MAGNETOSPHERIC DISTURBANCES IMPACT ON THE IONOSPHERIC DAILY FOF2 FREQUENCIES

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ABSTRACT

The polar cusp being a region of the free access of the solar wind into the inner magneto-sphere is also the site of turbulent plasma flow. The cusp area at low altitudes acts like a focus of a variety type of instability and disturbances from different regions of the Earth. Daily foF2 frequencies are discussed regarding the cusp position. The high time resolution wave measurements together with electron and ions energetic spectra measurements registered on the board of Freja satellite and Magion-3 and the electron density at the peak of foF2 layers collected from ground base ionosonde measurements were used to study the response of ionospheric plasma within cusp-cleft region to the strong geomagnetic storm.

In this paper we present the response of the ionospheric plasma to the disturbed conditions seen in the topside wave measurements and in the ionospheric characteristics maps obtained from the ground based VI network. The need of the cusp feature model for radio communication purposes is advocated.

1. INTRODUCTION

In the cusp-cleft region the solar wind particles have the most direct access to the Earth ionosphere and magnetosphere. The cusp is characterised by intense fluxes of low energy electrons and ions, which precipitate into the lower parts of the atmosphere, while the cleft region is characterised by less intense ion fluxes and slightly higher electron energies than in cusp. The cusp-cleft area at low altitudes acts like a focus of a variety type of instability and disturbances from different regions of the Earth. Particularly in this area the most of the disturbances that later are spread into the lower latitudes are generated.

The need of the accurate description of the ionospheric conditions for the propagation assessments is very obvious. Particularly the instantaneous maps of electron concentration enables to improve radio communication. Instantaneous maps of different ionospheric characteristics and parameters are the suitable source of information needed HF point-to-point and Earth-space ionospheric propagation assessments. Convenient accesses via INTERNET and e-mail to the most recent VI data open possibility to generate instantaneous maps of ionospheric characteristics in near real time. Such data are served by the International Space Environment Service – ISES, Ionospheric Despatch Centre in Europe – IDCE [1], that is a COST 251 European Action initiative (Cooperation in Scientific and Technical Research) [2], as well as by other prediction services or individual ionospheric stations. Unfortunately, generally the number of measurements locations is insufficient for the production of fully accurate maps, even over restricted geographical region. Additional information is introduced by the topside measurements of different origin; direct measurements of particles concentration, waves at the wide spectrum, temperature. The amount and variety of existing in almost real time this type of observations enables to clarify the direct magnetospheric impact on foF2 frequencies of the source of the disturbance, which is located also in the cusp-cleft region.

The procedure of plasmospheric impact on foF2 frequencies has been successfully applied for the improvement of radio communication maps at the disturbed night ionosphere [3], [4] while the mid-latitude trough model was introduced [5]. In this paper we present the response of the ionospheric plasma to the disturbed conditions seen in the topside wave measurements and in the ionospheric characteristics maps obtained from the ground based VI network. The need of the cusp feature model for radio communication purposes is advocated.

2. ELECTRON DENSITIES IN THE DAYS SIDE CUSP

Energetic particle precipitation into the ionosphere in the cusp-cleft region generates an increase of electron density and temperature. The electron temperature is increasing within few seconds after the start of precipitation event, but the electron densities change with few minutes delay. The width of the cusp can reach 10^o in latitude around noon and is extremely sensitive to the geomagnetic disturbances. The latitude movement of the cusp-cleft region can be assumed by the simple empirical formula deducted from satellite measurements on the board of INJUN V by Munch [6]. The invariant position of equatorward wall of the cusp is:

