Optical Depth Measurements of Clouds Using a Mie Scattering LIDAR System

Nofel D. Lagrosas, John L. Holdsworth, and Jose R. T. Villarin, S.J.
Department of Physics, Ateneo de Manila University, Quezon City, Philippines
E-mail: nofel@zuma.ps.admu.edu.ph; jholds@pusit.admu.edu.ph; jett@pusit.admu.edu.ph

Susana V. Dorado
Notre Dame of Marbel University, Koronadal, South Cotabato, Philippines
E-mail: susana@ndmu.edu.ph

INTRODUCTION

The optical properties of clouds are important factors in studying the global radiation balance. In particular, the optical depth distribution of clouds, which may be derived from the extinction coefficient, is useful in modeling the radiation distribution in the atmosphere (Pal et al., 1992). In the western Pacific tropics, little is known of the optical properties, including optical depth, of clouds despite this region being an extremely active and important one for global moisture transport (Dorado et al, 1998).

This paper presents the calculated optical depths of observed clouds at the Ateneo de Manila University, 14.64N, 121.07E, Manila, Philippines from LIDAR backscattered signals.

LIDAR, an acronym for Light Detection And Ranging, is the optical analogue of radar and is used in the field of atmospheric physics primarily for the study of clouds, volcanic particles, aerosols and dust.

METHODOLOGY

The LIDAR System

In the local setting, the Nd:YAG laser based Mie scattering LIDAR system is currently used for atmospheric research at the Manila Observatory. The LIDAR system used for this work is a fixed, vertically pointing system (Alarcon et al., 1996). The laser wavelength transmitted is the 532 nm green second harmonic of the Q-switched Nd-YAG laser. The linearly-polarized 120mJ nominal 5ns output pulse is expanded spatially 3 times, so that a well collimated beam at a pulse repetition frequency of 20Hz is obtained (Dorado et al, 1998). The backscattered signal is collected and focused by a 28-cm diameter Schmidt-Cassegraine telescope onto a photomultiplier tube (PMT) through a collimating lens and a 1nm bandpass filter. The analog voltage output of the PMT is digitized and averaged by the digitizing storage oscilloscope and stored in a computer via a LABView acquisition software suite.

The Algorithm

Software has been written to process the raw data in two stages where the second stage provides the optical parameters mentioned above. The equation of Klett (1981) is used to obtain the extinction coefficient. It has the form:

$$\alpha(r) = \frac{P(r)r^2}{\dfrac{P(r_m)r_m^2}{\alpha(r_m)} + 2\int_r^{r_m} P'(r')r'^2\,dr'}$$

where $P(r)$ is the backscattered signal; r is the altitude; r_m is the height at which the boundary value $\alpha(r_m)$ is applied. The said boundary value is calculated using the procedure presented by Klett (1986). Briefly, the procedure assumes that the extinction coefficient is constant over 0 to r_m and the average extinction over 0 to r_m is the same as that over r_o to r_m. The height r_o is the point of transmitter and receiver beam overlap in the case of clouds; where the visibility is low, the boundary value is computed using the iteration of the equation:

$$\Omega_m = \ln(1 + I\Omega_m)$$

where

$$\Omega_m = 2\,\alpha(r_m)[r_m - r_o]$$

and

$$I = (r_m - r_o)^{-1} \int_{r_o}^{r_m} \exp[\,S(r) - S(r_m)]dr$$

Here, S(r) is the range squared corrected LIDAR signal. If the iteration does not give $\alpha(r_m)$, the "default" equation is used that has the form

$$\Omega_m = (r_m - r_o)/r_o I.$$

From the said coefficient, the optical depth is calculated from the equation

$$\tau = \int_{r_1}^{r_2} \alpha(r)dr$$

The choice of the points r_1 and r_2 is based on the LIDAR signal. The point r_1 is the height wherein the signal coming from the clouds start to rise. The point r_2 is the location wherein the signal is already decreasing and has a value comparable with r_1.

RESULTS, DISCUSSION, AND CONCLUSIONS

The optical depths of clouds for dry months (March, April, and May) were computed for the years 1997 to 2000. Similarly, the said optical parameters were also processed for wet months (August, September, and October) for the years 1997 to 1999. Fig. 1a and 1b show the average optical depth profiles of clouds observed during regular morning data acquisition.

