物理過程の高精度化⇒ビン法雲微物理モデルの結果を用いた暖かい雨のバルクスキームの開発

Development of a bulk parameterization scheme of warm rain using results of a bin microphysical model for RICO case

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１． Relationship between models

⇒objectives：To improve bulk parameterization scheme using bin model results.

２． Model setting and results of numerical experiments

Model：CReSS, Case：RICO(trade wind cumulus)

３． Development of a bulk scheme

Ⅰ. Relationship between models

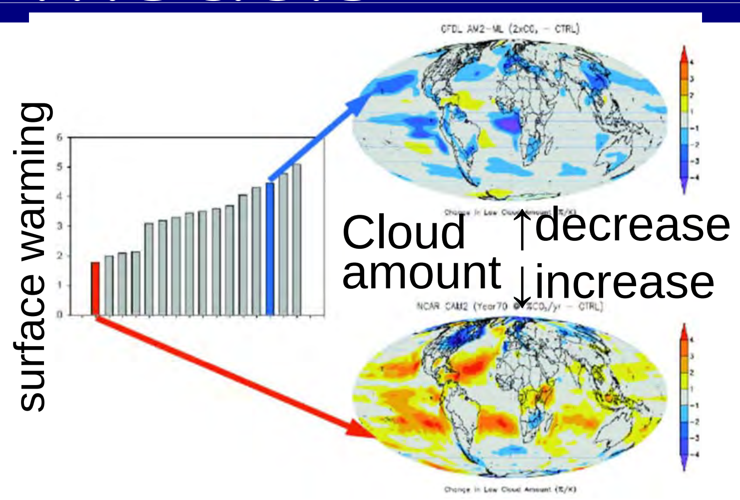
Large-Scale Model (GCM, Climate Model)
resolve larger than meso-scale
simulate heavy rainfall etc. O(Δx)>10km
using parameterization of Cu. Conv.

Dev. of Cu conv parameterization

Cu-convection Resolving Model
bulk microphysical scheme O(Δx)=100m

Dev. of bulk parameterization

Cu-convection Resolving Model
bin microphysical scheme



To improve Cu Conv para. scheme
Verified against observations.
Cu-conv. resolving models are used to produce supplementary data.

OBJECTIVES: To improve bulk parameterization scheme

How many categories (species) we should use for liquid water? two categories (cloud and rain), three categories (cloud, drizzle and rain), or more?

How many variables we should use for each categories? two(mixing ratio, number concentration), or more ?

Fields of trade wind congestus
typical cloud base 600 m
typical cloud top ~ 2000-3000 m

Example
RF-09
17 Dec 04
2004

From http://www.knmi.nl/samenw/rico/

RICO : Setting of Numerical Experiment

Grid

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

Domain Size 12.8km×12.8km× 4.0km

Number of Grids 128 x 128 x 100

Geostrophic Wind (cyclic lateral B.C.)

u : constant vertical shear $2x10^{-3}$ s^{-1}

v : uniform

pot. temp., water vapor : see Fig.1

Bottom surface B.C.

SST: 299.8 K ΔT=0.6℃

Large scale forcings

Subsidence : w = -0.005[m/s] z> 2260m

z<2260m : Constant Divergence

Horizontal advection (depending on z)

Duration : 24hours (last 4 hrs are analyzed)

Model: CReSS (Tsuboki et al.) with a bin scheme

GCSS participants

1 moment bulk

- MESO-NH
- SAM
- JAMSTEC
- Utah
- EULAG
- 2DSAM

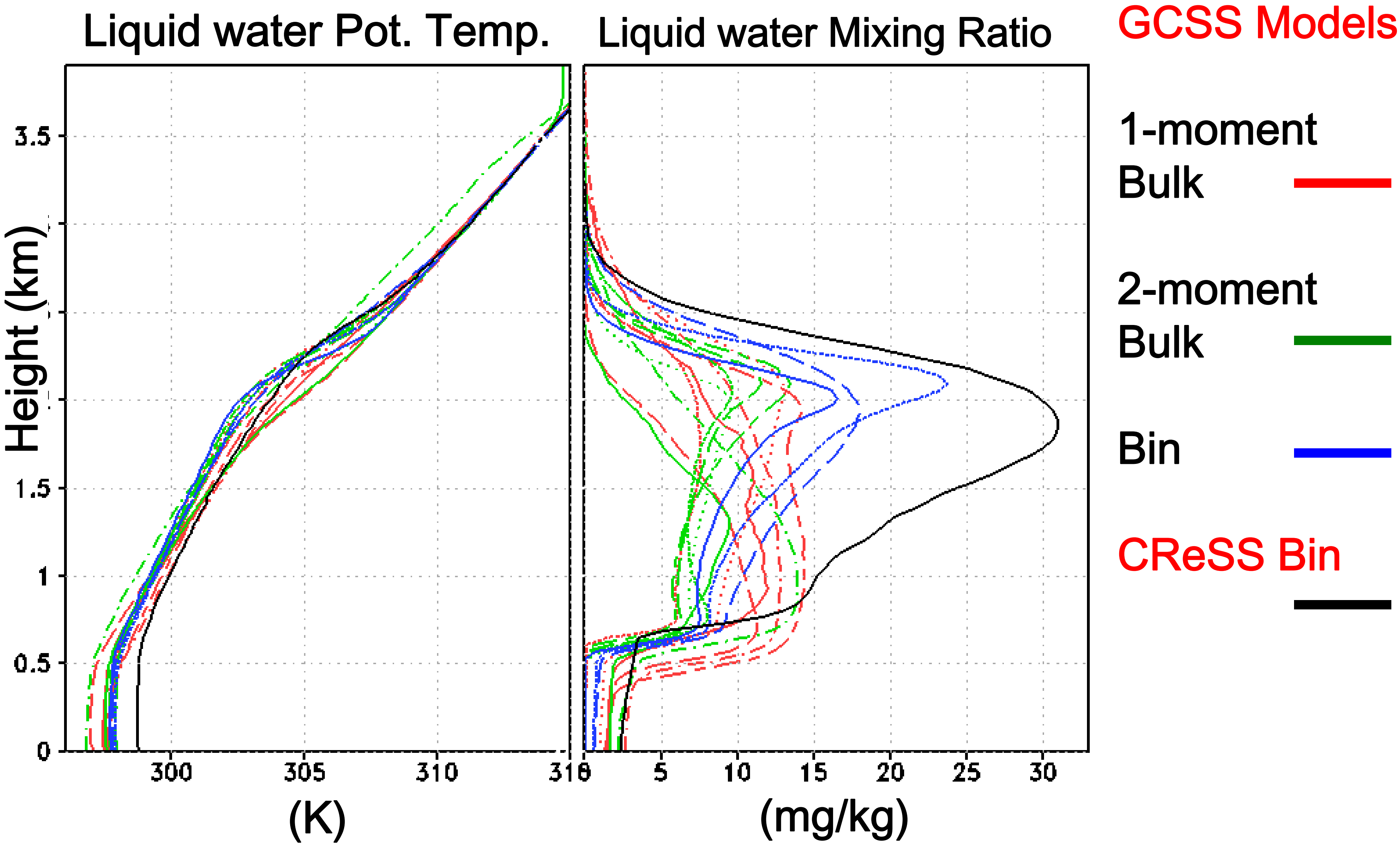
2 moment bulk

- DALES
- UCLA
- WVU
- COAMPS
- UKMO
- RAMS

bin

- RAMS@NOAA
- SAMEX
- DHARMA

Averaged vertical profiles (20-24 hr)