$$\Lambda = 80.0-2.2*Kp \qquad (1)$$

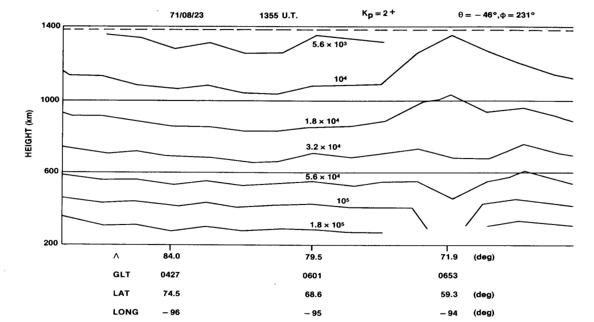
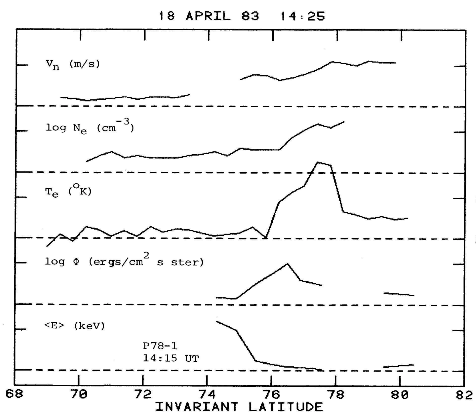


Fig. 1. ISIS-2 electron density contours in the cusp region for Kp=2+[7]) detected by the topside sounding technique



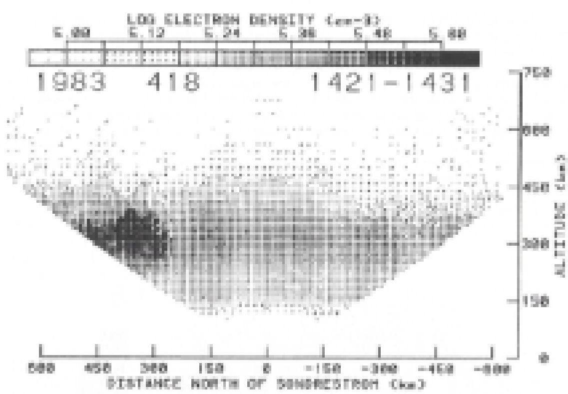


Fig. 2. Latitudinal variation of electron densities and temperatures detected by P78-1 satellite and by Sondesrtrom radar in the cusp-cleft region[8]

The variability in time and space of particle precipitation can produce gradients in electron density and, in consequence, small-scale irregularities responsible for spread F, trough gradient drift instability also.

The low altitude cusp area acts like a focus of a variety type of instability and disturbances from different regions of the earth. There has been done a wide range of different type of measurements in the cusp region during the last years; on the board of satellites and ground based. The first measurements have been performed on the board of the low orbiting satellites: Alouette 1, ISIS 1 and 2, OGO-4, DE-2, and the high orbiting satellites DE-1, HEOS, Hawkeye, Prognoz-7 and 8.

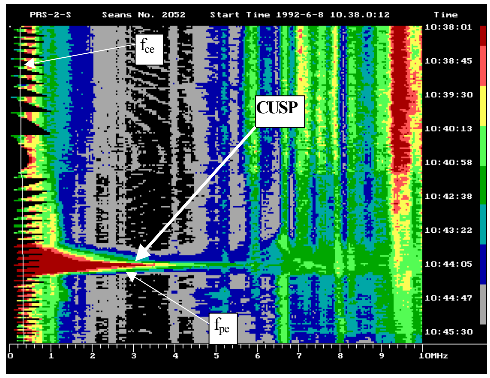


Fig. 3. Magion-3 measurements at 8.06.1992, at the altitude 1000 km. The sequence of electric field HF spectra registered along the orbit 2052. White line marks the local gyrofrequency at the altitude of satellite. The intense HF broadband emission appears around 10.44UT.

