Enhanced twilight glow caused by the volcanic eruption on Bali Island in March and September 1963[1]

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ABSTRACT

The paper describes photometric measurements made at Ahmedabad (23°N, 72°E) from Nov. 11, 1963 to March 3, 1964 on the intensity and polarisation of the enhanced twilight glow which was observed all over India from the end of September 1963 to March 1964.

It is attributed to scattering by aerosols presumably projected into the stratosphere by a volcanic eruption in Bali Island in March and September 1963.

M. P. Meinel & A. B. Meinel (1963) observing in Arizona reported brilliant golden sunset glows after late September 1963. They attributed the strong twilight coloration to the eruption of the volcano Agung, on Bali (8.3°S, 115°E), which occurred in March 1963. From the heights of the glow stratum estimated from the times of horizon disappearance of the short boundary of the Earth's shadow on the sun-illuminated dust, Meinel & Meinel (1964) concluded that the true height of the top of the dust layer is close to 20 Km above mean sea-level.

Increase in twilight glow and in the dust strips in the twilight arch have been observed from several places in the northern hemisphere from the fall of 1963 until the winter of 1963–64. Measurements of the twilight brightness (Volz, 1964; 1965) and of diffuse sky radiation during the day (Burdecki, 1964; Hogg, 1963) indicate a considerable increase of dustiness in the stratosphere.

The Times of India of 17 September 1963 reported that the 1700 m Mt. Batur volcano on Bali Island had erupted and after devastating 19 villages with lava, was emitting ash on the 16th September.

After the clearing of the monsoon clouds in late September, a greatly enhanced twilight glow was noted in many parts of India both in the morning and in the evening; and it was planned that a photometric study of the glow and its gradual decay should be undertaken. The same photometer and filters that were used by the author at Mt. Abu (24 °N,1200 m altitude) (Shah, 1968) in 1956–59 were rigged up and observations on the enhanced glow were started in Ahmedabad (23°N) early in November 1963. The observations were made on many cloudless days from the time of sunset to the time when the center of the sun was 14 deg. below the horizon (and on a few days at corresponding times before sunrise). These were continued till March 1964, by which time, the intensity of the glow had greatly diminished.

The photometer used consisted of a telescope with a circular field of about 1 deg. in diameter, a Chance filter transmitting in red (effective wavelength centered at 6600 Å) in conjunction with an RCA 1P22 photomultiplier as the light detector, a stable and sensitive D.C. amplifier and a current meter. The filter used had a sharp short wavelength cut-off at about 6200 Å and therefore most of the Chappius band of ozone absorption with a maximum intensity at 6100 Å would remain in the cut-off region of the filter.

Measurements of twilight sky illumination were made in the direction of the sun at an angle of 20 deg. above the horizon.

Fig. 1 shows graphs of the intensity I (in arbitrary units) at 20 deg. above the horizon in the sun's meridian plane against the sun's depression δ below the horizon on Nov. 11, 12, 27 and Dec. 17, 30 of 1963; Feb. 18 and March 3 of 1964. Unfortunately, twilight measurements

