Variations in low-latitude middle atmospheric thermal structure during the 15 January 2010 solar eclipse

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The altitude profiles of middle atmospheric temperatures are examined to study the effects of the solar eclipse on 15 January 2010 as it passed through the Indian longitudes. It was found that thermal structures exhibited strong inversion layers on the eclipse day, with large temperature deviations around 45, 50, 60, 75, 82 and 92 km altitudes compared to normal days. Fourier analysis revealed no significant changes in the gravity wave characteristics; however, the amplitudes of the observed waves were significantly higher (~ two times) compared to the normal days.

Keywords: Inversion layers, middle atmosphere, solar eclipse, thermal structure.

THE solar eclipse is a unique opportunity to study the effects of sudden thermal gradients brought into the atmosphere. During a solar eclipse, the shadow of the moon decreases the incoming radiation from the sun, causing changes in electron content, neutral composition and temperature. There are several reports suggesting large changes in the ionospheric parameters such as electron density/content and F-layer parameters[1–4]. Also, during a solar eclipse the shadow of the moon projected over the earth's atmosphere acts as a cooling source that propagates at supersonic speed. It can contribute to a gravity wave field and build up a wavefront that may produce atmospheric/ionospheric disturbances[5,6]. However, reports on the response of middle-atmospheric thermal structure to a solar eclipse are limited[7,8]. The 15 January 2010 eclipse over Gadanki (13.5°N, 79.2°E) had maximum obscuration of 82% at ~ 1330 h IST. Figure 1 shows the path of the eclipse in the Indian zone. We scrutinized the aspects of persistent changes in middle atmospheric temperature caused due to this eclipse with the help of satellite data.

We utilized data of sounding of the atmosphere using Broadband Emission Radiometry (SABER) on-board the Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) satellite for 13–17 January 2010. We used SABER version 1.07 temperature data for the present study. The SABER data have good temperature accuracy, with errors of order of ± 1.4 K in the lower stratosphere, ± 1 K in the middle stratosphere and ± 2 K in the upper stratosphere and lower mesosphere[9]. To optimize the data quality for a study of eclipse effects over the middle atmosphere, we used a grid of 10–20°N and 70–90°E for the SABER data. With this, we had 23 satellite profiles during 13–17 January 2010 (13 January – 6, 14 January – 6, 15 January – 3, 16 January – 6 and 17 January – 2) which can be utilized to obtain the persistent features in the middle atmosphere representing that particular day.

The partial reflection (PR) radar at 1.98 MHz was operated from Tirunelveli (8.7°N; 77.8°E). The PR radar makes use of the spaced antenna technique, and samples the horizontal winds in the 60–98 km altitude region. Full correlation analysis has been carried out to deduce the wind components following standard procedures presented elsewhere[10]. For the present study we utilized the average wind profiles for 0600–1800 h IST for a suitable comparison of eclipse effects on the middle atmospheric dynamics.

Figure 2 shows the temperature profiles obtained for altitude range 30–120 km observed during 13–17 January 2010. The latitude, longitude and time of satellite pass are shown in legends. One may note that gravity wave-like oscillations persist at the middle atmosphere throughout the duration under consideration irrespective of the time. An increase in the temperature values from 30 to 50 km altitudes and then a decreasing trend in temperature up to ~ 95–100 km altitudes followed by a sharp increase can be clearly noted in all the plots. The stratopause altitude, often described as the altitude of temperature maxima around 40–60 km, is consistent. Also, the mesopause altitude, described as the altitude of temperature minima around 70–100 km, is found to be around 95–100 km, consistent with a recent report[11].

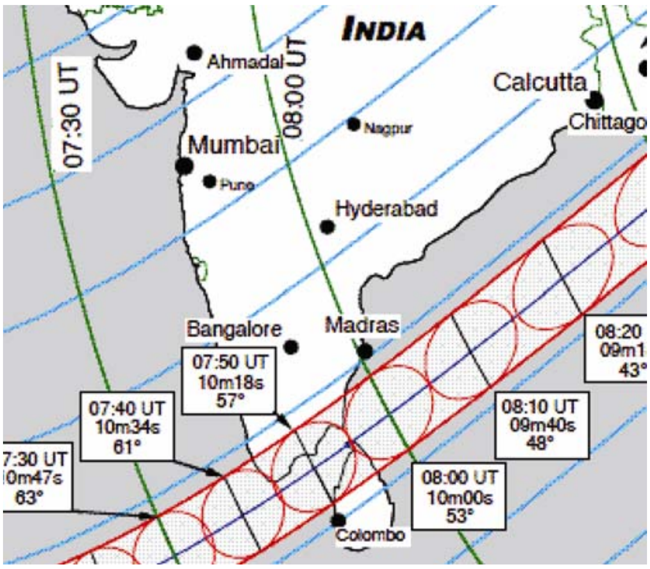

Figure 1. The 15 January 2010 solar eclipse path over the Indian zone (source http://eclipse.gsfc.nasa.gov/SEmono/ASE2010/ASE2010.html).

