A comparative study of VLF signals from several transmitters around the world as observed from Maitri station, Antarctica

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Abstract

To examine the behavior of the sunrise and sunset terminators, characteristics of the solar activities in the polar region and the possible seismic correlation with ionospheric anomalies a Stanford AWESOME VLF receiving system was installed at the Indian permanent Antarctic station Maitri during the 27th Indian scientific expedition to Antarctica. Almost five weeks of data was recorded successfully from several transmitters around the globe. The narrow-band signals show variation of the solar radiation and the signature of the prolonged day and night. We compare the signal of frequency 18.2 kHz with the same signal received at Kolkata and we present simultaneous observation of the variation of the sunrise and sunset terminators. We compare the diurnal signal amplitude variation with the LWPC model. We also present the broadband signal, contains the signature of sferics. The signals do not have a strong signature of whistlers because at the conjugate points, the lightning effects are minimum.

1 Introduction

Indian Centre for Space Physics, Kolkata (ICSP) participated in the 27th Indian Antarctica expedition, 2007-2008 during the summer period to observe the long distance propagation characteristics of the Very Low Frequency (VLF) signal. The data was recorded at the Indian permanent station Maitri (Lat. $70°45'57''$, Long. $11°44'09''$ E) from 5th January to 15th February 2008. Our main observing transmitter was the Indian Navy's VLF transmitter VTX which is located at Vijayanarayanam (Lat. $08°26'$, Lon. $77°44'$). For Antarctica, the propagation path is very long and is totally over the ocean. During this observation, we chose the summer period of the southern hemisphere in such a way that we got the "full day and no night" (no true sunset) condition as well as the true sunset condition. To understand the signal characteristics for a very long path and the changes of the sunrise/sunset terminators under an anomalous solar flux variation, Antarctica is absolutely a perfect place for these observations as the length of the day or the night can be very long. The prolonged day or night gives a test bed for verifying theoretical models of how an ionization and recombination take place. The sunrise and sunset terminators shifts, if any, would be higher before earthquakes, as the solar effect is minimum due to high inclination. So it is easier to study the possible correlation between ionospheric anomalies and seismic activities. As the place is near the polar region, the accumulation of the charged particles coming out from the sun or extra-terrestrial source can well interact with the magnetic field and the recorded signal will carry the information of these interactions.

2 The Instruments

The receiving station was built up at the vicinity of Indian permanent station Maitri. We have used crossed loop antenna of dimension 30ft $\times$ 30ft at the base, and 15ft in height (right panel of Fig. 1). The great circle distance of the transmitters from the receiver is much larger than that of the main receiving station (Kolkata) and therefore we have used antenna with larger area to receive the signal. We use the Stanford AWESOME VLF receiving system for data acquisition. In Antarctica we received seven transmitting frequencies and one channel has been tuned for receiving and checking the local signal generating from natural sources.

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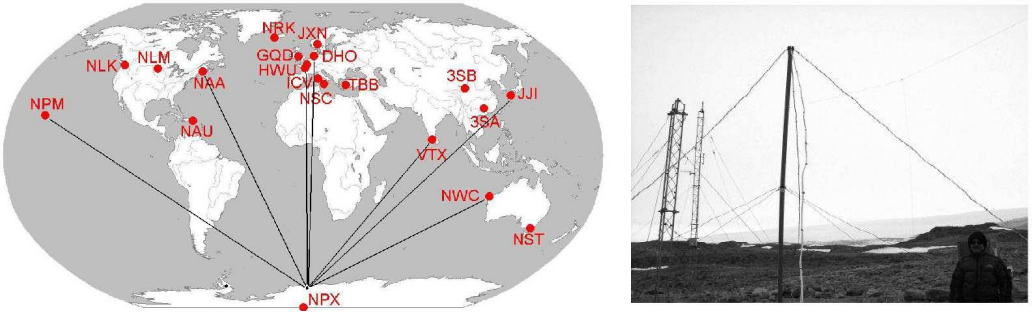

Figure 1: [Left]The positions of the transmitters we expected to receive. [Right]The cross loop VLF antenna at the Indian Antarctic station Maitri.

