ESA-JAXA Pre-Launch EarthCARE Science and Validation Workshop

13 – 17 November 2023 | ESA-ESRIN, Frascati (Rome), Italy

Evaluations of a microphysics scheme using the ground observation data and EarthCARE-like data

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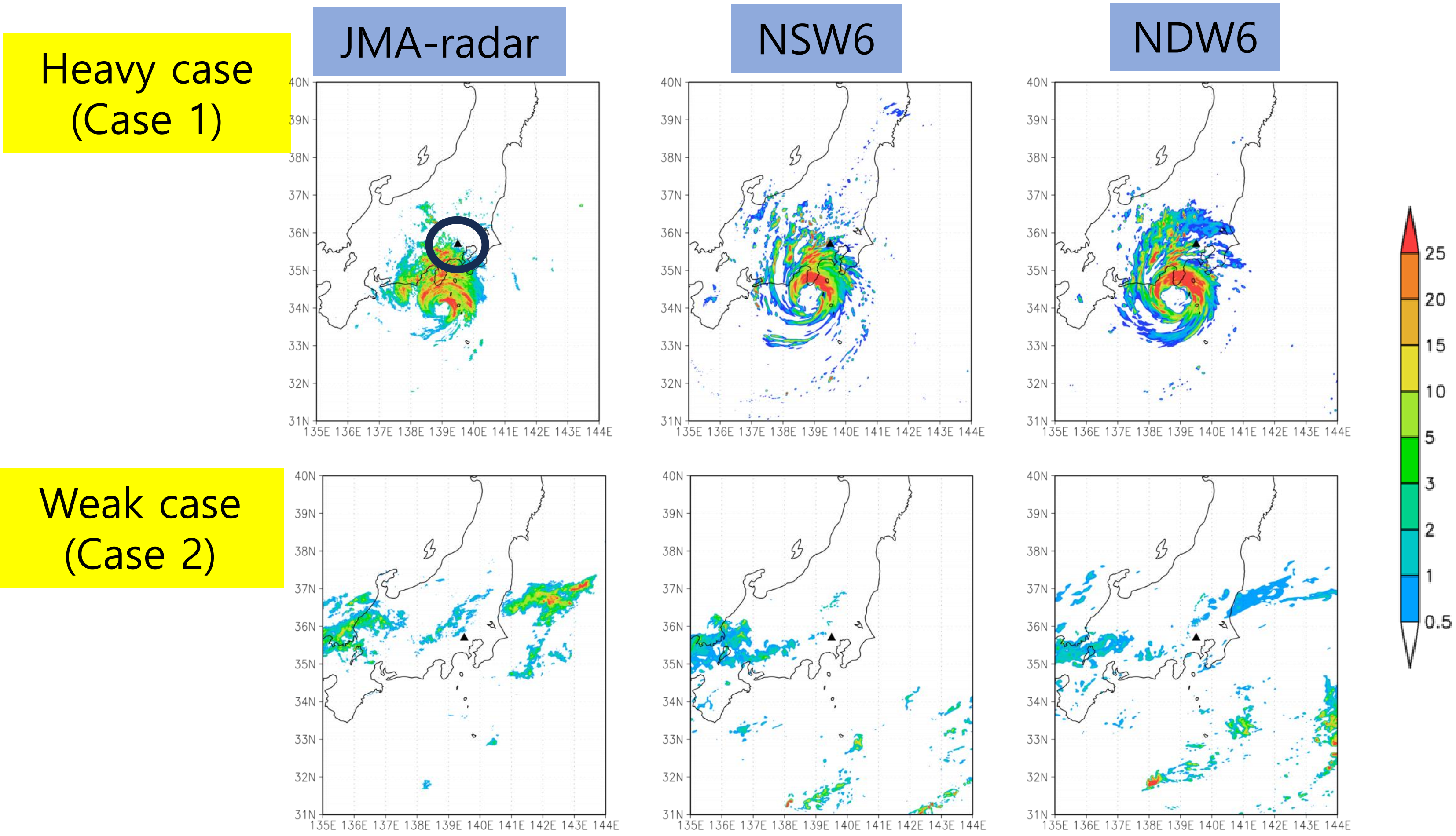
Introduction

- New observations, such as the Doppler velocity from EarthCARE, will provide new insights into the evaluation and improvement of a global storm-resolving model (GSRMs). Before launching the satellite, it is important to understand how to use the information on the Doppler velocity to evaluate GSRMs.
- We use the observation of the Doppler velocity by a cloud radar installed on the ground and investigate the methodology of evaluation of GSRMs using a sensor simulator for the Doppler velocity.
- We use the W-band Doppler cloud radar (HG-SPIDER) at Koganei-shi in Japan, which was installed in a similar setting to the EarthCARE CPR.
- We use the ground radar to understand how to use the observation by the EarthCARE CPR before the launch.
- In this study, we introduce an evaluation method for a cloud microphysics scheme using the vertical profile of the Doppler velocity for application to the EarthCARE observation.
- We evaluate two types of cloud microphysics schemes using this method.
- We investigate the EarthCARE-like simulations using the Joint simulator and discuss the results with different instrument settings with random errors.
- This study is based on Roh et al. 2023 (AMT in review).

Evaluation of two microphysics schemes in NICAM for two precipitation cases



- The Nonhydorstatic Icosahedral Atmospheric Model (NICAM; Satoh et al., 2014)
- The stretched NICAM(Tomita 2008a)

The minimum grid interval is approximately 800m.

Evaluation of two microphysics schemes like

NSW6: single-moment Water 6-categories (Tomita 2008b) with modifications by Roh and Satoh (2014)

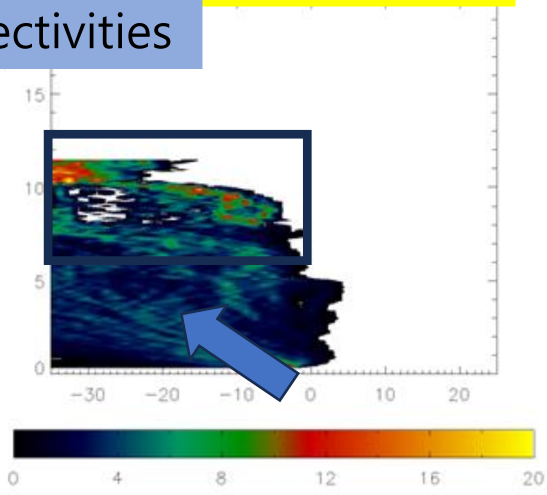
NDW6: double-moment Water 6-categories (Seiki and Nakajima 2014).

