Use of a Generalized Radar Simulator for the Validation of Precipitation Estimation from GPM Dual-Frequency Precipitation Radar Measurements

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Background

- The GPM core satellite has been launched successfully on February 28, 2014. A dual-frequency precipitation radar (DPR) is expected to have a potential to measure more accurate rainfall rate than precipitation radar onboard TRMM.
- The DPR is operated at two radio wave frequencies such as Ku-band (13.6 GHz) and Ka-band (35.5 GHz). Different features of received signals between two frequencies may enable us to classify the kind of hydrometeor (Please see the poster 108 by Kobayashi et al.)
- The use of Ka-band radio wave for a spaceborne radar is the first attempt. The signal may be contaminated by large attenuation and multiple scattering (MS).

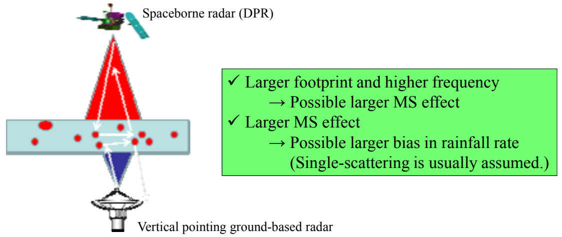

Fig. 1: Illustrating scattering of incident waves from the DPR and a ground-based radar.

Objectives

① Preliminary consideration using a numerical radar simulator.

② Multiple scattering effect and attenuation effect in radar signals from the DPR.

③ Polarimetric indicator(s) for MS effect.

Radar simulator accounting MS effect

- A forward Monte-Carlo method
- The propagation of incident waves
  - → Travelling within a radar sampling volume
- Received reflectivity
  - → Calculated from the number of photons returned to the antenna

1) Emit photons from radar to a rain medium.

2) Determine by the scattering coefficient the distance in which the photon travels to another raindrop.

3) Determine the scattering direction by the phase matrix.

4) Calculate the probability that the photon returns directly to the antenna,

5) Repeat until the photon goes out of the radar sampling volume or until the weight of photon becomes smaller than a threshold.

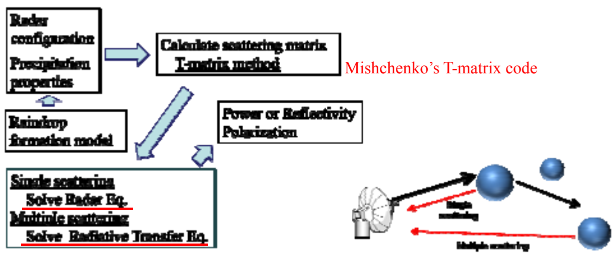

Fig. 2: Flowchart of our generalized radar simulator (GRASIA).

Configurations of case studies

- Vertical profile of rain rate based on WRF simulation
  5 profiles in warm rain regime assumed
  - model 1X: the original profile of rain rate from the control WRF run (light)
  - model 2X: double rain rate
  - ・
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  - model 5X: rain rate 5 times increased from the original profile (intense)
- Marshall and Palmer drop size distribution, drop shape of oblate (Beard and Chung, 1987)
- Beam width: 0.71 degree, Satellite altitude: 400 km, observation of nadir direction

Results on MS effect

- Increasing along with path length in a 4-km length rain layer
- **Negligible for Ku-band radio wave, but significant for Ka-band radio wave (Fig. 3)**
- MS contribution of about 20 % for light rain and about 40 % for moderate rain.
- Assuming the use of simple Z-R Eq. based on M-P DSD, 90 % of MS contribution results in 50 % of bias in rain rate.
- MS effect can be occurred even in intense rain events (Fig.4).
- LDR is one of good indicators of MS effect (Fig.5).
- The LDR observation by W-band radar can be useful for the ground validation in ranges attenuation effect is not so significant (Fig.6).

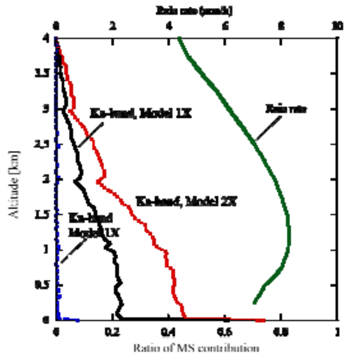


Fig. 3: Profiles of rain rate and MS contribution for each wave.

