ANNALI DI GEOFISICA, VOL. XXXIX, N. 4, August 1996

Mid-latitude ionosphere during two great geomagnetic storms

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Abstract

The ionospheric disturbances observed at many European ionosonde stations in association with the severe geomagnetic storms occurring on 19-20 December 1980 and 11-12 April 1981 were investigated by using the available ionospheric and geomagnetic data. During these storms the ionospheric *F* region underwent major changes at all mid-latitudes. However, the variations from storm to storm were much larger at lower mid-latitudes. These results support the view that even in assessing the response of the mid-latitude ionosphere to severe geomagnetic storms it is necessary to distinguish carefully between global, regional and local behaviour.

Key words *mid-latitude ionosphere – ionospheric disturbances – modelling, forecasting – computer images*

1. Introduction

In this paper we continue to search for an approach to the modelling and forecasting of f_0F_2 and $M(3000)F_2$ at geomagnetically disturbed time (Kutiev *et al.*, 1993; Cander *et al.*, 1993; Cander, 1993; Moraitis *et al.*, 1994). Numerical analyses of ionospheric data from the stations belong to the area 1°W-25°E, 40°-55°N were performed to characterize the irregular *F* region structure during the great magnetic storms and to define patterns for the initial and main phase effects of the mid-latitude ionospheric storms. The evidence for our conclusions concerning the complex space/time distribution of the plasma parameters during the ionospheric storms even in such restricted area of the mid-latitude ionosphere is given in the following results. To create the two- and three-dimensional (2D and 3D) computer images of daily hourly $D(\%)$ values during the storms of 19 December 1980 and 11 April 1981 data sets were taken from the following ionospheric stations in the PRIME area: Kaliningrad (54.8°N, 20.6°E), Slough (51.5°N, 0.6°W), Grocka (44.8°N, 20.5°E), Rome (41.9°N, 12.5°E) and Sofia (42.6°N, 23.3°E).

2. Results

In the geophysical sense December 1980 and April 1981 were characterized by a high level of solar activity ($R_i > 100$) and increased level of geomagnetic activity. The Sudden Commencement (SC)-type geomagnetic storms occurred on 19 December 1980 at 04.55 UT (SC1 in fig. 1) and 11 April 1981 at 08.24 UT (SC2 in fig. 1) and at 14.39 UT (SC3 in fig. 1) were followed by very disturbed days (maximum values of A_p were 79 and 121 respectively) and preceded by several geomagnetically quiet days from which 17 December and 10 April were chosen to represent the quiet

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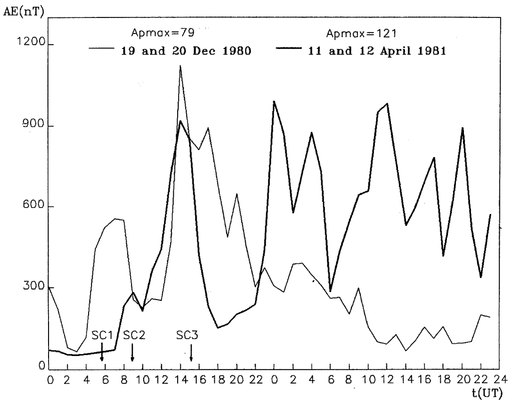

Fig. 1. *AE* index as a function of time.

conditions. Variations of the *AE* index during these geomagnetic storms are given in fig. 1.

These geomagnetic storms were associated with the ionospheric storms periods of great severity. The effects on the relative deviations $D(\%)$ in the F_2 layer critical frequency f_0F_2 from their respective quiet values vary significantly with time (local, universal, season, sunspot number), location (geographic and geomagnetic latitude and longitude, altitude) and the stage of the geomagnetic storm development. The morphology of these storms is shown in fig. 2 and 3 where $D(\%)$ is given as a function of time for two days of storms (2D images). Ionospheric storms can be classified in two groups with respect to f_0F_2, the negative and the positive storms corresponding respectively to a decrease or an increase in f_0F_2.

