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Ground-based Measurements of Some Minor Constituents During the Solar Eclipse - 1995

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ABSTRACT

A ground-based solar infrared spectro-radiometer was used for the measurement of atmospheric minor constituents over Delhi(28.7°N, 77.2°E and 220 meter MSL) during the solar eclipse of 1995. A decrease in water vapour and an increase in the aerosol optical depth were observed during the solar eclipse. An increase in solar irradiance was also evident in the wavelength range of 1200 nm to 1700 nm.

(Key words : Solar eclipse, Aerosol Optical depth, Watervapour, Solar irradiance)

1. INTRODUCTION

The natural phenomena of a solar eclipse is an occasional yet most important event in which solar radiation is completely or partially cut-off from reaching the Earth's atmosphere. Several experimental and theoretical approaches have been investigated to study the influence of solar eclipses on different minor constituents (Hunt, 1965; Silverman *et al.* 1975; Wuebbles, 1979; Elansky *et al.*, 1983; Burnett, 1985; Britayev *et al.*, 1983; Elansky *et al.*, 1992). The observations reported so far been mostly in the ultra violet and visible regions. The infrared radiation constitutes approximately 42% of the total incoming solar radiation(Houghton, 1985), and several minor constituents possess strong absorption bands in the infrared region. Ground-based infrared measurements have been used by several researchers as a means to measure different atmospheric constituents (Camy-peyret *et al.*, 1983; Evans *et al.*, 1992). A ground based solar IR spectroradiometer was installed at the National Physical Laboratory, New Delhi, India, and it has been used for the measurement

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of different atmospheric trace gases (Ghosh *et al.*, 1993). To study the impact of the solar eclipse on some important atmospheric species, especially O_3, NO_2, H_2O and aerosols, efforts were made during the October 24, 1995 solar eclipse. The infrared spectroradiometer was operated for the observations over Delhi, a tropical station where maximum obscuration was 96%.

2. EXPERIMENTAL SETUP

A heliostat was used to track the Sun. The solar radiation was focused on the entrance slit of the spectroradiometer by a Newtonian telescope. The in-built chopper, with a frequency of 163.4 Hz, at the entrance slit converted the continuum light signal to a square wave. The incident radiation was dispersed by the gratings blazed at 1600 nm, and it then passed through the filter to a detector fixed at the exit slit. The electrical signal generated by the detector was amplified by an auto-ranging lock-in amplifier with a preset preamplifier and phase angle settings for four different detectors, with sensitivity 10^{-14} amperes for photovoltaic and 10^{-7} volts for photoconductive detectors. The output of the lock-in amplifier was fed to the computer for data processing and analyses. A block diagram of the system is shown in Figure 1. The experimental details of the system have been discussed in an

