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Wind and temperature over Hyderabad during the solar eclipse of 24 Oct. 1995

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A special balloon flight was conducted jointly by National Scientific Balloon Facility of TIFR, Hyderabad, and India Meteorological Department, Hyderabad, during the solar eclipse of 24 Oct. 1995 to study the eclipse induced effects on wind and temperature profiles over Hyderabad (17°23′N,78°29′E). The balloon went up to 37 km. Maximum cooling by almost 9-10°C was observed below the tropopause at an altitude of 15.5 km (27% obscuration) and the tropopause was found to descend down by 300 m and got broadened. Changes in wind velocity were observed below the tropopause at 15.5 km.

1 Introduction

Solar radiation plays a key role in the photochemical and dynamical processes that take place in the earth's atmosphere and decides the structure, composition and dynamics of the atmosphere at all levels. During a solar eclipse, the passage of moon's shadow cuts off solar radiation in the path of totality resulting in cooling of the atmosphere, particularly, in the troposphere. Studies of the effects of solar eclipse on neutral atmosphere are very few[1-5]. The total solar eclipse of 24 Oct. 1995 over India provided an excellent opportunity to measure the temperature and wind profiles of the neutral atmosphere over Hyderabad (17°23′N,78°29′E) during the celestial event. To aid this study a special balloon flight was jointly conducted by the National Scientific Balloon Facility of Tata Institute of Fundamental Research (TIFR), Hyderabad and India Meteorological Department (IMD), Hyderabad, during the eclipse. The flight lasted from 7.20 a.m. at the ground level to 9.00 a.m. at the peak of the flight which was 37 km. The maximum phase of the eclipse (67.4% over Hyderabad) was at 8.38 a.m.

2 Control day profile

There was no control day flight possible at the same local time on any of the neighbouring days. However, there was a routine radiosonde flight of IMD at 5.48 a.m. on the eclipse day which went only up to 18.5 km. The eclipse time data have been compared with this morning flight data till 18 km. Data of three neighbouring morning flights, where the balloons reached up to 27 km, have been averaged to compute the control day profile between 19 and 27 km for comparison. This averaged profile has not been used for comparison below 18 km, since it could have given a smoothed profile and the finer aspects of the tropopause could not be observed due to its day-to-day variation. The dates of the neighbouring flights are: 22 Oct. 1995, 23 Oct. 1995 and 25 Oct. 1995. The balloon reached an altitude of 37 km during eclipse. But the eclipse data in the altitude range of 27-37 km could not be compared due to lack of proper control day flight.

3 Results and discussion

The variation of temperature with height during eclipse and its comparison with the control day profile is shown in Fig. 1. The balloon was at an altitude of 3 km at the time of first contact. No fluctuation in temperature can be observed till about 14 km. This is probably due to the sluggishness of the atmosphere to respond to the eclipsing of the solar disc, the relaxation time being of the order of 30 min. Rama Rao *et al.*[6] also observed sudden and significant oscillatory type fluctuation in minimum virtual height of F-layer (h' F) over Waltair (20°N) after a time lag of 30 min from the first contact during 24 Oct. 1995 solar eclipse. A significant drop in temperature is noticed thereafter and a maximum drop of 9.8°C is observed below the tropopause at an altitude of 15.5 km. The normal day-to-day variation of temperature is found to be ~(2-3)°C. Interestingly, the height of tropopause is found to descend down by 300 m from 17.1 km to 16.8 km during eclipse and the difference in temperature between the two levels of tropopause is about 5°C. Tropopause was also found to be spread out in height during the eclipse. The slope of the curve changed from ~ −4 on control day to ~ −11 below the tropopause (between 15 and 16 km) during the eclipse. The tropopause height has been checked for several days for morning and evening data. Normally, there is a rise in tropopause height in the evenings by few hundred metres possibly due to higher temperature in the evening. So, the tropopause height is expected to rise marginally by 8 a.m.(during eclipse) compared to its early morning value which has been considered in the control profile for comparison. So, the lowering of tropopause height and the change in its gradient are quite significant. Appu *et al.*[7] conducted a better-planned balloon campaign at Thumba (8°32'N) during the same eclipse and observed a strong cooling of tropospheric layers reaching a maximum of 9.5°C at 14 km in their second radiosonde flight at 11 a.m. on the eclipse day. Maximum obscuration at Thumba was 46% at 0841 hrs LT. Chimonas[8] used a model in which the main source of gravity waves was centered around 45 km although he recognized that cooling at around 90 km and in the troposphere could be the sources also. Bhattacharya *et al.*[9] observed a reduction in γ-ray flux in the energy range of 0.3-3.0 MeV measured during this total solar eclipse (TSE) event over Diamond Harbour (22°N), West Bengal. They have explained it on the basis of significant cooling that takes place during an eclipse due to which the production (Π−μ component) region of 90 g cm^{-2} (i.e., at about 16 km altitude) is pushed down to lower altitude making the path shorter for decay of μ-mesons to $e^{\pm}$ and thereby decreasing the γ-ray flux at sea level. Our observation supports this lowering of the level. Figure 1 shows that the temperature in the lower stratosphere between 20 and 25 km did not practically change in spite of higher obscuration at that time compared to its value when the balloon was below the tropopause. Appu *et al.*[7] observed a rise in stratospheric temperature in the 20-34 km layer. Warming by 2-3°C in the lower stratosphere was first observed by Quiroz and Henry[2] at Wallops Island (38°N).

