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TEMPERATURE AND DENSITY VARIATIONS IN THE DUSK AND DAWN PLASMASPHERE AS OBSERVED BY INTERBALL TAIL IN 1999 – 2000

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ABSTRACT

The data on cold ion fluxes measured by the ALPHA 3 instrument on Interball-Tail in July – October 1999 when the spacecraft crossed the dusk side outer plasmasphere, and in January – April 2000 when it crossed the dawn side plasmasphere are analyzed. Correlation of cold ion parameters in the plasmasphere with indices of geomagnetic activity and parameters of the external solar wind flow is examined. In the innermost observed part of the dawn plasmasphere ion temperature is increasing with MLT from post midnight to prenoon. In the outermost plasmasphere no temperature dependence on MLT was observed. It is revealed that cold ion density in the dusk and dawn side outer plasmasphere is increasing with increasing solar wind ram pressure.

INTRODUCTION

For almost 40 years the plasmasphere of the Earth has been intensively studied by whistler observations, geosynchronous satellites and DE-1, ISEE 1 and other satellites (Lemaire et al., 1998), but still there are a lot of unresolved questions concerning its formation and plasma characteristics. Rather comprehensive review of plasmasphere dynamics in the dusk side region was published by Carpenter et al. (1993) but the authors did not investigate plasma parameter variations during magnetic storms. Overall thermal structure of the plasmasphere was considered by Comfort (1996). For L- shells lower than 3 there were indications of pronounced diurnal variations. The mean evening temperatures were observed to be higher than morning temperatures. At the same time, the data on the responses of cold plasma parameters in the plasmasphere to geomagnetic activity variations are very limited. It is usually proposed from early whistler works that the density in the outer plasmasphere can be depressed in the aftermath of magnetic disturbances (Carpenter, 1993). Preliminary analysis of the INTERBALL 1/ALPHA 3 data revealed that cold ion density in the dusk side outer plasmasphere is increasing with increasing solar wind ram pressure (Kotova, 2000). The present paper continues to analyze statistically the data obtained by the INTERBALL 1/ALPHA 3 instrument in 1999 in the dusk side plasmasphere and in 2000 in the dawn side in order to examine dependencies of cold plasma parameters on the indices of geomagnetic activity and parameters of the external solar wind flow.

EXPERIMENTAL RESULTS AND DISCUSSION

The ALPHA 3 experiment for cold ion flux measurements including retarding plasma analyzer (RPA) was functioning on INTERBALL 1 during its active life. The description of the instrument could be found in Bezrukikh et al. (1998). Due to highly eccentric spacecraft orbit the plasmasphere was crossed every 4 days. Cold ion spectra were measured during 2 s once per ~ 2 minutes. The data collected from 19 orbits of INTERBALL 1 in July – October 1999 when the plasmasphere was crossed in the outer dusk sector (15 – 22 MLT) between $L \approx 3$ and $L \approx 5$ and from 21 passes in January – April 2000 across the dawn side plasmasphere (02 – 10 MLT, $2 < L < 5$) are analyzed. These times the spacecraft trajectory crossed the plane of magnetic equator almost vertically and thus almost the same flux tube was crossed twice.

Figure 1 presents scatter plots of proton temperature (left plots) and density (right plots) in the dawn (top plots) and dusk (bottom plots) plasmasphere reduced from the spectra measurements along the orbits. On every plot curves correspond to power fits, and the curves fitting the data in the dusk side plasmasphere (dashed) are reproduced on the top plots corresponding to the dawn plasmasphere. The temperature seems to be higher in the dawn outer plasmasphere than in the dusk plasmasphere. But this can not be stated confidently due to the large scatter of the data points and relatively small amount of points in the outer dawn plasmasphere. The density fitting curves coincide very well for the dusk and dawn measurements. The observed dependence N ~ L^{-4} well corresponds to the one proposed for a collisionless plasma.

Figure 2 compares cold proton temperature obtained from the ALPHA 3 measurements with the DE-1/RIMS temperature data published earlier (Comfort, 1996). The fitting curves shown in the left panels of Figure 1 were superimposed on corresponding panels of Figure 3 in Comfort (1996). Very good agreement between the data was found.

The dependence of proton temperature on the magnetic local time is considered in Figure 3. The data collected on the dawn side were divided into 2 groups for the innermost observed L – shells (L < 2.8) and for the outer L – shells (L > 2.8). It is seen that in the outer plasmasphere no MLT – dependence of cold proton temperature was observed, while in the inner plasmasphere temperature is increasing from post midnight to pre noon. On the dusk side only the outer plasmasphere (L > 3) was crossed and no dependence of proton temperature on MLT was found. The temperature increasing with MLT in the inner plasmasphere is apparently connected with photoelectron heating of the ionosphere and the outer plasmasphere is not so tied to the ionospheric parameters. However it is necessary to thoroughly compare the experimental data with theories to make reasonable conclusions on whether photoelectrons are the only source of even inner plasmasphere heating.

