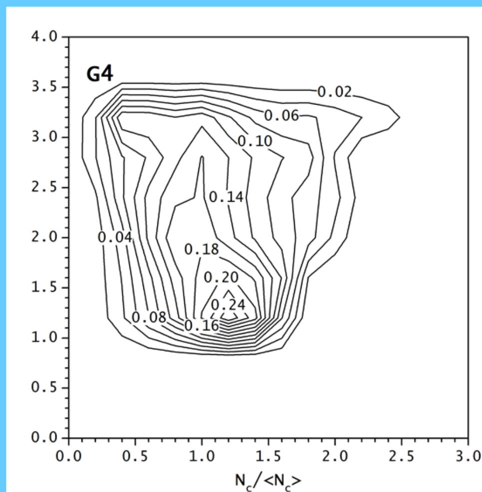
Δh=100 m; Δz=40 m; L ~ 51 km 512x512x100

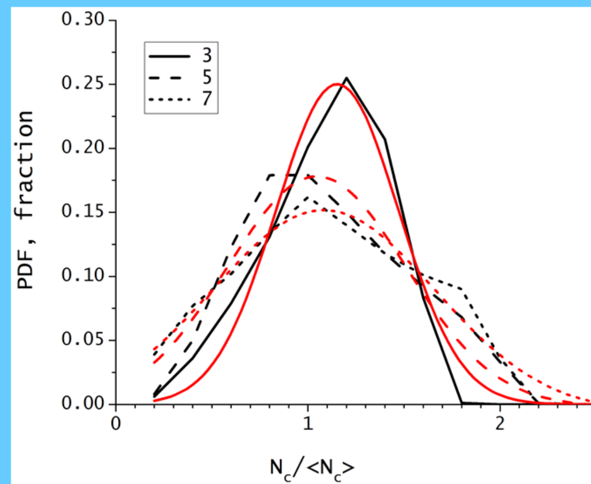
RICO	**Trade wind shallow Cu**
TOGA COARE	**Cu congestus**
VOCALS	**Sc clouds**

Kogan, Y. L., D. B. Mechem, 2016: A PDF-Based Formulation of Microphysical Variability in Cumulus Congestus Clouds. *J. Atmos. Sci.*, 73, 167-184.

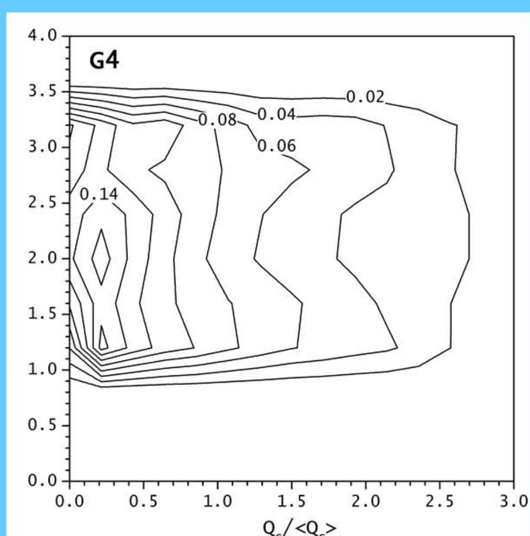
Kogan, Y. L., D. B. Mechem, 2014: A PDF based microphysics parameterization for shallow cumulus cloud. *J. Atmos. Sci.*, 71, 1070-1089.

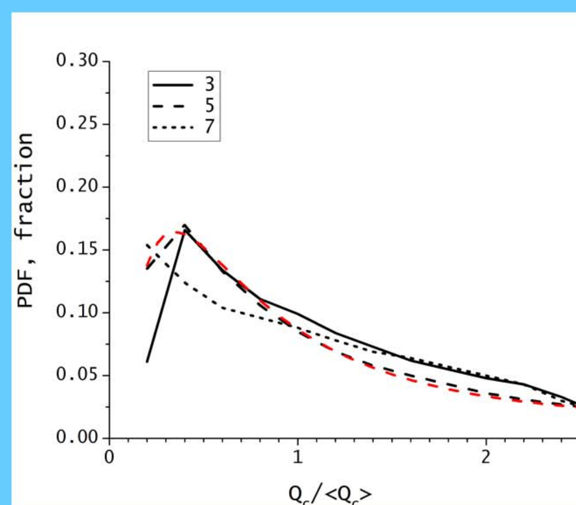
$$\varphi = q_c / \overline{q_c} \qquad \psi = N_c / \overline{N_c} \qquad \zeta = q_r / \overline{q_r}$$