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Considering the eclipse day (15 January 2010) as a special case, 13, 14, 16 and 17 January were treated as normal days. The average profiles for individual-day of satellite passes were hence subtracted with the average of profiles observed on 13, 14, 16 and 17 January 2010 to find out the deviations of individual day from the normal day averages during the period under consideration. We plot these deviations in Figure 3, with *x*-axis as altitude and *y*-axis being the deviation in average daily temperature value from the average mean value for normal days. One may note large oscillatory features on all the cases, with eclipse day variability being significantly larger than the other days. Noteworthy are the presence of waves with short vertical wavelengths of ~ 5–10 km on all the days. A large amplitude (~ 15 K) wave was noted on 15 January at the upper mesospheric altitude (80–100 km) with vertical wavelength ~ 15 km.

To find out if there was substantial difference in wave characteristics on the eclipse day compared to the normal days, we carried out spatial Fourier analysis on the temperature deviation data as described in Figure 3. The results of the Fourier analysis are shown in Figure 4. It is evident that waves with vertical wavelengths ~ 2 km, 3 km, 5–6 km and 10–15 km are dominant in the data. One may note that in terms of vertical wavelength spectra, it is difficult to find differences between eclipse day and the normal days, which indicates that possibly no specific waves generated by the eclipse existed for long durations so as to be observed in the mean thermal structure. However, one can note that the amplitudes of waves on the eclipse day are much larger compared to the normal days. Also, on normal days, for 2–4 km vertical wavelengths, the amplitudes are ~ 1 K, whereas on the eclipse day they are ~ 2 K. Similarly, vertical wavelength spectra at 5–6 km wavelength scales reveal maximum amplitude of ~ 2.2 K on normal days, which is ~ 3.8 K on the eclipse

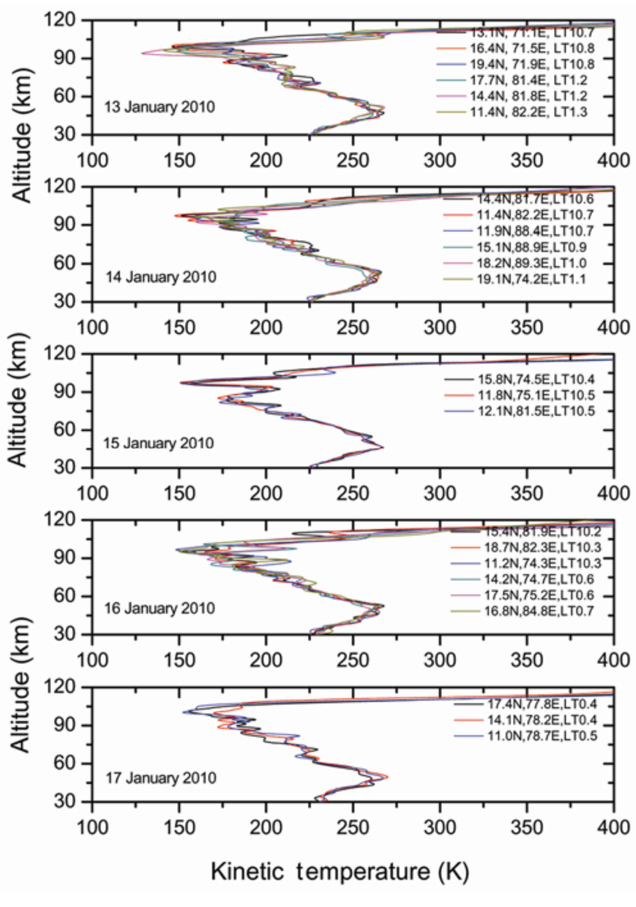

Figure 2. SABER-deduced temperature profiles for altitude range 30–120 km. Shown as legends are coordinates and local time of observation.

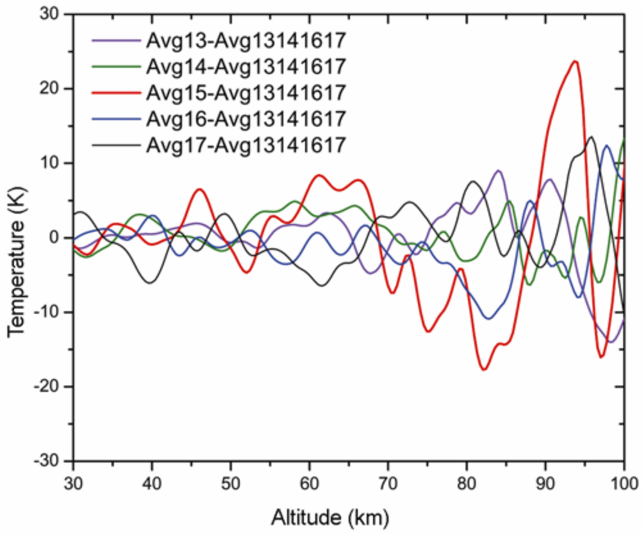

Figure 3. Temperature deviation on individual days from control (normal) days (i.e.. 13, 14, 16 and 17 January 2010). Large oscillations are noteworthy on all the days, with 15 January 2010 having the largest amplitude.

