

# DETERMINATION OF CERTAIN CLOUD PARAMETERS BY LASER LOCATOR

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**Abstract**

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*GEOPHYSICS*

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## DETERMINATION OF CERTAIN CLOUD PARAMETERS BY LASER LOCATOR

*(Presented by Academician E. K. Fedorov, March 30, 1970)*

In the propagation of laser radiation in a cloud medium, backscattering serves as a method for studying the fine structure of a cloud.

Let us divide the path of propagation of the laser beam inside the cloud ( $z \geq z_0$ ) into identical, sufficiently small segments  $\Delta z = z_i - z_{i-1}$ , in each of which the scattering coefficient  $\sigma(z)$  may be regarded as constant. Let us renumber these segments in the sequence of increasing integers, beginning with one. We shall assign the value of the scattering coefficient inside the  $i$ -th segment to the point  $z_i$  and denote it by  $\sigma(z_i)$ .

Then, under the assumption that pure single scattering exists, one can obtain the expression

$$\sigma(z_i) = \frac{2P(z_i)z_{i-1}^2 \exp \left[ 2\sigma_0(z_0 - \Delta z) + 2\Delta z \sum_{j=0}^{i-1} \sigma(z_j) \right]}{P_0 S c \tau K Q}, \quad (1)$$

where  $P_0$  is the emitted power,  $P(z_i)$  is the power received from the  $i$ -th segment of the cloud,  $z_{i-1}$  is the distance to the  $i$ -th segment,  $z_0$  is the distance to the cloud,  $\sigma_0$  is the attenuation coefficient along the path to the cloud ( $z \leq z_0$ ), assumed constant,  $S$  is the area of the receiving antenna,  $\tau$  is the duration of the pulse emitted by the laser,  $K$  is the transmission coefficient of the receiving-transmitting optics, and  $Q = 0.1/2.26\pi$  is the modulus of the backscattering vector of the phase function, normalized to unity and adopted for clouds according to (1).

One of the practically important questions in the use of laser locators for studying clouds consists in extending the method in such a way that the effect of multiple scattering could be included in the data-processing system in the simplest possible manner.

Let us note that if sounding of a cloud is carried out along an inclined path, then the relation of the height  $H_{i-1}$  to the coordinate along the beam  $z_{i-1}$  is given by the expression  $H_{i-1} = [z_0 + (i-1)\Delta z] \sin \vartheta$ , where  $\vartheta$  is the angle of

Fig. 1

Figure 1: Fig. 1

elevation of the beam above the horizon. Then, instead of segments, one may speak of horizontal layers  $\Delta H = \Delta z \sin \vartheta$ .

Having determined the profile of the scattering coefficient  $\sigma(z)$ , one can calculate the distributions of liquid water content  $q(z)$  and of the concentration of mean droplets  $N(z)$  in the cloud, if the function of the size distribution of cloud droplets is specified. For the frequently used gamma distribution <sup>(2)</sup> and for the ratio of the optical cross section to the geometrical one, equal to two, the calculations lead to the formulas

$$q(z) = \frac{2\sigma(z_i)(\mu + 3)a\rho}{3(\mu + 1)}, \quad (2)$$

$$N(z) = \frac{\sigma(z_i)(\mu + 1)}{2\pi(\mu + 2)a^2}, \quad (3)$$

where  $\rho$  is the density of water,  $a$  is the mean droplet size, and  $\mu$  is the parameter of the gamma distribution of droplets by size.

When using a laser locator with characteristics  $P_0 - 2$  MW,

$\tau = 30$  nsec,  $\lambda = 6943$  Å,  $2r = \sqrt{S/\pi} = 10$  cm, the distributions indicated above were determined.

For clouds of low optical density, the upper and lower boundaries and the profile of the scattering coefficient were measured. At high optical density, the lower boundary and the profile of the scattering coefficient in the subcloud layer and inward to 100-250 m were determined. Under the assumption that  $a = 5$  μm and  $\mu = 2$ , the liquid-water content and the concentration of mean droplets were calculated.

As an illustration, Fig. 1 shows an oscillogram of the backscattered signal from a cumulus humilis cloud (*Cu hum*) and the scattering coefficient  $\sigma(z)$  and liquid-water content  $q(z)$  calculated by the method described above. The cloud was sounded at an angle  $\vartheta = 30^\circ$  ( $H = 0.5z$ ). The attenuation coefficient along the path to the cloud, assumed constant, was determined from the scattering oscillogram in the near zone and proved to be  $\sigma_0 = 3.6 \cdot 10^{-5} \text{ m}^{-1}$ .

### Fig. 1

Fig. 2 shows an oscillogram of scattering from a stratocumulus cloud (*Sc*) and the calculated scattering coefficient and liquid-water content.  $\sigma_0$  has the same value as in the first case. At a depth of about 250 m, the "scattering coefficient" begins to increase sharply because of the effect of multiple scattering

Fig. 2

Figure 2: Fig. 2

(an optically dense medium), and its calculation by formula (1) loses meaning (the dashed curve in Fig. 2). In both cases the profile  $\sigma(z)$  correlates well with the shape of the received signal.

**Fig. 2**

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