Validation of JMANHM+HUCM through comparisons with satellite and aircraft observation in DYCOMS-II period

Yousuke Sato[1], Teruyuki Nakajima[1], Kentaroh Suzuki[2], Jørgen B. Jensen[3], Takashi Y. Nakajima[4], and Hideaki Takenaka[5]

1: Atmosphere and Ocean Research Institute, University of Tokyo

2: Department of Atmospheric Science, Colorado States University

3: National Center for Atmospheric Research

4:Research and Information Center, Tokai University

5: Center for Environmental Remote Sensing, Chiba University

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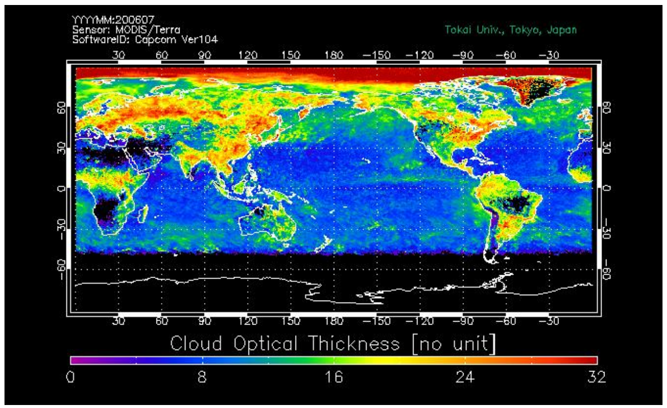
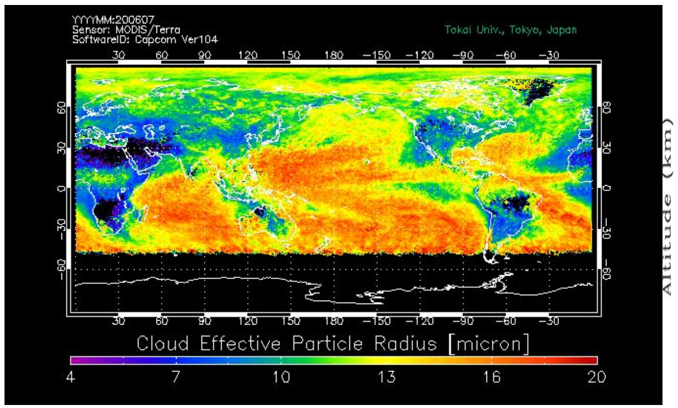
Introduction1 (Warm cloud)

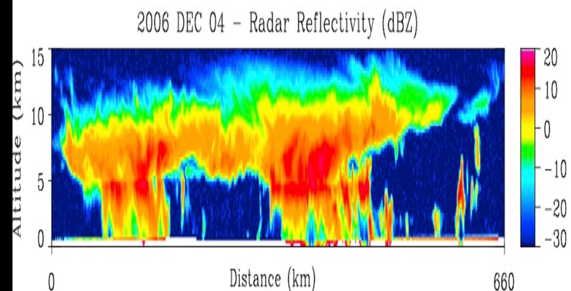
- Warm clouds make significant influence on radiation budget of earth's climate (Klein and Hartmann 1993).
- Radiative properties of cloud are characterized cloud optical parameter like Cloud effective radius (r_{eff}) and optical thickness (τ).
- τ and r_{eff} are observed by satellite and aircraft (e.g. Han et al. 1994, Kawamoto et al. 2001, Brenguier et al. 2001).
- τ and r_{eff} are closely related to cloud microphysics.
- Recently vertical structures of clouds are observed by active sensor boarded on CloudSat satellite.



Example of global distribution of τ (retrieved by CAPCOM algorithm by T. Y. Nakajima)



