An efficient method to account for microphysical inhomogeneity in mesoscale models

Yefim Kogan

NorthWest Research Associates
Redmond, WA

Supported by the US Office of Naval Research

EGU General Assembly 2020
4-8 May 2020 , Vienna, Austria

Problem

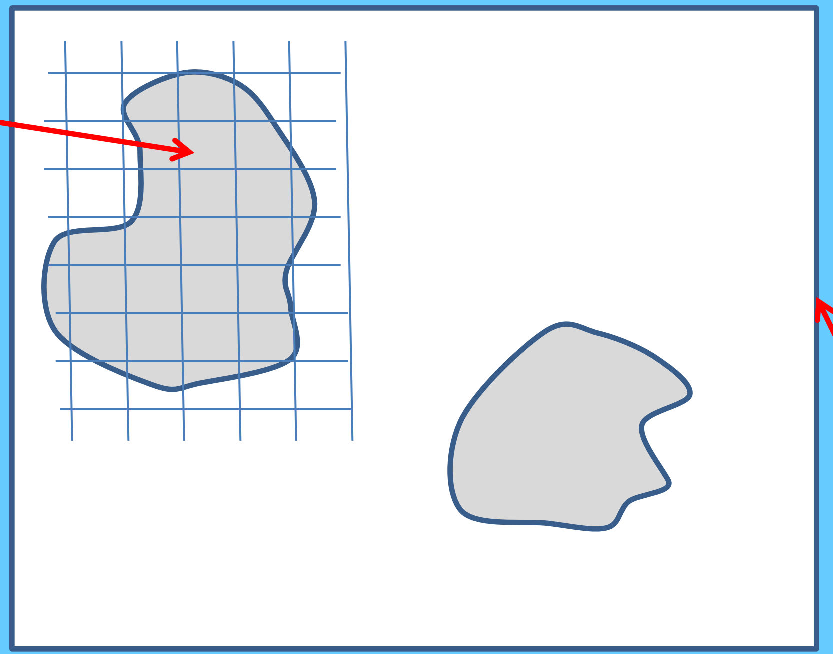
Accounting for microphysical inhomogeneity in mesoscale/NWP models requires averaging *local* process rates over mesoscale grid

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

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

Approach

1. **LES experiments in a domain size of a mesoscale grid**
2. **Use high resolution LES data to calculate Joint PDF of microphysical variables and conversion rates**



mesoscale /NWP model requires averaging *local* process rates (*lpr*) over a mesoscale grid using Joint PDFs (JPDF) of q_c, N_c

NWP averaged Process rate

$$P(V_1,V_2,\ldots) = \int lpr(q_c, N_c)\, JPDF\, (V_1,V_2)\, dq_c dN_c$$

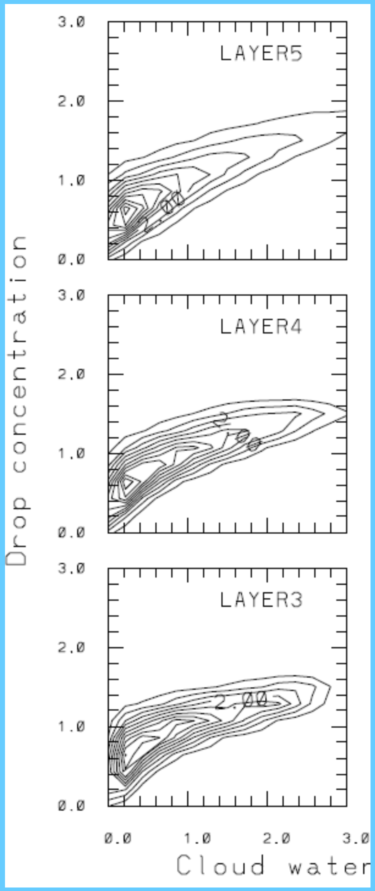
LES data:

- **Source for JPDFs and parameterization development**
- **Benchmark for parameterization verification**

RICO project studied trade wind shallow Cu

Examples of Autoconversion JPDF (qc, nc)