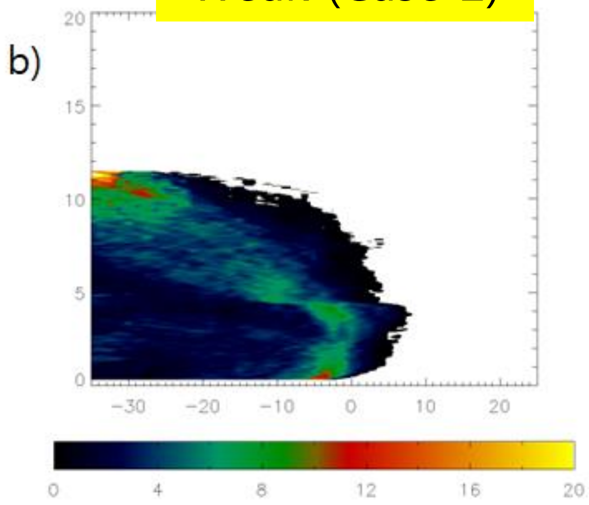
Observed CFADs of radar reflectivity and Doppler velocity for two cases

Heavy (Case1)

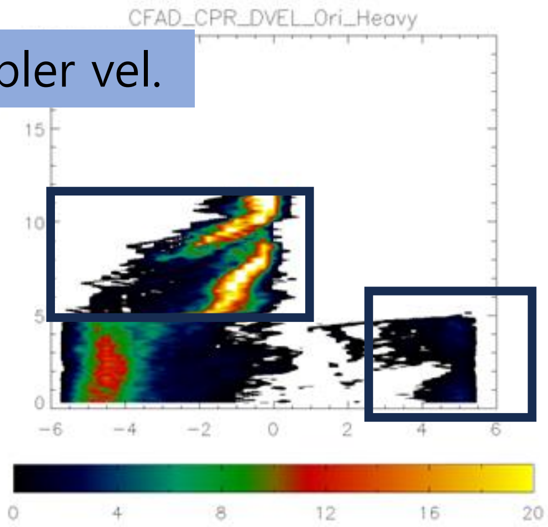
Weak (Case 2)

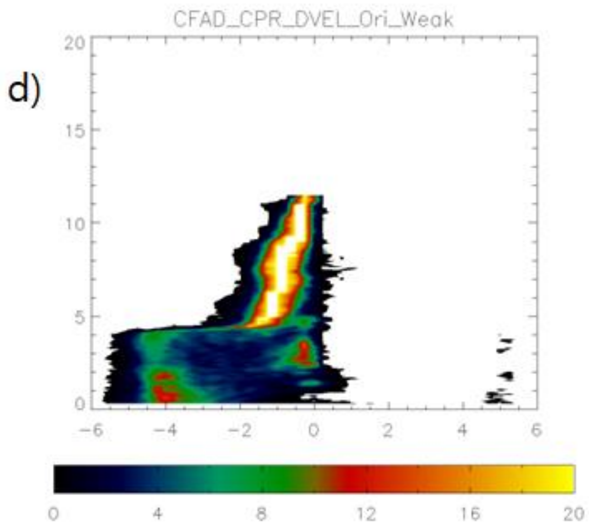
Reflectivities





Doppler vel.





- The sampling size in the heavy precipitation case is relatively a fewer than the weak precipitation because of the wet attenuation.

- The CFADs radar reflectivities in Case 1 show a decrease in the radar reflectivity because of the attenuation of rain.

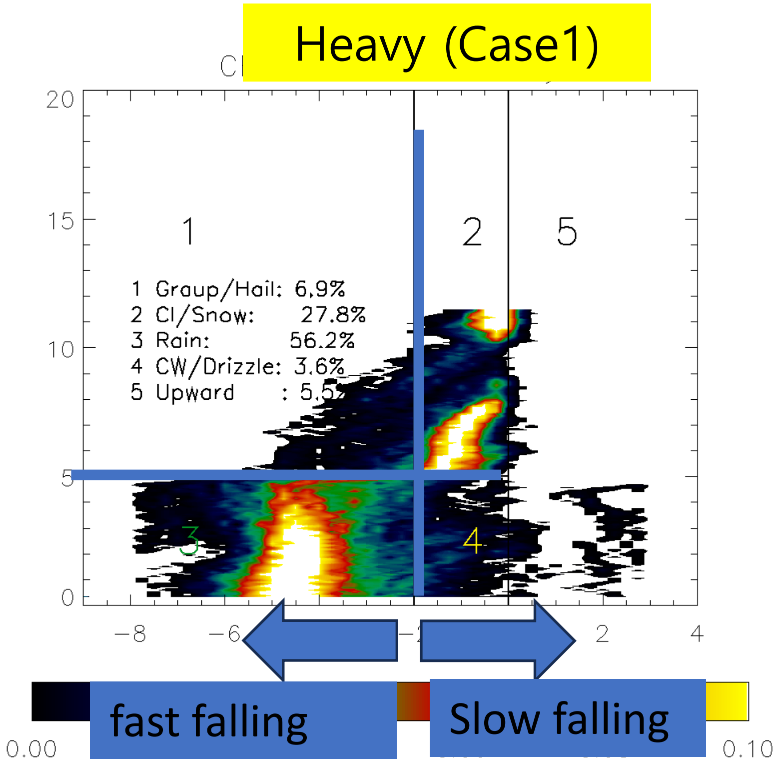
- The Case 2 shows the CFADs are similar to the CloudSat's result.

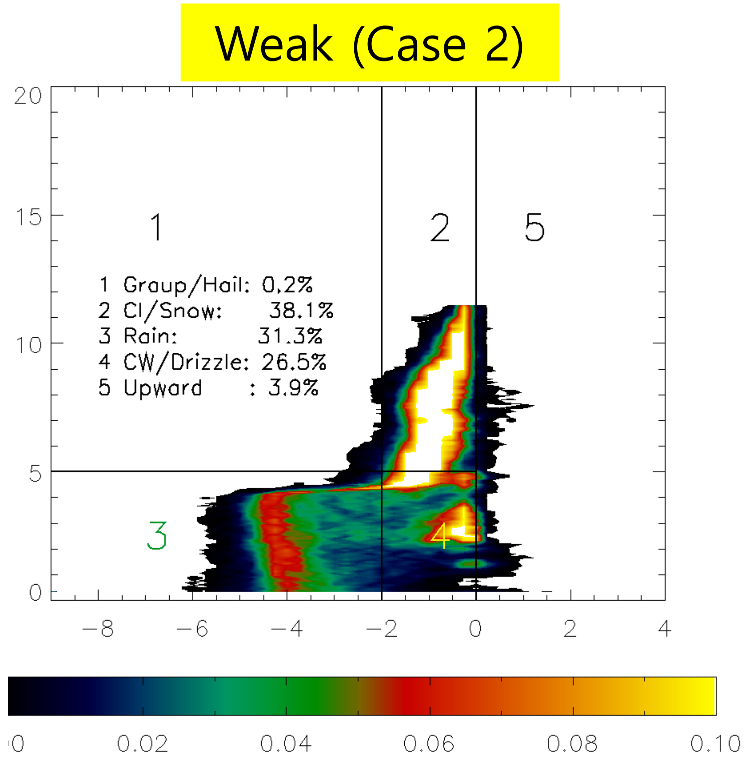
- The expectation of the EarhCARE CPR is the better performance of Doppler velocity for extreme precipitation free to the wet attenuation.

