Uncertainties Associated with the Scattering Properties of Ice Crystals in CERES-MODIS Retrieval of Cirrus Clouds

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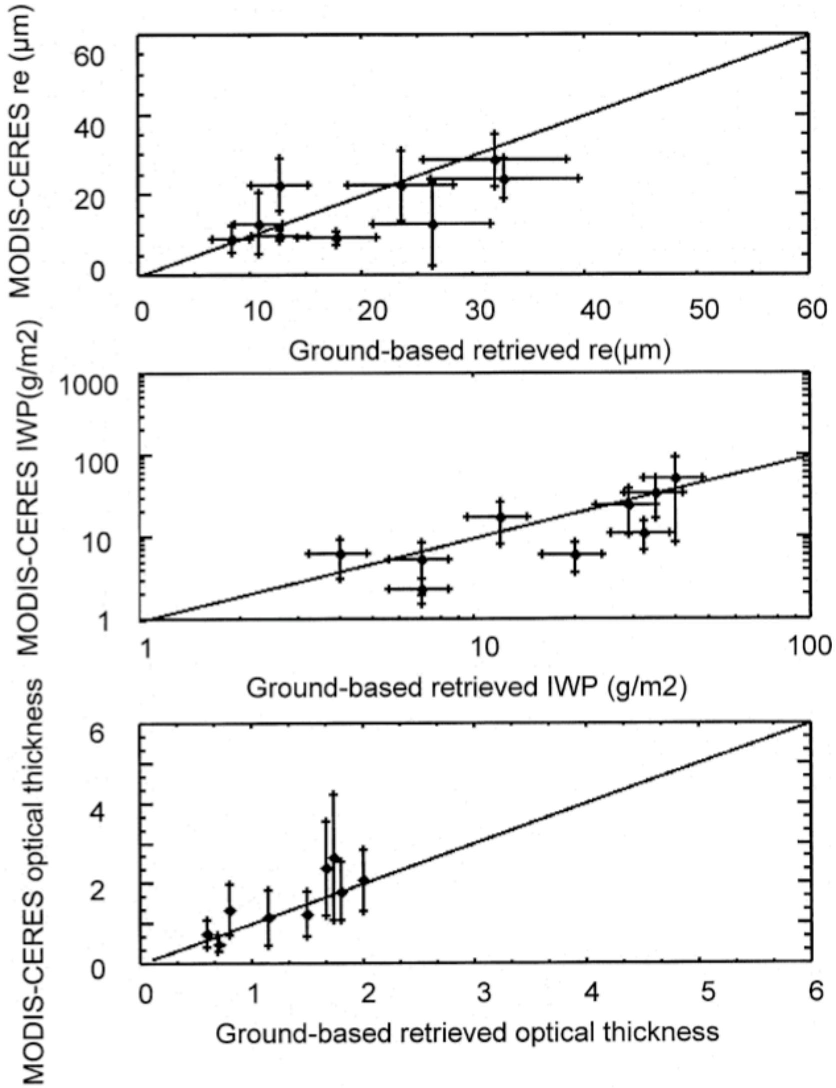
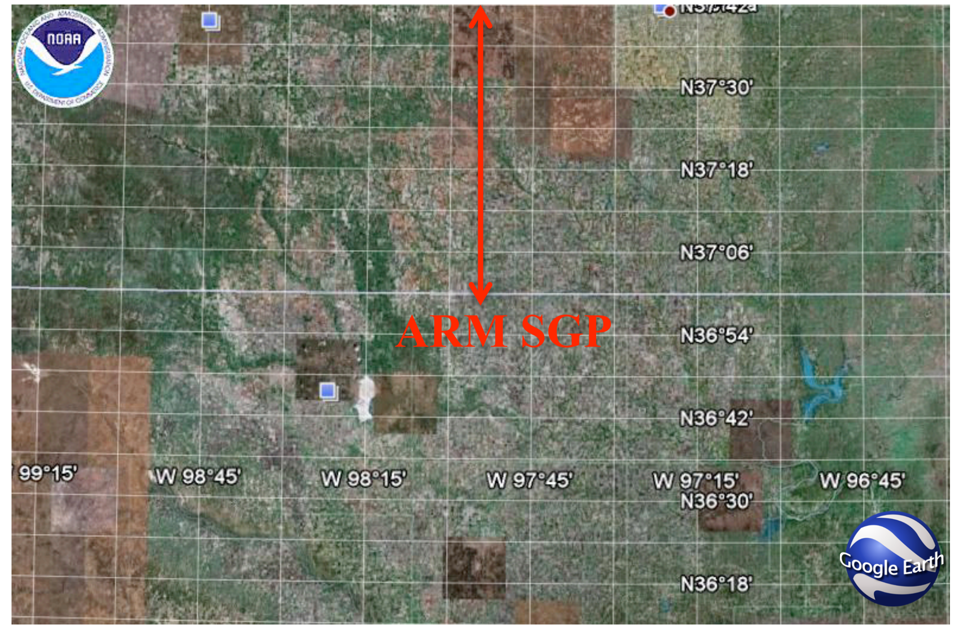