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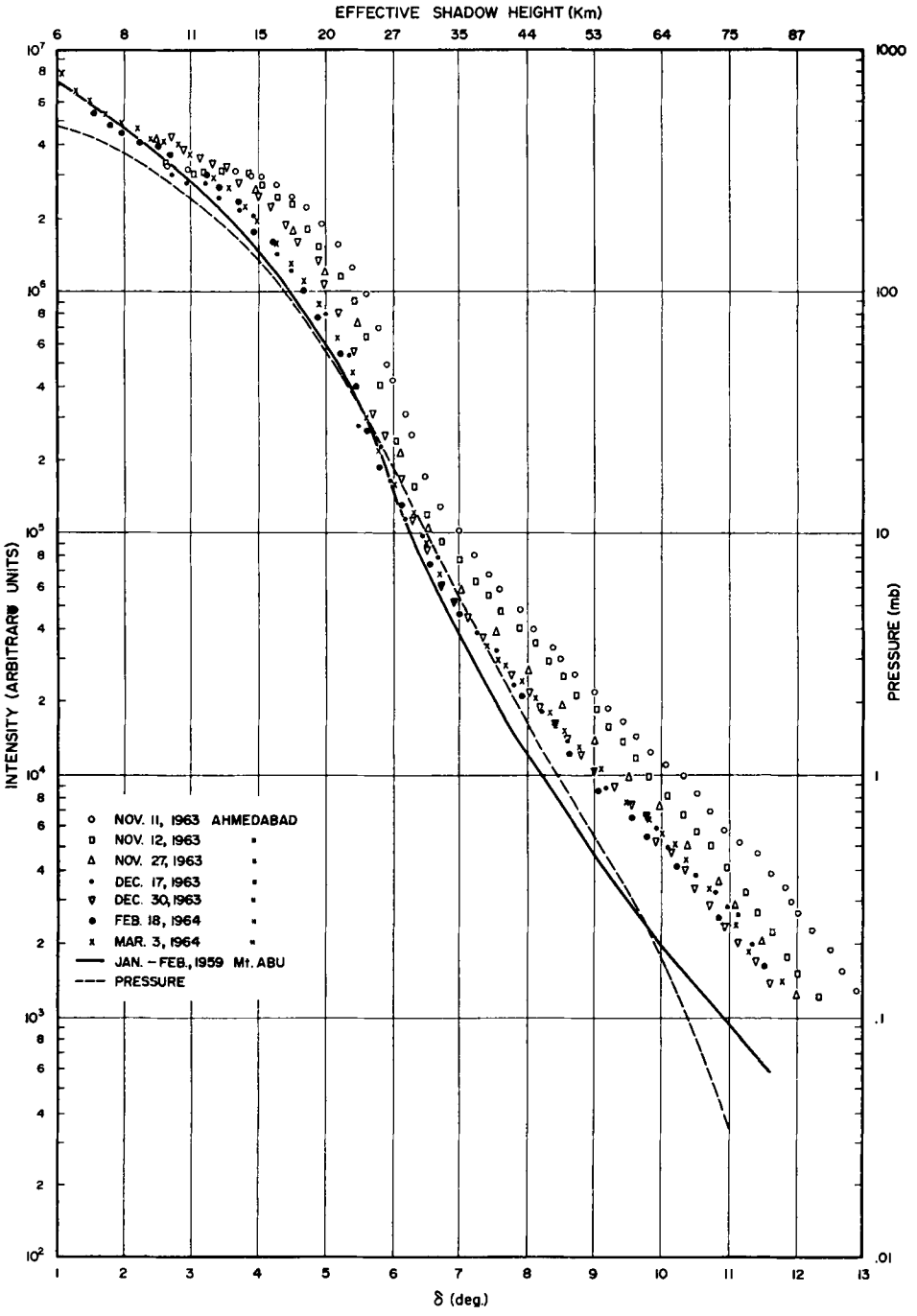

Fig. 1. Twilight sky illumination (at 6600 Å) in the sun's vertical at 20 deg. above the horizon, for different δ. Scale at right, pressure as a function of effective shadow height.