Rainfall Intensity and LWP (15+1 models)

GCSS models

1-moment bulk

Red Circle

2-moment bulk

Green Circle

Bin

Blue Open Circle

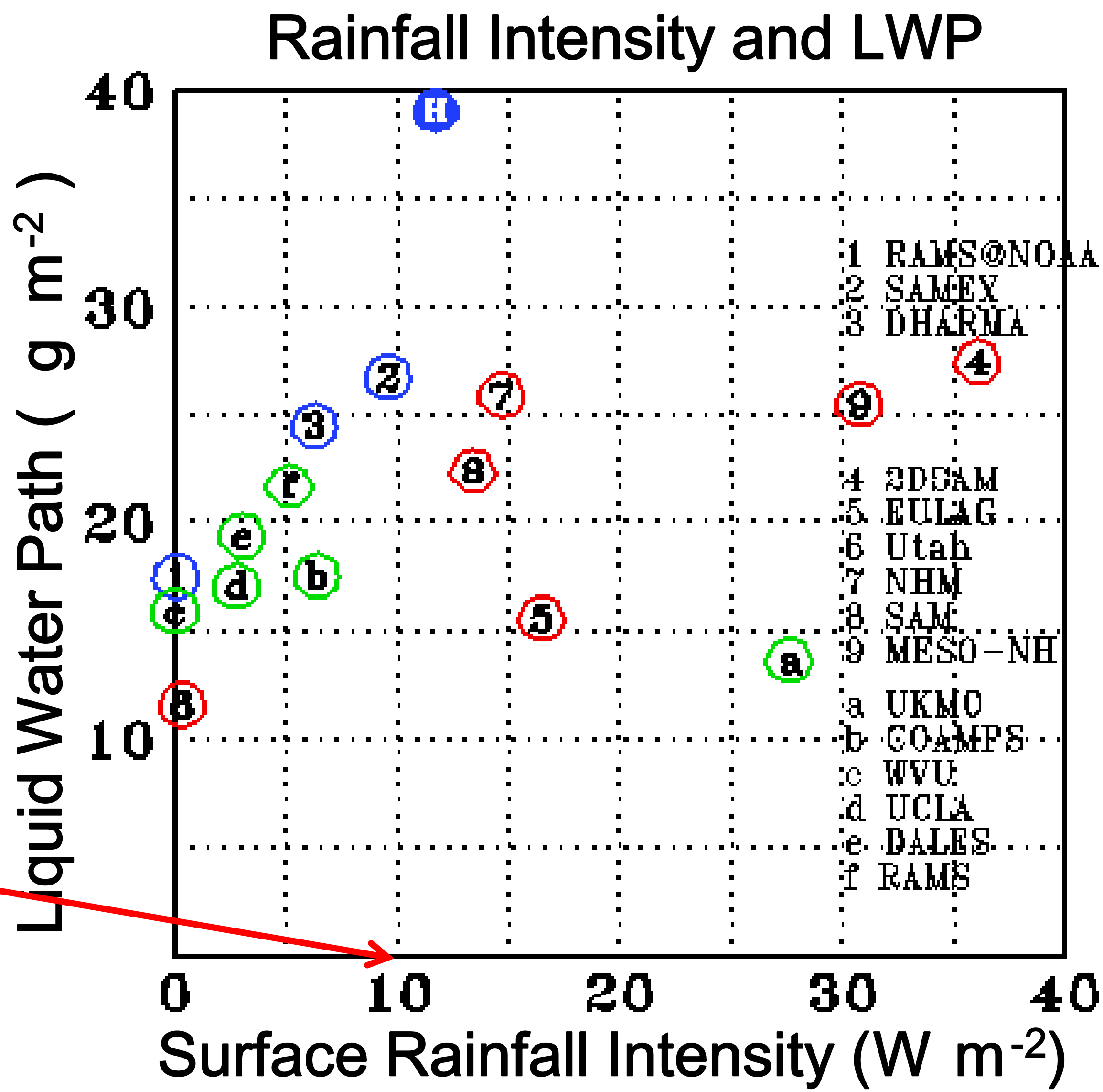
CReSS-Bin

Blue Closed Circle

(Estimates from observation is 10 W m^{-2})

→LWP might be too large.

We are examining the process using Kinetic Driver program (proposed by Shipway).



Development of a bulk scheme

Our bin model uses 70 bins from r(radius) =1μm to 2.9 mm. Two variables, mixing ratio and number concentration, are used for each bin.

As a first trial, developing a **two-categories two-moments** bulk scheme, we divide liquid particles into **two** groups, i.e., cloud droplets and rain drops, by the boundary of r=47.9μm. We use two variables for each group.

q_c and q_r : mixing ratios of cloud water and rain water, respectively.

n_c and n_r : number concentrations of cloud water and rain water, respectively.