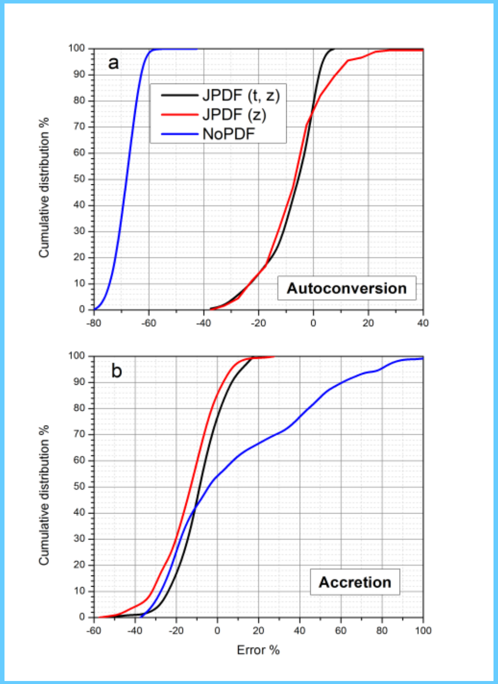
RICO



Benchmark JPDF are obtained from time-dependent dataset of a cloud system as it evolves under changing ambient conditions

"Generic" JPDF – from the whole dataset characterizing the cloud system as a whole

RICO



1. **Errors of the *Generic* JPDF are about the same as for the *Benchmark* JPDF (black vs red curves)**
2. ***Generic* JPDFs can be a-priori integrated to yield a 1D *V-factor***
3. **This *V-factor* is a function of *z* only**

Process rates can be a-priori integrated using Generic JPDF

$\varphi = q_c / \overline{q_c}$ $\psi = N_c / \overline{N_c}$ Non-dimensional cloud mixing ratio and drop concentration

Mesoscale autoconversion rate - ntegrate generic JPDF

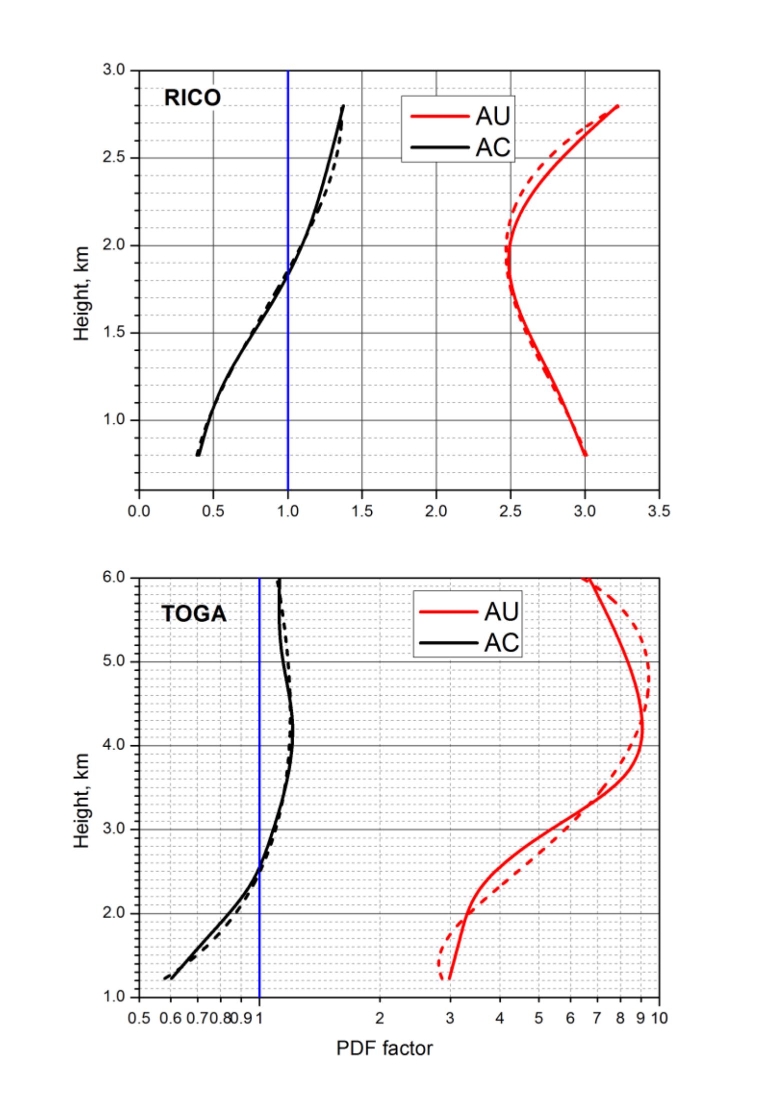
$$\overline{R}_{auto} = \overline{C_{au} q_c^{\alpha} N_c^{\beta}}_{\,c} = C_{au} \left(\overline{q_c}\right)^{\alpha} \left(\overline{N_c}\right)^{\beta} \iint \varphi^{\alpha} \psi^{\beta} \, \Omega\Big|_{\overline{q_c}\,\overline{N_c}} (z,\varphi,\psi)\, d\varphi d\psi$$

