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Multiple Scattering Lidar and Cloud Properties

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A multiple scattering lidar technique was developed for the remote sensing of cloud properties. The technique is based on the simultaneous detection of infrared (1.054 μm) lidar returns at three concentric fields of view. This configuration allows for the measurement of the multiple scattering contributions to the lidar radiation backscattered by the cloud droplets.

The multiple scattering contributions are not only functions of optical depth but also of particle size through the strong dependence of forward scattering on size parameter. A simplified model of the multiple scattering contributions is derived as a series expansion in terms of the field-of-view angle θ. The expressions depend on the scattering coefficient and the average cross-section radius of the particles at range R, and on path integrals of the same quantities. The measured data at the three instrument's fields of view are fitted to a second degree polynomial in θ at each lidar range. By equating the numerical values of the coefficients of the fitted polynomial to the theoretical expressions, we can solve simultaneously for the extinction coefficient and the average cross-section radius. The lidar operates at a wavelength of 1.054 μm. However, assuming a general parametric function for the particle size distribution, for example a Gamma function for cloud droplets, we can extrapolate the solutions to other wavelengths and calculate parameters of meteorological interest such as the cloud liquid water content.

The paper describes the solution method, and compares lidar-derived vertical profiles of the cloud liquid water content and extinction coefficients at 0.55 and 10.6 μm with *in situ* measurements performed from an aircraft or a cable car running up and down a mountain shrouded by clouds.

Sample comparison results are shown in Fig. 1. The *in situ* aircraft data were calculated from the droplet size distributions measured at 15 particle size intervals between 2 and 40 μm in diameter by a wing-mounted PMS FSSP-100 probe. The aircraft measurements were made at a distance ranging from 1.4 to 2.9 km from the lidar site. The aircraft did not fly closer to the lidar because of eyesafety regulations and, for the case shown, it started its descent from a point within the cloud. The cloud cover was relatively homogeneous at the time of the measurements of Fig. 1. The lidar profiles are averages of the solutions calculated from the consecutive individual returns recorded during the 5-min period centered on the aircraft flight through the cloud. The agreement between the *in situ* and lidar data is very good. More results obtained in this and in another experiment will be presented. Both the scattering coefficient and the particle size solutions were necessary to calculate the results of Fig. 1. Hence, the multiple scattering inversion method gives more information than the conventional method, does not require a boundary value nor a backscatter-to-extinction relation, and gives good accuracy.

Acknowledgments

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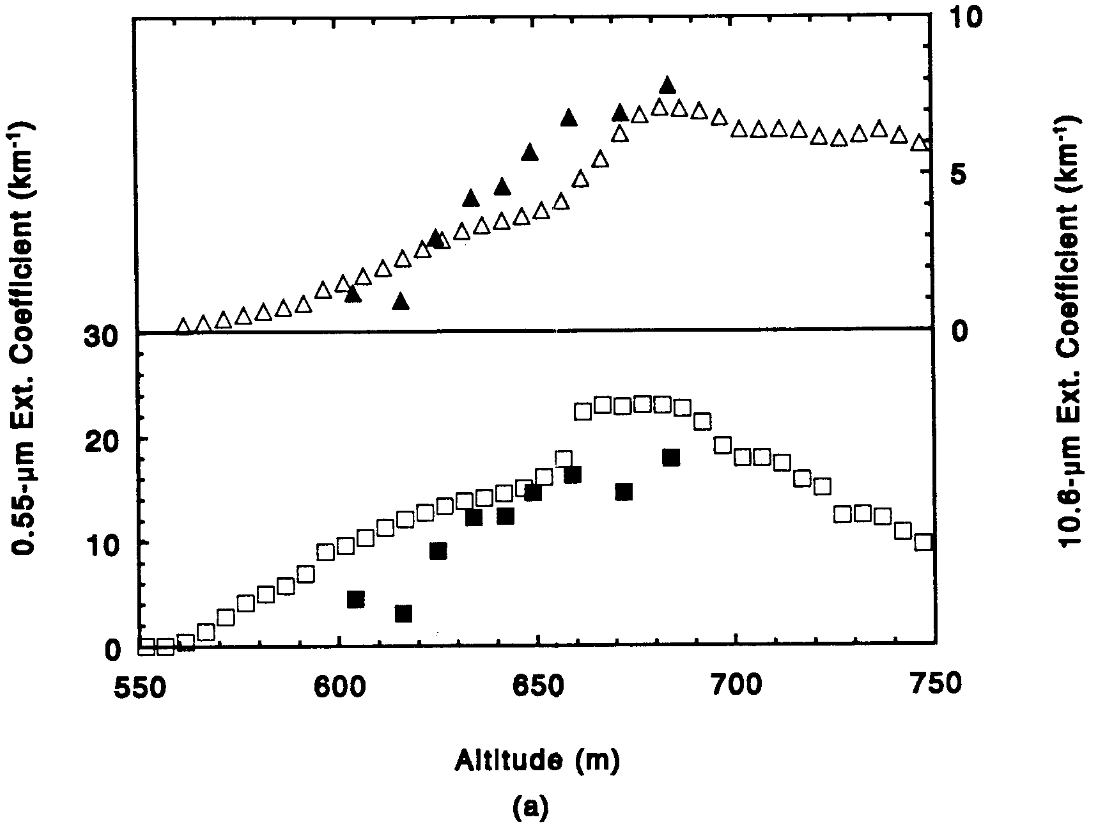