The results show that there is a significant decrease of cloud optical depth from the year 1997 to 1998 and a corresponding increase from the year 1998 to 2000. This may be the due to the fact that the El Niño phenomenon started in 1998 causing a decrease in rainfall rates all over the country. A more pronounced monthly difference of cloud optical depths between 1997 and 1998 is shown in Fig. 2. Clouds are found at a higher altitude during dry months, compared to wet months (Fig. 3).

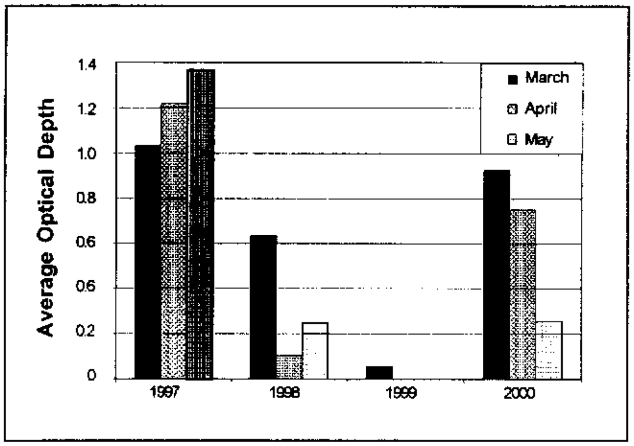

Fig. 1a. Average optical depths of clouds measured during the months of March, April, and May

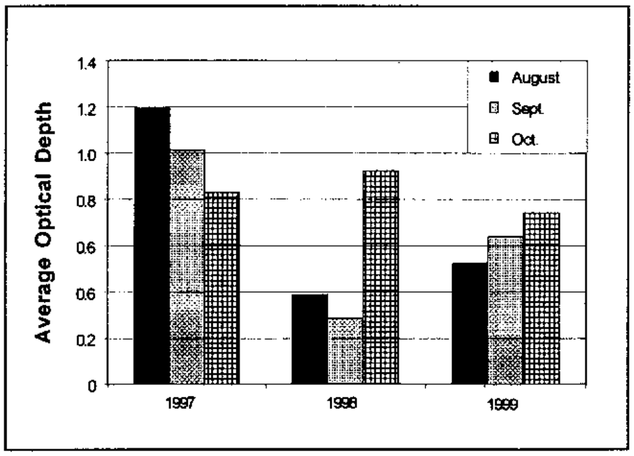

Fig. 1b. Average optical depths of clouds measured during the months of August, September, and October

The results show the capability of the present Mie scattering LIDAR system to extract optical depth values for clouds. The results represent a specific local measurement of clouds but may be used to infer a variation typical of regional climatological events. Regular data acquisition and processing will lead to gradual development of a data bank of optical depth values. These results can then be used as measured data for future atmospheric modeling of regional radiation factors.

