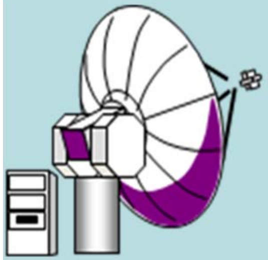
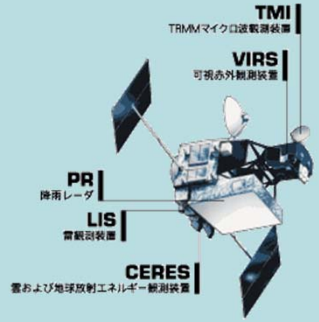
PMM201401

Radar simulation studies on space-borne measurements of precipitation





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We will examine issues to be solved for GPM measurements of precipitation.

Background

The DPR has a potential to measures more accurate rainfall rate than the PR.

JAXA has developed a robust algorithm for accurate measurements of precipitation (Iguchi-san presented).

However, the DPR is a new instrument.

In particular, space-borne Ka-band radar is the first attemt for measurements of precipitation.

There may have some unknowns.

Radar simulation studies are needed.

Background DPR—Ka

Radio wave frequency

3----14GHz ： Weather Radar for rain (Ku)

35—95GHz ： Radar for cloud (Ka)

Higher reflectivity for higher frequency.

Comparing with Ku,

Ka detects 40 times higher reflectivity

○ Detects weak rain Great advantage !

However, it leads to

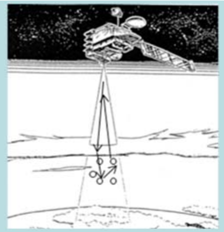
○ Multiple scattering (MS)contribution

○ Larger attenuation

Disadvantages !

レーリー散乱断面積	10GHz	14GHz	35GHz	94GHz
σ	1	3.86	148	7724

Why multiple scattering ?



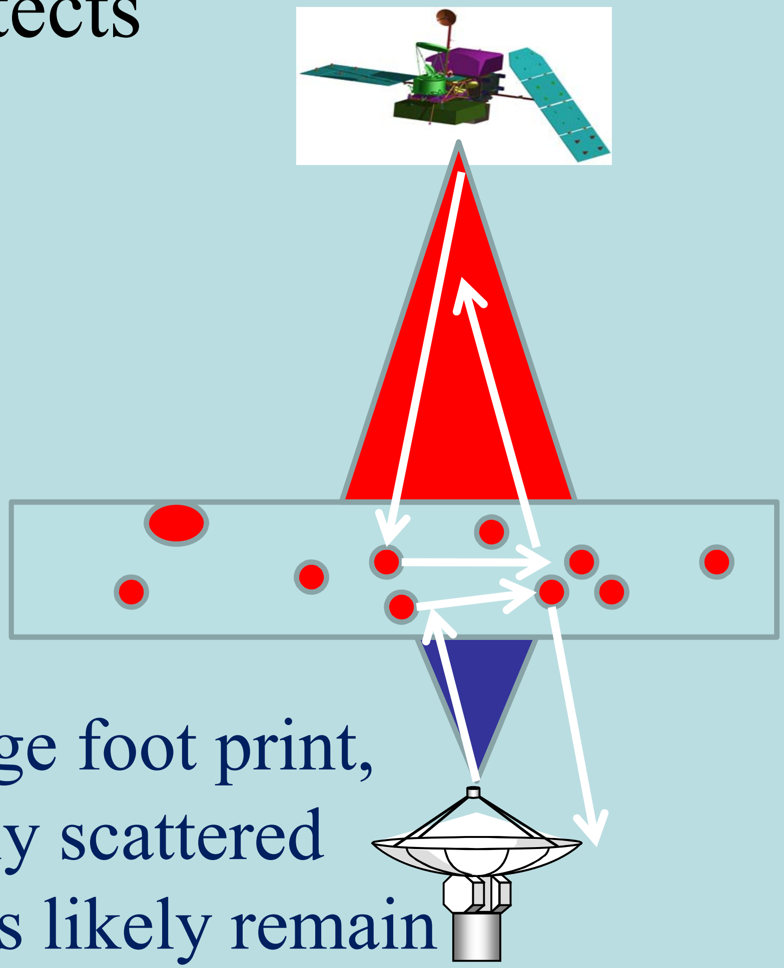
A space-borne radar operated at higher frequency, likely detects MS signals, because

1) foot print is larger
2) higher reflectivity

In rain rate estimate, single scattered signal is usually assumed

=>

Ms contributions results in biases.



For large foot print, multiply scattered photons likely remain in the FOV.

Objective

Objective of our study is to examine following issues by using physically-based radar simulator (GRASIA、Monte Carlo).

Q:

1. Does MS contribution really occur in DPR? In what conditions? Heavy rain?
2. How to analyze the ground validation results from the view point of MS effects.
3. Is there a method to identify the MS effects? Empirical relation MS contribution= f (Ku, Ka)
4. Assimulation studies of pol. Radar and GPM.

Research Plan

1. Multiple scattering (MS)
   Examining MS contribution for realistic rain in the DPR configurations
2. Ground-based polarimetric radar
   Simulating polarimetric parameters, such as LDR, attenuation for GV
3. Identification of MS effects
   Develop a method to estimate the MS contribution from DPR, ie. dual frequency measurements
4. Assimulation studies of pol. Radar and GPM.

Radar Simulator

1. Grasia Radar eq.
2. Monte Carlo

The simulator is based on scattering theory and is able to apply to space-borne and polarimetric radar.

