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EFFECT OF LOCAL TIME ON THE F2 -REGION RESPONSE TO THE GEOMAGNETIC STORM OF JANUARY 28, 1985

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ABSTRACT

The F2-region response to the storm of January 28, 1985, was investigated in this research using some ionospheric stations from East Asian and Euro-African sectors. The sectors were chosen because of their huge time difference, which enabled the proper identification of whether or not plasma is redistributed owing to sunrise effect when a storm occurs. The storm occurred around 14:00 universal time (UT), which corresponded with local time (LT) of Euro-African sector of between 1-4 p.m. and 10-11 p.m. of East Asian sector. From the result obtained, it was concluded that sunrise effect could redistribute the plasma when a geomagnetic storm occurs due to the fact that the three low latitude stations in Euro-African behaved in an undefined manner, while the response of the East Asian stations agreed with existing theories.

Keywords: F2-region, geomagnetic storm, universal time, local time, ionospheric stations

INTRODUCTION

The significant impact of space weather on human activities in the areas of satellite communication, ground based technological systems, electric power grids and the performance and reliability of satellites, especially during severe geomagnetic storms makes the study of space weather imperative. Space weather refers to the conditions of the sun, the solar wind, magnetosphere and the ionosphere. The manifestation of space weather is the intense aurora activity, which occurs during magnetic storms.

Danilov (2001) regarded the F2 region response to a geomagnetic storm as a rather complicated event that consists of the so-called positive and negative phases, which have very complicated spatial and temporal behaviors. According to him, the principal features of the positive and negative phase distribution and variable have been explained on the basis of the principal concepts during a geomagnetic disturbance as an input of energy into the polar ionosphere, which changes thermosphere parameters, such as composition, temperature and circulation in the F2 region. The circulation spreads the heated gas to lower latitude.

This research was undertaken using ionospheric effect of a single geomagnetic storm with a definite specialty rather than using data that is averaged from a number of different storms. The study of the ionospheric storm phenomenon using statistical averages derived from a number of storms could lead to wrong conclusions partly because of the great variability of this phenomenon, and also due to the fact that during storms, many different processes are at work and their effects may be superimposed on one another and they may partly cancel each other.

It is the main purpose of this research to investigate the effect of local time on the F2-region response to geomagnetic storms. The storm of interest is the January 28, 1985 event. The research was conducted using six stations (Dakar, Johannesburg, Kiev, Ouagadougou, Slough and Rome) from the Euro-African sector and four (Yakutsk, Wakkanai, Kokubunji and Manilla) from the East Asian sector.

MATERIALS AND METHODS

Data and method of analysis: The data used in this study consists of hourly values of foF2 obtained from some of National Geophysical Data centre's SPIDR (Space physics Interactive Data Resource) global network of ionosonde stations and other parameters such as B_z, D_{st}, proton density and Flow Speed were obtained from OMNIWEB.

In order to properly study the effect of local time on the F2 region response to the geomagnetic storm of January 28, 1985, we chose to study the response of two different sectors in their upper, mid, and lower sections. The sectors were East Asian sector, and Euro-African sector. Table 1 and 2 listed the stations under each sector and their corresponding geographic co-ordinates.

Table 1: Ionosonde stations of Euro-African sector

Section	Geographic co-ordinates		Difference between LST and UT (in hours)
	φ	λ	
S1ough	51.60° N	10.10°E	+1
Kiev	50.50°N	30.50°E	+2
Rome	41.80°N	11.83°E	+1
Dakar	14. 80°N	17.40°W	-1
Ouagadougou	12.40^{0}N	1.53^{0}E	0
Johannesburg	26.10°S	28.10°E	+2

Table 2: Ionosonde stations of East Asian sector

Section	Geographic co-ordinates		Difference between LST and UT (in hours)
	φ	λ	
Yakutsk	62.00°N	129.60°E	+9
Wakkanai	45.40°N	141.70°E	+9
Kokubunji	35.70°N	139.50°E	+9
Manila	14.70°N	121.10°E	+8

