CLiMMATE

CLoud Microwave Measurements of ATmospheric Events

Modeling, Simulation and Comparison Study of Cirrus Clouds' Ice Crystals

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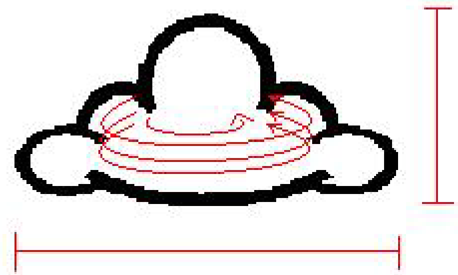
SPIE
The International Society for Optical Engineering

•Macrophysics characteristic :

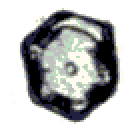
Layers, top height, base long, etc.

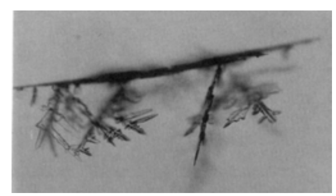


Microphysics components:

- Ice water content
- Crystal size distribution
- Crystals' shape

Hexagonal Plates



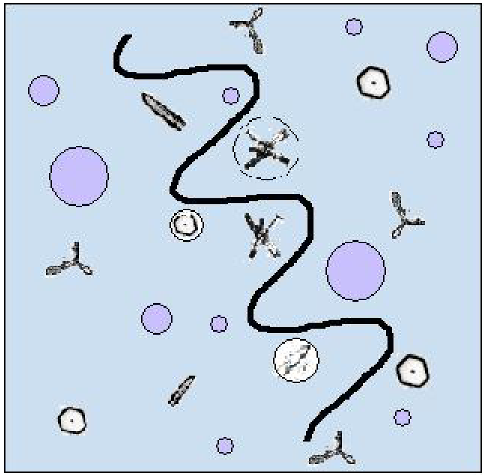


Dendrite

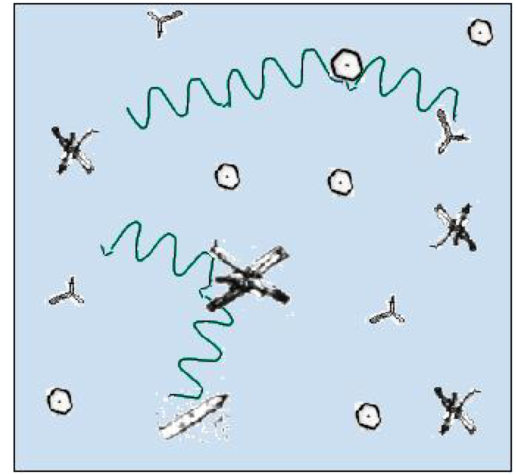
Bullet

Bullet Rosettes

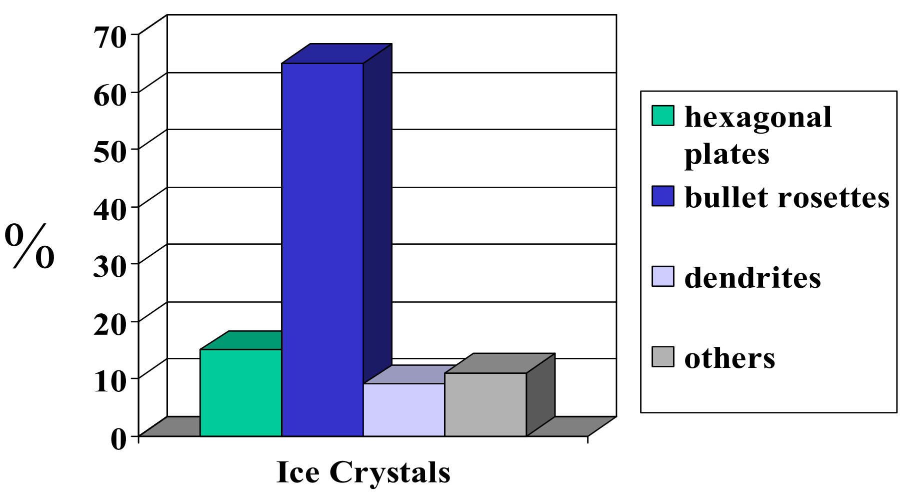
Rayleigh effect of 33 GHz Signal (λ_{fs} = 9.1 mm)

