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Lidar retrieval of optically thick stratocumulus

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Clouds play an important role in the Earth's radiation budget and hence climate; total optical depth and cloud base height in particular affect a cloud's radiative impact. Direct returns from lidar contain information on only the first 2 or 3 cloud optical depths before being rapidly attenuated; however, multiply scattered returns contain information from deeper within a cloud layer. We have previously shown that lidar with multiple-field-of-view receivers can be used to retrieve profiles of extinction coefficient and total optical depth to $\sim$35 optical depths, but even a single-field-of-view receiver (for example, CALIPSO) has the potential to give total optical depth in optically thick clouds. Combining information from multiply scattered returns with physically based prior information of a cloud's adiabatic properties near cloud base allows retrieval of cloud thickness in very optically thick clouds even where none of the multiply scattered photons are able to penetrate to cloud base.

We present a scheme, based on optimal estimation theory, to retrieve vertical cloud profiles and total optical depth in liquid stratocumulus from a single-field-of-view spaceborne lidar. The method employs a fast forward model of multiply scattered returns and adiabatic prior constraints. In regions not constrained by data, super-adiabatic profiles are prevented by constraining the gradient of liquid water content to be no steeper than an adiabatic cloud profile. Using data from CALIPSO we demonstrate that we are able to retrieve cloud properties to much greater optical depths than using the direct return alone. This forms the liquid part of a larger "unified" retrieval algorithm that is being developed and we present prospects to use this method as part of a synergistic retrieval scheme for EarthCARE.