# Multiple Scattering Effects on detecting multi-layered clouds with space-borne Lidar

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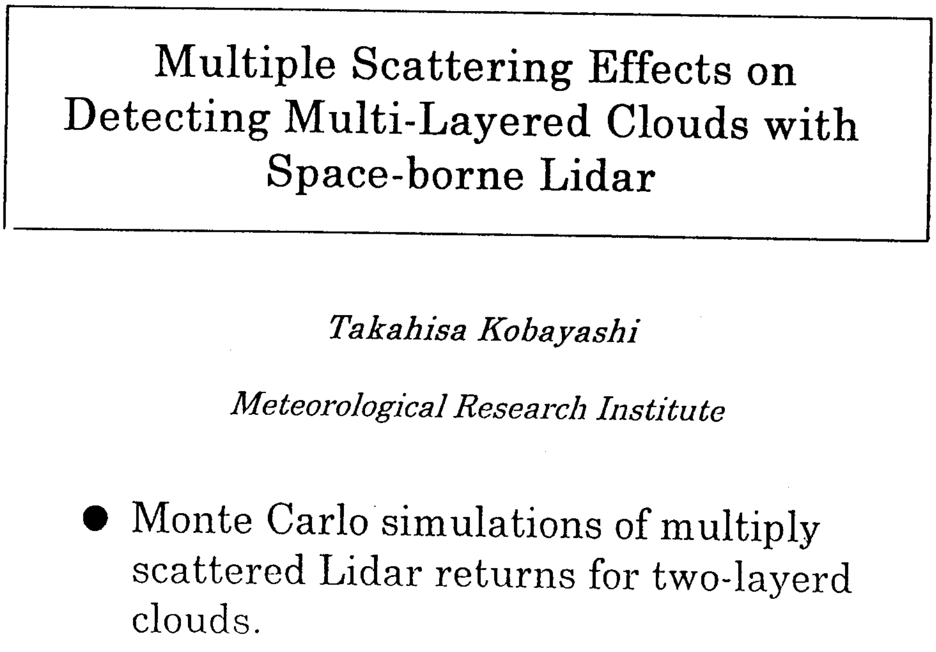
One of the important issues in establishing the cloud/radiation interaction is the clarification of cloud overlap in the vertical. Passive radiometers equipped on satellite are effective tools for measuring cloud optical thickness. However, the measurements of vertical structure of multi-layered clouds are very imited. Current lack of a reliable technique to derive overlap statistics leads to uncertainties in climate research. In GCM study, somewhat artificial overlap assumptions, like random, minimum or maximum overlap, have been used for the overlap statistics of partially cloudy layers. The GCM results suggest that the Earth's radiation budget are strongly modified by the choice of these assumptions.

A space-borne lidar is useful for the detection of multi-layered cloud system in which relatively thin upper clouds are involved. In this paper, we discuss the multiple scattering effects on the lidar measurements of multi-layered clouds system by using a Monte Carlo model. A Monte Carlo model, which directly simulates the trace of photons, has been developed for multiply scattered lidar signals. The results show that a space-borne lidar has a considerable potential for detecting lower cloud. Even for relatively thick clouds in upper layer, thicker clouds in lower layer can be detectable associated with significant multiple-scattering contributions from lower clouds.



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- Monte Carlo simulations of multiply scattered Lidar returns for two-layerd clouds.

