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COLD PLASMA DISTRIBUTION IN THE EQUATORIAL PLANE AS SEEN FROM *IN SITU* MEASUREMENTS AND INFERRED FROM LOW-ALTITUDE OBSERVATIONS OF ENERGETIC ELECTRONS

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1. Introduction

In papers by *Yahnina et al.*, [1996], *Titova et al*, [1998], *Trakhtengerts et al.*, [1996], *Pasmanik et al.*, [1998] a phenomenon called as "cliff" has been described and studied. The "cliff" is a sharp increase of the quasi-trapped flux of energetic electrons, measured by low altitude satellite, associated with the increase of precipitating flux. The largest gradient of the flux intensity is directed toward the pole and characterized by several times increase of the flux, when the latitude increases by 0.1-0.2 degrees. It has been suggested [*Trakhtengerts et al.*, 1996; *Pasmanik et al.*, 1998] that the cliff is the result of cyclotron interaction between eastward drifting energetic electrons and whistler waves at the dense and cold plasma gradient. The interaction occurs at the western edge of the so called "tongue" of the detached plasmaspheric plasma, which is formed during the recovery phase of a geomagnetic storm [e.g. *Carpenter et al.*, 1993].

To verify the hypothesis it is important to compare the cliff observations with in situ measurements of the plasmaspheric plasma. In this paper we present such a comparison on the basis of simultaneous measurements of energetic electrons at low altitudes and cold ions at geosynchronous orbit. For this aim we used the data of MEPED instrument measuring the particles with energy >30 keV onboard the satellites NOAA-12 and 14 [*Hill et al.*, 1985] and data obtained from the MPA instrument onboard the LANL satellites [*McComas et. al*, 1993, *Moldwin et al*, 1994].

2. Observational results

2.1. Event of September 27, 1996

On the top of Fig. 1 daily variations of cold (<130 eV) ions along the geosyncronous orbit are presented. Strong enhancement of the cold plasma density is seen at 1030-1250 UT. The western edge of this enhancement was detected at MLT=15. Close to the time, when geosynchronous spacecraft 1991-080 entered the region of dense plasma, satellites NOAA-12 and NOAA-14 crossed the plasmasphere latitudes at MLT=17.6 and 13.7, respectively. NOAA-12 detected the cliff phenomenon while NOAA-14 did not. The location of the cliff projection into equatorial plane was X=0.45 R_E, Y=4.5 R_E. According to the interpretation of the cliff, it must be detected at the western edge of the detached cold plasma. Indeed, mutual location of the cliff and western edge of dense plasma on geosynchronous orbit reasonably represents the plasmaspheric "tongue" boundary.

2.2. Event of March 21, 1996

Fig. 2 presents the observations, which have been done on March 21, 1996. For this case the dense plasma region exhibited some dynamics. At 0830-1030 UT the dense plasma has been detected by spacecraft 1994-084 at MLT=16.0-17.5, but at 1530 UT the spacecraft 1990-095 entered the dense plasma at MLT=13. Let us consider the NOAA satellite data obtained during passes around the times when the geosyncronous spacecraft met the western boundary of dense plasma. Like in the case considered above, when the region of dense plasma was observed in evening sector the satellite NOAA-12 crossing the evening sector detected the cliff, while the satellite NOAA-14 in the afternoon sector detected only well trapped population without any specific features. Seven hours later, in accordance to the expansion of the dense plasma region to the west, the cliff was also observed in the afternoon sector. The expansion of the dense plasma was likely related to the growth of the geomagnetic activity as evidenced by a gradual increase of Kp-index (not shown). Notice that changeable electron flux with several cliff-like structures takes place in the evening sector during pass 25101n of NOAA-12. This probably means that the density distribution inside the detached plasma region in the evening sector is very structured.

