ATMO 689

POLARIMETRIC RADAR METEOROLOGY

Homework #2

Due: 19 October 2004

1. The refractive index (m=n-*i*k) is a measure of the polarizability of matter and hence governs the response of an idealized hydrometeor to an incident radar wave. As a result, one must know the refractive index in order to calculate radar observables such as differential reflectivity for each hydrometeor type from Gans theory (e.g., Herzegh and Jameson, 1992). The real (n) and imaginary (k) components of the refractive index for both liquid water and solid ice are given below *. Due to riming and aggregation, some idealized ice hydrometeor types are mixtures of ice and air (e.g., graupel, snow). As a result, we must estimate the bulk density of an ice and air mixture. Debye (1929) showed that the quantity K/ρ is nearly constant for ice-air mixtures where K is the dielectric factor and ρ is the bulk density of the ice-air mixture. *Use Debye's approximation to calculate the refractive index (m) for each idealized ice hydrometeor with a given bulk density in Table 1 (i.e., finish Table 1 below).*

Table 1. Density and refractive index for idealized hydrometeor types.

Hydrometeor Type	**Density (g cm^{-3})**	**Real component of the refractive index (n)***	**Imaginary component of the refractive index (k)***
Rain	1.0	8.99	1.47
Solid ice (hail, frozen drop, ice crystal)	0.917	1.78	2.4×10^{-3}
Graupel	0.6		
Low Density Graupel	0.3		
Snow (or Aggregates)	0.12		
Low Density Snow	0.03		

* Assuming λ = 10 cm and T = 0° C (see Table 4.1 and 4.2 from Battan, 1973 from lecture notes)

2. As in Herzegh and Jameson (1992), calculate and plot the differential reflectivity (Z_{dr}, dB) as a function of axis ratio (a/b = minor/major) associated with the six idealized hydrometeor types using Gans theory for oblate spheroids as presented in lecture.

3. Assuming that the axis ratio (a/b) of a raindrop can be related to the equivalent spherical diameter of a raindrop (D_{eq}, cm) according to $a/b = 1.03 - 0.62{*}D_{eq}$ (Pruppacher and Beard 1970), plot Z_{dr} as a function of D_{eq}, assuming a reasonable range

of drop sizes. Using your results from question 2 and 3, list *typical* ranges of Z_{dr} for each hydrometeor type in Table 1, assuming typical ranges of a/b or D_{eq} from the cloud physics literature.

4. Atlas et al. (1953) showed that for randomly tumbling hydrometeors (e.g., hail), which are governed by Rayleigh-Gans scattering theory, the linear depolarization ratio (*ldr*) can be approximated by

$$ldr = \frac{1 - 2\sqrt{z_{dri}} + z_{dri}}{3 + 4\sqrt{z_{dri}} + 8z_{dri}} \qquad [1]$$

where intrinsic differential reflectivity $z_{dri} = z_{dr}$ for the same *non-tumbling* (or non-canting) oblate spheroid hydrometeor. Note that both variables in [1] have linear units. In other words, LDR(dB) = $10\log_{10}$(ldr) and Z_{dri}(dB) = $10\log_{10}$(zdri). It should be understood that the actual Z_{dr} for a randomly tumbling particle is zero. Using [1] and the results from question 2 above, calculate and plot LDR for randomly tumbling hail (i.e., solid ice) as a function of axis ratio (a/b). Assuming typical values of a/b for hail, list a typical range of LDR for hail from your plot.