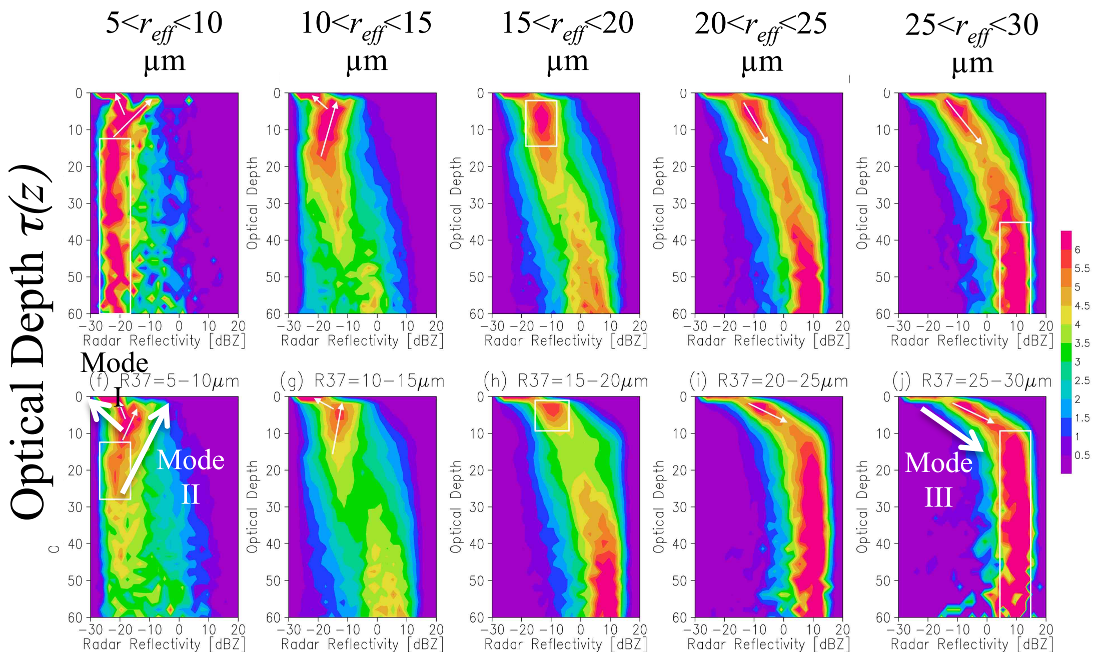
Example of global distribution of r_{eff} (retrieved by CAPCOM algorithm by T. Y. Nakajima)



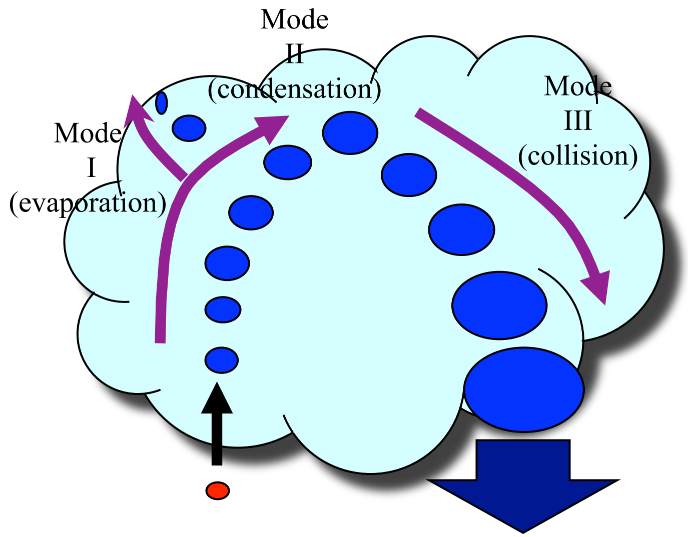
Stephens et al. (2008)

Introduction 2 (CFODD)

- Nakajima et al. (2010) suggested Contoured Frequency Optical Depth Diagram (CFODD) from CloudSat and MODIS satellite observation.
- Suzuki et al. (2010) and Nakajima et al. (2010) suggested cloud growth regime shown in CFODD.
- There no studies about CFODD by three-dimensional bin model.



(Suzuki et al. 2010)



(Suzuki et al. 2010)

One of the target of our study is to understand these satellite derived interpretations by numerical model.
Spectral bin microphysical model is strong tool.

