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The ionospheric storm studies: further development of the mapping technique

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Abstract
The technique of using instantaneous maps for ionospheric storm studies is further developed. Integral parameters are introduced characterizing the main features of each map. These parameters are the net volumes of Δf_0F_2, $\Delta M(3000)F_2$ and their gradients. The magnetic storm 1-2 March, 1982 was considered and it was found that before the storm commencement and in recovery phase the Net Gradient (NG) is directed steadily to the East, while in the main phase it turns southward. NG shows where the changes of the F-layer come from. The net volume of Δf_0F_2 (NF) correlates well with *Dst* and *AE* indices.

Key words *ionospheric storms – instantaneous maps – ionospheric plasma parameters*

1. Introduction

A new technique was developed for studying of ionospheric storms, using instantaneous maps of f_0F_2 and $M(3000)F_2$ (Kutiev *et al.*, 1993; Kutiev and Bradley, 1993). This approach is based on the assumption that the monthly median values of these parameters represent the quiet conditions and the storm time changes can be obtained by their subtraction from the instant measurements. The hourly values of Δf_0F_2 and $\Delta M(3000)F_2$ from all available European ionosondes are used to produce instantaneous maps. These maps give a two-dimensional distribution of the storm time deviations from the quiet conditions. A simple theory was developed, giving the production/loss rate and drift velocity by calculating the time derivatives of Δf_0F_2 and $\Delta M(3000)F_1$ from two successive hourly maps. It was found that maps are quite informative and it is difficult to follow the F layer behavior directly from them. That is why we are searching for integral characteristics which would make the maps easier to interpret.

2. Net volume parameters NF, NM, NG and NA

In Kutiev *et al.* (1994) a new quantity «net volume» was introduced, which is the total positive minus total negative deviations in a map, normalized by the total number of grid points. The net volume of Δf_0F_2 (NF) is plotted in fig. 1, along with maximal and minimal values of the hourly maps during the magnetic storm of 1-2 March 1982. The two extremal curves show that the positive and negative deviations of f_0F_2, so called ionospheric storms,

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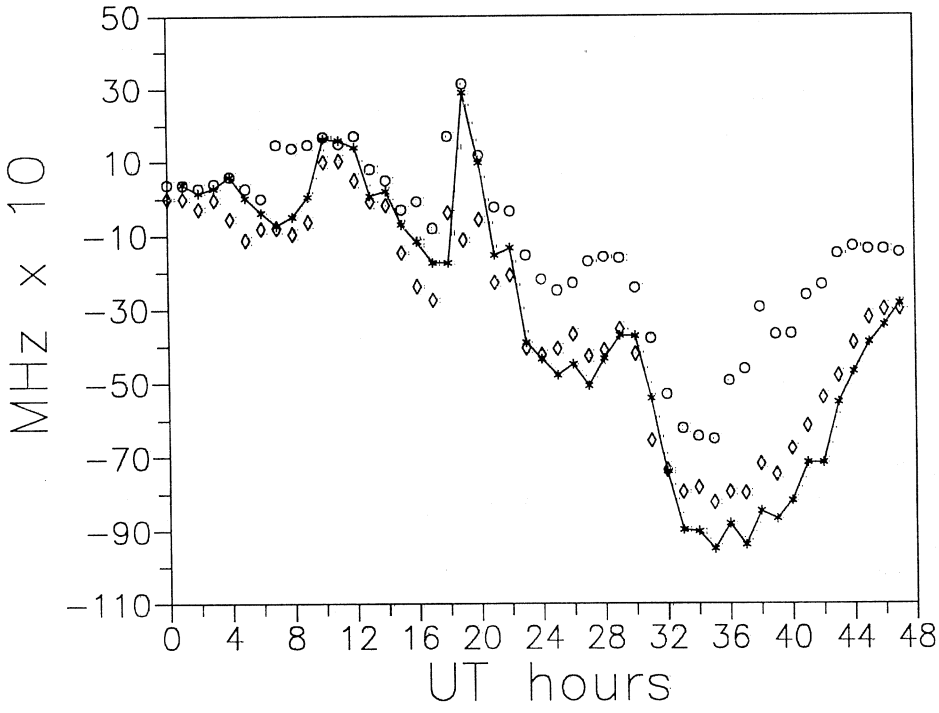

Fig. 1. The maximal Δf_0F_2 value of each map is plotted with open circles along the course of the magnetic storm 1-2 March, 1982. The minimal values are marked with open diamonds. The NF values are denoted with asterisks and connected with a full line.

do not occur simultaneously in the PRIME area, but depend on the location. NF parameter characterizes the main variation of Δf_0F_2, although its negative variations exceed those of the minimal curve. This happens because NF is the average of all negative Δf_0F_2 over the whole area. In the same way we calculate the «net volume» of $\Delta M(3000)F_2$, (NM).