A matter of considerable interest is the dependence of cold ion parameters in the plasmasphere on the level of geomagnetic activity. The attempt to find any meaningful dependence of plasmasphere density variations on magnetic activity indices failed and we tried to look at any correlation with external solar wind parameters as the solar wind interaction with the terrestrial magnetosphere causes the majority of processes in the near Earth space. One-hour averaged solar wind parameters were taken from NSSDC OMNIWeb (http://nssdc.gsfc.nasa.gov/omniweb/ow.html) and supplemented by the WIND Solar Wind Experiment (SWE) data (Ogilvie et al., 1995). Again, no correlation was found for the density of the innermost observed part of the dawn plasmasphere. But for the outer plasmasphere it appears that cold proton density is increasing with increasing solar wind ram pressure. Figure 4 shows plots of plasmasphere density versus solar wind ram pressure. The plasmasphere density was taken at almost constant L – shell: L = 3.5 ± 0.2. This L –

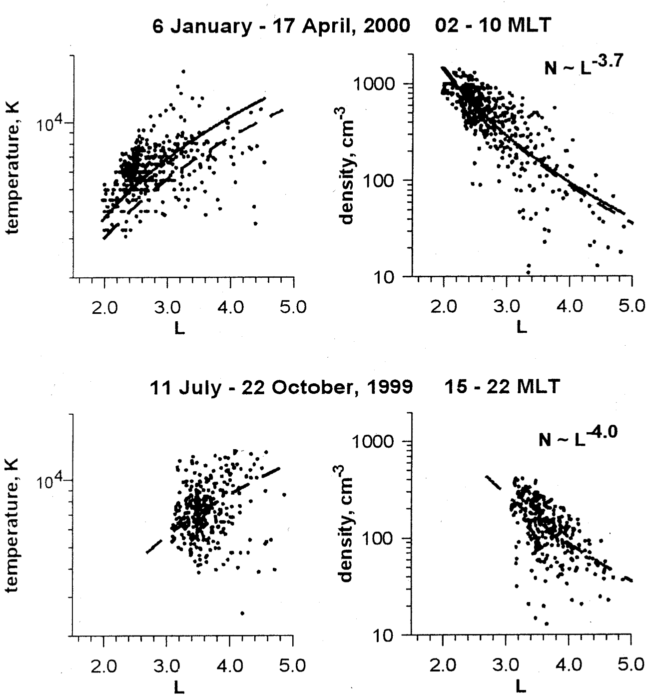

Fig. 1. Temperature and density in the dawn and dusk plasmasphere as functions of L - shell

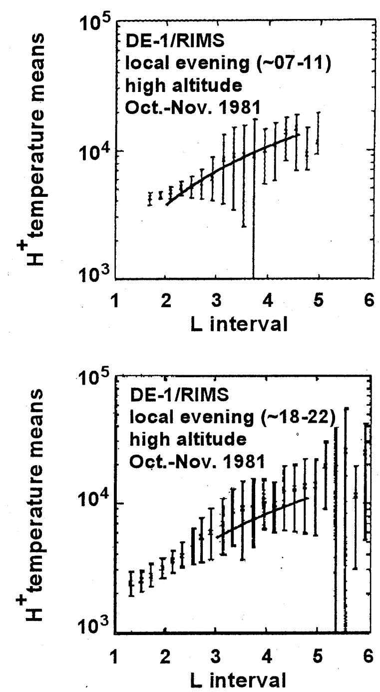

Fig. 2. Comparison of mean temperature profiles deduced from DE-1/RIMS and INTERBALL 1/ALPHA 3.

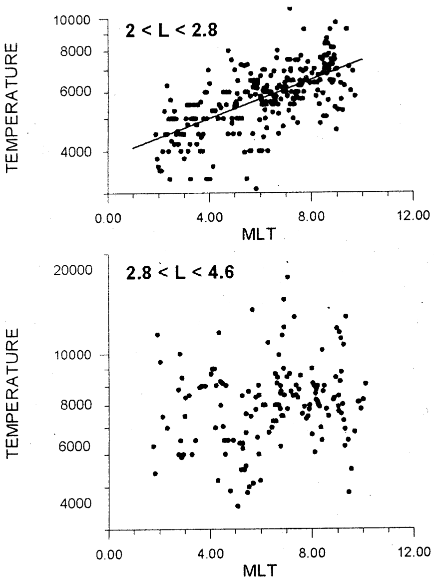

Fig.3. Dawn side cold proton temperature as a function of MLT for the innermost observed L – shells and the outer L – shells.

shell was chosen because it is the innermost observed shell for the dusk side crossings and we avoided taking points very close to the plasmapause in the region of steep density gradient. Solar wind pressure was calculated for the hour of plasmasphere observation (a, d); 6 (b, e) and 12 (c, f) hours prior to the plasmaspheric measurements. The correlation of the cold proton density in the dusk outer plasmasphere (bottom panels) with the solar wind ram pressure is apparently the best when the solar wind parameters are refered to the hour of plasmasphere measurements (correlation coefficient R = 0.59), though correlation is still present when the solar wind parameters are taken 6 hours before the measurements in the plasmasphere (R = 0.47). In case the solar wind parameters are taken 12 hours earlier than the plasmaspheric measurements, no correlation is observed. The picture looks somewhat different for the outer dawn plasmasphere (top panels). For the dawn side the correlation between the plasmasphere density and solar wind ram pressure is also present when the solar wind parameters are taken 12 hours before the plasmasphere measurements (for the panel 'a' R = 0.56, for the panel 'c' R = 0.53). In a number of cases there are no solar wind data to be compared with the dawn plasmaspheric data and this leads to a less number of points on the top panels. It is worth to mention that on 29 March 2000 the plasmapshere was observed at time when the solar wind was very weak and this case needs to be specially analyzed.

