ON THE PRESENCE OF A VOLCANIC STRATOSPHERIC DUST STRATUM OVER A POLLUTED ATMOSPHERE: MEXICO CITY.

IGNACIO GALINDO* AND J. L. BRAVO*

RESUMEN

A partir de mediciones actinométricas efectuadas en la Ciudad de México desde octubre 1974, hasta marzo 1975, se han detectado valores altos de extinción producidos por aerosoles. Substrayendo los valores básicos debidos a la capa "normal" contaminada de la bruma de la ciudad, se obtienen valores de turbidez que indican una reducción media local de la transparencia atmosférica de 2.6%. Observaciones visuales apoyadas con fotografías de crepúsculos brillantes y coloreados percibidos unos 35-40' después del ocaso son consistentes con los reportes previos de Meinel y Meinel y Volz, entre otros, de la gran difusión de la capa de polvo volcánico originada por erupcciones ocurridas entre el 13 y 23 de octubre de 1974 en el Volcán de Fuego de Guatemala.

ABSTRACT

Anomalous aerosol high extinction values have been detected from turbidity measurements made in Mexico City since November 1974 until March 1975. After substraction of the background turbidity values due to the "normal" polluted haze of the city one obtains

* *Instituto de Geofísica, UNAM.*

turbidity values that indicate a mean local reduction of atmospheric transparency of 2.6%. Visual observations sustained with pictures of colorful twilight glows noticed about 35-40' after sunset are consistent with several earlier reports of Meinel and Meinel and Volz, between others, of the wide spread of the volcanic dust stratum originated from volcanic eruptions ocurred between the 13 and 23 October 1974 at the Volcán de Fuego in Guatemala.

Several earlier reports from Meinel and Meinel (1975), Volz (1975) and McCormick and Fuller (1975) seemed to indicate a wide spread of a volcanic dust stratum originated in Guatemala at Volcán de Fuego (14.5 N. 91 W) from eruptions ocurred between the 13 and 23 of October 1974. The above reports contain results from visual and instrumental observations made in relative distant places: Mazatlán, Baja California, Mexico and Arizona, New México, Boulder (1975), Virginia, Boston, Florida and Puerto Rico in the USA.

THE MEXICO CITY OBSERVATIONS

a) The atmospheric turbidity measurements

Our Central Observatory of Atmospheric Radiation (19.3 N, 99 W, 2,268 m a.s.l.) located at the University grounds in the outskirts of the City performs since 1957 continuous measurements of most of the components of the radiation field; between them, direct radiation is measured with and without filters with calibrated pyrheliometers and Volz Photometers every 10' under clear skies.

The Linke and Feussner Pyrheliometer No 670164 is coupled with a multichannel Hewlett Packard Data Adquisition System and routinely used. The above instrument has been calibrated against the Ångström Pyrheliometer No. 166. Both instruments took also part in the Miami International Pyrheliometric Intercomparison of April 1974 before GATE.

Figure 1 shows the average minimum values of the Schuepp's (1949) turbidity coefficient B obtained from total pyrheliometric observations ($0{,}28 \leqslant \lambda \leqslant 5.0\ \mu$). B is evaluated with numerical methods previously developed (Galindo, 1975 and, Galindo and Muhlia, 1970) assuming

$\lambda^{-1.3}$ dependence and incorporating molecular scattering, 0_3 CO_2 and water vapor absorption. Atmospheric water content is estimated from surface humidity. The solid curve represents the average minimum values for the period 1967-1974. The dashed line represents the mean monthly minimum values of turbidity measured from October 1974 to June 1975.

One sees that from November 1974 to February 1975 there is an increase in turbidity with its peak in December 1974 decaying slowly to reach the mean minimum value in March. April and May show also a slight deviation of the average but compatible with their statistical variation, during June, precipitation was very intense so the wash-effect for the atmospheric pollution –(mainly dust, for this time of the year, see Galindo, 1965)– is consequently, very strong.

As we shall discuss later, volcanic activity was visually noted –due to anomalous turbidity– from December 1974 to March 1975. Therefore we have studied the mean transparency reduction by taking the monthly minimum values of turbidity from November 1974 to March 1975 and, after separation of molecular scattering we use the following proposition

$$\overline{B}_{min} = \overline{B}_{min_{1967\text{-}1974}} - \overline{\Delta B} - \overline{\Delta B}_{io} - \overline{\Delta B}_{min}$$

where

$\overline{B}_{min}$ is the actual minimun observed value

$\overline{B}_{min_{1967\text{-}1974}}$ is the minimum average for the series 1967-1974.