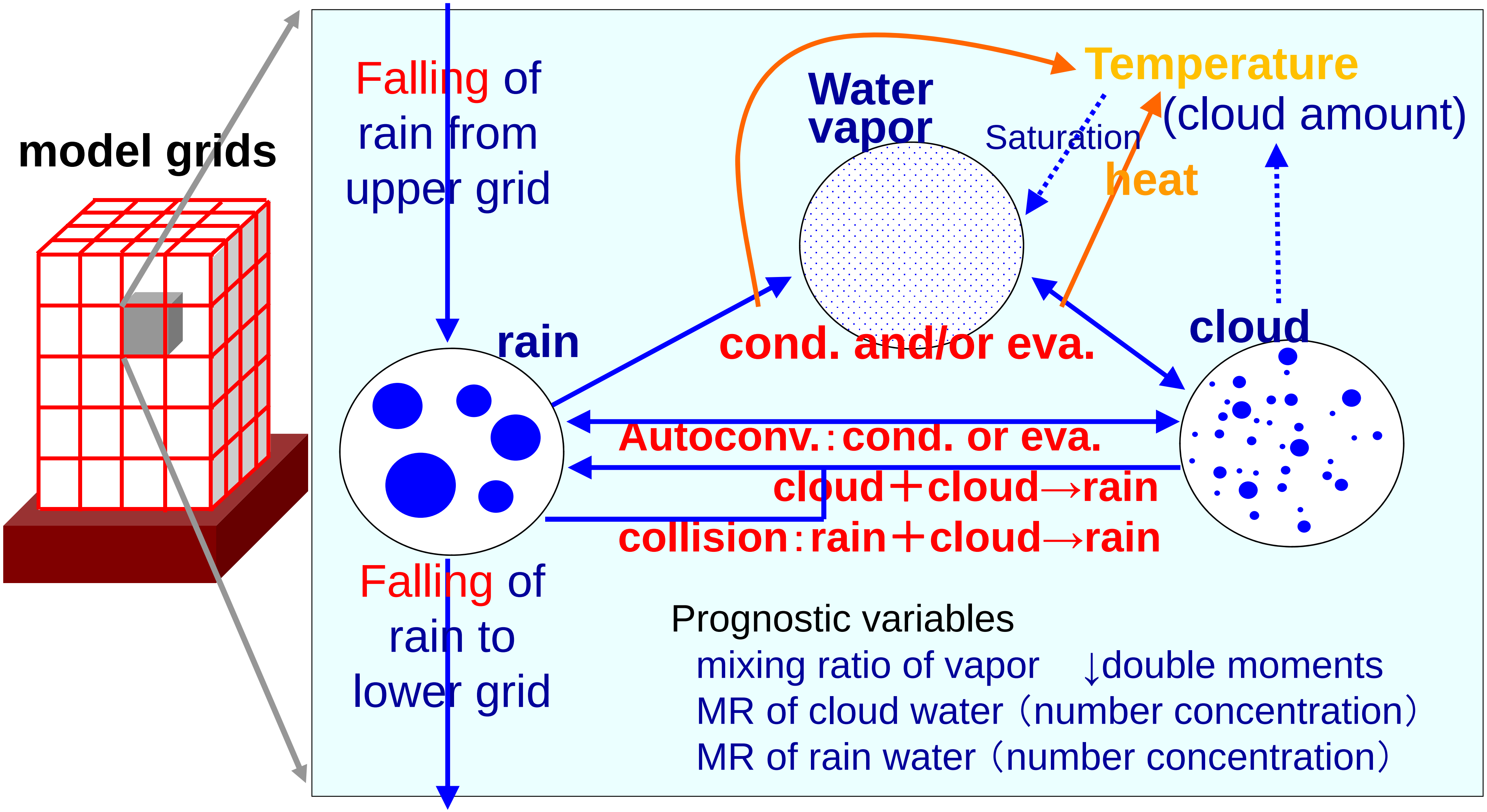
In a bulk scheme, conversion from cloud to rain is important. There are three processes.

1. condensational growth of cloud droplets to rain. Autoconversion 1.
2. collision-coalescence between cloud droplets to make rain. Autoconversion 2.
3. collision-coalescence between cloud and rain. Collision-coalescence.

Data for each process at each grid point at each time are stored during the 4 hours.

Microphysical processes in bulk scheme

Liquid water is divided into cloud (no falling) and rain (with falling)



Development of a bulk scheme

Parameterization

Process	independent variables
cond. & eva. of cloud	cloud, environment
cond. & eva. of rain	rain, environment
auto1 (c → r by cond.)	cloud, environment
auto1 (r → c by eva.)	rain, environment
auto2 (c+c → r)	cloud, environment
collision (r+c → r)	cloud, rain, environment
falling	cloud, rain, environment

For each process y, using a formula

$$\log y = a_0 + a_1 \log x_1 + a_2 \log x_2$$

the kind of variables and coefficients (a_0, a_1, a_2) are determined from the condition which gives the minimum value of

$$S = \sum_i (\log y_i - a_0 - a_1 \log x_{1i} - a_2 \log x_{2i})^2$$

example↓

$$\mathrm{Auto}_{\mathrm{Lee}} = e^{0.363} q_c^{2.184} (q_v - q_{vs})^{0.173}$$

Variables (assuming a two moment bulk scheme)

cloud : q_c, n_c, m_c(average mass), r_c(average radius), σ_{logr}, etc.

rain : q_r, n_r, m_r(average mass), r_r(average radius), σ_{logr}, etc.

environment : temp. , pot. temp., vapor mixing ratio, r.h., super.s., w, etc.

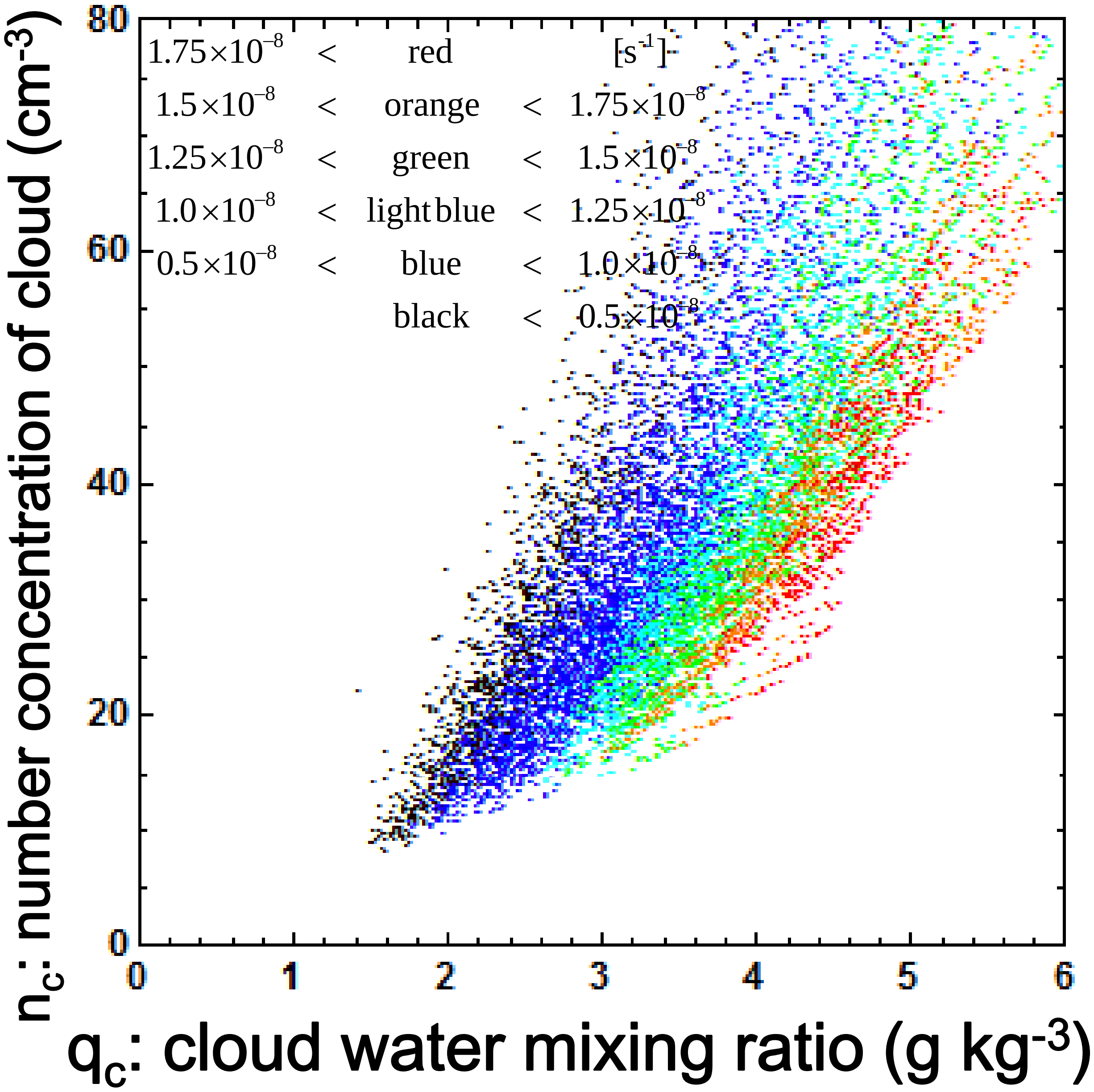
Dependence of autoconversion 2 on q_c and n_c

