A comparative experiment of warm rain bin schemes using a kinetic driver
暖かい雨に関する ビン法雲微物理モデルの比較実験

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

Ⅰ. Objectives: To improve bulk parameterization scheme

Target：bulk scheme for warm rain (boundary layer clouds)

Boundary layer clouds are important for climate study.
Bulk parameterization schemes are used in large-scale models.
However, there are many ambiguous parameters in the schemes.
➡ To improve the bulk schemes, we will use the results of bin scheme models.

Model：CReSS with Kuba-Fujiyoshi bin model

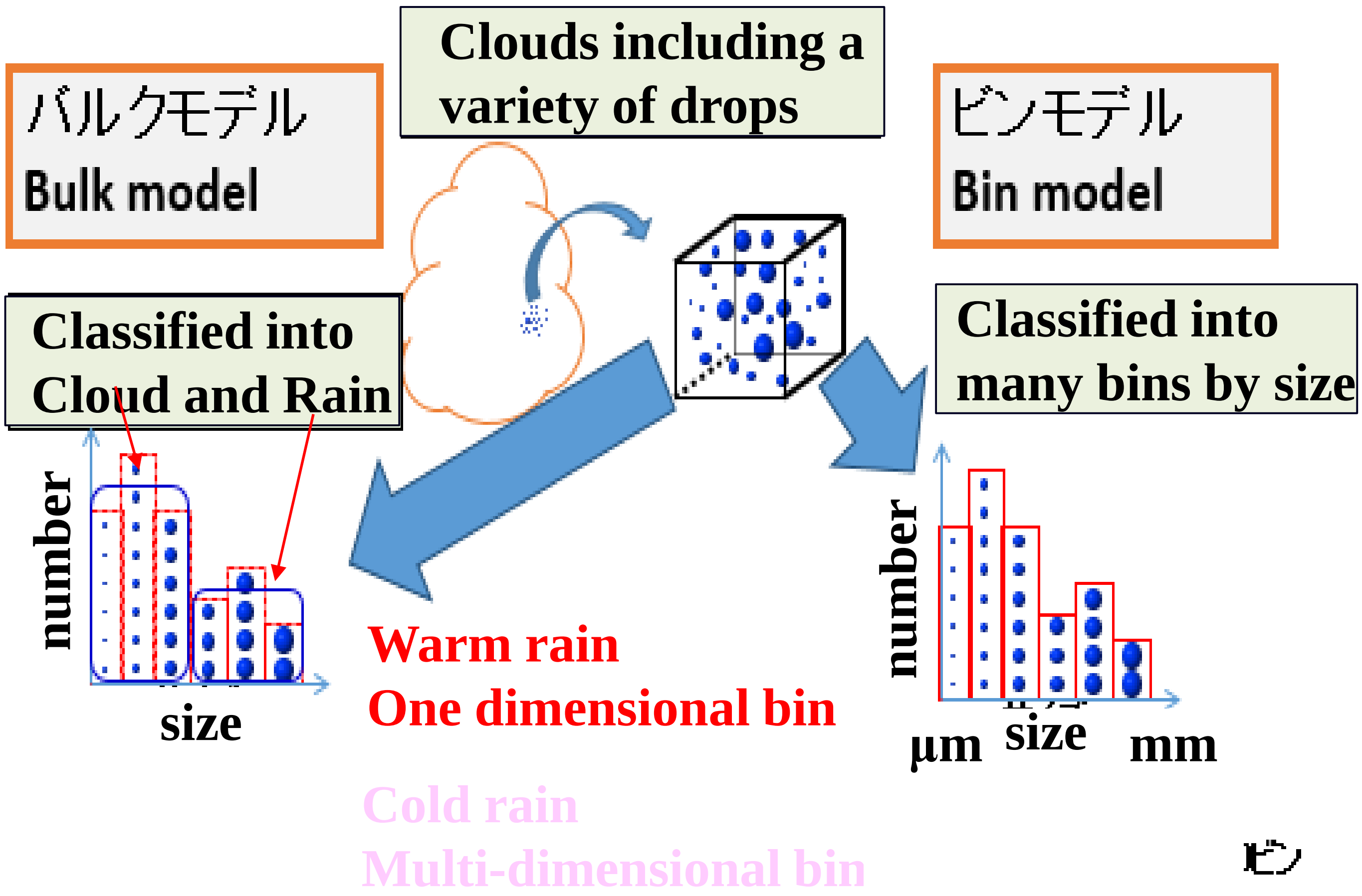
Case ： RICO(Bermuda area, **trade wind cumulus**) model intercomparison case
↑GCSS(GEWEX cloud system study)

Results： layered structure (average potential temperature etc.), is well simulated, however, …

Problems and what to do：

There are many differences between the results of bin models.
Also in bin models, there are many ambiguities.
Improve the bin model by intercomparison experiments using **KiD (Kinematic Driver for microphysics intercomparison)** and comparison of the results with observations.

What occurs in clouds and what we are modeling



Processes included

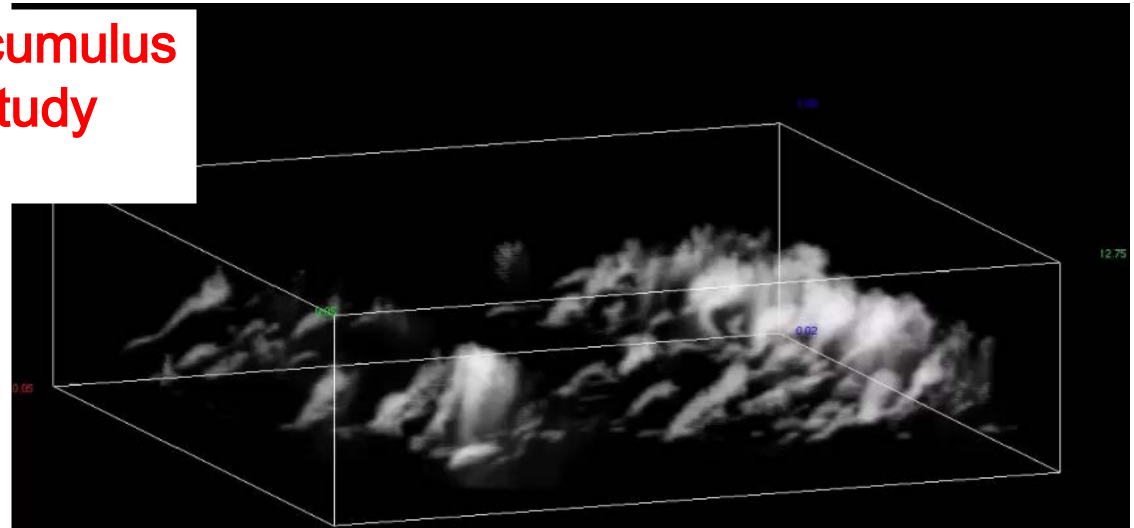
1. **Activation of aerosols**
   maximum value of super saturation determines the number of activated aerosols
2. **Deposition growth**
   the difference of the basic equations is whether the integration of time is used or not.
3. **Collision-coalescence**
   whether the kernel of the collision includes the effect of turbulence.

We used 71 bins whose ratio of mass between adjacent bins is $2^{1/2}$.
However, for comparison, the results with 34 bins will be presented.

The details of the differences of the bin models will be omitted.

II . Inter comparison experiments (LES)

RICO : Bermuda area, trade wind cumulus
Case of GEWEX Cloud System Study
http://www.knmi.nl/samenw/rico/


Basic wind is from right to left in the lower layer.
Figure shows liquid water.