Purpose

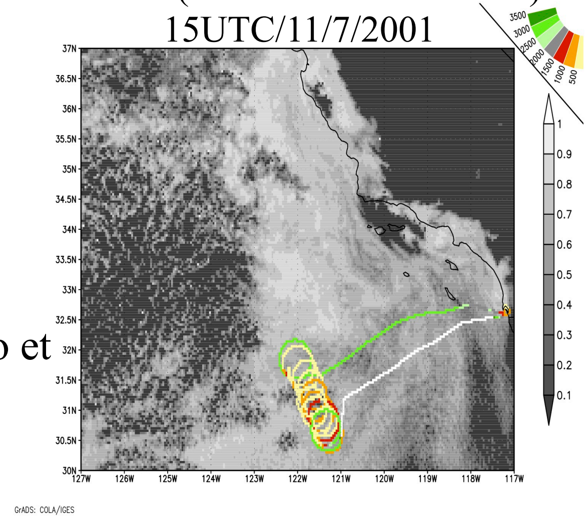
- Final goal :
  - To represent CFODD by three-dimensional downscaling simulation.
  - To confirm the validity of the interpretation of Nakajima et al. (2010)
  - To investigate the time evolution of CFODD.
- Problem
  - Computational resources are not enough to perform wide-area calculation.

<u>Purpose of this study</u>

1. To calculate warm cloud by idealized experiment.
2. To compare model results with observation results to confirm the validity of the model.
3. To validate the model through comparison of model results with observation results.
4. To calculate CFODD from model results.

Observation Data

Albedo (retrieved from satellite)
15UTC/11/7/2001



<u>Satellite observation</u>

- Satellite : GOES-10
- Period : 15UTC 11 July 2001 (same day as DYCOMS-II RF02 flight)
- Region : 30N^o～ 24 N^o, 120W^o～130W^o
- Retrieval Algorithm : CAPCOM (Comprehensive Analysis Program for Cloud Optical Measurements, Nakajima and Nakajima 1995, Kawamoto et al. 2001)

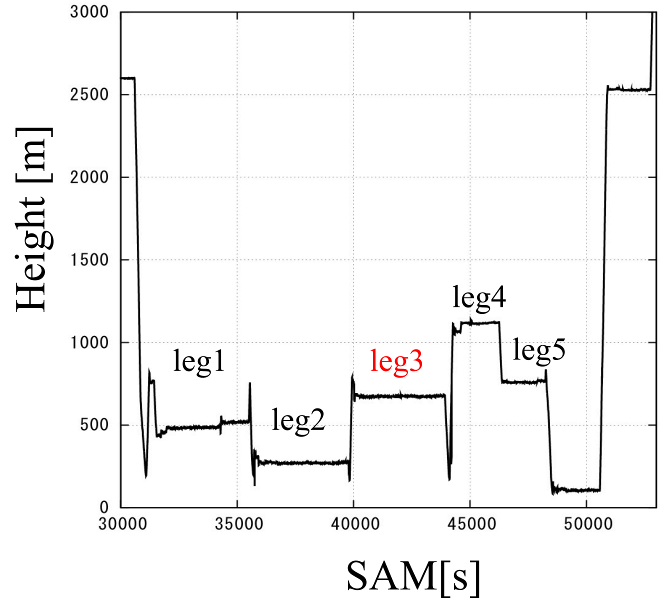
<u>Aircraft observation</u>

- Aircraft : C-130
- Period : 6UTC～12UTC 11 July 2001 (RF02 flight)
- Analyzed data :
  - Profile of LWC, r_{eff} – averaged 5 profile
  - SDF of hydrometeor : averaged leg 3

    (30 % height from cloud top)
- Instrument :
  - LWC, : Gerber Probe
  - Size distribution function of Cloud :

    FSSP-100, C260X, 2D-C Probe

Flight height [m] of RF02 flight



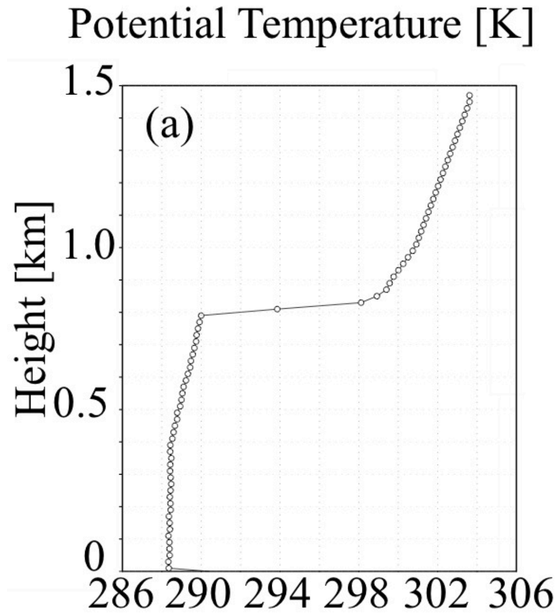
<u>Radar simulator</u>

- Radar simulator developed by Okamoto et al. (2007, 2008)