Fig.1

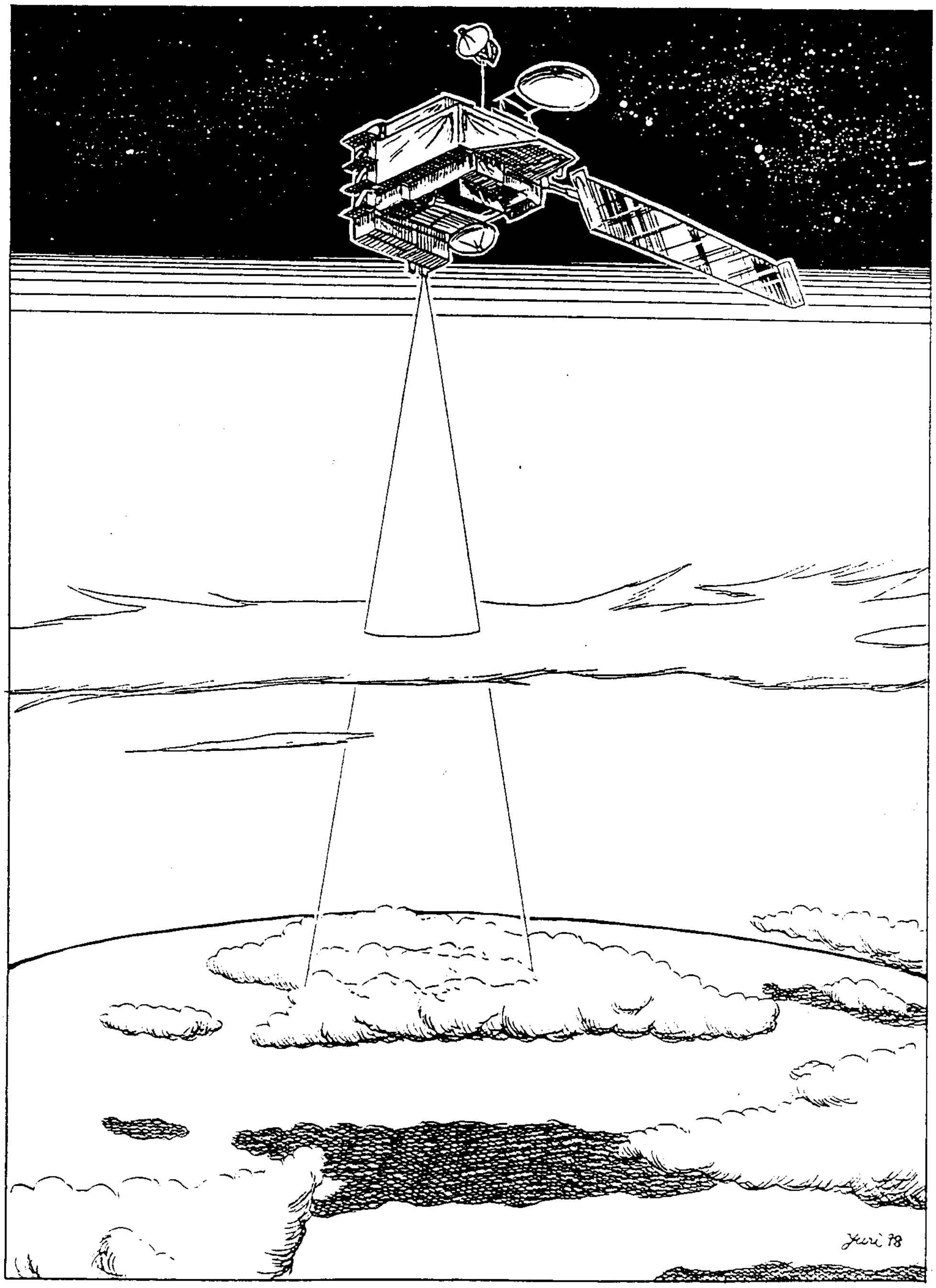

Fig.2 Schematic figure of space-borne lidar measurements of multi-layered clouds.