Grid
$\Delta x = \Delta y = 100\text{m}, \Delta z = 40\text{m}$

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 $2\times10^{-3}\ s^{-1}$
v : uniform
pot. temp., water vapor

Bottom surface B.C.
SST: 299.8K ΔT=0.6℃

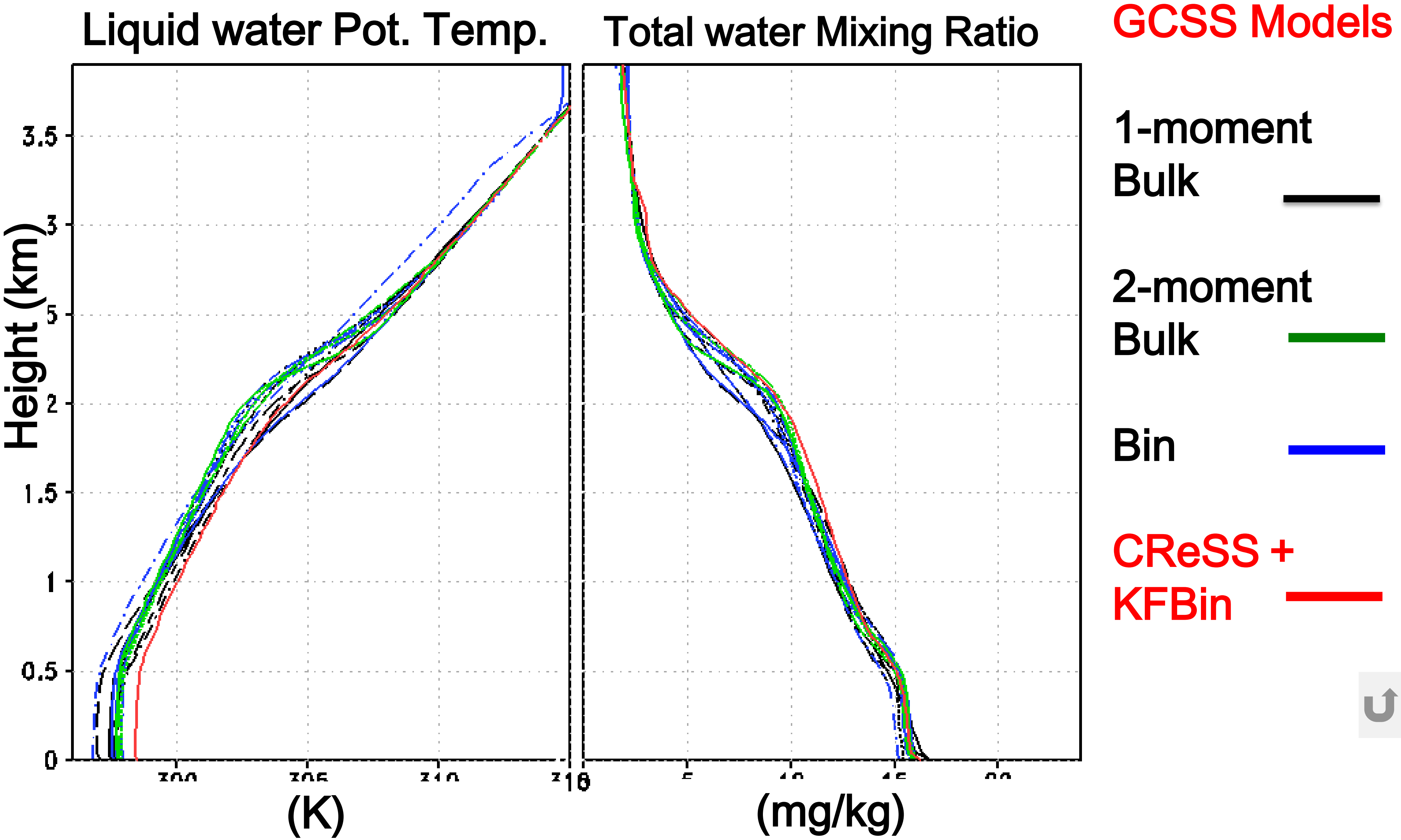
Large scale forcings
Subsidence
z> 2260m : w = -0.005[m/s]
z<2260m : Constant Divergence
Horizontal advection (depending on z

Duration : 24hours (last 4 hrs are analyzed)

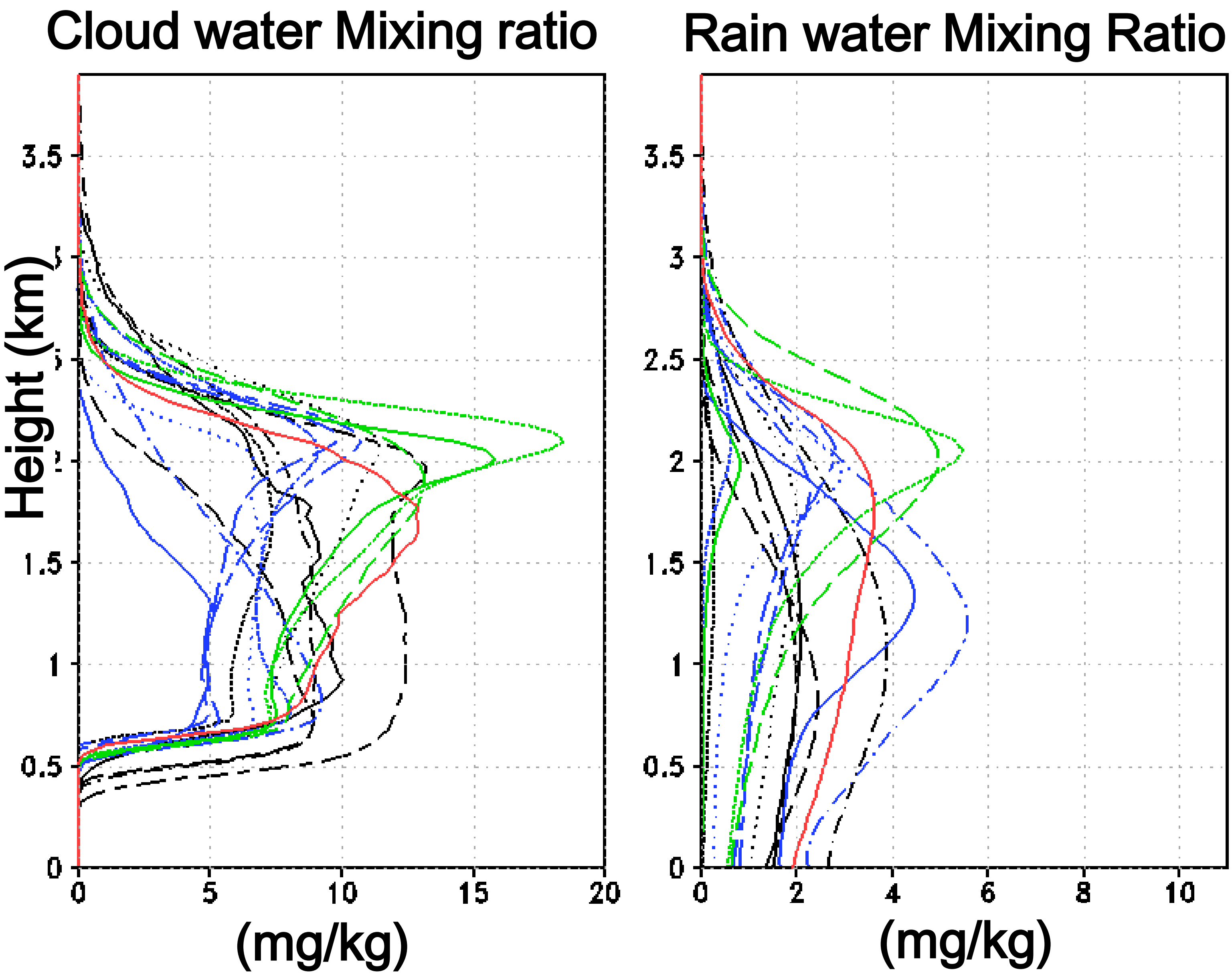
Cloud physics models

1 moment bulk	2 moment bulk	bin
MESO-NH	DALES	RAMS @NOAA
SAM	UCLA	SAMEX
JAMSTEC	WVU	DHARMA
Utah	COAMPS	
EULAG	UKMO	
2DSAM	RAMS	

II-2. Averaged vertical profiles (20-24 hr)



II-3. Averaged vertical profiles (20-24 hr)



GCSS Models

1-moment Bulk

2-moment Bulk

Bin

CReSS + KFBin

Cloud : r≦47.9μm

II-4. Cause of the difference and KiD

Cause of the difference

Dynamical model

- basic equation
- advection scheme
- diffusion scheme
- subgrid-scale scheme

Cloud physical model

- classification (cloud, rain etc.)
- number of variables (moments)
- equation for each process,
  - activation, (initial cloud distribution
  - deposition, conversion, $v_T$etc

⇒To examine what produces the difference, we use KiD.