3 The Observations and Results

The AWESOME receiving system at Maitri worked satisfactorily. Though we tuned our receiving system to receive seven transmitting frequencies only data from VTX was less noisy. To compare the results with Kolkata we ran a similar AWESOME set up at Kolkata.

In presenting the data received at Maitri station we used the Universal Time (UT) because that is the local time for Maitri. For Kolkata we used the Indian Standard Time (IST) (UT+05:30:00). In the left panel of Fig. 2, we present the broad-band data of the receiver. This shows the entire received frequency band (0-50 kHz). The background was not entirely noise-free since the generators were used to supply powers. The horizontal lines represents the very low frequencies. The spectrum also has some vertical lines which are the signatures of the sferics.

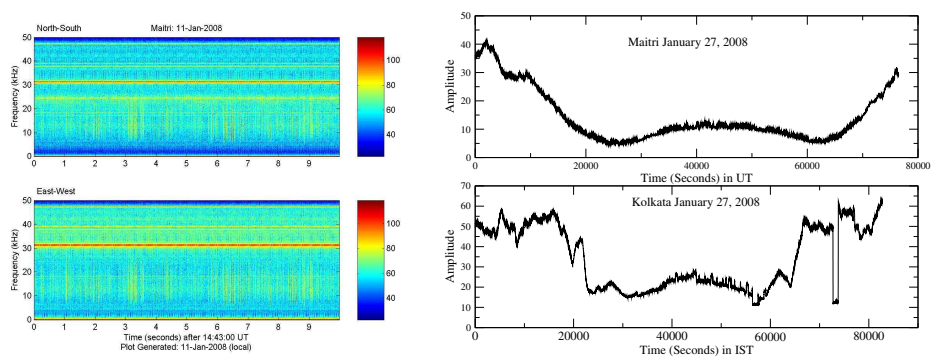

Figure 2: [Left] The broadband data received from Maitri stations for 11th January 2008 recorded at 14:43:00 UT for the time period of 10 seconds. The upper panel is for the north-south antenna and the lower panel is for the east-west antenna. [Right] The variation of signal amplitude as observed from Maitri station (see text for details).

In the right panel of Fig. 2, we present the signal amplitude of VTX of 18.2 kHz received at Maitri (Upper panel). In this Figure we plotted the data of 27th January, 2008. We compare it with the data received from Kolkata (Lower panel). The data received from Maitri is totally different that of from Kolkata. First of all the signal strength is weaker due to long distance propagation. In Kolkata, there are night-time signal fluctuations and a strong drop and rise of the signal amplitude during the sunrise and sunset terminators respectively. The sunrise and sunset terminators are quite distinct and the signal shows the clean signature of the D-layer appearance and disappearance. In Maitri, as there was no true sunset there was 24 hour of sunlight and solar radiation is always dominant. So there are no night-time fluctuations. As there is no sunset it is obvious that the D-layer does not disappear completely. So the changes of solar flux due to the rotation of the sun can only change the height and the ion-density profile of the ionosphere and these

changes are not drastic. That is why the signature of D-layer appearance or disappearance is comparatively flatter and there is no sign of the so called "terminators". The changes in the data is due to slower regular solar flux variation. The D-layer preparation time and the disappearance times are very long and there is a distinct signature of the solar flux variation with zenithal angle around the mid day.

