Impact of Ice Crystal Roughness on Satellite Retrieved Cloud Properties

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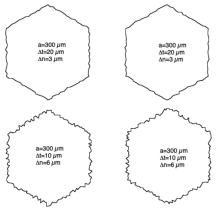
Current Cirrus Models Inadequate

Cirrus cloud optical depths τ (heights z_e) are often over (under) estimated when derived from solar reflectances. In situ data suggest smaller asymmetry factors, **g**, than used in most retrieval models. Multi-angle measurements point to smoother phase functions than for solid, smooth xtals.

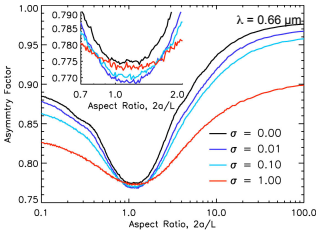
Calculations show that solid crystals with *roughened facets* or *embedded bubbles* --both observed in real cirrus particles-- yield smoother phase functions & smaller **g** values compared to smooth crystals.

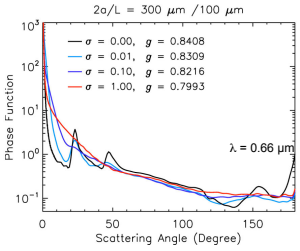
Rough models are tested in the Langley retrieval methods to improve the retrieved τ & z_e.



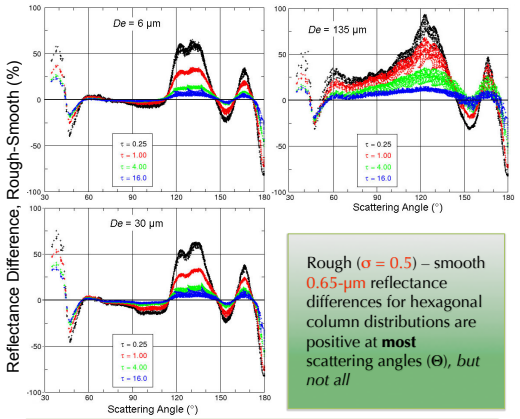
Roughness imposed on surface in terms of slope $\Delta n/\Delta t$ and its frequency of occurrence, defined by a Gaussian distribution[4]

Asymmetry factor depends on both aspect ratio & particle roughness:
σ is roughness factor[4]





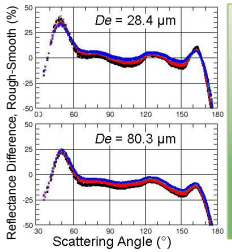
Increasing roughness factor yields increasingly smoother phase functions[4]



Rough (σ = 0.5) – smooth 0.65-μm reflectance differences for hexagonal column distributions are positive at **most** scattering angles (Θ), *but not all*

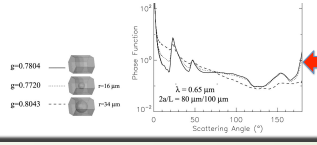
Testing Rough Crystal Models

- Develop reflectance lookup tables (LUTs) for the various size distributions of hexagonal ice column crystals used in the Langley algorithms[3] for σ = 0.5, 1.0
  - 0.65, 1.6, 2.1, 3.7, 3.9 μm
- Substitute rough crystal LUTs in the enhanced Visible Infrared Shortwave-infrared Split-window Technique (VISST) and apply to geostationary and polar-orbiting satellite data
- Compare retrieved cirrus optical depths and heights from rough crystal model retrievals to those based on smooth crystals and standard enhanced method



Rough (σ = 0.5) – smooth 3.75-μm reflectance differences for hexagonal column distributions are positive at **most** angles for very small xtals, but are mostly negative at most angles for *De > 40 μm*

Net effect: IWP varies little for smooth or rough models

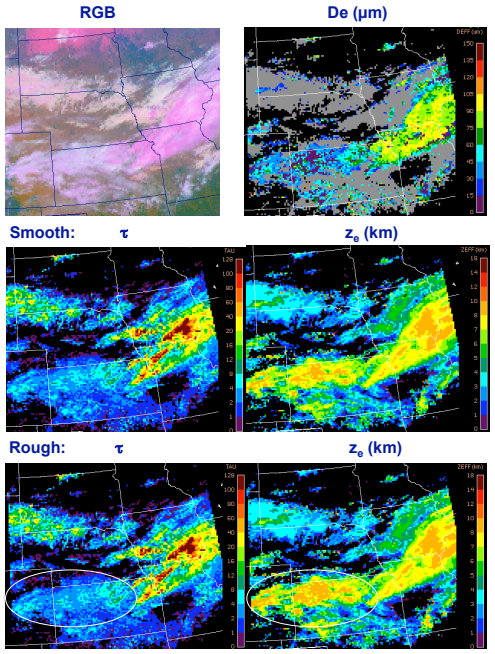


Bubbles in xtals also smooth the phase function[5]

Results

- Differences in GOES-11 cloud optical depths using smooth & rough (σ = 1) vary w/ hour (Θ)
  - below: 1745 UTC (Θ = 124°), $\tau_{rough} < \tau_{smooth}$
  - not shown: other hours, small changes up or down

GOES-11 retrievals, 18 Mar 2009, 1745 UTC



Future Work

- Compare results to ARM site retrievals
- Test models based on ice crystals with embedded bubbles[5]; smaller ***g***
- Implement method combining VISST & CO_2-slicing to retrieve best estimate of optical depth, De, and ***g***

References

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