KiD Kinematic Driver for microphysics intercomparison (Shipway, Met. Office)

Common setting for dynamic process(velocity fields, initial T, q_v are given) advection scheme : ULTIMATE

Cloud Physical model

We can put our own model.
Following examples can be used.
Thompson07, 09, Morrison(2B),
Tel-Aviv University(TAU, bin)

CASES

1D(GCSS-Warm, Mix, Deep),
2D(Cu, St, squall line)
WMO-workshop cases.

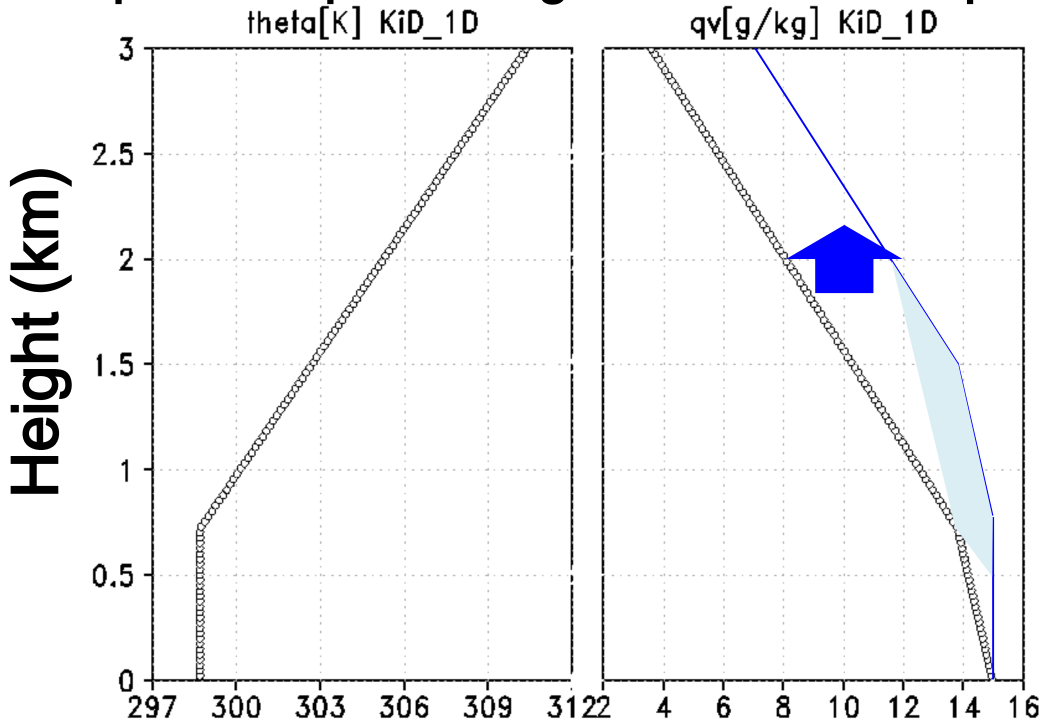
\+ **2DResults of CReSS for RICO**

Ⅲ. KiD(Kinetic Driver)

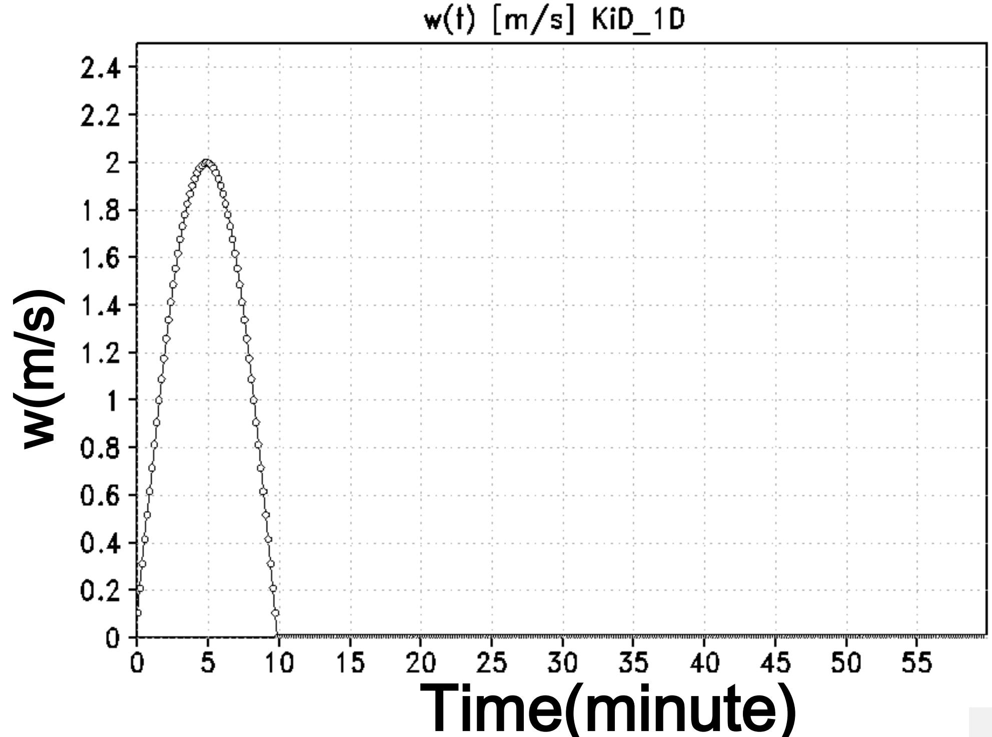
Ⅲ－1. 1dimension（1D、warm1）

Initial profiles

pot. Temp. mixing ratio of water vapour



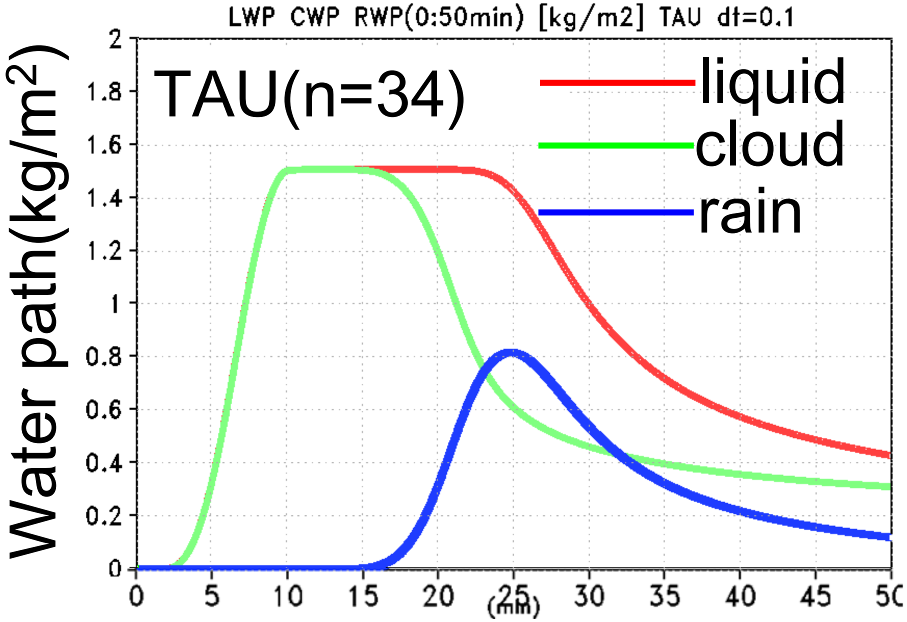
Time change of w, which does not depends on position.

