Characteristics of travelling ionospheric disturbances observed in total electron content over Waltair

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Received 14 January 1991; revised received 4 April 1991.

Continuous data of total electron content (TEC) obtained at Waltair (17.7°N, 83.3°E) during the low sunspot activity period of 1983-85 have been used to study the diurnal and seasonal variations of travelling ionospheric disturbances (TIDs). The level of occurrence is markedly higher in winter than in summer. The onset time in the occurrence of TIDs is generally found to be around 0800-0900 hrs LT in all the three different seasons. The diurnal variation has its maximum around 1600 hrs LT both in winter and summer. During the equinoxial months, the occurrence of TIDs is observed both during daytime and nighttime hours. No TID activity is seen between 0200 and 0800 hrs LT in any season. From the most probable periods of 10-30 min duration observed from the spectra it is inferred that the occurrence of medium scale TIDs is more probable at this low latitude station. The variation in the amplitudes of TIDs ranges from 0.2 to 3.75 TEC units in the entire data considered. The amplitudes show a linear relation with the periods of the waves, longer periods having larger amplitudes.

1 Introduction
A travelling ionospheric disturbance (TID), in general, may be regarded as a quasi-periodic electron density irregularity in the F region which often moves through large horizontal distance of several hundreds to thousands of kilometres with very little attenuation. Among the major dynamical processes in the F region of the ionosphere, TIDs play a significant role and have been studied for over three decades and the studies are still being conducted with much interest. It has now been established that TIDs are the manifestations of the atmospheric gravity waves in the neutral atmosphere, which propagate through the ionosphere over very long distances. A number of experimental techniques are employed to study the characteristics of TIDs, of which the Faraday rotation technique is the most inexpensive and simplest one.

2 Faraday rotation (FR) technique
This technique essentially consists of measuring the changes in polarization angle of a VHF signal from a satellite. The polarization angle varies (with time) with the variation of the total electron content (TEC) between the satellite in space and the receiver on the ground. Although TEC is an integrated parameter over the entire height range, it has maximum contribution from the F region and thus the variations reflect mainly variations in the F-region ionization.

The aim of the present investigation was to study the characteristics in the occurrence of TIDs and the distribution of their periods and amplitudes at a low latitude station, Waltair (17.7°N, 83.3°E), in the Indian sector.

3 Data and method of analysis
Faraday rotation data recorded continuously at Waltair using the VHF radio beacon signal (136 MHz) transmitted from the geostationary satellite SIRIO during the low sunspot activity period of 1983-85 were considered for the study of TIDs in the ionospheric electron content.

From an examination of the individual Faraday rotation records, quasi-periodic variations have been observed in many of the records. All such records during the period under consideration were chosen for further analysis for the study of TIDs. From these records, the periods and amplitudes of each of the wave and the local times of
The data and main features of TIDs observed during 1983-85 are given in Table 1. It may be seen from this table that although the data are available to an extent of about 90 per cent of the days during all the three different seasons, the occurrence of TIDs is found to be maximum during winter months and minimum during equinox and summer months. The average periods and amplitudes also show similar seasonal variations.

4 Results and discussion

4.1 Diurnal variation in the occurrence of TIDs

The data on the quasi-periodic variations extracted from the changes in the polarization angle, described above, were considered for studying the percentage occurrence of TIDs during the three different seasons, namely, winter, equinox and summer.

A typical record of the TIDs superposed over the Faraday rotation angle is presented in Fig. 1. It is seen from this record that the fluctuations are random, showing varied periodicities and amplitudes. It may also be seen from this figure that the wave structure is present continuously from 0900 hrs LT to 2100 hrs LT. The TIDs present on this Faraday rotation record are found to have periods varying from a minimum of 12 min to a maximum of 28 min. It is also observed from this record that the vertical amplitudes vary from a minimum of 0.4 TEC (2%) units to a maximum of 1.6 TEC (8%) units.

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Fig. 1 — Sample record of Faraday rotation showing the presence of quasi-periodic variations (TIDs) in TEC
probability, the peaks occurring around 1200, 1600 and 2000 hrs LT.

Garg et al., using the ATS-6 data of Delhi for a similar low sunspot activity period of 1975-76, reported that practically no TIDs are observed before 0900 hrs LT and the occurrence is maximum during winter daytime hours. With similar data (ATS-6), Deshpande et al.8 and Sen Gupta et al.9 reported that the occurrence of TIDs is maximum during daytime hours of the winter months. However, Das et al.10 from the ETS-II data during 1979 reported that in addition to the winter daytime maximum, there is a secondary diurnal peak around the midnight of summer months.

In recent years (1978-81), Hunsucker and Har- greaves11, from the data of a high latitude station, Fairbanks (65°N), have reported the presence of these waves during 98 per cent of all daylight hours. Cao Chang12 from the data of a mid-latitude station, Xianxang, reported that TIDs mainly occurred in winter days and in summer nights and were nearly absent during equinoxes. The daytime events in Cao Chang's data are confined to 1030-1530 hrs LT with peak occurrence around 1330 hrs LT and the nighttime events mainly occurred between 2045 and 0130 hrs LT with peak occurrence around 2230 hrs LT.