The study is concerned with variations in foF2, with respect to local time due to the geomagnetic storm of January 28, 1985. However, the F2 region response to geomagnetic storms is most conveniently described in terms of D_{foF2}, that is, the normalized deviations of the critical frequency foF2 from the reference: (Chukwuma, 2003)

$D_{foF2} = [foF2 - (foF2)_{ave}]/(foF2)_{ave}$

Hence, the data that was analyzed consisted of respective hourly values of D_{foF2} on January 28-30, 1985, with the January 28 being the main phase and January 29-30 being the recovery phase. The reference for each hour was the average value of foF2 for that hour calculated from five quite days, January 23-27, 1985, preceding the storm. The use of D_{foF2} rather than foF2 provided a first order correction for temporal, seasonal and solar cycle variations so that geomagnetic storm effects are better identified.

RESULTS AND DISCUSSION

Geomagnetic and interplanetary observations: The results of the study being considered were shown in figures I-III. Figure I showed measured parameters of solar wind plasma: the interplanetary magnetic field component, B_z, ion density, flow speed, and low latitude magnetic index, D_{st} for the period January 26-30, 1985.

According to Vieira *et al.* (2001), storms are classified as follows: weak (D_{st} >-50nT), moderate (-50nT<D_{st} >-100nT) and intense (D_{st} <-100nT). Based on this classification, the D_{st} plot for January 26-30 (Figure I) showed that the interval 00:00UT on January 26 till 23:00UT, next day, recorded a quiet period. Thereafter, a weak storm with minimum D_{st} value of -46nT at 02:00UT was formed and lasted till 11:00UT on January 28, 1985. However at about 12:00UT, D_{st} nosedived to -61nT signaling the commencement of a moderate storm. This gradually snowballed into an intense storm at 14:00UT with a D_{st} value of -116nT on the same day.