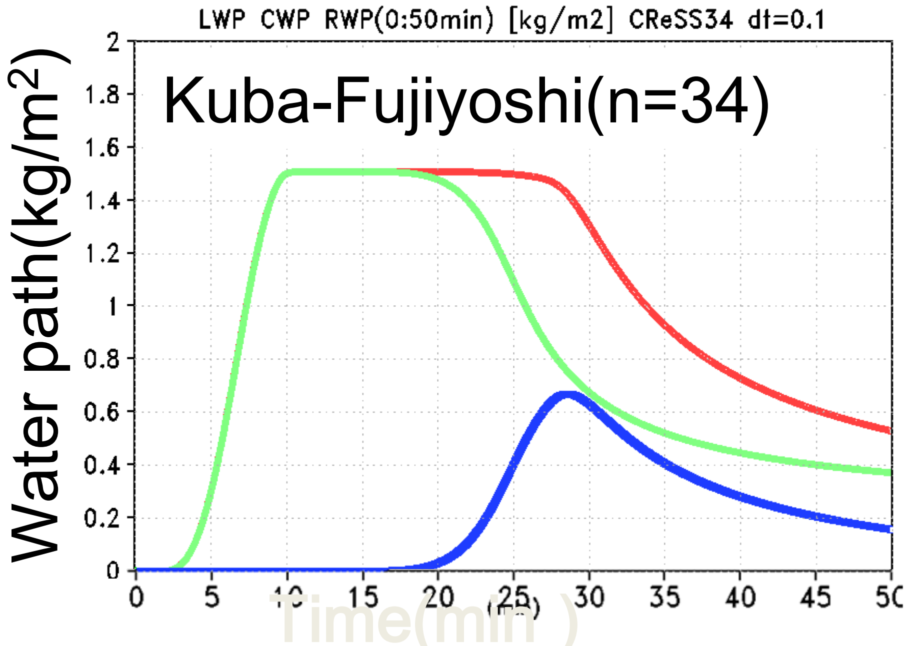


Because of rising, the air is saturated.

In this case, the temperature is kept fixed in spite of the condensation, for simplicity.

III—1' KiD-1D Result. Time change of water path





Difference between TAU and KF

KF: originally n=70.
n=34 is used for comparison.

(The ratio of the masses of the adjacent bins is 2.)

KF: conversion from cloud to rain is slow, especially with n=70.

III— 2 2D experiment (flow pattern resulted in CReSS)

Several 2D experiments are performed using simple flow pattern.
The results are reasonable.
Then, we used the flow pattern resulted in 2D CReSS simulation.

Grid: Δx = 100m, Δz = 40m

Time interval: Δt =1sec., Δt bin=0.1sec.

Domain Size 12.8km× 4.0km

  Number of Grids 128 x 100

Geostrophic Wind (cyclic lateral B.C.)

  u : uniform v : uniform

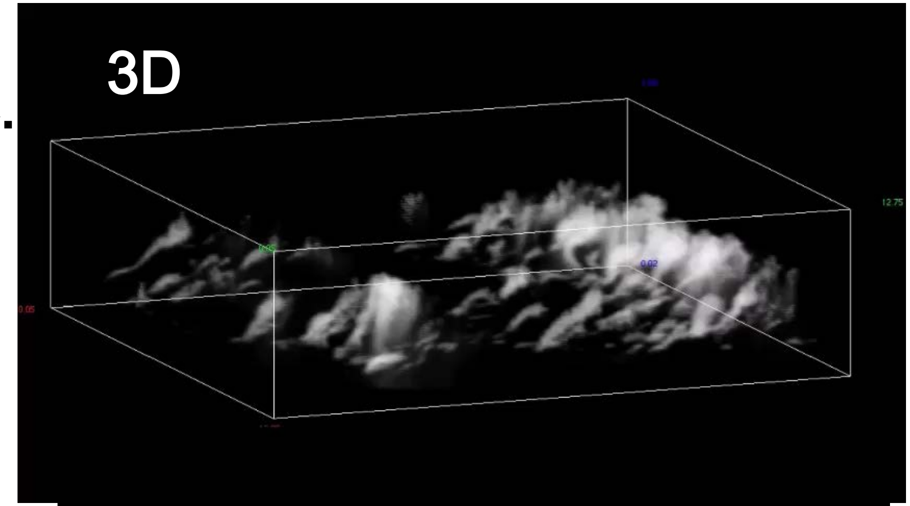
  pot. temp., water vapor : RICO case

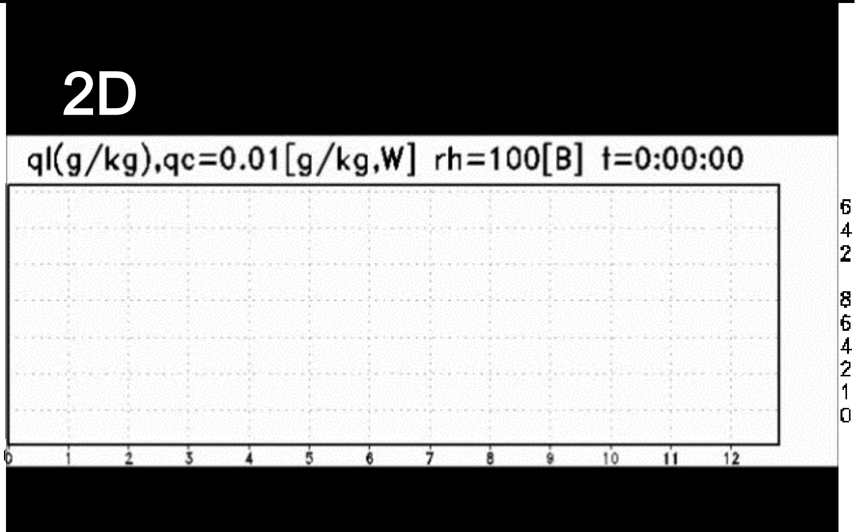
Bottom surface B.C.

  Fix surface flux.

Large scale forcings: same as GCSS

Duration : 24hours





We stored flow fields every 1 sec.

III— 2 2D experiment (flow pattern resulted in CReSS)