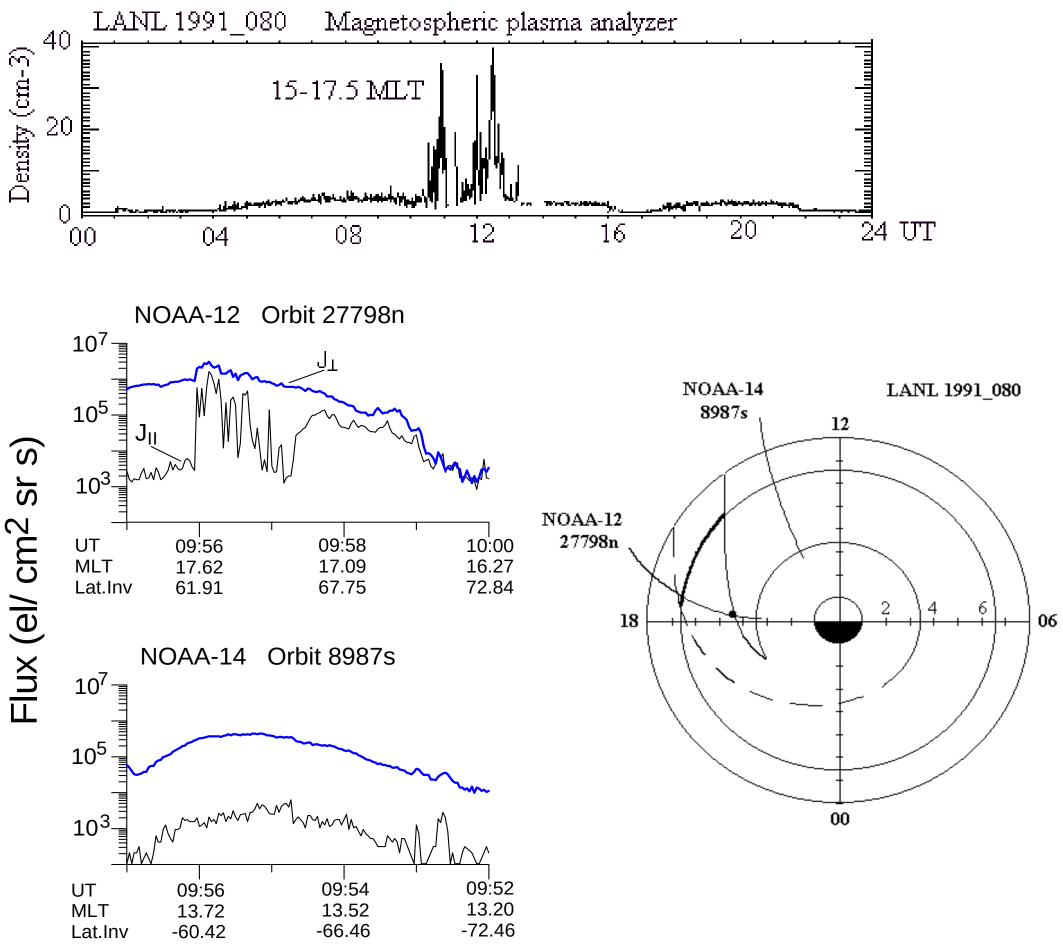


Fig.1. Top: Density of cold (<130 eV) ions as measured by spacecraft 1991-080 during Sept. 27, 1996. Bottom left: Energetic electron data obtained by satellites NOAA-12 and -14. The cliff phenomena is seen in the NOAA-12 data at latitude ~62^{O}. Bottom right: Equatorial projection of the trajectories of satellites LANL and NOAA. Thick segment at the geosynchronous orbit marks the observed dense plasma region. Black dot indicates location of the cliff. Assumed positions of plasmasphere as well as plasmaspheric "tongue" deduced from observations are shown schematically by solid and dashed lines.

3. Dependence of diffusion parameter on cold plasma density

One of important characteristics of the pitch-angle diffusion process is a ratio of precipitating and trapped fluxes (diffusion parameter). Increase of this ratio signifies intensification of the particle scattering and vice versa. Examination of several events similar to that described in Figs. 1, 2 allowed us to conclude that there is a clear dependence of this ratio in the cliff on cold plasma density *Nc* at the western edge of the detached plasma structure. The experimental dependence is shown in Fig.3 by crosses. Within the range of observed *Nc* values, the pitch angle distribution of energetic electrons becomes more isotropic with increase of *Nc*.

Let us briefly consider this dependence in the framework of the cliff formation model suggested by *Trakhtengerts et al.* [1996] and developed by *Pasmanik et al.* [1998]. Eqs. (1) and (2) in the latter paper for the basic self-consistent set for quasi-stationary cyclotron interactions of energetic electrons and whistler waves near the sharp gradient of the cold plasma density. From these equations, it is easy to see that the maximal isotropization is determined by the maximal wave energy density ε which, in its turn, depends on the initial growth rate γ_0 at the entrance into the interaction region. The larger is γ_0, the faster is ε growth, and the larger is its maximal value. The latter is reached in the point where γ becomes equal to the wave damping rate ν in process of its decrease due to the isotropization of the energetic electron distribution. Calculations show that for the parameters deduced from observations, γ_0 increases with *Nc*. According to the discussion above, this provides the increase of the maximal isotropization. Note that this dependence was not considered by *Pasmanik et al.* [1998] because their detailed analysis was made under assumption of sufficiently large cold plasma density when γ_0 does not increase with *Nc*.