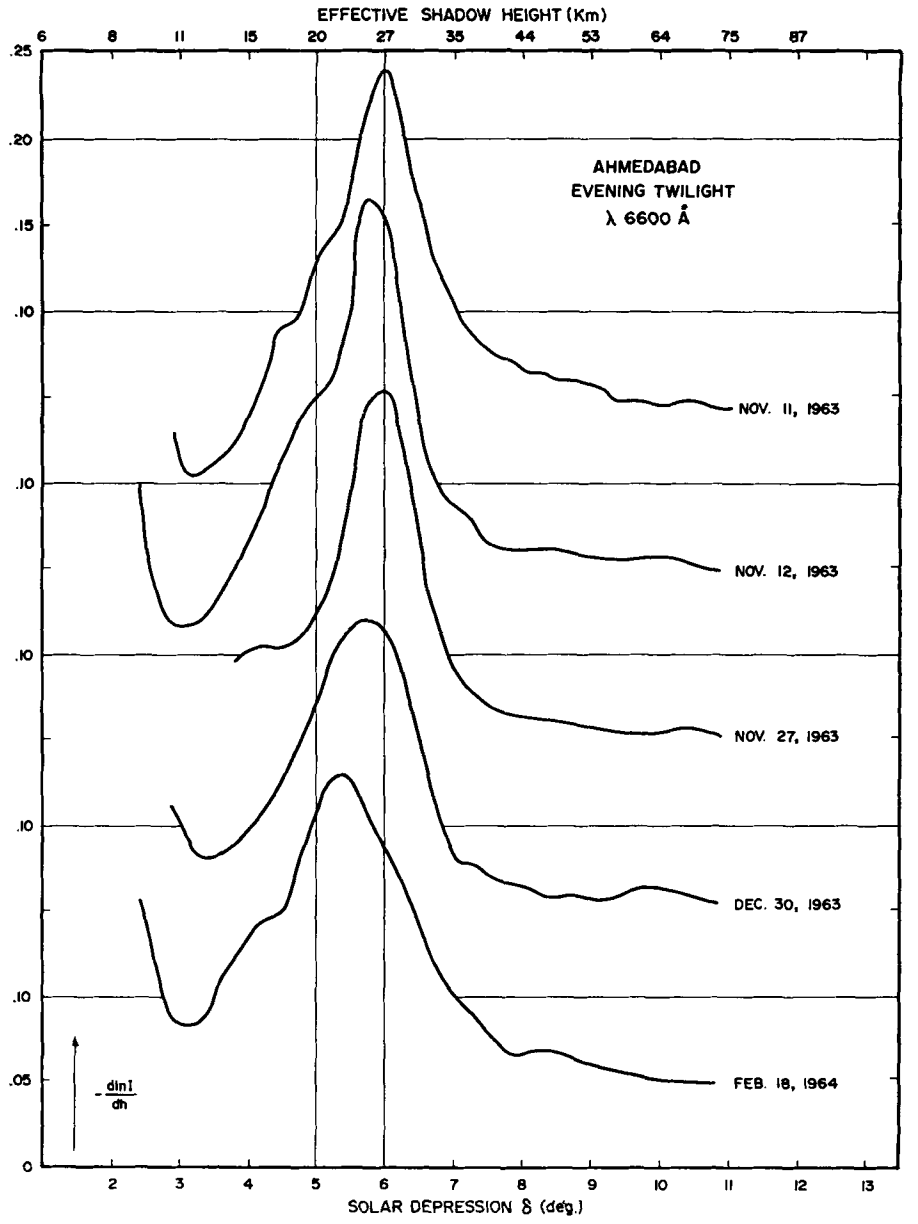

Fig. 2. Plots of values of $-(d \ln I)/dh$ against solar depression δ.

at Ahmedabad are not available for period prior to eruption on Bali. However, twilight intensity measurements made at Abu during the winter of 1959 with the same photometer and filter are plotted in Fig. 1 for comparison. The values of the pressure at the effective shadow heights (the vertical height of a point where direction of observation meets the refracted grazing solar rays with closest approach at a height of 6 km from the earth) have also been plotted in Fig. 1. The following points may be noted:

1. On Nov. 11 and 12 the intensity was much higher than those previously observed at Abu. The course of the curve was also different.

On the first day of observation the intensity at 5 deg. sun's depression was 1.5 times and 2.5 times larger than that on Nov. 27, 1963 and Feb. 18, 1964 respectively. The intensity of the glow did not change significantly from Feb. 18 up to the last day of observation on March 3, 1964. The intensity on Nov. 11 was almost 3 times larger than that observed during the winter of 1959 at Mt. Abu.

A considerable increase in red intensity at 4.5 deg. sun depression and 20 deg. elevation was also observed by Volz (1964) at Weissenau during the winter of 1963–64 compared to that during the winter of 1959–60, at Boston (Volz & Goody, 1962).

2. The very high values of intensity on Nov. 11, 1963 and subsequent days have shown that forward scattering by aerosols can add substantially to the scattered light and intensity of the glow.

