Multiple Scattering Effects on Space Borne Lidar

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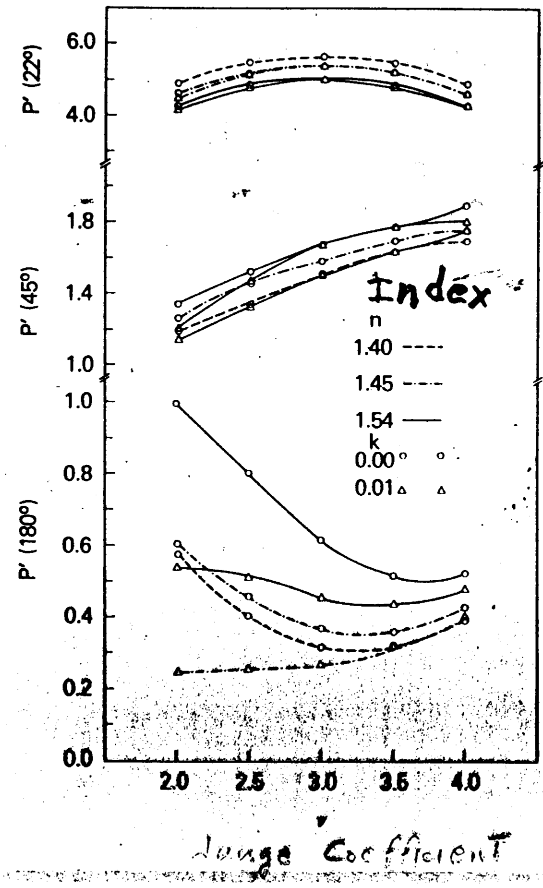
Multiple scattering calculations have been carried out for space borne lidar. The calculations have been done principally by Monte Carlo radiative transfer. The special emphasis is on the multiple scattering signal that is received after the ground return signal when without multiple scattering there will be no signal. It has been shown that the multiple scattering for space borne lidar will be a much more significant factor than for airborne systems for similar system field-of-view (FOV) (Spinhirne, 1982). Even for aerosol haze there can be a significant multiple scattering factor. The ground single scattering return will typically be followed by a significant multiple scatter signal when aerosol or thin cloud atmospheres are involved. The signal principally results from second order scattering consisting of a forward scatter event in the atmosphere and a ground scattering. For surface altimetery such as planned for the GLAS (Geoscience Laser Altimetery System) mission, calculations show that the multiple scatting is a pulse length stretching effect that can lead to altimetry error of several tens of centimeters. At FOV of one milliradian or more , the multiple scatter signal from a ground and atmospheric forward scattering can persist for several micro seconds. There is a preferential forward scatter angle as a function of reciever annular FOV. Since aerosol forward scattering is more directly related to extinction than the 180° backscatter that is principally observed by lidar, it is suggested that the post ground return signal from multiple scattering could possibly be applied to obtain a normalization to improve the retrieval of optical thickness from lidar.

Reference:

J. D. Spinhirne, "Lidar clear atmosphere multiple scattering dependence on receiver range," Appl. Opt., **21**, 2467(1982).