One particular result of numerical calculations is shown in Fig. 3 by the solid line. It shows the same tendency as experimental data do. This result, to our mind, confirms the validity of the suggested model of cliff generation. It is worth noting that the theoretical plot shown would depend on different parameters such as energetic electron flux, their characteristic energy and pitch-angle distribution etc. Details of these dependencies will be presented elsewhere.

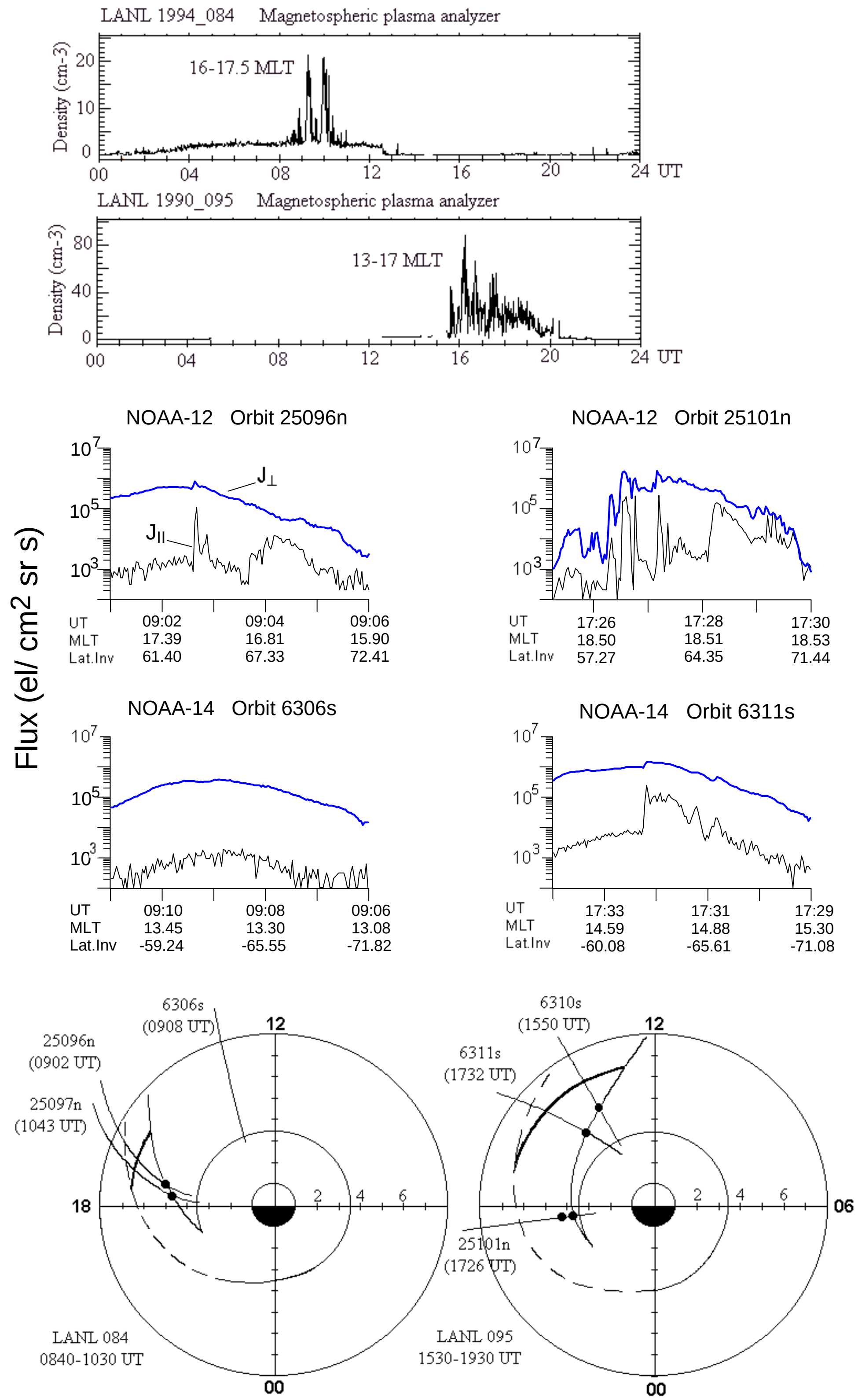
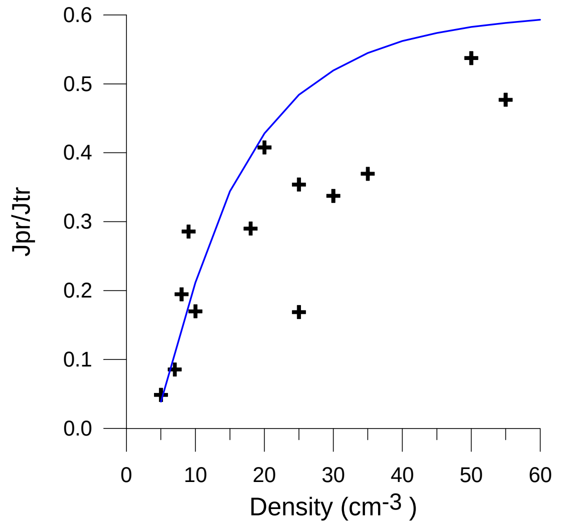