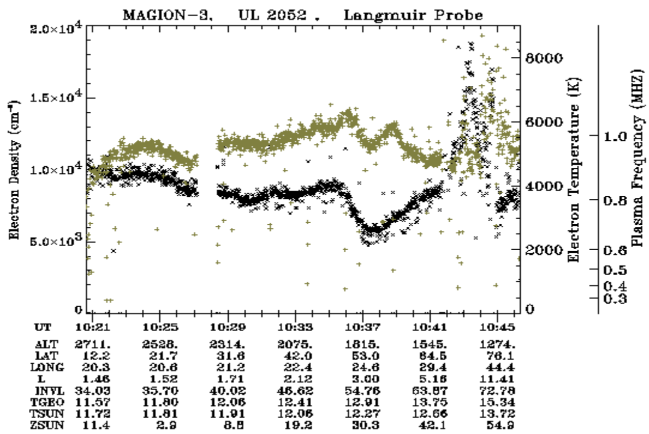


Fig.4. Langmuir probe measurements along the orbit 2052 in the cusp region. The enhancement of electron temperature(grey +) are correlated with HF emission.[9]

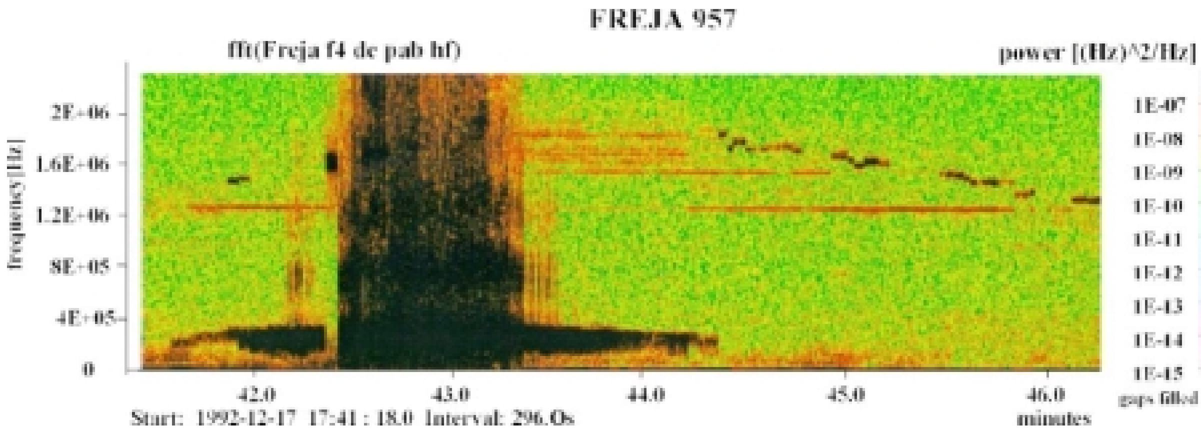


Fig. 5. The cusp region over the Atlantic Ocean seen from the board of Freja satellite 17.12.1992 at 18UT.

The most resent high-time resolution observations from Viking, Freja, Apeks-Magion-3, and Interball extend our knowledge on the physical processes in the cusp region. Figures 1 and 2 show cusp signatures detected on the board of ISIS 2 and simulatanesy by P78-1 satellite and Sondesrtrom radar facility.
As the example, HF radio spectrometer measurements show cusp phenomena with well-defined parameters. Cusp feature indicated by Magion-3 well-manifested enhancements of local electron density at the altitude around 1200 km is shown in Fig. 3. Langmuir probe measurements conducted on this satellite, correlate with HF measurements, displayed the pronounce enhancements of electron temperature and density. (Fig. 4).

The cusp has been also registered on the board of Freja satellite. The well manifested enhancement of electron density at altitude around 1600 km in the cusp area is shown on the Fig. 5.

3. MAPS OF foF2 IONOSPHERIC CHARACTERISTIC

The COST 251 instantaneous mapping model has been produced for operational use in telecommunication systems[10]. It gives an operational tool that enables to generate a map for specific epochs using randomly data-sparse regions from different origin; vertical incidence ionospheric soundings, as well as radar, or in situ measurements from satellites and rockets.

Some cases when the cusp-cleft region was observed from the satellites were checked in order to correlate satellite observations with a cusp signature extracted from foF2 maps.