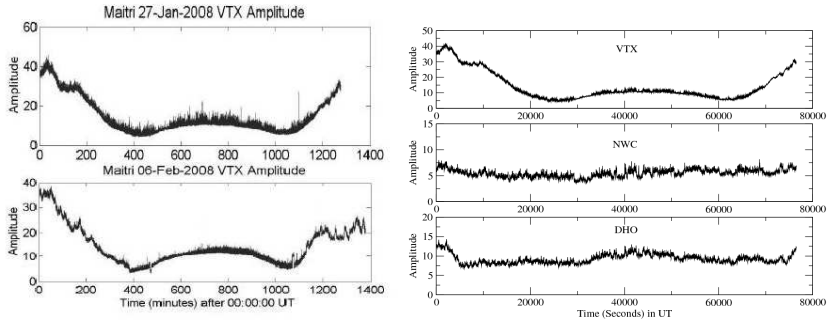

Figure 3: [Left] Narrow-band VTX data at 18.2 kHz at Maitri station on two days. (upper panel) Data recorded on 27th January, 2008 when there was no true sunset. (lower panel) Data recorded on 6th February, 2008, when there was a true sunset for a few minutes. [Right] Samples of the narrow-band data from several stations on 27th January, 2008. The upper panel is for VTX, the middle is for NWC and the lower is for DHO. Note the signal from NWC is very noisy and weak despite being more powerful station and closer to Maitri than VTX. DHO signal is also noisy and weak.

In Fig. 3 (left) we plot the data received from two different solar condition. The upper panel is the data during the time where there was no true sunset (27th January, 2008) and the lower panel is the data when there was true sunset (6th February, 2008) for few minutes. Clearly the data for 6th February shows the night time signal amplitude fluctuations for a shorter time period. In Fig. 3 (right) we show a comparison of signals from VTX, NWC and DHO stations which are at a distance of 10045 km, 8169km and 13775km respectively from the receiver. Note that the NWC transmitter, though more powerful than the VTX transmitter and though NWC-Maitri path also over the sea, the received signal is very weak, noisy and less varying than the VTX data.

We compute a calibration curve where we compare how the sunrise and sunset terminators (if any) change with the local sunrise/sunset time. We also compare it with sunrise/sunset time of Kolkata and VTX. In Fig. 4 (left) we plot the sunrise/sunset time at Kolkata (SR-KOL/SS-KOL), VTX(SR-VTX/SS-VTX) and Maitri (SR-MAITRI/SS-MAITRI) and the sunrise/sunset terminators (SRTERM-MAITRI) and (SSTERM-MAITRI) as a function of days. The plot is in UT. The plot shows that the sunrise and sunset terminators exhibit regular variation but their changes with respect to the true sunrise/sunset time is very slow.

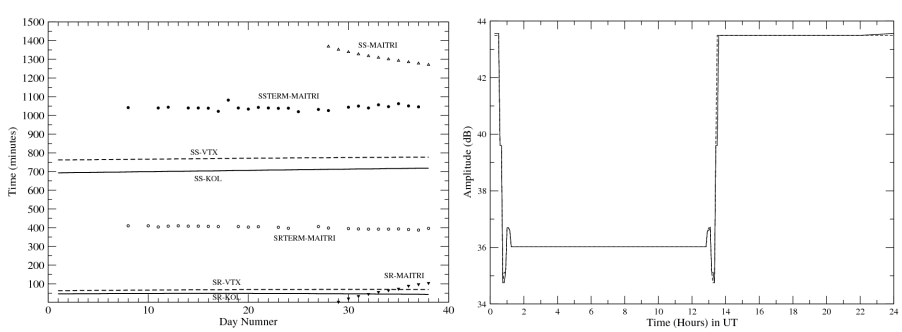

Figure 4: [Left]The calibration of sunrise/sunset terminators for VTX, Kolkata and Maitri with respect to sunrise/sunset time for five weeks of data. [Right] The diurnal signal amplitude variation using the LWPC model for 27th January 2008 (dashed) and 6th February (solid), 2008.

We present in the right panel of Fig. 4 the diurnal amplitude variation of the VLF signal using the Long Wavelength Propagation Capability (LWPC) model for the two days as mentioned in the left panel of Fig. 3. The signal amplitude changes slightly during the sunrise and sunset. Though the propagation is westward from VTX, the day time signal amplitude is smaller than the night-time. This may be due to high latitude effect. This will be studied elsewhere.

4 Conclusion

The observation of the VLF signal in a geographically special region like Antarctica was very successful. The quality of the data was extremely good even though the propagation path was very long. The signal amplitude for VTX shows the unusual variation of solar flux and the 'whole day and no night' condition has been observed in the data. We developed a calibration curve for the shorter period of time and using this curve the analysis for the seismo-ionospheric coupling is in progress.

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6 References

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