Development of a CrIS Simulator for Clouds and Dust Aerosols

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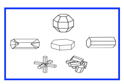
1. Objectives

The objective of this study is to develop a Cross-track Infrared Sounder (CrIS) radiance simulator for aerosols and clouds. We have also developed three sets of high spectral bulk scattering models of dust aerosols and ice and water clouds for CrIS. In this study, dust aerosol particles are assumed to be tri-axial ellipsoids and the single scattering properties of ellipsoidal dust-like aerosol is based on an existing database. The single scattering properties of individual ice crystals are based on the latest updated database of various nonspherical ice crystal habits, which include droxtals, hexagonal plates, hexagonal hollow columns and solid columns, three-dimensional bullet rosettes, and aggregates with both smooth surface and severely roughened surface. The single-scattering properties of water droplets are derived from the Lorenz–Mie theory. We use this model to study the different IR high spectral radiative properties of dust aerosols, water clouds and ice clouds for future algorithm developments of dust detection and cloud thermodynamic phase determination.

2. Ice cloud scattering properties

Ice crystals **Size distributions**

MODIS Collection 5



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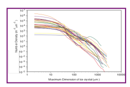
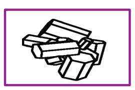


(Baum et al., 2005)

MODIS Collection 6



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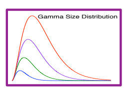
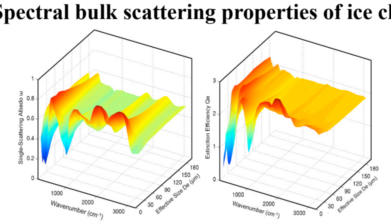
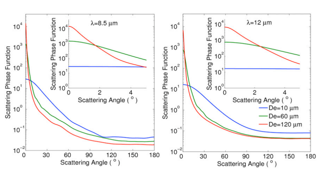


Gamma distribution

Spectral bulk scattering properties of ice cloud

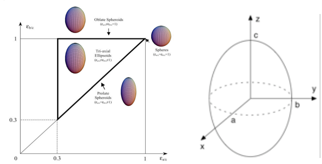




Scattering phase functions of ice clouds for various effective particle sizes at wavelengths of 8.5 (left) and 12.0 µm (right).

3. Optical scattering properties of tri-axial ellipsoidal mineral dust aerosols.

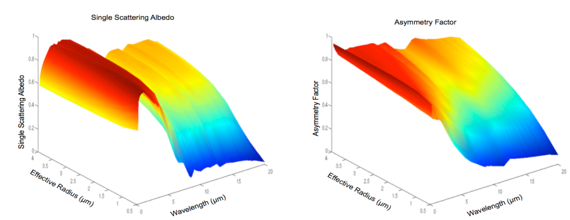
The single-scattering properties of dust particles are computed from a combination of the Lorenz–Mie theory, the ADDA method, the T-matrix method, and the IGOM method. The tri-axial ellipsoidal model was used to mimic the overall shapes of dust particles (*Meng et al., 2010*)



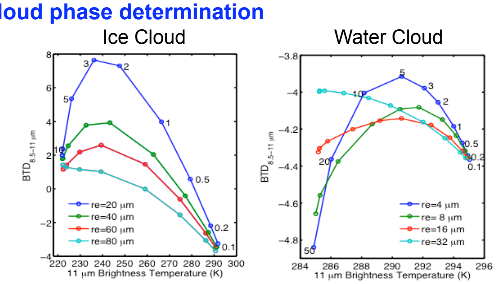
$$c \ge b \ge a$$
$$\varepsilon_{a/c} = a/c \qquad \varepsilon_{b/c} = b/c$$
$$0.3 \le \varepsilon_{a/c} \le \varepsilon_{b/c} \le 1$$

The morphology of ellipsoids in 2-D aspect-ratio space. The computation domain is the triangular area, including the three sides.

Spectral bulk scattering properties of dust aerosol

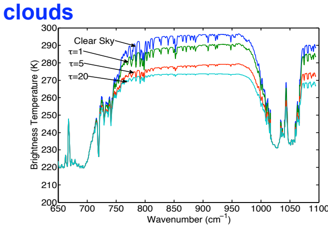


4. Cloud phase determination



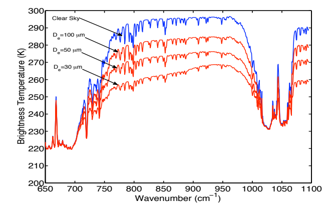
$BTD_{8.5-11}$ versus the 11 µm brightness temperature for ice cloud (left) and water cloud (right)

5. Infrared high spectral radiative properties of water clouds



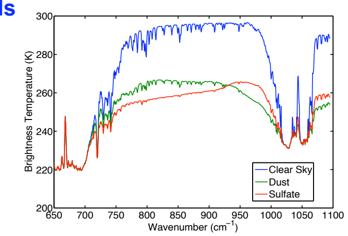
The CrIS band 1 brightness temperatures simulated using the LBLRTM+DISORT model for clear-sky and cloudy cases. The cloud optical thickness are assumed to be 1, 5, and 20. The effective particle sizes is 10 µm. The surface and cloud top temperatures are 300 and 288 K, respectively.

6. Infrared high spectral radiative properties of ice clouds



The ice cloud water path for ice cloud layers is assumed to be 0.01 kg/m² while the effective particle sizes are 30, 50, and 100 µm. The surface and cloud top temperatures are 300 and 232 K, respectively.

7.Infrared high spectral radiative properties of aerosols



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Reference:

[1] Baum, B. A., P. Yang, S. Nasiri, A. K. Heidinger, A. J. Heymsfield, and J. Li, 2007, Bulk Scattering Properties for the Remote Sensing of Ice Clouds. III: High resolution spectral models from 100 to 3250 cm-1 *J. Appl. Meteor. Clim.* 46, 423-434.

[2]Meng, Z., P. Yang, G. W. Kattawar, L. Bi, K. N. Liou, I. Laszlo, 2010: Single-scattering Properties of Nonspherical Mineral Dust Aerosols: A Database for Application to Radiative Transfer Calculations, *J. of Aerosol Science*, 41, 501-512.