Mace et al., 2005; Mace et al., 2002



- *Linear correspondence is found in all of the comparisons.*

- *The CERES-MODIS ice cloud particle size tends to be smaller on average compare to the ground-based retrievals.*

- *The CERES-MODIS ice cloud optical thickness is larger than the corresponding one derived from ground-based data.*

What is the Source of the Uncertainties?

Ice & Water Clouds

- *Error in the atmospheric emissivity and assumed surface albedo (Han et al., 1994; Platnick and Valero, 1995; Minnis et al., 1998; Minnis et al., 1995)*

  Optical thickness would be over estimated in CERES-MODIS retrieval over snow and ice covered areas. (Spangenberg et al., 2004; Xiong et al., 2002)

- *Error of retrieved cloud properties from different solar and viewing geometries.*

  The error in satellite-derived cloud properties depends on solar zenith angle, viewing zenith and relative azimuth angles. Differences between two satellite views can be as large as 15% for water clouds and as large as 20% for ice clouds at certain sets of angles or times of day. (Kato and Marshak, 2009; Ayers et al., 2005; Mace et al., 2005; Chambers et al., 1997; Zuidema and Evans, 1998; Varnai and Marshak, 2003)

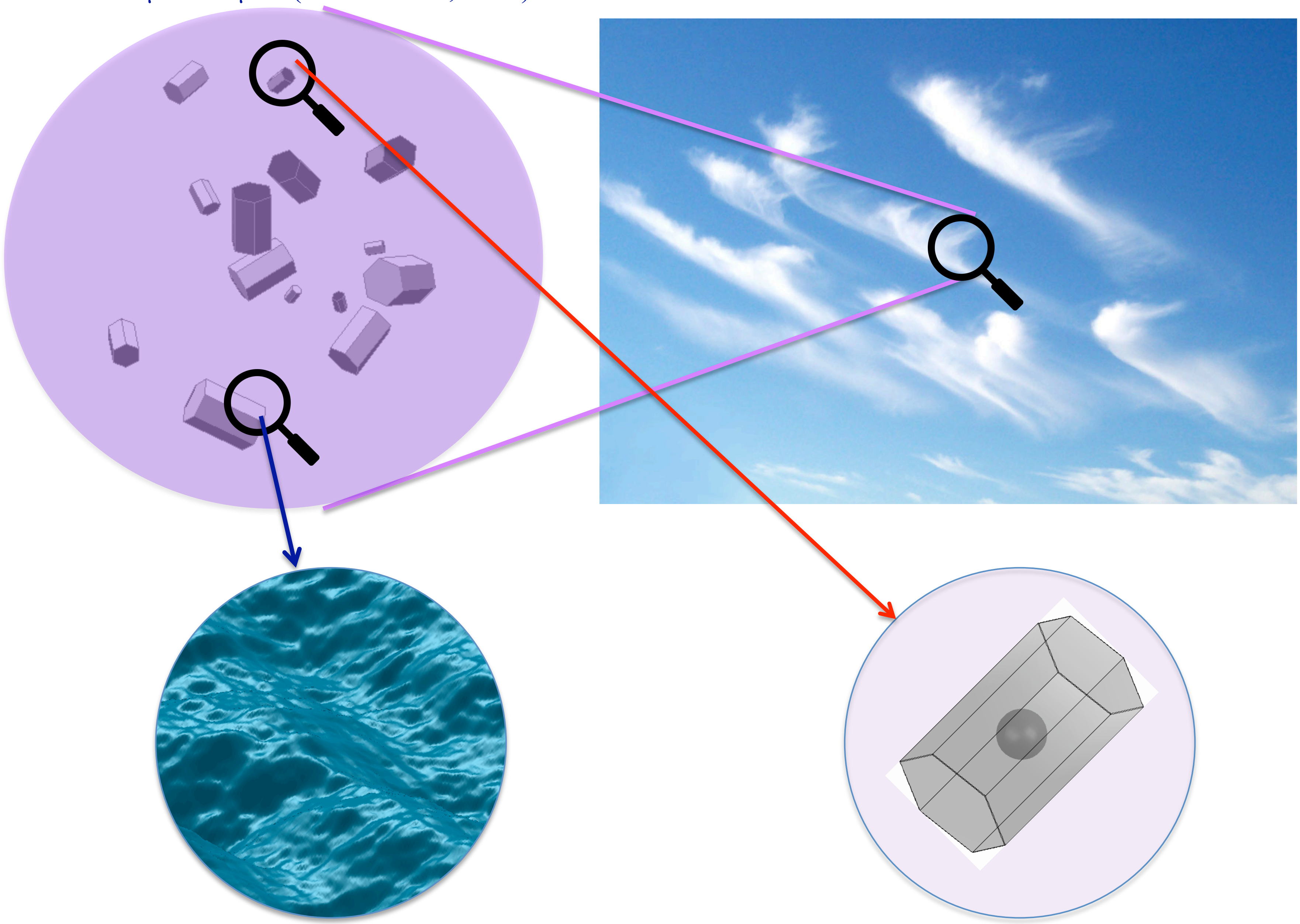
Ice Clouds

- *Horizontal and vertical inhomogeneity of ice cloud particle size distribution contribute to the uncertainty associated with the CERES-MODIS and ground-based retrieval algorithms.*

  For midlatitude cirrus clouds, ice crystals in the top layers are normally small pristine particles, whereas ice crystals near cloud base tend to be larger. (Heymsfield et al., 2002; Mace et al., 2005; Heymsfield and Iaquinta, 2000; Hogan and Illingworth, 2003)

- *Scattering properties of ice cloud particles?*

2a/L= 5µm/5µm, 5µm/10µm, 10µm/10µm, 20µm/20µm, 40µm/50µm, 60µm/120µm,100µm/300µm, and 160µm/750µm. (Minnis et al., 1998)



• *The geometric optics method is employed to computer the single-scattering properties of ice crystals.*

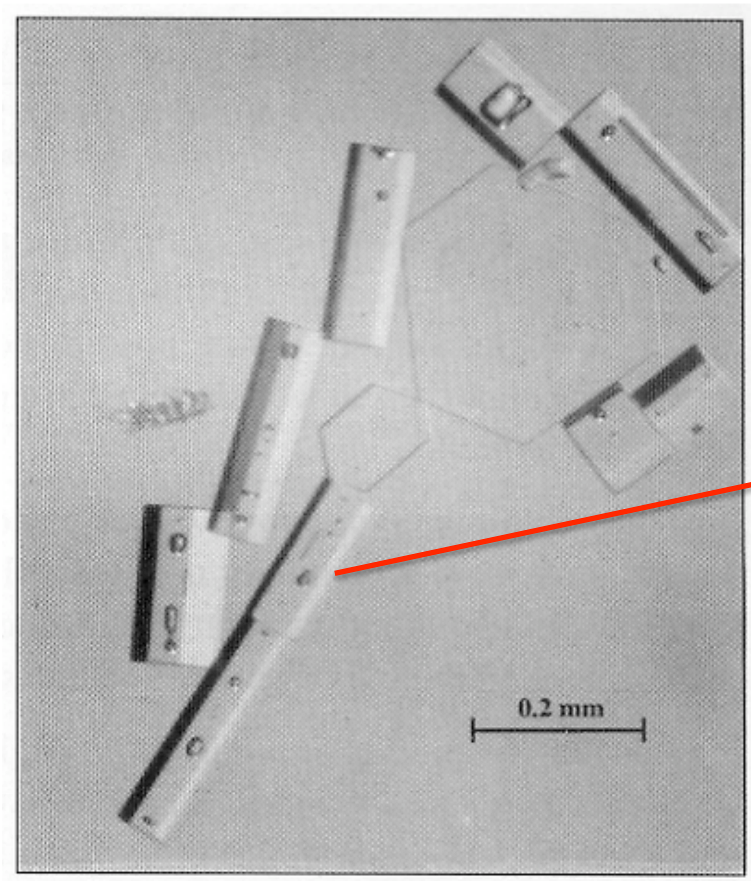
• *For a given reflection and refraction event, we assume that a local facet is randomly tilted with a slope that is randomly sampled on the basis of the Gaussian distribution and the Box-Muller method as follows:*