Lakha Singh et al.13, using the ETS-II data of three nearby stations around Hyderabad (lat. 17.4°N) during the winter months, reported that one group of TIDs occurred between 0000 and 1500 hrs LT and the other between 1600 and 2200 hrs LT with peak occurrence around 1200 and 1800 hrs LT respectively. Thus the maximum occurrence of TIDs during winter daytime periods observed in the present study is in conformity with the results reported by many of the earlier workers7-13.

4.2 Distribution of periods

The quasi-periodic variations (TIDs) super- posed on the diurnal variations of the Faraday ro- tation have varying periodicities from one sample to the other and even in the same sample from one wave to the other. In the data that are scaled, although the periods vary from a minimum of few minutes to a maximum of several hours, waves with periods varying from 4 to 90 min, that are observed to occur more frequently, are consid- ered for the present study. The periods derived from such waves are grouped into 5-min intervals and their percentage occurrence in each group are computed for the three different seasons. The results are presented in Fig. 3. The histograms corresponding to the winter months show the
The presence of wave periods ranging from a minimum of 10 min to a maximum of 60 min. Periods from 15 min to 40 min occur more frequently during these months with periods of 20-30 min having maximum probability of occurrence. In the equinoxes, periods with 10-30 min duration are more probable. During the summer months, where the occurrence of TIDs is generally low, periods with 10-15 min are more probable.

Deshpande et al., from the data of ATS-6 obtained from five different Indian stations during 1975-76, reported that the daytime TIDs have a most probable period of 20 min while the nighttime periods range from 20 to 30 min. Recently from a mid-latitude station, Cao Chang has reported the occurrence of periods from 15 to 80 min with most probable period of 34 min. Lakha Singh et al., from TEC measurements, have reported that the most probable period of TIDs lies between 15 and 35 min.

From the phase path measurements at Waltair, Satya Ramesh observed two categories of waves, namely, the acoustic waves with periods in the range 3-11 min and gravity waves with periods in the range 11-24 min. Thus the periods observed in the present study fall in the range of periods reported earlier by other workers, and also from this station using a different technique.

4.3 Distribution of amplitudes
For the study of amplitudes of these quasi-periodic waves, scaling on the peak-to-peak amplitude extent has been carried out. The amplitudes thus obtained are found to vary from a minimum of 4° FR to a maximum of 75° FR, which correspond to 0.2 and 3.75 TEC units respectively. The distribution of these amplitudes for the three different seasons are presented in Fig. 4. It is seen from this figure that the amplitudes with 0.25 to 1.25 TEC units are more probable in all the three seasons.

Deshpande et al. showed that the amplitudes vary from 0.5 to 1.0 TEC units while Das et al. reported their variation from 0.4 to 1.25 TEC units in winter and 0.35 to 0.7 TEC units in summer. Hunsucker and Hargreaves have reported that this variation is from 0.5 to 4 TEC units. Thus the amplitudes of the TIDs observed in the present data lie in the range of values reported by other workers from similar measurements.

4.4 Relation between periods and amplitudes
While scaling the data, it is generally observed that there exists a relation between the period and its amplitude. Out of the total data on 605 waves
scaled, about 100 independent and clear samples were chosen for studying the probable relation between the periods and their amplitudes. A scatter plot of the different periods of TIDs and their corresponding amplitudes are presented in Fig. 5. It is seen from this figure that the periods vary from 4 to 50 min and the corresponding amplitudes vary from 0.2 to 3.5 TEC units. Thus there is a significant and definite trend in the distribution of these points indicating that the vertical amplitudes of TIDs increase with the increase of their time periods. This result is in agreement with the results reported earlier by Das et al.\textsuperscript{10}, Murthy and Rao\textsuperscript{15} and Krishnam Raju\textsuperscript{16}.

4.5 Power spectral analysis of TIDs

The FR records of three typical days showing quasi-periodic variations were chosen from the three different seasons and were considered for the study of the power spectral distribution of the wave periods. The data were carefully scaled at every 2-min intervals for each of these three days. After removing the diurnal trend, the resulting FR values were plotted as a function of local time and are presented in Fig. 6. From this figure it is seen that the amplitudes of these waves are lowest on the summer day and highest on equinoctial and winter days.

Also these values were subjected to the spectral analysis\textsuperscript{17} to derive the dominant periods. The power spectra thus obtained are presented in Fig. 7. It is seen that the first dominant period occurs at 17 min on the equinoctial day, 15 min on the summer day and 28 min on the winter day. The second dominant period in the spectrum is found to be around 11 min on equinox and summer.
days and 14 min on the winter day. Thus the wave periods are generally found to vary from 11 to 28 min at this latitude. Similar measurements made at Waltair during the moderately low sunspot activity period (1982-83) by phase path technique also revealed the presence of the dominant periods varying from 11 to 24 min. However, Iyer and Nagpal\textsuperscript{18} reported the occurrence of significant peaks in the range 10-15 min in the TEC data of ATS-6 recorded during 1975-76 at a mid-latitude station, Slough (51.5°).

Acknowledgement
One of the authors (DSVVDP) wishes to express his sincere thanks to the University Grants Commission, New Delhi for providing him a research fellowship under the Special Assistance Programme in the Department of Physics, Andhra University, Waltair.

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