Several 2D exper
The results are re
Then, we used th

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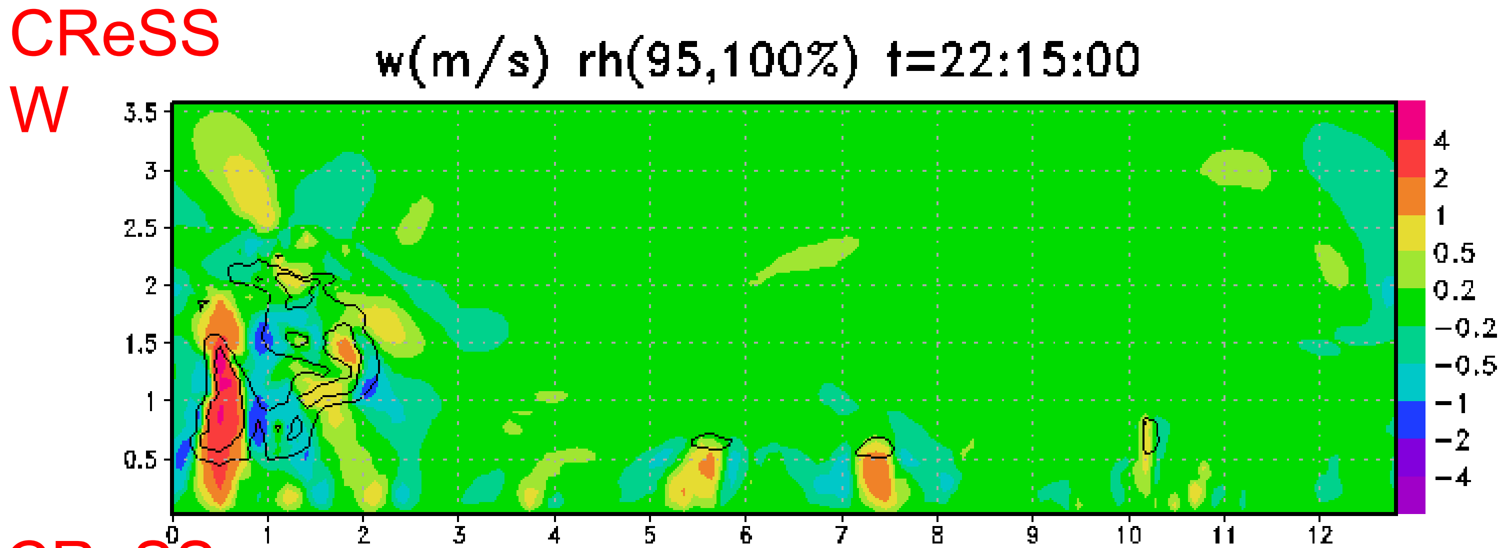
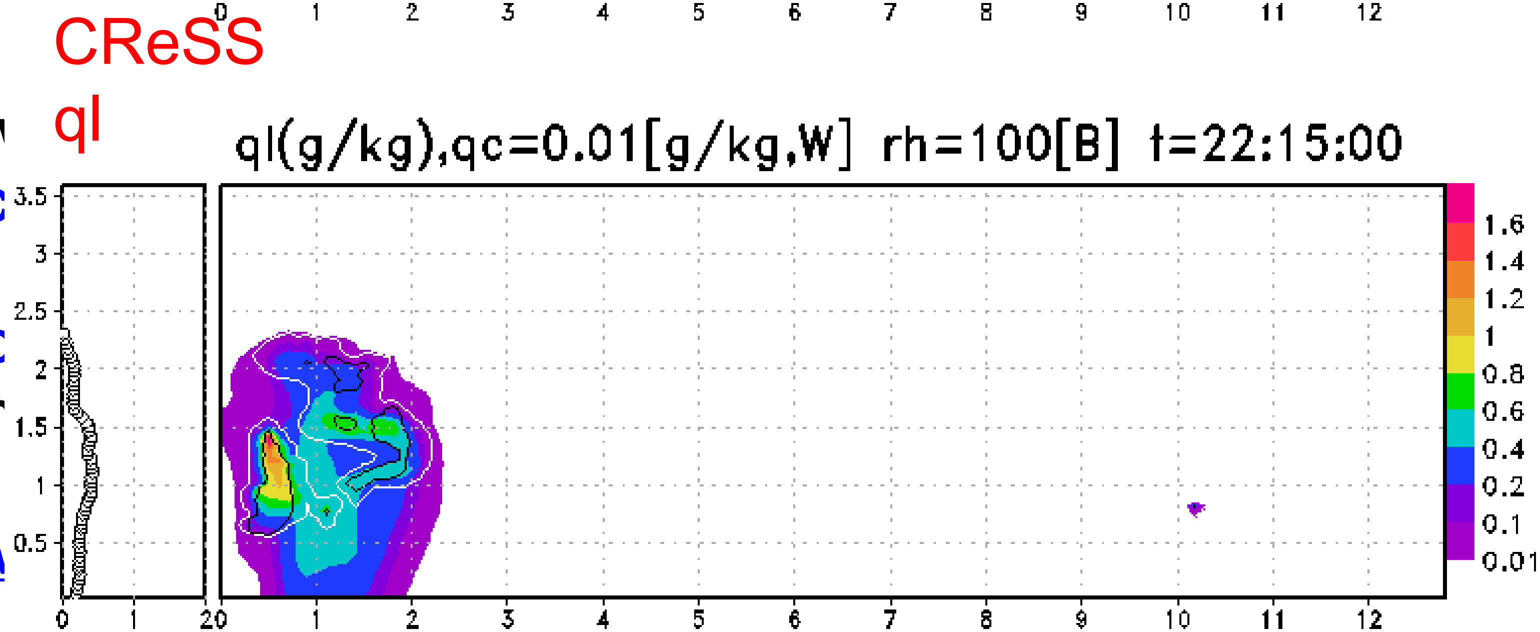




III― 2 2D experiment (flow pattern resulted in CReSS)

Flow fields in CReSS

advection

+ cloud physics

KF and TAUscheme

Liquid water mixing ratio⇒

upper：CReSS+KF

center：KiD+KF

lower：KiD+TAU

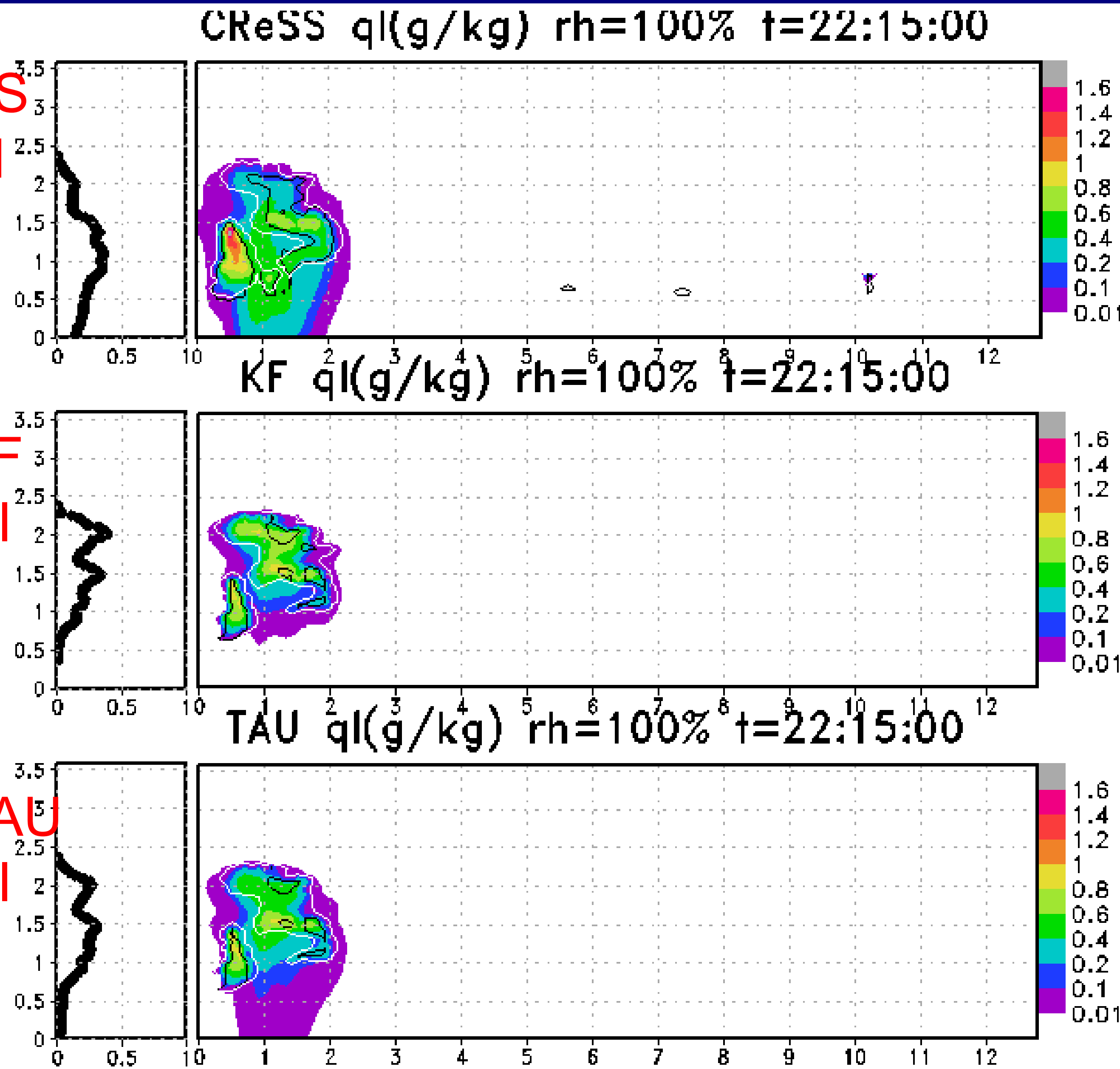
Left ：average in cloud

Right ：pattern

CReSS KF ql

KID KF ql

KID TAU ql



III— 2 2D experiment (flow pattern resulted in CReSS)

liquid water mixing ratio(left) and cloud amount(right)
KF(Red) and TAU(Green)

