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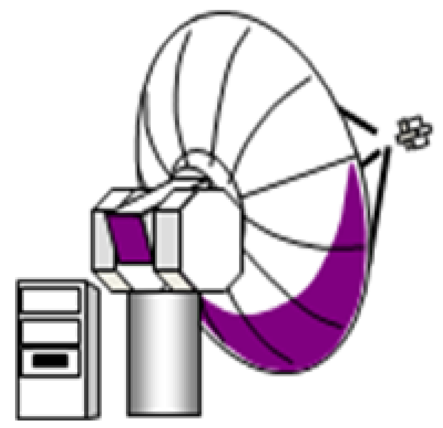


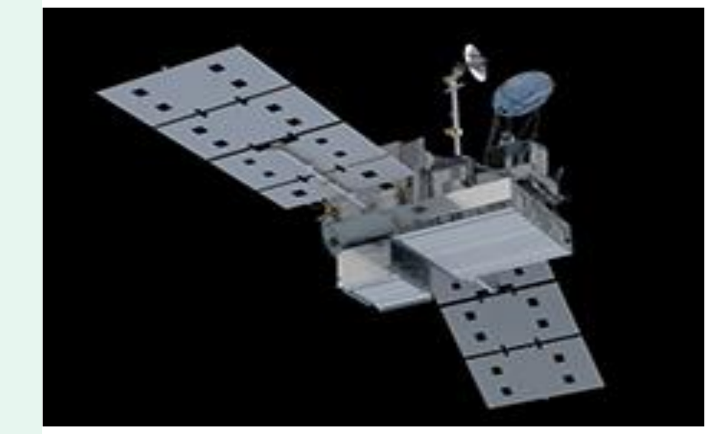
Radar simulation studies for hydrometeor classification from range profile of dual-polarization radar signatures

-A new method to estimate range variation of attenuation-

Takahisa Kobayashi[1,2] , Mistuharu Nomura[1] ,Soichiro Sugimoto[1], Ahoro Adachi[2] , Nobuhiro Nagumo[2] and Hiromaru Hirakuchi[1],

[1] *Central Research Institute of Electric Power Industry,1646, Abiko 270-1194 Japan*

[2] *Meteorological Research Institute, 1-1 Nagamine, Tukuba,305-0052, Japan*



Introduction

Needless to say, precipitation type classification is important for accurate precipitation fall rate estimate from radar observations. In addition, it is necessary to know whether the current precipitation is rain, dry snow or wet snow to prevent disasters caused by accretion of snow on electric power line. → **Fig.1**

Many methods for precipitation type discrimination using dual-polarization radar have been developed so far. Most methods use the polarimetric radar signatures such as Ze, Zdr, Kdp etc. measured at each radar resolution volume.

In the present study, we focus on the range variations of Ze and Kdp to estimate the attenuation properties of precipitation. Attenuation properties are usually studied for the attenuation correction but can be also used for precipitation type discrimination. The attenuation depends on precipitation type as well as precipitation fall rate and is useful in particular for classification of rain ,dry snow, and wet snow.

We have developed a new method to estimate the range variation of attenuation. It estimates the relative magnitude of the attenuation in the radar propagation path. ->**Fig.2**

Therefore, it can not be applied to the attenuation correction, but can be useful for hydrometeor classification in the propagation path.

Fig.1 Snow on the electric power line.

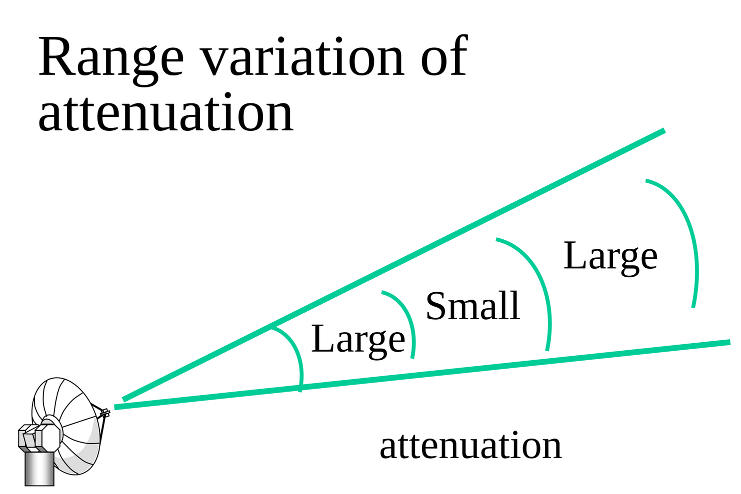


Fig.2 Range variation of relative attenuation .