For autoconversion2, the combination of (q_c and n_c) gives the minimum value of S, in all the combinations of the variables in the previous slide.

Right figure shows autoconversion2 in color using the axes of (q_c, n_c) .

From small to large; black, blue, light blue, green, orange, red.

We determined the coefficients in the formula by log-linear regression.



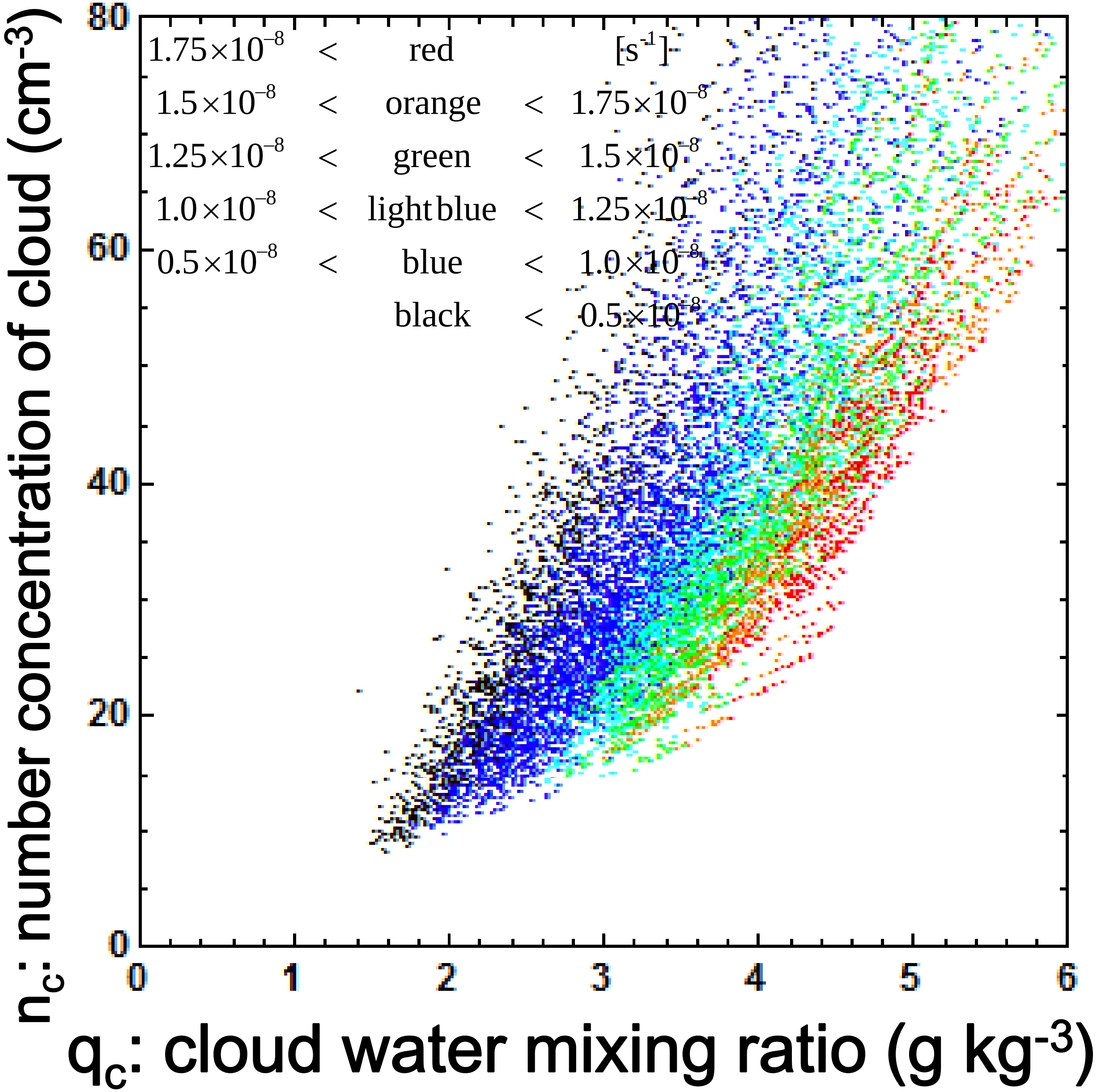
Dependence of autoconversion 2 on q_c and n_c

We compared the log-linear-fitting

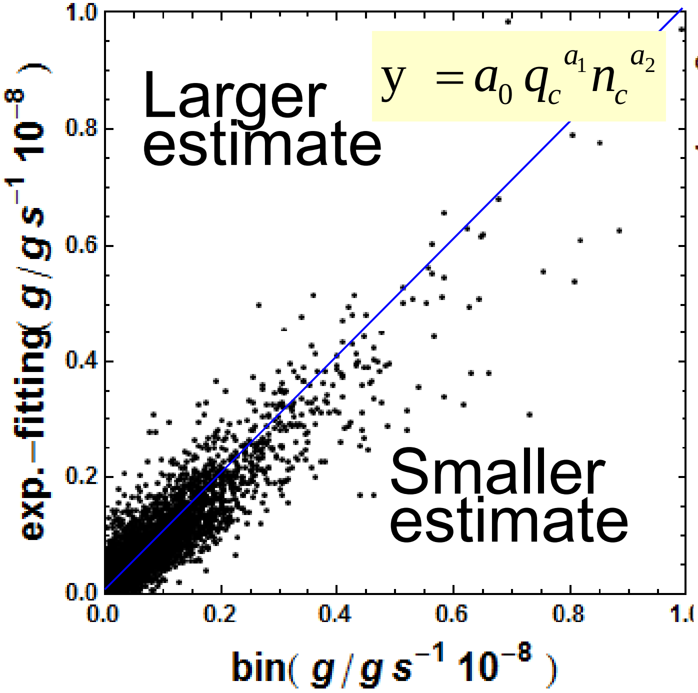
$$\log y = a_0 - a_1 \log q_c - a_2 \log n_c$$