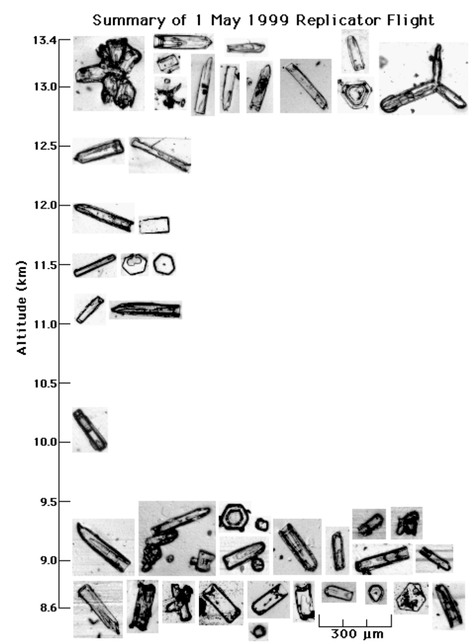


Mie effect of 95 GHz Signal (λ_{fs} = 3.2 mm)



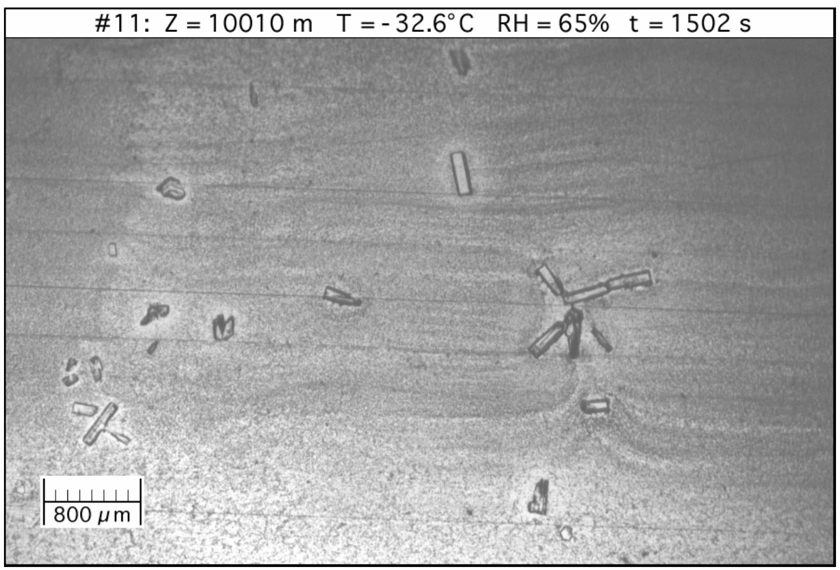
Cirrus Clouds Composition

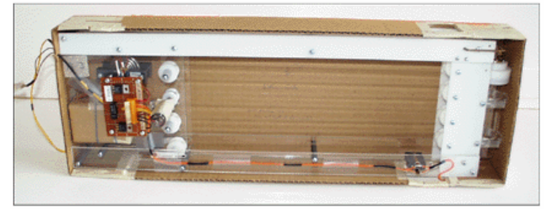


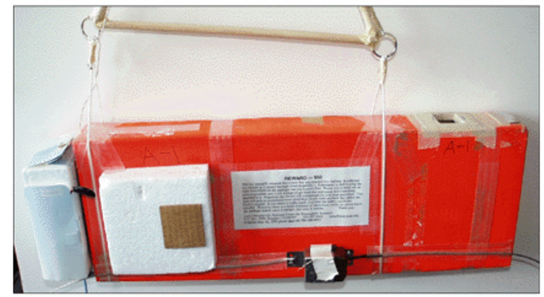


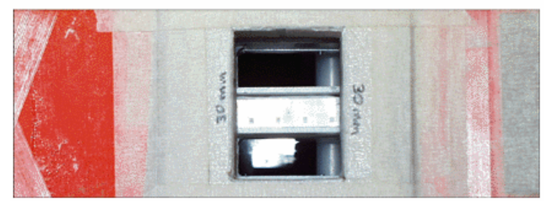
Bullet and Bullets Rosettes Model

National Center for Atmospheric Research (NCAR)
Video Ice Particle Sampler (VIPS)









