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Discussion

Comment on extinction measurements and single scattering albedo in the 0.5 to 1.05 μm range for a laboratory cloud of hexagonal ice crystals [Rimmer, J.S., Saunders, C.P.R., 1998, Atmos. Res. 49, 177–188.]

Neil J. Bacon [a,*], Stephen G. Warren [b]

[a] *Physics Department, University of Washington, Seattle, WA 98195, USA*
[b] *Atmospheric Sciences Department, University of Washington, Seattle, WA 98195, USA*

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The purpose of this note is to point out an error in the method by which Rimmer and Saunders (RS) deduced the wavelength-dependent single-scattering albedo of ice crystals from measurements of their extinction of light. The single-scattering albedo ω_0 is the ratio of scattering to extinction and, for particles large compared with the wavelength, ranges from 0.5 for highly absorbing particles to 1.0 for zero absorption—the minimum value represents the contribution to scattering by diffraction.

The method of RS attempts to exploit the reduction in apparent extinction brought about by forward scattering (due to diffraction) into the acceptance cone of the detector. The authors cite Hutt et al. (1992) (H) for their Eq. 2, which relates the apparent extinction σ_{m} (measured by the detector) to the true extinction σ, as:

$$\sigma_m = \sigma(1 - \omega_0 D), \quad (1)$$

where D is a factor that takes account of forward scattering. D is defined by H as 'the fraction of *scattered* light reaching the receiver' (emphasis added). In their analysis and evaluation of σ_{m} to infer ω_0, RS rely on a statement made by H that as the beam acceptance angle is increased until practically all of the diffracted light is gathered by the detector, D increases to an asymptotic value of 0.5 (see H, Fig. 8).

However, because of the way D was defined, this is true only if $\omega_0 \approx 1$. In the large-particle limit, diffraction accounts for half the *extinction*, which is the same as half

* Corresponding author. Tel.: +1-206-543-6223; fax: +1-206-543-0489; e-mail: neilb@u.washington.edu

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the scattering only if there is no absorption. The correct statement is that for large particles, the asymptotic value of 0.5 is obtained not by D but by $\omega_0 D$. If this is introduced into (1), the equation reads $\sigma_m = \sigma/2$, and there is obviously no information about ω_0 to be gained from a measurement of σ_m.

It stands to reason that, assuming the only contribution to the detector is from the diffraction part, there should be no dependence of the apparent extinction on absorption, i.e., on the single-scattering albedo. This point was in fact made by H (p. 5128) in reference to falling snow crystals: ''in the geometrical limit the fraction of the scattering coefficient associated with diffraction is equal to half the extinction coefficient, regardless of the albedo of snow at that wavelength. In other words, half of the light that is scattered and absorbed by the snow appears in the diffraction part...''

The values of ω_0 given by RS in their Figs. 5 and 6, as low as $\omega_0 = 0.6$ at a wavelength of 1.0 μm, are therefore spurious. For surface snow grains in the same size range as the ice particles studied by RS, ω_0 is in the range 0.97 to 0.999 at 1.0 μm [Wiscombe and Warren, 1980, Fig. 3]. To obtain values of ω_0 as low as those reported by RS would require strongly absorbing particles—something like the oily smoke of the 'nuclear winter' scenario, for which $\omega_0 = 0.64$ at visible wavelengths (National Research Council, 1985, Table 5.7).

As a separate point, we note that both H and RS assumed that the forward scattering into the detector was due solely to the diffraction part of the phase function. For ice crystals, this assumption is sometimes inaccurate. In the case of pristine plates, direct transmission at 0° is as much as 15% of the phase function in the visible, although much less in the near infrared [Fu, 1996].

References

Fu, Q., 1996. An accurate parameterization of the solar radiative properties of cirrus clouds for climate models. J. Climate 9, 2058–2082.

Hutt, D.L., Bissonette, L.R., St. Germain, D., Oman, J., 1992. Extinction of visible and infrared beams by falling snow. Appl. Opt. 31, 5121–5132.

National Research Council, 1985. The Effects on the Atmosphere of a Major Nuclear Exchange. National Academy Press, Washington, DC, 193 pp.

Rimmer, J.S., Saunders, C.P.R., 1998. Extinction measurements and single scattering albedo in the 0.5 to 1.05 μm range for a laboratory cloud of hexagonal ice crystals. Atmos. Res. 49, 177–188.

Wiscombe, W.J., Warren, S.G., 1980. A model for the spectral albedo of snow: I. Pure snow. J. Atmos. Sci. 37, 2712–2733.