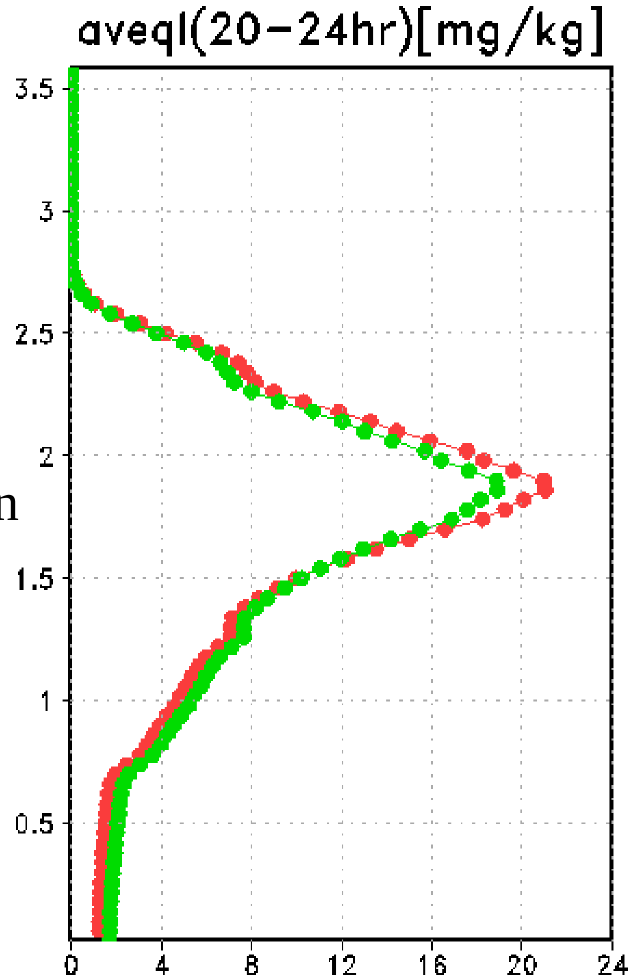
Average from 20:00～24:00
Difference with schemes KF and TAU.

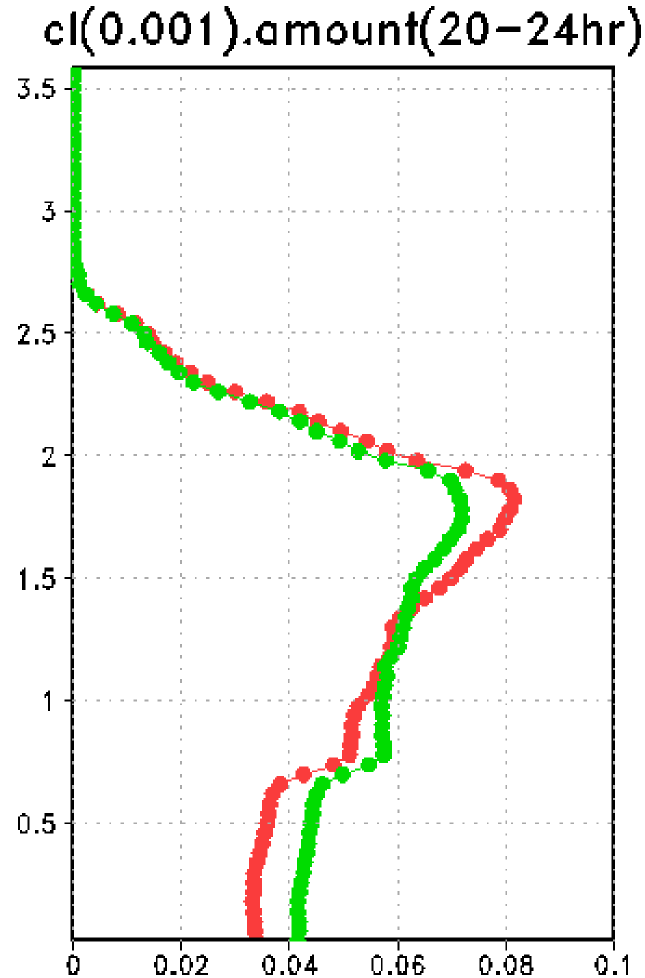
Cloud grid is the grid with liquid water mixing ratio > 0.001[g/kg]

More liquid water is stored in clouds with KF scheme, than with TAU scheme.

The precipitation is a little larger in TAU than in KF.

Conv. is slow in KF than in TAU





III－３ 2D. cloud physical process divided into 3 parts.

Vertical profiles of averaged liquid water mixing ratio (t=20-24hr)

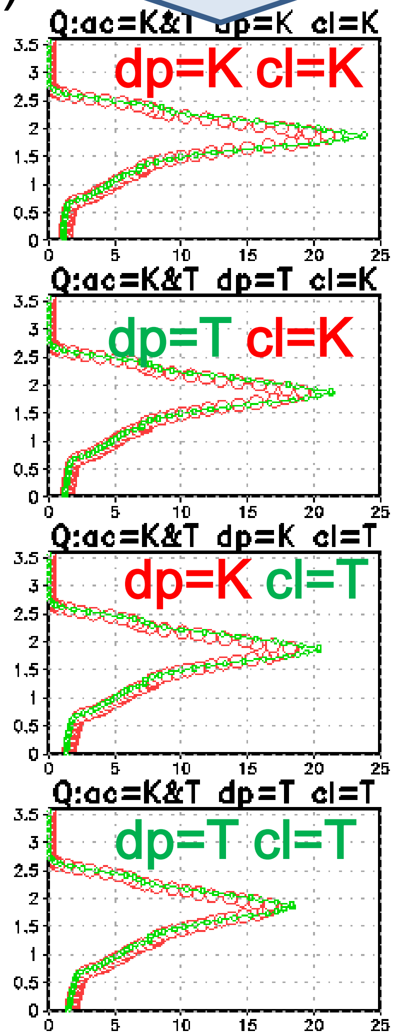
Basic scheme is KF.
The cloud physical process is divided into 3 parts; activation, deposition, and collision.

For each process, **K(Kuba-Fujiyoshi)** or **T(Tel-Aviv Univ.)** can be selected.

We performed 8 runs.

ac：activation
dp：depositional growth
cl：collision-coalescence.