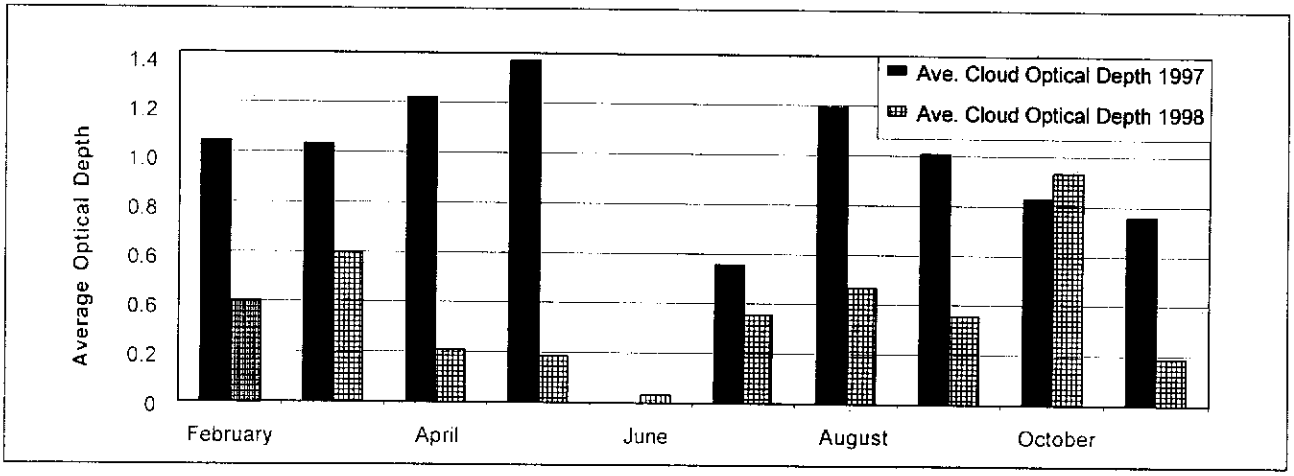

Fig. 2. Monthly Comparison of Average Optical Depth Between 1997 and 1998

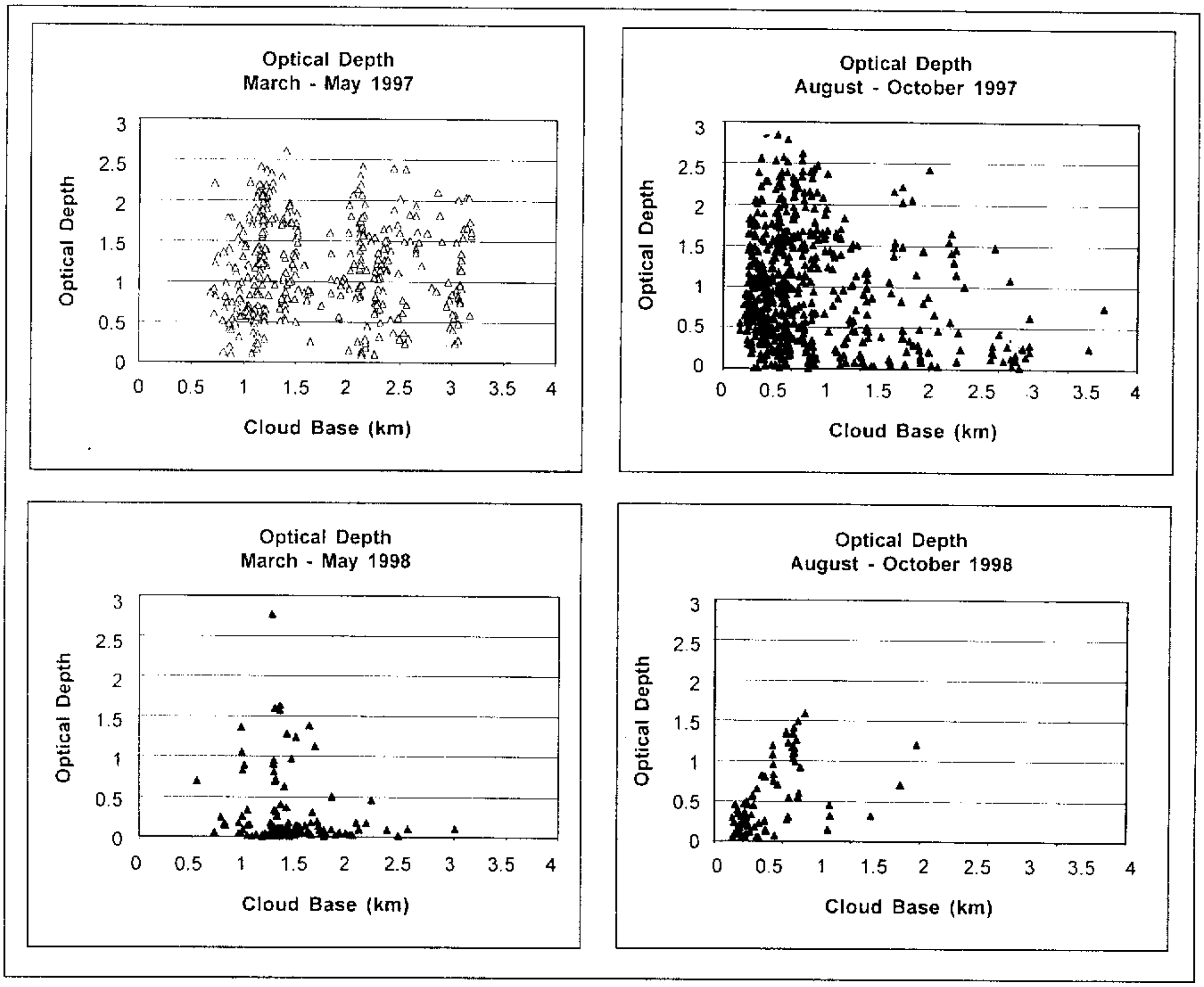

Fig. 3. Comparison of optical depths with cloud base for dry and wet months for the years 1997 and 1998

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