The maps contain one very important characteristic of the F layer – the gradients of Δf_0F_2. The gradients give the direction from where the influences causing the disturbances come. We calculated east-west and north-south components of the gradient by subtraction of the values of two neighboring grid ponts. Then the vector gradients were obtained as well as their angles. The angle accounts from 0° in west direction to 360°, counterclockwise. The «net volume» of the vector gradient (NG), positive to south and angles (NA) are calculated and plotted in fig. 2.

3. Some physical considerations

Figures 1 and 2 give the time variations of the integral parameters during the magnetic storm. They exhibit some interesting features. First, it is surprising that the variations of NF abd NM are quite similar. On the second day of the storm NM shows a large negative disturbance as it does NF. If we consider that $M(3000)F_2$ has a reverse proportionality to hmF, we may conclude that on the second day the F layer is shifted upwards. Usually, when hmF increases, f_0F_2 also increases, due to the reduced recombination rate. The behavior shown here could be explained if we assume a

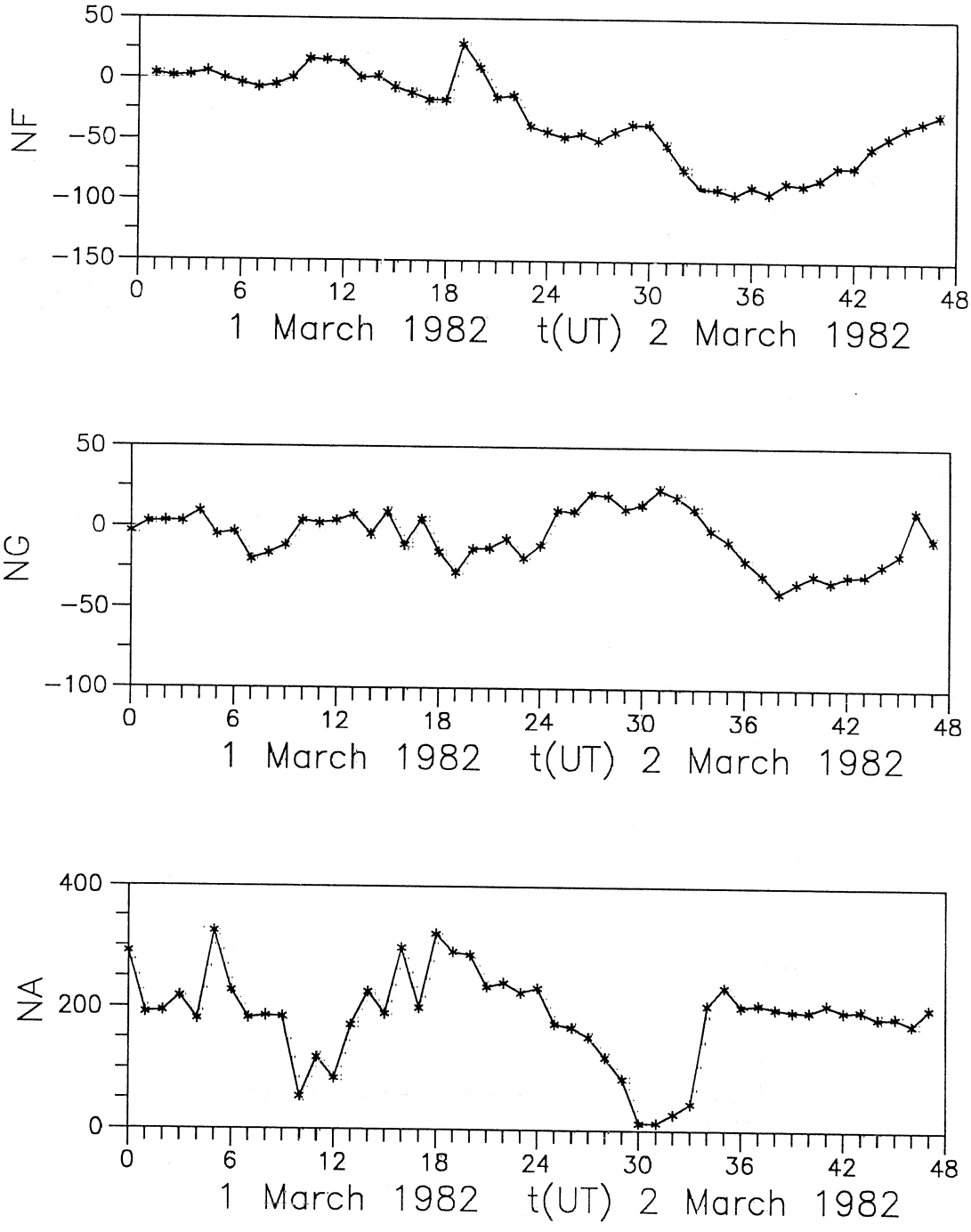

Fig. 2. Integral parameters during the same magnetic storm as in fig. 1. Net density (NF) – upper panel; net density gradient (NG) – middle panel; net gradient angle (NA) – lower panel.