The Grasia and Monte Carlo allows

- ◆ arbitrary shape, size, type and orientation of raindrops

Monte Carlo also allows

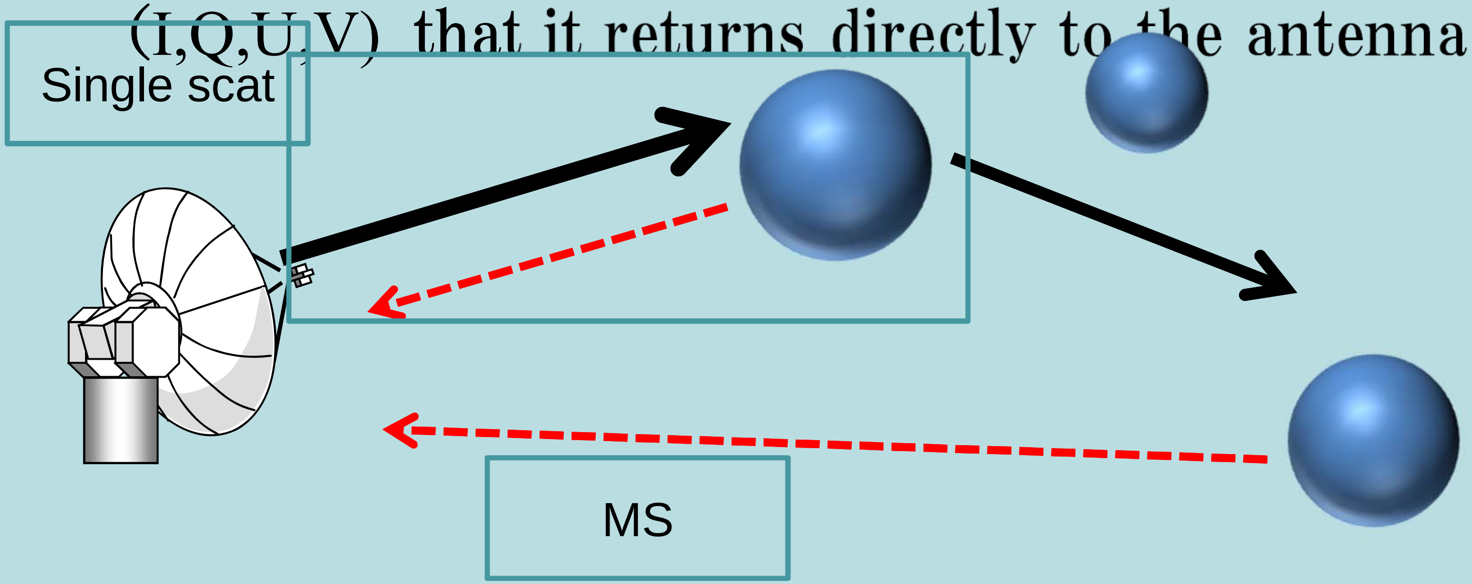
- ◆ multiple scattering contribution

The simulators generate radar received power and polarimetery.

Space-borne radar simulator -Monte Carlo method-

1) Emit photons from radar to rain medium
2) Determine the distance the photon travels until it interacts with a rain drops by scattering coefficient
3) Determine the scattering direction by the phase matrix。
4) Repeat until the photon escape radar resolution.

At each scattering event, calculate the probability (I,Q,U,V) that it returns directly to the antenna



Flow of Radar Simulator

Radar configulations

Precipitation properties

Raindrop Formation model

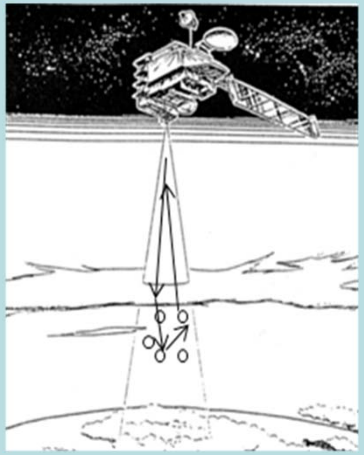
Calculate Scatering matrix
T-matrix,
SVM method
etc.

Solve Radar Equation
Single scattering
Solve Radiative Transfer Eq.
Multiple scattering

Radar returns
Power
Polarization

Examine various effects on rain rate measurements

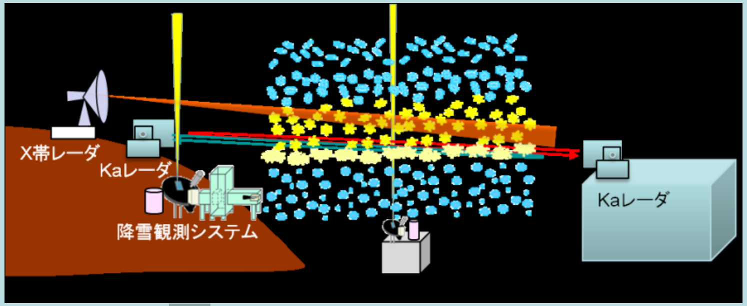
Image of our study



DPR congurations

GV

Ka-radar

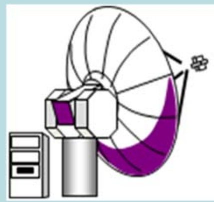


Radar Simulator
GRASIA,
Monte Carlo

Precipitation
model

MS Effects
polarimetry

Measured
precipitation properties
DSD, shape etc



Identifications of MS effects

Polarimetric Radar

Assimulation

Simulation conditions

1. <u>Precipitation model</u>

- Vertical profile ：see figure
- Drop size distribution：M-P distribution

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

- Drop shape：Oblate Drop

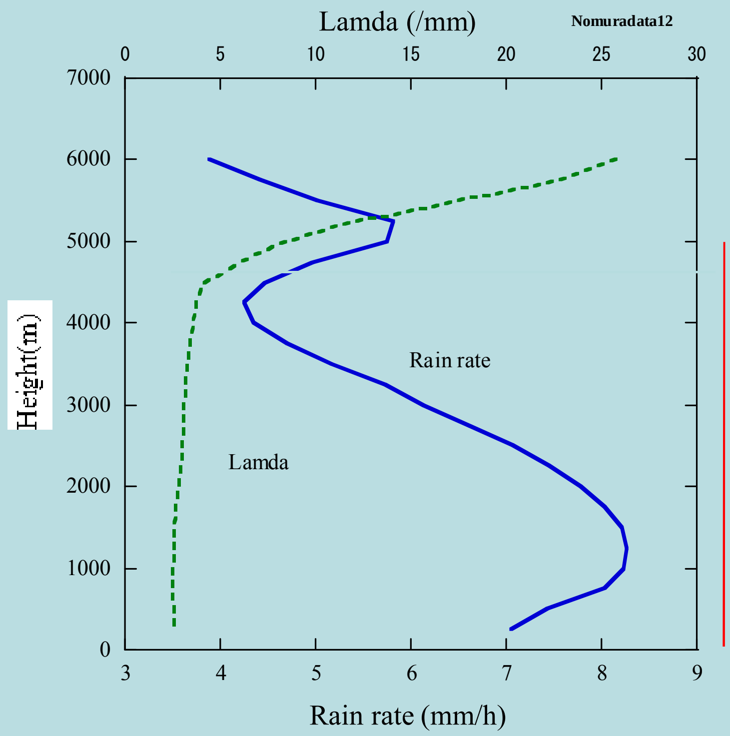
  axis ratio depends on size

- Rain rate

  model 1x：8mm/h at 1km

  2x 16mm/h….5x

  …. 5x 40mm/h



2. <u>Radar</u> Ku-Band (13.6 GHz)

   Ka-Band (35.5 GHz)

Beam Width ： 0.71 deg Satellite altitude：400km

1. Multiple scattering contribution

Questions:

(1) MS contribution in real rain?

(2) Effects of MS on rainfall rate estimate ?