$\overline{\Delta B}$ the predicted tendence, 2.5% according to Joseph and Manes (1971).

$\overline{\Delta B}_{io}$ the instrumental and observational errors, estimated to be 1% for the instrumental system and 2% taken as observational, i.e., due to the inhomogenety of the optical media.

$\overline{\Delta B}_{min}$ the increment of atmospheric turbidity due to the stratospheric dust stratum.

with $\overline{\Delta B}_{min} = .012$ one obtains an optical thickness $\Delta\delta = .027$ and a corresponding vertical transmission of $\overline{\Delta T} = .973$, i.e., there is an average of atmospheric transparency reduction of about 2.6% for the period November-March. Volz (1975) have derived from the measured values at Sacramento Peak in New Mexico $\overline{\Delta B} \approx 0.01$, an atmospheric transparency reduction of about 2.3%.

b) The visual observations

In spite that Mexico City is from the above reported places the nearest one to the volcanic source (about 500 n. m.), we have noticed colorful twilights first at the end of December 1974. However, during January the daylight skies were observed to be bluish ashen with sunsets showing colorful twilights which ended with purple light (reddish afterglow). Initially we suspected this to be due to anomalous emissions of industrial origin but, one could observe besides the glows, the presence of two well defined haze layers of different colors separated in between very clear air. The lowest layer showed to be the "normal" strong yellow haze typical for this time of the year containing mostly natural dust and industrial pollutants, with height about 3 km (Galindo, 1965). At the top of this layer stayed very clear air of variable thickness (initially was of about 6 km and by the end of March it was reduced to 1 km). The upper dust stratum had a height of about 18 to 20 km the color of which varied between reddish to violet.

The above variable described haze "sandwich" remained visible over the city from January until the end of March 1975, however, during February it was not observed. From March to April the stratospheric dust layer vanished and only colorful streaks 30' after sunset were observed, these streaks showed a whole range of colors, from light yellow, green up to pink ones.

Pictures 1 and 2 taken at the university grounds were selected to show the evolution of the dust stratum from January to March 1975. Picture 1 corresponds to the sunset of the 13 of January, it shows the clear air in between, its height is estimated to be about 6-7 km,

the upper part, gray at its botton changes slowly to violet in the top and corresponds to the volcanic dust stratum.

Picture 2 taken on the sunset of the 5 of March shows the almost disappearance of the clear air, however, both haze layers are still perfectly distinguishable because their different colors.

The above described color slides show the boundaries of both layers, it seems that the abrupt observed changes between the hazy atmosphere and the nearby clear atmosphere are correlated with the mixing power and the residence time of both layers. At the time of the year when these slides were taken the atmosphere over Mexico City is quite dry, in particular January, February and March are the months with the lowest vapor content (see fig. 2). With the increase of atmosphere water vapor the vertical transport increases and the mixing power of the aerosol particles increases with the subsequent reduction of the boundaries.

According with the Meinels (1975), the enhanced stratospheric dust layer moved initially westward to recurve at Hawaii and returned far norther (Mazatlán, Baja California and some of the American Southern states), from there is seems that the volcanic cloud took a Southeast trajectory, this explanation might clear up the question why we had the presence of the colorful twilights relatively late in November with its maximum in December and January. The March striated and weaker twilights after its disappearance in February would indicate the encircling of the earth by the initial cloud.

Note added in proof: During the last revision of the draft paper striated twilight glows have been observed since 19 September 1975 in Mexico City during sunsets and sunrises. However, the streaks are weaker than in December 1974 and January. Reddish afterglows defines a unique layer of about 20 km height, i.e., the mixing depth is powerful enough now and one can not distinguish anymore between the botton industrial haze layer and the enhanced stratospheric dust. These last observations indicate that the spread of the aerosol injected into the stratosphere by the explosion of the volcán

de Fuego in Guatemala, had encircled the earth and finally that the abatement of the volcanic dust cloud have started. Slides taken of different days might be obtained from the authors. Sept. 30.75.

ACKNOWLEDGMENTS

The authors are indebted to Dr. F. Volz, who made us very useful criticisms.

BIBLIOGRAPHY

FERNALD, F. (Quoted in 10, Vol. 7, 1975).

GALINDO, I., 1965. Turbidometric Estimations in Mexico City using the Volz Sun Photometer, PAGEOPH, 60(189).