and the exponential fitting

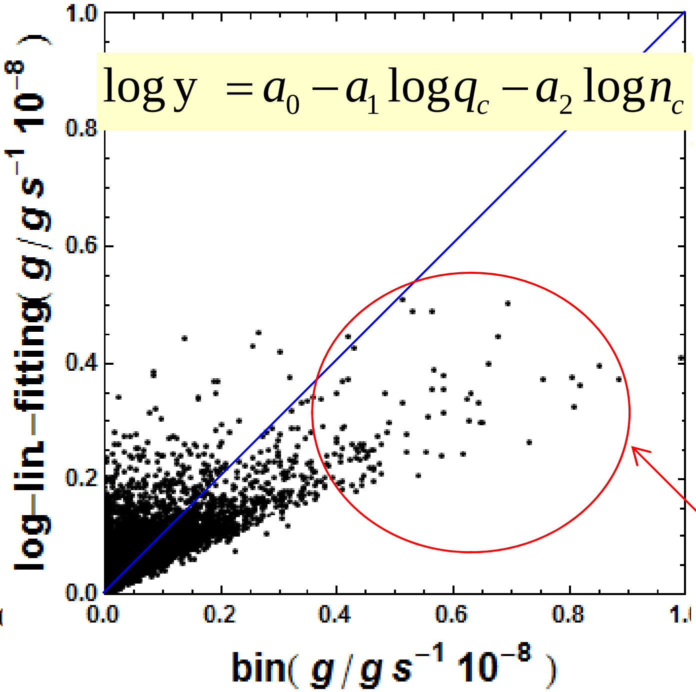
$$y = a_0 \, q_c^{\,a_1} n_c^{\,a_2}$$



Correlation between bin results and fitting results



Bin and exp.-fitting



Bin and log lin.-fitting

We compared the log-linear-fitting

$$\log y = a_0 - a_1 \log q_c - a_2 \log n_c$$

and the exponential fitting

$$y = a_0 q_c^{a_1} n_c^{a_2}$$

The results show that the errors in the log-linear fitting in large values are large.

- Correlation coefficients

	Exp.-fitting	Log lin.-fitting
Correlation	0.948	0.849

Dependence of autoconversion 2 on q_c and n_c

We compared the **log-linear-fitting**

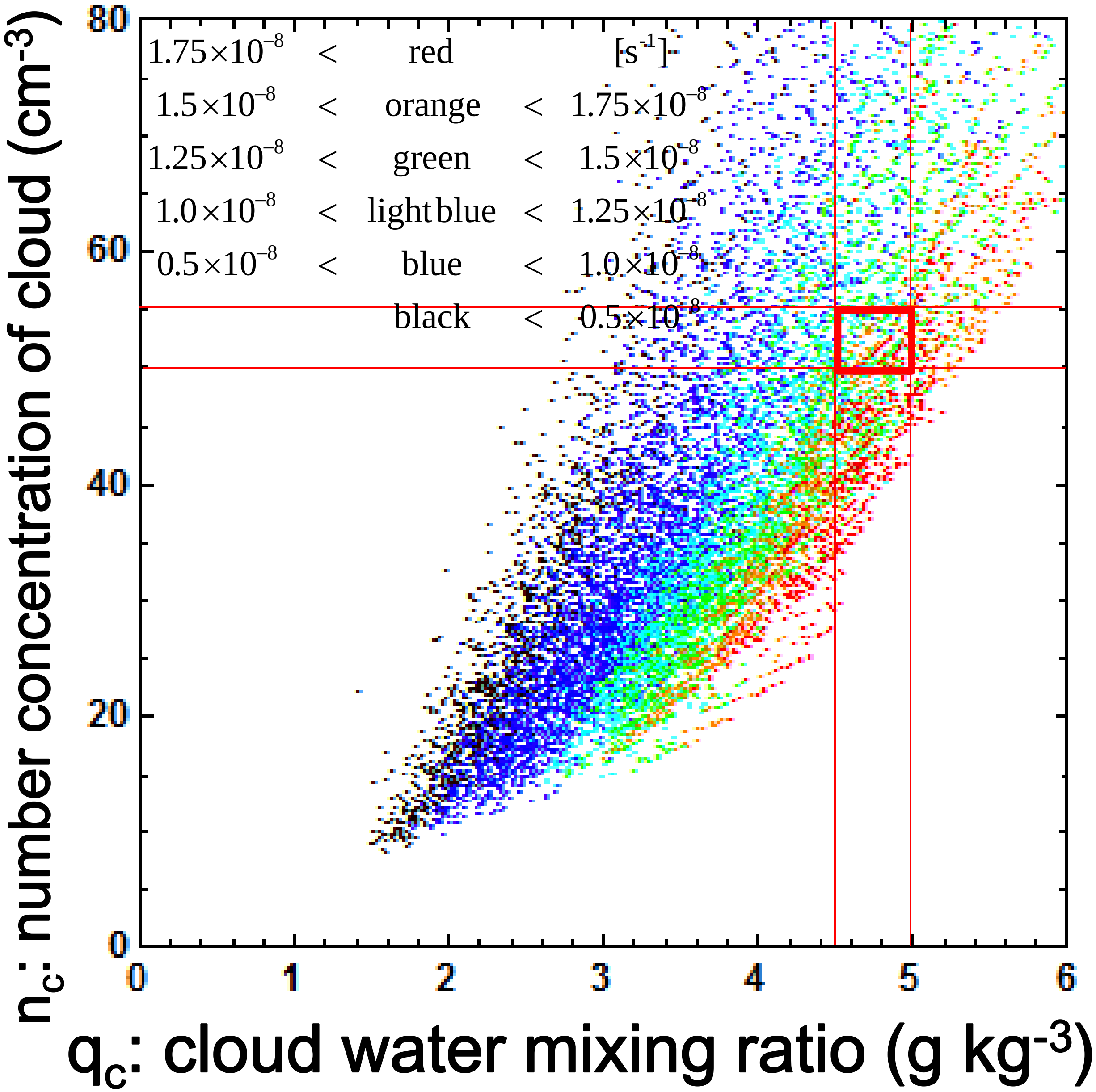
$$\log y = a_0 - a_1 \log q_c - a_2 \log n_c$$

and the **exponential fitting**

$$y = a_0 q_c^{a_1} n_c^{a_2}$$

The results show that the errors in the log-linear fitting in large values are large.