Fig. 6 presents foF2 instantaneous map European area constructed with the use of PLES model for the correlated with 2052 Magion-3 orbit moment of time (10.30UT), see also Figure 3 and 4. Unfortunately, 1-hour resolution VI measurements were available only. That is why the map was artificially shifted in longitude for half an hour in order to simulate the homogeneous circumstances existing during satellite measurements.

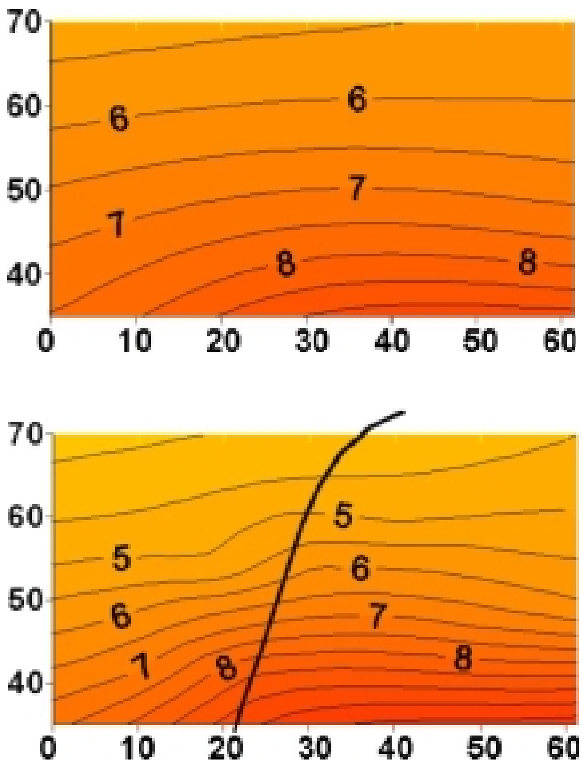


Fig. 6. FoF2 maps(MHz) for European area. top instantaneous map at June 6, 1992, 10.30 UT, bottom COST 251 median map [11].

Such procedure represents a simplification, but enables to compare the cusp signatures measured on the board of satellites to these observed in F2 layer. Median map is shown for comparison.

Cusp area observed on the board of Freja satellite at December 17, 1992 over the Atlantic Ocean at 18 UT(see also Fig. 5) [12] has been relocated into European area by presentation of foF2 map for four hours earlier moment of time (14UT) when the cleft was situated above Europe.

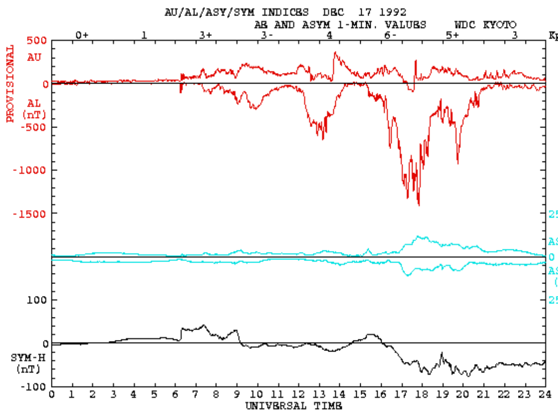


Fig. 7. Magnetic activity described with the use of different indices during December 17, 1992.

Confirmation of the correctness of this stratagem (trick, manoeuvre) is magnetic activity during the period of interest (see Fig. 7).

Figure 8 presents foF2 instantaneous foF2 map. Well-pronounced enhancement of foF2 is seen at high latitudes around 20°E.

The ground based direct measurements are highly perturbed, but the cusp phenomenon is well manifested even for such general set of data. However the need of the map for radio communication purposes forces to employ the theoretical model of the cusp feature, which can be made on the base of satellite data.

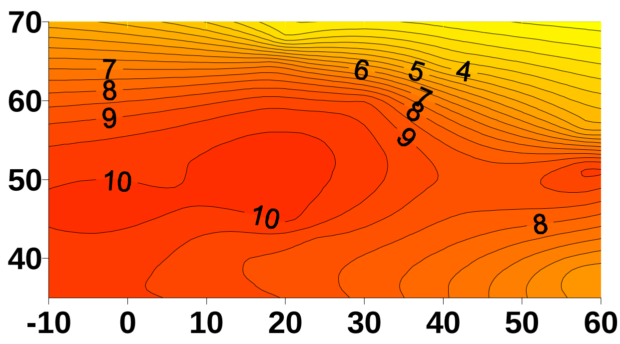


Fig. 8. FoF2 instantaneous map (MHz) for European area for December 17, 1992, 14 UT.