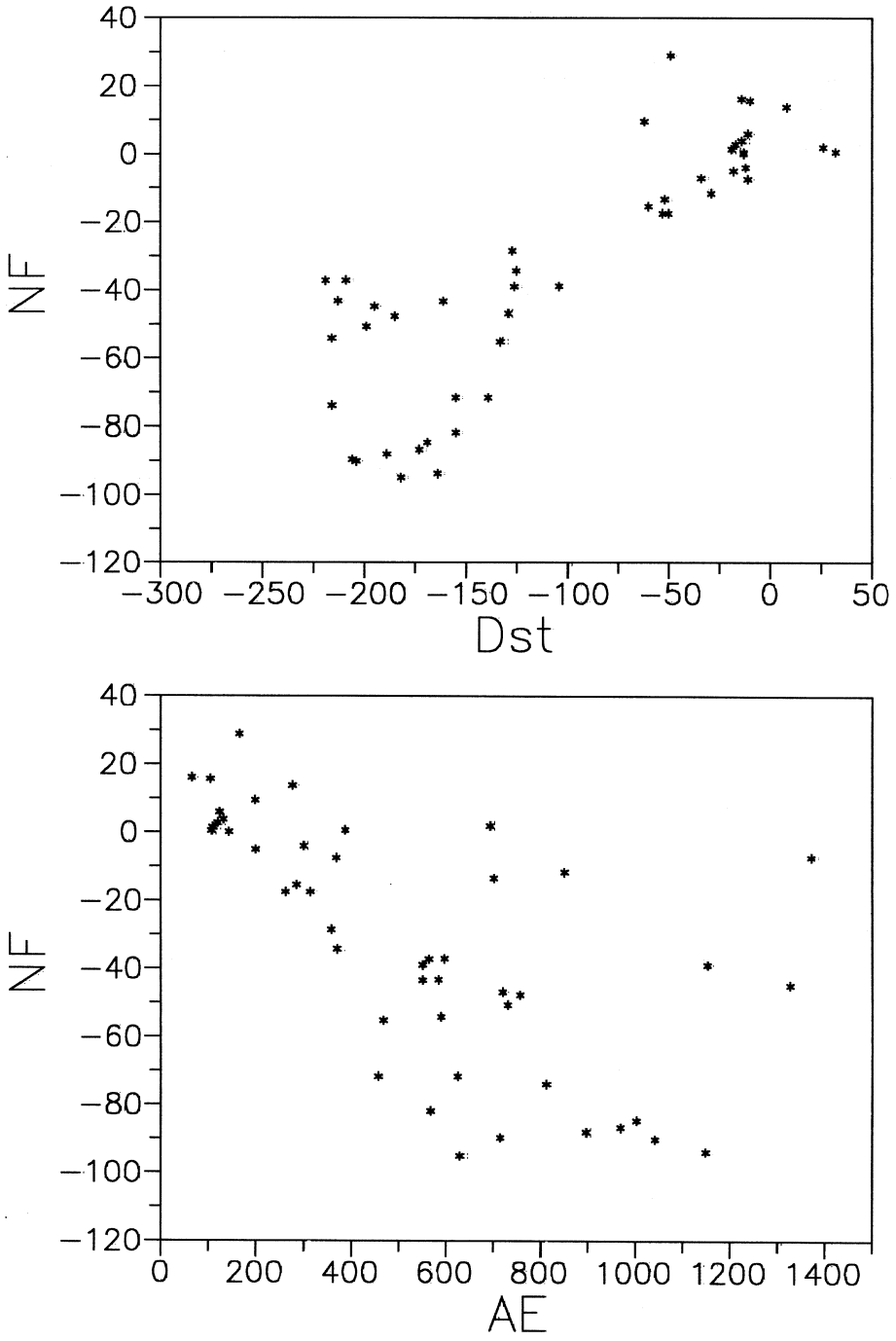

Fig. 3. Net Δf_0F_2 (NF) *vs. Dst* (upper panel) and *AE* (lower panel) during the same magnetic storm as fig. 1.

wind blowing from the north carrying an air richer in N_2 and O_2. We further have to calculate *hmF* from $M(3000)F_2$ and f_0E using the relation given in Bradley (1975) and to obtain its net volume. The net gradient NG and its angle NA can also give interesting information. In the initial phase of the storm (around the 22nd hour on the plot) when a negative NF develops, the net gradient has a southern component which means that the negative storm starts to propagate from north to south. The actual propagation is first towards east then the vector rotates through south to west. When the lowest NF value is reached, NG changes its direction and becomes negative, while the vector steadily directs eastward. This means that an increased ionization begins to develop from the west. It is obvious that this phenomenon is local time dependent, but this analysis will be performed in the next paper.

During the same storm, NF is plotted against *Dst* and *AE* indices in fig. 3. Both plots show clear dependencies and reveal again the usefulness of the integral parameters. A further analysis is planned to be carried out in the near future.

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