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LIDAR MONITORING AT MID LATITUDE OF THE STRATOSPHERIC AEROSOL PERTURBATION PRODUCED BY THE EL CHICHÓN ERUPTION

A. D'ALTORIO*
G. VISCONTI*

RESUMEN

Reportamos mediciones lidar de la perturbación en la carga de polvo atmosférico producida por la erupción volcánica de El Chichón. Las mediciones abarcan un período de 19 meses y se toman en una estación de latitud media. El análisis de la tasa de dispersión de fondo y la dispersión de fondo integrada como una función de la altitud muestra que hasta fines del verano de 1982, contribuían a la densidad óptica principalmente las capas de elevada altitud ($\geqslant$ 25 km). Desde el otoño de 1982 la llegada de la nube principal a latitud media formó una sola capa amplia que se extendía de 15 a 30 km. La lenta disminución en la altitud de esta capa, 7 - 8 km en 12 meses, se atribuye en parte a la circulación general y a las velocidades de asentamiento de las partículas de polvo. Se muestra que nuestros datos de densidad óptica son compatibles con otras mediciones similares independientes.

ABSTRACT

We report lidar measurements of the perturbation in the atmospheric dust load produced by the El Chichón volcanic eruption. The measurements extend for a 19 month period and are taken at a mid-latitude station. Analysis of the backscattering ratio and integrated backscattering as a function of altitude show that until the end of summer 1982, optical thickness was contributed mainly by high altitude ($\geqslant$ 25 km) layers. Since the fall of 1982 the main cloud arrival at mid latitude formed a broad single layer extending from 15 to 30 km. Slow decay in the altitude of this layer, 7 - 8 km in 12 months, is attributed to a contribution of general circulation and settling velocity of the dust particles. It is shown that our optical thickness data are consistent with similar independent measurements.

* *Dipartimento di Fisica, Università degli Studi-L'Aquila. 67100 l'Aquila, Italy.*

INTRODUCTION

On April 4, 1982 the El Chichón volcano in Mexico (17.3°N, 93.2°W) erupted injecting large amounts of gas and ashes in the lower stratosphere. Similarly to the Mt. St. Helens eruption of 1980 the cloud produced by El Chichón received considerable and detailed attention through ground, airborne and satellite observations. Our earlier report (D'Altorio and Visconti, 1983) contained observations of dust arriving in the summer of 1982 at mid-latitudes in the Northern Hemisphere. Although interpretation of uncorrelated ground observations present some problems (Pitari and Visconti, 1983) statistics of the relevant lidar data over a long period of time could give indication about the residence time of the dust in the stratosphere. These data should help to discriminate between the role of the general circulation and a simple sedimentation process in determining the residence time. Single station observations could contribute in any case to the data base needed to understand the spreading pattern of the dust. Extensive data from northern mid latitude stations have been reported (Hirono and Shibata, 1983; Reiter *et al.*, 1983) as well as *in situ* particle measurements (Hofman and Rosen, 1983) and airborne lidar systems (McCormick and Swissler, 1983; Swissler *et al.*, 1983). These data coupled with the low latitude (De Luisi *et al.*, 1983) and southern hemisphere observations (Clemesha and Simonich, 1983) should constitute a formidable data set to compare the modeling results on the global transport of dust. An important implication of global dust dispersion is the timing and geographical distribution of the possible climatic effect.

In this paper we will report the results of 19 months of observation taken with our lidar system (D'Altorio *et al.*, 1981) at the University of L'Aquila lidar station in Preturo near L'Aquila (42°N, 13°E). Data will be presented in terms of lidar backscattering ratio and optical thickness (integrated backscattering function) in different altitude bands. The interpretation of data will be presented with typical lidar profiles taken at different periods of our observations. A description of our lidar system has been given in D'Altorio *et al.* (1981). The only improvement in this case is a higher power (0.7J/pulse) of the transmitting laser.

OBSERVATIONS

Lidar backscattering ratios as a function of altitude and time starting from May, 1982 are reported in Fig. 1. The data shown are the results of a total of 120 night observations. Each profile is an average of about 150-200 shots taken in a 2hr period. Data are available earlier than May, however this is the month in which the signal from El Chichón was clear over previous minor events (Reiter *et al.*, 1982). To facilitate the interpretation of this figure we show in Fig. 2, typical lidar profiles taken at quite regular intervals or in particular difficult situations to interpret.