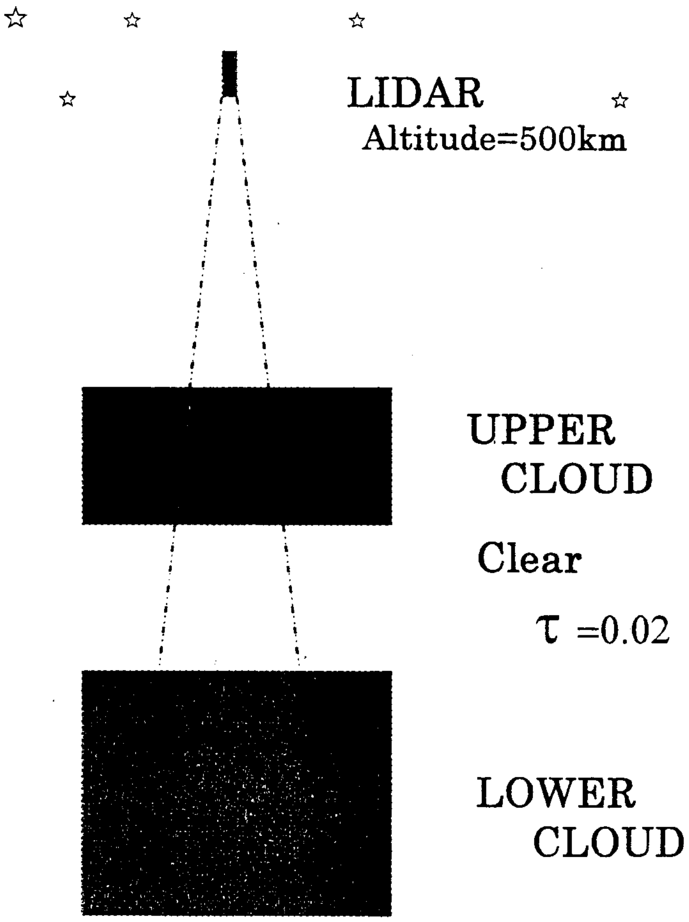

Fig.3 Two-layered cloud model used in the present study.

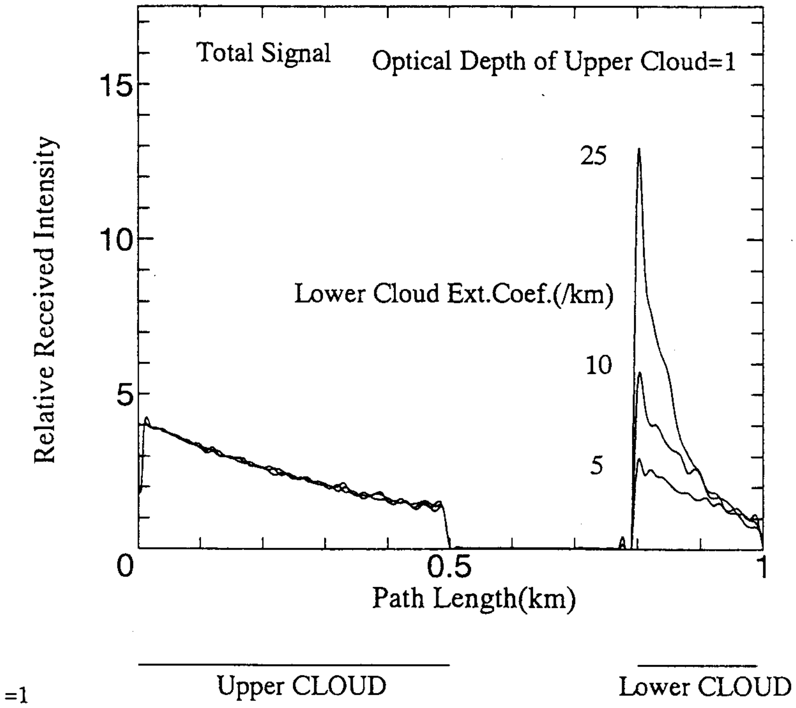

Fig.4 The relative lidar returns from the two-layered cloud model. The optical thickness of upper cloud is one and the extinction coefficients of lower cloud are 5, 10, and 25 (/km).The discontinuities at a length of 0.5km and 0.8 km indicate the upper-cloud base and lower-cloud top, respectively.