The December 1980 storm was negative for all its phases as seen at Slough and Kalingrad. However, this was not the case for Rome and Grocka ionospheric stations. At these lower latitudes, no major disturbances were seen during the first few hours. The first effect of the storm occurred late in the evening when the f_0F_2 started to increase and remained at the high positive level until the end of the main phase of the geomagnetic storm. Finally, all four stations seemed to show a recovery to pre-storm conditions on the following day (20 December).

The April 1981 event generally gave similar variations at all ionospheric stations. The variations show a short-lived positive phase lasting a few hours after the SC3. This was much larger at Sofia where the onset of the negative phase was also more sudden. The main effect was a strong negative phase lasting more than 24 h at all stations.

The 3D images shown in figs. 4 and 5 represent the latitudinal and longitudinal variations of $D(\%)$ values for the same cases. Among different methods of interpolation for the production of contour maps, the Kriging approach based on the theory of regionalized variables has certain statistical optimal properties in the sense that the estimates are unbiased and have known minimum variances (Davis, 1986). It has the advantage that the weighting factors depending on the distance separation are given directly from the semi-variogram and so are separately evaluated for each epoch and as a function of geographical position. Based on this approach, a method was developed to use the sequence instant 3D images of f_0F_2 in investigating the detailed behaviour of the ionospheric F region during the course of geomagnetic storms. Figure 4 provides this example illustrating the regional distribution of December 1980 storm effects, while fig. 5 concerns the April 1981 event. Evidently employing 3D images, the ionospheric f_0F_2 behaviour in restricted area of Europe can be seen more clearly.

3. Conclusions

In this paper spatial and temporal distributions are shown of two ionospheric storms seen from five PRIME stations. Examining the results of a multi-station analysis of the f_0F_2 response to the 19-20 December 1980 and 11-12 April 1981 events, it can be said that these events produced substantial and overly severe F region storm effects. In addition, the storm in figs. 2 and 4 is quite separate from the storm in figs. 3 and 5. It suggests that the variations from storm to storm are much larger at lower mid-latitudes. Then, it might be argued that the changes with a season are also much more im-

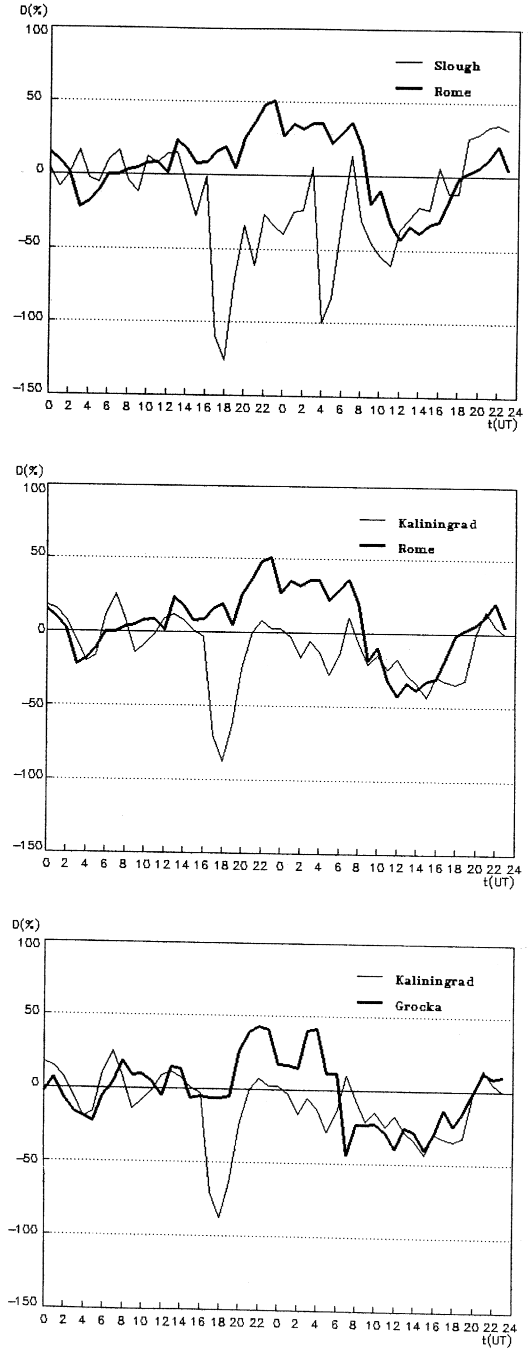

Fig. 2. *D*(%) at different ionospheric stations as a function of time during 19 and 20 December 1980.