GALINDO, I. and A. MUHLIA, 1970. Contribution to the Turbidity in Mexico City, *Arch. Met. Geoph. Biokl.*, B, 18, 169.

GALINDO, I., 1975. Physikalische und mathematische Untersuchungen zur atmosphärischen Trübung, *Arch. Met. Geoph. Biokl.*, B, 23, 225.

JOSEPH, J.H. and A. MANES, 1971. Secular and Seasonal Variations of Atmospheric Turbidity at Jerusalem, *J. Appl. Met.* 10(453).

McCORMICK, M. P. and W. M. FULLER, Jr., 1975. Lidar Measurements of two intense stratospheric dust layers, *Appl. Optics*, 14(4).

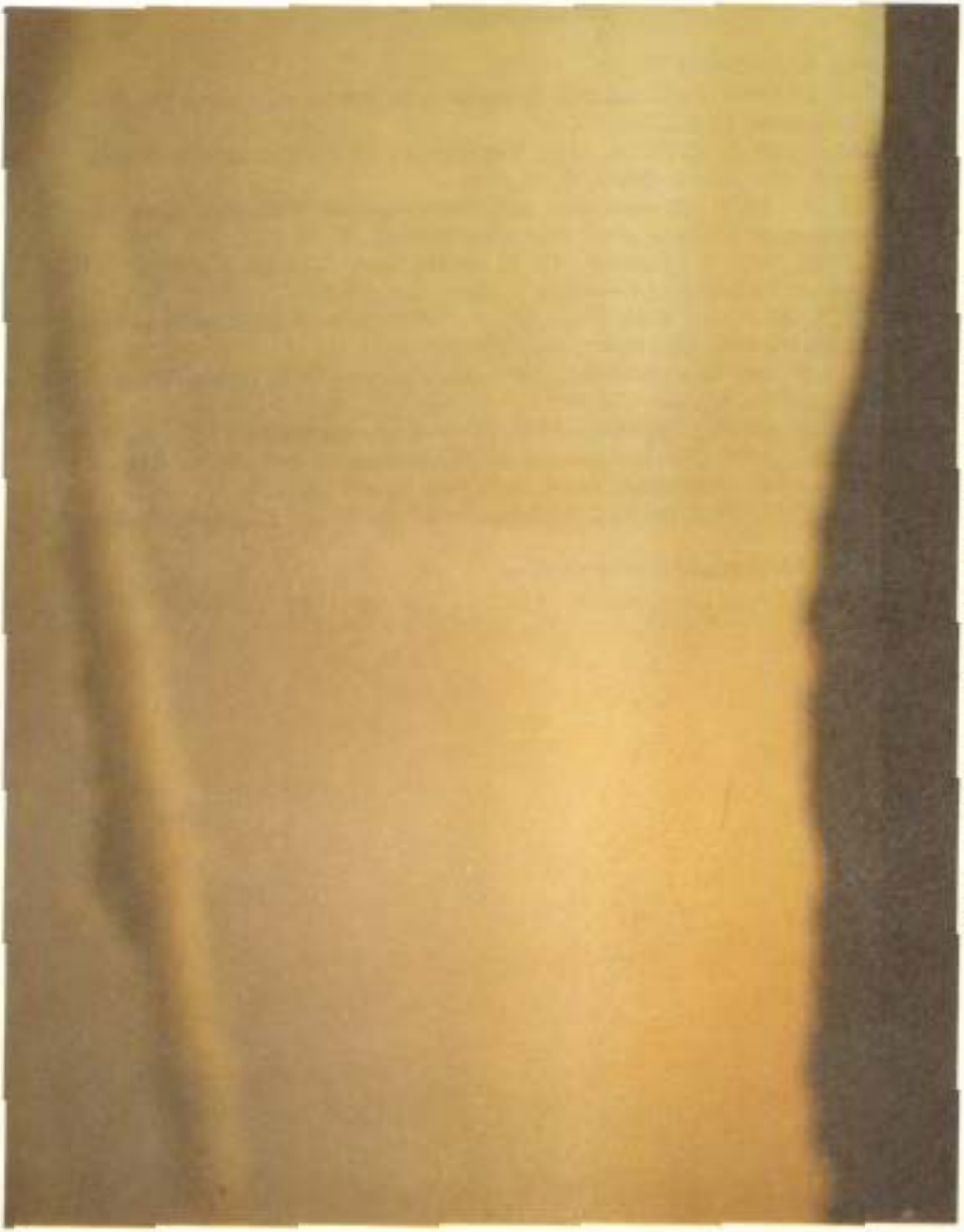
MEINEL, A. B. and M. P. MEINEL, 1975. Stratospheric Dust-Aerosol Event of November, 1974, *Science*, 188-477.