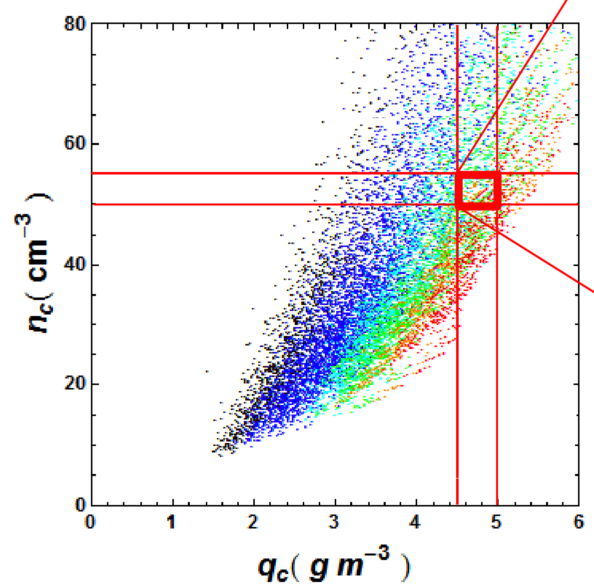
Although autoconversion2 is approximated roughly in terms of q_c and n_c, the variation is not so small in a small region of (q_c,n_c).

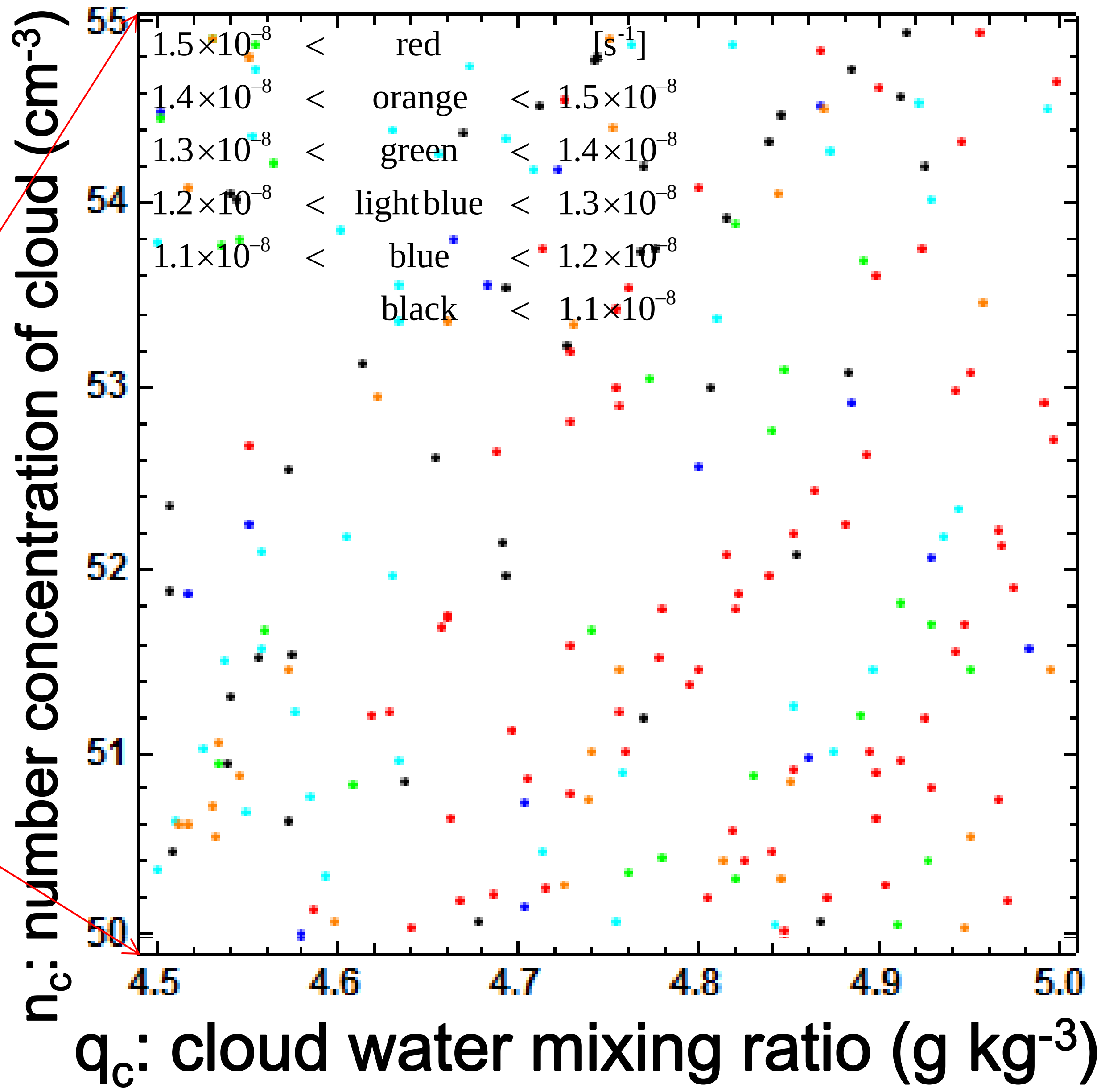


Dependence of autoconversion 2 on q_c and n_c

Although autoconversion2 is approximated roughly in terms of q_c and n_c, the variation is not so small in a small region of (q_c,n_c).

The color of dots is not well distributed.