Activation
Red :K
Green :T



Summary - 1

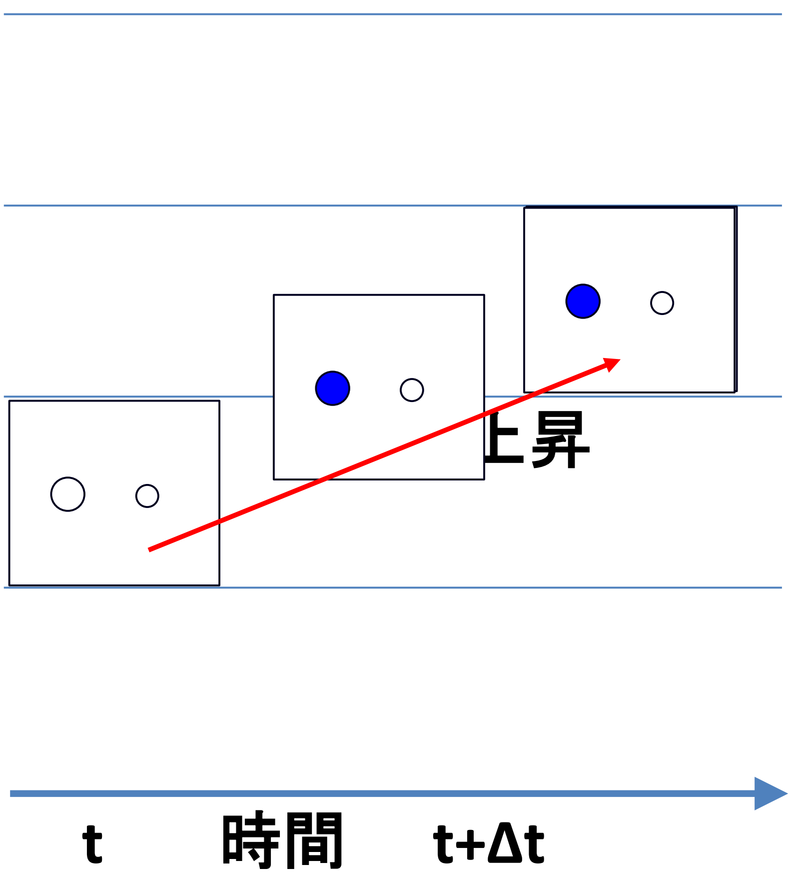
- A numerical experiment of cumulus convection observed during RICO was performed using a bin microphysical model developed by Kuba and Fujiyoshi.
- 久芳－藤吉が開発したビン法雲微物理モデルを使い、RICOで観測された積雲の数値実験を行った。
- We are improving the model by comparing the results with TAU model and observational results.
- テルアビブ大学のビンモデルや観測結果との比較を通じて、モデルの改良を行っている。
- Especially we compared the results of two bin models by dividing the models into three processes, i.e.,
  1. activation process of aerosols, 2. depositional growth process, and 3. Collision-coalescence process.
- ビンモデルの雲微物理過程を、１．活性化、２．凝結成長、３．衝突併合成長の３つの部分に分けて、２つのビンモデルの比較をおこなった。

Summary - 2

- The results show that
  - for the effect of activation process, ql in cloud is larger in TAU than in KF.
  - for the effect of deposition and collision processes, ql in cloud is larger in KF than in TAU.
  - The surface precipitation is large when ql in cloud is small.
- 結果は、活性化では、KFモデルはTAUよりも雲内凝結水が少なく、凝結成長と衝突併合成長では、KFモデルの方がTAUよりも雲内凝結水を多くした。これらの結果、全体としては、 KFモデルの方がTAUよりも雲内凝結水を多くした。地表面降水は、雲内凝結水が少ないほうが多くなった。
- We would like to compare the results with some observation, and …
- 今後、観測結果（粒径分布、凝結水量と降水量の関係など）とも比較して、よりよいものにしていきたい。

雲微物理過程ー１．初期粒径分布の決め方

パーセルの上昇と活性化



最大過飽和度が雲粒数密度を決める

よく使われるが、できれば使いたくない式。

$n_{acti} \propto exp(a*(rh-100))$

↑格子のrh（相対湿度）を使っていいか？

単純な方法としては、最小粒径に不足個数分を加える方法がある。が、

活性化される核の数は、十分に細かい格子と時間間隔で考えるべき

大きな粒子が活性化したら、相対湿度は低下する➡小さな粒子は活性化しない。

➡KFは、パーセルモデルの結果を使ったパラメタリゼーション（wの関数で総数を決めて、「分布させた。）

Time change of size distribution of q_c in growing

Size distribution of q_c at the maximum q_c level **during t=101-600sec**

Left(TA) , Right(KF)

black : dt=0.1sec, dz=25m

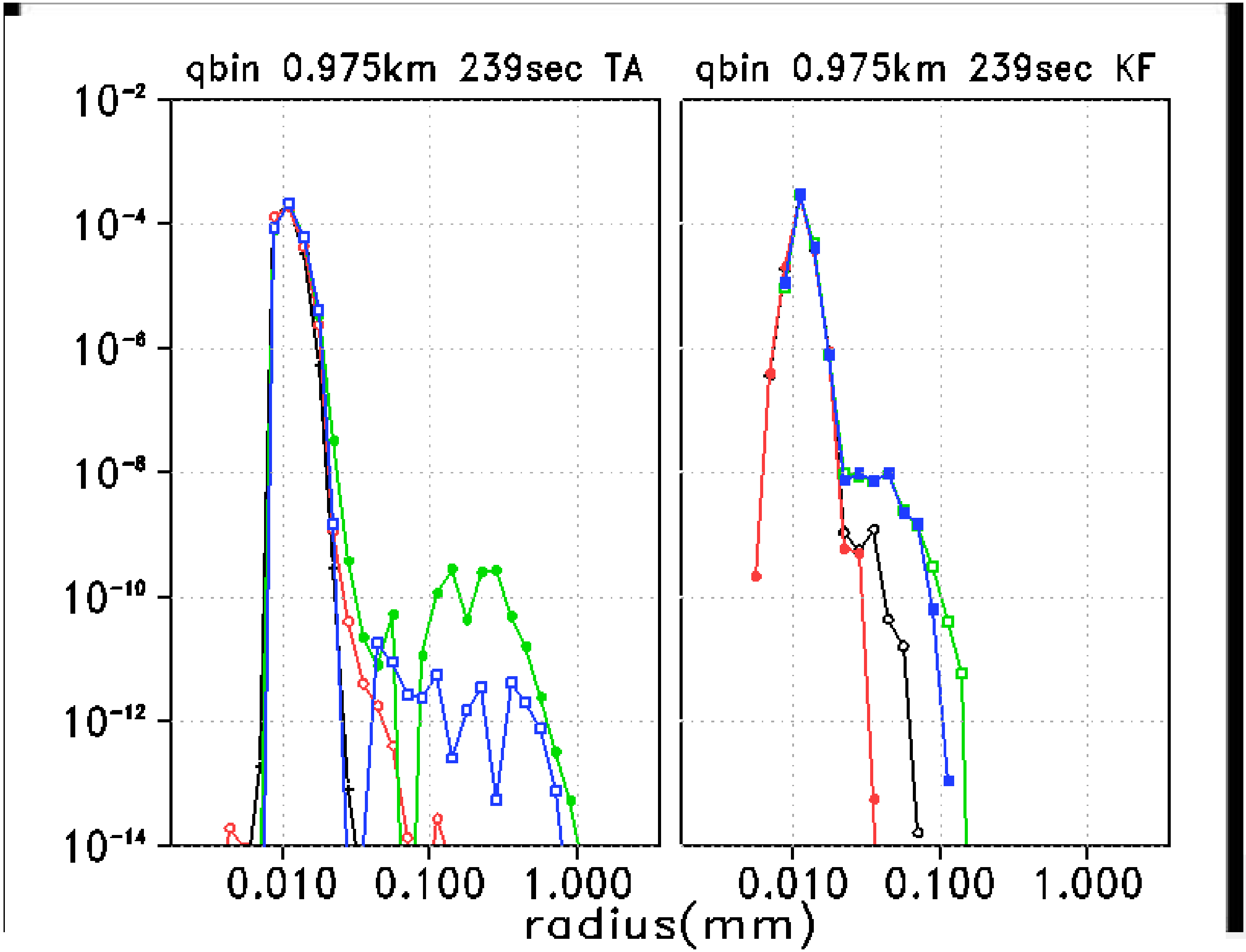
red : dt=0.01sec, dz=25m

green : dt=0.1sec, dz=2.5m

blue : dt=0.01sec, dz=2.5m

KF

Initial distribution of n_c is calculated by the use of <u>parameterization scheme</u> determined by a parcel model.

