P1.30 A TECHNIQUE FOR COMPUTING HYDROMETEOR EFFECITVE RADIUS IN BINS OF A GAMMA DISTRIBUTION

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1. INTRODUCTION

As part of the Geostationary Operational Environmental Satellite R (GOES-R) and National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (NPP) risk reduction activities at the Cooperative Institute for Research in the Atmosphere (CIRA), we have proposed to create synthetic imagery in advance of the launch of an instrument. To produce synthetic imagery in ice clouds, scattering of solar radiation in ice crystals has to be accounted for while computing brightness temperatures. Scattering and absorption properties of inhomogenous ice crystals can be computed using anomalous diffraction theory. Also geometric ray tracing methods can be used to compute the same optical properties. This paper discusses the results arising from using different computation methods as well as the impact of different averaging methods to account for crystal size distributions. For example, computing the effective radius within bins of a gamma distribution of particle sizes.

2. EFFECTIVE RADIUS IN BINS

The Regional Atmospheric Modeling System (RAMS) (Pielke et. al 1992) assumes a Gamma size distribution of hydrometeors (Meyes et. al 1997). Synthetic satellite imagery at 3.9 µm is being created from RAMS output as part of the GOES-R risk reduction activities. One consequence is the need for a representative particle size for the computation of brightness temperatures. We have noted an unexpected variation of brightness temperatures with optical properties. These optical properties were calculated using Modified Anomalous Diffraction Theory (MADT) (Mitchell 2000; Mitchell 2002). Optical properties have recently been parameterized based on light scattering calculations (ice tables) (Yang et. al 2000). In order to compare both methods, the effective radius of the entire distribution was needed. Further, the effective radius was computed within bins of the size distribution.

Computation of the effective radius requires knowledge of the ice water content and projected area of the entire distribution. As a result, the incomplete gamma function was used to compute ice water content and projected area within bins. That is, the incomplete gamma function was used to compute the ice water content and projected area from size zero to size d1. These values were then subtracted from new values based on the incomplete gamma function from size zero to size d2, where d2 is greater than d1. From this information, the effective radius in a bin can be computed from the ice water content and projected area within a bin. As an example, an ice cloud was specified to have mass mixing ratio of 1 g kg and a number concentration of 10^8 particles m^{-3}. The mean diameter for this homogeneous cloud was 11.8 µm while the effective radius was 8.0 µm; both values are for the whole distribution. The effective radius for the bins is shown below.

d1/dn	re(µm)	inc gamma	bin mass(g/kg)	sum mass(g/kg)
0.00	4.29	0.055	0.05514	0.0551
1.68	6.50	0.345	0.28945	0.3446
3.37	8.57	0.666	0.32180	0.6664
5.05	10.37	0.863	0.19614	0.8625
6.73	11.98	0.951	0.08837	0.9509
8.42	13.45	0.984	0.03325	0.9842
10.10	14.81	0.995	0.01110	0.9953
11.78	16.08	0.999	0.00340	0.9987
13.47	17.28	1.000	0.00098	0.9996
15.15	19.83	1.000	0.00009	1.0000

In this table, dn was the characteristic diameter and had the value of 5.9 µm. In particular, the effective radius of the distribution, 8.0 µm, was similar to the effective radius of the bin that contained the most mass, 0.32180 g kg^{-1}. This was the third bin that spanned d1/dn from 3.37 to 5.05. Repeating this procedure with different values of number concentrations revealed that the effective radius of the distribution was similar to the effective radius of the bin that contained the most mass. Currently, methods are being developed to combine the optical properties and, in particular, the phase function from all the bins into one set of bulk values. These values will then be used to compute brightness temperatures at 3.9 µm. As a consequence, 3.9 µm brightness temperatures were computed using the mean diameter of the distribution (MADT) and the effective radius of the distribution (ice tables).