MEINEL, A. B. and M. P. MEINEL, 1975. *Personal communication.*

SCHÜEPP, W., 1949. Die Bestimmung der Komponenten der atmosphärischen Trübung aus Aktinometermessungen, *Arch. Met. Geoph. Biokl.*, B, 1, 257.

VOLZ, F., 1975. New volcanic Twilights from the Fuego Eruption, *Science* 189(48).

VOLZ, F., 1975. *Personal communication.*



Picture 1. Sunset (January 13th, 1975) taken at the University grounds.

Picture 2. (March 5th, 1975) taken in the same direction as picture 1.

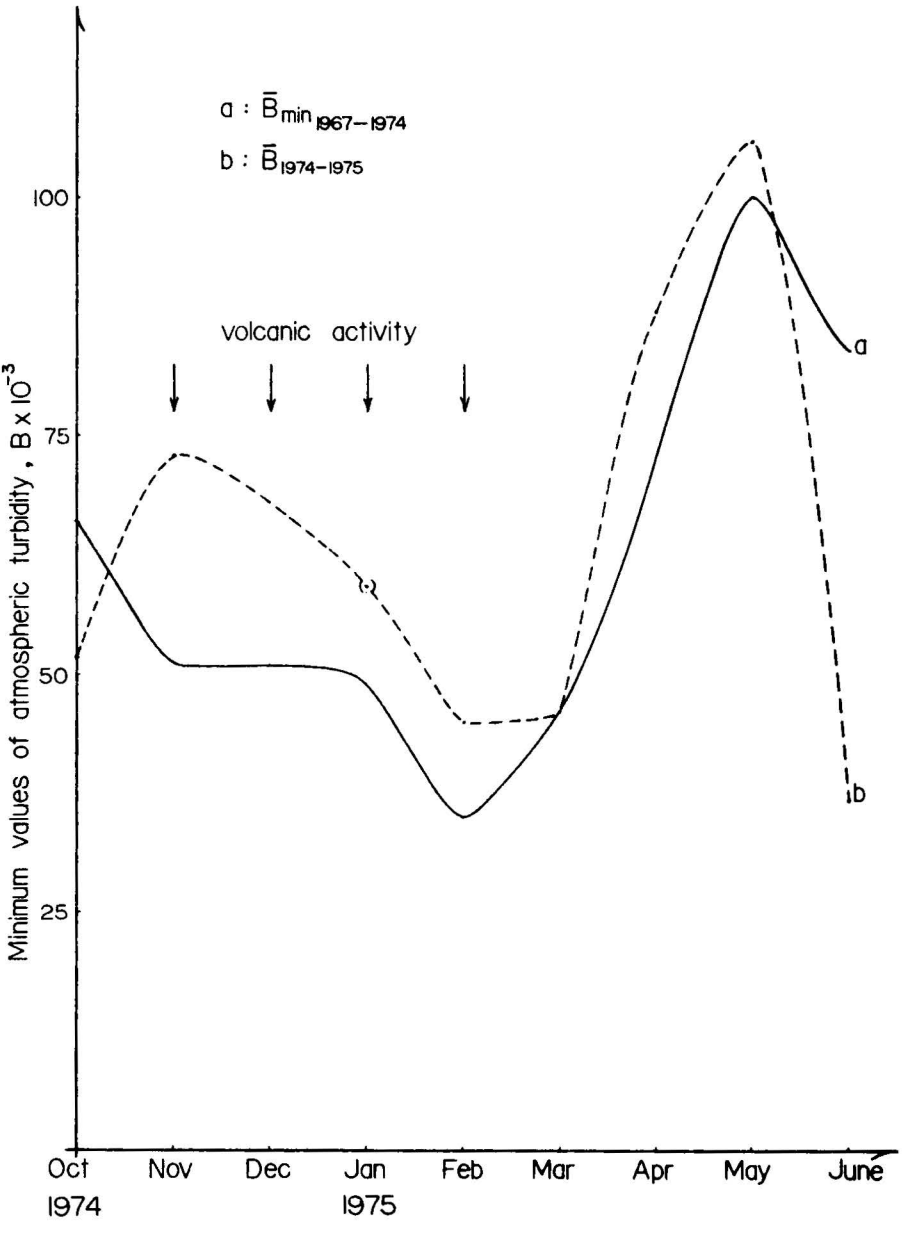

a : $\bar{B}_{min\ 1967-1974}$
b : $\bar{B}_{1974-1975}$
volcanic activity
Minimum values of atmospheric turbidity, B x 10^{-3}
100
75
50
25
a
b
Oct
1974
Nov
Dec
Jan
1975
Feb
Mar
Apr
May
June