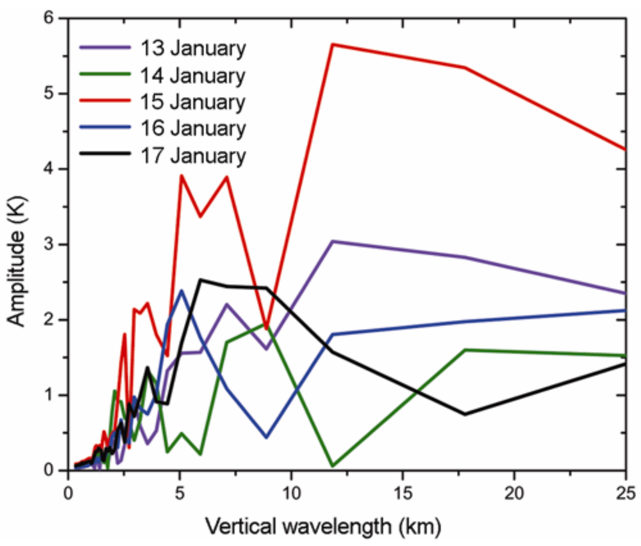

Figure 4. Vertical wavelength spectra for daily average temperature profiles during 13–17 January 2010. Note the existence of similar wavelengths on all the days.

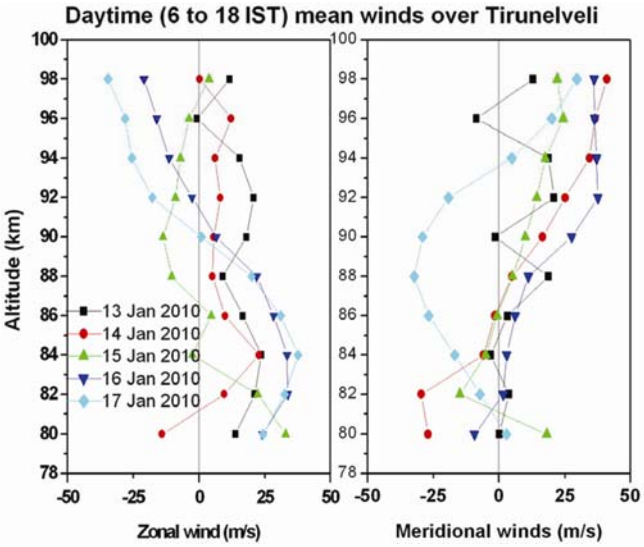

Figure 5. Daytime mean zonal and meridional wind profiles as observed by MF radar over Tirunelveli (8.7°N; 77.8°E).

day. Further vertical wavelength spectra of 10–20 km scales exhibit amplitude of ~ 5.7 K on the eclipse day, which is approximately double compared to the spectral amplitude on normal days.

The solar eclipse effects on the middle atmosphere are not well understood so far. The excitation of some distinct wave modes which should be uncommon to the normal days due to the sudden cooling effects of moon shadow was anticipated[5]. It is noticed that the thermal structure shows significant differences on the eclipse day compared to the normal days, which is possibly because of solar isolation effects. The decrease in the mesospheric temperature at ~ 80 km and increase in temperature at ~ 90 km is evident in the data. However, it is difficult to confirm whether such changes are caused by cooling and heating associated with solar eclipse-induced effects on the O_3 chemistry as anticipated because of the strong wave modulations. Also, the deduced vertical wavelength spectra of SABER data showing the existence of similar vertical wavelengths clearly indicate that there were no special wave modes triggered by the solar eclipse of 15 January 2010 while its passage through the Indian longitudes. Our results are in contrast to the study made by Aushev *et al.*[12], who reported substantial changes in mesospheric temperature during the eclipse time. They also reported the presence of wave-like oscillations in their data. However, their dataset does not include consecutive days and close to the eclipse day. Hence the discussion on the specific waves generated by eclipse is debatable. There is a possibility that we do not notice any substantial changes in SABER data because the satellite passes have large time differences from the time of obscuration. Nonetheless, as our motive is to see the persistent changes in the middle atmosphere caused by the eclipse, the present study is limited to the large-scale impacts.