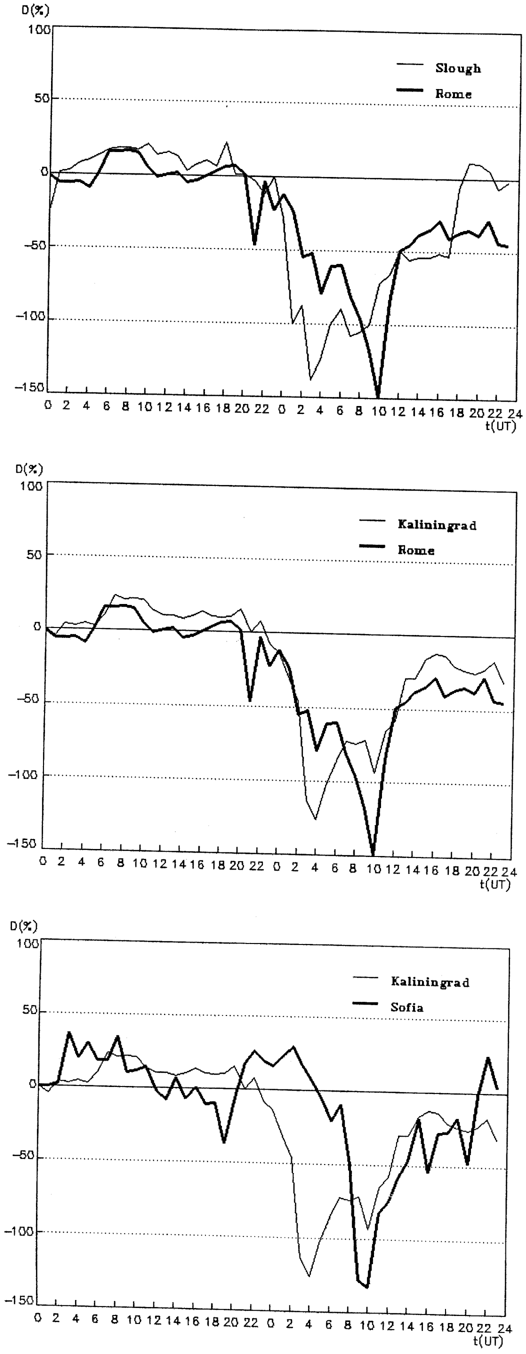

Fig. 3. *D*(%) at different ionospheric stations as a function of time during 11 and 12 April 1981.

