Investigation of hydrometer optical properties consistent with spaceborne cloud radar observations

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1. Introduction

Various satellite observation data are assimilated in the numerical whether prediction (NWP) system. However, the data assimilation of cloud profiling radar (CPR) onboard CloudSat and EarthCARE satellites has not been implemented in the operational global NWP system, because of the narrow observation coverage of spaceborne nadir-looking CPR, uncertainty of cloud representation in the global NWP model, and difficulty of assimilating clouds associated with complex cloud process. In the global data assimilation system of Japan Meteorological Agency (JMA), the observed atmospheric radiances are assimilated by using the radiative transfer model RTTOV. Recently, the radar simulator was introduced in RTTOV version 13. We target the assimilation of CPR radar reflectivity using the RTTOV radar simulator in order to improve the reproducibility of vertical structure of cloud and water vapor. In this study, we investigate the hydrometer optical properties consistent with CPR radar reflectivity observations for the CPR data assimilation using the RTTOV radar simulator.

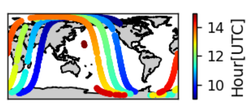
2. Comparison between meteorological model and observations

JMA's global spectral model (JMA-GSM)
Horizontal resolution : 20 km (55 km in data assimilation)
Hydrometers：Mixing ratios of cloud water and ice, and fluxes of rain and snow
Radar reflectivity Zr is calculated by using RTTOV 13.0 (Geer et al., 2021).

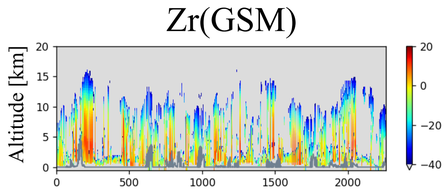
Radar reflectivity Zo(55km) is averaged and quality controlled radar reflectivity of EarthCARE CPR Echo product at the 55 km horizontal resolution.

Time period: 11-24 August 2024

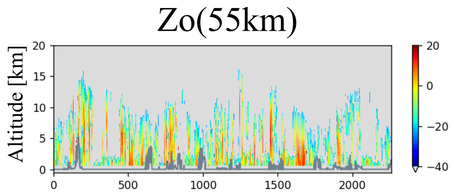
6-hour satellite orbit



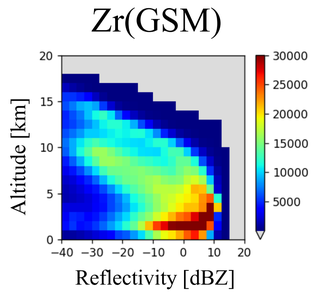
Zr(GSM)



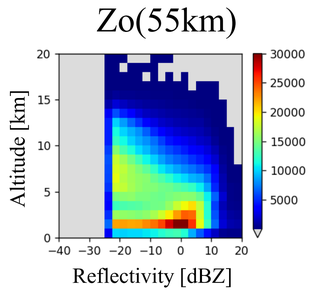
Zo(55km)



Zr(GSM)



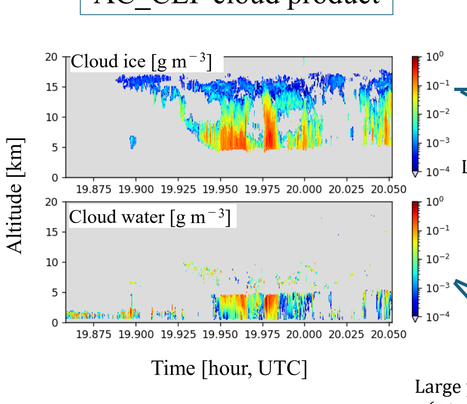
Zo(55km)



3. Calculation of Zr using JAXA AC_CLP product

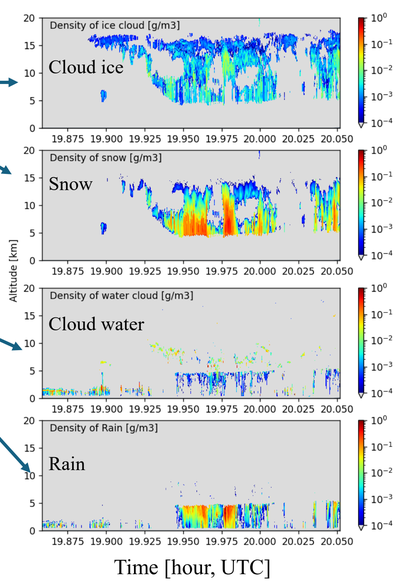
Radar reflectivity Zo(1km) : EarthCARE CPR Echo product
Radar reflectivity Zr(AC) is calculated by using the EarthCARE AC_CLP (CPR+ATLID 2 sensors) cloud product and RTTOV 13.0.
Time period: 11-24 August 2024

AC_CLP cloud product

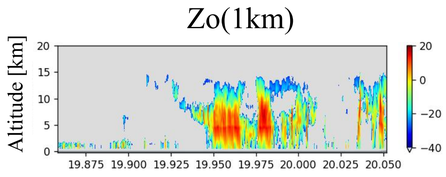


4 hydrometer types used in RTTOV

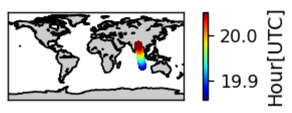
Small particles ($r \leq 50\mu m$)
Large particles ($r > 50\mu m$)
Small particles ($r \leq 50\mu m$)
Large particles ($r > 50\mu m$)