Model description and experimental set

Model [JMANHM+HUCM (Iguchi et al., 2008)]

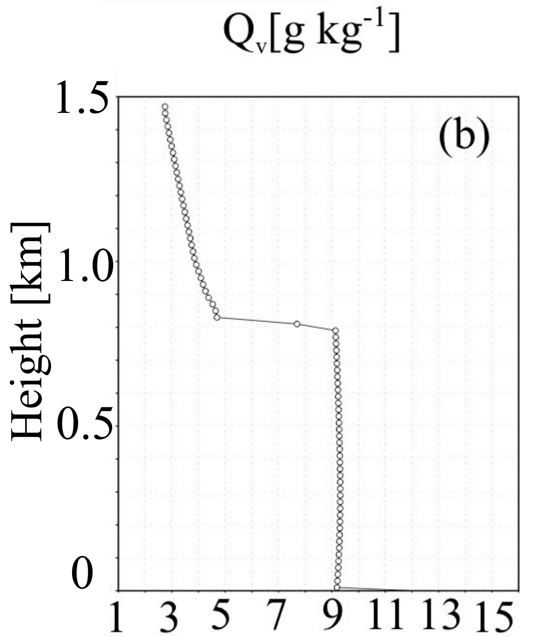
- Dynamics : JMANHM (Saito et al., 2001, 2006)
- Turbulence : Deadroff (1980)
- Cloud Microphysics :
  - HUCM (spectral bin) (Khain et al., 2000)
    - nucleation, condensation/evaporation, collision (only warm cloud)
- Radiation : Stevens et al. (2005)
- Regeneration of aerosol : Feingold et al. (1996)