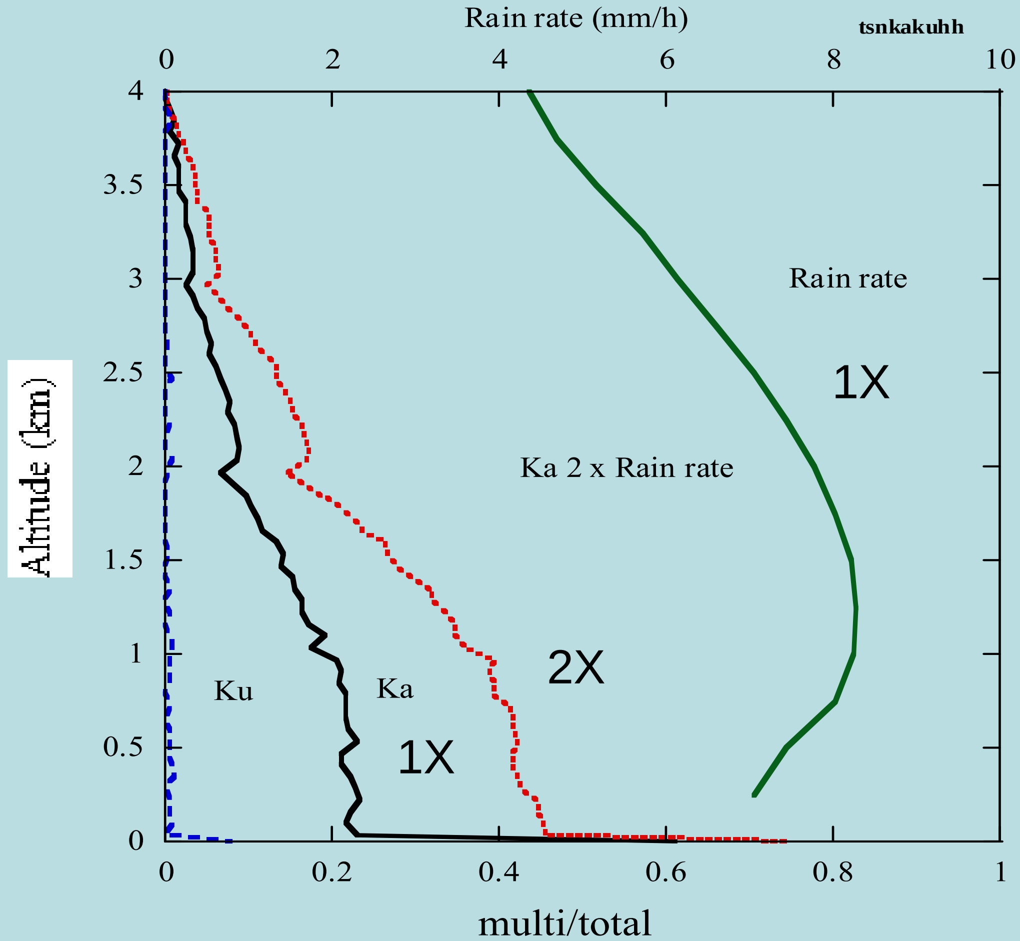
MS of 10% -> ? % in rain rate erreo

(3) Ka radar detectability?

(4) Identification MS contribution ?

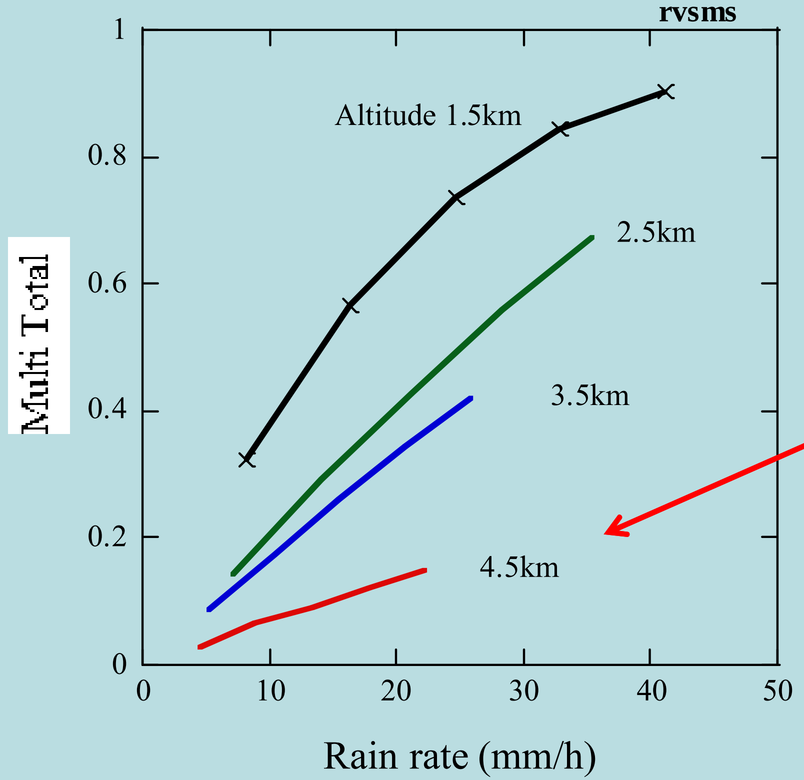
MS contribution
Vertical profile

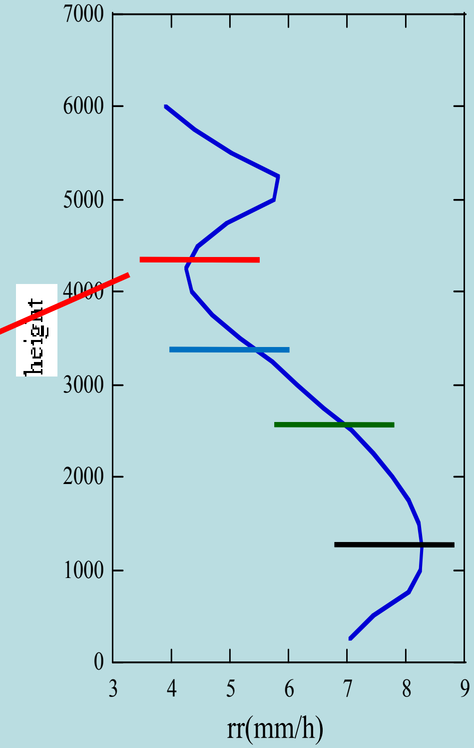
MS contribution increases with path length in rain layer.
Negligible MS at Ku band.
Significant MS at Ka band, 40% at 0.5 km.



MS contribution vs rain rate

MS contribution at altitude of 1.5, 2.5, 3.5 and 4.5 km for model 1x…5x.