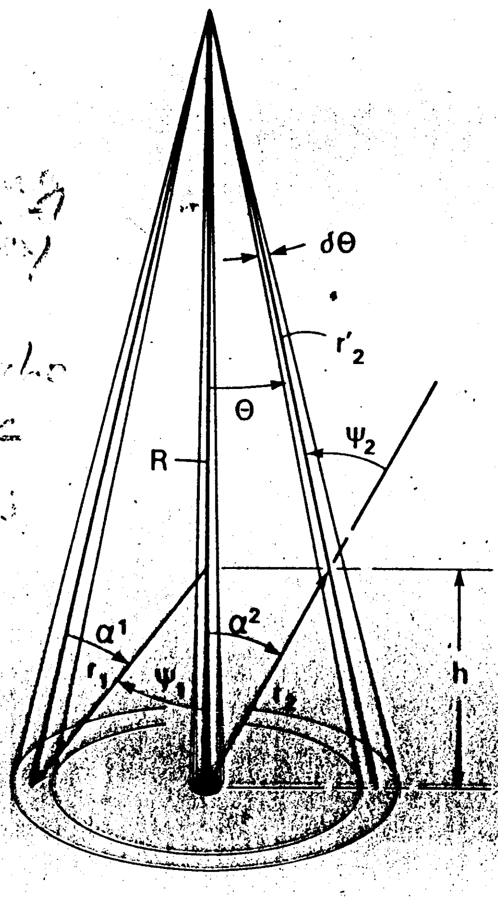
Aerosol Scattering

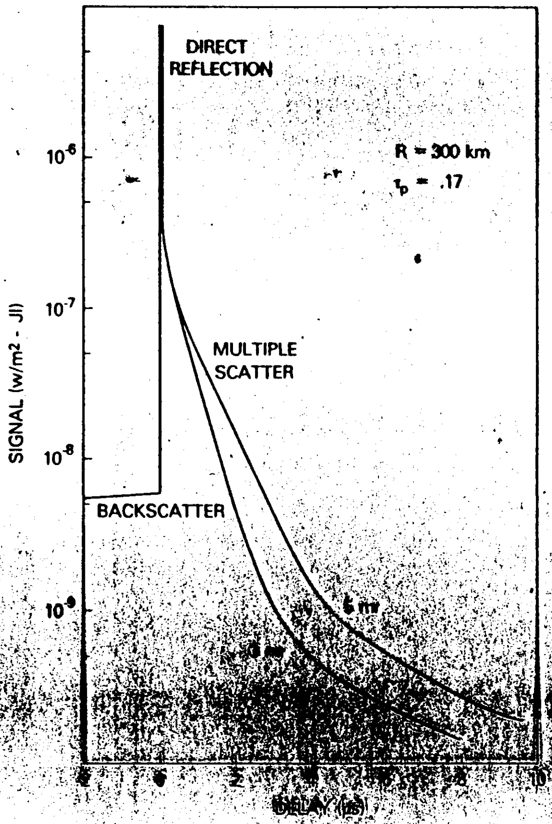


Foward Scatter

Backscatter not well related to extion

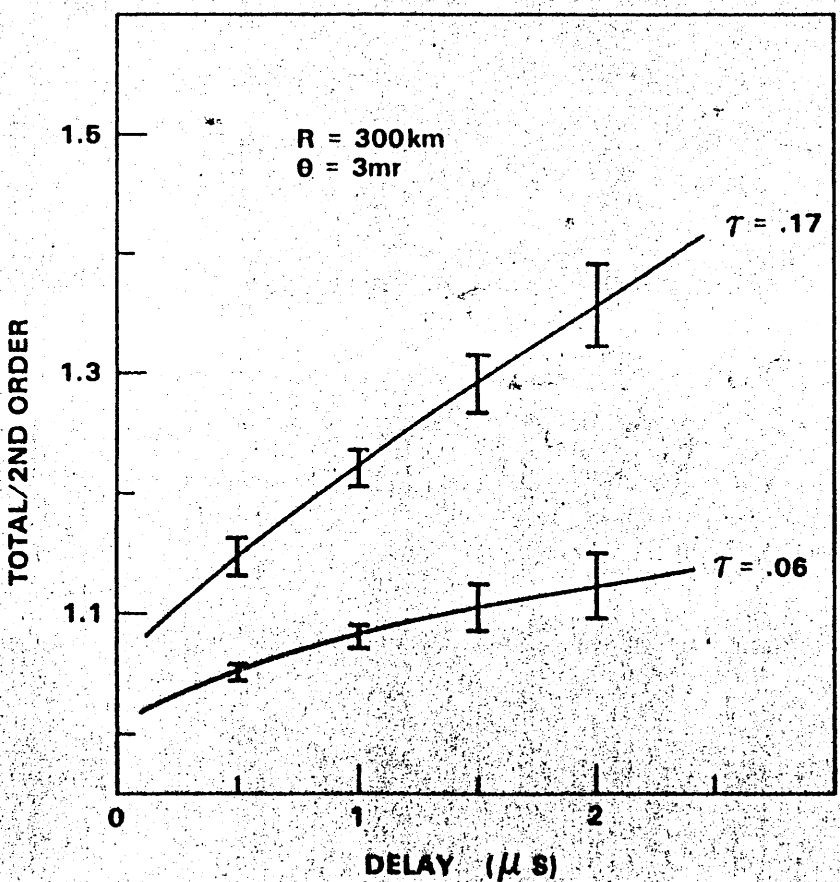
Scattering Geometry for Monte Carlo & Analytic Calculations