The unfolding method to the Doppler velocity above 3 m/s

The Joint histograms between Doppler velocity and altitude

Doppler velocity=
(The radar reflectivity-weighted fall velocity of hydrometeors)
+(vertical air motion)

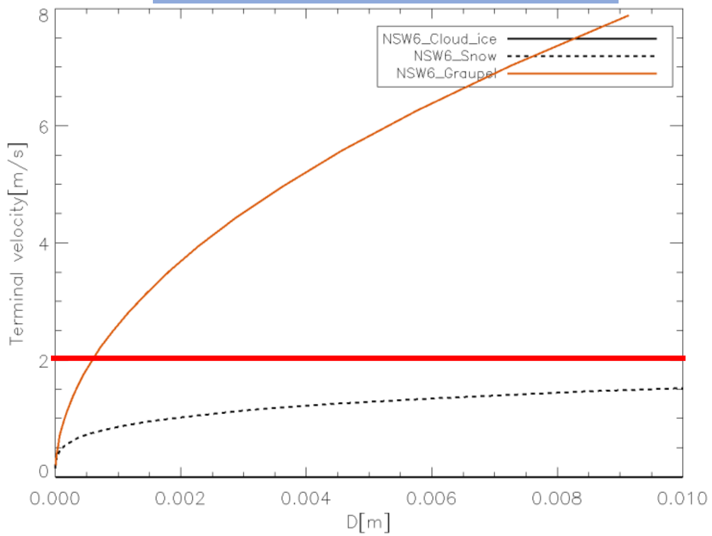




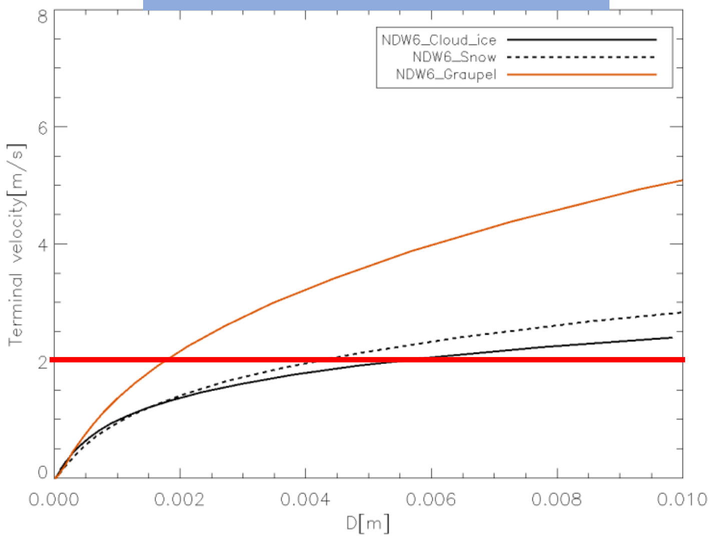
- The rain fraction is dominant in Case 1 and the cloud ice/snow fraction is dominant in Case 2.
- The Case 1 shows the discontinuous fraction near 10 km altitude because of the sampling issue.