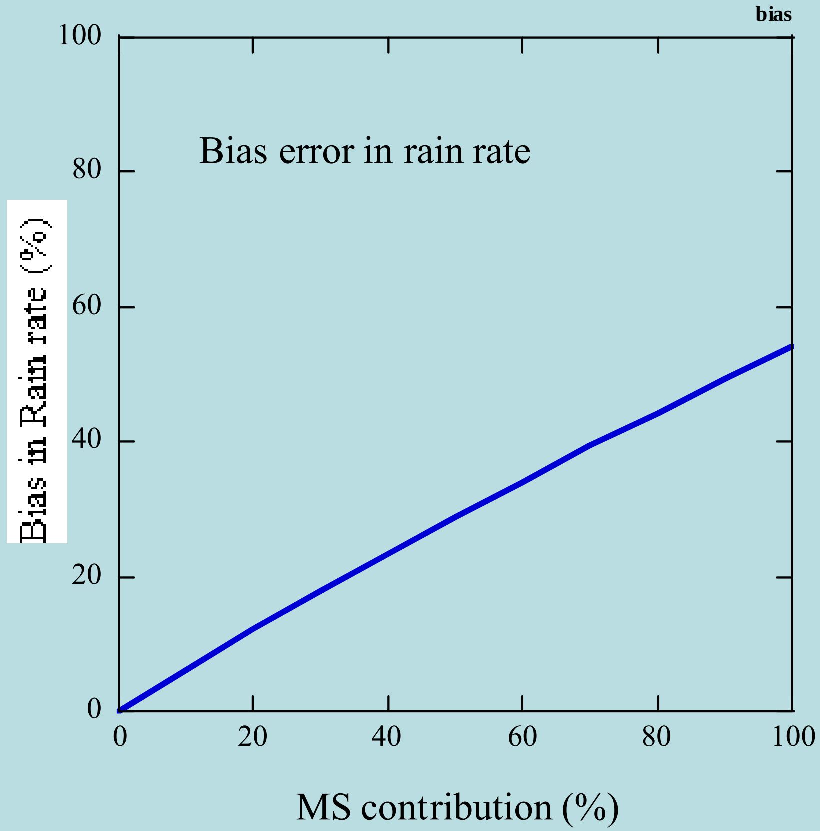




MS contribution increases with rain rate. MS contribution is 90% at altitude of 1.5 km. Bias in rain rate?

Bias in estimated rainfall rate

Bias in R estimated from simple Z-R relationship



$$Z = aR^b$$

$$a = 200 \quad b = 1.6$$

$$R = (Z/a)^{1/b}$$

MS contribution of 90% results in 50% bias in rain rate!! MS of 90% appears at intense rain.

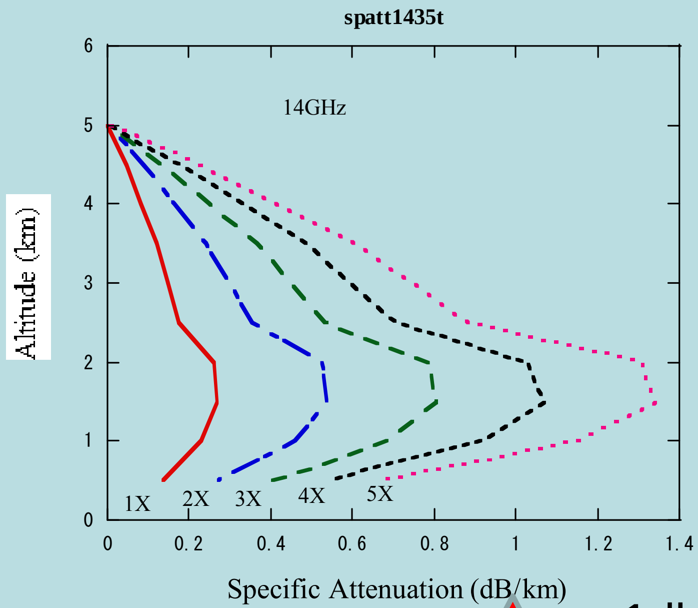
Can Ka band radar detect such rain?

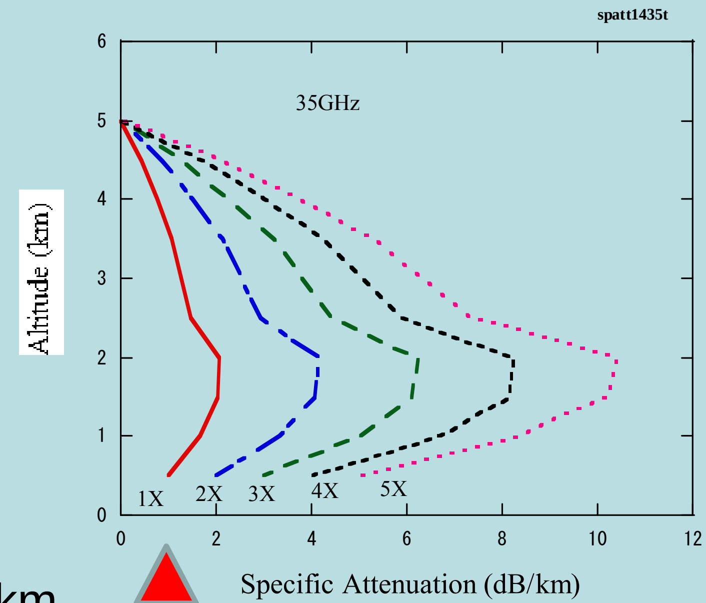
Attenuation

Ka-band radar suffers significant attenuation for heavy rain in which MS occurs.

(Ms contribution of 90% at rain rate of 40mm/h.)

Q: Can Ka radar detect such intense rain?