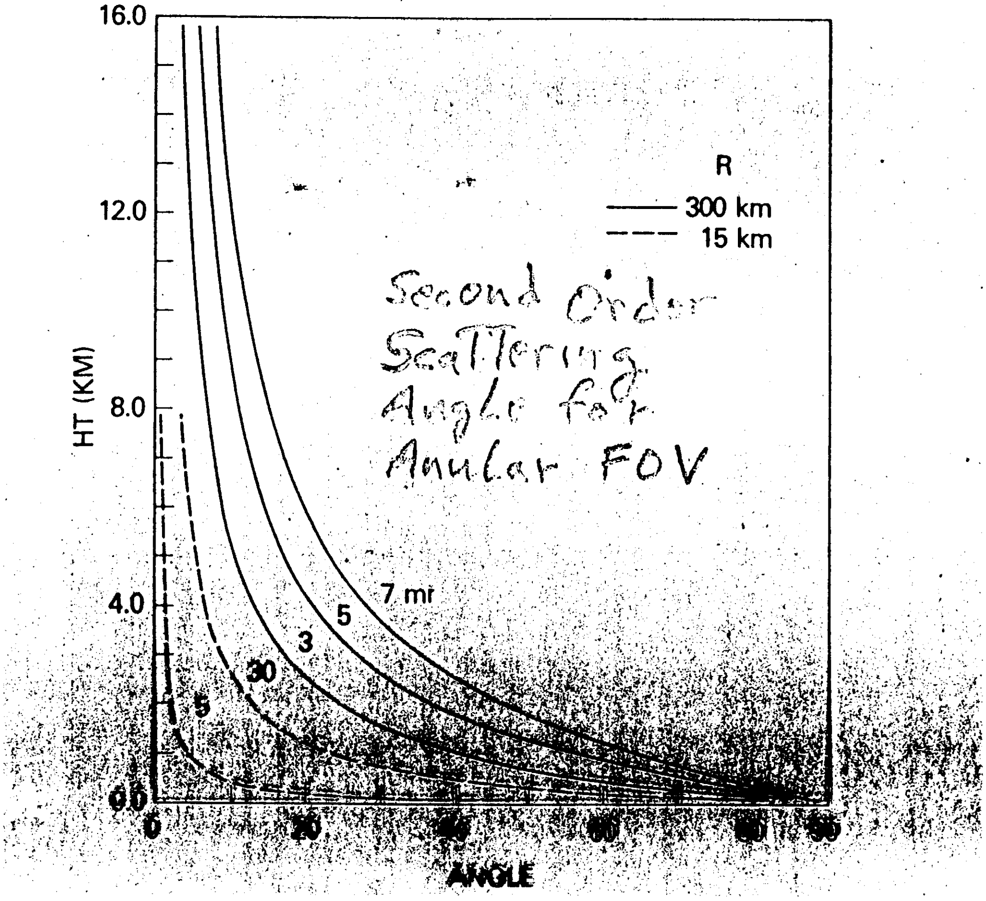


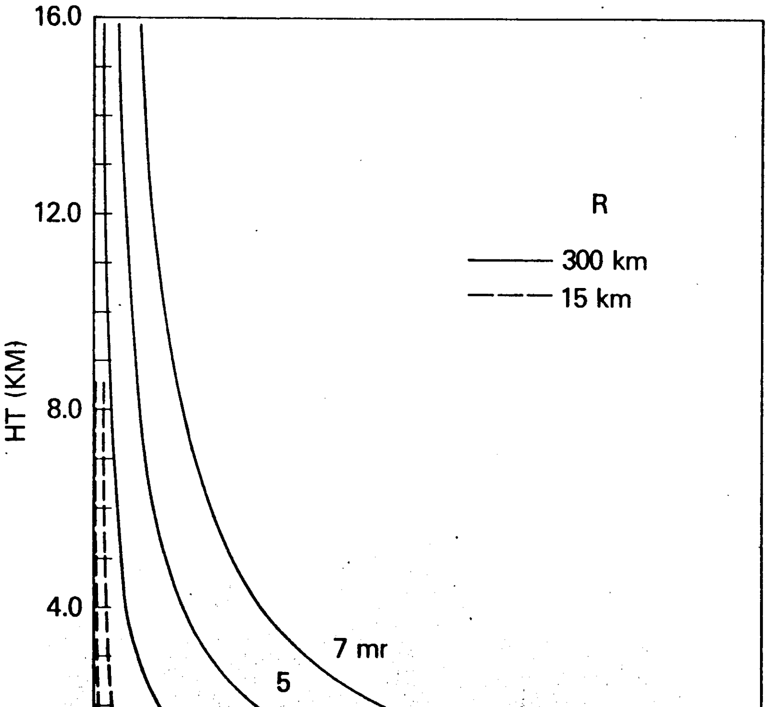


Multiple Scattering