$$f(s) = \frac{1}{\sigma\sqrt{\pi}} \exp(-s^2/\sigma^2)$$

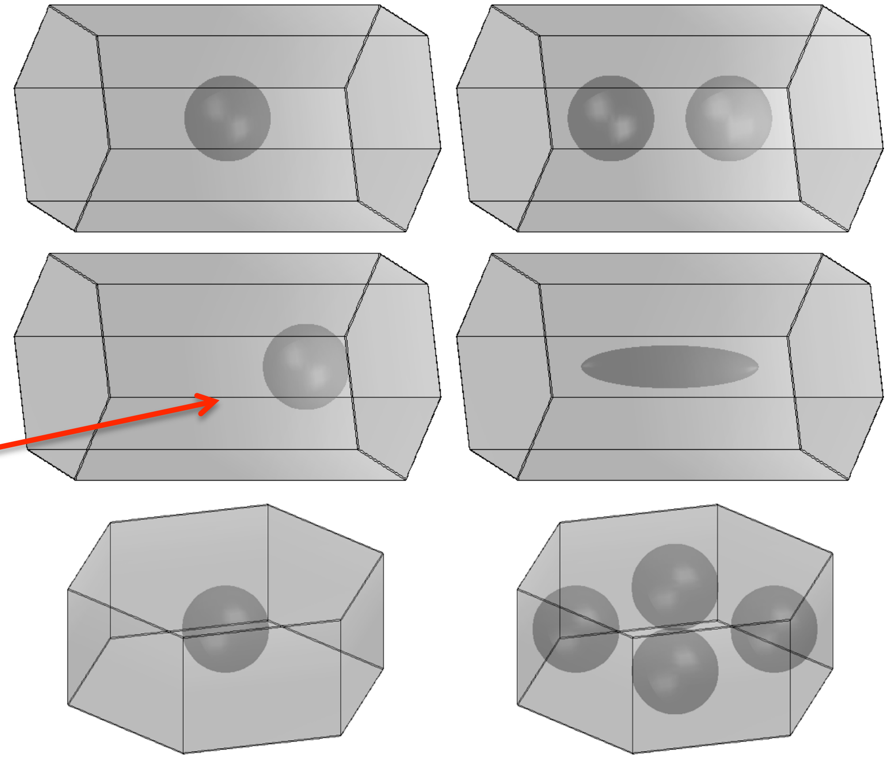
$$s = \sigma(-\ln\xi_1)^{1/2}\cos(2\pi\xi_2)$$

where ζ_1 and ζ_2 are random numbers distributed uniformly between zero and one, f indicates the probability distribution function and $\sigma^2/2$ is the variance of the distribution.