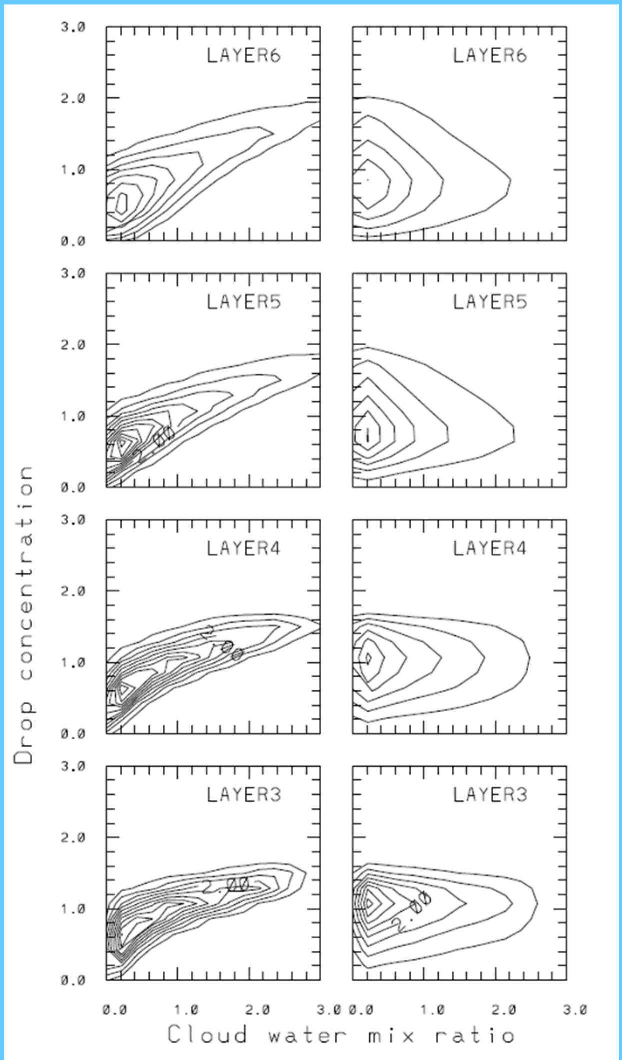
***$N_{c:}$* Gaussian**



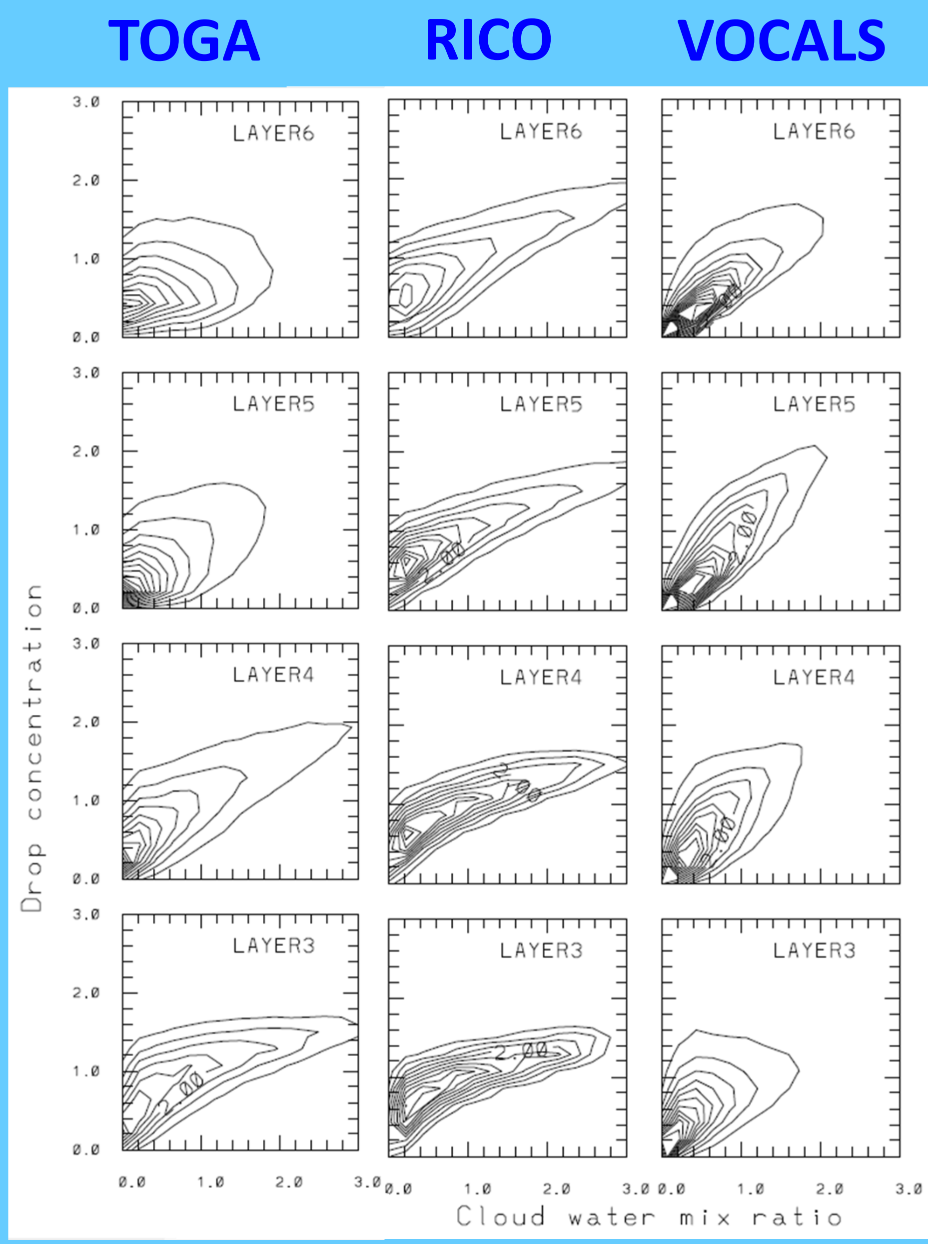