The cause of the seeming plasmaspheric density enhancement with increasing solar wind pressure might be the convection electric field in the outer plasmasphere, which was not taken into account in data processing. The average large scale dawn – dusk electric field E ~ 0.05 – 1.5 mV/m (scaling in magnitude with K_p) (e.g. CRRES observations, Rowland and Wygant, 1998) results in plasma convection velocity $V_{conv} = E/B \leq 2$ km/s in the equatorial plane directed approximately toward the Sun. This velocity component is considerably less than the spacecraft velocity $V_{sp} \sim 5 - 8$ km/s mostly perpendicular to the equatorial plane and thus such electric field results in insignificant density variations of less than 10 %. Even extreme electric fields of 6 mV/m, which were sometimes observed in the evening sector (Rowland and Wygant, 1998), can cause density variations up to 40%. Consequently, large-scale electric fields hardly can account for the observed dependence of ion density in the outer plasmasphere on solar wind ram pressure.

CONCLUSIONS

Analysis of the data on cold plasma fluxes measured along 19 passes of INTERBALL 1 across the dusk side outer plasmasphere in July – October 1999 (3 < L < 5) and along 21 passes in January – April 2000 across the dawn side plasmasphere (2 < L < 5) can be summarized as follows.

- Cold ion temperatures obtained with the ALPHA 3 experiment very well correspond to DE 1 measurements.
- In the innermost observed part of the dawn plasmasphere ion temperature is increasing with MLT from post midnight to prenoon. In the outermost plasmasphere no temperature dependence on MLT was observed.
- On average ion densities seem to be alike on the same L-shells (3 < L < 5) in the morning and evening sectors of the plasmasphere.
- It is revealed that cold ion density in the dusk and dawn side outer plasmasphere is increasing with the solar wind ram pressure. This dependence should be taken into account while constructing theoretical models of the plasmasphere and should find its straightforward explanation.

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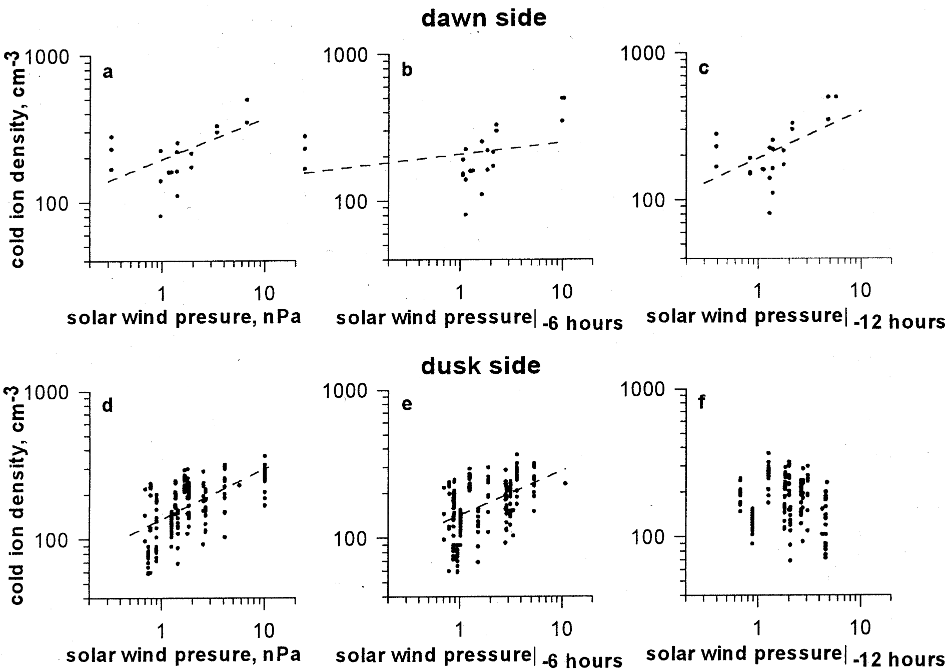

Fig. 4. Cold ion density in the plasmasphere at L = 3.5 ± 0.2 versus solar wind ram pressure. a, d – the average solar wind parameters are taken for the hour of plasmasphere observation; b, e – the solar wind parameters are taken 6 hours prior to the plasmaspheric measurements; c, f - the solar wind parameters are taken 12 hours prior to the plasmaspheric measurements.

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