Yang and Liou, 1998; Macke et al., 1996; Yang et al., 2008; Press et al., 1992



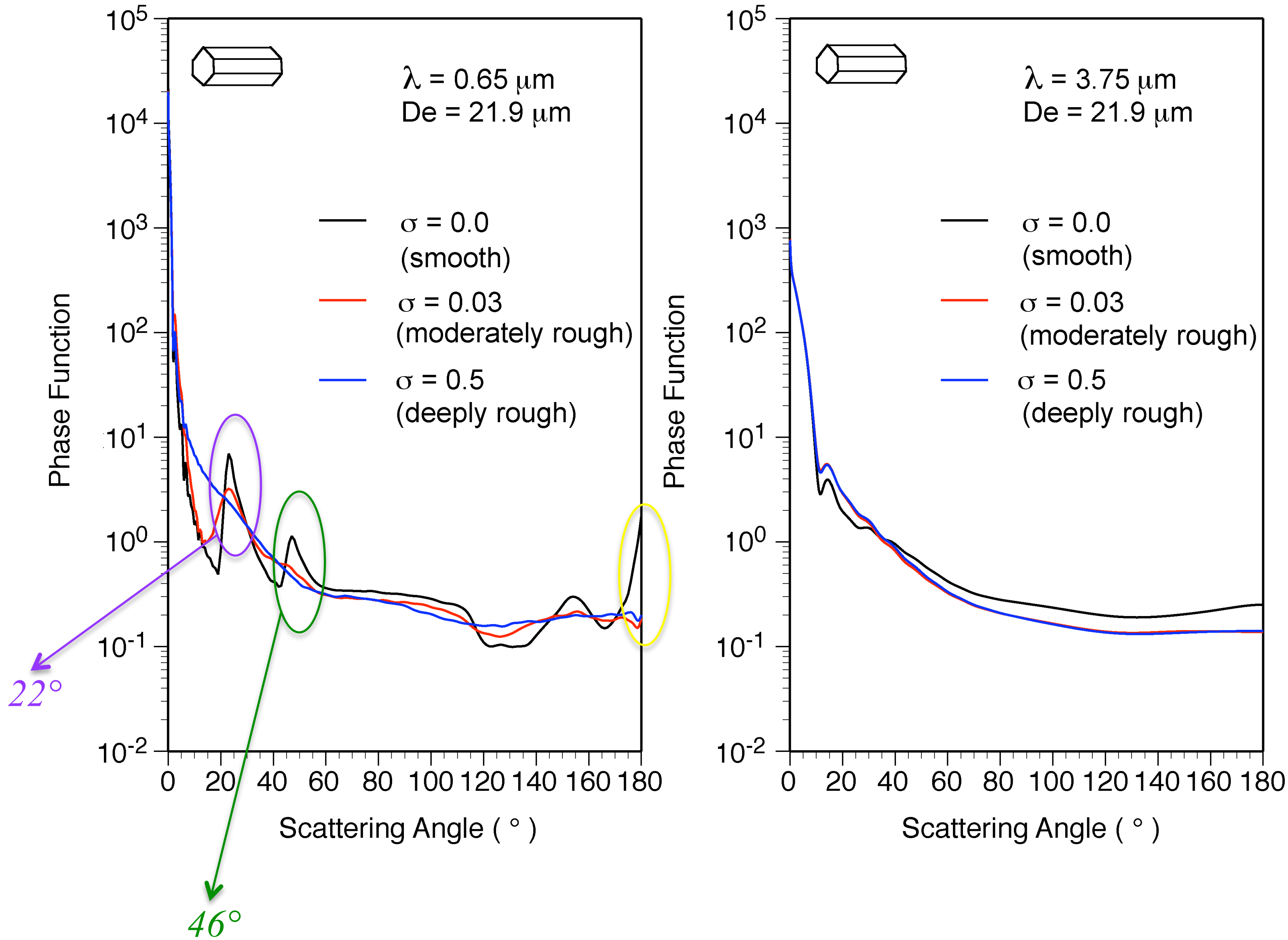
Walter Tape, Atmospheric Halos,