The Vt(terminal velocity)-D relationship between NSW6 and NDW6

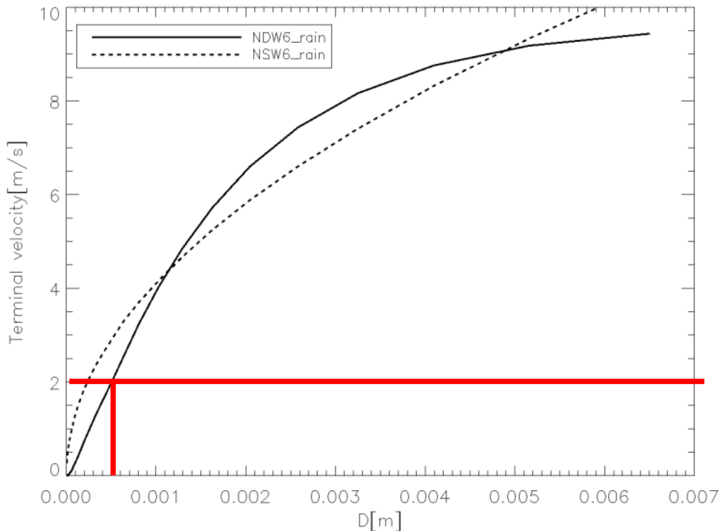
Ices for NSW6



Ices for NDW6

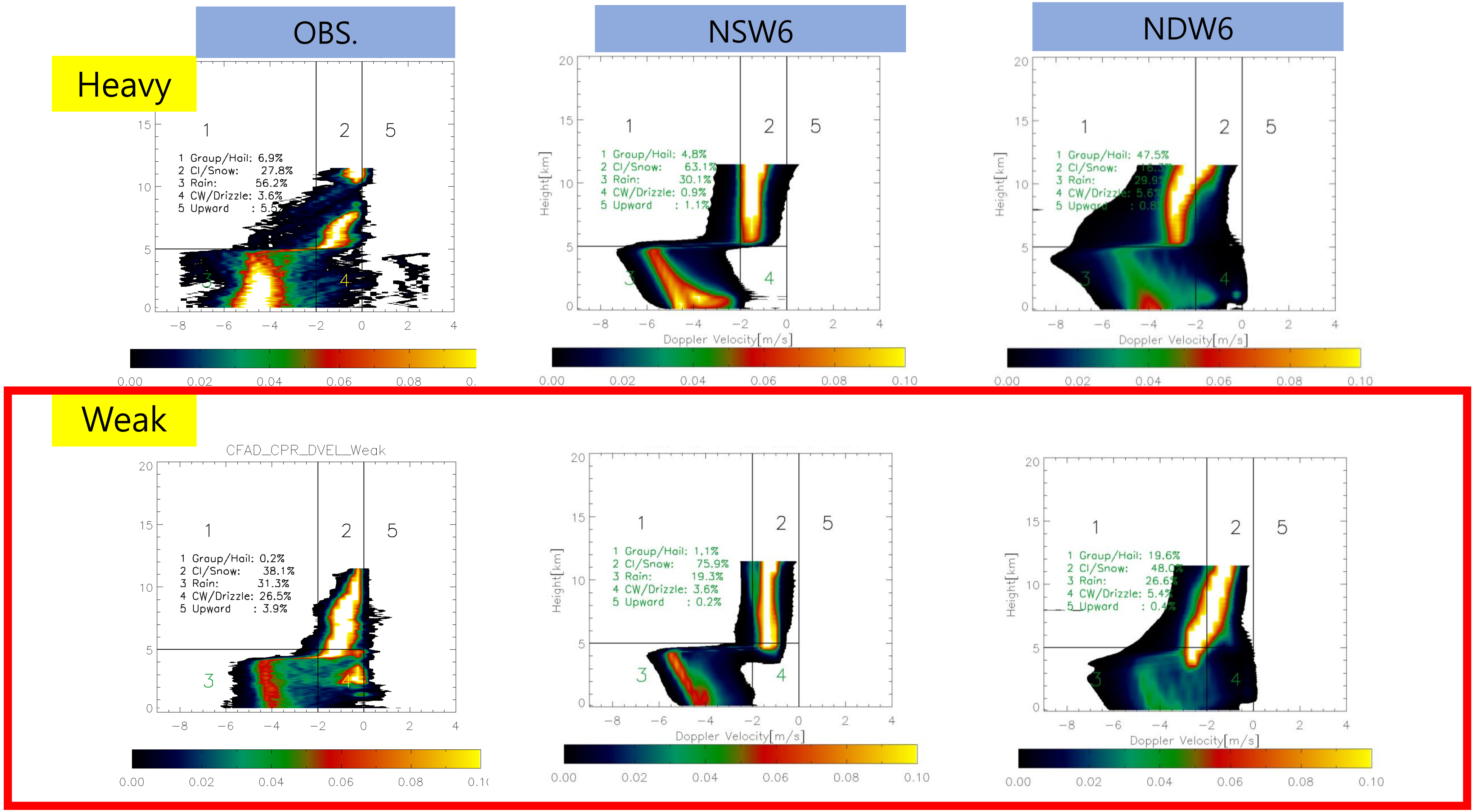


Rain

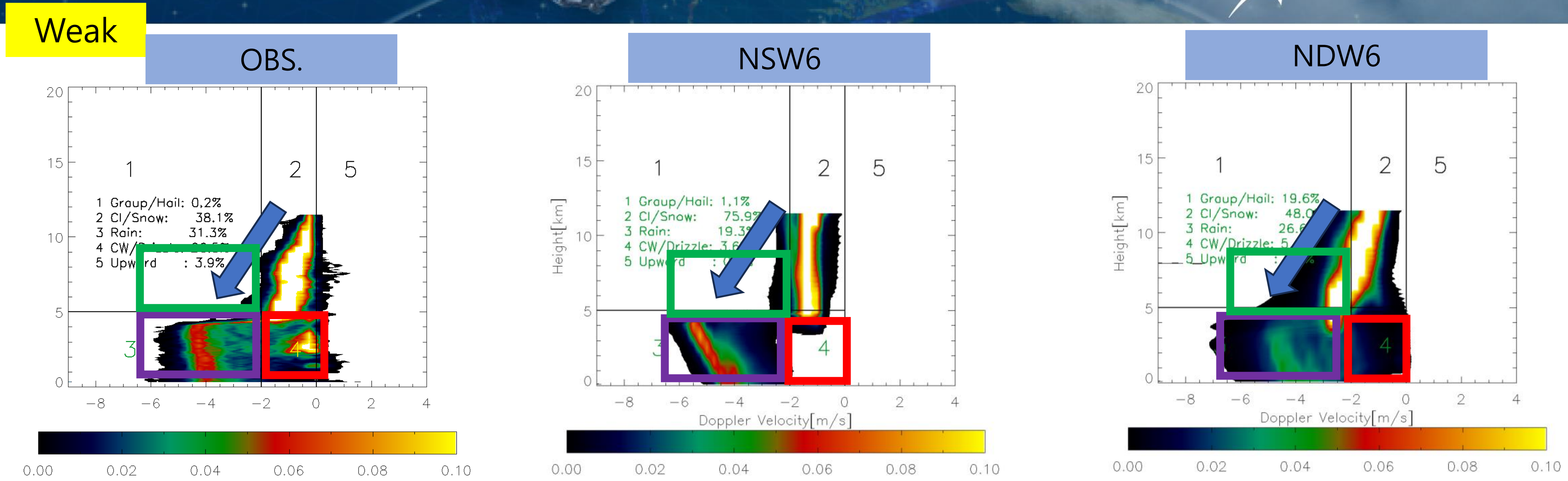


- The graupel from NSW6 has a faster terminal velocity than the graupel from NDW6.
- The terminal velocity of cloud ice and snow is slower in NSW6 than in NDW6.
- The terminal velocity of rain is also different for each microphysics.
- This means that the definitions of ice hydrometeors are different. And it affects the classification of hydrometeors.

Evaluation of the two microphysics schemes



Interpretations of the results



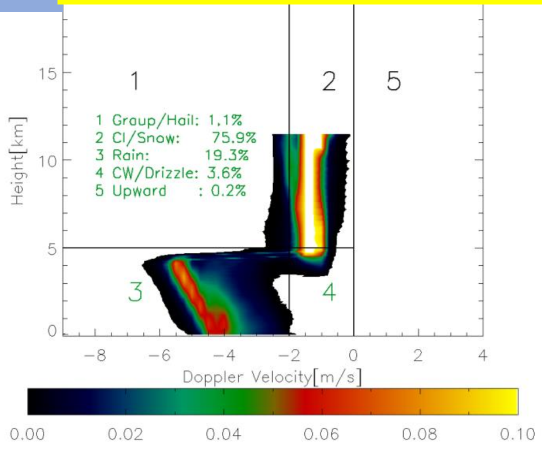
1. The growth of ice particles
2. Separation between rain and drizzle
3. Riming particles (graupel/hail) with fast terminal velocity
4. The rain size distribution
5. The slope of the Doppler velocity of rain

$$v_{t[r,s,g]}(D) = c_{[r,s,g]} D^{d_{[r,s,g]}} \left(\frac{\rho_0}{\rho}\right)^{1/2}$$

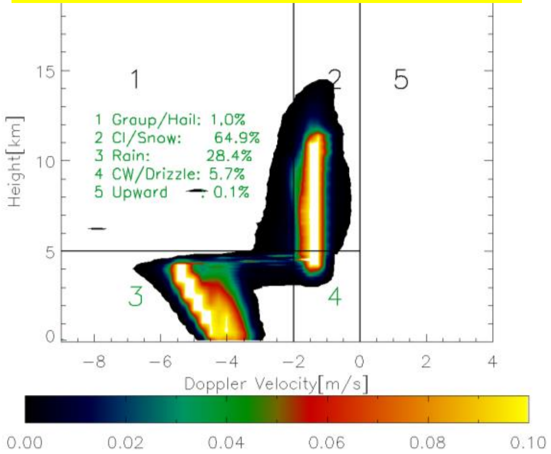
Application to the EarthCARE-like data without random error

