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Latitudinal variations of stormtime ionospheric response

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Abstract : We have studied the average day time and night time storm behaviour for the three seasons at Ramey (28 7° N, low latitude), Sagamore Hill (50 0° N, mid latitude) and Goose Bay (58.6° N, high latitude) falling in the same longitude of about 290° E during the solar maximum years 1980-'81. The average day time and night time storm variations are found to be positive, irrespective of the season, for the low latitude station The high latitude station exhibits a negative response during summer and equinox for both day time and night time storms; this response is mixed during winter. The mid-latitude station exhibits a positive day time response and a largely negative night time response during equinox

Keywords : Stormtime ionospheric TEC, latitudinal variations

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1. Introduction

'Ionospheric storms', are characterised by large scale deviations of an ionospheric parameter from its monthly median, average or otherwise typical behaviour. Although extensive studies have been conducted on the storm time total electron content (TEC) behaviour (Ref. [1] and references therein), a clear picture has not yet emerged for the TEC behaviour under disturbed conditions [2,3]. The storm variations of the electron content manifest complicated features depending on the stage of storm development, location, season and local time of occurrence. A few case studies have been conducted on the global response of TEC on the basis of multi-station observations [4,5] and the current status of TEC and scintillation studies has been recently reviewed [6]. However, a serious limitation of most of these studies is that the observing stations do not fall on a constant longitude and hence cannot provide a true picture of storm time TEC variations as the storm time effects are mixed with the longitudinal differences in TEC. The present study therefore deals with the average storm time behaviour for the local day time (0800-1700) and night time (2000-0500) SC storms observed at low (Ramey : geographic latitude 17° N, geographic longitude 289° E and geomagnetic latitude 28.7° N) mid (Sagamore Hill 42.6° N, 290°E and 50.0° N) and high (Goose Bay 47°N, 286°E and 58.6°N) latitudes falling in the same longitude zone.

2. Data and analysis

As mentioned above this study deals mainly with the latitudinal and seasonal variations of ionospheric storms. We have therefore analysed 6 day time and 9 night time storms in summer; these figures for winter and equinox are 1 and 8 and 9 and 6 respectively at three latitudes given above for the solar maximum years 1980-'81.

The hourly TEC values obtained for the stations, using the geostationary satellite ATS-5 during the solar maximum years given above, were used in the present study. We have analysed 39 storms with $A_p > 25$ during this two year period by considering seven quiet days (with $A_p < 10$), prior to each storm. The deviations in TEC (Δ TEC) on an hourly basis were obtained by subtracting the seven day average values prior to the storm commencement from the values of TEC during the storm period. The average hourly percentage TEC variations (% Δ TEC) were obtained for both the day time and night time storms during the three seasons for the three latitudes.

3. Results

Figures 1, 2 and 3 are respectively the plots of average (% Δ TEC) with local time for the three seasons summer, winter and equinox at Ramey, Sagamore Hill and Goose Bay. The

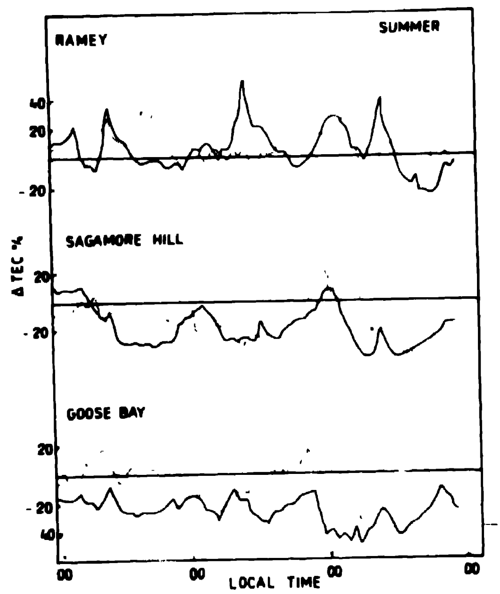

Figure 1. Plot of average Δ TEC% *versus* local time during summer for the three stations Ramey, Sagamore Hill and Goose Bay. The solid lines represent the average response for day time storms while the dotted lines indicate the same for night time storms.

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The most significant results obtained from the present study are

1. During summer the average day time TEC response is predominantly positive for the low latitude station. But for mid and high latitudes the response is mostly negative. The average response for the night time storms are also predominantly positive for the low latitude station and negative for the mid and high latitude stations.
2. During winter both day time and night time average responses are positive for low and mid latitudes. But high latitude responses for day time are both positive and negative; this includes a positive response which is very sharp.
3. During the equinox both day time and night time average responses are positive for low latitude and that of high latitude is negative. But the mid latitude response is positive during day time and negative during night time.