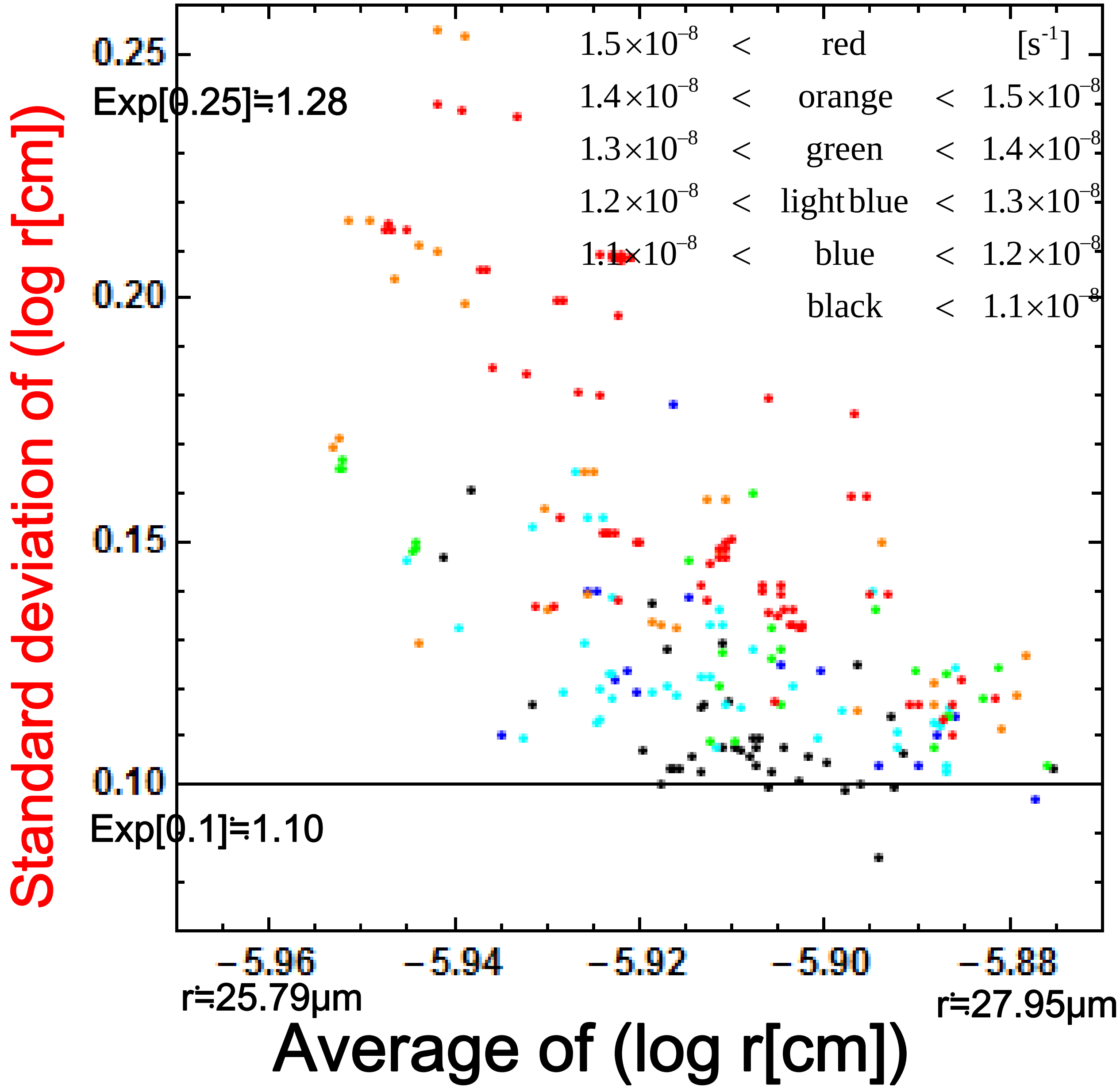


Dependence of autoconversion 2 on log(r)

Although autoconversion2 is approximated roughly in terms of q_c and n_c, the variation is not so small in a small region of (q_c,n_c).

The result plotted in terms of "**average of log(r)**" and "standard deviation of log(r) $=\sigma_{logr}$" indicates that the autoconversion2 rate is closely related to σ_{logr}.

Although 3 variables scheme including σ_{logr} makes S smaller, 2variables schemes including σ_{logr} do not make S smaller than (q_c,n_c) scheme.



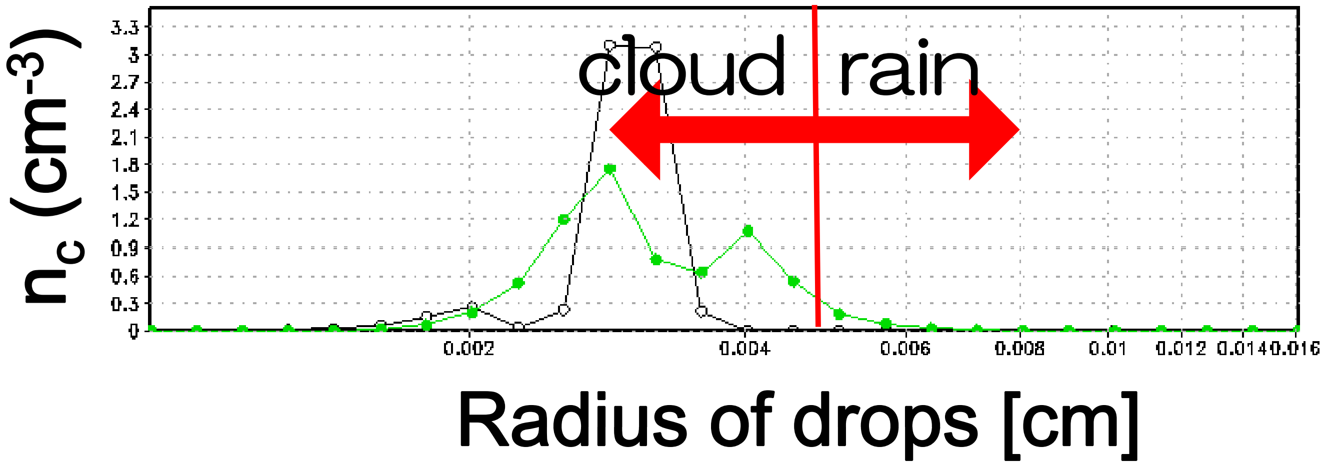
Size distribution of cloud droplets

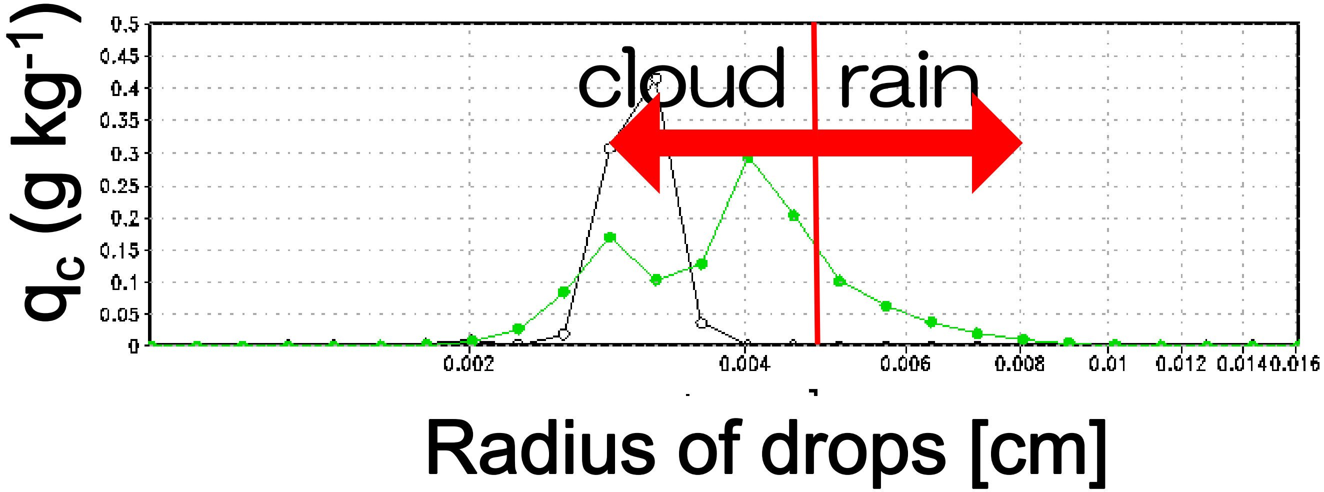
Although autoconversion2 is approximated roughly in terms of q_c and n_c, the variation is not so small in a small region of (q_c,n_c).

