Weak Correlation of Ice Cloud Water Content with Millimeter Radar Cross-section

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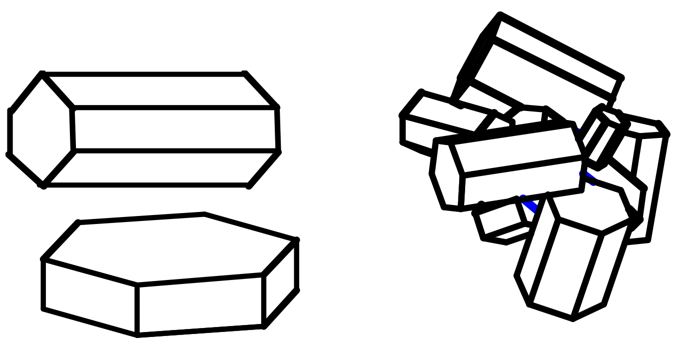
Introduction

The lack of information about particle shapes, orientations, and size distributions in ice clouds introduces uncertainty in the retrieval of IWC from cloud radar backscatter cross-section.

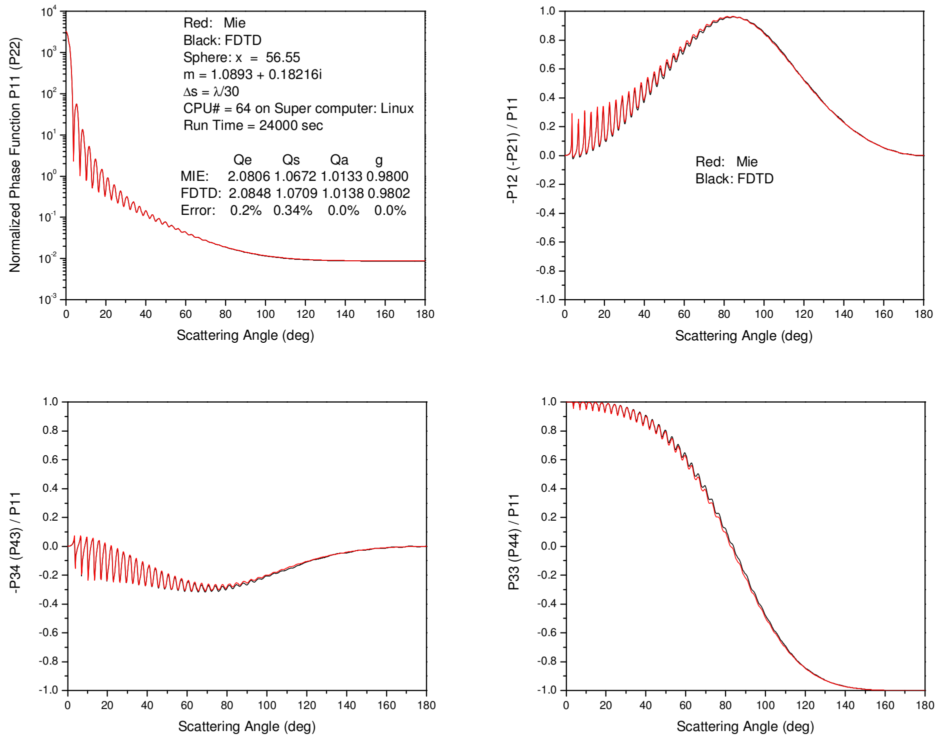
In this work, cloud radar cross-sections of various ice clouds are modeled to examine the relationship between the radar signal and the IWC.

The ice cloud particle sizes are from 30 *in-situ* measurements. The ice crystal shapes are assumed simply to be hexagonal columns, plates, and aggregates.