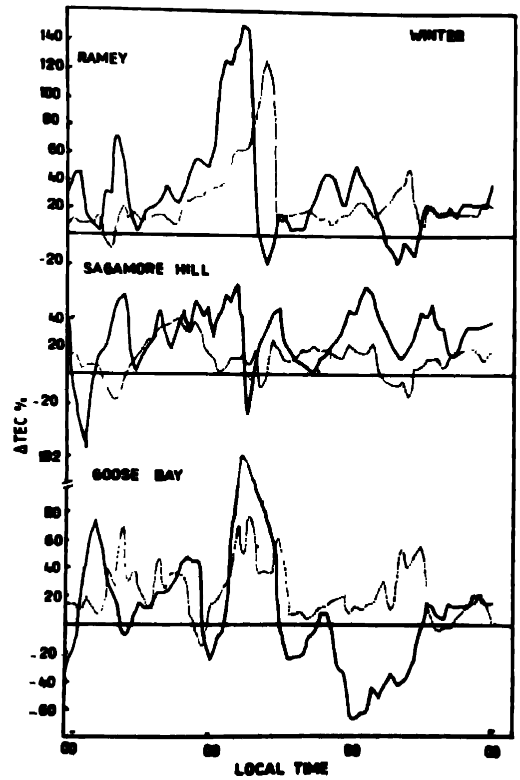

Figure 2. Plot of average Δ TEC% *versus* local time during winter for the three stations Ramey, Sagamore Hill and Goose Bay. The solid lines represent the average response for day time storms while the dotted lines indicate the same for night time storms.

4. The most predominant positive variations are observed during winter for all the three latitudes irrespective of the time of occurrence of the storm.

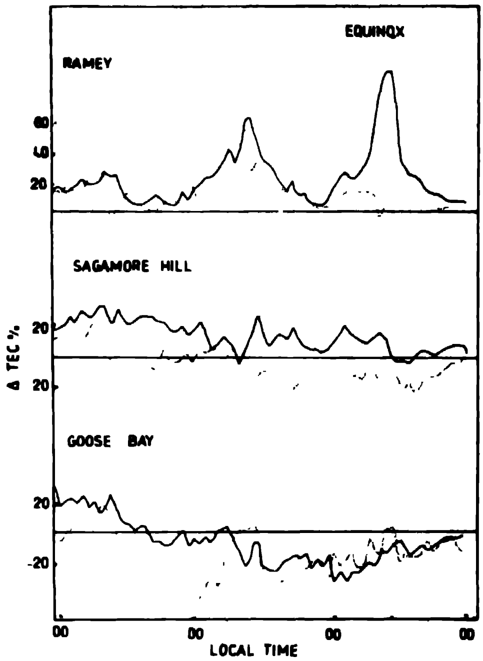

Figure 3. Plot of average Δ TEC% *versus* local time during equinox for the three stations Ramey, Sagamore Hill and Goose Bay. The solid lines represent the average response for day time storms while the dotted lines indicate the same for night time storms.

4. Discussion

The possible processes which might contribute to the magnetic storm associated ionospheric variations are : (1) Electromagnetic drift associated with storm time electric field; (2) Enhanced thermospheric circulation (waves and winds) generated by auroral zone heating during magnetic storms and the consequent increased loss rate; (3) Compression of plasmasphere by enhanced solar wind and (4) Changes in atmospheric composition due to enhanced thermospheric circulation.

At low latitudes the electrodynamic $E \times B$ drift is very effective in transporting ionisation in the ionosphere [7]. It is also believed that at low latitudes atomic oxygen is enhanced by transport from higher latitudes [8] and/or the upswelling in auroral oval [9]. This, combined with the upward lifting of the ionised medium caused by the storm time eastward electric fields and equatorward neutral air winds would give prolonged enhancements in electron density values and TEC [10]. However, the behaviour of the ionosphere during a magnetic storm is controlled by two opposing effects : one by meridional neutral air wind which causes an increase of electron content and the other by local thermospheric temperature rise which causes a decrease of electron content. The former mechanism may play a prominent role in producing a positive enhancement of TEC. The rare negative variations of TEC for low latitudes could be only due to a rise in thermospheric temperatures [11].

A mechanism operating at mid latitudes for producing a negative response is the compression of the plasmasphere by an enhanced solar wind during magnetic storms. Under quiet geomagnetic conditions the earth's plasmasphere extends to $L = 4$ to 5. During geomagnetic storms the plasmasphere gets compressed causing the mid latitude trough to move to lower latitudes. This could result in a steep drop in TEC at mid latitudes which is particularly impressive if it terminates in a positive storm phase [12]. This may be responsible for negative TEC variations at mid latitudes.

