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Changes in Surface Irradiance and Meteorological Parameters Associated with the Annular Solar Eclipse of 15 January 2010

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Abstract. An Annular Solar Eclipse (ASE) occurred on 15 January 2010, which was observed in most parts of India. This paper reports the changes observed in solar irradiance and meteorological parameters (temp [T], relative humidity [RH] and dew point) associated with the ASE mainly at three locations (Greater Noida, Kanpur and Hyderabad) in India that are located far away from the eclipse path. A decrease in solar irradiance in the range of 25-59% (maximum in Hyderabad and minimum in Greater Noida) as well as a slight decrease in RH is observed during solar eclipse. The radiosonde and AIRS data show changes in the normal trend of meteorological conditions at different pressure levels indicating strong influence of solar eclipse.

Keywords: Annular solar eclipse, Solar irradiance, Meteorological parameters, HCHO, Aura-OMI satellite.
PACS: 40

INTRODUCTION

The Indian Space Research Organization (ISRO) planned several experiments at various locations in the country to study the influence of annular solar eclipse (ASE) of 15 January 2010 on atmospheric, meteorological, and ionospheric parameters. The maximum magnitude of ASE was 0.919, the longest until 23 December 3043, with a maximum length of 11 min and 7.8 sec at 1.62^0 N, 69.29^0 E [1, 2]. The ASE entered in Indian region at 11:05 IST, reached to maximum phase at 13:20 IST for about 10.4 min and exited India at 15:05 IST. The maximum phase of solar eclipse was seen in India for 10.4 min [3]. A set of observations, meteorological, surface ozone and other trace gases were made at different locations in southern parts of India, Thiruvanathapuram (8.55^0N, 76.77^0E), Kanyakumari (8.48^0N, 77.33^0E), and Kannur (11.9^0 N, 75.4^0 E, 5 m amsl) [2-5]. A strong influence of ASE was observed on the surface ozone, decrease by ~30 ppb, about 25 ppb less than the normal value, while NO_2 increased up to 5 ppb observed increase in NO_2 amount is likely due to low photolysis rate during solar eclipse [4, 5].

Pronounced changes in the lower atmospheric boundary layer dynamics and various meteorological parameters at Gadanki (13.5^0 N, 72.2^0 E), India were observed [6, 7]. The solar eclipse also affected the regional circulation systems which was evidenced by Subrahamanyam and Anurose [2], they observed weakening of the sea breeze flow and random breeze pattern at Thumba (8.5^0N, 76.9^0E) located at the southern tip of India using ground and balloon borne GPS radiosonde. Further, they observed 87% dimming in the solar irradiance from its normal value and decrease in the magnitudes of turbulent fluxes of kinetic energy and surface layer turbulent fluxes of heat and momentum at Thumba. Babu et al. [8] observed changes in the vertical profile of aerosol black carbon in the atmospheric boundary layer associated with the solar eclipse. In this paper, we show changes in solar irradiance and meteorological parameters over three locations, i) Hyderabad (17.22^0N, 78.28^0E), located in the central-southern part of India and two locations in northern India, ii) Greater Noida (28.28^0N, 77.29^0E), located about 50 km east of Delhi and, iii) Kanpur (26.51^0N, 80.23^0E); these three locations are far away from the solar eclipse path. Here, we report quantitative changes in solar radiation flux up to 25 – 59% associated with the annular solar eclipse.

Annular Solar Eclipse of 15 January 2010

The eclipse of 15 January 2010 was seen at annular within a narrow stretch of 300 km (Fig. 1a) across central Africa, Middle East, Maldives, southern India, Bangladesh, Myanmar and China. Fig. 1b shows the Terra (image

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taken at 10.30 hrs. local time) and Aqua (taken at 13.30 hrs. local time) MODIS satellite images over south Asia on 15 January 2010, Aqua image clearly shows dark parts of the image over southern peninsular India and the Bay of Bengal due to reduced sun's intensity at the time of solar eclipse. The dark area seen in the Terra image, left-south corner over the southern Arabian Sea and tropical Indian Ocean indicate the position of the solar eclipse 2-3 hours before its maximum phase over southernmost India.

