Global statistics of microphysical properties of cloud-top ice crystals

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1: Introduction
Ice properties are important for radiation, cloud evolution, precipitation efficiencies, etc. Ice properties are known to vary with, e.g., temperature, humidity (see Fig. 1 left and below), and ice nuclei availability. Determining such relationships in the complex atmosphere remains elusive.

2: Optical properties of ice crystals

- Ice number
- Shape scattering
- Phase function
- Ice thickness

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-scale since they are far more important than the macro-scale (habit). Also ‘habit’ is non-quantifiable. Simple hexagonal plates and columns are used as proxies for complex ice.

3: Shape and asymmetry parameter retrieval approach

Aspect ratios and roughness of proxy hexagonal prisms are retrieved by matching multi-angle polarised reflectance at 120-150° scattering angles with a model. The relation between polarisation and aspect ratio and roughness can be seen on the right.

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

4: Data
- POLARIS-MODIS calibrated data at 6.5 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 $a$ is defined by the Length and Width of hexagonal prisms
- Effective radius: defined by the total volume (mass/void ice density) and area
- Ice crystal roughness: is a optical proxy for any microscale distortion of a smooth, radiating ice crystal
- Other, similar parameterizations obtain similar results

6: Global distribution of average optical thickness (of ice clouds with e-r)

High, cold clouds
Low, warm clouds

7: Yearly-averaged global distribution of cloud-top properties

Effective radius
Aspect ratio
Roughness
Asymmetry parameter

8: Seasonal variation of profiles (for ice clouds over ocean with e-r)

9: General tendencies

- Effective radius
- Asymmetry parameter
- Aspect ratio
- Roughness

10: Impaired % bias on MODIS C6 retrieved $r$ and $a$ from constant asymmetry parameter

MODIS collection 6 retrieves an ice model with an asymmetry parameter of 0.754 in the visible.

When the real asymmetry parameter is e.g. this assumption creates biases of $(a-0.754) \times 100\%$, 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 minimum value of 0.7
- Results are filtered for acceptable RMS value for fit
- Ocean surface is assumed for low optical depths

References
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