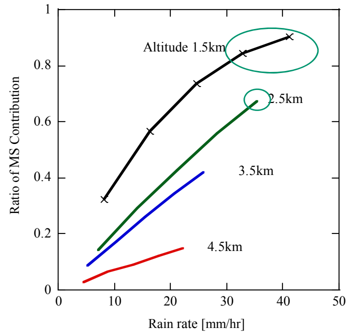


Fig. 4: Relationship between rain rate and MS effect.

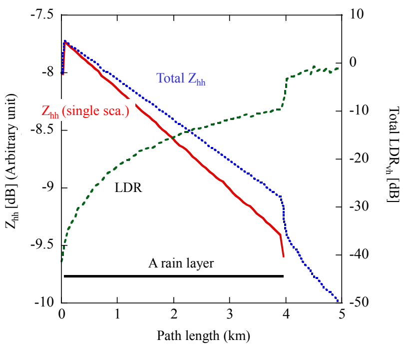


Fig. 5: Profiles of reflectivity and LDR.

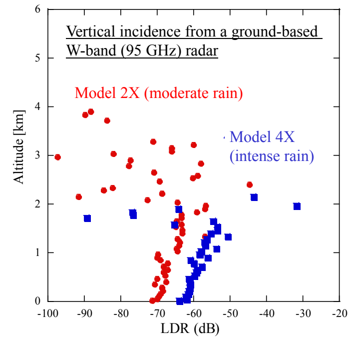


Fig. 6: Profiles of W-band LDR for two rain models.

Results on attenuation effect

- Specific attenuation for Ka-band radar can reach approximately ten times larger than Ku-band radar (ex., 3.5dB (Ku-band) and 27 dB (Ka-band) in Model 5).
- Ka-band radar has not sensitivity enough to detect reflectivity in the lower atmosphere.
- For example, the MS contribution rate in Ka-band is 0.3 at 2.5 km in Model 5 (Fig.4) but received signal is detective. Then, the bias of rain rate can be 15 % (Fig.7).
- The relation between two signals by single-scattering changes by the effect of multiple scattering in intense rainfall.
  → DPR algorithm must account MS effects (Battaglia et al. 2015 JGR).

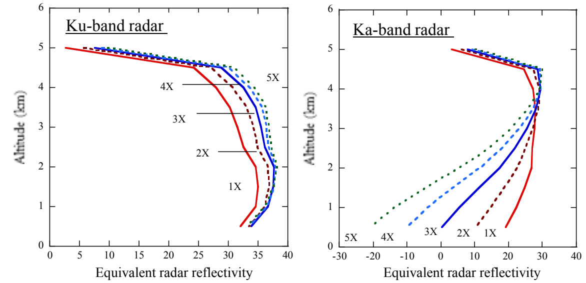
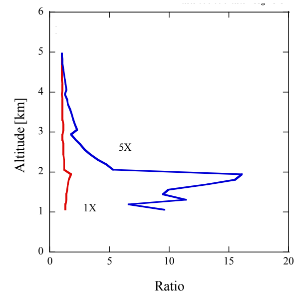


Fig. 7: Profiles of Ze (Left: Ku-band, Right: Ka-band)



$$Ratio = \frac{Z_{Ka}^{total}/Z_{Ku}^{total}}{Z_{Ka}^{single}/Z_{Ku}^{single}}$$

Fig.8 Profiles of the relation between signals from two radars.

Summary

- Significant contributions of multiple scattering and attenuation are simulated by a physically-based radar simulator in a simple cofiguration.
- MS can easily occur in Ka-band radar signals of intense rainfall, which causes the serious error of precipitation amount. The work by Battaglia et al. (2015 JGR) gives good suggestions.
- Ka-band radar signal is heavily contaminated by attenuation, but MS effect can occur at higher altitudes in case of moderate and light rainfall events.
- LDR can be a good indicator of MS. The use of a W-band radar may be useful for ground validation.
- Consideration of the correction algorithm of MS effect is a future research topic.

Acknowledgements

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