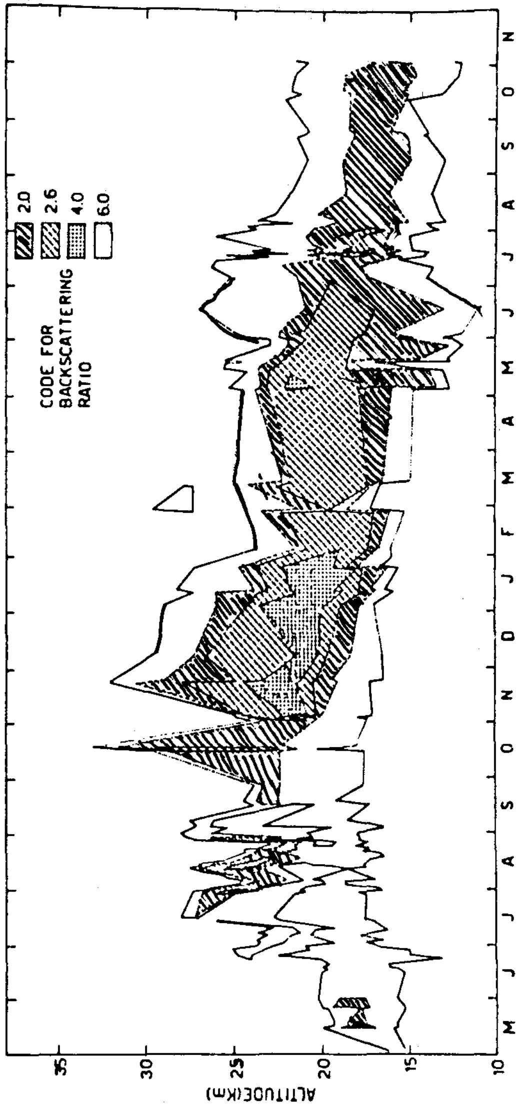

Fig. 1. Backscattering ratio measured during the 19 months period reported in the text. Code for the shaded areas is indicated. The solid line refer to backscattering ratio 1.4. The dotted lines refer to period without data. The most notable are September-October, 1982; March and April 1983 and June 1983.

Careful examination of these two figures show that until November 1982, the dust at mid latitudes was transported in a quite sporadic fashion and with a multi-layer vertical structure. This constitutes an interesting feature because the bulk of the volcanic cloud residing in tropical latitudes was not characterized by this multilayered structure neither in July (Labitzke *et al.*, 1983) nor October (McCormick and Swissler, 1983). The penetration pattern at mid latitude has been apparently characterized by low altitude tenuous layers at first, around 20 km, and then starting from August with strong layers around or above 25 km which represented the fringes of the main cloud located at lower latitude. This main cloud seems to spread at our latitude starting in late fall due to the activation of a more efficient northward and downward stratospheric circulation typical of winter time. This is an agreement with previous and more recent model calculations (Pitari and Visconti, 1983). Confirmation that at this point dust is being transported from the main cloud can be found in the shape of the layer which is now single and broad extending from 15 to 30 km. From Fig. 1 and 2 another interesting feature of the data is the very

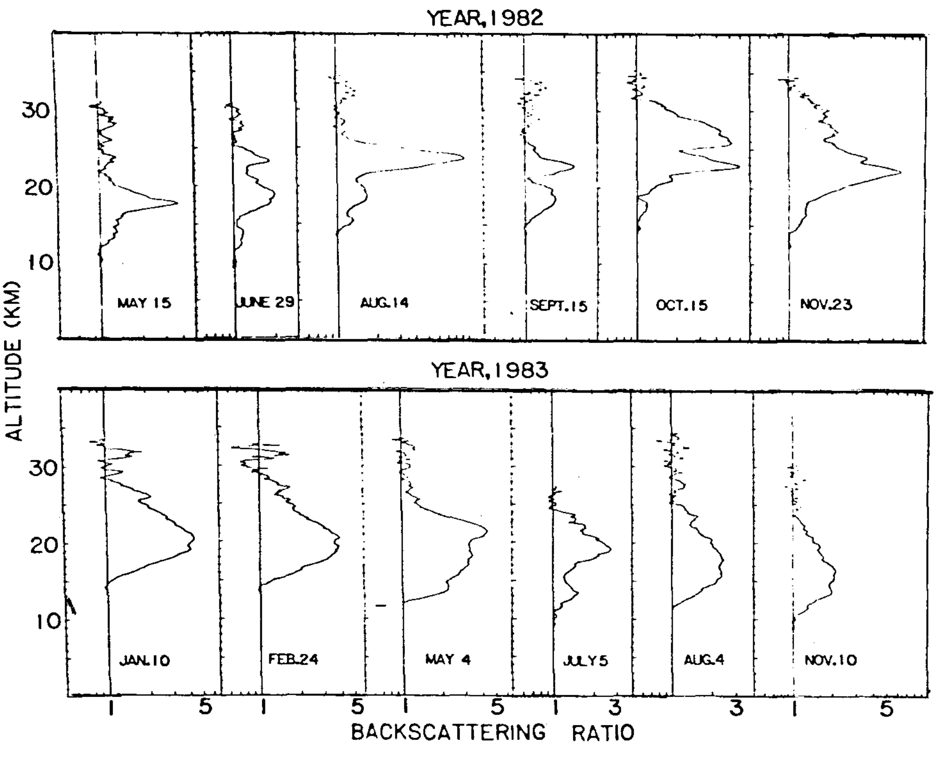

Fig. 2. Backscattering profiles from which Fig. 1 was drawn. These are typical sections of Fig. 1, which are necessary to explain same complex feature of that plot. Notice the log scale.