Result of integration:

<u>1D variability factor which is a function of *z* only</u>

$$\overline{R}_{auto} = C_{au} \left(\overline{q_c}\right)^{\alpha} \left(\overline{N_c}\right)^{\beta} V_{au}(z)$$

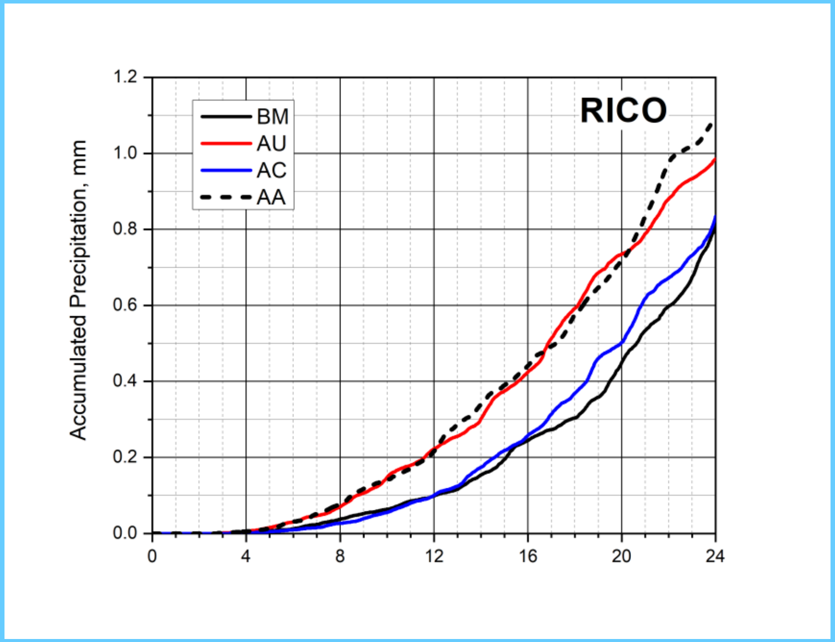
V-factor profiles



Can be analytically approximated by 3rd order polynomial (dashed lines)

$$V_{au}(z) = \sum_{i=0}^{3} A_i z^i; \quad V_{accr}(z) = \sum_{i=0}^{3} B_i z^i$$

Including the *V-factor* (inhomogeneity) increased surface precipitation in LES experiments



BM -benchmark run (no V-factor)
AU -run with autoconversion V-factor
AC -run with accretion V-factor
AA -run with both factors included

Conclusions

1. ***V-factor* can be easily implemented in mesoscale models**
2. **Inhomogeneity potentially can significantly increase precipitation, but mesoscale case studies are needed**
3. **Details:** *Kogan, Y. L., 2018: Using a Variability Factor to Account for Cloud Microphysical Inhomogeneity in Mesoscale Models,* **.** *J. Atmos. Sci., 75, 2549–2561*