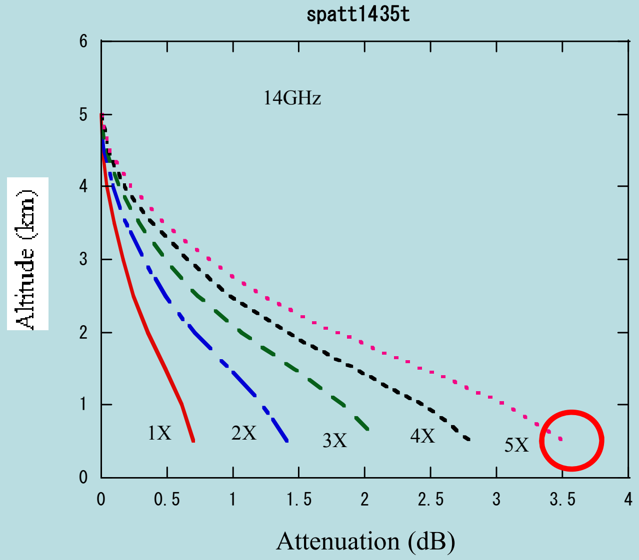




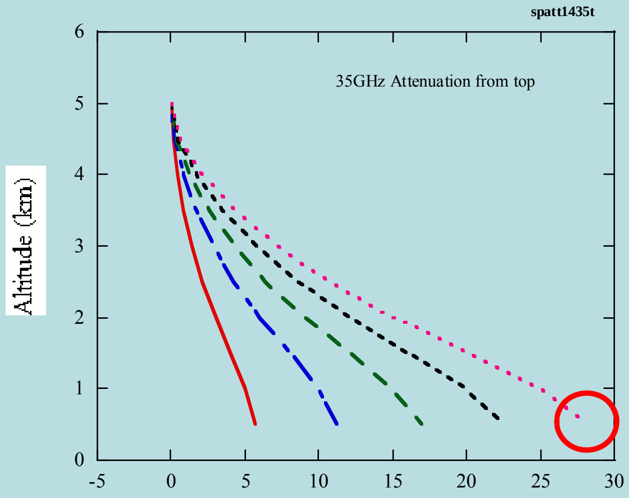
1db/km

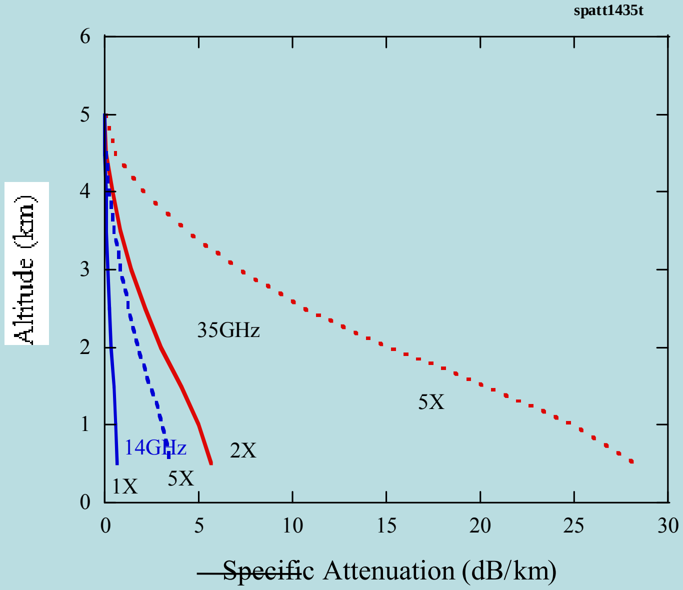
Specific attenuation is ten times larger at Ka-band than that at 14 GHz.

Cumlative Attenuation
Total attenuation from top

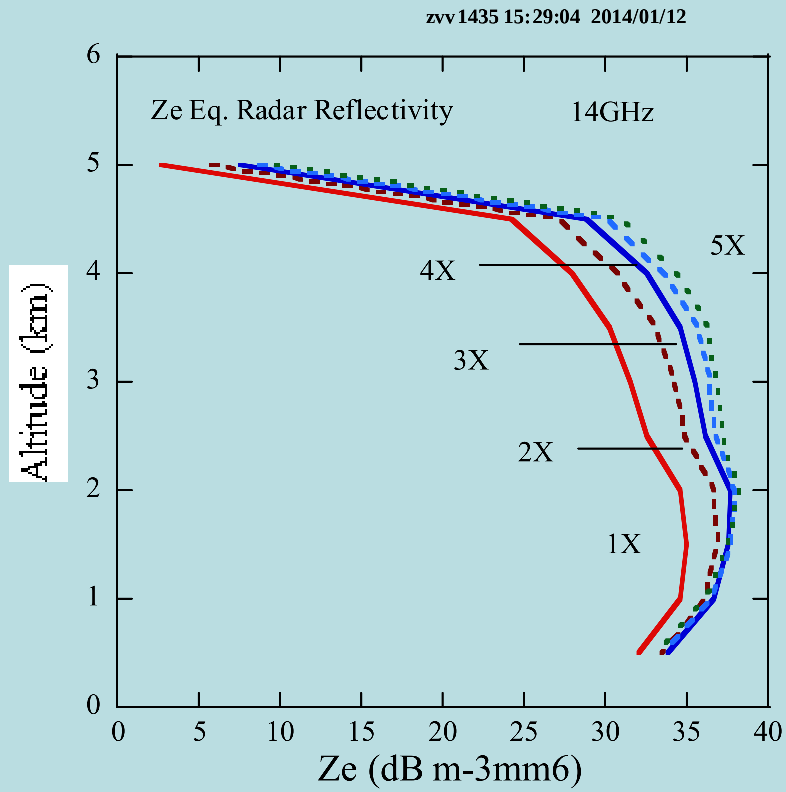


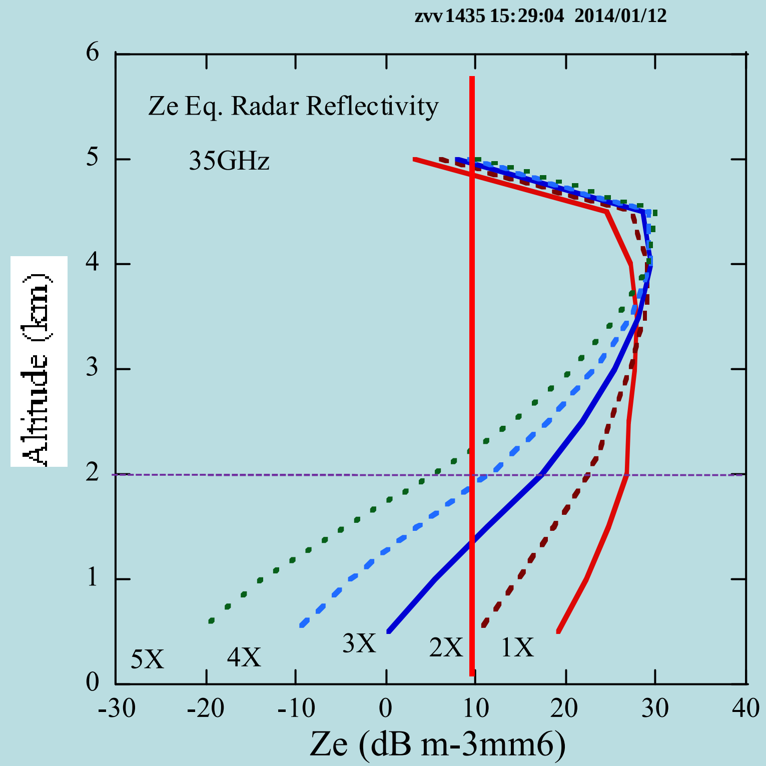
Attenuation is
3.5db at 14GHz
27dB at 35 GHz
for model 5x.