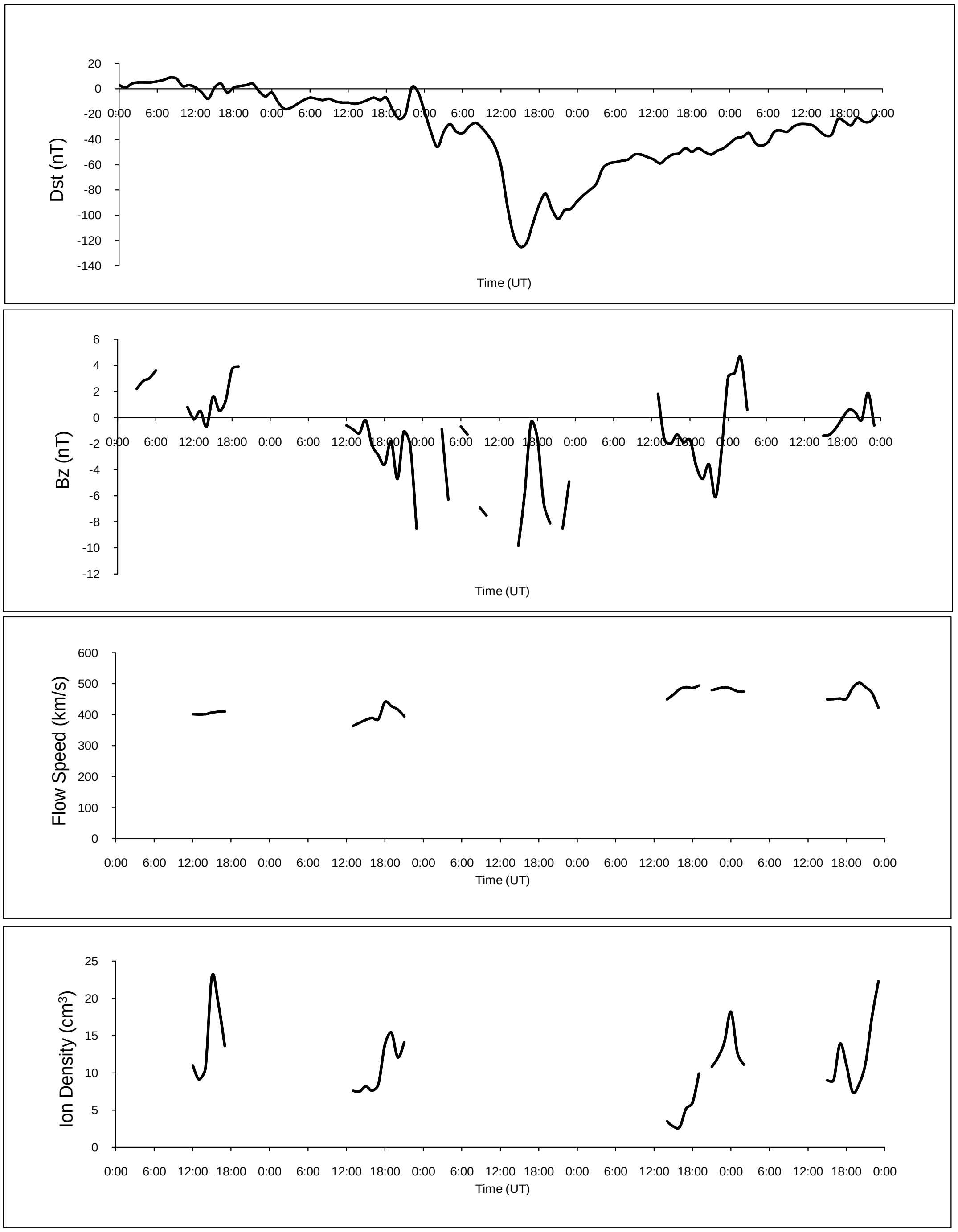

Figure 1 One-hour averages of the solar wind plasma parameters versus Time (in UT) for January 26-30, 1985.

This intense storm lasted up to 3 (three) hours between 14:00UT and 17:00UT before D_{st} started increasing again and reached a value of -92nT at 18:00UT. The recovery took quite a while as the intense storm reduced to a moderate storm that lasted throughout January 29, before it recovered to -24nT at 17:00 on January 30. Most of the days preceding the storm were quiet days as evidenced from the graph.

The plots for the interplanetary magnetic field component, B_z, proton density and flow speed (Figure I) showed that there was paucity of data, which would not allow for adequate interpretation of these parameters. Despite this, it could be seen from the graph of the B_z that it turned southward at the time of commencement of the intense storm. In addition, despite the unavailability of data for proton density, it could be seen from the graph that it reached 22.9cm^{-3} at 15:00 UT on January 26. This development could be said to have signaled the arrival of a shock in the interplanetary medium (Nielsen and Honary, 2000; Strickland *et al.,* 2001). Consequently, the enhanced solar wind density drove the plasma sheet density leading to the injection of ring current and this could be responsible for the sharp D_{st} depression as seen on January 29 between 11:00 UT and 22:00 UT.

The flow speed value of 506km/s at 10:00 UT on January 28 was another strong indicator of storm. According to Gonzalez *et al.* (2001) and (2002), intense magnetic storms (D_{st}<-100nT) occur when the solar wind speed is substantially higher than the 'average speed' of 400km/s.

Ionospheric response: During geomagnetic storms, ionospheric F region plasma parameters experience disturbances and in response, the electron density is either significantly enhanced or depleted resulting in positive or negative ionospheric storm respectively. It is of interest therefore, to explain the response of the ionosphere to the intense geomagnetic storm of January 28, 1985. The storm time (14:00 UT) was so chosen so that stations in the Euro-African sector will be at noon and those at the East Asian sector will be at dusk. Whatever variations that arose from the plot of the D_{foF2} of these two sectors could therefore be traced to sunrise effect, owing to their different time zones.

The D_{foF2} at the Euro-African sector were shown in figure II. The stations considered in this sector were Slough, Kiev, Rome, Dakar, Ouagadougou and Johannesburg. The mid latitude station of Slough (54.5^{0}N) experienced depletion at 21:00 UT on January 29 only to start reversing at about 04:00UT on January 30 before further depletion at 19:00UT on the same day. Kiev (50.5^{0}N), also a mid-latitude station, experienced depletion at 20:00UT on January 28 only to start a process of reversal one hour later at 21:00UT.