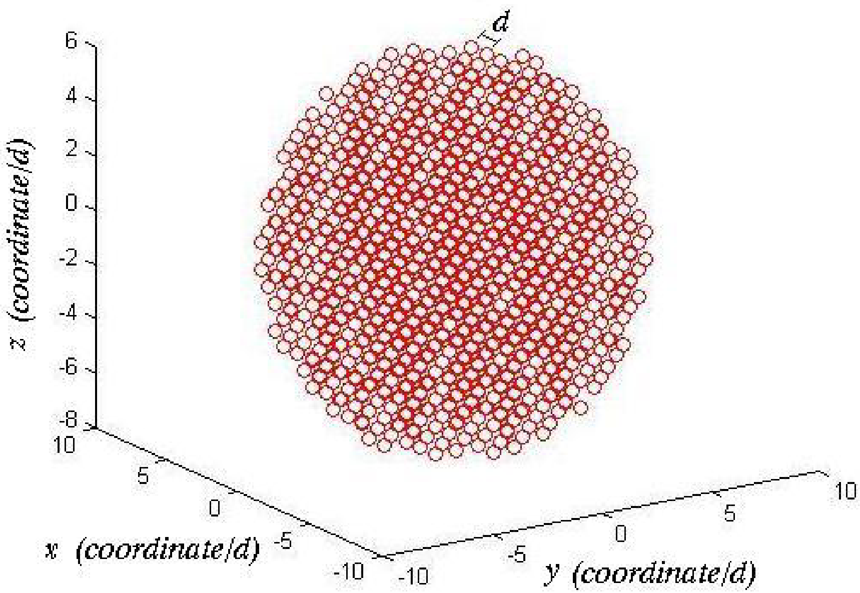
$$w = 0.25L^{0.7856} \quad L < 0.3\text{mm}$$

$$w = 0.185L^{0.532} \quad L \geq 0.3\text{mm}$$

DDScat Software

Replace the target geometry by an array of N dipoles.

Discrete-dipole approximation.



Polarizable dipoles array over a cubic lattice describing a sphere

Some implemented shape are: sphere, hexagons, prism, etc.

DDScat criteria

$$|m|kd < 0.5$$

- *m* as the complex refractive index of the object material
- *k* as the wavenumber of the surrounding medium
- *d* is the minimum distance that should exist between dipole

Bullet Toolbox for DDSCAT

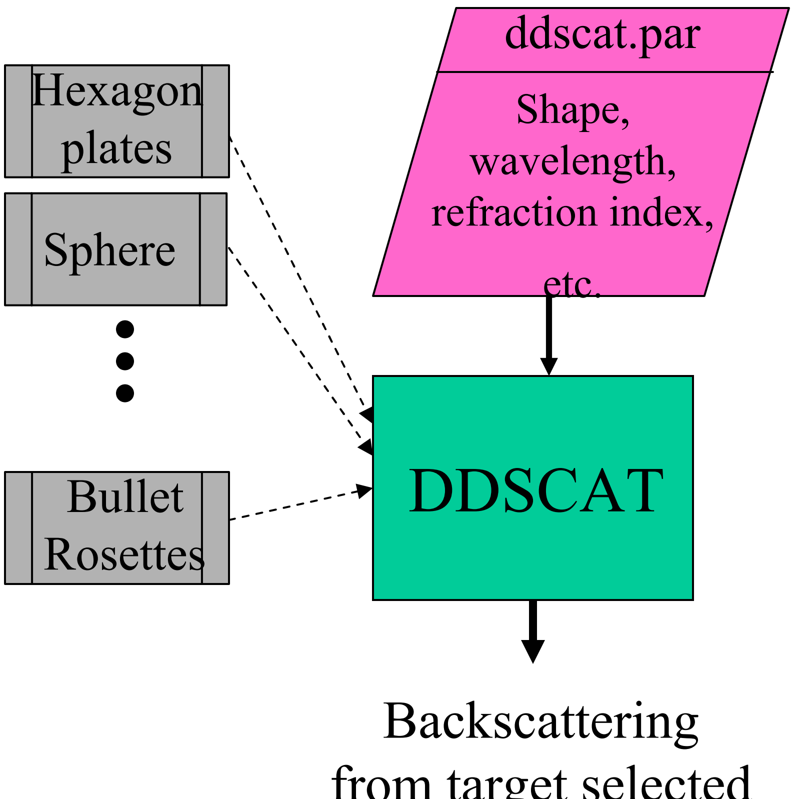
We create:

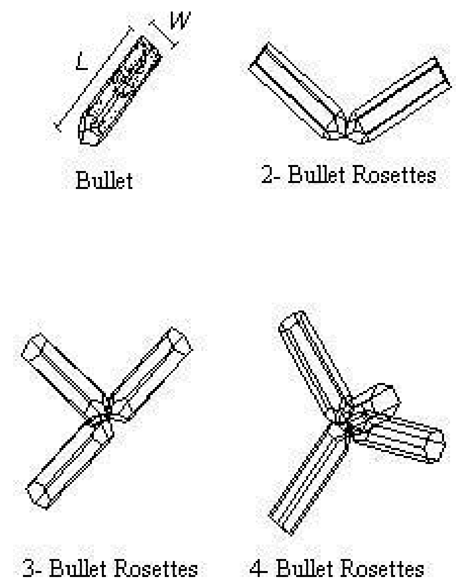
Bullet and Bullet Rosettes subroutines

ddscat.par:

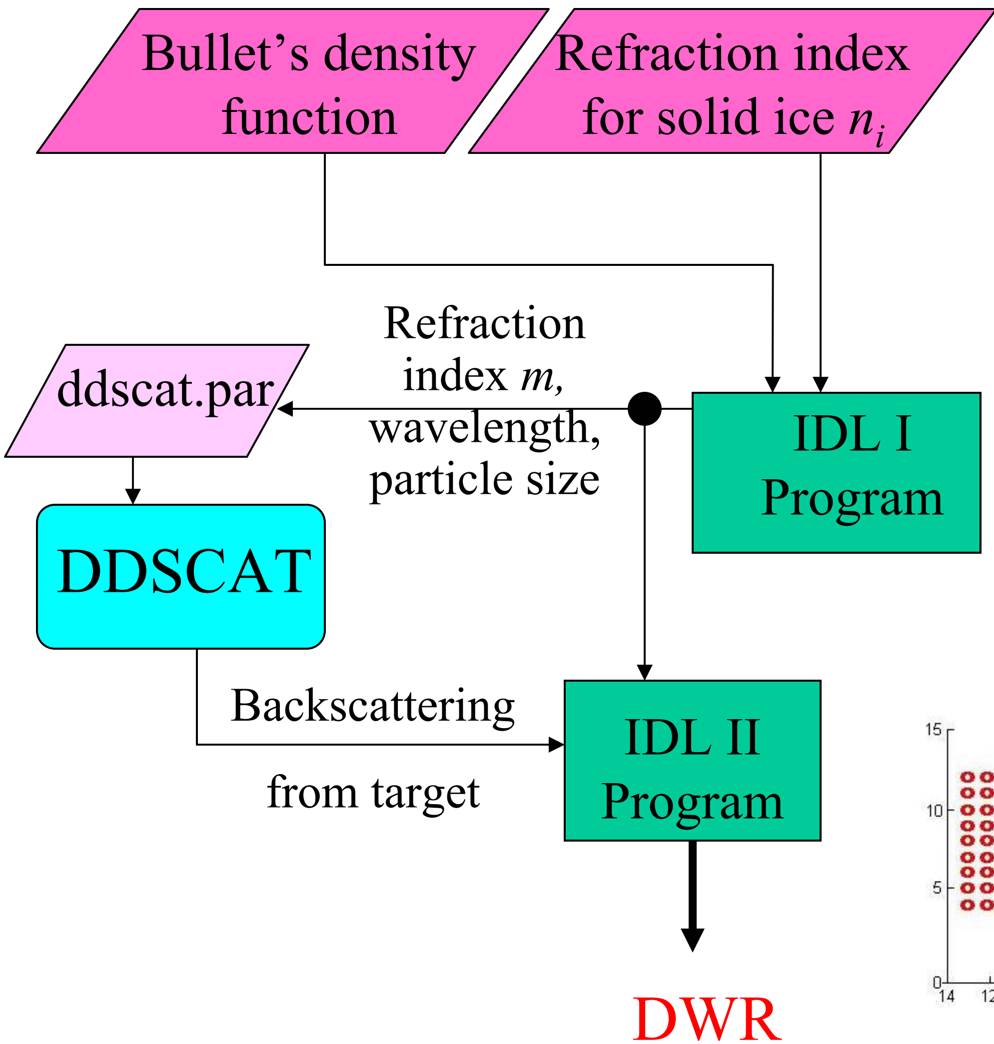
Par1=*L* (longitude bullet)

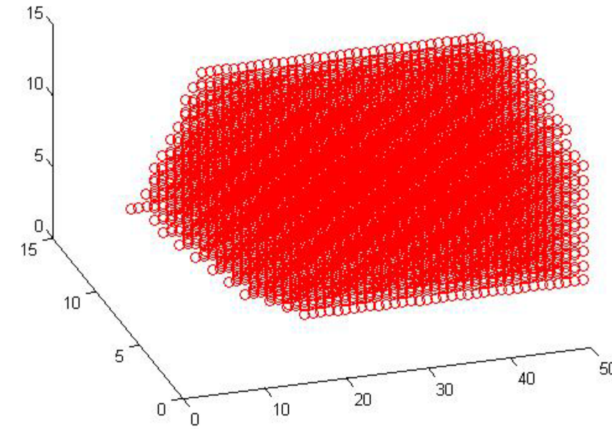
Par2= *B* (Number of bullets)



