Understanding Optical Scattering Effects in Degraded Visual Environments

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Problem & Motivation

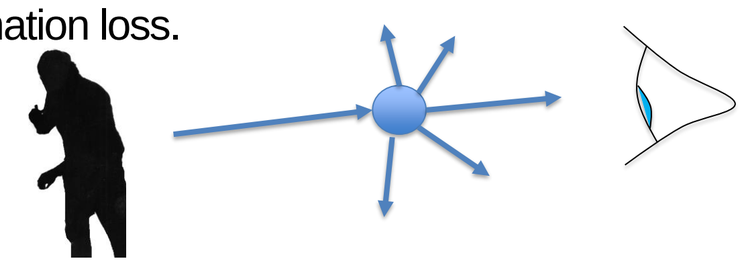
- When light interacts with small particles the light is scattered into different directions causing a decrease in signal and loss of information.
- These obscured environments negatively affect imaging and ranging in critical national security situations, and can result in loss of life.

11 dead in helicopter crash off Florida Coast due to thick fog: Wink News, March 11, 2015

- Any improvement in imaging or ranging in obscuring environments will not only save money and man power, but also lives.
- We can look to solve this problem by better understanding it with Monte-Carlo simulations and scattering probability analysis.

Approach

Light scatters off the particle in the obscuring environments (water droplets in fog) which results in information loss.

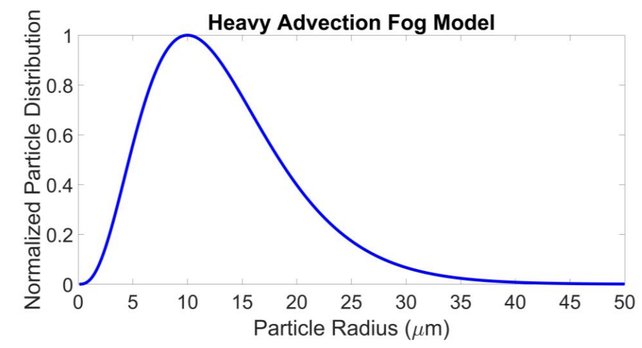


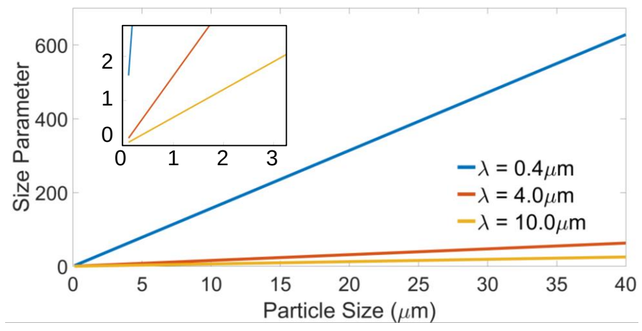
Scattering of light is affected by:

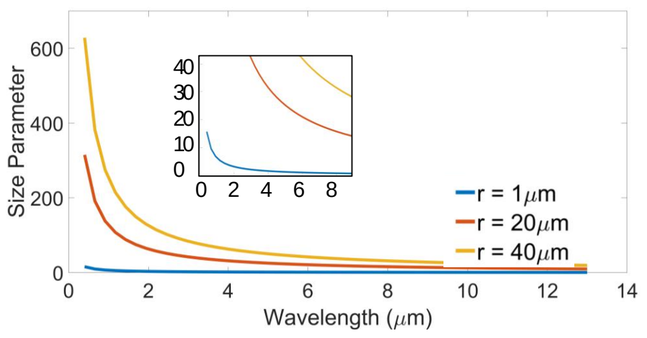
- Wavelength of incident light (0.4-13 μm) , λ
- Fog particle size (0.1 to 40 μm for fog), r
- Index refraction of water, n (wavelength dependent)

Summarized by dimensionless quantity:

Size parameter: $x = \frac{2\pi n r}{\lambda}$.