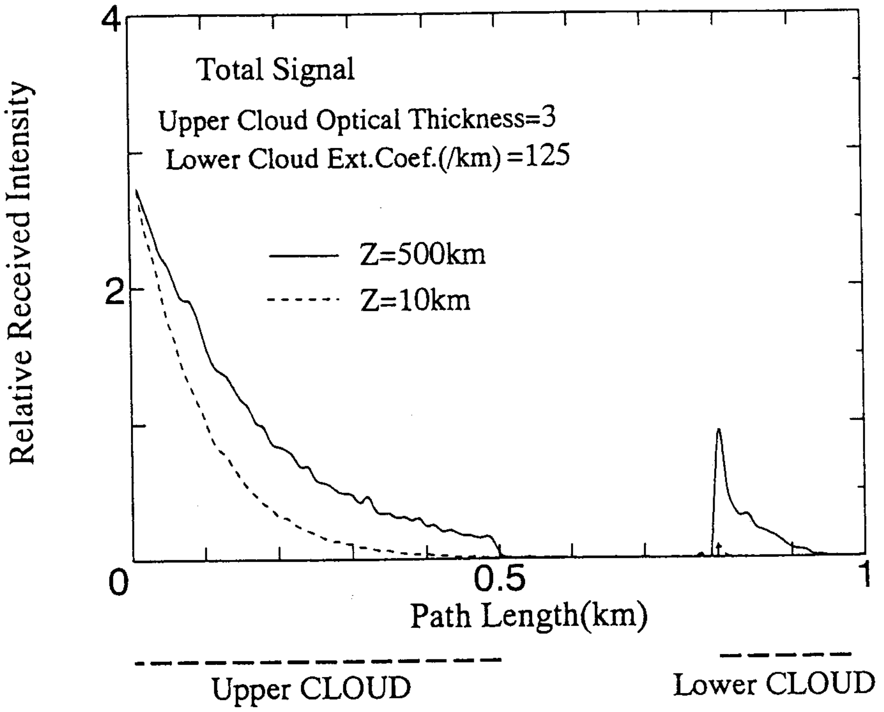

Fig.5 Same as in Fig.4 except for optical thickness of upper cloud is three and extinction coefficients of lower cloud are 25, 50, and 125 (/km).

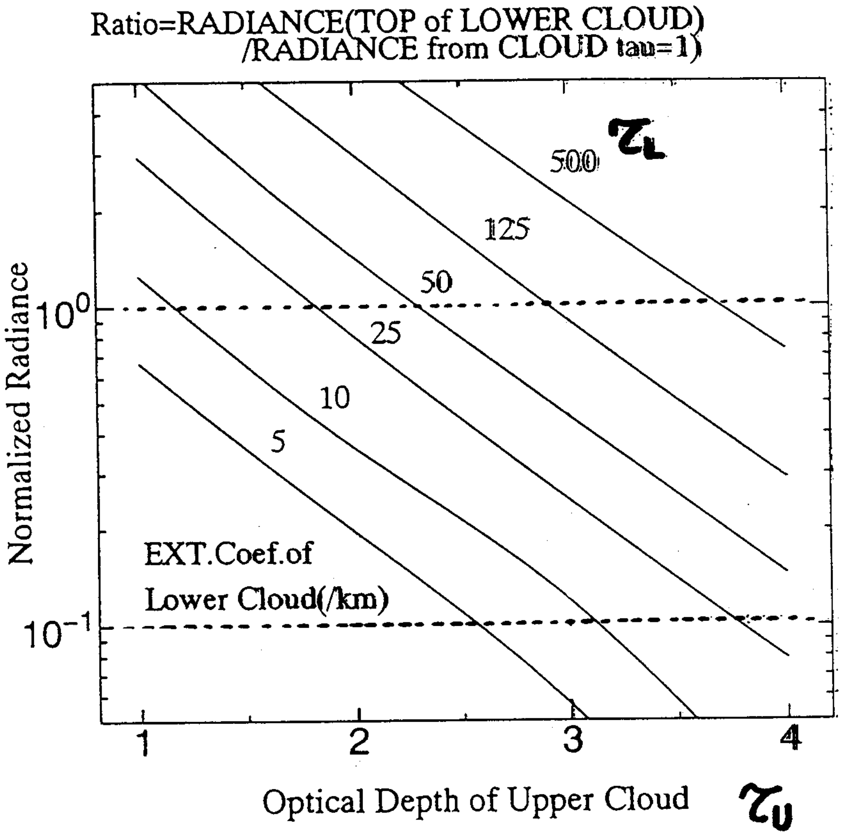

Fig.6 Ratios of lidar returns from the two-layered cloud models to those from a single-layered cloud of optical thickness one. Ratios of various values of the extinction coefficients of lower clouds are plotted as a function of the upper-cloud optical thickness.