Antarctic Reseach Series, volume 64,1994



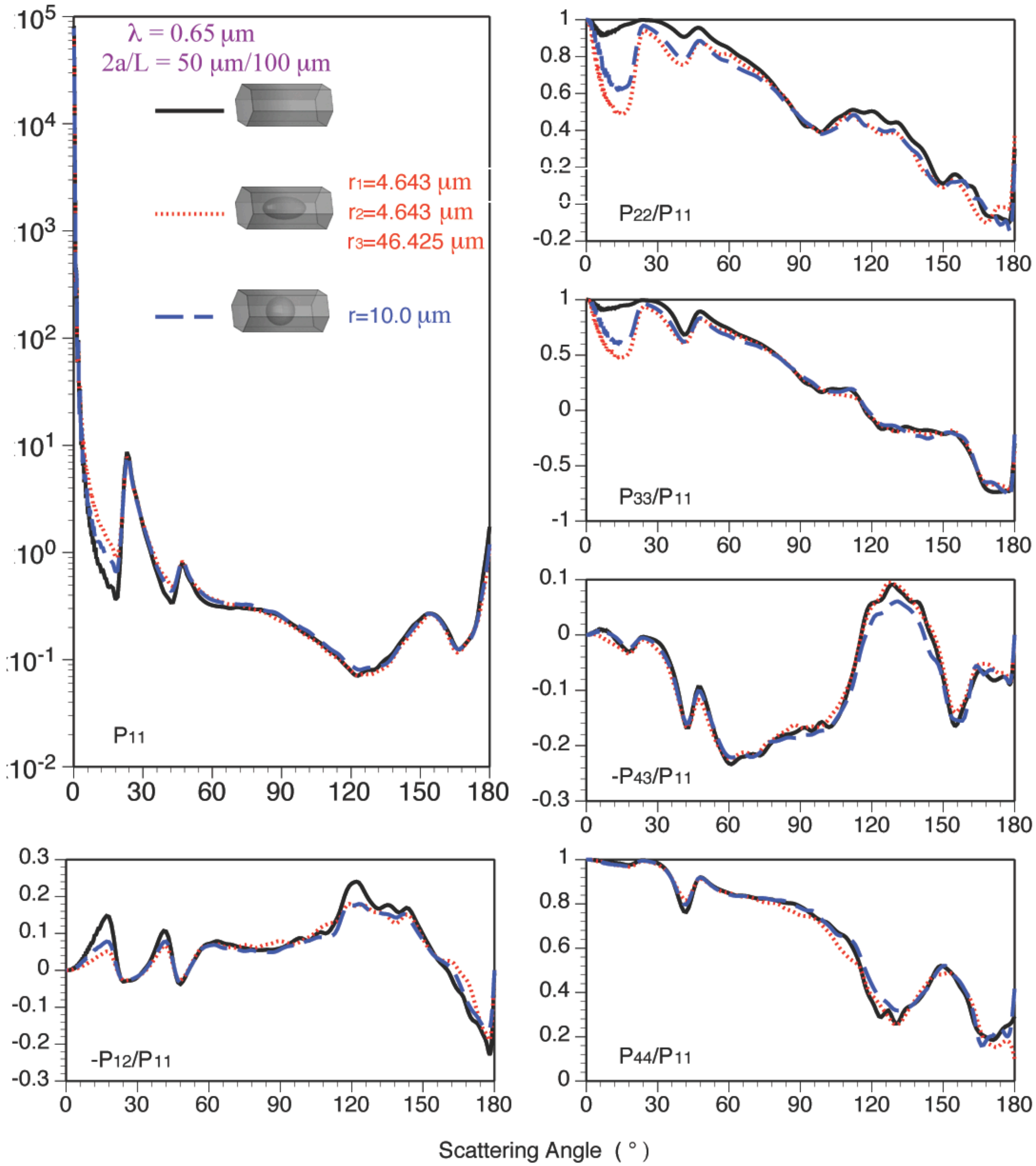
$$\frac{(x-x_r)^2}{r_1^2}+\frac{(y-y_r)^2}{r_2^2}+\frac{(z-z_r)^2}{r_3^2}=1$$