NSW6

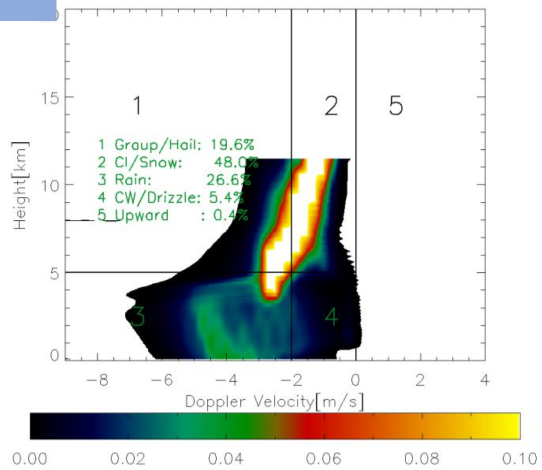
Ground observation

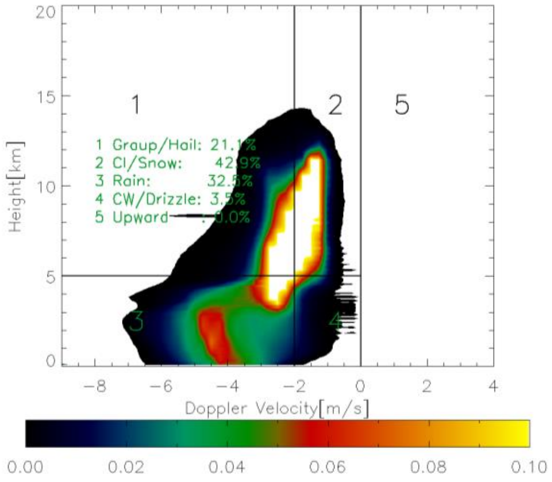


EarthCARE-like



NDW6





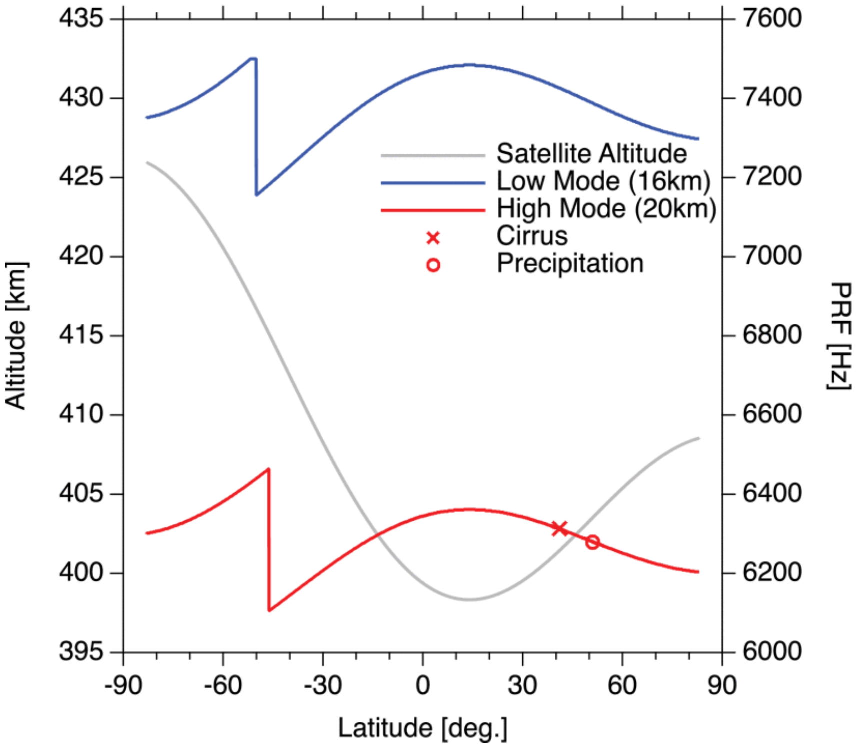
The change of the settings

- The increase of the observation range to 20km
- The change of the vertical resolution
  75m → 99.9308m
- The change of the threshold
  --40 dBZ → -15 dBZ