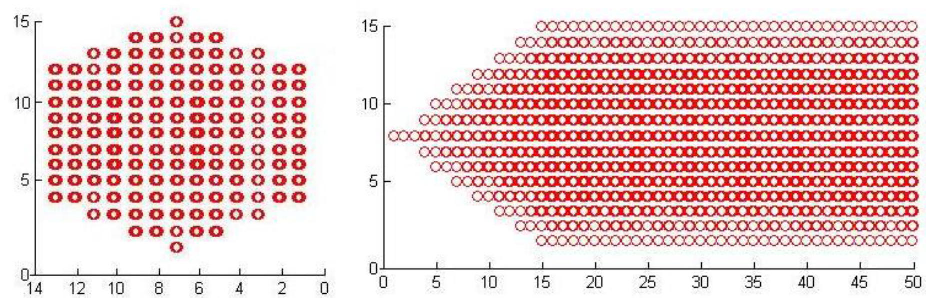


Bullet Simulation



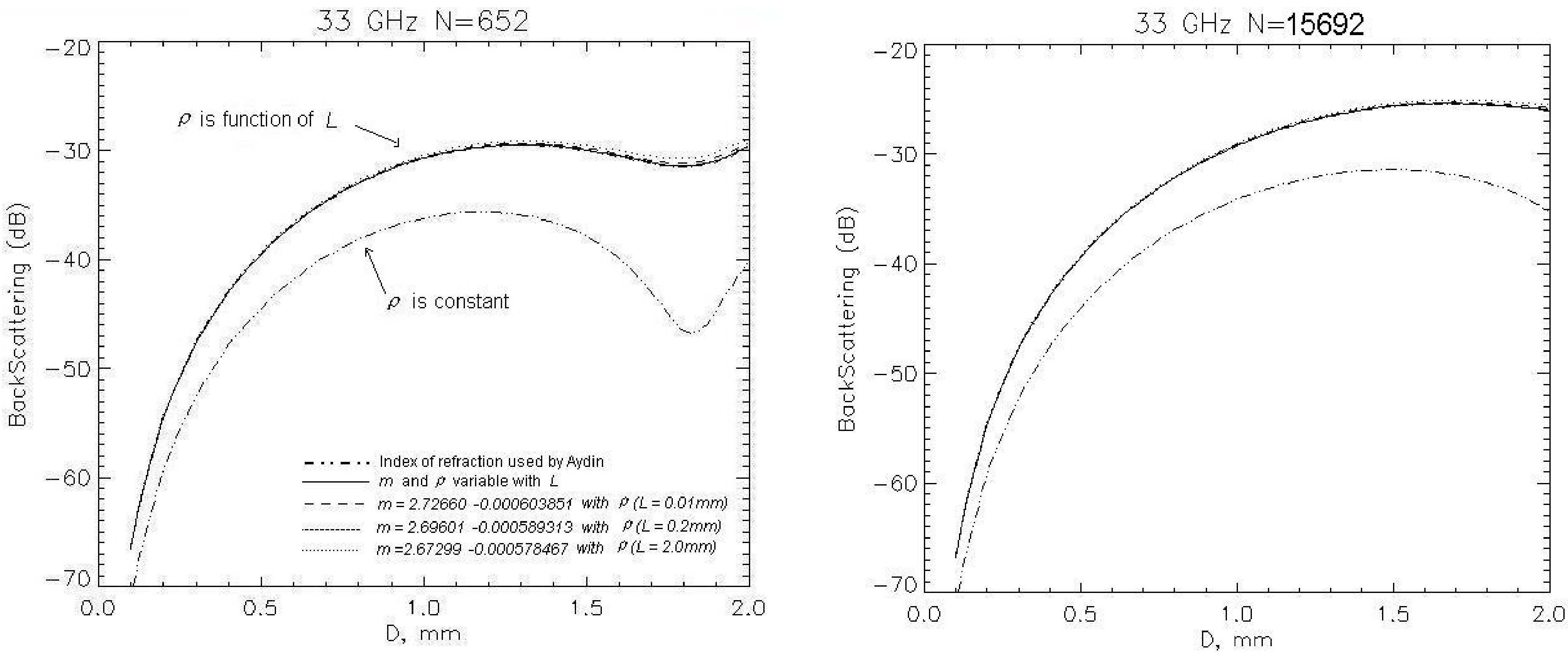


- N = 2304 dipoles
- m =1.04595 + j4.459e-5



Backscattering from Bullet-33GHz

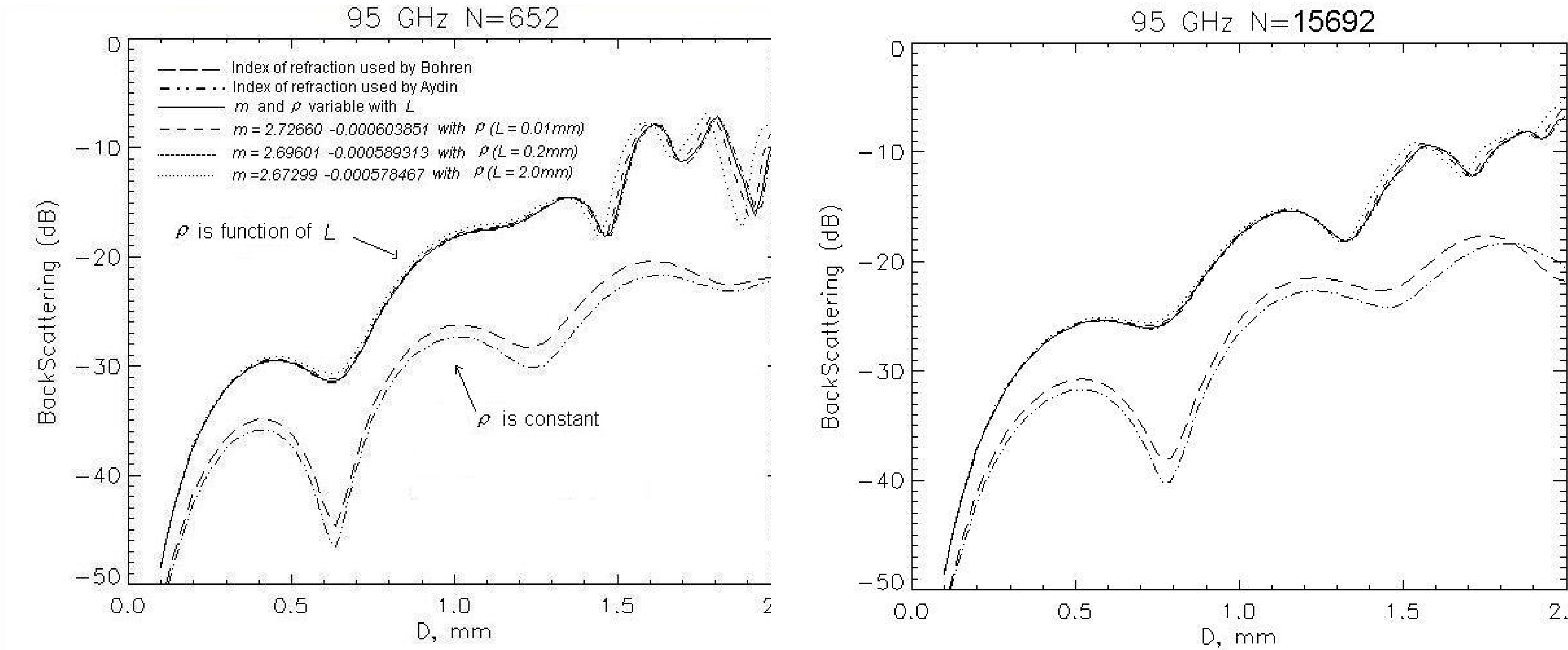
The top traces are for density as a function of *L*, and the bottom group of traces is given with ρ constant.



Backscattering in dB (10 logσ_b) of different indexes of refraction to 33GHz a) with 652 dipoles array, b) with 15692 dipoles array.