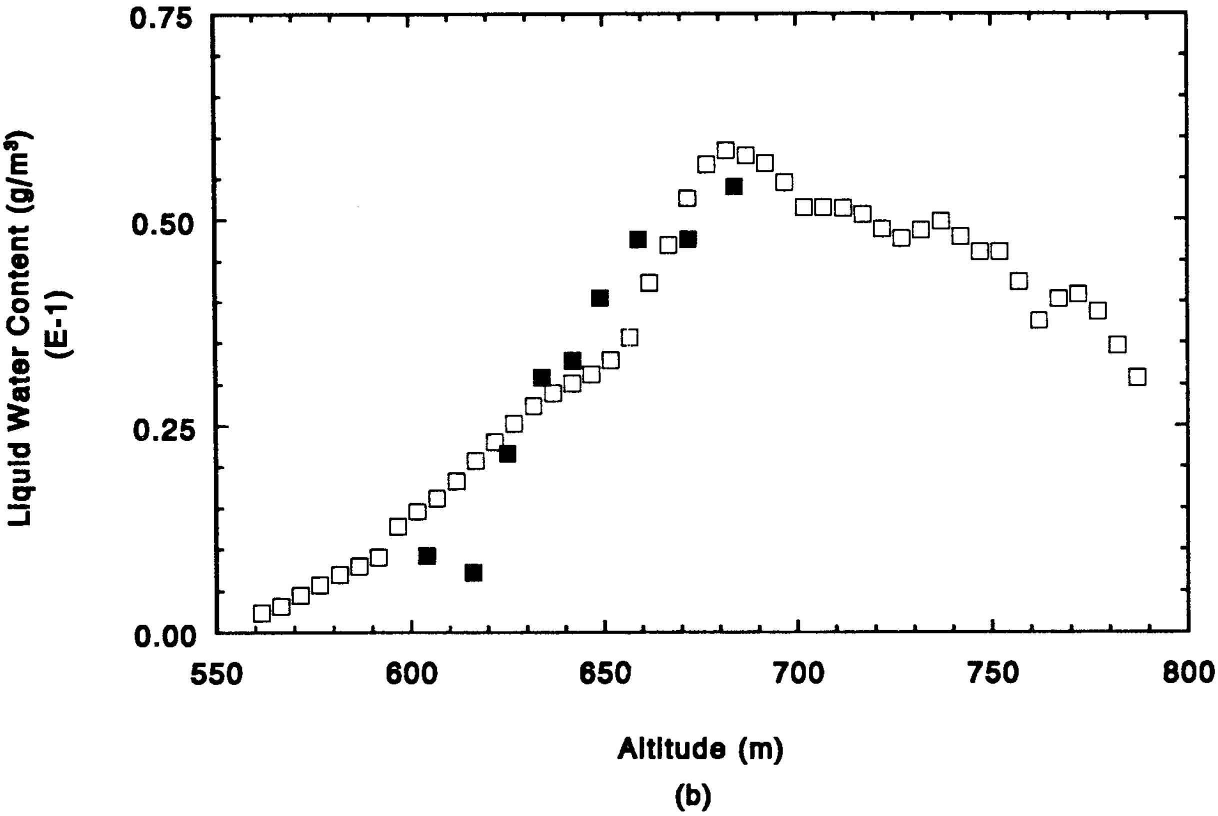

Figure 1: Comparison of lidar and aircraft profiles of a cloud layer for a) the extinction coefficients at 0.55 and 10.6 μm and b) the liquid water content. Solid symbols: aircraft data; Open symbols: lidar data.