4. CONCLUSIONS

Magnetospheric disturbances impact on the ionospheric daily fof2 frequencies is remarkable and can be closely related to the cusp feature.

Geographical position of the cusp determined by high-latitude topside measurements seems to be very close to the disturbance seen at the foF2 maps obtained from PLES model even with some doubts concerning the mapping accuracy and the topside data interpretations. In spite of these limitations almost real time availability of both VI and topside measurements makes possible the use of these for the practical improvement of radio communication maps. Now the topside measurements can be treated not only as the indicator of the high altitude local disturbance that statistically will influence the electron concentration below, but as the physical source of redistribution of the electron concentration that while use more simple models will give exact numbers of it. Future works will refinements to the dayside cusp-cleft model for radio communication purposes.

5. ACKNOWLEDGMENTS.

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6. REFERENCES

1. Stanislawska, I., T. L. Gulyaeva, and R. Hanbaba, Ionospheric Despatch Centre in Europe, *Phys.Chem.Earth(C)*, Vol. 24, 4,.355-357,1999.

2.Hanbaba R., COST271 Final Report, SRC Warsaw, 1999.

3. Rothkaehl, H., I. Stanisławska, R. Leitinger, and Y. Tulunay, Application of a Trough Model for Telecommunication Purposes, Phys.Chem.Earth(C), Vol 25(4),.315-318, 2000.

4. Stanisławska, I. and H. Rothkaehl, PLES model in the plasmapause diagnostic, *Adv. Space Res.*, (in press) 2001.

5. Bradley, P. A., G. Juchnikowski, H. Rothkaehl, and I. Stanislawska, Instantaneous maps of the European middle and high-latitude ionosphere for HF propagation assessments, *Adv. Space Research*,Vol 22(6), 861-864, 1998.

6. Münch J.W,Brown H.J., Pilkingon G.R, Sagalyn R,C, Wildmann P.J.L, Thermal Electron
Densities And Temperatures In The Days Side Cusp Region, *JATP,* Vol. 39, 699, 1977.

7. Muldrew D.B., Observations Of The Cusp With Topside Sounders, *The polar cups,* NATO Asi Series, D. Reidel Publish Comp. Dordrecht, Holland , 377, 1985.

8. ForsterJ.C., Holt J.M., Kelly J.D. and Wickwar V.B., High resolution of electric field and F-region plasma parameters in the cleft Ionosphere, *The polar cups,* NATO Asi Series, D. Reidel Publish Comp. Dordrecht, Holland , 349, 1985.

9. H. Rothkaehl, HF plasma emission detected in cusp region at ionospheric altitude. Adv. Space. Res, Vol Vol. 23 No 10, 1769, 1999.

10. Stanisławska, I., G. Juchnikowski, R. Hanbaba, H. Rothkaehl, G. Sole, and Z. Zbyszyński, COST 251 Recommended Instantaneous Mapping Model of Ionospheric Characteristics, *Phys.Chem.Earth(C)*, Vol 25, 4, 291-294, 2000.

11. Mikhailov, A. V., V. V. Mikhailov, and M. G. Skoblin, Monthly median foF2 nad M(3000)F2 ionospheric model over Europe, *Annali di Geofisica*, 39,.791-805, 1996.

12. H.Rothkaehl, J.Błęcki, K. Stasiewicz , A. Eriksson, HF-VLF Plasma Waves Excitation During Geomagnetic Storm In The Polar Cusp Region, proc. *ESA ClusterII Workshop, Multiscale and Multipoint Plasma Measurements,* Londyn 1999.SP,449, 331, 2000.