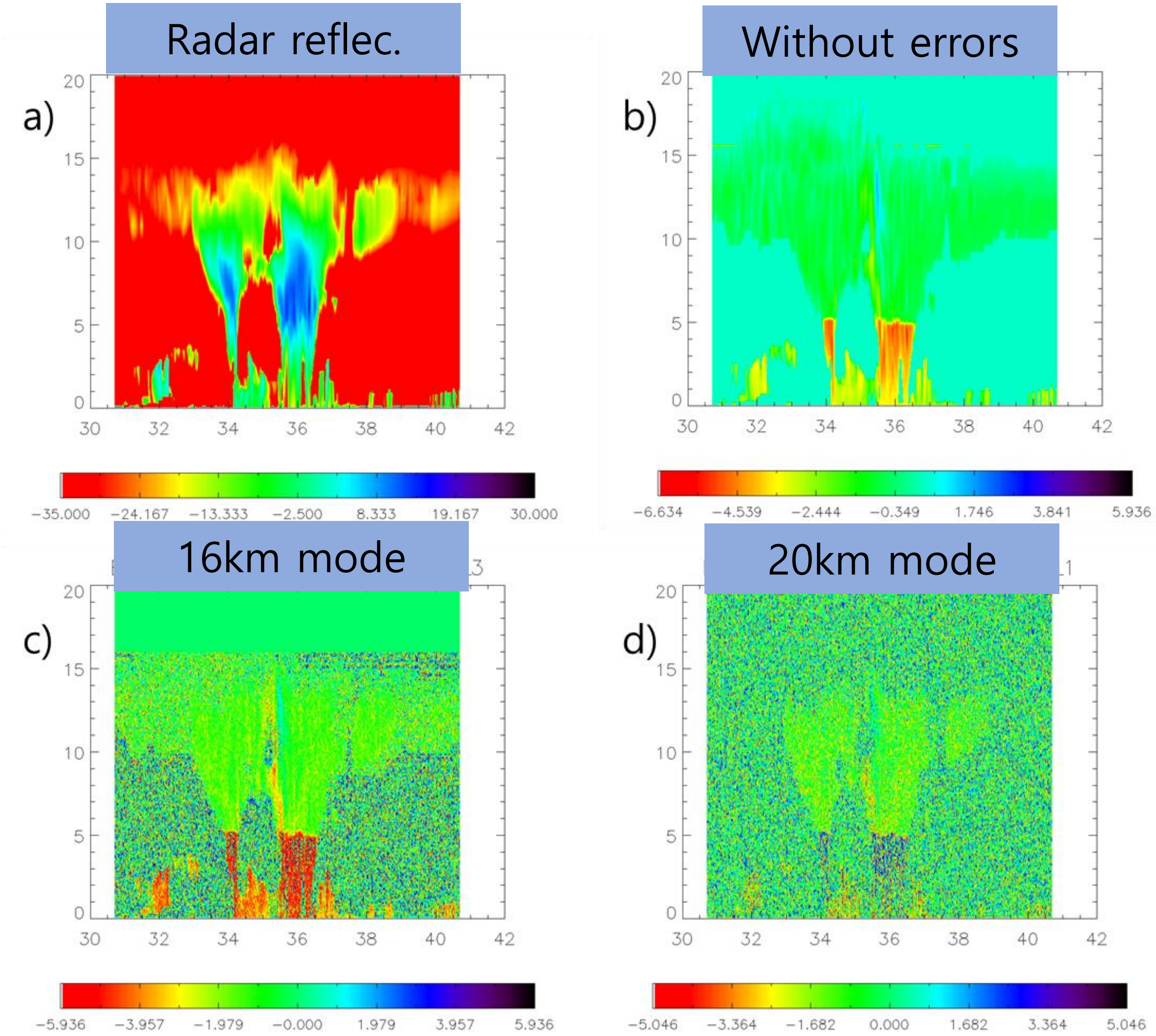
The expected results

- The characteristics are consistent with the ground observation.
- The increase of the fraction of rain and graupel/hail
- The decrease of the fraction of cloud water and drizzle

The impact of the observation window mode on the random errors



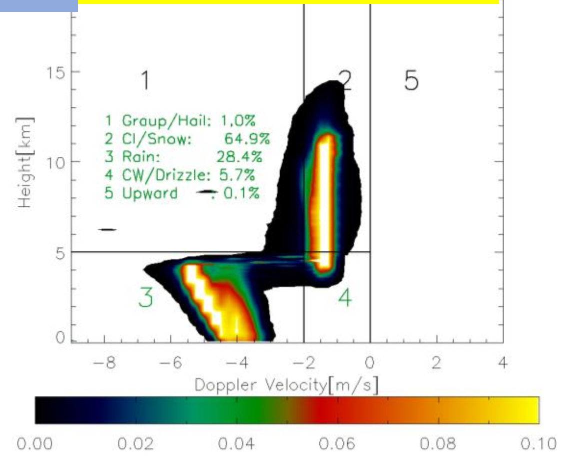
Hagihara et al. 2021



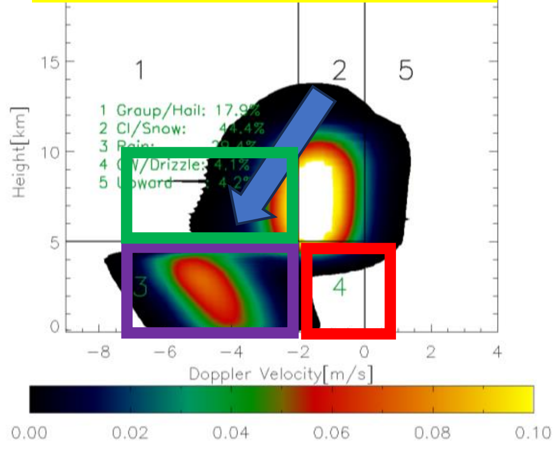
Application to the EarthCARE-like data with low mode (16km observation window)

NSW6

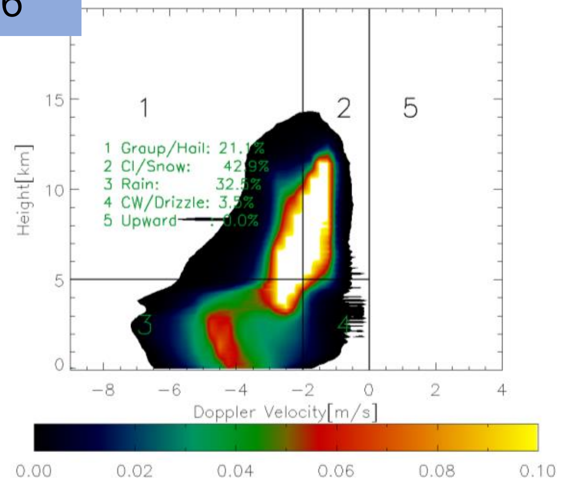
No errors

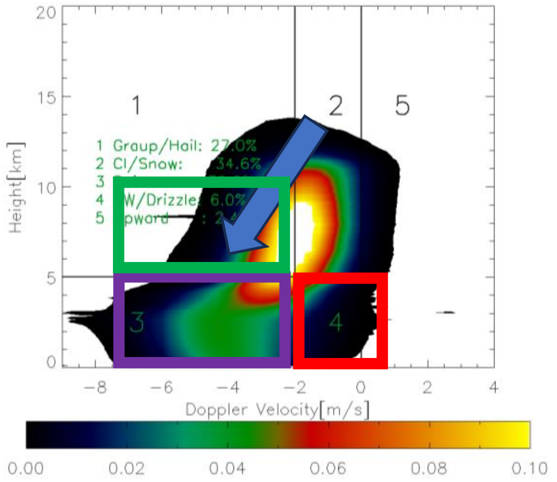


Low mode



NDW6



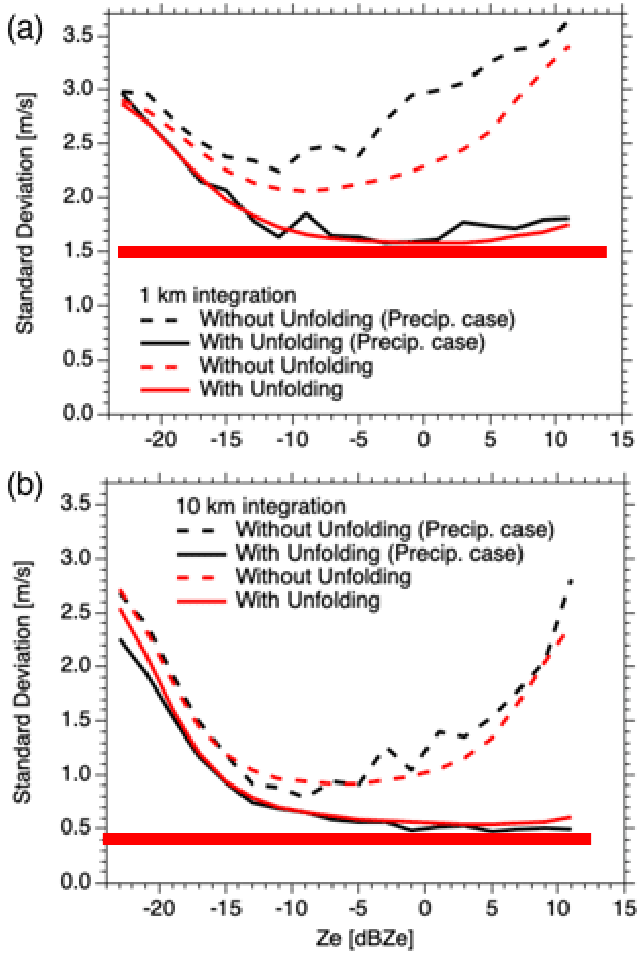


- We applied random errors with the low mode to the simulation results.
- The random errors make broadening of the variance of Doppler velocity.
- The results are consistent with the previous results with no errors.