OBSERVATIONS AND DATA USED

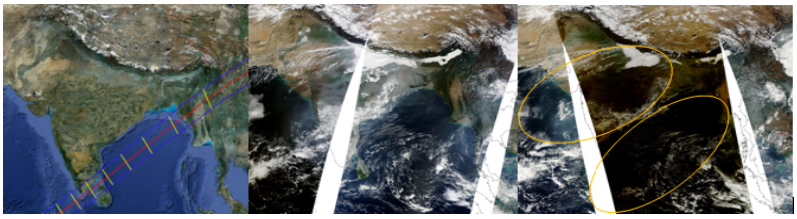


FIGURE 1. (a) shows path, northern (blue) and southern (blue) limits, central in red and yellow lines crossing the path indicate the position of maximum eclipse at 10 minute intervals (source http://eclipse.gsfc.nasa.gov) of annular solar eclipse of 15 January 2010, (b) MODIS Terra (10.30 hrs) and (c) MODIS Aqua (13.30 hrs).

Solar irradiance data (0.3 to 3 micron) over Hyderabad, Greater Noida and Kanpur were measured by Kipp and Zonen pyranometer. Kanpur data are taken from AERONET website (www.iitk.ac.in/aeronet). Hyderabad data are obtained at National Balloon Facility campus and we operated a pyranometer at Greater Noida location. The meteorological data are taken through the website (http://meteo.infospace.ru/wcarch/html/index.sht). Furthermore, radiosonde data were also used for three days 14 (pre-eclipse), 15 (during eclipse) and 16 (post-eclipse) January 2010, available over Delhi (28.58^0N, 77.20^0E, 216 m amsl) and Colombo (6.90^0N, 79.86^0E, 7 m amsl).

RESULTS AND DISCUSSION

Figure 2 (a-c) shows the daytime variation of solar irradiance flux (Wm^{-2}) observed on 14, 15 and 16 January 2010 at Greater Noida, Kanpur and Hyderabad, respectively. The solar flux variations in Greater Noida show lower values due to cloud cover during the most parts of the day. As a direct consequence, the effect of the solar eclipse in the irradiance flux over the region is not clearly observed, despite the fact that for the time interval of the solar eclipse the irradiance on 15 January is significantly reduced from the values of the previous and next days. The maximum intensity of solar irradiance (690 W m^{-2}) over Kanpur is observed on 14 January 2010 whereas very low on 16 January 2010 in the range of 0 - 100 W m^{-2} due to dense haze and fog. On the day of solar eclipse, solar flux varies up to 400 Wm^{-2}, while the several peaks and gaps indicate partly obscure of the observations by clouds. The observed solar flux is likely to be affected by the clouds which was difficult to avoid. The effect of the solar eclipse in the reduction of solar flux is clearly seen during 11:15 to 15:10 hrs. However, it must be noted that during this time interval some cloud formation affected the irradiance measurements causing some peaks and gaps during 11:10 to 13:00 hrs LST, while from 13:00 to 14:00 the solar flux was gradually decreasing and increasing again till 15:00 LST. Overall, the decreasing pattern in the solar irradiance at the duration of the solar eclipse is clearly observed over Kanpur contrary to the observations in Greater Noida. Hyderabad is located at a lower latitude, therefore, the solar flux is larger compared to other two locations (Kanpur and Greater Noida). On 16 January, the solar flux over Hyderabad is larger and shows normal diurnal behavior, the maxima peak of the solar flux is observed during noon time. The measurements on 14 January 2010 show low solar flux values associated with small diurnal variations because of cloudy conditions over Hyderabad. The effect of solar eclipse is clearly visible on the solar flux observed over Hyderabad with a minimum solar flux at 13:10 hrs at the time of maxima phase of the solar eclipse (Fig. 2c). In the morning hours of 15 January 2010 the solar flux does not present a gradual increase, as in the 16 January, due to partly cloudy conditions reducing the solar amount at the surface. However, the large gap from 12:00 to 14:00 hrs LST is indicative of the solar eclipse and is not attributed to dense cloud formation, which is not favored in this season due to stable weather conditions.

Comparing the daily average of the total solar flux on 15 January 2010 and for the whole month of January (Figure 3a) for three locations, the solar flux was found to be reduced up to about 32%, 25% and 59%, at Kanpur,

Greater Noida and Hyderabad, respectively on the solar eclipse day for the duration of the solar eclipse compared to the average solar flux received over these cities for the same duration for the month of January 2010. The small change in solar flux over Greater Noida is likely due to greater distance along the path of the solar eclipse and is also due to higher latitude. The change in solar flux over Greater Noida was observed to be larger in the afternoon hours i.e. declining phase of the solar eclipse. Subrahamanyam and Anurose [2] found 77% loss of solar flux due to solar eclipse at the southern station Thumba (8.5^0N, 76.9^0E), while Nishanth et al. [3] observed 89% loss of solar flux during the maximum phase of the solar eclipse at Kannur (11.9^0N, 75.4^0E).