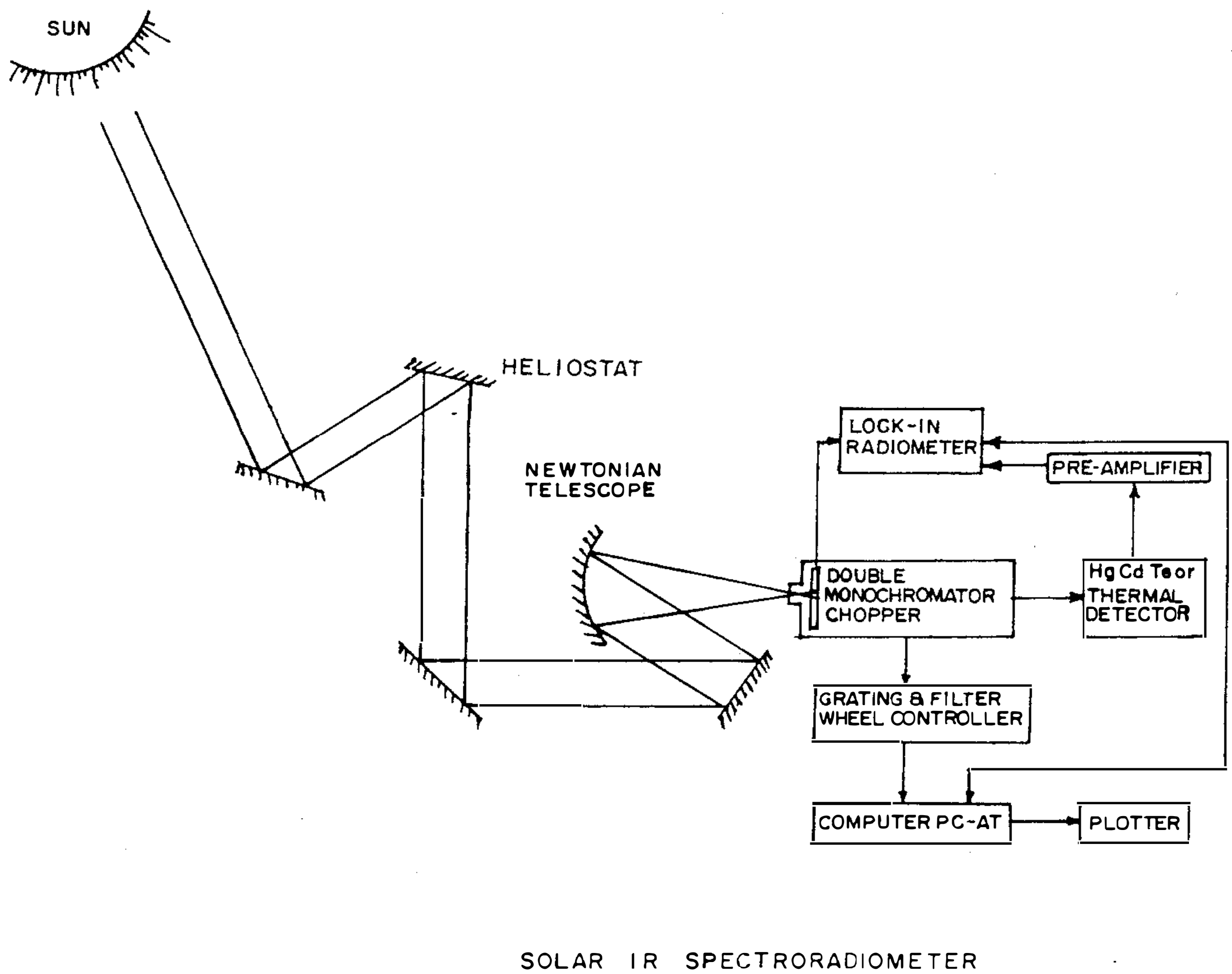

Fig. 1. Block diagram of the infrared spectroradiometer

earlier paper (Ghosh et al., 1993). The system was calibrated with the IR source, and a wide range thermal detector, with the noise equivalent power (NEP) of 10^{-8} watts and sensitive in the spectral range of 700 nm to 20000 nm were used in the present study. The scanning rate was 30 nm/min, and the response time of the lock-in amplifier was 0.3 sec. The uncertainity in calibrated values of irradiance is estimated to have been about 8 %. The corresponding maximum error in the integrated column considering the maximum and minimum values of irradiance in the observed spectra was less than 7%. The stray light for these wavelengths was less than 0.1% with a maximum error of 3%.

3. OBSERVATIONAL TECHNIQUES

Water vapour has strong absorption at 1400 nm, whereas it is almost free from atmospheric absorption at 1200 nm. The large size aerosols present in the atmosphere are mainly responsible for the scattering of solar radiation at 1200 nm. Attempts were made to measure the changes in the water vapour content and the aerosol optical depth during the eclipse. Observations were carried out during, before and after the solar eclipse day. The meteorological conditions were good for these observations. The solar spectra are recorded with 5 nm resolution in the spectral range of 1200 nm to 1700 nm. The observed spectra for 26 Oct 1995 are shown in Figure 2. Other minor constituents also possess absorption bands in the