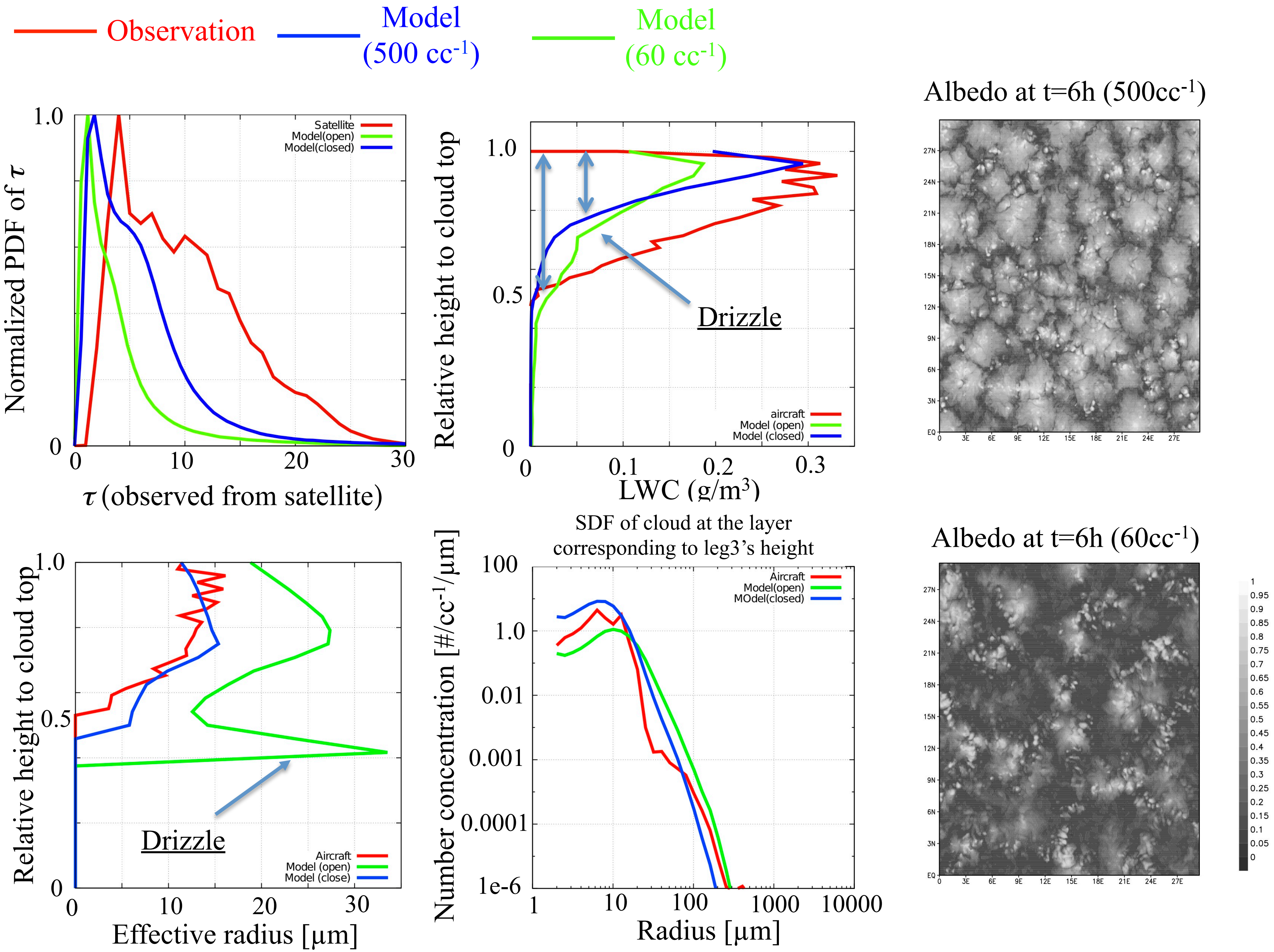


Experimental set (Ackermann et al. 2009)

- Calculation domain : 30 km × 30km × 1.5 km
- Grid resolution : 50m (horizontal), 20m (vertical)
- Aerosol chemical component and amount: Sulfate (60 cc^{-1}, 500cc^{-1})
- Calculation time : 6 hour (dt=0.5 s for dynamics)
- Surface flux : 16 Wm^{-2} (latent), 93 Wm^{-2} (sensible)
- Large scale subsidence : 3.75×10^{-6} s^{-1}
- Initial dynamical condition :

  Based on DYCOMS-II RF02 model study (Ackermann et al., 2009)



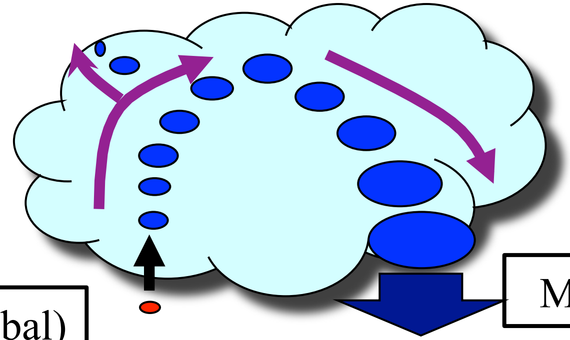


Observation
Model (500 cc-1)
Model (60 cc-1)
Normalized PDF of τ
τ (observed from satellite)
Satellite
Model(open)
Model(closed)
Relative height to cloud top
LWC (g/m3)
aircraft
Model (open)
Model (closed)
Drizzle
Albedo at t=6h (500cc-1)
Albedo at t=6h (60cc-1)
Relative height to cloud top
Effective radius [μm]
Aircraft
Model (open)
Model (close)
Drizzle
SDF of cloud at the layer corresponding to leg3's height
Number concentration [#/cc-1/μm]
Radius [μm]
Aircraft
Model(open)
MOdel(closed)

