NIGHTTIME IONISATION ENHANCEMENTS OBSERVED WITH THE ATHENS DIGISONDE

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ABSTRACT

Six geomagnetic storms were analyzed, in a two-fold investigation of nighttime ionisation enhancement events. First, we present observational evidence that their occurrence is strongly dependent on the solar wind conditions leading to magnetic storms. Then we investigate the ionospheric structure over Athens during such events to argue on their nature, since they were always accompanied by an upwelling of the F2 layer. According to our findings, nighttime positive effects and height enhancements are attributed to two distinct mechanisms. The increased nighttime density can only be speculated to be due to increased downward plasmasheric fluxes.

OCCURRENCE OF NIGHTTIME IONISATION ENHANCEMENTS

Six storm periods occurred in September and October 2000 were analysed. The solar wind - magnetosphere system were studied by inspecting observations from the ACE spacecraft (solar wind magnetic field and plasma), the auroral oval and the Disturbed storm time (Dst) magnetic field, to investigate the conditions under which nighttime ionisation enhancements occur. To observe the ionospheric response at middle latitudes, data from six middle latitude stations were analysed [1]. As an indicative case, we present the main solar wind and Dst observational remarks for two successive magnetic storms with totally different characteristics. (a) 12 - 13 October 2000: This storm has an initial phase associated with an SSC. The main phase lasts only 5 hours during which the IMF-Bz exhibited very sudden changes, with variations of very large magnitude (form 15 nT to -18 nT). This is classified as impulse storm. (b) 13 - 16 October 2000: This storm has no initial phase and the main phase is caused by a slowing increasing IMF-Bz that reached the value of -14 nT in about 28 hours. These IMF conditions are reflected to the Dst index exhibiting a prolong main phase with no signature of initial compression phase. This is a gradually evolving storm.

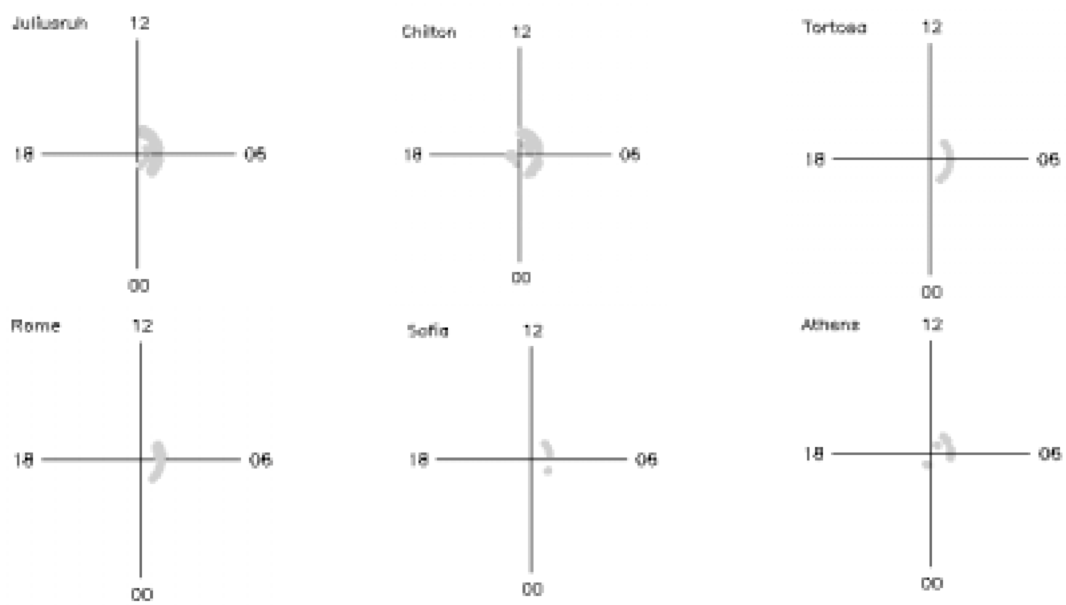

Fig.1: The polar plots of the relative deviation in foF2 parameter from their respective quiet values, versus the local time for the October 12-13 geomagnetic storm, for six stations consisting a north-south chain.