After Ground Return

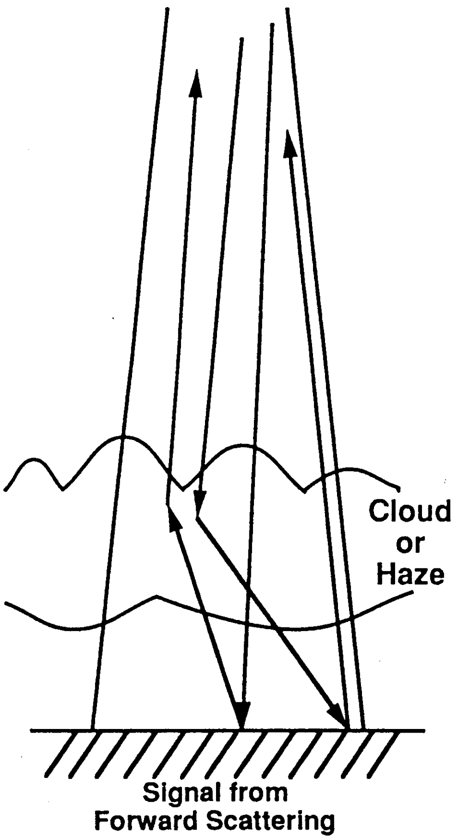
Spinhirne Applied Opt. 1982, 2462.