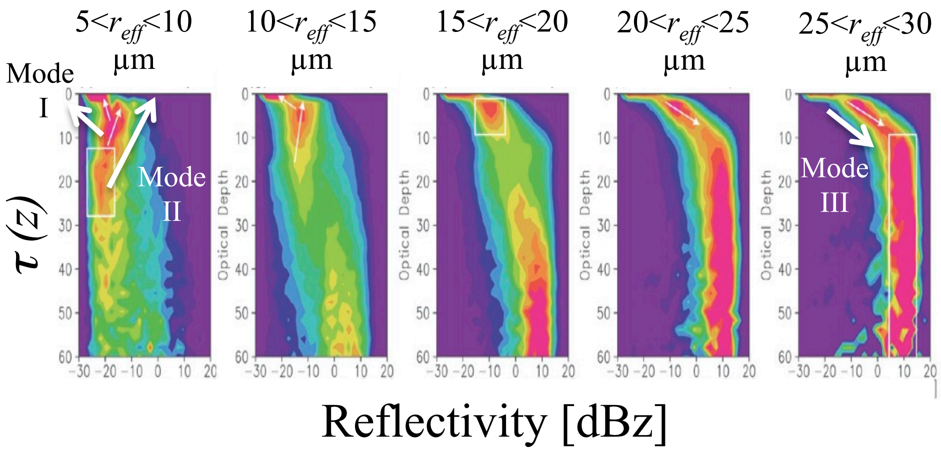
Summary of comparison with observation

- The effective radius of model is close to that obtained from aircraft observations.
- Size distribution function of model don’t have large difference from observed from aircraft.
- Liquid water content and effective radius obtained by model is similar to that by observation.
- Clouds in the model are optically thinner than those observed.
- Experimental set is one of the reason of difference.

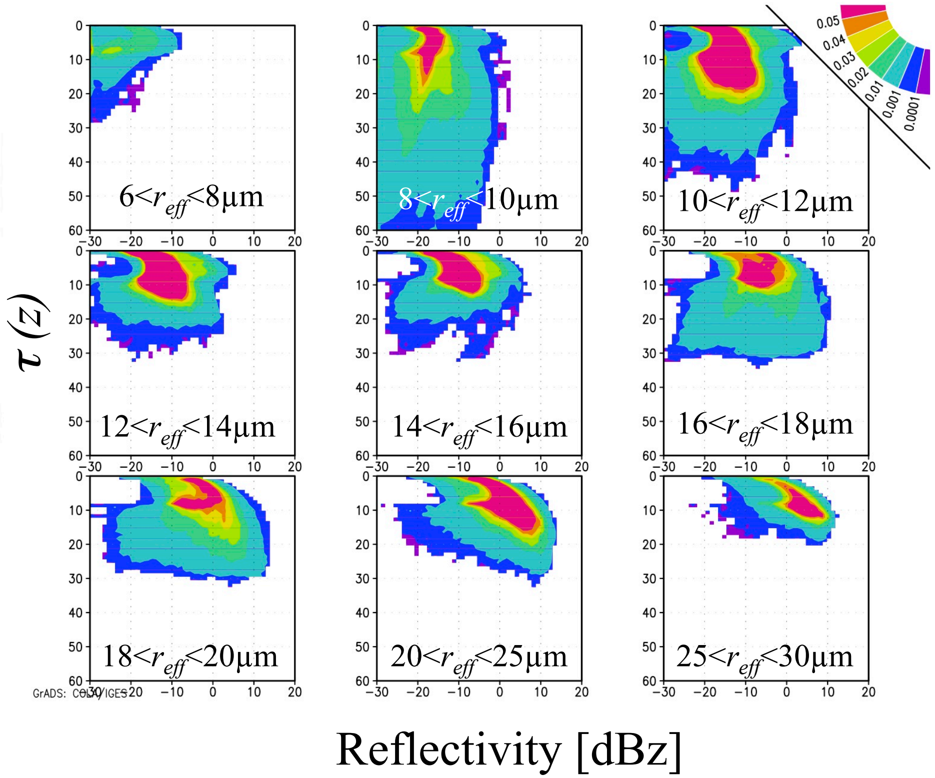
CFODD



Satellite (Global)