Vertical ozone profiles measured by India Meteorological Department during this eclipse (24 Oct. 1995) have been published[10]. Figures 2 and 3 show the smoothed (3-point running average) vertical ozone profiles for Robertsganj (24°39'N) and Ramgarh (23°38'N) stations, respectively, which were in the path of totality. A decrease of ozone concentration can be seen below the tropopause and marginal difference or even higher concentration can be found above 20 km. Devanarayanan and Mohankumar[11] also observed similar ozone variation during the total solar eclipse event of 16 Feb. 1980. The total ozone for Robertsganj and Ramgarh as measured by IMD during the eclipse is given in Table 1. Table 1 does not show any variation in total ozone during the eclipse which is quite expected in view of its long life time in the stratosphere. But the vertical

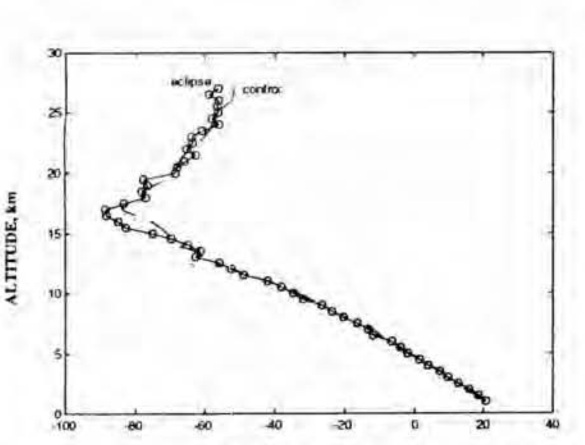

Fig. 1—Variation of temperature with height during eclipse (circle) and control day

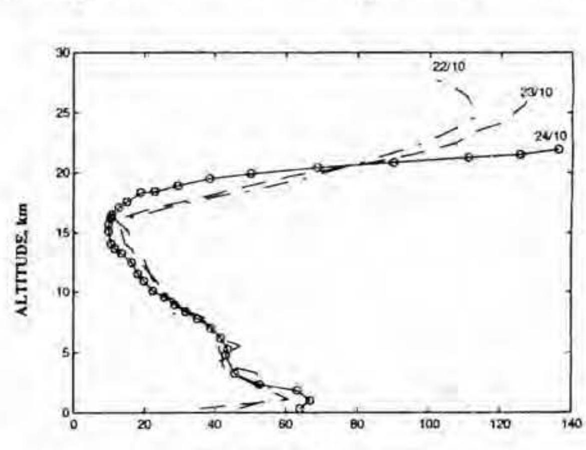

Fig. 2—Comparison of vertical ozone distribution during solar eclipse (circle) of 24 Oct. 1995 with control day profile at Robertsganj (24°39'N)

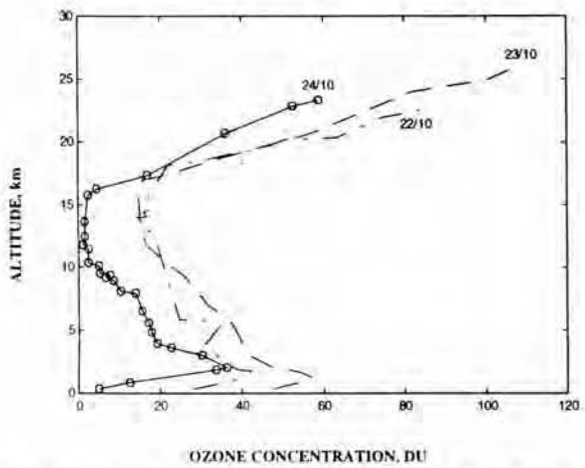

Fig. 3—Comparison of vertical ozone distribution during solar eclipse (circle) of 24 Oct. 1995 with control day profile at Ramgarh (23°38′N)