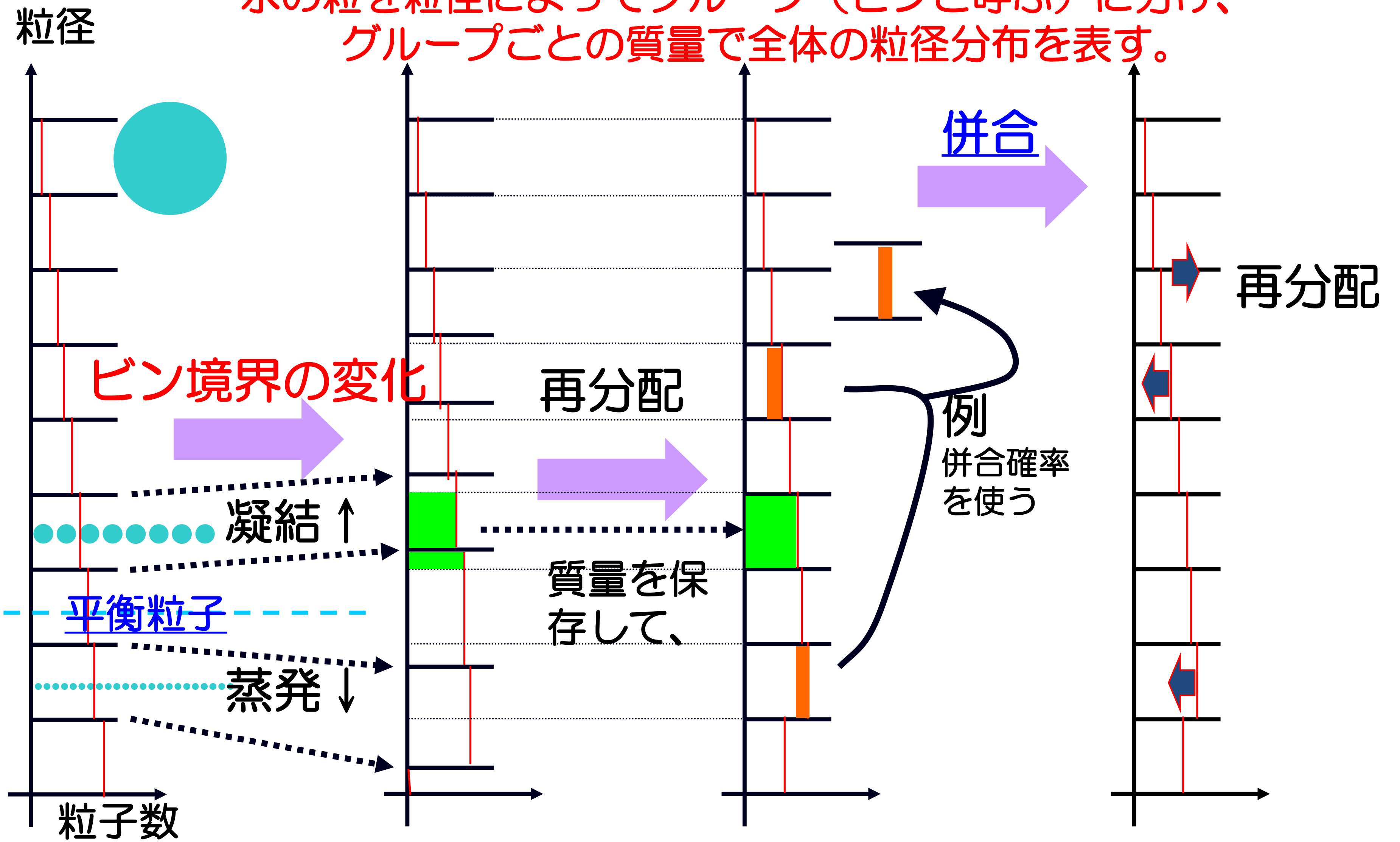


KF: dependency is small.

KFの特徴

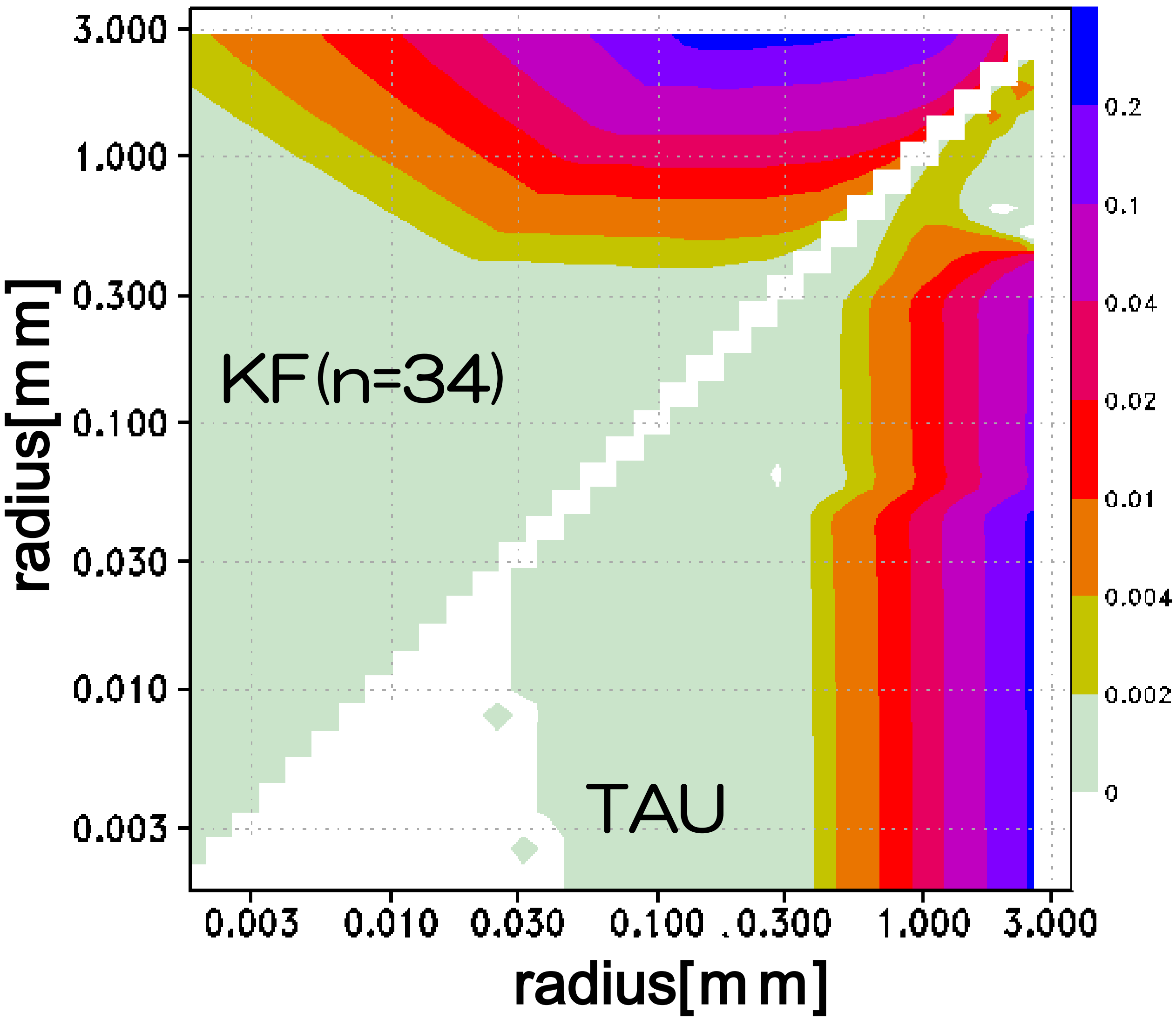
雲微物理過程－2．凝結水の雲物理過程での変化

水の粒を粒径によってグループ（ビンと呼ぶ）に分け、
グループごとの質量で全体の粒径分布を表す。



単純な方法（２変数）：各ビンの平均粒径を出して、それで丸ごと移動させる。

Collision efficiency used in KF and TAU



Situation: only two kinds of drops exist. Number densities are 10^2/kg and 10^4/kg.

Coalescence probability during 0.1 sec.

The origins of the difference?

KF34.based on Hall(1980). linear interpolation in each bin. The effects of velocity perturbation is not included.

TAU. Assumption of K(x,y)=x+y is used. The effects of change in each bin is estimated by assuming a size distribution.

This does not seem to be related to the rapid decrease in n_c with height.

→ We should use more complicated situation.