3. There was a general fall of intensity of the glow after Nov. 11, 1963, with some ups and downs from one day to another, till the middle of Feb. 1964, by which time it had settled down but the gradient was still quite different from normal, or similar. This follows also from the polarisation of Feb. 1, 1964 (see Fig. 3).

Double tropopauses and associated jet streams are commonly associated with western disturbances which affect North India in winter and spring, and they would be responsible for transporting some of the dust from the subtropical stratosphere to northern latitudes and to lower altitudes, thus sufficient to remove most of the surplus dust. About three months of western disturbance activity seems to be sufficient to dump the surplus dust into lower stratosphere.

4. The curves of log I and log p against solar depression δ diverge steadily after 7 deg. and the difference increases with increasing δ. This means that the ratio of I to p increases with increasing shadow height when it exceeds 30 km. This is due mainly to multiple scattering from the lower atmosphere (Dave & Ramanathan, 1956).

Large intensity observed at large depressions for the same profile may be largely due to the contamination by Ahmedabad city lights.

Fig. 2 presents plots of $-(d \ln I)/dh$ against the solar depression δ where h is the effective shadow height. The values of the effective shadow heights corresponding to different δ are also given at the top scale of the Fig. 2.

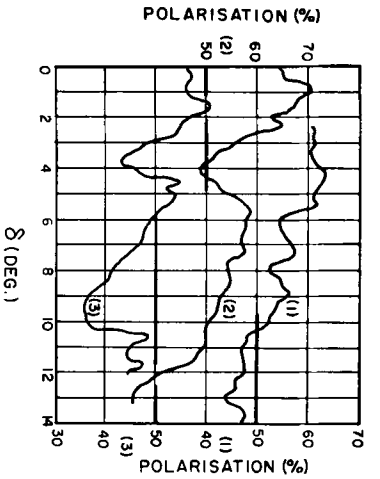

Fig. 3. Percentage polarisation of red light (at 6600 Å) from zenith sky during evening twilight over Ahmedabad for different δ. (*1*) 30 May 1955 (probable normal conditions), (*2*) 11 Jan. 1964, (*3*) 1 Feb. 1964.

The very small value of the ratio near $\delta = 3°$ on Nov. 11 and 12 indicates that at the corresponding height of 12–13 km the sky intensity was changing very little as the sun was going down. This could only be due to increased light coming from above.

The subsequent increase in $-(d \ln I)/dh$ as the sun was going down was due to the rising of the earth's shadow across the dust layer. The values of $-(d \ln I)/dh$ is equivalent to inverse of smoothed scale height of the actual atmosphere (dust scale height superimposed on molecular scale height) (Bigg, 1964) and therefore its distribution in the vertical will represent vertical distribution of aerosols in the atmosphere. Fig. 2 further suggests that the height of maximum concentration is between 20 and 27 km.

Curves showing the polarisation of the zenith sky light measured by the author with polaroid and red filter (6600 Å), at Ahmedabad in May 1955, on Jan. 11 and Feb. 1, 1964 are shown in Fig. 3. The strong depolarisation observed in 1964 at solar depression of 4 deg. may be noted. This should be expected if the scattering is due to particles. The effective height of the base of the layer directly illuminated at the zenith corresponding to 4 deg. solar depression below horizon will be about 18 km (allowing for refraction and screening height of 6 km). This

confirms the existence of a stratospheric layer at this level.

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ПОВЫШЕННОЕ СУМЕРЕЧНОЕ СВЕЧЕНИЕ, ВЫЗВАННОЕ ИЗВЕРЖЕНИЕМ ВУЛКАНА НА ОСТРОВЕ БАЛИ В МАРТЕ И СЕНТЯБРЕ 1963 г.

В статье описаны проведенные в Ахмедабаде (23 сев. ш., 72° вост. долг.) с 11 ноября 1963 г. по 3 марта 1964 г. фотометрические измерения интенсивности и поляризации повышенного сумеречного свечения, которое наблюдалось по всей Индии с сентября 1963 г. по март 1964 г. Это свечение приписывается рассеянию на аэрозольных частицах, предположительно выброшенных в стратосферу при извержениях вулкана на острове Бали в марте и сентябре 1963 г.