Fig.2. Two upper panels show the cold plasma density variations during the day of March 21, 1996 as observed by geosynchronous LANL spacecraft 1994-084 and 1990-095. In the middle: Energetic electron data from satellites NOAA-12 and -14. Bottom: Schematically presentation of NOAA satellite trajectories, dense plasma regions on geosynchronous orbit (thick segments), cliff locations (black dots), and plasmasphere structure in the equatorial plane.

Fig.3: Maximal degree of isotropization as dependent on cold plasma density *Nc*. Theoretical curve was obtained for the following parameters: L = 4, electron energy W_0 = 45 keV, initial trapped energetic electron flux at the altitude of NOAA satellite was kept constant at Jtr = $8*10^6$ el/cm^2 s sr.

The experimental data are shown by crosses.



4. Conclusions

We showed close relationship between the locations of the detached cold plasma boundary and specific "cliff" -like type of energetic electron precipitation. In addition, the dependence of the diffusion parameter in the cliff on plasma density is found. These results imply the correctness of the model of cliff generation suggested by *Pasmanik et al.*, [1998]. It also indicates the possibility of use of the cliff observations at low altitudes for diagnostics of the cold plasma distribution in the inner magnetosphere.

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References

Carpenter D.L., B.L. Giles, C.R. Chappell, P.M.E. Decreau, R.R. Anderson, A.M. Persoon, A.J. Smith, Y. Corcuff, and P. Canu, Plasmasphere dynamics in the duskside bulge region: a new look at an old topic, J. Geophys. Res., *98*, 19243-19271, 1993.

Hill V.D., D.S. Evans, H.H. Sauer. TIROS/NOAA satellites space environment monitor. Archive tape documentation, NOAA Tech. Mem. ERL SEL-71, 50pp. Environs. Res. Lab., Boulder. 1985.

McComas D.J., S.J. Bame, B.L. Barraclough, J.R. Donart, R.C. Elphic, J.T. Gosling, M.B. Moldwin, K.R. Moore, M.F. Thomsen. Magnetospheric plasma analyzer: initial three-spacecraft observations from geosynchronous orbit. J. Geophys. Res., V.98, N A8, 13453-13465, 1993.

Moldwin M.B., M.F. Thomsen, S.J. Bame, D.J. McComas, K.R. Moore. An examination of the structure and dynamics of the outer plasmasphere using multiple geosynchronous satellites. J. Geophys. Res., V.99, N A6, 11475-11481, 1994.

Pasmanik D.L., V.Yu. Trakhtengerts, A.G. Demekhov, A.A. Lubchich, E.E. Titova, T.A. Yahnina, M.J. Rycroft, J. Manninen, T. Turunen. A quantitative model for cyclotron wave-particle interactions at the plasmapause. Ann. Geophys., 16, N3, p.322-330, 1998.

Titova E.E., T.A. Yahnina, A.G.Yahnin, B.B. Gvozdevsky, A.A. Lubchich, V.Yu. Trakhtengerts, A.G. Demekhov, J.L. Horwitz, F. Lefeuvre, D. Lagoutte, J. Manninen, T. Turunen. Strong localized variations of the low-altitude energetic electron fluxes in the evening sector near the plasmapause. Ann. Geophys., 16, N1, p.25-33, 1998.

Trakhtengerts V.Yu., A.A. Lubchich, A.G. Demekhov, T.A. Yahnina, E.E. Titova, M.J. Rycroft, J. Manninen, T. Turunen. Cyclotron model for quasi-steady precipitation of energetic electrons at the plasmapause. Proceedings of XIX Apatity seminar "Physics of auroral phenomena", 73-76, Apatity, 1996.

Yahnina T.A., E.E. Titova, A.G. Yahnin, B.B. Gvozdevsky, A.A. Lubchich, V.Yu. Trakhtengerts, A.G. Demekhov, J.L. Horwitz, J. Manninen, T. Turunen. Some features of the energetic electron precipitation in the evening sector. Proceedings of XIX Apatity seminar "Physics of auroral phenomena", 70-72, Apatity, 1996.