Within a same (q_c,n_c) region, the size distribution of cloud droplets are different and the autoconversion2 rate differs from case to case.

As σ_{logr} becomes large (green case) autoconversion2 tends to become large.

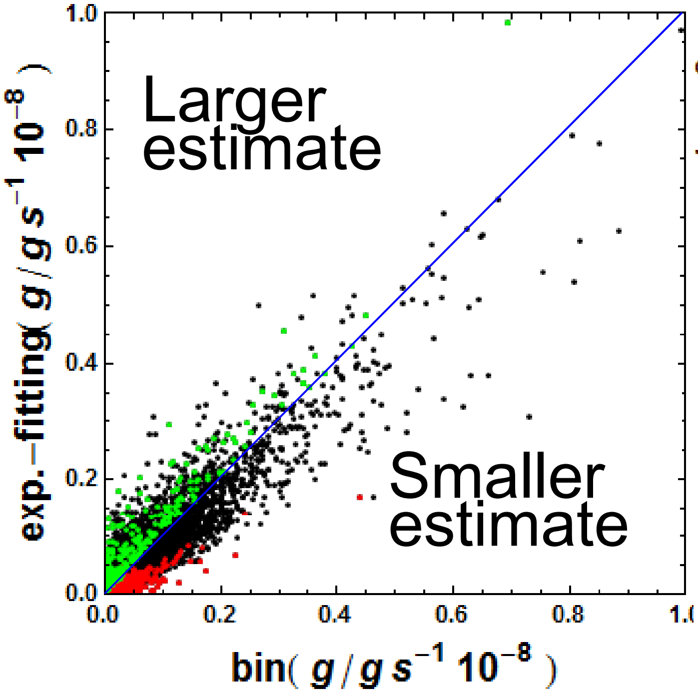
σ_{logr} is a good candidate for independent variable for autoconversion2 parameterization.



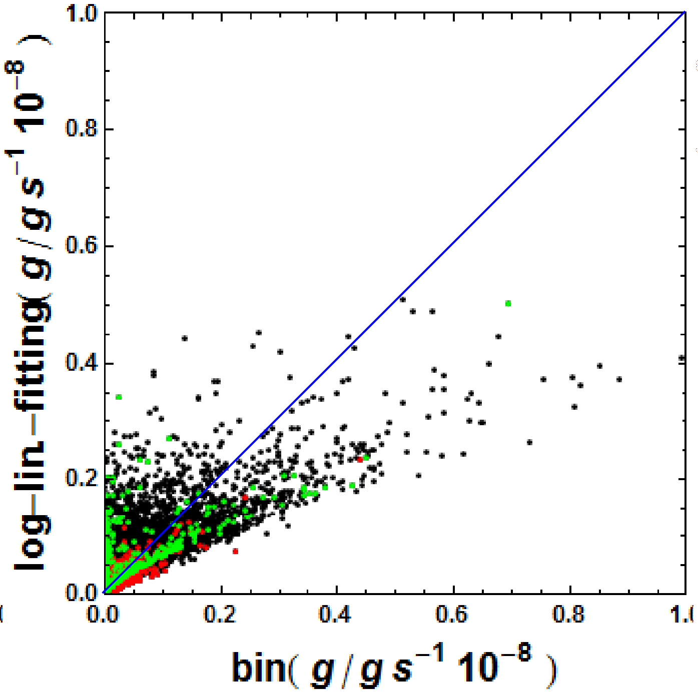


Cloud r≦0.00479cm

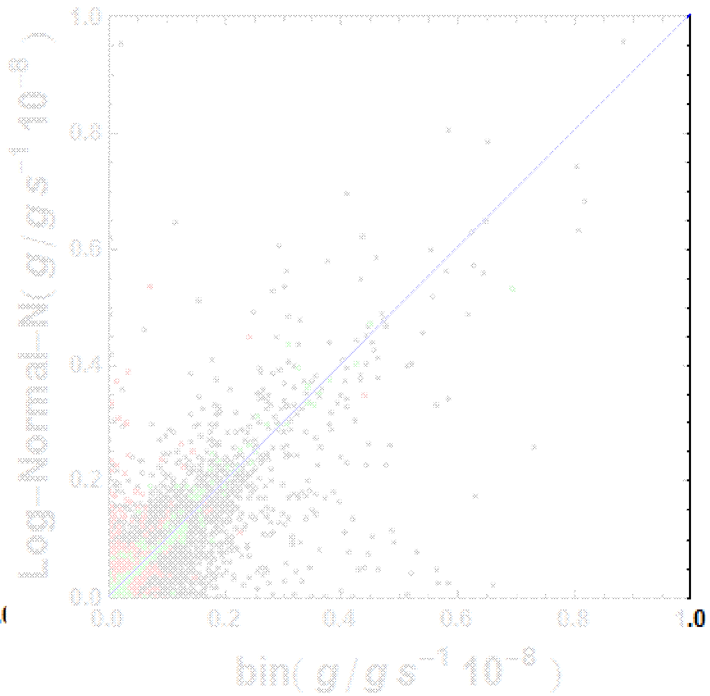
Correlation between bin results and fitting results



Bin and exp.-fitting



Bin and log lin.-fitting



Bin and log-normal distribution fitting.

Red:large σ_{logr} Green: small σ_{logr}

	Exp.-fitting	Log lin.-fitting	Log-Normal
Correlation	0.948	0.849	0.934

Summary - 1

- ビン法雲微物理モデルを使いRICOで観測された積雲の数値実験を行った。
- A numerical experiment of cumulus convection observed during RICO was performed using a bin microphysical model.
- その結果を用い、新しいバルク法を開発しつつある。
- Using the results, we are developing a new bulk scheme.
  - （続く）
  - (continued)

Summary - 2

- 指数関数での近似は対数線形近似よりも良い結果を与える。
- Exponential fitting gives better results than the log-linear fitting.
- autoconversion2は、q_c と n_cで表すのがよいが、変動も大きい。
- Although autoconversion2 is approximated roughly in terms of q_c and n_c, the variation is not so small in a small region of (q_c,n_c).
- 粒径半径の標準偏差σ_{logr}とautoconversion2 との間に関係がある。σ_{logr} が大きいとautoconversion2 が大きい。→ ３変数スキーム
- The results plotted in terms of “average of log(r)” and “standard deviation of log(r) $=\sigma_{logr}$” indicate that the rate of autoconversion2 is closely related to σ_{logr}. When σ_{logr} is large, autoconversion2 is larger than the value estimated by (q_c,n_c). → try to develop 3-variables scheme?