Fig. 1

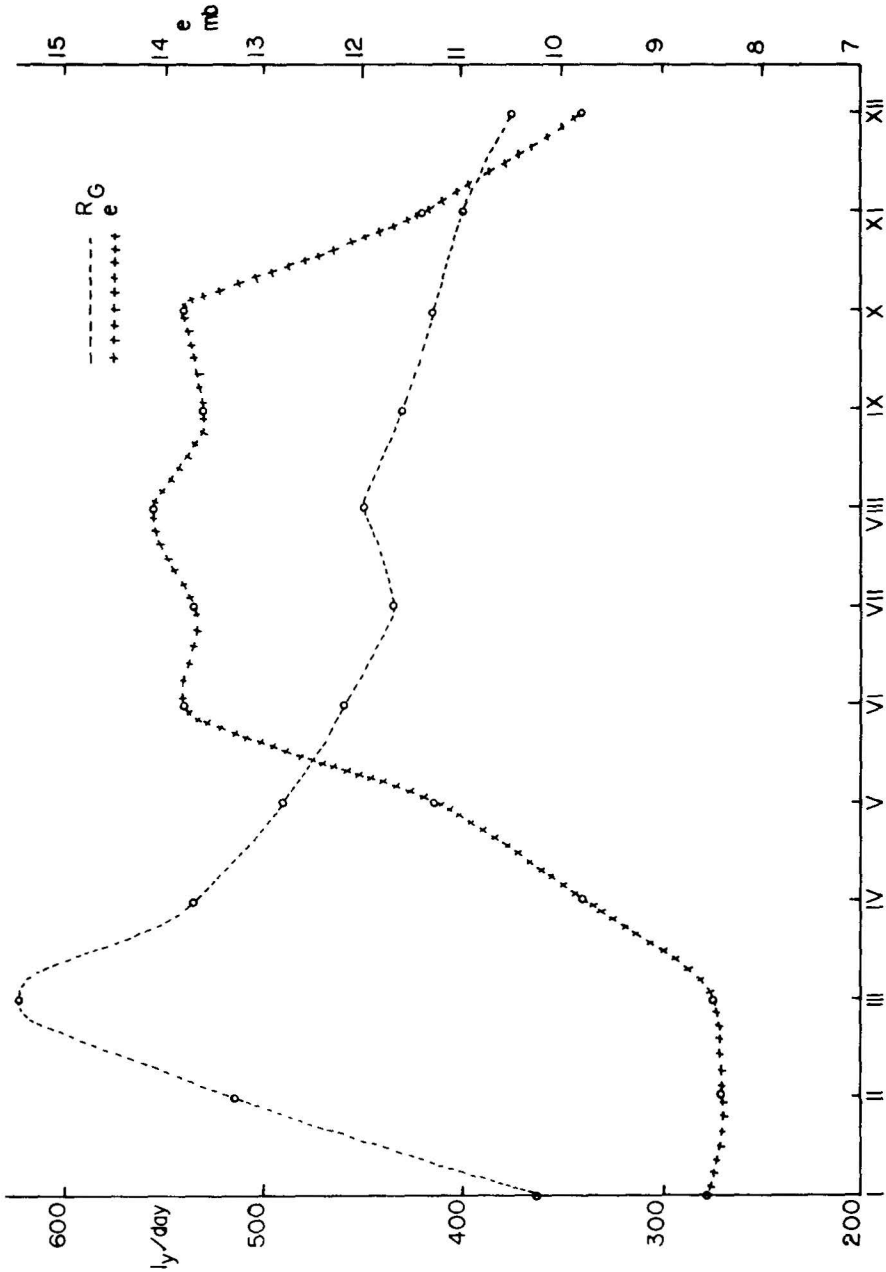


FIG. 2 MEXICO CITY (19°20'N, 99°10' 54" W, 2,268 m. a.s.l.) MEASURED VALUES DURING THE INTERNATIONAL GEOPHYSICAL YEAR (1957–1958) OF TOTAL SHORT WAVE-INCOMING RADIATION R_G AND WATER VAPOR PRESSURE e AT THE SURFACE