slow decrease of the altitude of the later coupled to the decrease of the maximum value of the backscattering ratio. Both these cloud effects result from the global transport of the dust. However the very slow decrease in the altitude of the layer could be easily attributed to the sedimentation velocity of the particles. Average decrease in the altitude of the layer is about 7 - 8 km in 1 year. This is much faster than the rate expected from sedimentation alone. Particles with 0.15 μm would take several years to go through the same altitude interval.

Fig. 3 shows the optical thickness as a function of time at 590 μm, calculated using a backscattering to extinction ratio 0.015 sr^{-1}. This value is based on the

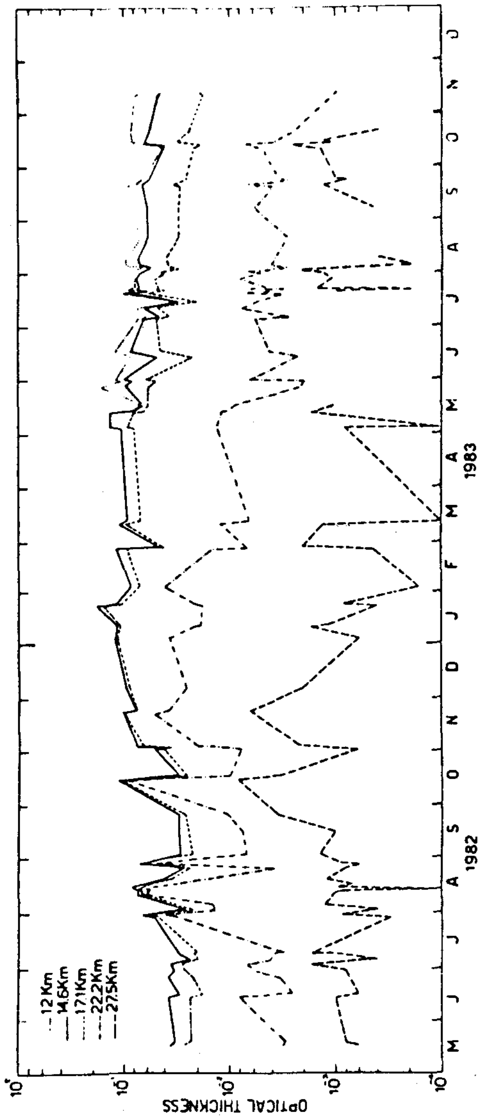

Fig. 3. Optical thickness above the altitude indicated for the period May 1982-November 1983. The line at 27.5 km is discontinued due either to lack of data or not significant values.

background aerosol model of Russell *et al.* (1981) and may not be appropriate for post volcanic conditions. At the beginning of the record shown, most of the dust load seems to be above 15 km while in the summer of 1982 the appearence of high altitude layers is evident because the bulk of dust load is now mainly above 22 km. Until spring of 1983 most of the optical thickness seems to be above 17 km, while the slow decay of the altitude of the dust layer is evident from the increasing splitting of the 22.2, 17.1 and 14.6 km line. Also from the spring a large amount of dust appear to be contained between 12 km and 14.6 km. Another proof on the location of the layer and its behavior in time is given in Fig. 4, where we have plot-