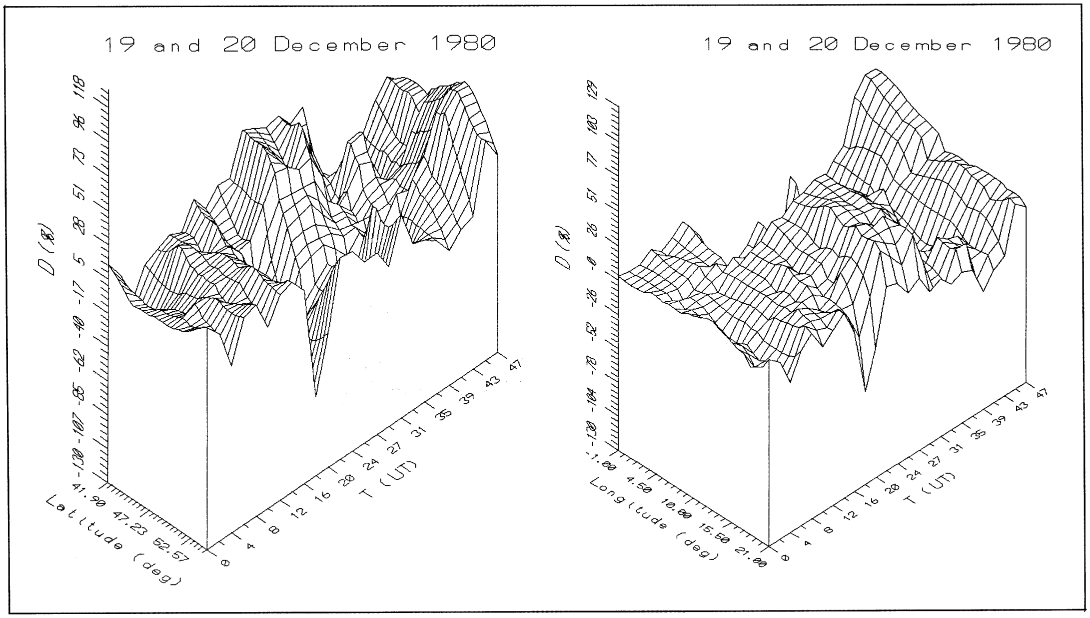

Fig. 4. *D*(%) as a function of latitude, longitude and time during 19 and 20 December 1980.

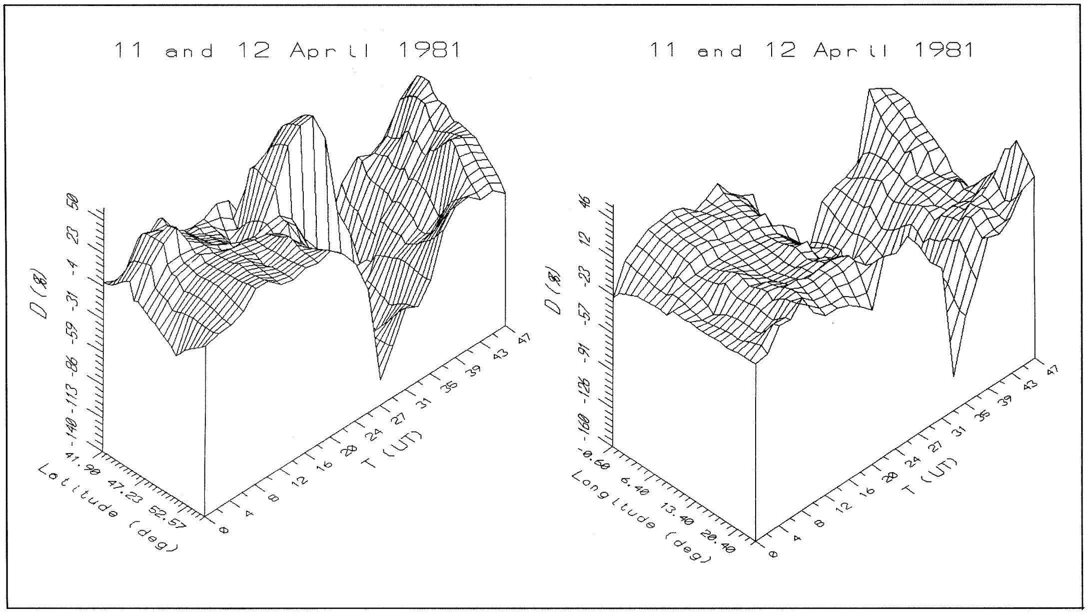

Fig. 5. *D*(%) as a function of latitude, longitude and time during 11 and 12 April 1981.

portant at Rome, Grocka and Sofia than at Slough and Kaliningrad. Therefore, even in assessing the response of the mid-latitude ionosphere to strong geomagnetic storms it is necessary to distinguish carefully between global, regional and local behaviour. Bearing in mind that in many respects a great geomagnetic storm triggers ionospheric effects that are more predictable than the effects of weaker geomagnetic disturbances, the practical implications of this fact are clear. For any improvement in forecasting under most conditions at the mid-latitude ionosphere an observational network would be required capable of reporting real-time ionospheric measurements from a grid 5° in latitude and 10° in longitude.

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