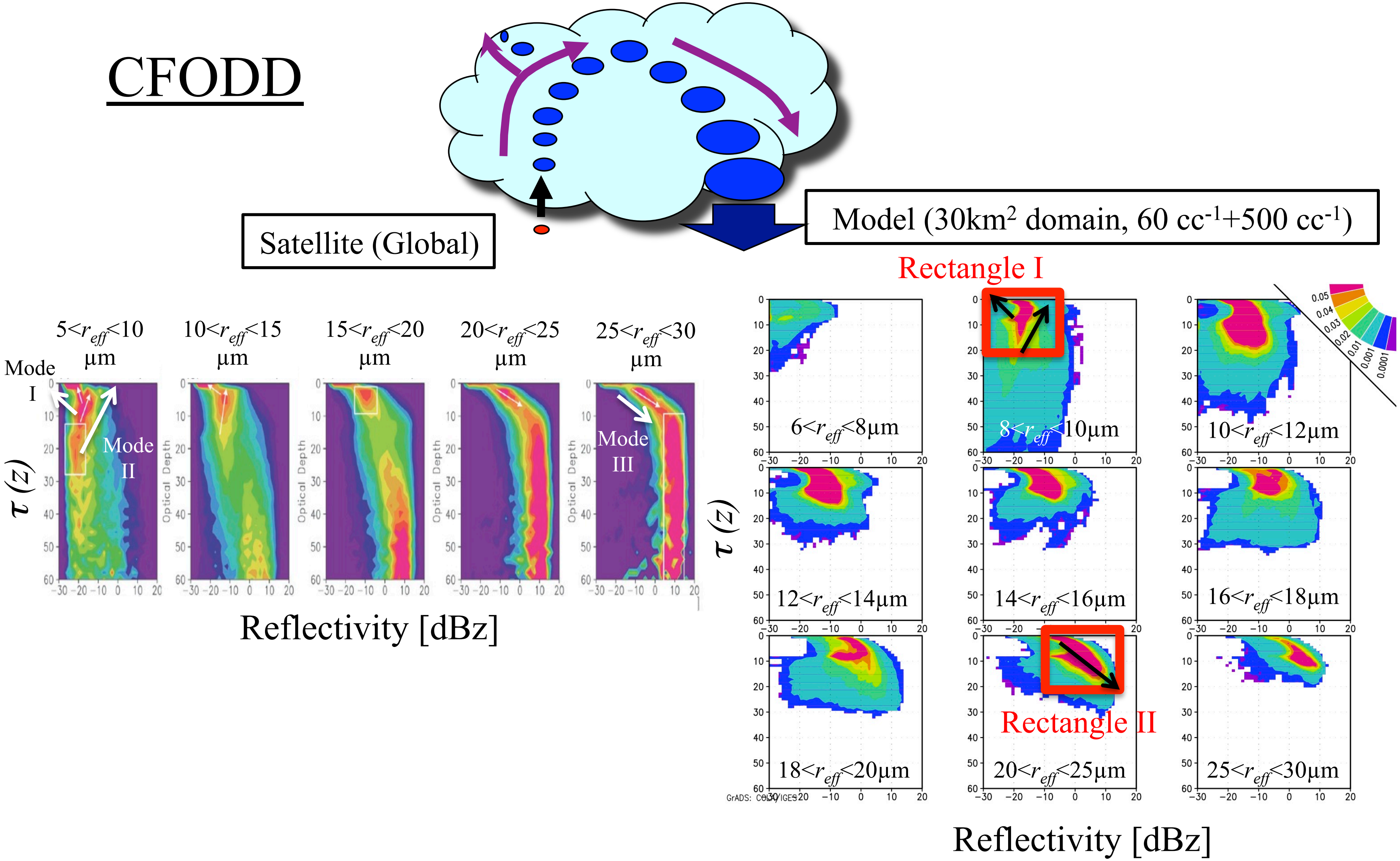


Model (30km^2 domain, 60 cc^{-1}+500 cc^{-1})