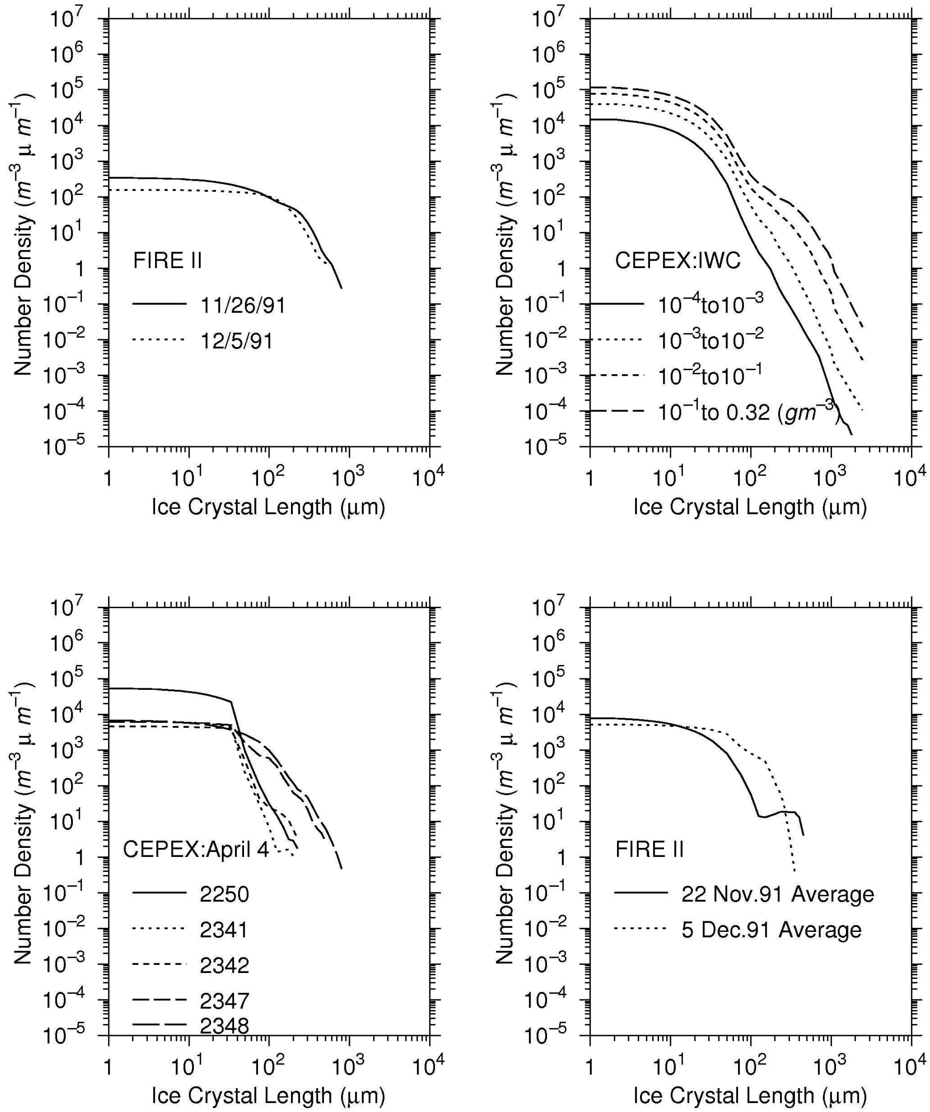
The backscattering cross-sections of the ice particles are calculated by the finite-difference time domain (FDTD) method.



