INVERSION OF TWO WAVELENGTH LIDAR DATA FOR CLOUD PROPERTIES

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The inversion of the lidar equation to derive quantitative properties of the atmosphere has continued to present considerable difficulty. Even when the lidar system parameters are known, one is still confronted with a single equation having two unknowns; namely the attentuation coefficient σ (m^{-1}) and the backscatter coefficient β (m^{-1} sr^{-1}). To perform the inversion it is necessary to have additional information. Even for non-absorbing scattering media where the volume scattering coefficient σ_s equals σ one would have to know a priori the backscatter phase function $P_\pi/4\pi$ since $\beta = \sigma_s (P_\pi/4\pi)$. Lacking this information the solution can be obtained by assuming a relationship between β and σ. The relation, $\beta = c\,\sigma^k$, (1) where c and k are constants, has been widely used.

With this approach the inversion of the lidar equation has been carried out in a variety of ways of which the backward inversion[1,2] provides a more stable solution. This method recently brought to the forefront by Klett has been widely discussed in the literature and extensions related to the contribution due to molecular scattering and the spatial dependence of the parameters have been undertaken with some success[3,4]. Klett's procedure is found to give better results for media with medium to high σ. For media with very low σ and very high σ with considerable multiple scattering, such as in clouds, the accuracy of this procedure is more in doubt. However, very few quantitative experimental evaluations of this inversion procedure have appeared in the literature.

In this paper we wish to report on the results of a study in which we have utilized Klett's procedure for analysis of cloud backscatter measurements made simultaneously at two ruby lidar wavelengths (694 nm, 347 nm). With one lidar system a cloud is probed at the two wavelengths and the backscatter measured simultaneously by separate receivers. As a result we can obtain two σ profiles which should differ only because of the wavelength dependence of the scattering.

The two wavelength measurements can provide better insight into the applicability of the inversion procedure. We have observed that the values of σ of the clouds (to be used is the initial input into the inversion at the two wavelengths) differ considerably for most clouds with the shorter wavelength having larger σ. The match between the inverted σ profiles at the two wavelengths is better in the lower parts of the profiles while the divergence between them with pulse penetration is a real feature unresolved by the inversion technique.

This divergence, however, may be attributable to the differential multiple scattering at two wavelengths which is not taken into account in the inversion procedure.

Since the beam replenishment in multiple scattering builds up with pulse penetration depth, this causes the effective cloud σ to be reduced from the initial single-scattering value. In the relationship (1) between σ and β the above effect can be included by increasing the value of k used in the inversion. The σ profile inversions with different k values have been investigated in our analysis.

Another limitation of the inversion method has been observed. For a significant number of clouds the backscatter profiles at the two wavelengths had significantly different range dependence and as a result the inverted σ profiles were very different. Changes in the boundary values of σ or in k values used in the inversion were not able to provide a satisfactory match between the two σ profiles. Such behaviour would indicate that the size distributions in the clouds were significantly varying in space and as a result the application of the inversion procedure was inaccurate.

Experimental data will be presented to demonstrate the effects and the implications on the applications of the inversion method will be discussed.

References:

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