The graph of Rome shows that it experienced a pronounced enhancement from 10:00 UT to 20:00 UT on January 28. From the D_{st} plot, it could be seen that D_{st} reached a value of -116nT at 14:00 UT which is a very convenient value to identify an intense storm. However, unlike the other mid-latitude stations, Rome (41.8^{0}N) experienced enhancement between 18:00UT and 20:00UT. With a time difference of +1, the storm commenced at 3pm (14:00+1) local time in Rome. This anomaly could therefore be described by effect of sunrise, which would have redistributed the plasma.

The lower latitude station of Dakar (14.8^{0}N) experienced enhancement 22:00 UT on January 28 before being depleted at 01:00 UT on January 29 and experienced further depletion at 23:00 UT on January 29. The D_{foF2} plot for Johannesburg (12^{0}N) showed that it experienced a sudden enhancement on January 29 and recovered almost immediately at 01:00 UT.

The D_{foF2} plot for Ouagadougou (12.4^{0}N) showed that it started experiencing enhancement around 10:00UT on January 28, before a sudden sharp depletion occurred at about 19:00 UT on the same day before the enhancement commenced again at about 23:00 UT on the same day, which was followed by a sharp depletion at 06:00 UT on January 29. It would be noted that the first sudden depletion that occurred at 19:00 happened when the D_{st} value started increasing again.

The D_{foF2} variations for the stations considered in the East Asian sector were plotted in figure III. Yakutsk (62.0^{0}N) experienced enhancement between 08:00 UT and 11:00 UT on January 28. Throughout the duration of the storm, there was really nothing to suggest depletion and this indicated a positive storm in the upper latitude station of Yakutsk. Having a time difference of +9, the time of storm which occurred at 14:00 UT on January 28 is 11pm at Yakutsk. At this time, the distribution of plasma could not be affected by sunrise.

At Wakkanai (45.4^{0}N) there was enhancement in the early hours which, was followed by depletion around the storm time at 15:00 UT. The station later experienced enhancement at 03:00 UT on January 29 and intermittent swings between enhancement and depletion for the rest of the period.

At Kokubunji (35.7^{0}N), there were spikes of enhancement at 09:00 UT and 21:00 UT on January 28 and at 10:00 UT on January 29. Depletion occurred here just like the other mid-latitude station of Wakkanai at about 15:00 UT around the time of storm on January 28.

At low latitude station of Manilla (14.7^{0}N), there was a pronounced enhancement with a peak of 245% around 20:00 UT on January 28. However, a minor depletion occurred on the 29th and 30th with intermittent swings of enhancement in between.

Comparing the low latitude stations from Africa (i.e., Dakar, Ouagadougou and Johannesburg), it could be seen that while some are predominantly positive storm, the other is negative. This could be because sunrise effect has redistributed the whole plasma. A look at the low latitude station of Manila at the East Asian sector showed a positive ionospheric storm as expected of most low latitude stations at a local time where there is no sunrise effect.

It could be seen that the ionosphere above the stations of the East Asian sector recorded predominantly positive ionospheric storm with varying percentage. The enhancement is greatest at Manilla as expected of a low latitude station. A puzzling feature here is the greater enhancement at the upper latitude of Yakutsk compared to that of Wakkanai and Kokubunji. If the enhancement at

Yakutsk is lower than that at Wakkanai, we would have concluded it still follows the normal trend as depletion is known to decrease down the latitudes (Chukwuma, 2003; Danilov, 2001).