The two types of storms result to different ionospheric response at middle latitudes. The polar plots of the relative deviation in foF2 parameter from their respective quiet values, df%, versus the local time for the October 12-13 geomagnetic storm, are presented in Fig.1 for six stations consisting a north-south chain. The black dots represent positive foF2 deviations, while the grey dots represents negative deviations. The size of dots corresponds to the df% magnitude, which is classified in three categories: (a) from 15% to 30%, (b) from 30% and 50% and (c) larger that 50%. Deviations less than 15% are neglected. Ionisation depletion is evident in all middle latitude stations. The polar plots for the gradual evolving storm occurred on October 13-16 are presented in Fig.2. Positive storm effects are recorded in the most southward stations while positive phases are vanishing above 42º geomagnetic latitude. Consistent results were obtained from the analysis of four more magnetic storms of variable intensity. We have thus strong observational evidence demonstrating that the observation of positive storm effects from ground ionosondes at night is strongly dependent firstly on the solar wind conditions leading to magnetic storms. Given that geomagnetic storms are evolving gradually, the observation of positive effects at night depends also on the storm intensity and on the latitude of the observation point [1].

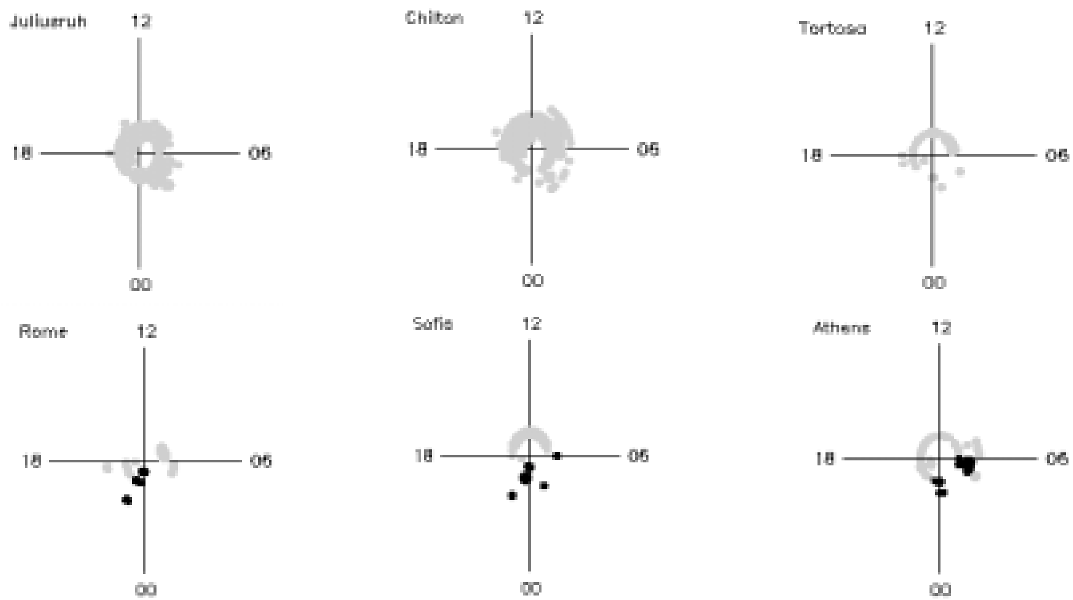

Fig.2: Same as Fig.1 for the storm occurred from October 13 (at 1200UT) to 16, 2000.

