Global statistics of microphysical properties of cloud-top ice crystals

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NASA grant # NNX14AJ28C

A11B-1880

Ice properties are important for radiation, cloud evolution, precipitation efficiencies, etc. Ice properties are known to vary with, e.g., temperature, humidity (see Fig. on left and below), and ice nucleation availability. Determining such relationships in the complex atmosphere remains elusive.

2. Optical properties of ice crystals

Optical thickness
Ice number
Mass
Area
Shape

Ice crystal shape characteristics mostly determine phase functions:
1. Aspect ratio of crystal components (meso-scale)
2. Surface roughness, distortion, impurities or cavities (micro-scale)
3. Habit (macro-scale)

We focus on micro- and meso-scales since they are far more important than the macro-scale (habit). Also "habit" is not quantifiable. Simple hexagonal plates and columns are used as proxies for complex ice.

3. Shape and asymmetry parameter retrieval approach

Aspect ratio and roughness of proxy hexagonal prisms are retrieved by matching multi-angle polarized reflectance at 0°, 15°, and 30° scattering angles with a model. The relation between polarization and aspect ratio and roughness can be seen on the right below.

The asymmetry parameter is uniquely determined by aspect ratio and roughness as seen below.

4. Data
- POLARIS-MODIS calibrated data at 46 km resolution for 2007
- MODIS collection 6: effective radius and optical thickness and height
- Conservative ice cloud filter: POLARIS-MODIS phase index = extra rainbow detection phase index

5. Definitions
- Aspect ratio is defined by the Length and Width of hexagonal prisms
- Effective radius is defined by the total Volume (mass/total ice density) and area.
- Ice crystal roughness is a optical proxy for any incoherent distortion of a smooth, radially symmetric ice crystal. Other, similar parameterizations obtain similar results.

6. Global distribution of average optical thickness (of ice clouds with t > 5)

High, cold clouds
Lower, warm clouds

7. Yearly averaged global distribution of cloud-top properties

Effective radius
Aspect ratio
Roughness

8. Seasonal variation of profiles (for ice clouds over ocean with t > 5)

High, cold clouds
Lower, warm clouds

9. General tendencies

Effective radius
Asymmetry parameter
Aspect ratio
Roughness

10. Implied % bias on MODIS C6 retrieved t and r from constant asymmetry parameter
MODIS collection 6 retrievals assume an ice model with an asymmetry parameter of 0.754 in the visible.

When the real asymmetry parameter is p. g., this assumption creates biases of (p - 0.754) x 100%, as seen below. Maps on the right show average biases.

11. Notes
- Most of the crystals are identified as plate-like.
- Roughness is often found to be its maximum value of 0.7.
- Results are filtered for acceptable RMS value for fit.
- Ocean surface is assumed for low optical depths.

References
van Diedenhoven et al. 1. Ant 2012.
4. JAS 2010.
5. Fridlind et al. 2010.
6. Fröhlich et al. 2015.