In general the reduction of ionisation during geomagnetic storms has been explained in terms of an increase in rate coefficients of the reactions [13] or due to changes in neutral composition of O/O_2 and O/N_2 [14-17]. The local thermospheric temperature is highest in summer and lowest in winter. The increase in reaction rate coefficients due to temperature rise and decrease of composition ratio due to thermal expansion of the lower atmosphere and consequent plasma loss are highest in summer and least in winter [18]. This results in lower ionisation density values and TEC in summer than in winter. This study therefore asserts the dominance of this phenomenon in day time and night time storms for all the three latitudes.

As a result of the upper atmospheric heating at high latitudes, atmospheric circulations are generated near the turbopause in both hemispheres. Air thus moves up at high latitudes followed by an equatorward motion and moves down at low latitudes followed by a poleward motion. Thus the density of atomic oxygen at high latitudes is depressed while it is enhanced at low latitudes. Accordingly the electron density in the *F*-region decreases at high latitudes and increases at low latitudes. This may be a possible reason for the positive TEC enhancement of the low latitude station irrespective of season and time of occurrence. This can also explain the negative electron density variations often observed at high latitudes especially during the summer and equinox. Generally, the atmospheric circulations during storms will cause a general depression of the *F*-region density which explains the prolonged negative TEC values at high latitudes. However, the precipitating particles enhance the electron density in the F_2 region thus accounting for the small positive enhancements at high latitudes. The precipitating particles, however, may not contribute much to the electron density variations at mid and low latitudes [19].

5. Conclusions

1. For low latitudes, the average day time and night time storm variations are found to be positive irrespective of season.
2. At mid latitudes, the average day time and night time responses are both positive and negative during the equinox, positive during the winter and negative during summer. But high latitude response is negative during equinox and summer and it is a mixed one during winter.

3. **The maximum positive response observed at low latitudes, is much higher compared to the nearly equal peak responses at mid and high latitudes in the case of both day time and night time responses.**

4. **The positive TEC responses observed in winter for all the three latitudes, are higher than that of summer for both day time and night time storms.**

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References

[1] Michael J Buonsanto *J. Geophys. Res.* **100** 23857 (1995)

[2] J B Evans *J. Atmos. Terr. Phys.* **35** 593 (1973)

[3] A R Jain, M R Deshpande, G Sethia, R G Rastogi, H S Gurum, A V Janve and R K Rai *Indian J. Radio Space Phys.* **7** 111 (1978)

[4] J A Klobuchar, M Mendillo, F L Smith, R B Fritz, A V Da Rosa, M J Davis, P C Yuen, H Roelofs, K C Yeh and B J Flaherty *J. Geophys. Res.* **76** 6202 (1971)

[5] E A Essex, M Mendillo, J P Schodel, J A Klobuchar, A V Da Rosa, K C Yeh, R B Fritz, F H Hibberd, L Kersley, J R Koster, D A Matsoukas, Y Nakata and T H Roelofs *J. Atmos. Terr. Phys.* **43** 293 (1981)

[6] K N Iyer *Indian J. Radio Space Phys.* **22** 277 (1993)

[7] D S V V D Prasad and P V S Rama Rao *Indian J. Radio Space Phys.* **22** 391 (1993)

[8] H Volland *J. Atmos Terr. Phys.* **41** 853 (1979)

[9] H Rishbeth, T J Fuller-Rowell and A S Rodger *Phys. Scr.* **36** 327 (1987)

[10] C A Reddy, S Fukao, T Takani, M Yamamoto, T Tsuda, T Nakamura and S Kato *J. Geophys Res* **95** 21077 (1990)

[11] Y N Huang, K Najita, T H Roelofs and P C Yuen *J. Atmos. Terr. Phys.* **36** 9 (1974)

[12] M Mendillo, J A Klobuchar and H Hajeb-Hosseineih *Planet. Space Sci.* **22** 223 (1974)

[13] L Thomas and R B Norton *J. Geophys. Res.* **71** 227 (1966)

[14] M J Seaton *J. Atmos. Terr. Phys.* **8** 122 (1956)

[15] G A M King *Planet. Space Sci.* **9** 95 (1962)

[16] R A Duncan *J. Atmos. Terr. Phys.* **31** 59 (1969)

[17] N Chandra and G R Herman *Planet. Space Sci.* **17** 841 (1969)

[18] P V S Rama Rao, P Sriram and P T Jaya Chandran *Indian J. Radio Space Phys.* **23** 340 (1994)

[19] H Kohl *J. Atmos. Terr. Phys.* **28** 879 (1976)