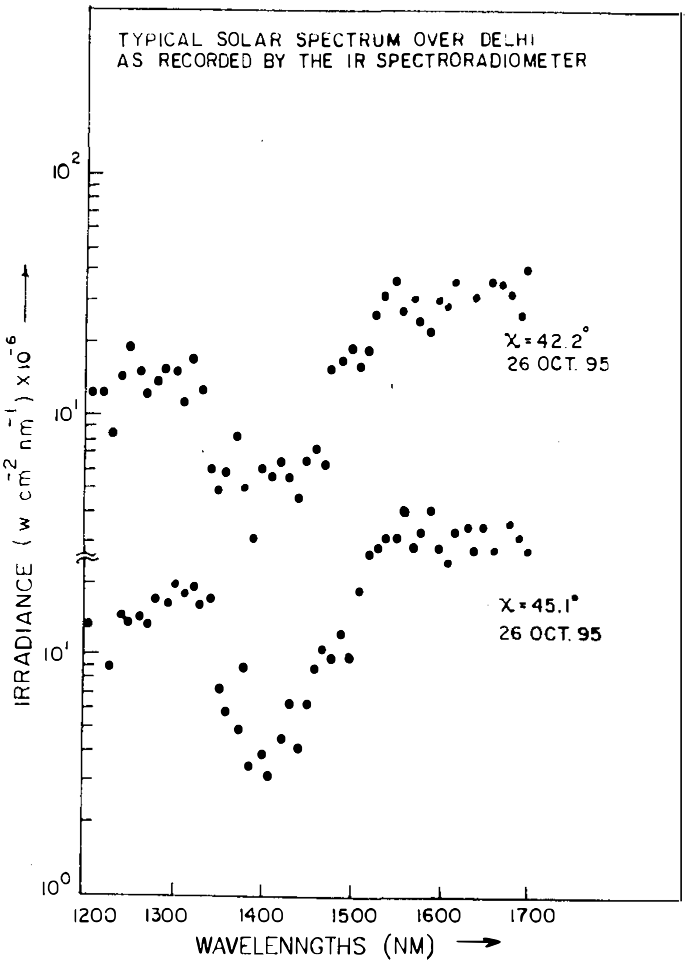

Fig. 2. Observed solar spectrum as recorded by the IR spectroradiometer.

near IR region and in the IR region usally. Different spectra in the spectral range between 1000 nm and 10000 nm were also recorded with 1 nm resolution for the derivation of the integrated column content of O_3, NO_2 and H_2O. The eclipse timing was 0724 Indian Standard Time(IST) to 0952 IST with the maximum phase at 0834 IST. The observations were carried out from 0700 IST to 1100 IST on the eclipse and on other (control) days. Using the recorded spectrum, the aerosol optical depth was obtained following Junge(1963), while the integrated column content of different molecules were determined following Ghosh et al.(1993). The irradiance at the top of the atmosphere(I_0) was derived from the Langley plot and used for the calculation of the aerosol optical depth.

4. RESULTS AND DISCUSSION

The derived aerosol optical depth for different days are shown in Figure 3. The integrated water vapour contents, calculated for different solar zenith angles, are shown in Figure 4. It is clear from these figures that there was a decrease in the water vapour content and an increase in the aerosol optical depth during the eclipse. This decrease in water vapour during the eclipse may have occured due to the decrease in the atmospheric temperature which might have changed the phase of water from a vapour to a liquid state. The increase in the aerosol optical depth may have occured due to the coagulation of liquid water with aerosol, thereby forming larger size aerosols. The possiblity of a local source cannot be eliminated as the night before was Diwali, an Indian festival in which a huge amount of fireworks are set off. Thus, the large amount of sulphur dioxide and other gases realeased in the atmosphere might have converted into aerosols. There was a cooling of about 5°C to 7°C at surface due to which there was a suppressed level of atmospheric turbulence which may have also resulted in the increase of the aerosol optical depth. Other constituents, such as