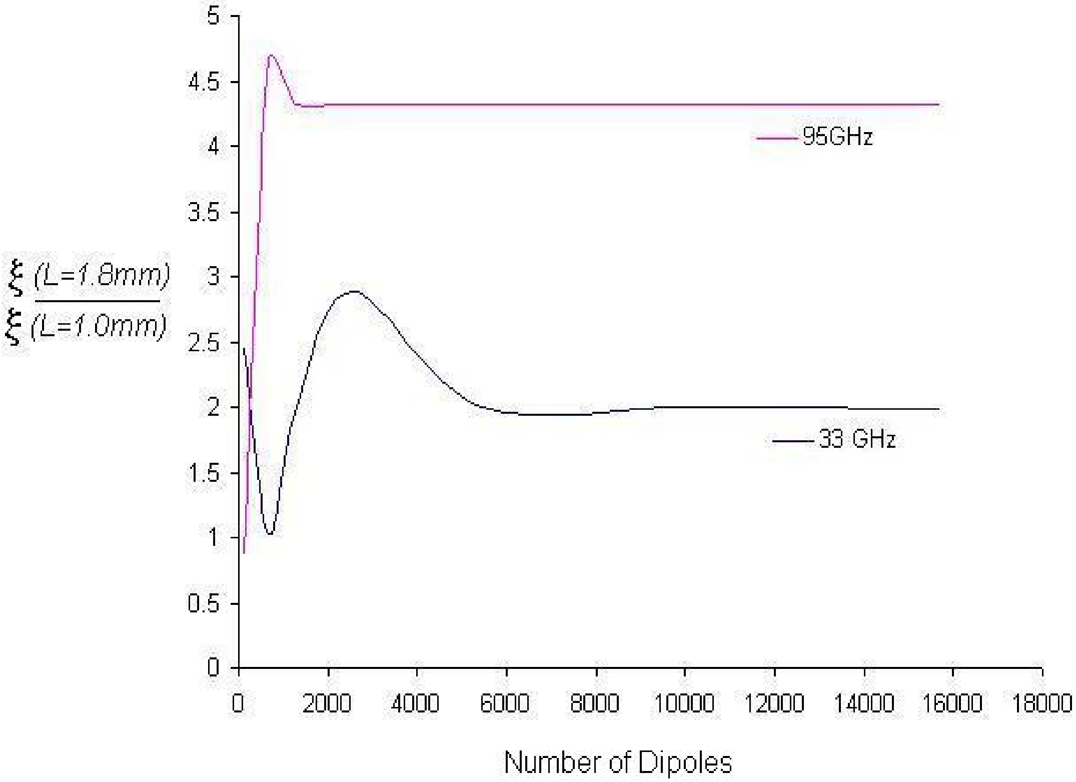
Backscattering from Bullet-95GHz

The top traces are for density as a function of L, and the bottom group of traces is given with ρ constant.



Backscattering in dB (10 logσ_b) of different indexes of refraction to 95GHz a) with 652 dipoles array, b) with 15692 dipoles array.

DDScat Performance



Ratio between two points of backscattering coefficient for different dipole numbers

Backscattering Ratio

L_h=1.8mm

L_l=1.0mm

$$\frac{\xi(L_h)}{\xi(L_l)}$$

- We chose to use 15,692 dipoles to be extra conservative, (Consistency was found for N> approximately 6,000).
- The computing time using 15692 dipoles is ~5 hours (@95GHz) and ~2.5hrs (@33GHz) with an IBM Intellistation Z Pro Type 6866, Pentiun 3 with 392,624 KB RAM.

DWR from Bullet

$$DWR = 10\log\left(\frac{\lambda_l{}^4 \left|K_w(\lambda_h)\right|^2 \int_0^\infty \xi_b(D,\lambda_l,\rho) D^{2+\mu} \exp\left[-(3.67+\mu)\frac{D}{D_0}\right] dD}{\lambda_h{}^4 \left|K_w(\lambda_l)\right|^2 \int_0^\infty \xi_b(D,\lambda_h,\rho) D^{2+\mu} \exp\left[-(3.67+\mu)\frac{D}{D_0}\right] dD}\right)$$

•λ_l & λ_h are the values of the smallest (33GHz) and largest(95GHz) frequency, respectively

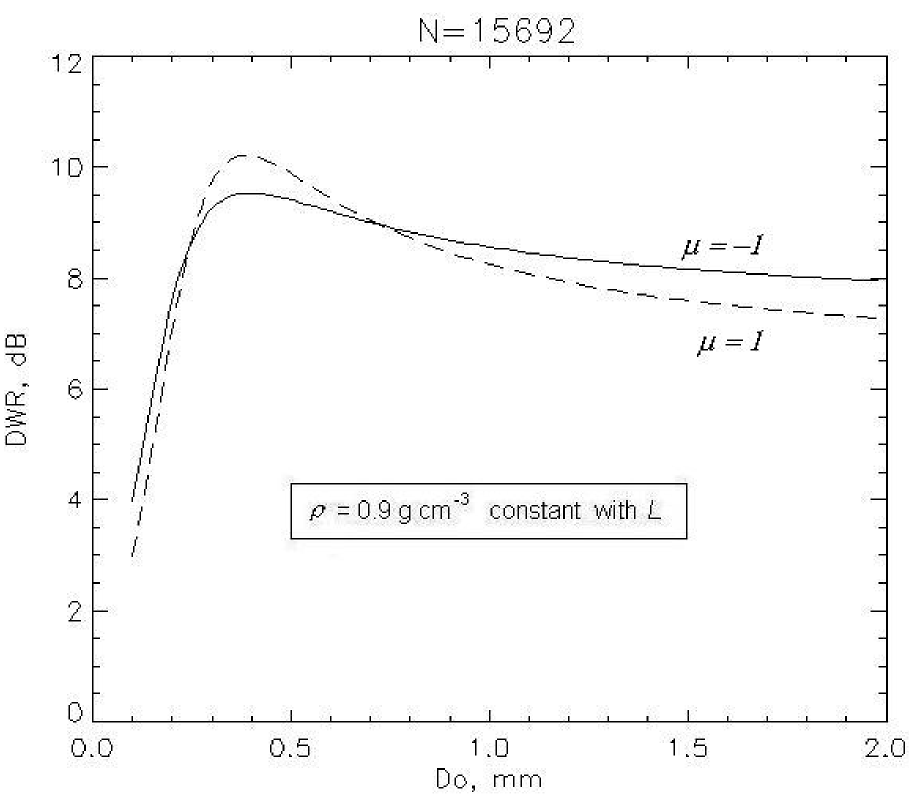
•K_I is an dimensionless quantity that depends on the index of refraction and on the density (for ice we assumed 0.176 for both frequencies).