THE NATURE OF NIGHTTIME IONISATION ENHANCEMENTS

The AE index recordings, in 1-min. resolution, and the true height profile ionospheric observations from the Athens Digisonde, in 15-min resolution, are presented in Fig.3 during this period. Three F2 region characteristics, the critical frequency foF2, the peak height of the F2 layer, hmF2, and the F2 thickness parameter, B0, in addition to the ionogram derived ITEC [2] estimates were used to extract these plots. All parameters were compared to their diurnal quiet time behaviour, formed by the average of the quiet days October 20 (-2 nT < Dst < 7 nT and Kp < 1) and October 21 (0 nT < Dst < 18 nT and Kp < 2-), when no substorm activity was detected by the AE indices. Also during the day before, October 19, 2000, only weak isolate substorm activity was recorded by the AE index at auroral latitudes, when –13 nT < Dst < 3 nT and Kp < 3. The relative deviations from their respective quiet values are presented for hmF2, foF2 and ITEC. The absolute magnitude of the hmF2 together with the lower F2 layer boundary (hmF2-B0) is also presented in Fig. 3, to determine the height limits of the F2 layer. The solid lines represent the observed parameters, while the dotted lines represent their diurnal quiet time pattern. The vertical dotted lined correspond to local midnight. An upwelling of the F2 layer, limited to the dark hemisphere, in response to enhanced geomagnetic activity, is evident in both storm events. These increases are common features of the ionospheric behaviour during events of either ionisation depletions or enhancements at night. They appear even in storm recovery phases, always limited to the dark side hemisphere and the more intense effects occur during the more magnetospherically active periods [3].

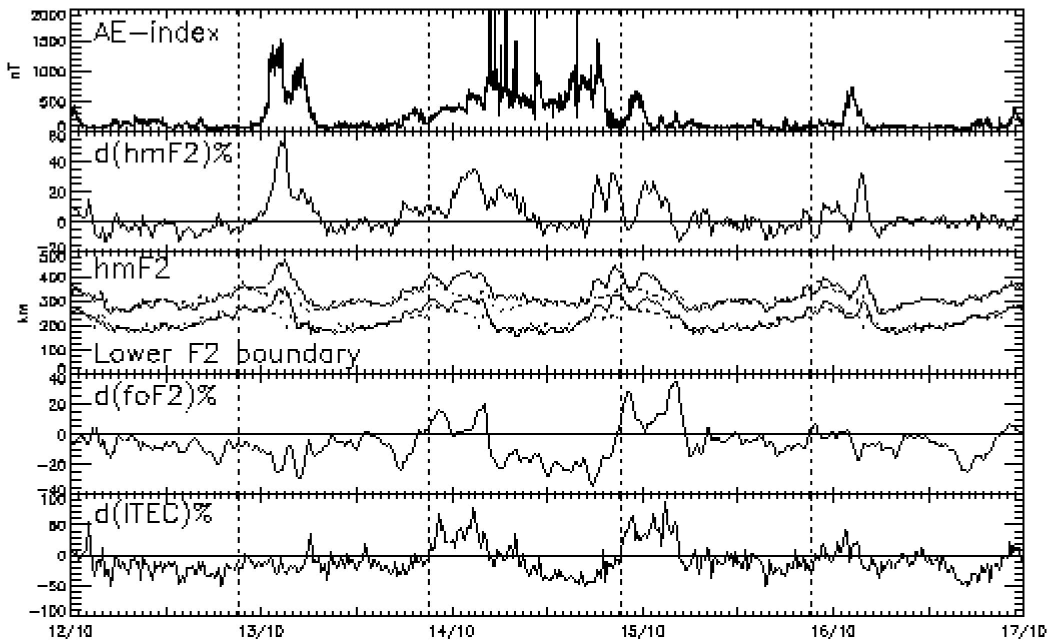

Fig.3: The overview plot that describes the ionospheric conditions over Athens in response to geomagnetically disturbed conditions recorded from October 12 to 16, 2000 is presented (see text for details).