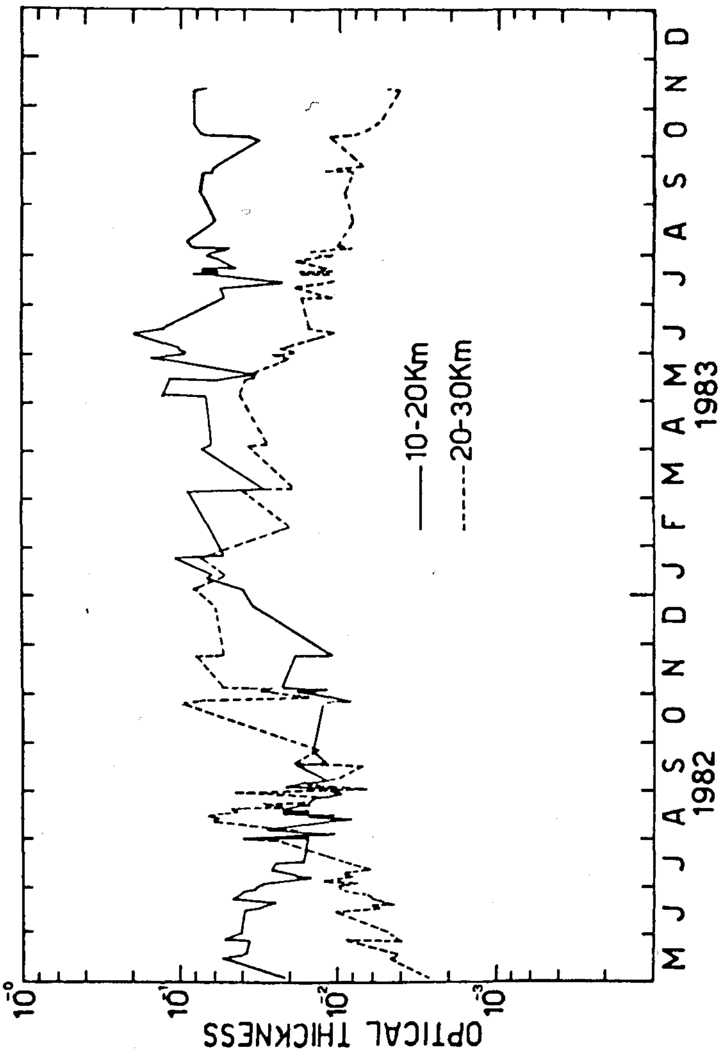

Fig. 4. Optical thickness corresponding to the altitude band between 10-20 km and 20-30 km. Values for the optical thickness reported in this figure and the previous one are obtained for backscattering to extinction ratio 0.015 sr^{-1}.

ted the optical thickness comprised between 10 - 20 km and 20 - 30 km. Again we see that in the spring of 1982 dust intrusion at mid latitude happened mainly at relatively low altitude. Contribution from the high altitude layer starts to be important in summer of 1982 until late fall when the signal from the main cloud starts to dominate our records. It is interesting to note that the total optical thickness from Fig. 3 reaches a maximum in January, 1983 while the thickness of the 10 - 20 km layer has a maximum in July of the same year. This effects points out the importance of the high altitude dust in determining the total optical thickness.

DISCUSSION AND CONCLUSIONS

We will discuss the results of our measurements starting from the transport modalities from tropical to mid-latitude. From ours and similar data taken in Europe (Reiter *et al.,* 1983) it is apparent that dust reached mid altitude as early as May with layers in the 15 - 20 km altitude range. The sporadic intrusion of dust continued in the summer with strong high altitude layers which already had a considerable optical thickness. These observations are consistent with a more careful analysis of results from a three-dimensional time dependent model. (Pitari and Visconti, 1983) previous modeling efforts on volcanic dust transport utilized two-dimensional zonally averaged models (Cadle *et al.,* 1976; Remsberg *et al.,* 1982; Capone *et al.,* 1983) or three dimensional tracer simulation which had marginal resemblance with the actual volcanic cloud (Mahlam and Moxin, 1978). Pitari and Visconti (1983) have shown how there could be considerable inhomogeneity in the zonal direction which is time dependent especially in the fall or winter hemisphere. The sporadic character of latitudinal transport is also indicated by studies related to the seasonal and latitudinal behavior of stratospheric ozone (Rood and Schoeberl, 1983).

Another interesting feature of our data deals with the steady decrease in the altitude of the main layer after it reaches the maximum optical thickness, in the winter-spring of 1982-83. Analysis of 3D results would tend to attribute this behavior to a combination of both the general circulation and sedimentation velocity. In the summer circulation dust is essentially in the rising branch of a cell going from the tropical to mid latitudes. During this time dust settling could just compensate the rising motions. In fall and winter general circulation is more poleward and downward explaining the steady decrease in the altitude of the layer.

Actually analysis of data shown in Fig. 1 tends to support this behavior. Layers observed in the summer and early fall of 1982, although sporadic appears at a rather constant altitude. A steady descent of the layer starts at the end of 1982. However the sporadic character of the layer in the summer makes difficult to give a quantitative estimate of this effect.

Final consideration should be given to the columnar dust load measured at our site as a function of time compared to airborne lidar measurements as a function of latitude (Swissler *et al.*, 1983). These measurements give in October-November, 1982 values of 8 x 10^{-2}. Our values of 0.1 seems to fit well this independent measurements considering they were obtained with a backscattering to extinction ratio of 0.015 and at a different wavelength. The conversion factor obtained by Swissler *et al.* is about 0.022 sr^{-1}.

In conclusion data taken at our site when compared with similar available data indicate a sporadic dust intrusion at mid latitude and summer followed by the winter massive transport due to the mean circulation. This combined with sedimentation velocity of the dust particles is responsible for the altitude time dependent behavior of the main layer. Optical thickness measured at our site seem to be consistent with independent data taken with an airborne lidar.

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