Application to the EarthCARE-like data with high mode (20km observation window)

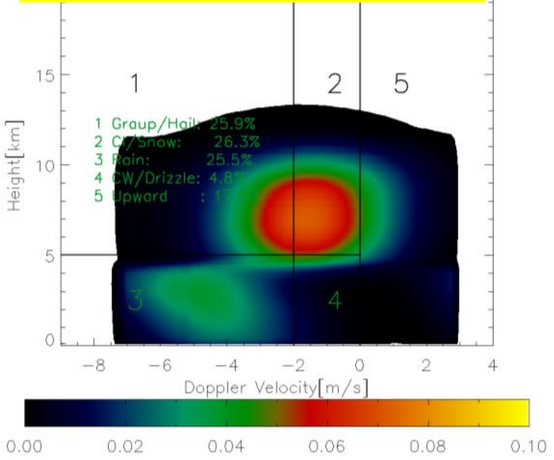
NSW6

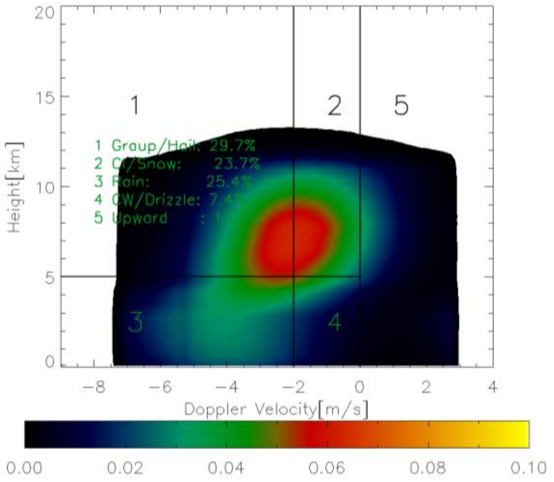
No errors



Hagihara et al. 2023

High mode





- The high mode shows the large random errors in the joint histograms—however, the pattern of the growth of the ice particles in NDW6.

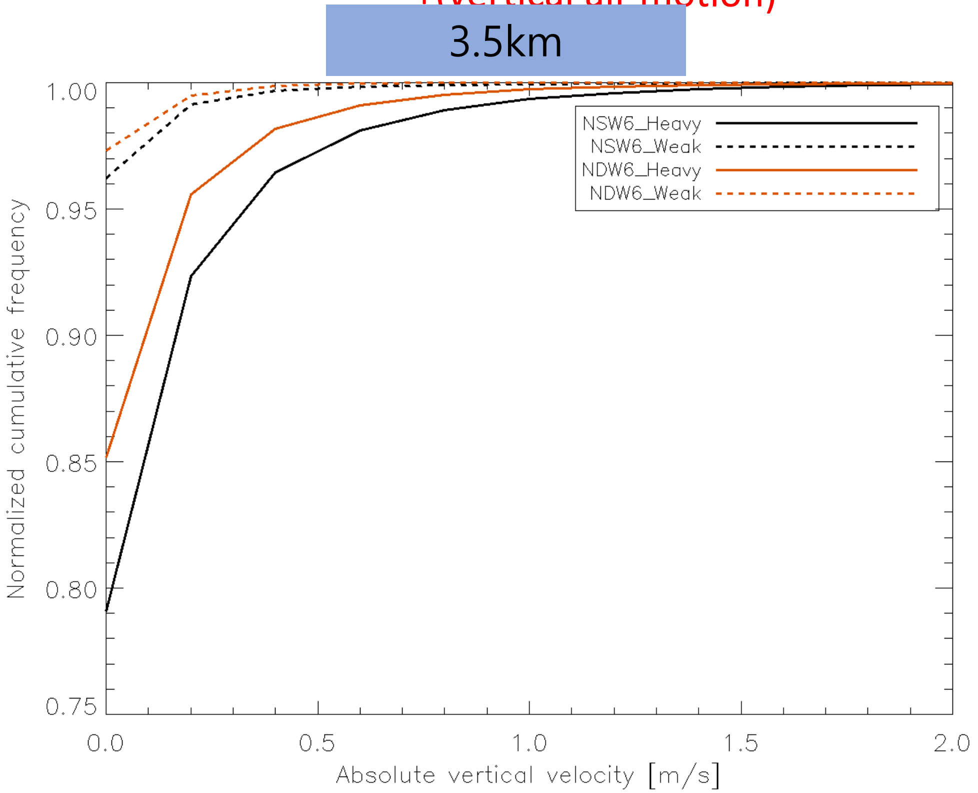
- In this study, we did not consider the integration method like the official product.
- The official product consists of two kinds of sampling data: 1km and 10km.
- The 10km integration product reduces the random errors of the Doppler velocity.