Of interest are larger amplitudes of the waves observed on 15 January 2010 compared to the normal days. A viable explanation for such large amplitudes on the eclipse day is as follows. When the shadow of the moon moves from west to east at supersonic speed, instant cooling is induced in the earth's atmosphere and temperature gradients are induced on the eclipse path. The advancing edge of the shadow continuously moves ahead to cool the atmosphere, at the same time reducing the temperature gradient. This in turn will result in reduced zonal winds. The reduced zonal winds will result into less wind-induced wave-filtering processes throughout the atmosphere. Therefore, the wave inputs to higher altitudes will become larger compared to the normal days. To examine the above, we plot in Figure 5 zonal and meridional winds averaged for 0600–1800 h IST, measured by MF radar. It can be noticed that on the eclipse day the wind magnitudes were significantly lower compared to the other days. The mean winds for 13–17 January 2010 at ~ 85 km altitude were estimated to be ~ 18, 12, 6, 25 and 32 m/s respectively. This indicates significant reduction in mean winds on the eclipse day and hence weakening of the wave-filtering processes because of the winds. This in turn indicates more wave energy inputs to higher altitudes on the eclipse day as noticed in the SABER data.

The unavailability of time-series data on mesospheric temperature limits us to carry out a comprehensive study on the sustainable effects of the eclipse at mesospheric altitude. However, the current study indicates that possibly the increased wave energy inputs due to eclipse-induced reduction in mean winds are more important for large-scale middle atmospheric circulation than the triggered waves. A comprehensive study, including ground and space-based measurements on temperature and wind fields in the middle and upper atmosphere will throw some light on these unexplored aspects.

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An efficient high-throughput protocol based on 2D-HN(C)N for unambiguous H^N and ^{15}N backbone assignment in small folded proteins in less than a day

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An efficient high-throughput method for sequential assignment of backbone $^1H^N$ and ^{15}N, atoms in less than a day (using 2–4 2D spectra; total data collection in 4–8 h) has been proposed here. This is based on sequential correlations and specific patterns of peaks around the glycines, alanines, serines/threonines (internal check points) observable in the F_1–F_3 projection planes of the 3D-HN(C)N spectral variants. The F_2–F_3 projection planes of the spectra provide unique identification of the check points. The protocol has been demonstrated on two $^{13}C/^{15}N$-labelled proteins: ubiquitin and calbindin-D9k. In either case complete H^N and ^{15}N backbone assignments were obtained in less than a day each. The method would be valuable for NMR structural studies of small, well-folded proteins.

Keywords: Backbone assignment, check points, sequential amide correlation, structural proteomics.

BIOMOLECULAR nuclear magnetic resonance (NMR) spectroscopy has expanded dramatically in recent years and is now a powerful tool for the study of structure, dynamics and the interactions of biomolecules[1]. The only limitation for high-throughput NMR studies in the context of proteomics research is the long time needed to record a set of multidimensional NMR experiments for sequence-specific assignment and thus for structure determination. This also imposes a condition of long-term stability on the protein samples. Additionally, some proteins in solution tend to precipitate in a matter of days, thereby reducing the time available to record NMR data. This has shifted the focus of methodology development in NMR to: (i) reducing the number of NMR experiments to derive the required information, (ii) increasing the speed of data collection, and (iii) developing high-throughput procedures and algorithms/techniques for fast data analysis. There have been efforts to reduce the experimental time by adopting reduced dimensionality techniques[2–4]. Even so, these methodologies require either extensive collection of NMR data[3,4] or the data analysis is not straightforward[2]. In this background, we present here an efficient protocol based on 2D versions of HN(C)N[5,6] to obtain unambiguous sequence-specific H^N and ^{15}N backbone assignment in small, well-folded proteins.

The protocol basically extracts the necessary information (sequential correlations and check points for assignment of $^1H^N$ and ^{15}N atoms) from two experiments, termed herein as (i) 2D-hncNH (or the F_2–F_3 projection plane of the 3D-HN(C)N spectrum[5,6] recorded by avoiding the t_1 evolution) which provides unique identification of the check points, and (ii) 2D-hNcnH (or the F_1–F_3 projection plane of 3D-HN(C)N spectrum[5,6] recorded by avoiding the t_2 evolution) which provides two types of amide correlations on the ^{15}N–^1H HSQC-type spectrum: (i) intra-residue correlation [$^1H^N_i$–$^{15}N_i$] and (ii) inter-residue correlation [$^1H^N_i$–$^{15}N_{i+1}$]. Each of these can be recorded in a few hours time (1–2 h). These acquisition times are much less than what would be required for 3D experiments. Moreover, these can be recorded with larger number of increments and scans per FID without significantly increasing the acquisition time. Moreover, in such 2D-projection experiments, the slight signal attenuation

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