

Determination of the optical thickness and effective radius of clouds from reflected solar radiation measurements

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Abstract

Nakajima et al. (1990, 1991) describe a method to determine the optical thickness (τ) and effective radius (r_e) of stratiform cloud layers from reflected solar radiation measurements, considering the approximations provided by the asymptotic theory. The asymptotic theory shows that the reflection (and transmission) properties of thick layer depend essentially on two parameters of the atmosphere, the scaled optical thickness (τ') and the similarity parameter (s) together with the reflectivity of the underlying surface.

Computations performed using Mie theory for liquid water clouds indicate that the optical thickness can be estimated from reflections measurements in wavelengths lower than $1\mu\text{m}$, since the similarity parameter is almost zero (conservative scattering). On the other hand, the reflection function is sensitive to particle size at wavelengths near 1.65 and $2.16\mu\text{m}$.

Radiative transfer calculations (figure 1) show that it is possible determine the optical thickness and effective radius nearly independently, and thus measurements errors in one channel have little impact on the cloud optical property determined primarily by the other channel.

In order to find the optimum values of effective radius and optical thickness, the technique proposed by Nakajima et al consist in minimizing the next statistic:

$$\chi^2 = \sum_i \left[\ln R_{meas}^i(\mu, \mu_0, \phi) - \ln R_{meas}^i(\tau, r_e, \mu, \mu_0, \phi) \right]^2$$

Comprehensive measurements of marine stratocumulus measurements acquired off the coast of California (as a part of the FIRE IFO program) were used in order to provide comparisons between remote sensing and in situ estimates of cloud optical and microphysical properties.

The observations were carried by two aircrafts equipped to measure radiometric and microphysical parameters.

Figure 2 compares the retrieved effective radius with in situ values as function of the flight distance. It is possible to observe a good spatial correlation between r_{center} (corrected remote sensing effective radius) and $r_{in\ situ}$. However the remote sensing r_e systematically overestimates the real value of r_e . Good correlations between $\tau_{remote\ sensing}$ and $\tau_{in\ situ}$ were obtained as well.

Nakajima et al. (1991) are able to explain the overestimation of effective radius introducing additional absorption by water at $2.16\mu\text{m}$.

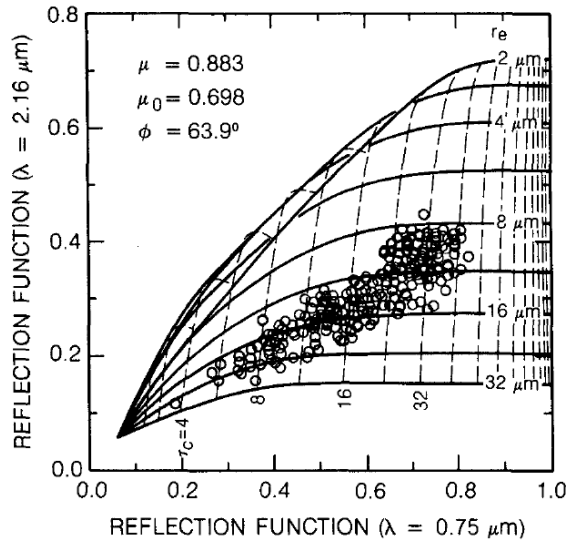


Figure 1: Theoretical relationships between the reflection function at 0.75 and 2.16 μm . for various values of optical thickness and effective radius.

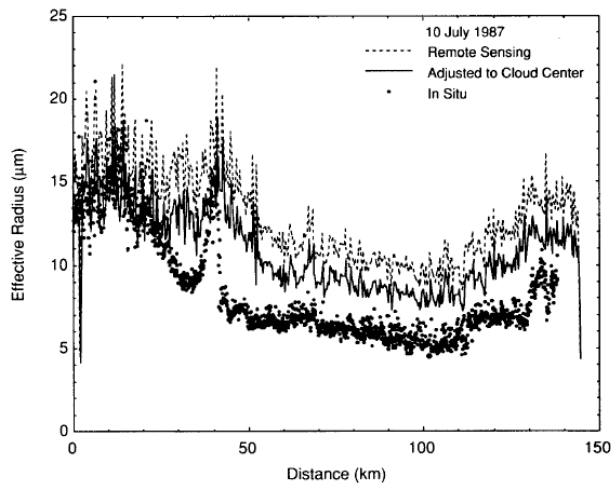


Figure 2: Comparison of the effective radius as a function of the distance.

References:

Nakajima, T. and M. King, 1990: Determination of the Optical Thickness and Effective Particle Radius of Clouds from Reflected Solar Radiation Measurements. Part I: Theory. *J. Atmos Sci.*, 42, 1878-1893

Nakajima, T., M. King, J., Spinhirne, L. Radke, 1991: Determination of the Optical Thickness and Effective Particle Radius of Clouds from Reflected Solar Radiation Measurements. Part II: Marine Stratocumulus Observations. *J. Atmos Sci.*, 728-750.