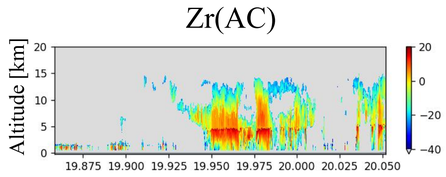
Zo(1km)



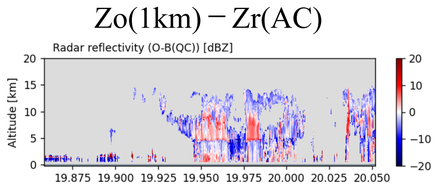
20UTC on 18 August 2024



Zr(AC)



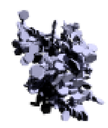
Zo(1km) − Zr(AC)



4. Sensitivity to particle size distributions and shapes

	Rain	Snow	Cloud water	Cloud ice
Standard	Sphere, MPD	LPA, PSD-F07T	Sphere, MGD-W	LCA, PSD –F07T
R_{new}	Sphere, MGD-Rnew	LPA, PSD-F07T		
S_{new}	Sphere, MPD	8CA, PSD-F07M		
R_{new}+S_{new}	Sphere, MGD-Rnew	8CA, PSD-F07M		

Large plate aggregate (LPA)



Large column aggregate (LCA)

8-column aggregate (8CA)

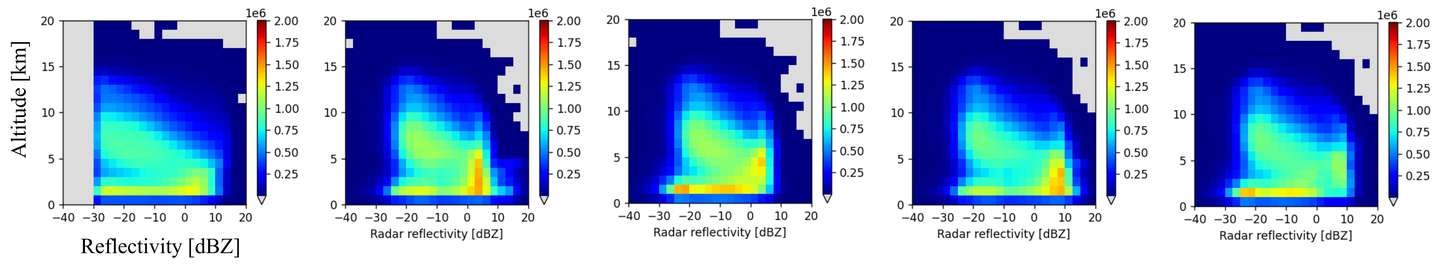
Eriksson et al. 2018

Particle size distribution (PSD)：
Marshall-Palmer distribution (MPD),
Field et al. 2007 (PSD-F07T:tropical, PSD-F07M:midlatitude)
Modified gamma distribution (MGD)
- MGD-W ($\mu = 2, \Lambda = 2.13 \times 10^5, \gamma = 1$)
- MGD-Rnew ($\mu = 3, \Lambda = 4.00 \times 10^4, \gamma = 1$)

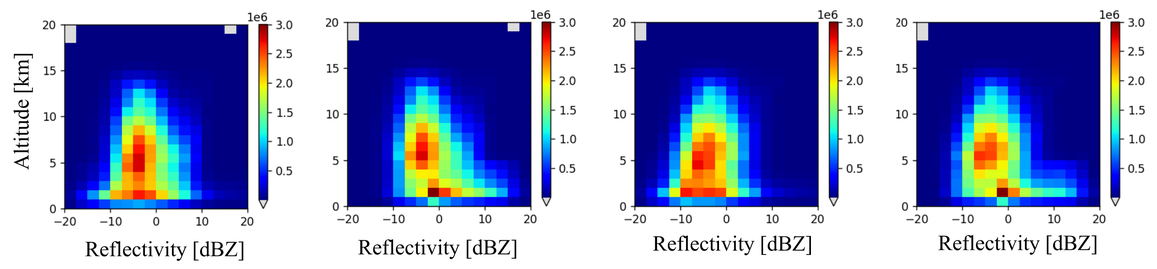
MGD

$$n(D) = N_0 D^{\mu} \exp(-\Lambda D^{\gamma})$$

Zo(1km)　Zr(AC, Standard)　Zr(AC, R_{new})　Zr(AC, S_{new})　Zr(AC, R_{new}+S_{new})



Zo(1km) − Zr(AC)



5. Summary

- We compare calculated radar reflectivity using JMA-GSM and EarthCARE AC_CLP product and radar reflectivity observed by EarthCARE CPR.
- In the frequency distributions of Zr(GSM) and Zr(AC), there is a peak between +5 and +10 dBZ below 5 km altitude, which are not seen in that of Zo(1km).
- By adjusting the particle size distribution and shapes of rain and snow, Zr(AC) became closer to Zo(1km).