Eq. Radar Reflectivity





Significant decreases in Ze at 35 GHz. Data at 35 GHz is difficult to detect at lower altitude. MS contribution at 2.5 km is 30% and leads to bias of 15% in rain rate.

Ratio of 35 and 14 GHz radar Reflectivity MS effect?

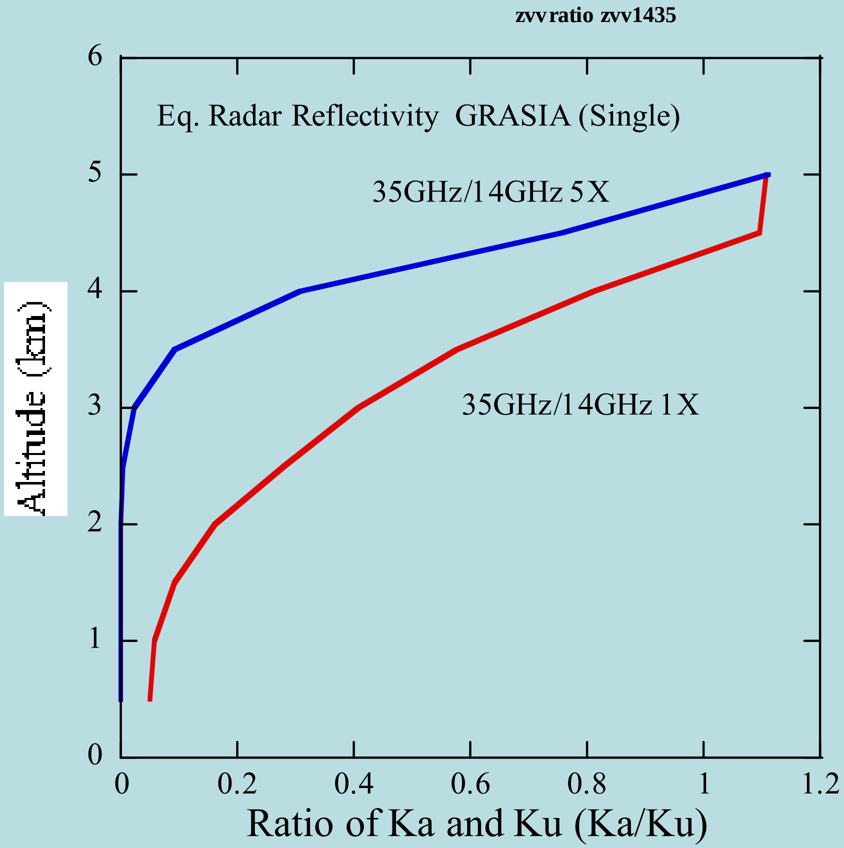
DPR is a dual frequency radar.

Algorithm of rainfall rate estimate is based on a relationship between Ka-band and Ku band radar signals.

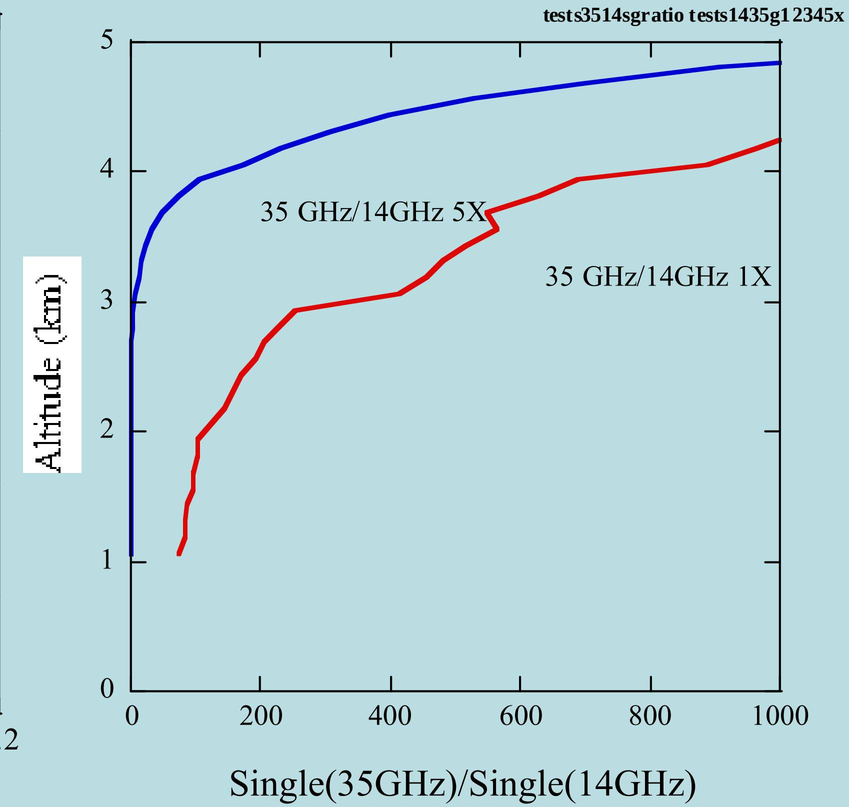
Q:

<u>MS contributions modify this relationship?</u>

Ratio of Ze at Ka and Ku single scattered signal

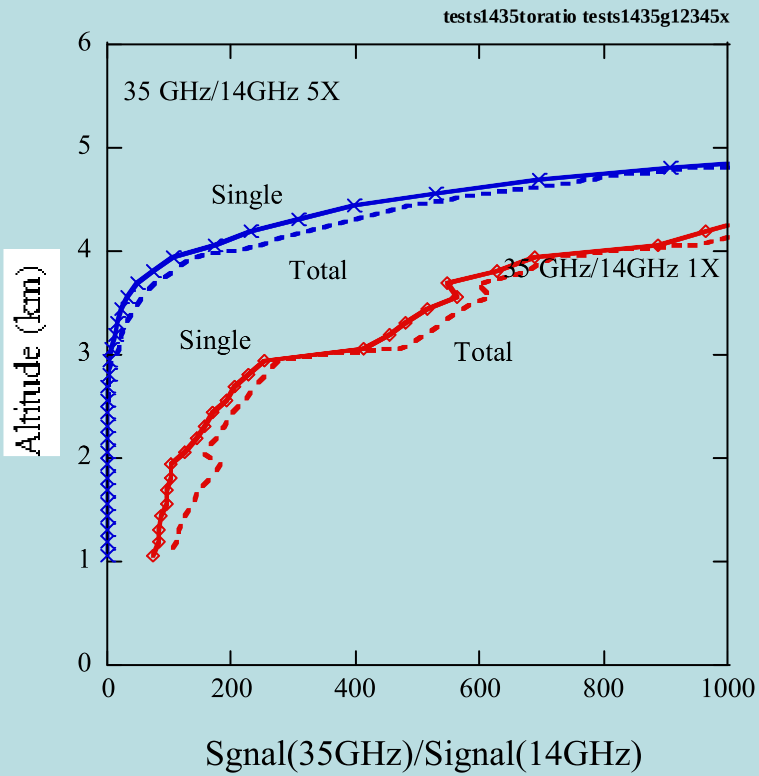


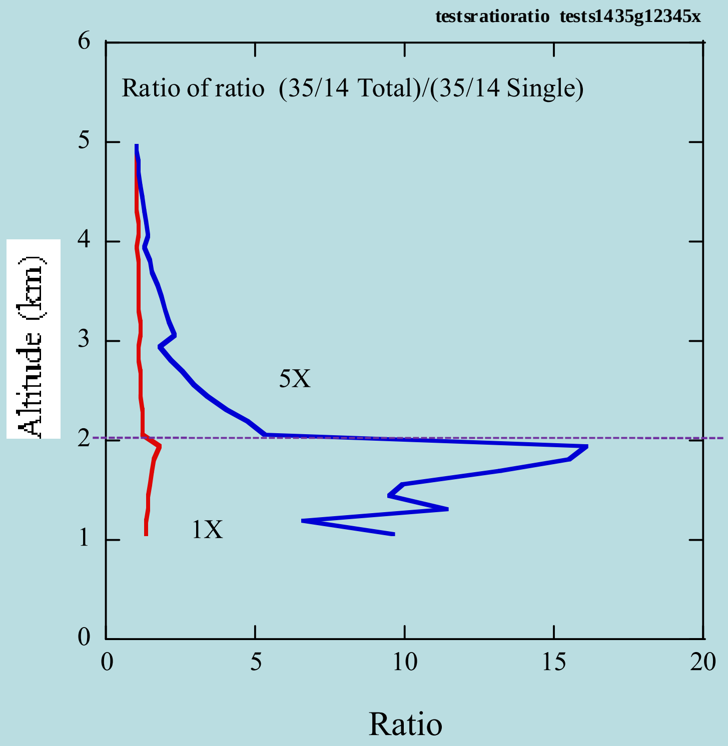
GRASIA



Monte Carlo

Ratio of Ze at Ka and Ku
MS effects





MS effects modified the ratio of received power at 35 GHz and 14 GHz. Data at 35 GHz is difficult to detect at lower altitude. The ratio is about five times at altitude oof 2km for 5x model.

Can we identify MS contribution?

To correct MS effects, identification of the MS contribution is needed.

Can we?

1) LDR (Linear depolarization ratio) is one of index of MS effects.
2) Analysis of GV results and make recurrence formula for MS effects
3) Dual frequency measurements
   MS effects are different for 14 and 35GHz which can be used to estimate MS effects.

Identification of MS in GV
-LDR-

Linear Depolarization Ratio

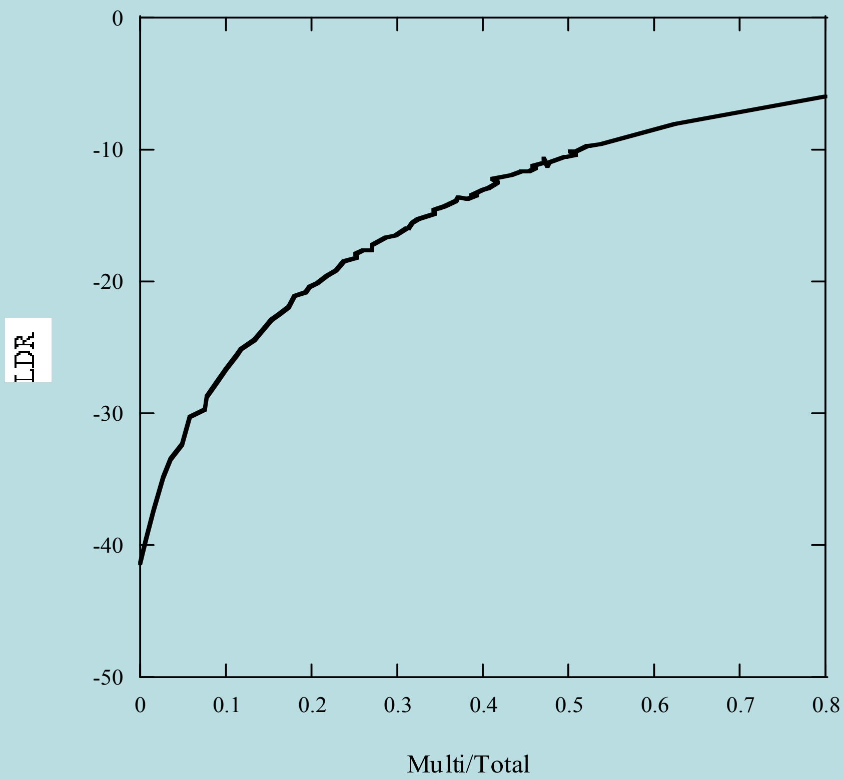
$$LDR = 10\log\left(\frac{|S_{vh}|^2}{|S_{hh}|^2}\right) \quad (dB)$$