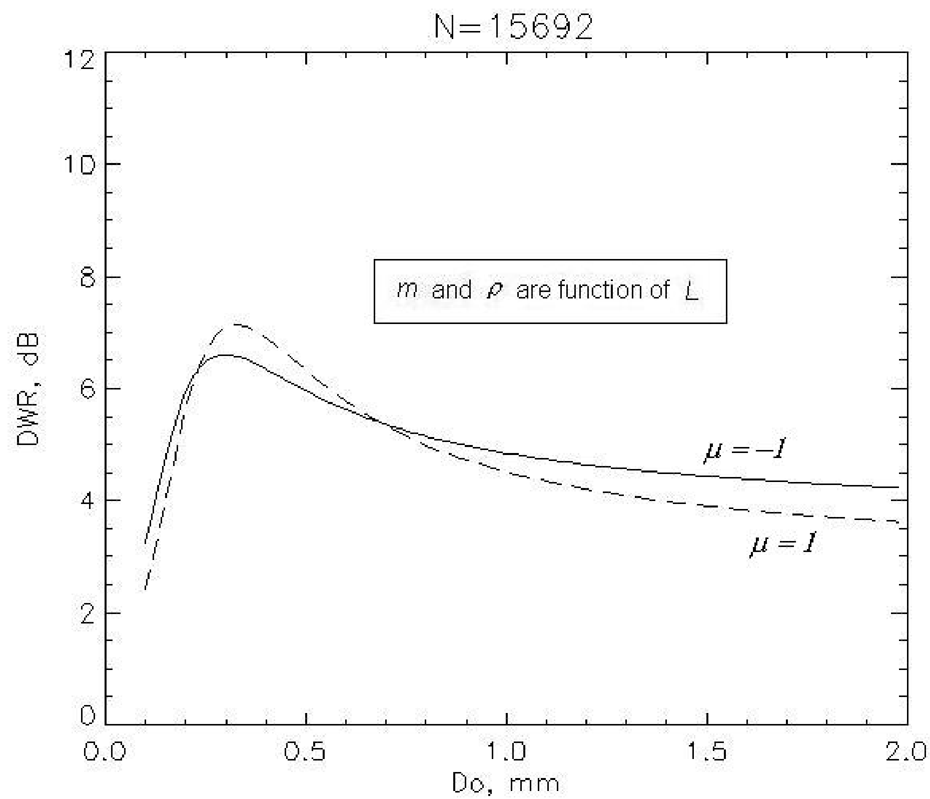
•The backscattering, ξ_b, for both frequencies is given by DDSCAT and this one depends on the target's diameter, *D,* which is the length of the bullet, *L*, and on other physical properties as the density and permittivity.

•The parameter μ describes the order of the gamma distribution and can be values between 2 and - 2.

DWR Results

DWR from the bullet ice crystal.
Both plots were calculated using 15,692 dipoles for the DDScat code.





a) Index of refraction and bulk density used by Aydin,
b) Index of refraction and density as a function of crystal length

Conclusions

- For a range between 0.01 – 2 mm, negligible changes can be found when varying the index of refraction.
- Significative changes were found when using density models that do not correspond to the natural condition of the ice crystals such as shape, temperature and height.
- The principal variation was obtained when using a density model of 9 g cm^{-3} because this model does not correspond to the typical shape nor the temperature of the bullet rosette nor the height.
- Density was found to have a large effect in the ice crystals backscattering.
- Complying with the DDscat criteria: consistent results were found when using 6,056 or more dipoles.

Future Work

- Compare the simulated backscattering to actual radar reflectivities and DWR of data taken with UMass CPRS radar system experiment in Australia, 1995.
- Disseminate the new DDScat toolbox for ice crystal bullets or bullet rossettes.

UPRM Center for

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