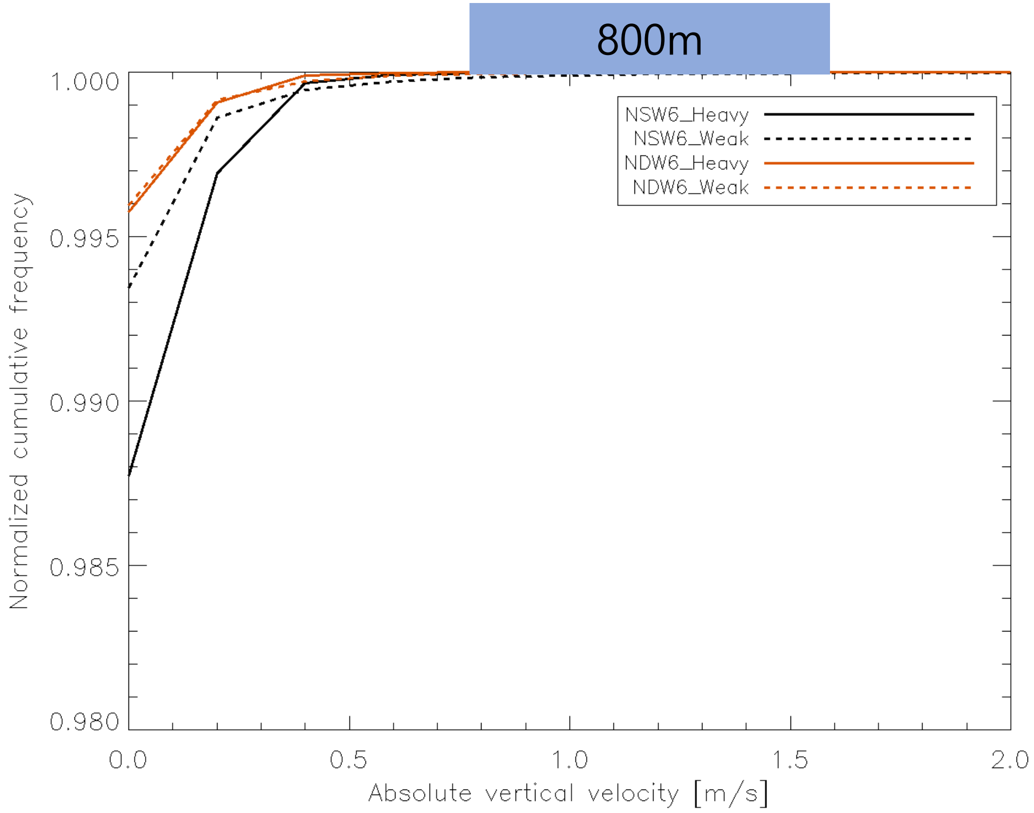
Summary

- We introduced a hydrometeor classification method using a joint histogram of Doppler velocity and height.
- The merits of the vertical pointing Doppler velocity like
  - Free to attenuation correction
  - The high fraction from the terminal velocity of hydrometeors
- We evaluated two microphysics schemes (NSW6 and NDW6) in NICAM using the 94 GHz vertically pointing radar in NICT.
- The choice of microphysics is more sensitive than the case dependency.
- The lessons from the ground observation data shows
  1. The growth of ice particles
  2. Separation between rain and drizzle
  3. Riming particles (graupel/hail) with fast terminal velocity
  4. The rain size distribution
  5. The slope of the Doppler velocity of rain
- The EarthCARE-like data shows the characteristics of the microphysics schemes.
- It is better to investigate the extreme precipitation cases than the ground observation because it is free from wet attention.
- We expect the Doppler velocity of EarthCARE will understand microphysical processes and improve a global km scale model

Cumulative PDFs of the absolute vertical air velocity in NICAM

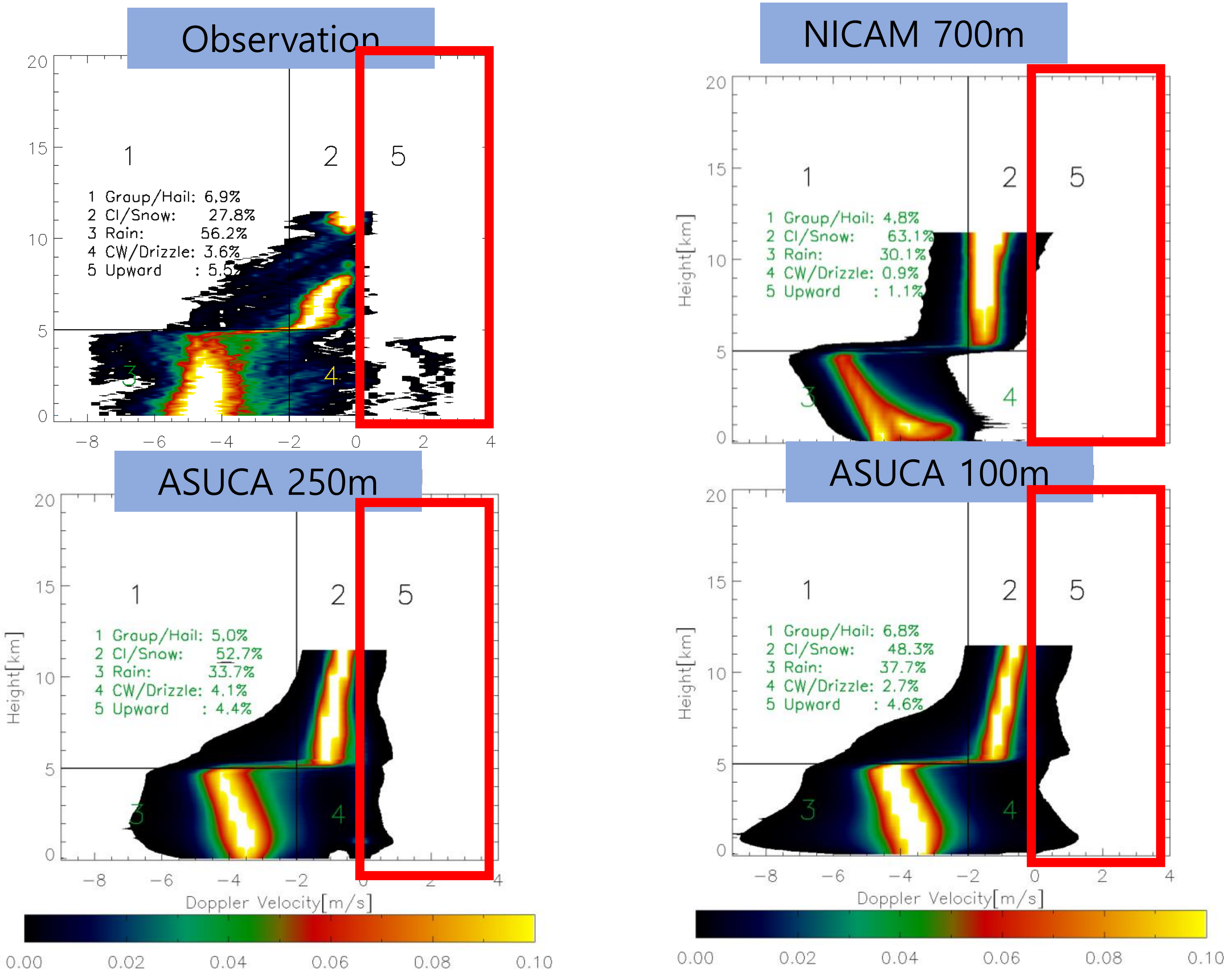
Doppler velocity=
(The radar reflectivity-weighted fall velocity of hydrometeors)
+(vertical air motion)





- The cumulative normalized distribution of the absolute vertical velocity with 0.2 m/s bins for echoes with radar reflectivity greater than -40 dBZ.
- All simulations show that nearly 80% of the echoes have less than 0.2 m/s vertical air motion.

The impact of the turbulences on the results using a regional model (ASUCA)



- LES reproduces the upward motion successfully.

Surface clutter