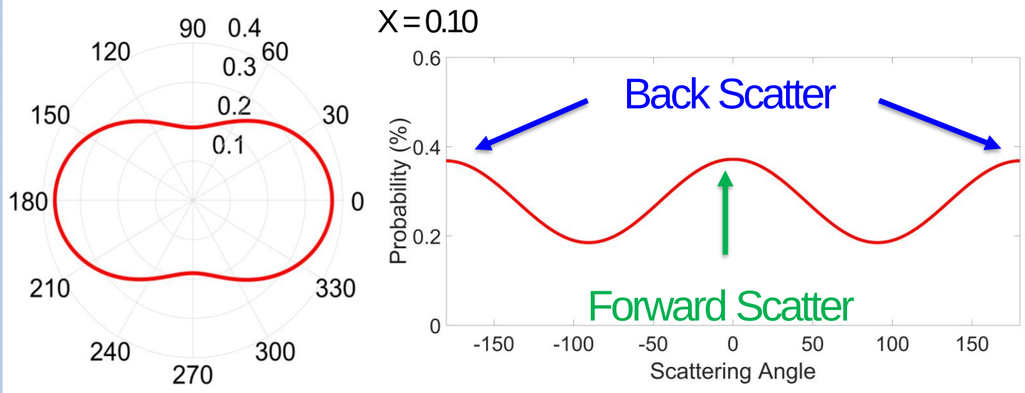




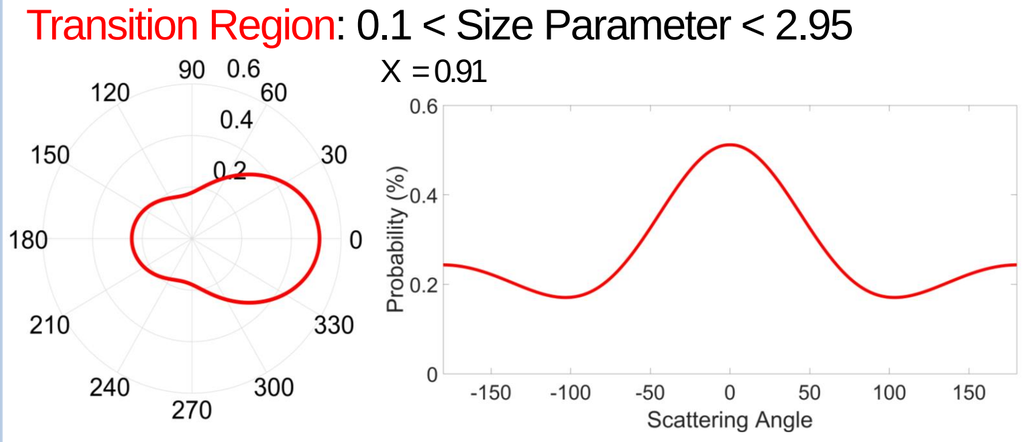
Results

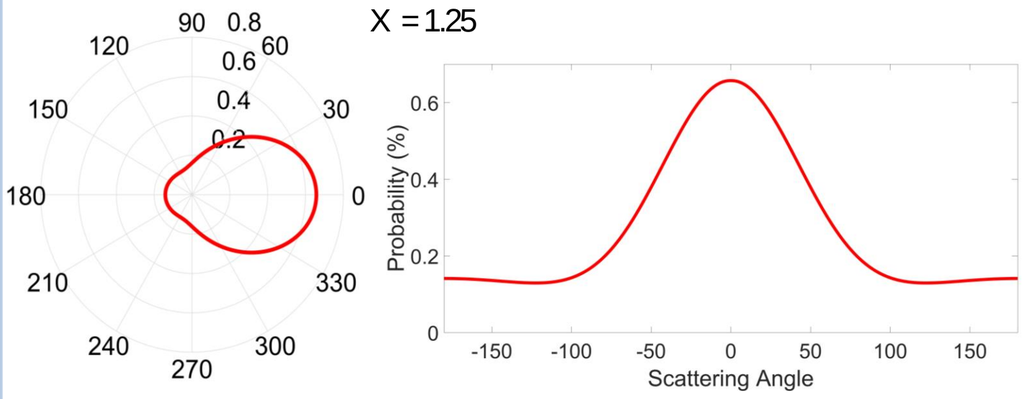
As size parameter increases, the likelihood of scattering in the forward direction becomes more probable.[1,2]