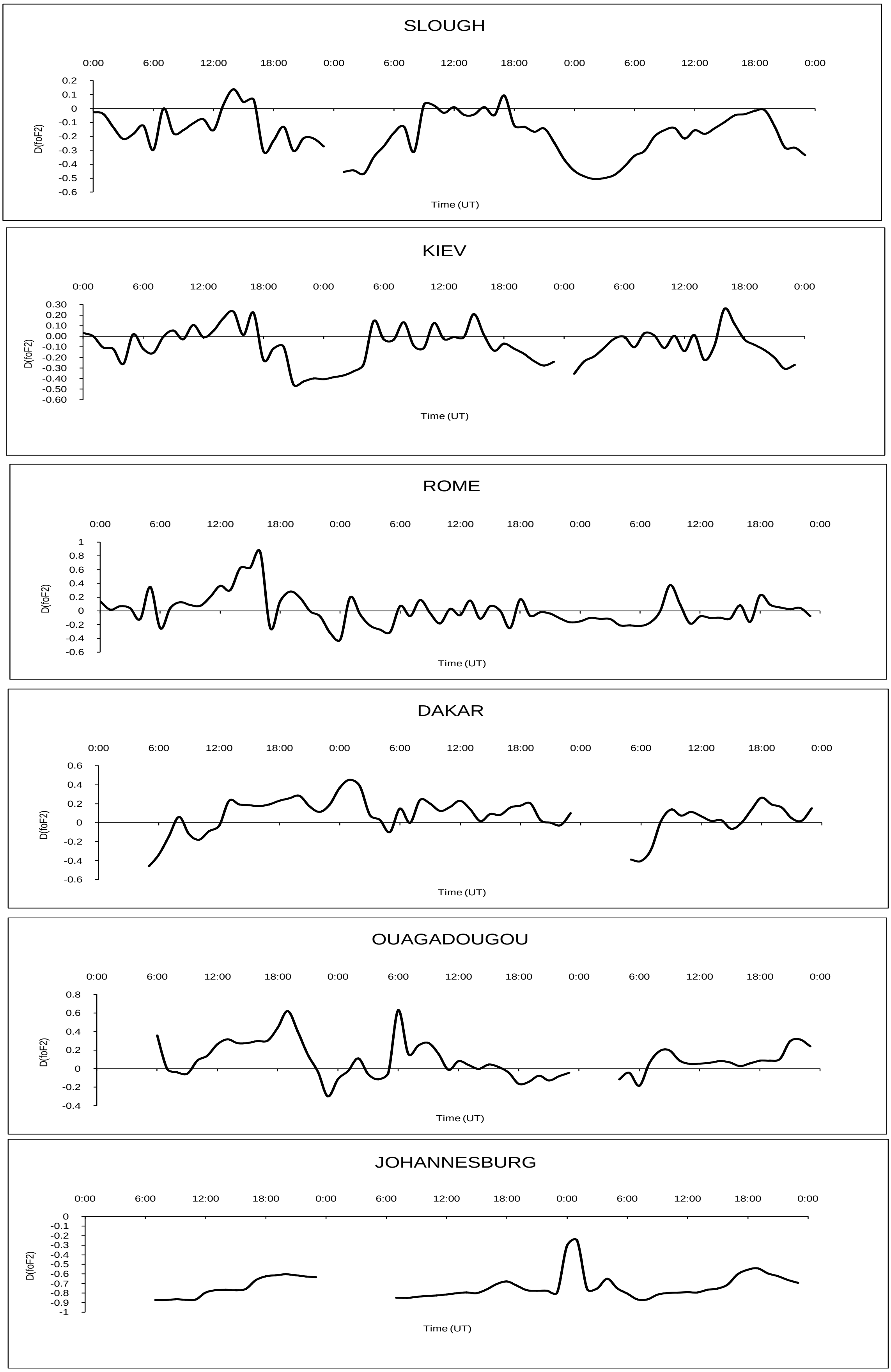

Figure 2 : Variation in DFof2 at the Euro-African Sector during January 28-30, 1985