Svh : cross polar signal

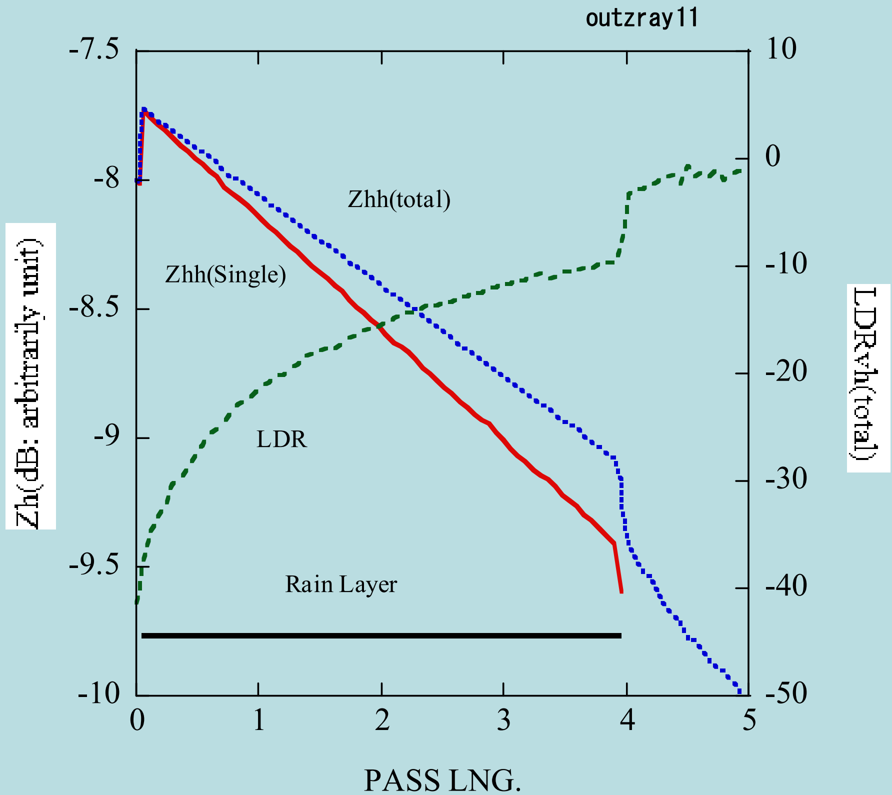
Shh : co-polar signal

LDR increases with MS contribution.

LDR is a measure of MS contribution.

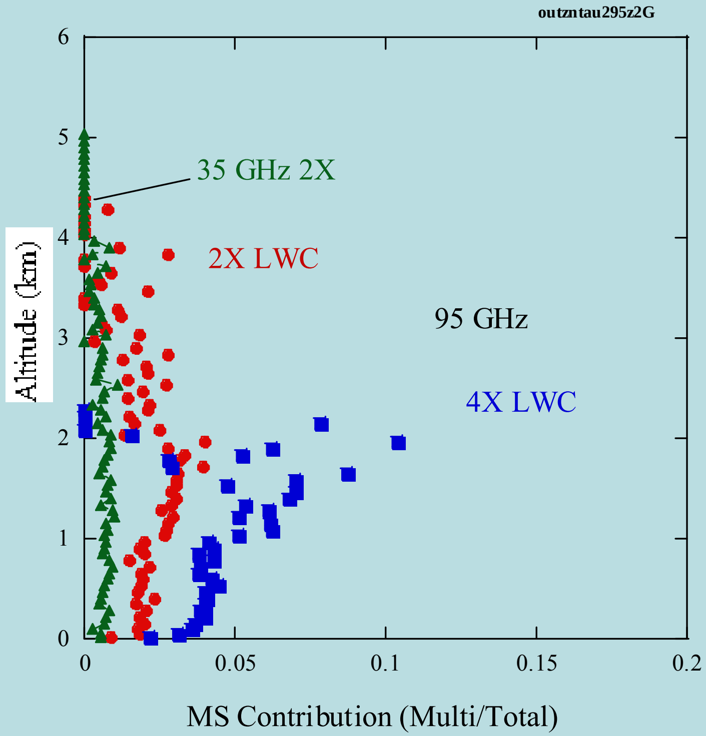


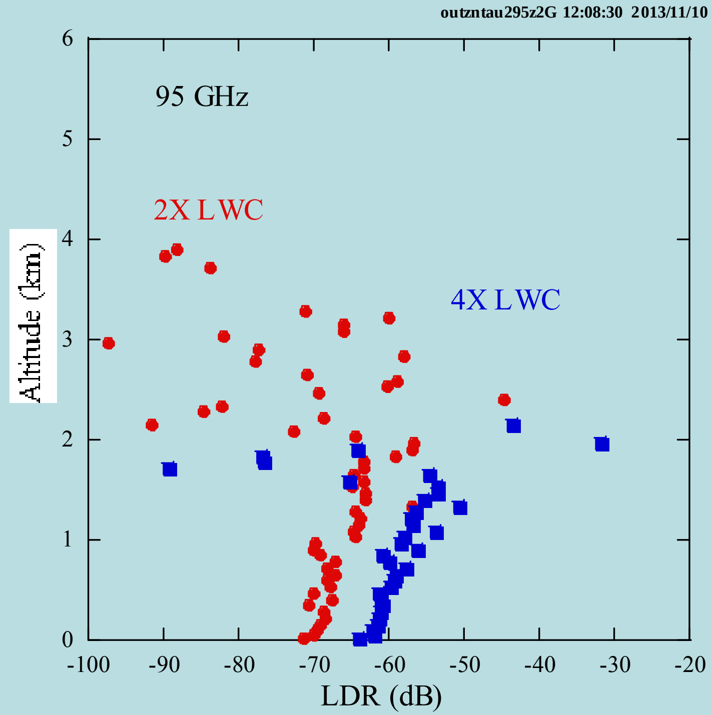
LDR
Space-borne radar



LDR (green) increases with MS contribution.
However, no LDR is available in GPM.
Use of ground-based radar?

LDR
-Vertical pointing ground-based radar-





LDR is difficult to measure with ground-based radar at lower frequencies than 35 GHz.

But radar at 95GHz may be useful.

Transmission property inGV

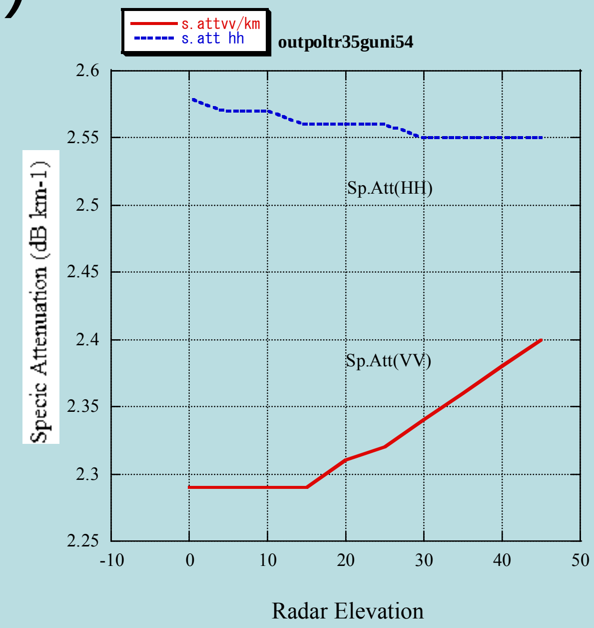
Transmission properties may be able to identfy MS effect.

Cross-polarization descriminator XPD may be a measure of MS contribution.

XPD=20log(Ehv/Ehh)

Cullently just idea.

Need to examine.



Summary

MRI

We have examined MS effects by using physically-based radar simulator.

1) Significant multiple scattering contributions occurs in intense rain at Ka band radar.

2) Although significant attenuation at 35GHz, MS efects may appear for intense rain.

3) Identification of MS effetcs may be achieved from LDR measuremwnts.