To investigate the characteristics of the observed height enhancements we studied the nighttime height-density ionospheric structure during disturbed periods. The 3-D plot of the true height variation for various plasma frequencies for the nighttime hours of 13-14 October, is presented in Fig.4 as a representative example. The results from the analysis of 10 cases of height variations at night can be summarized as follows: The observed height variations have wave-like characteristics. Their periodicity ranges from 1 h to 5.5 h, tending toward smaller periodicities during ionisation enhancements and before local midnight, when the ionisation density is greater. This dependence on ionisation density may be a possible explanation for the wave-like enhancement observation to be more evident during nighttime positive effects. During daytime hours the fluctuations are totally disappeared, but then other mechanisms like ion drag dominates.

In an effort to quantitatively relate the auroral activity with the ionospheric response at middle latitudes, the rate of AE index increase was estimated for the most clear cases, and it is presented in Fig.5 as a function of the time delay in height enhancement observations with reference to the onset of an energy dissipation episode. It is obvious that the time delay of height enhancements increases with the decreasing AE index derivative, indicating that the height enhancements are strongly associated to the rate of the solar-wind energy dissipation at the auroral ionosphere and they are of auroral origin.

CONCLUSIONS

Nighttime ionisation enhancements and nighttime F2 uplifting are attributed to two distinct mechanisms. Height enhancements are wave-like disturbances that most probably originate in the auroral oval region and propagate toward the equator like TID disturbances [4]. On the other hand, nighttime ionisation enhancements observed in terms of foF2 do not share the same wavy appearance, which may mean that they are not connected to TIDs, nor to auroral oval origin. The increased nighttime density can only be speculated to be due to increased downward fluxes from the plasmasphere [5].

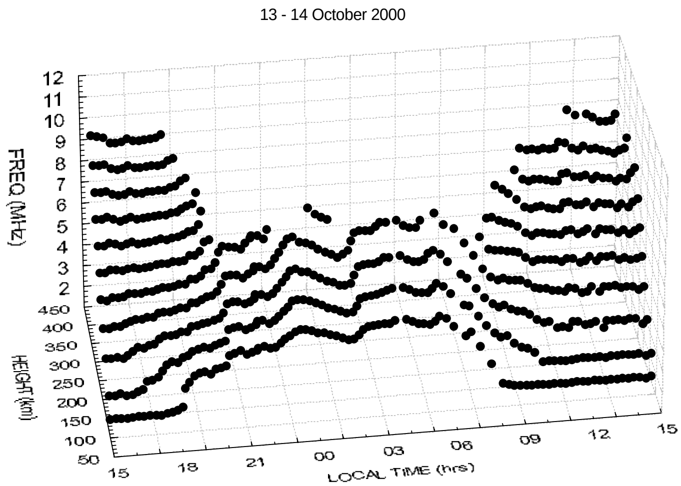

Fig.4. The 3-D plot of the height variation for plasma frequencies 2-12 MHz versus the local time for the night hours between 13 and 14 October 2000. Ionisation enhancement was observed over Athens.

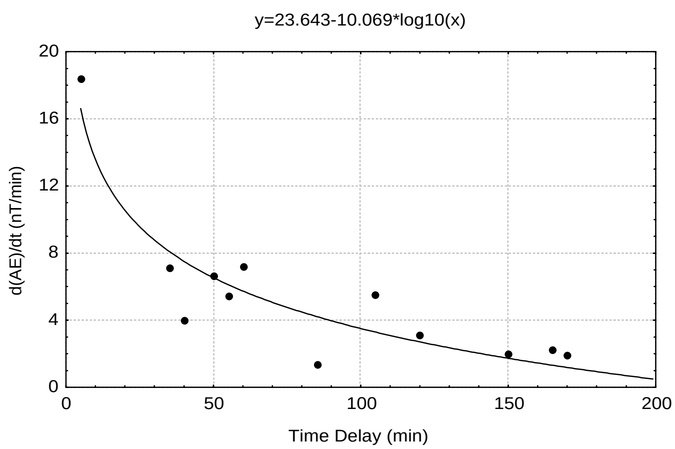

Fig.5.The rate of AE index increase, estimated for 12 clear cases of nighttime height enhancements, as a function of the time delay in height enhancements observation with reference to the onset of an energy dissipation episode.

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