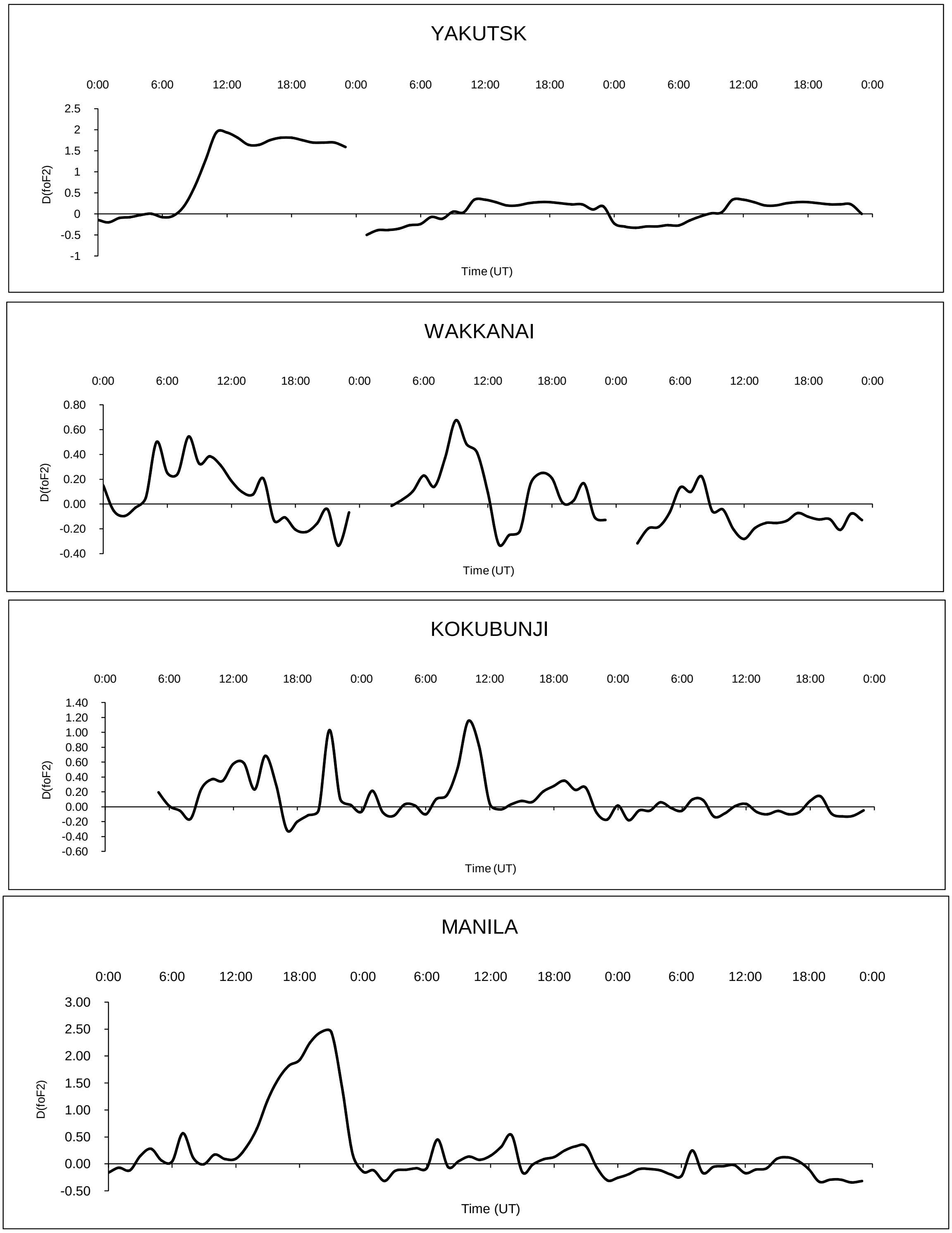

Figure 3 : Variation in DFof2 at the East Asian Sector during January 28-30, 1985

CONCLUSION

From the January 28, 1985 storm that was considered, we could conclude that sunrise effect could redistribute the plasma owing to the fact that the three low latitude stations in Africa behave in an undefined pattern. In addition, it could be added that at the East Asian sector, where there was no sunrise effect due to its local time, the response of the ionospheres under consideration agreed with Danilov (2001), that the so-called positive and negative phases have very complicated spatial and temporal behavior.

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