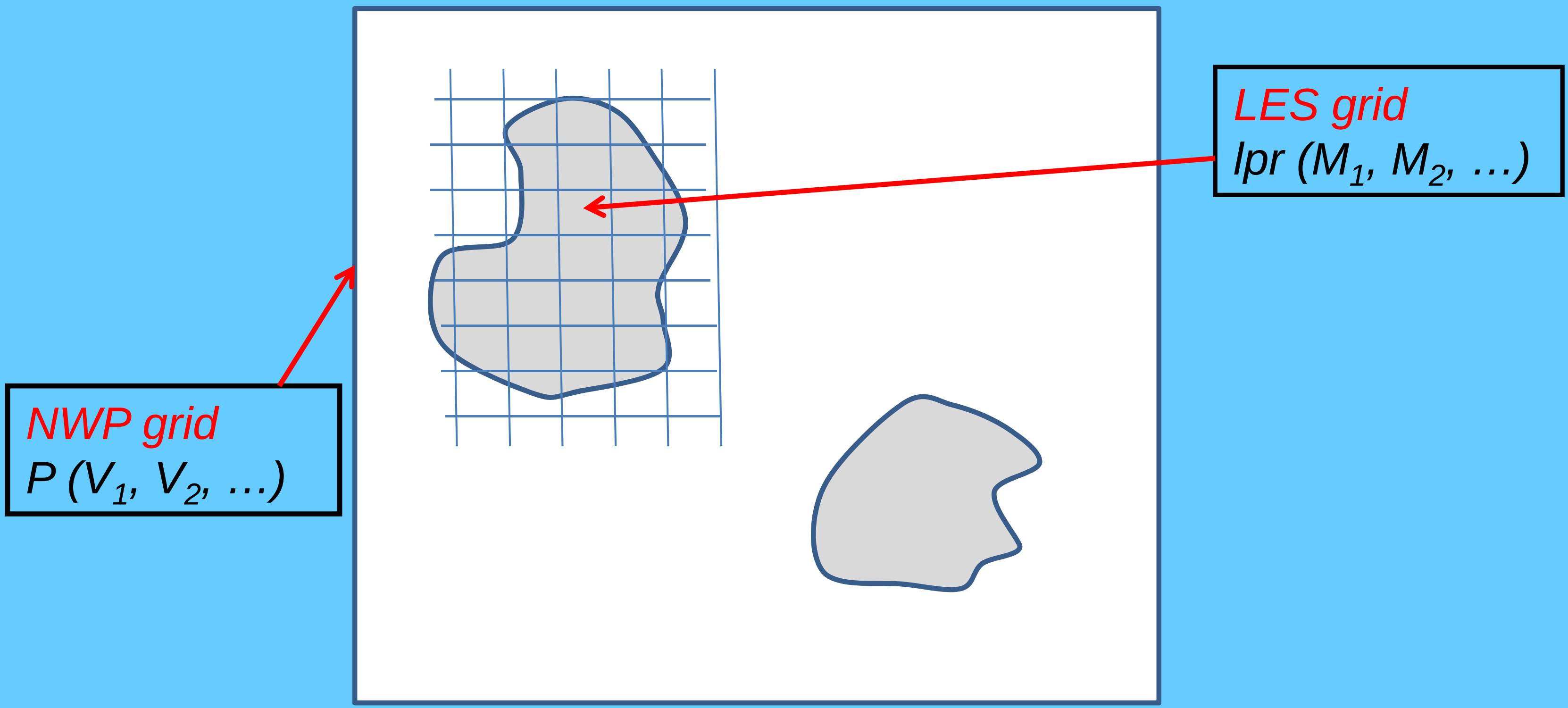
***Q_c*: Log-normal**

2D joint PDF(*Qc, Nc*) vs PDF(*Qc*)*PDF(*Nc*)



JPDFs of qc, nc