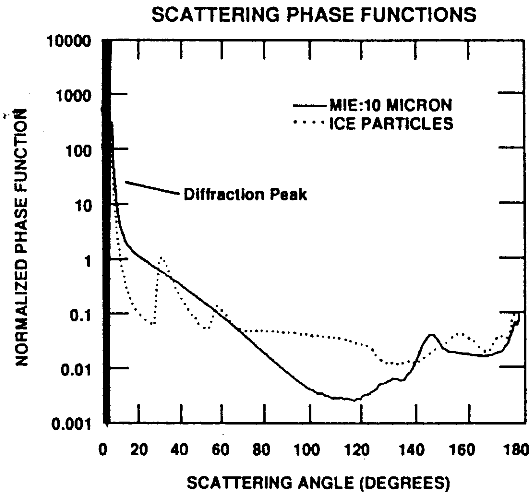


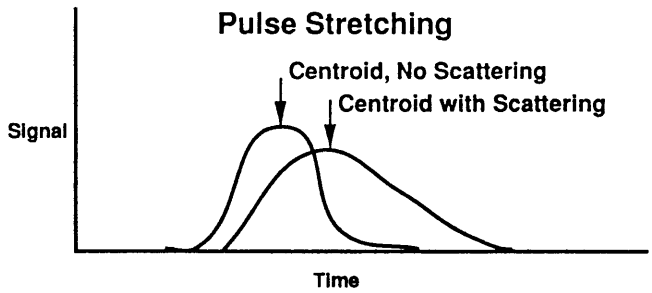

16.0
12.0
8.0
4.0
0.0
HT (KM)
R
300 km
15 km
Second Order
Scattering
Angle for
Anular FOV
7 mr
5
3
30
5
0
20
ANGLE

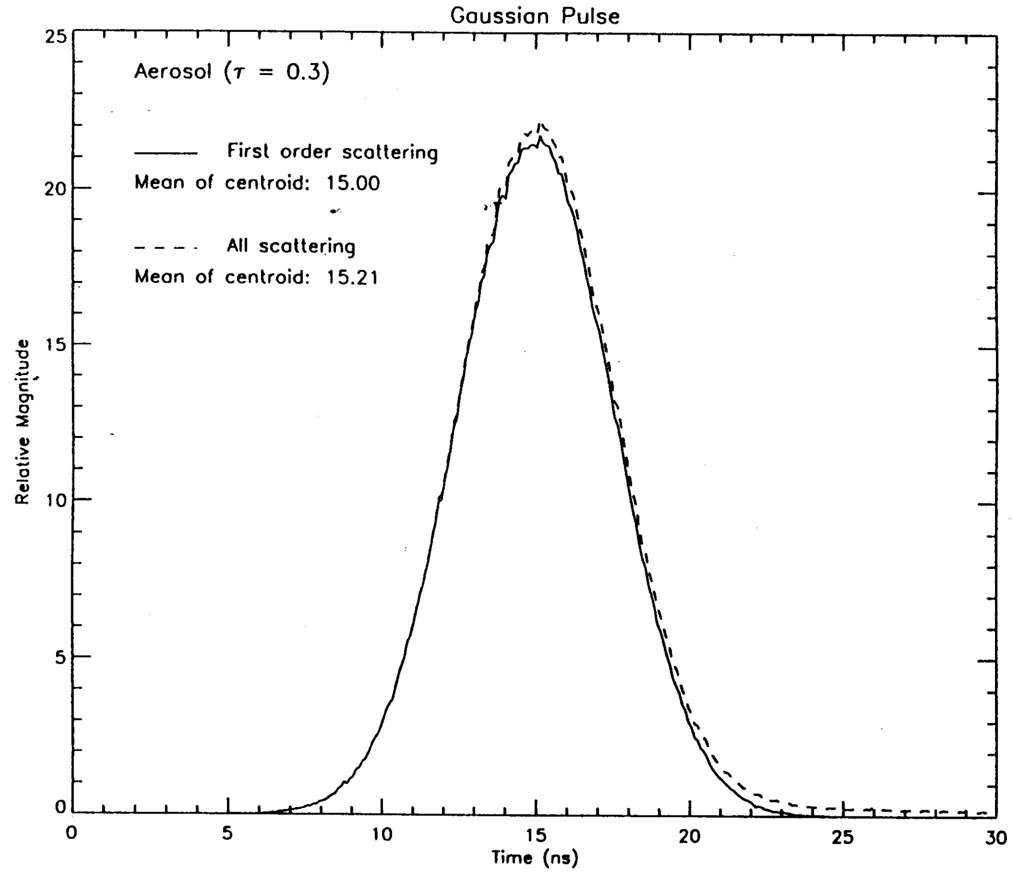

16.0
12.0
8.0
4.0
0.0
HT (KM)
R
300 km
15 km
7 mr
5
3
30
5
0.0
2.0
4.0
6.0
DELAY (μs)