Isotropic: Size Parameter < 0.1

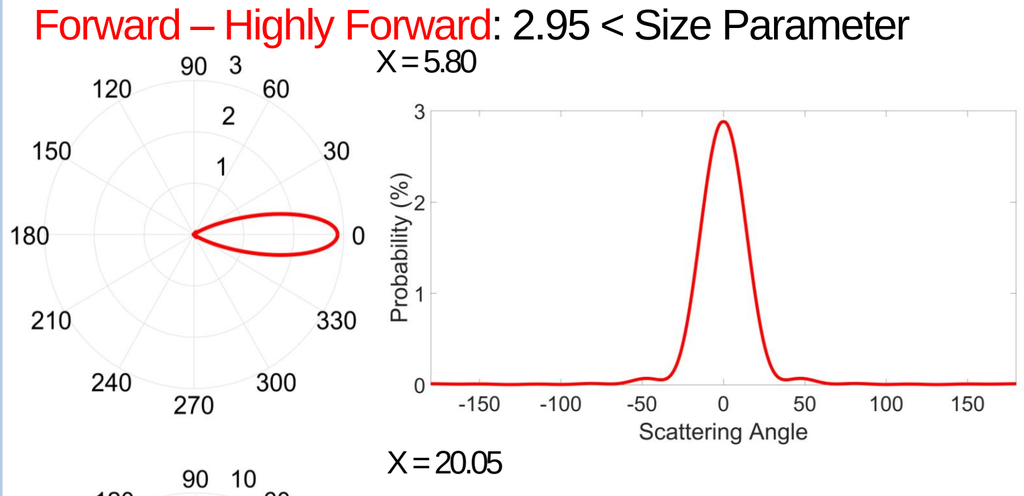


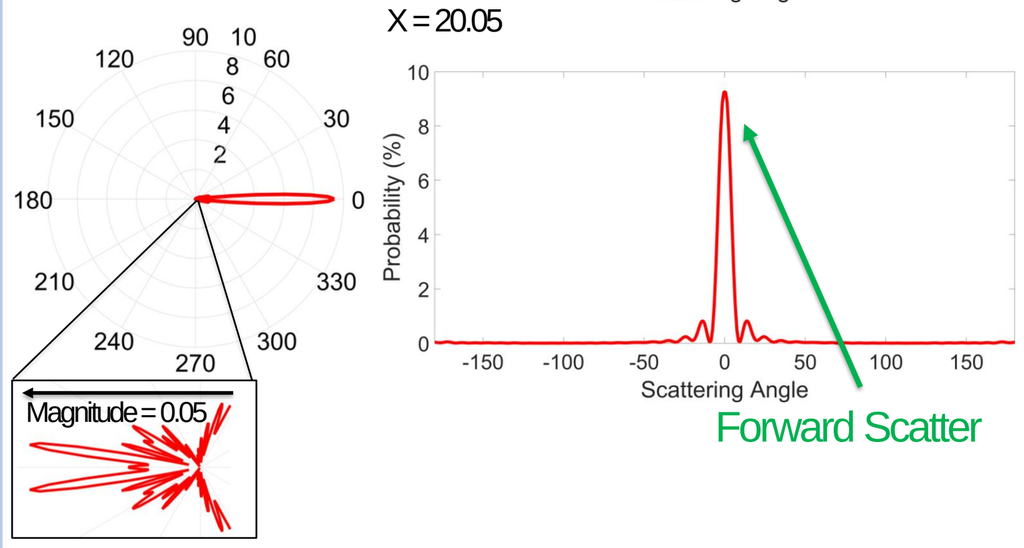
Transition Region: 0.1 < Size Parameter < 2.95





Forward – Highly Forward: 2.95 < Size Parameter





Even with highly forward scattering patterns, there is still a miniscule chance of a backscattering.

[1]G. Mie, "Beitrage zur Optik truber Medien, speziell kolloidaler Metallosungen," Ann. der Phys. Ser. IV 25, 377–445 (1908).

[2]C. Bohren and D. Huffman, Absorption and Scattering of Light by Small Particles (John Wiley & Sons, Inc., 1983)

Conclusions & Significance

- For the majority of wavelengths & particles sizes of fog, the scattering probability distribution is forward.
- We can use this data and understanding to implement smart sampling within Monte-Carlo simulations to quicken simulation run-time and accuracy.

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