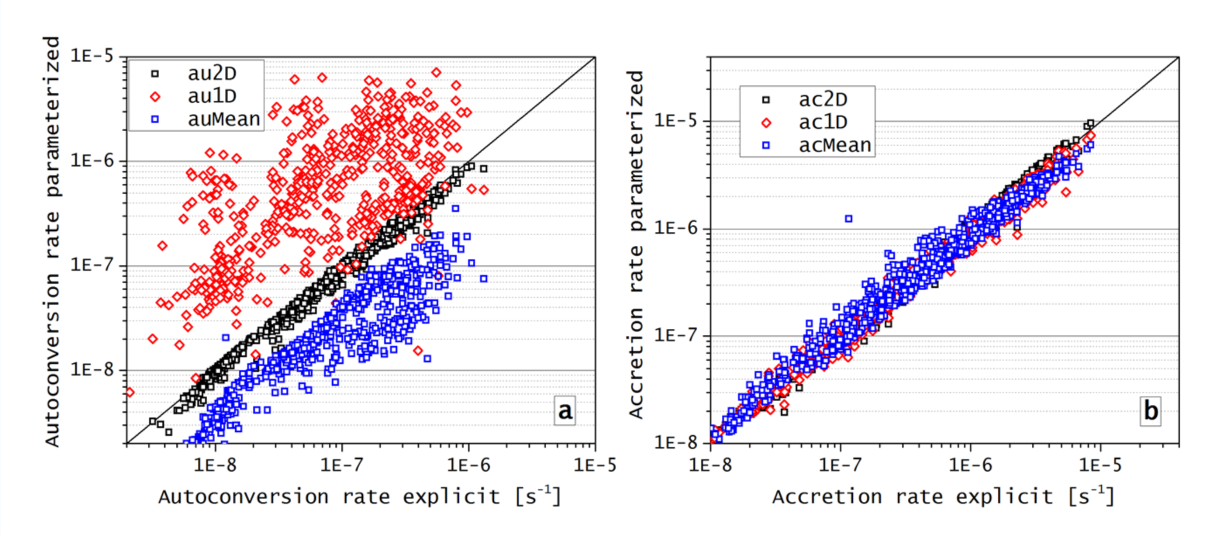



LES grid
Ipr (M_1, M_2, …)
NWP grid
P (V_1, V_2, …)

Testing of different PDF formulations:

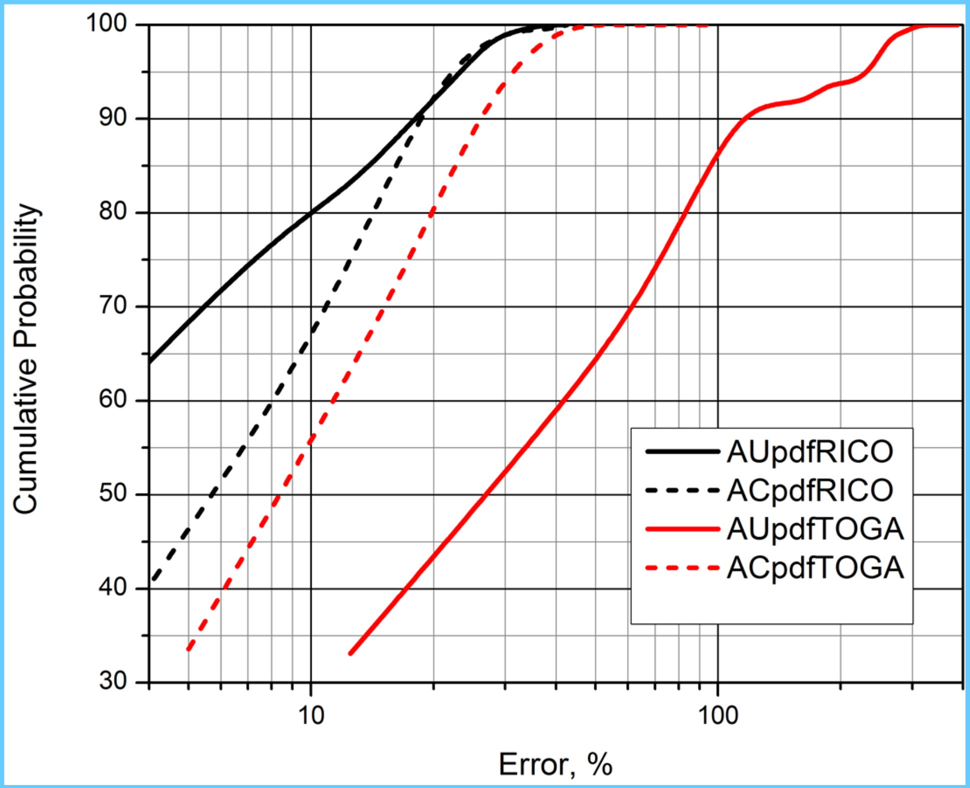
Joint 2D, 1Dx1D, no PDF

Autoconversion Accretion



TOGA vs RICO PDF comparison

Err=(P/E-1)*100.



RICO simulation: TOGA vs RICO pdfs

Solid: autoconversion
Dashed: accretion

Questions

1. Which processes/errors are more important, which are less?
2. How errors in rates translate to forecast errors?

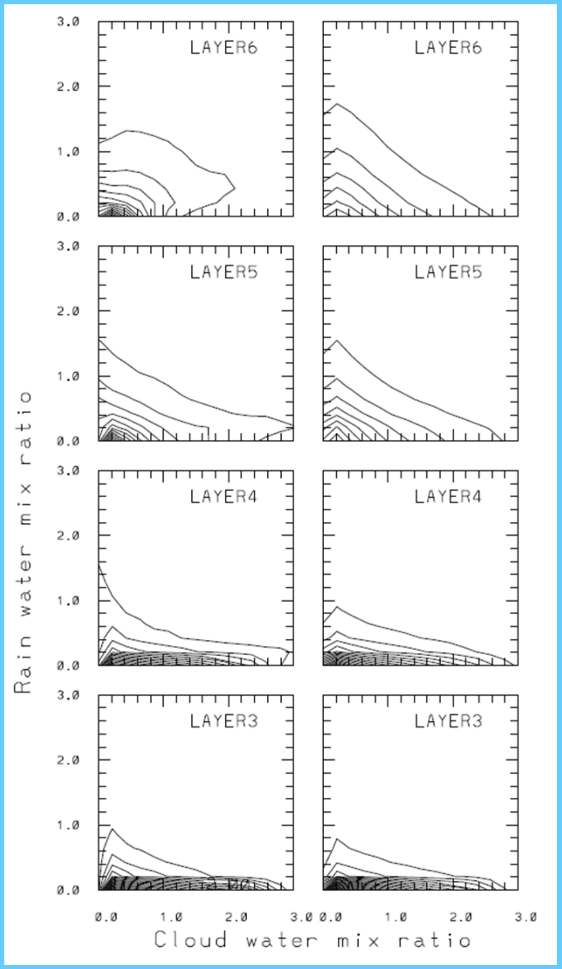
One size fits all?

- A “unified” PDF may not be possible

- “Smart” NWP models should be able to recognize cloud type at particular regions and apply correct PDF formulation

2D joint PDF(q_c, q_r) vs PDF(q_c)xPDF(q_r)

RICO



TOGA