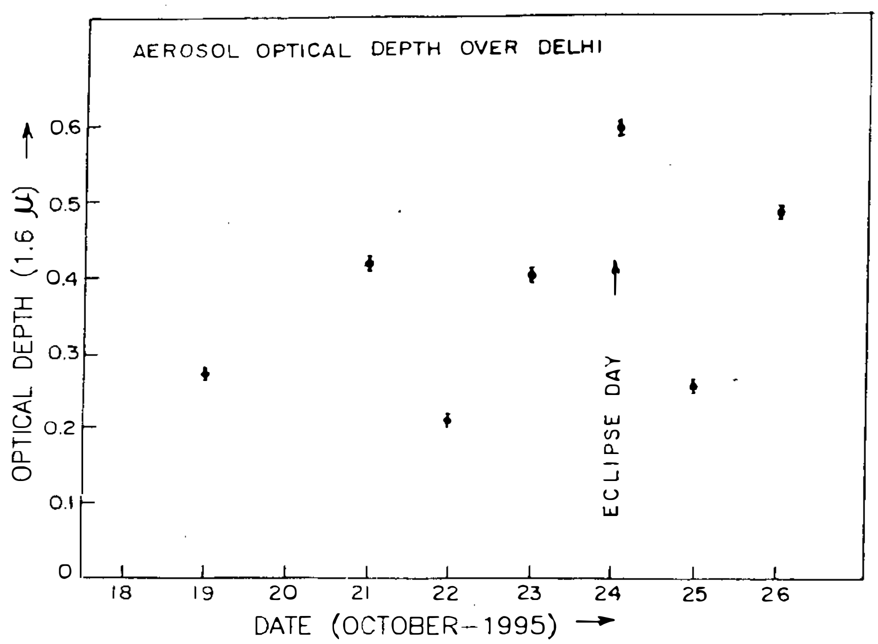

Fig. 3. Day to day variations in aerosol optical depths over Delhi

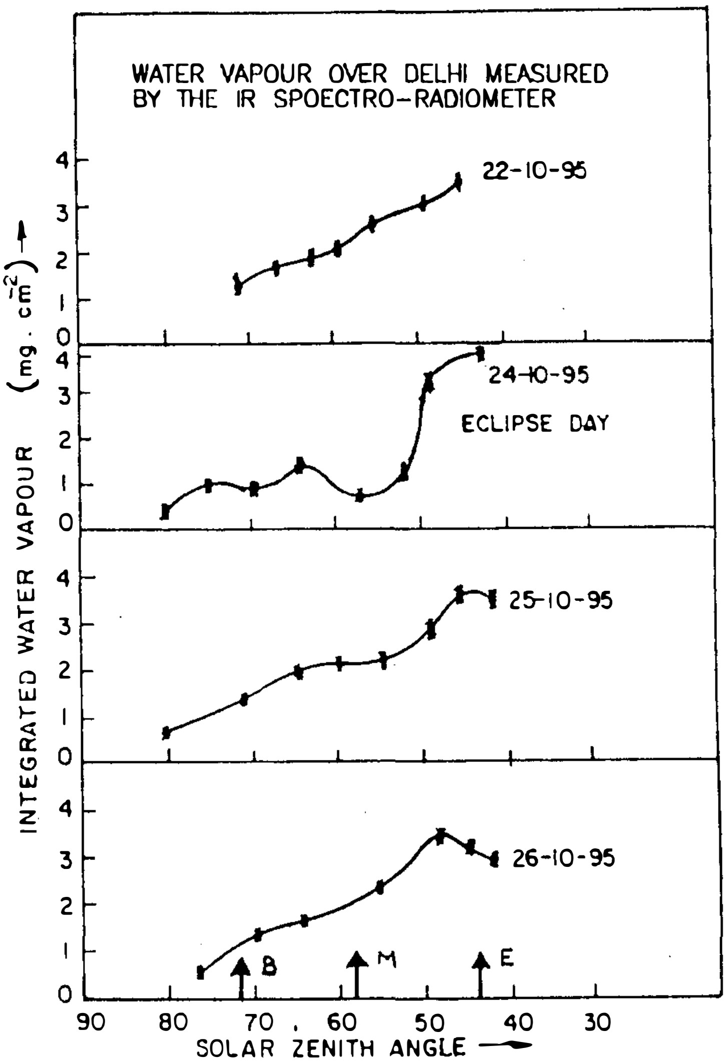

Fig. 4. Variations in the integrated water vapour in the morning hours for different solar zenith angles. B - Begining, M - Maximum phase and E - End of the eclipse.

O_3 and NO_2 were derived, and the preliminary result shows that there is no significant change in the ozone values however, a decrease in NO_2 column content was observed during the eclipse period.

The measured IR irradiance in the spectral range of 1200-1700 nm give rise to an interesting feature shown in Figure 5. There was an increase in the irradiance at 1200 and 1700 nm during the eclipse day compared with other normal day observations. The observed increase may have been due to the scattering of aerosols or due to the reflection and emission from the lunar surface during the eclipse.

5. CONCLUSIONS

On the basis of the experiments, the following conclusions are drawn :

(1) The solar eclipse had only a short-term impact on the minor atmospheric constituents,