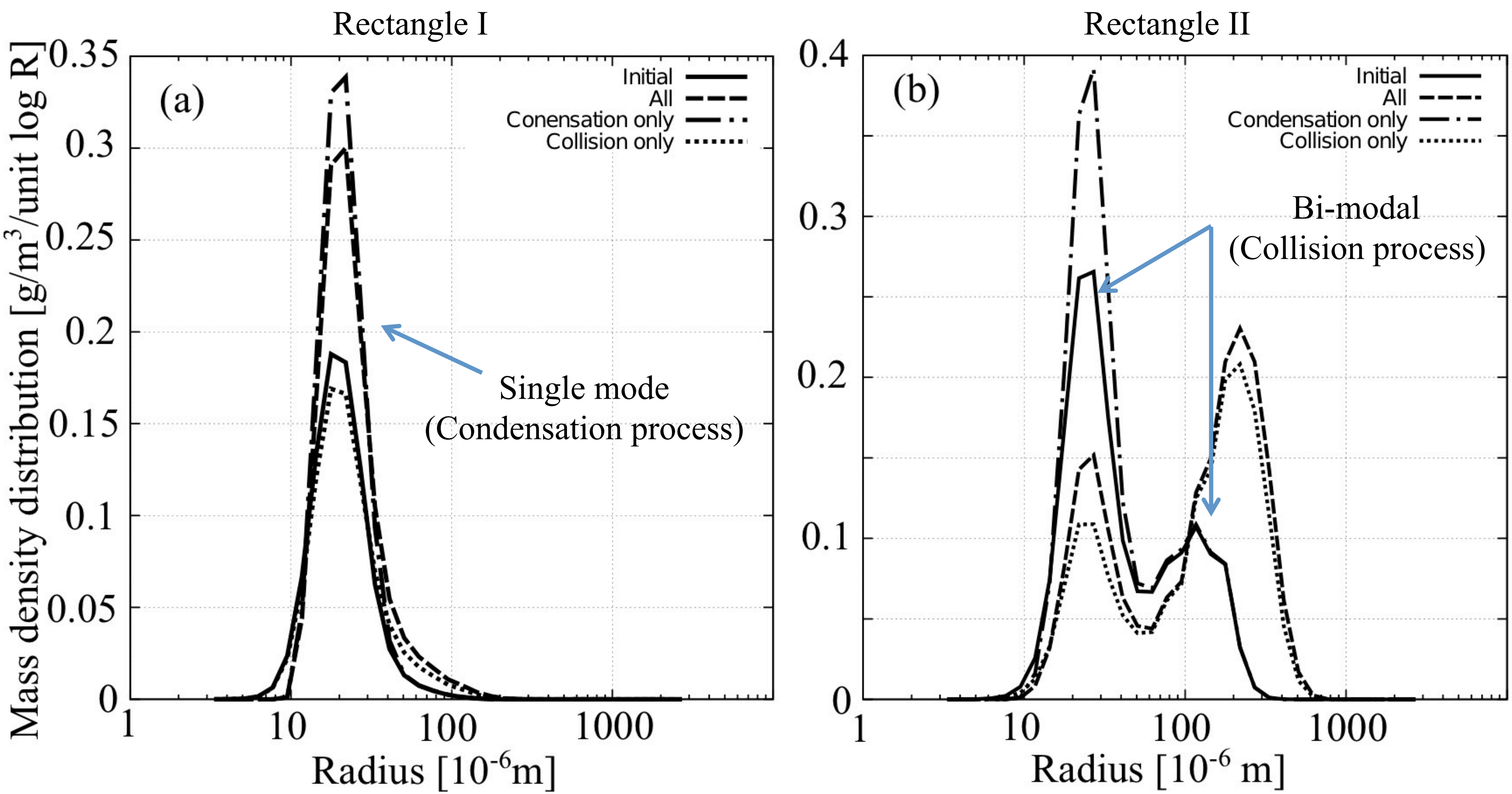
- CFODD obtained by the model doesn't have contours on optically thick area.
- Reflectivity of small particles (i.e. <10 µm) is larger than that observed.

CFODD



- CFODD calculated by the model can represent the tri-modal distribution shown in CFODD obtained from satellite observation.

Size distribution function (SDF)



- SDFs of clouds in rectangle I is mono modal distribution, and those in rectangle II shows bi-modal distribution.
- Clouds in rectangle I mainly grow by condensation/evaporation.
- Clouds in rectangle II mainly grow by collision.

Summary and future work

Summary

- The model results agree with aircraft observation.
- The model underestimated the optical thickness of cloud.
- CFODD are firstly calculated by 3-D spectral bin microphysical model.
- Model derived CFODD represent tri-modal structure of CFODD, which is observed by satellite
- Investigations of SDFs supports the interpretation of Nakajima et al. (2010) about CFODD.

Problem

- Clouds in model are optically thin and cloud top height is ~1000m.
- It is hard for CloudSat to detect these clouds.
- Experimental set up is not realistic (uniform, idealized) to compare satellite observation and calculation domain is narrow

Future work

- We need calculate CFODD obtained from optically thicker cloud by model.
- We need calculate clouds in realistic initial and boundary condition.