3. COMPARISON OF 3.9 µm BRIGHTNESS TEMPERATURES

A homogeneous cloud layer was specified between 10 and 12 km. This cloud was composed of pristine ice crystals having a mass mixing ratio of 1 g kg^{-1}. Values of number concentration varied between 10 and 0.1 particles m^{-3} during a series of runs. The cloud was assumed to be over central Oklahoma on Julian day 185 and at 1900 UTC. Brightness temperatures using MADT used a fixed value of 0.87 for the asymmetry factor. This value was used to compute the phase function based on the Henyey-Geenstein formulation. For the second method, optical properties and the phase function were extracted from ice tables built from light scattering calculations. Brightness temperatures for both methods were calculated using the Spherical Harmonic Discrete Ordinate Method (SHDOM; Evans 1998). Figures 1-3 show the variation of 3.9 µm brightness temperatures with mean diameter, effective radius, and number concentration. Results indicate that brightness temperatures computed using MADT are consistently warmer than those computed using ice tables.

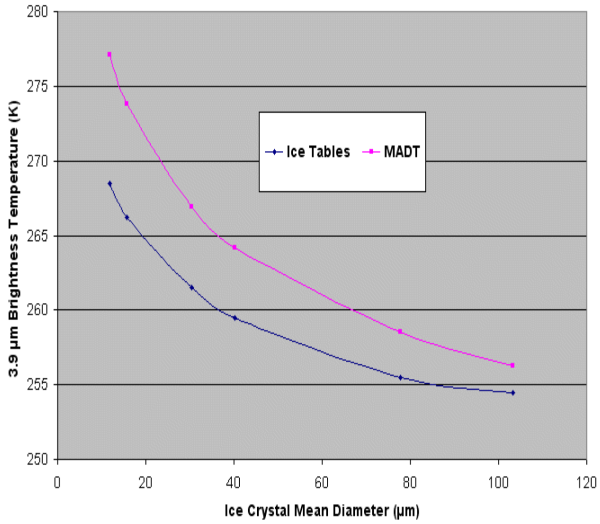

Figure 1: Brightness temperatures vs mean diameter.

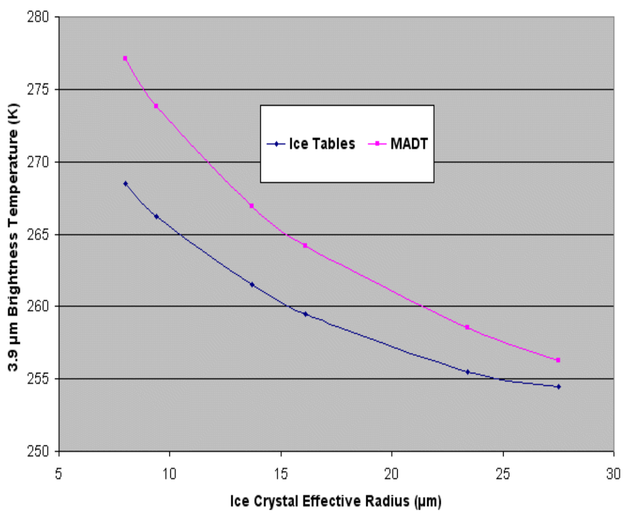

Figure 2: Brightness temperatures vs effective radius.

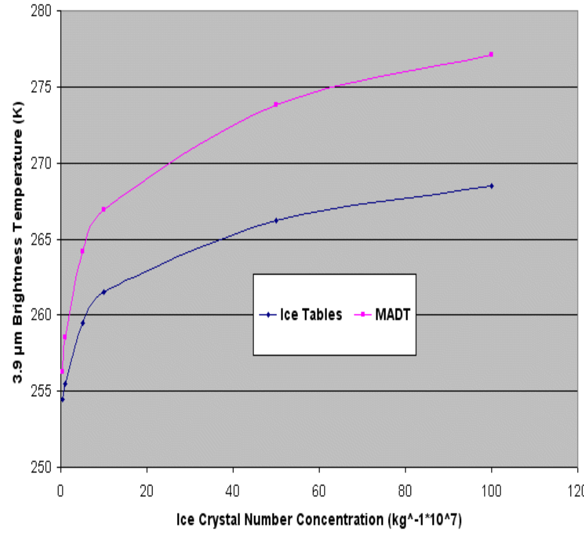

Figure 3: Brightness temperatures vs number concentration.

5. Future Plans

Further calculations will be done in order in quantify differences between radiance values using MADT and the ice tables. In addition, sensitivity tests will be conducted to examine the impact of varying the number of terms in the phase function.

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