Simulations: Simulator GRASIA-P

* Drop size distribution N(D) (DSD) D:diameter (mm) Λ : slope parameter

  $N(D) = N_0 \exp(-\Lambda D)$

* Raindrop shape : oblate

  axis ratio is fixed as 0.6 for snow,

  axis ratio varied with size for rain (Beard and Chuang, 1987)

Phase matrix : T-matrix method .

Refractive index of snow: M-G theorem

A parameter Q_Z : parameter related to PIA

Ze^t the intrinsic Ze (in linear scale) is assumed to be given by :

$$Z_e^t = aKdp^b \quad (1)$$

Ze^m :the measured Ze (in linear scale) can be given by

$$Z_e^m = akdp^b - 2PIA \quad (2)$$

PIA: 1 way path integrated attenuation:

Take the difference between Ze^t and Ze^m. However, since the coefficient a in Ze^t is unknown, arbitrary constant x is used instead for a in Ze^t.

$$Z_e^t - Z_e^m = xkdp^b - (akdp^b - 2PIA) = kdp^b(x-a) + 2PIA \quad (3)$$

Dividing by Kdp ,

$$Q_Z = \frac{xKdp^b - Z_e^{meas}}{Kdp^b} = (x-a) - \frac{2PIA}{Kdp^b} \quad (4)$$

The parameter is refered here as Qz, which is related to attenuation.

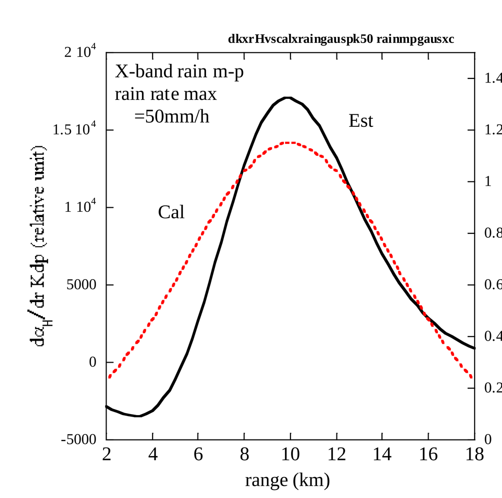


Fig. 3 Estimated and theoretical attenuation for rain.

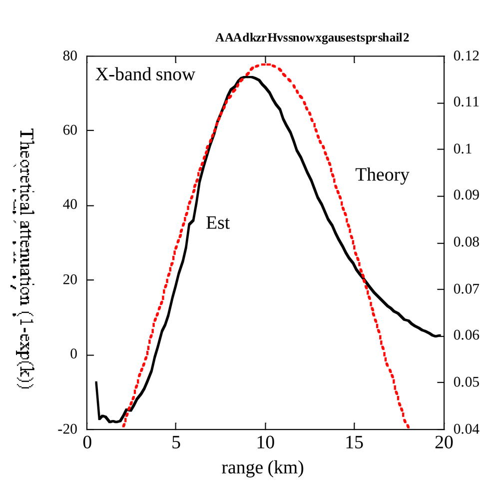


Fig. 4 Estimated and theoretical attenuation for snow.

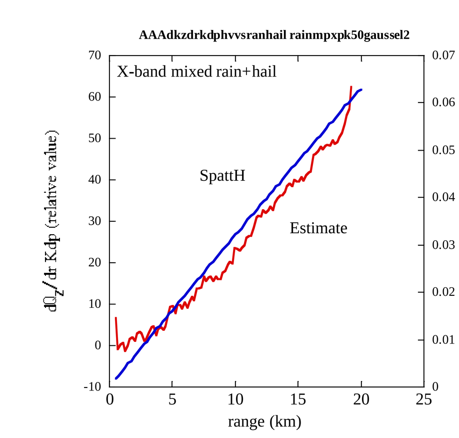


Fig.5 Estimated and theoretical attenuation for mixed phase.

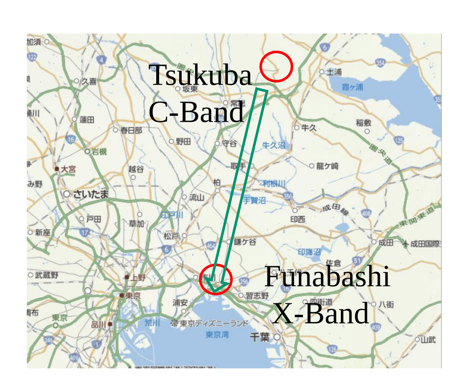


Fig. 6 Locations of Tsukuba C-band and Funabashi X-band radar.