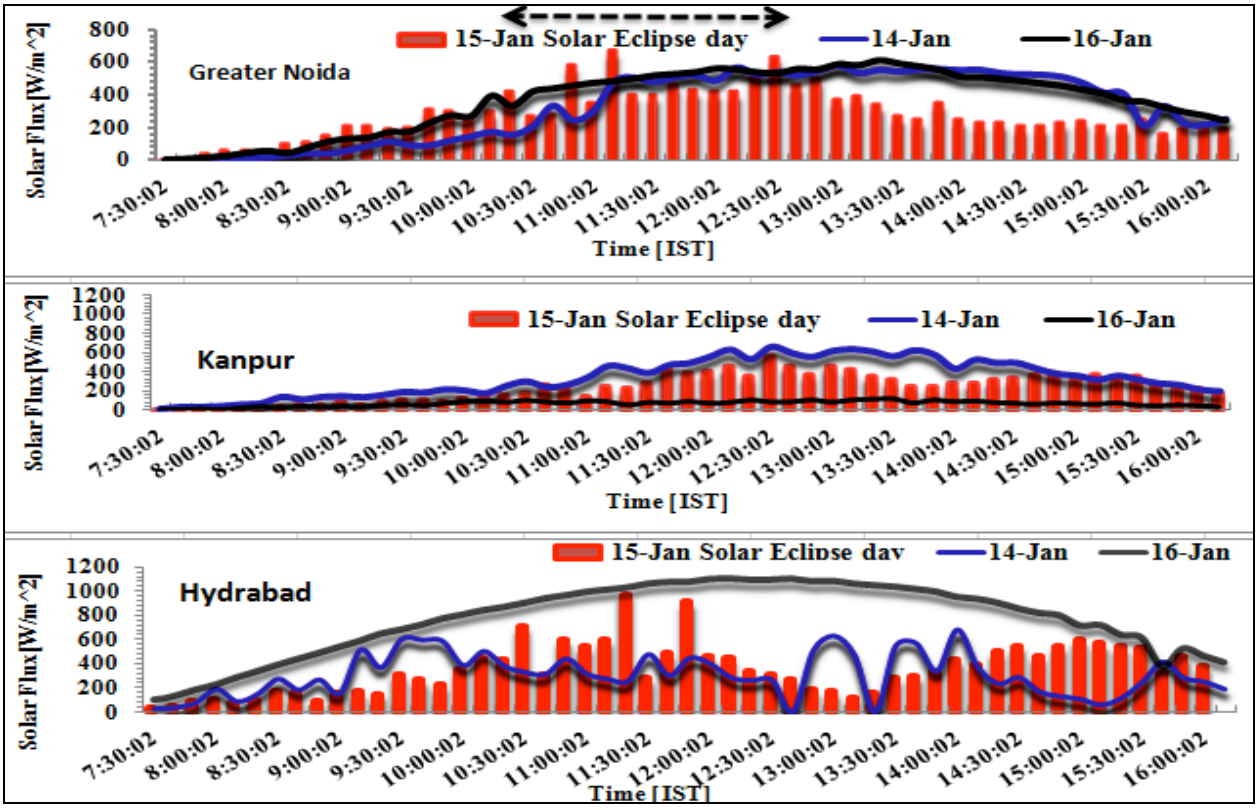
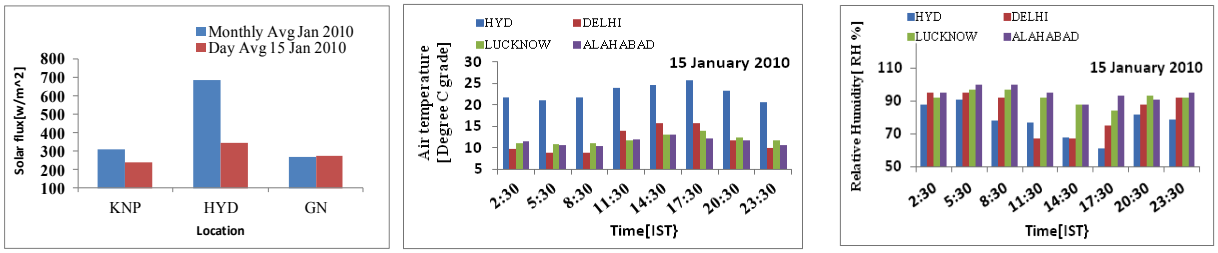


FIGURE 2. Solar flux measured on 14-16 January 2010 during 7.30 – 16.10 hrs at (a) Greater Noida, (b) Kanpur and (c) Hyderabad; dotted arrow on the top shows duration of the observed solar eclipse.