Table 1—Ozonesonde data for Robertsganj and Ramgarh as recorded by IMD before/on the eclipse day

Date in Oct. 1995	Time hrs IST	Total ozone DU	
		Robertsganj	Ramgarh
22	1110	253	255
23	1000	265	251
24	0801	277	254

distribution of ozone, which has a bearing on the temperature structure, has changed during the eclipse in a manner similar to that of temperature variation. However, there are some reports showing that the atmospheric ozone balance gets disturbed during total solar eclipse events[12-14]. During the same eclipse (24 Oct. 1995), Niranjan *et al.*[15] observed that the solar flux at ozone sensitive wavelengths in the UV and visible solar spectrum increased for about one hour after the eclipse event, which indicates lower atmospheric columnar ozone during the eclipse recovery phase and for about one hour after the eclipse event, compared to that on a normal day.

Figures 4 and 5 show zonal wind and meridional wind over Hyderabad for the eclipse day and the control day profiles, respectively. No appreciable change is observed in the troposphere other than at 15.5 km where both zonal and meridional wind velocities are found to be changed by approximately 8 ms^{-1}. The wind variations are not much appreciable except at few altitudes and cannot be directly attributed to the obscuration of the sun. Appu *et al.*[7] observed strengthening of winds above 10 km during this eclipse. Observations during eclipse (80%) at Fort Sherman[3], Panama Canal Zone (9°20′N) showed a change of zonal wind velocity by 6 ms^{-1}, whereas the meridional flow remained unchanged in the upper stratosphere. Experiments conducted during total solar eclipse of 1980 over India[4] do not show any appreciable change in wind velocity which can be treated as real variations caused by solar eclipse.

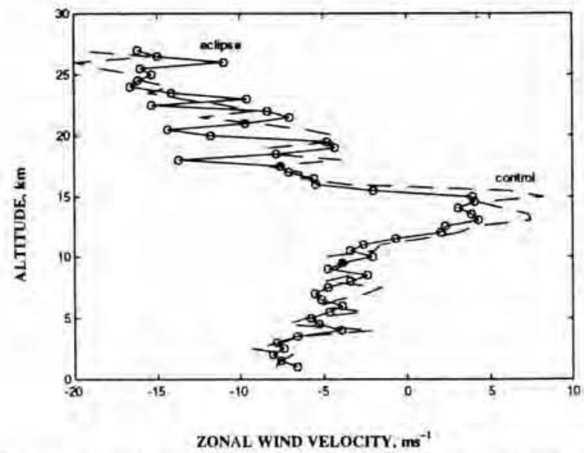

Fig. 4—Altitude variation of zonal winds during eclipse (circle) and control day

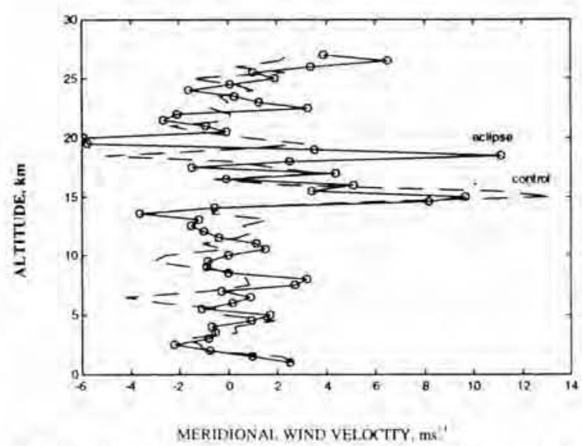

Fig. 5—Altitude variation of meridional winds during eclipse (circle) and control day

4 Concluding remarks

The present experiment shows strong cooling below the tropopause, lowering in its height and broadening of the tropopause. The large amount of cooling cannot be explained on the basis of solar obscuration alone. Behaviour of several other parameters which were studied during the solar eclipse of 24 Oct. 1995 were presented at the Indian National Space Science Symposium, 1996, held at Hyderabad and at the International eclipse Symposium in Taiwan, 1996, and showed that the variation of several parameters during the eclipse did not follow the obscuration pattern.

Chakrabarty *et al.*[16] measured the vertical column abundance of ozone during this solar eclipse using a Dobson's spectrometer. They observed an unexpected short term fluctuation in ozone which cannot be explained by variation in the rates of conventional photochemical and dynamical processes during a solar eclipse. They have suggested that a disturbance in the form of compression and rarefaction might have been created at the time of the onset of the celestial phenomenon.

Considering the interesting features revealed by various studies, we strongly feel that more number of experiments should be properly planned during solar eclipse events to confirm eclipse induced effects on atmospheric parameters.

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