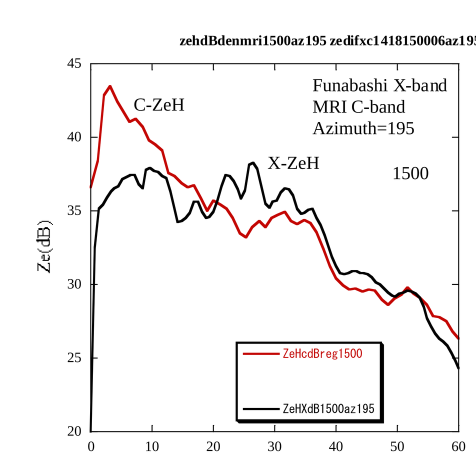


Fig.7 Range profiles of ZeH measured with X and C-band radars.

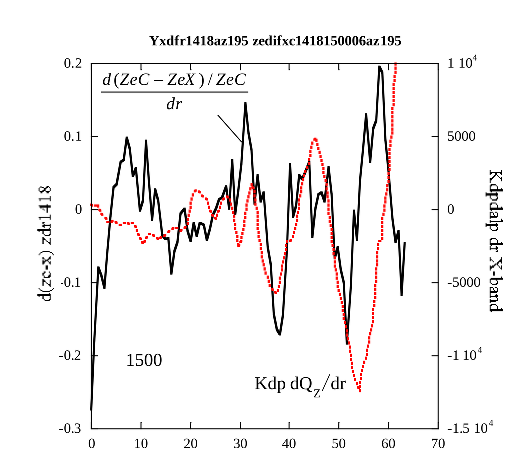


Fig.8 Range variation of attenuation estimated from the DFR(black line) and MAQ (red line) for snow.

Method for estimate range variation of attenuation : MAQ

1. Range derivative of Q_Z

Parameter Q_Z is related to the PIA and tends to monotonically increases with the radar range provided that the coefficients a and b are constant.

The PIA can be estimated from Q_Z if the coefficients a and b are given. However the coefficients are usually unknown. we take range derivative of Q_z

$$-\frac{dQ_Z}{dr} = \frac{1}{kdp^b}\frac{2dPIA}{dr} \quad (5)$$

<= **A measure of attenuation**

The specific attenuation of difference of Ze (Ad) is given by

$$A_d \equiv \frac{dPIA}{dr} = -\frac{kdp^b}{2}\frac{dQ_Z}{dr} \quad (6)$$

Although coefficient b remains, the coefficient a is removed.

Simulations and observations

We have examined the method by using radar simulations for rain, snow and mixed phase and observations ion snow.

Simulation

Fig.3 Rain: Estimated Ad (red line) and the theoretically calculated value (black line) when the rain fall rate changes in Gaussian with the range. The precipitation intensity is the maximum 20 mm / h at the radar range of 10 km.

Fig.4 Snow: Same as Figure 3 but for snow in which the water fraction of snow changes in Gaussian with the range.

Fig.5 Mixed phase: Same as Figure 3 but for mixed phase of rain and hail in which the fraction of rain changes linearly with the range.

Simultaneous measurements of X and C-band radars in snow

Estimate range variation of attenuation from MAQ and dual frequency method (DFR,kobayashi ,2015 Radar conf.)

Fig.6 Locations of X and C-band radars.

Fig.7 Range profiles of ZeH measured with X and C-band radars. Although there are some differences in Ze at a low altitude near Funabashi, the overall tendency at locations farther than 10 km is in good agreement.

Fig.8 Range variation of attenuation estimated from the DFR(black line) and MAQ (red line) for snow. The both variations are in good agreement except for range<10km.

Conclusions

We have developed a new method to estimate radar range variation of precipitation attenuation by dual-polarization radar signatures. It estimates relative values of attenuation in the radar propagation path. It cannot be applied to the attenuation correction, but is useful for precipitation type determination. A parameter Q_Z which is related to the attenuation, is introduced. A range derivative of Q_Z can be a measure of attenuation and is used to estimate the range variation of attenuation. As a result of verifying the developed method by simulation and observations, we found that this method works well in rain, snow and mixed phase.

T. Kobayashi: kobay@mri-jma.go.jp