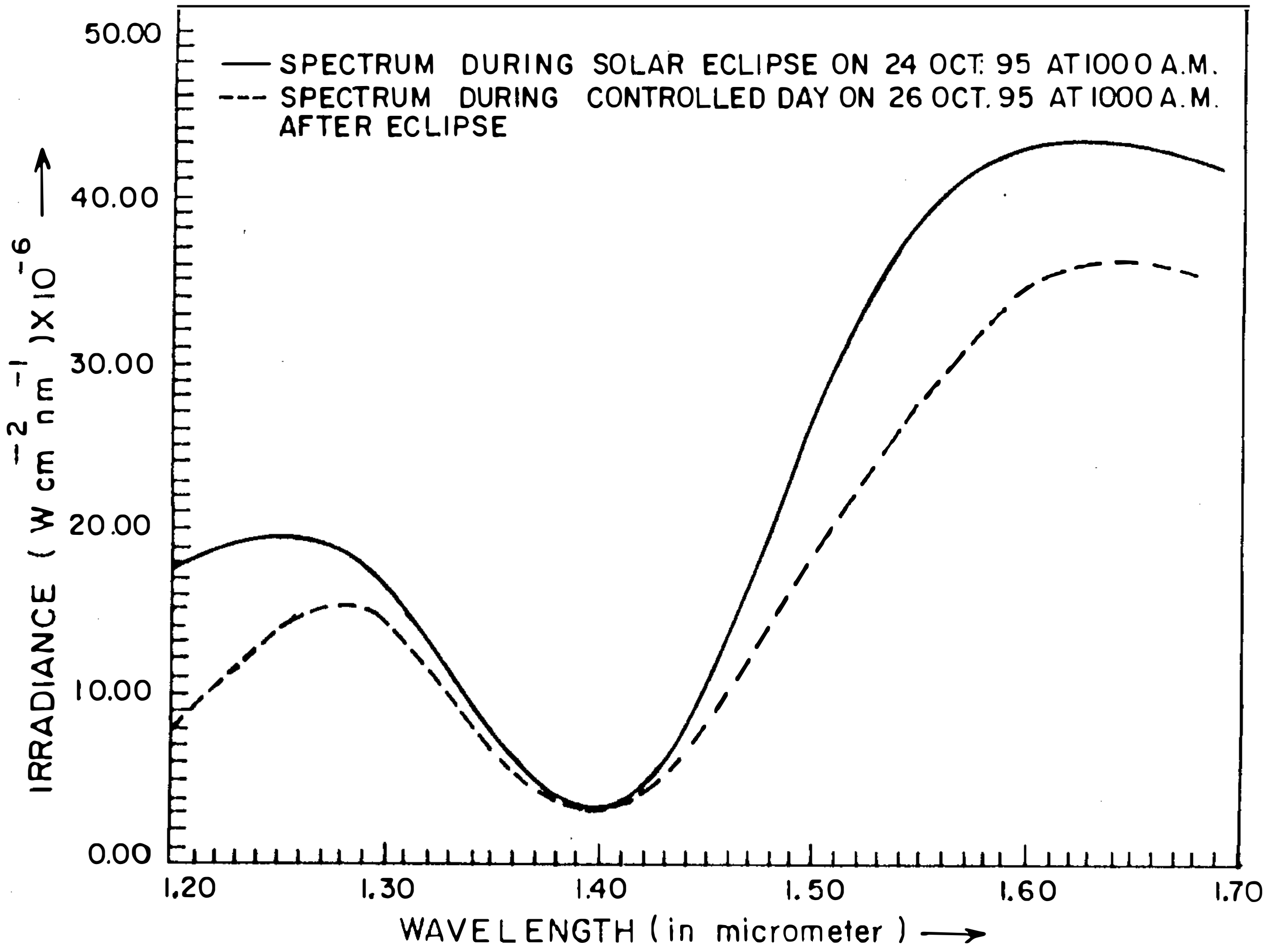

Fig. 5. Direct solar irradiance measured between 1200 and 1700 nm.The solid line shows the solar irradiance obtained on the eclipse day, whereas the dotted line shows the irradiance obtained on anormal day.

especially on water vapour and aerosols.

(2) The observed results are representative for a tropical station, but more supporting observations are required to ascertain the causes of higher irradiance at 1200 nm and 1700 nm as observed in the present case.

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CORRIGENDUM

Authors Kuang-Jung Chen, Yih-Hsiung Yeh and Chuen-Tien Shyu have reported seven production errors that occurred in their article "*Qp* Structure in the Taiwan Area and Its Correlation to Seismicity" appeared on pages 409-429 in the December 1996 *TAO*, Vol. 7, No. 4. They were all in typesetting Eq. (1) to Eq. (7). The correct equations are:

Eq. (1) on page 411,

$$\dot{A}\,(r,f) = A_0(r,f)\; e^{-\pi f t^*}$$

Eq (3) on page 411,

$$A(r,f) = (2\pi f)^2 S(f)\, G(r,f)\; e^{-\pi f t^*}$$

Eq (4) on page 412,

$$\ln(r,f) = \ln A_0(r) - \pi f t^*$$

Eq (5) on page 412,

$$\frac{d(\ln\ A(r,f))}{df} = -\pi t^*$$

Eq (6) on page 414,

$$t^* = \sum_{i=1}^{n} t_i\, Q_{io}^{-1}\, \delta_i$$

Eq (7) on page 414,

$$\delta t^* = \sum_{i=1}^{N} \delta_i T_i \left(\frac{T_{io}}{t_i}\, Q_i^{-1} - Q_{io}^{-1}\right)$$

Also, on the 8th line of page 414, the correct sentence should be:

" t_i is value for the travel time in blocks of the initial model."