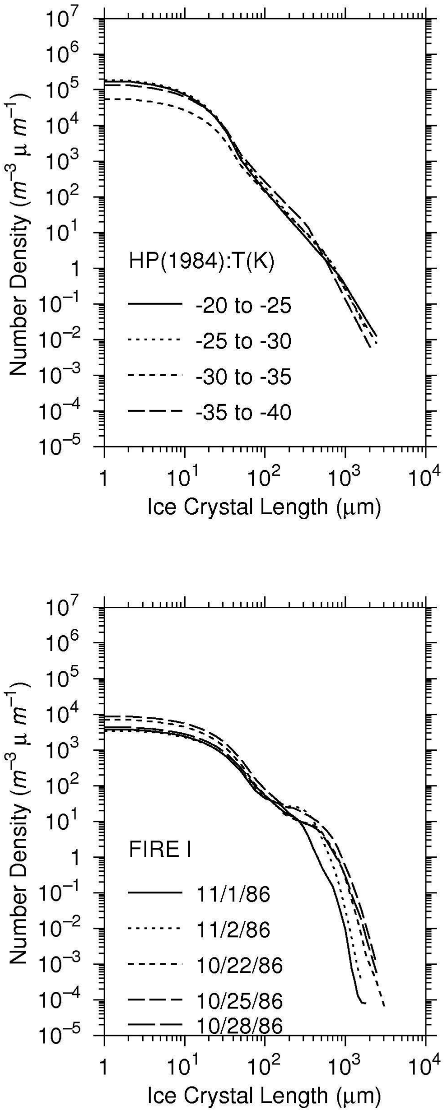
Highly accurate calculation for arbitrarily-shaped particles by the 3D UPML FDTD



Comparison of phase matrix elements from Mie theory and the FDTD for a sphere of size parameter of 56.55



Extrapolated cirrus cloud particle size distributions based on *in-situ* aircraft observations



Extrapolated cirrus cloud particle size distributions based on *in-situ* aircraft observations (continue)

Method

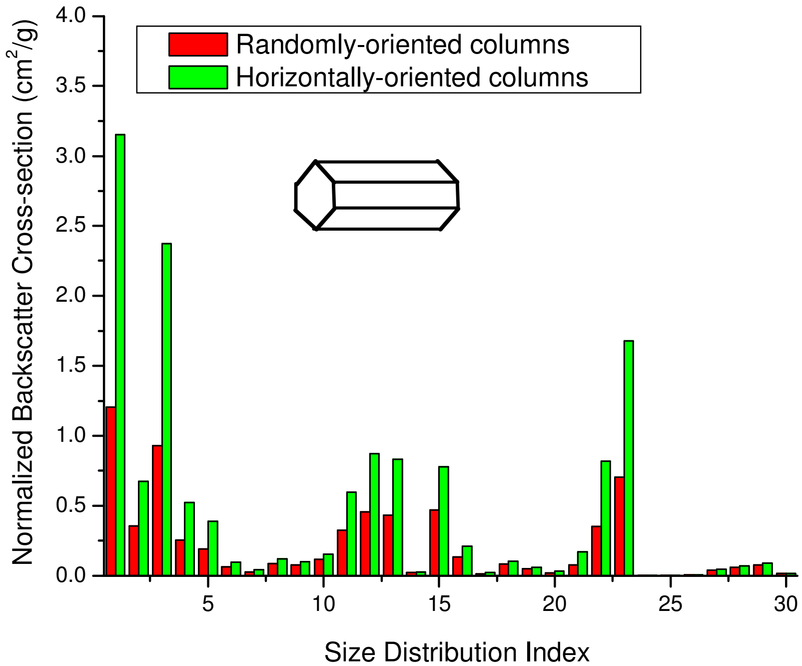
The backscattering cross-sections per unit volume of the cirrus cloud σ_b is calculated using