Xie et al., 2009

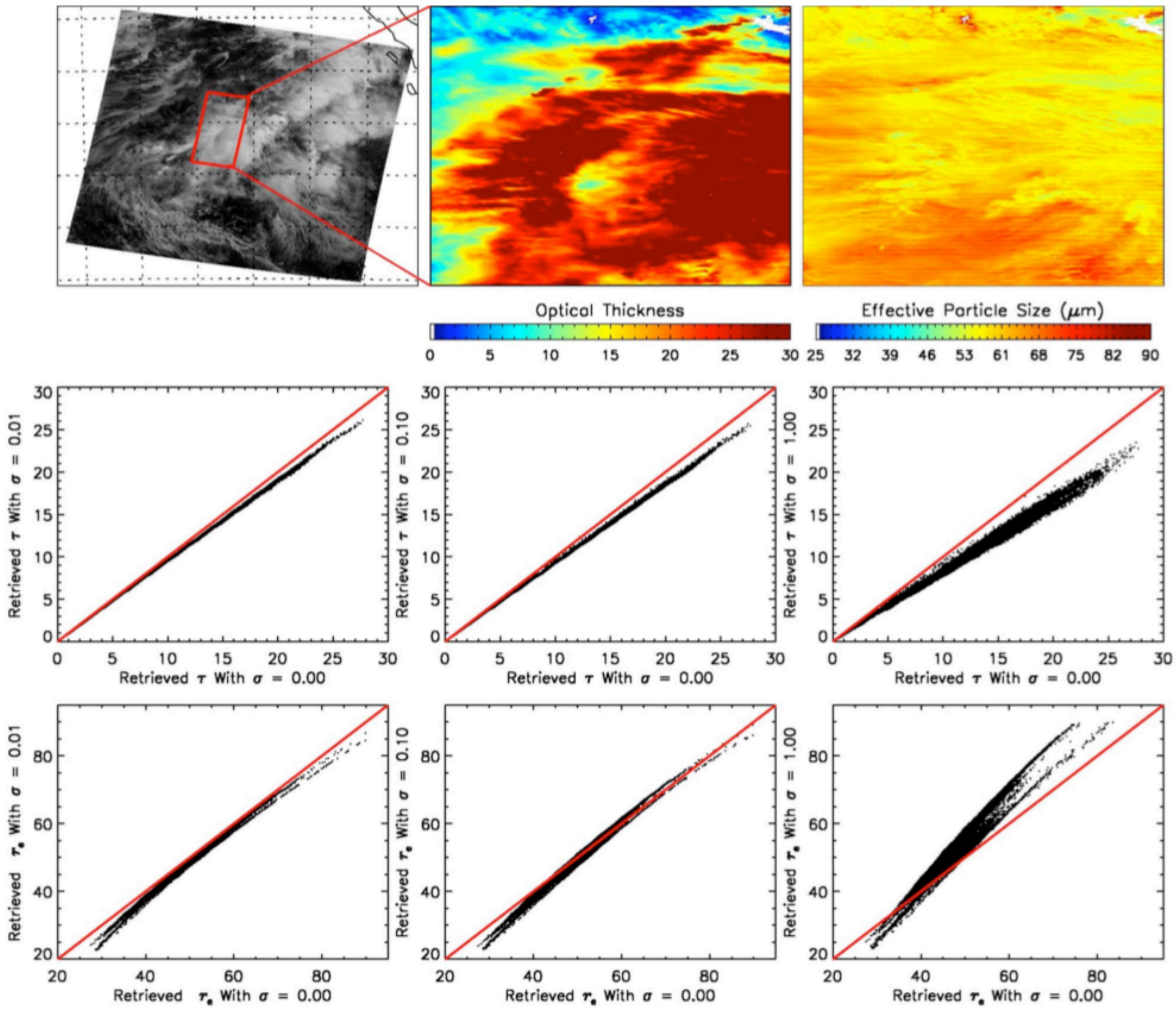
Scattering Properties of Ice Crystals with Surface Roughness