(a) (b) (c)

FIGURE 3. (a) Comparison of observed average solar flux in the month of January 2010 and average on the solar eclipse day (15 January 2010) during 7.30 – 16.10 hrs at Kanpur, Hyderabad and Greater Noida, variations of air (b) temperature and (c) relative humidity during 7.30 – 16.00 hrs at Kanpur, Hyderabad and Greater Noida.

Meteorological parameters (air temperature and relative humidity) over Hyderabad and at three locations in the northern India, i.e. Delhi, Lucknow (about 70 km north-east of Kanpur) and Allahabad (about 200 km east of Kanpur) are shown for the day of solar eclipse (15 January) for different times during the day (Figure 3b,c). It is difficult to infer the influence of solar eclipse on air temperature, however, relative humidity is found to drop during

solar eclipse (clearly infer at time 14.30 hrs) almost at all the three stations (Figure 3c). Since we do not have continuous record, it is difficult to say that if the drop in relative humidity (RH) is associated with the solar eclipse. The drop in RH is higher at Hyderabad during solar eclipse compared to other locations (Figure 3c).

A comparison of relative humidity over Delhi and Colombo show a reduction in the relative humidity from 45% on the surface to about 7% in the pressure level 700 – 500 hPa, a maxima peak of relative humidity at 300 hPa. Such anomalous changes could be attributed to the solar eclipse but it is difficult to affirm due to non availability of data on other dates. We also show relative humidity at Puttalam (8°02'N, 79°50'E) on 14-16 January 2010 observed at 06.00, 12.00, 18.00 and 24.00 hrs, drop in relative humidity is clearly observed on the day of solar eclipse (Figure 4a). At Puttalam location (8^0 02'N, $79^0$50'E), the relative humidity is shown for

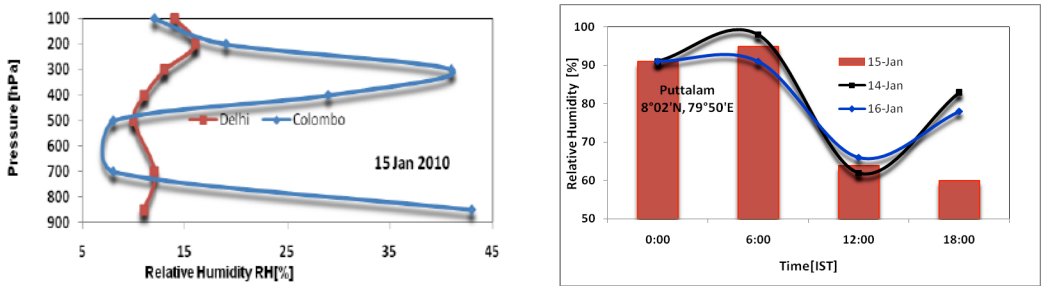


FIGURE 4. Variation of relative humidity (%) (a) on 15 January 2010 at Delhi and Colombo, and (b) at Puttalam on 14 – 16 January 2010, a sharp reduction in relative humdity is observed at 18 hrs on the day of solar eclipse.

different times for 14-16 January 2010, on solar eclipse day, 15 January 2010 the relative humidity shows pronounced drop (Figure 4b) associated with the solar eclipse.

SUMMARY

Our results show a pronounced drop in solar irradiance during solar eclipse at Hyderabad, Kanpur and Great Noida. The maximum change in solar irradiance observed at low latitude stations close to the path of the solar eclipse far away from the path, at higher latitude the decrease in solar irradiance is found to be less. The duration of drop in the solar irradiance varies depending upon the time of solar eclipse along the path. A quantitative reduction of solar flux and changes in meteorological parameters observed at three different locations will be of great importance in understanding the solar terrestrial scientists in understanding the solar-terrestrial processes.

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