$$\sigma_b = \sum_{i=1}^{38} \sigma_{bi} n_i \Delta L_i,$$

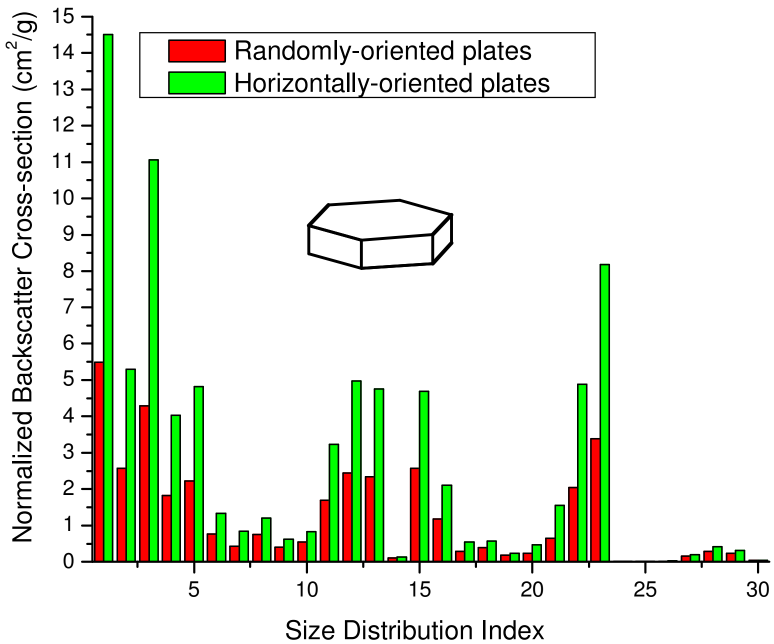
where σ_{bi} is the backscattering cross-section for particles in the *i-th* bin, n_i is the number density of ice cloud particles in the unit of m^{-3} μm^{-1}, and ΔL_i is the bin size in the unit of μm.

The backscattering cross-section normalized by the ice water content as σ_b/IWC, which is a quantity in a unit of cm^2/g showing the relationship of IWC with cloud radar measurements.

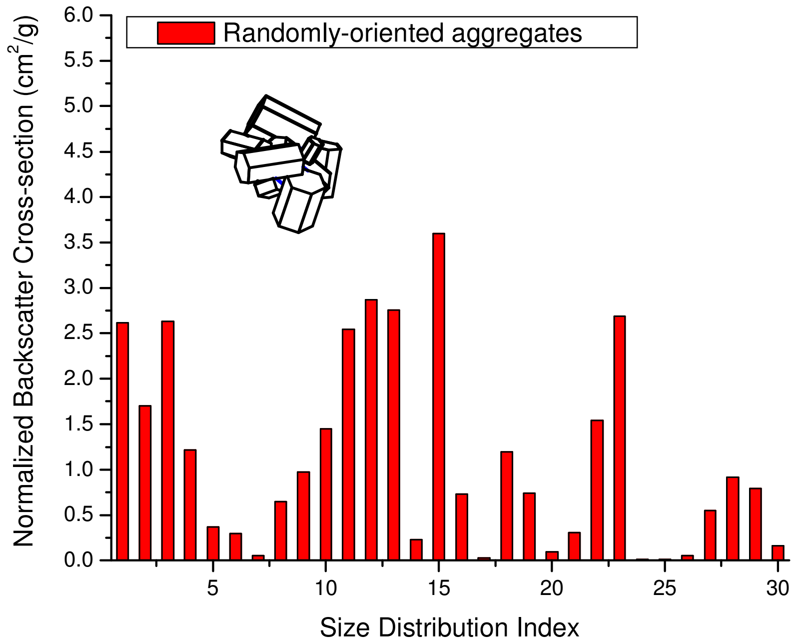
Result



Radar cross-sections per gram of ice water for clouds composed of column-like ice crystals with 30 size distributions and different orientations at 94 GHz.



Radar cross-sections per gram of ice water for clouds composed of plate-like ice crystals with 30 size distributions and different orientations at 94 GHz.



Radar cross-sections per gram of ice water for clouds composed of randomly-oriented ice crystal aggregates with 30 size distributions at 94 GHz.

Conclusion

For different particle shapes, orientations, and size distributions of ice clouds, same amount of cloud ice water causes very different radar backscattering, which indicates the associated uncertainty in IWC retrievals from cloud radar measurements.

The particle size distribution is obviously one of the most important factors for constraining the retrieval of IWC, which requires multi-wavelength measurements.

Particle shapes and orientations are also very important information for IWC retrieval.