Scattering Properties of Inhomogeneous Ice Crystals



Xie et al., 2009

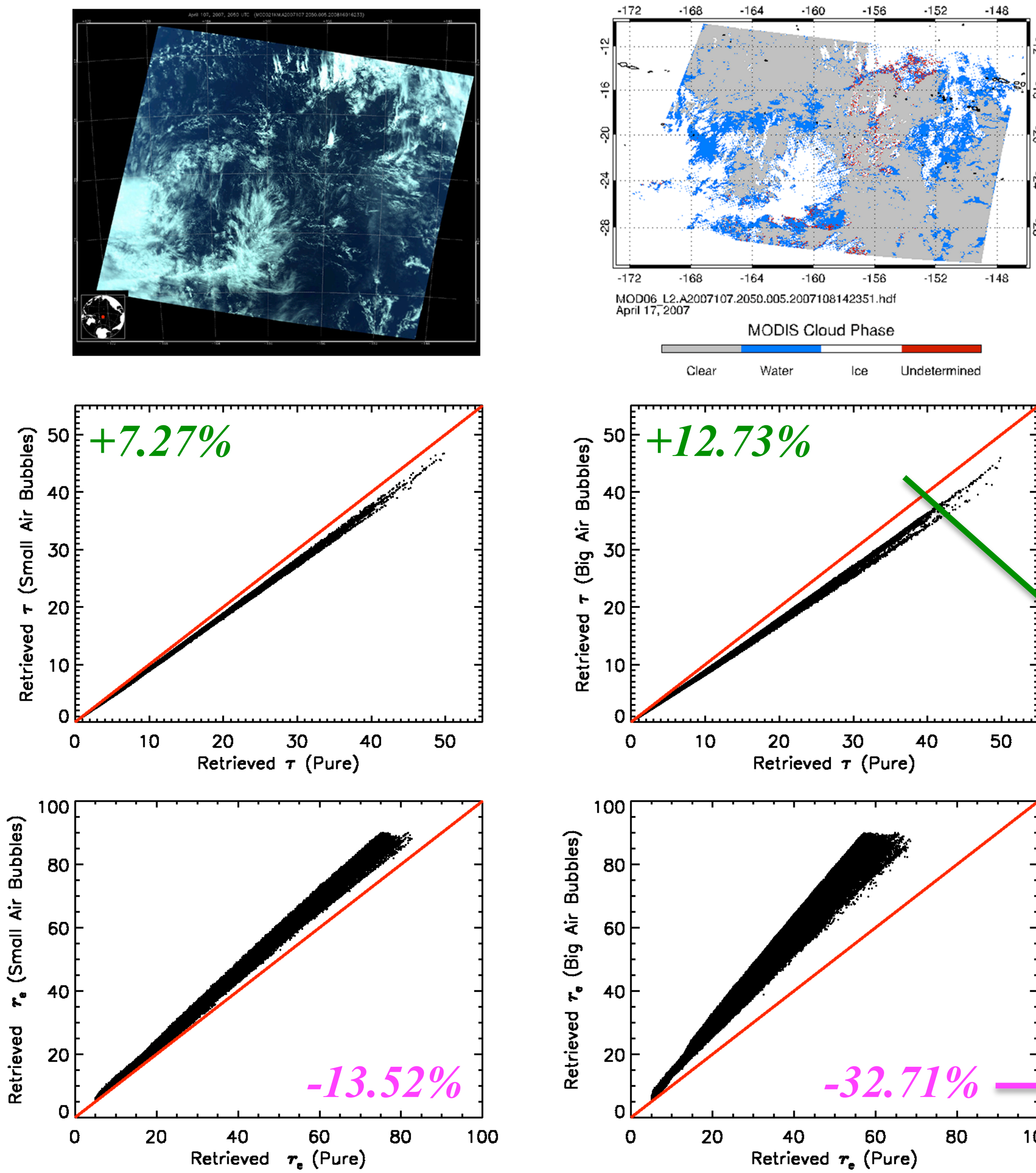


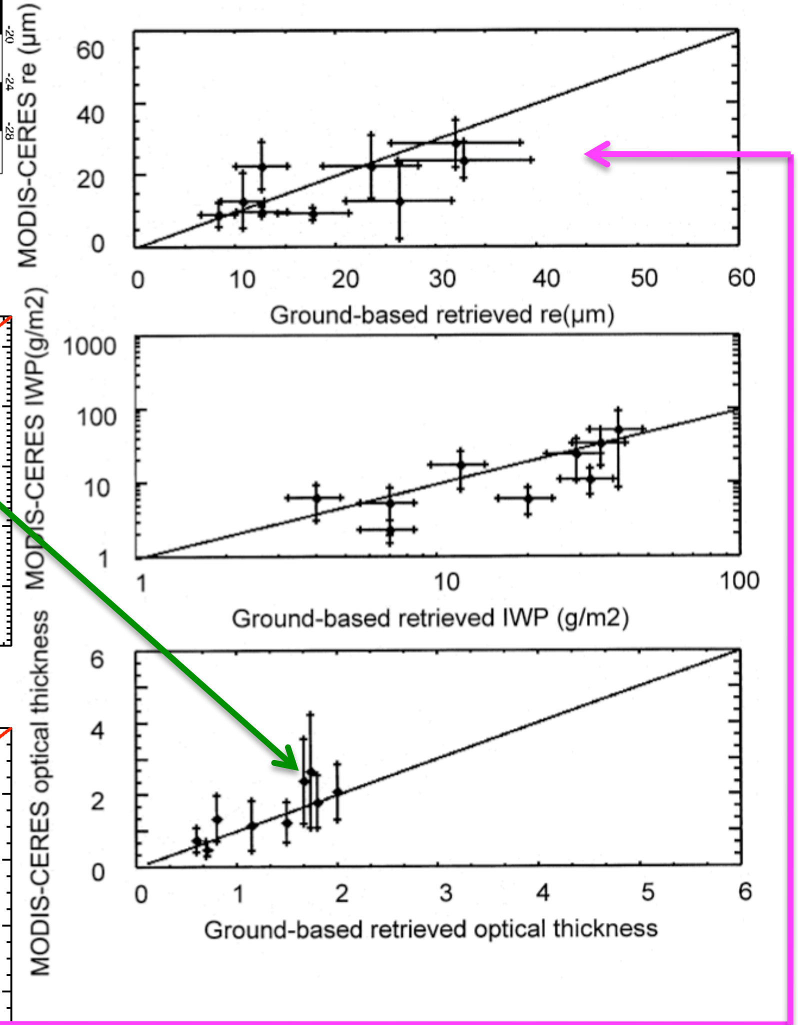
MODIS granule image (RGB=band 4:3:1), the retrieved ice cloud optical thickness, and the effective particle sizes with roughness σ=0.00 (upper panels).

The comparisons of retrieved ice cloud optical thicknesses from different roughness conditions: σ=0.00, 0.01,0.10, and 1.00 (middle panels).

The comparisons of retrieved ice cloud effective particle sizes from different roughness conditions: σ=0.00, 0.01,0.10, and 1.00 (bottom panels).

Yang et al., 2008





Mace et al., 2005; Mace et al., 2002

Xie et al., 2009

Summary

✓ *The surface roughness and inhomogeneity of ice crystals can smooth the phase functions, diminish the 22° and 46° halo peaks, and reduce the backscatter in comparison with the ice crystals used in CERES-MODIS retrievals.*

✓ *In case of deep roughness condition or inhomogeneous ice crystals, the dominant effect of surface roughness and ice crystal inhomogeneity is to decrease the values of the retrieved ice cloud optical thickness and to increase the values of the retrieved effective particle size.*

✓ *The single-scattering properties of ice crystals are one of the uncertainties in CERES-MODIS retrieval of ice clouds.*

✓ *Other morphological parameters may also substantially modulate scattering properties and CERES-MODIS retrievals of ice clouds.*