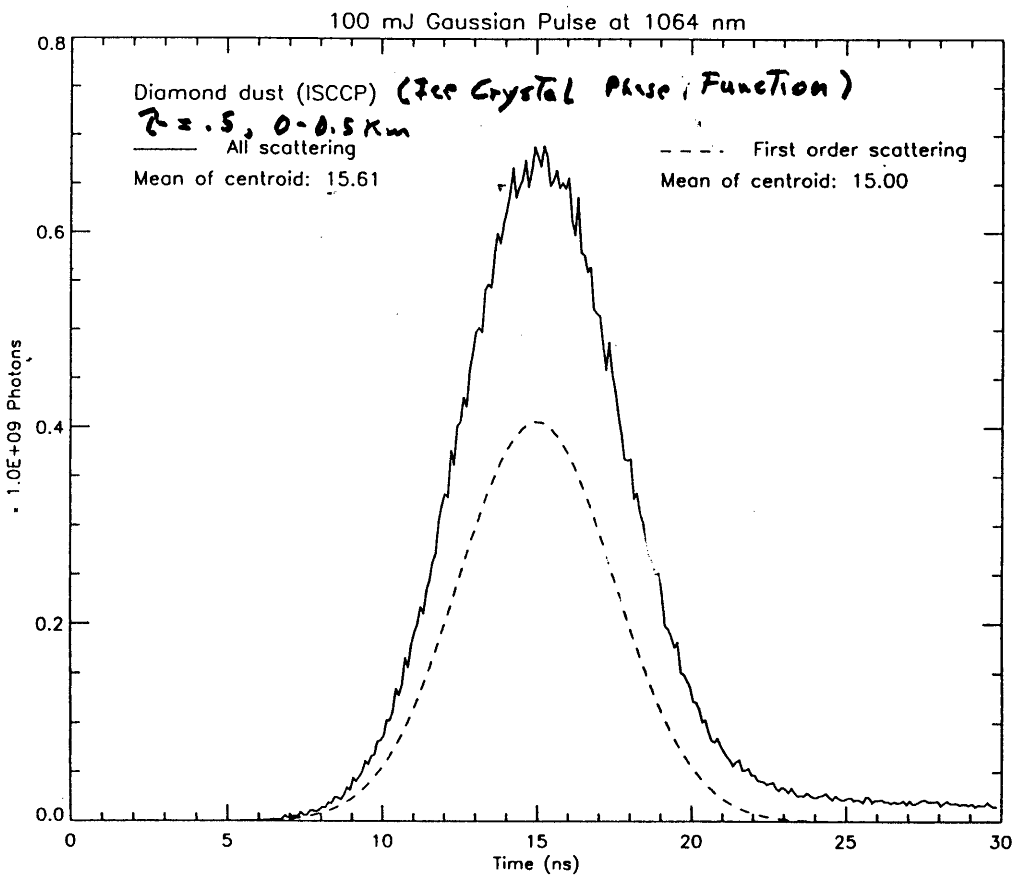
Surface Altitude Error From Atmosphere Scattering








Gaussian Pulse
Aerosol (τ = 0.3)
First order scattering
Mean of centroid: 15.00
All scattering
Mean of centroid: 15.21
Relative Magnitude
Time (ns)
0
5
10
15
20
25
30


100 mJ Gaussian Pulse at 1064 nm
Diamond dust (ISCCP) (Ice Crystal Phase Function)
τ = .5, 0-0.5 Km
All scattering
Mean of centroid: 15.61
First order scattering
Mean of centroid: 15.00
* 1.0E+09 Photons
Time (ns)
0.0
0.2
0.4
0.6
0.8
0
5
10
15
20
25
30