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New aspects in plasmaspheric ion temperature variations from INTERBALL 2 and MAGION 5 measurements

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Abstract

INTERBALL 2 (1996) and MAGION 5 (1999–2001) cold plasma measurements provided the possibility to deduce new aspects of ion temperature distributions in the Earth's plasmasphere during magnetically quiet and moderately disturbed times. Proton temperatures in the plasmasphere were compared along the magnetic field lines to electron and ion temperatures measured by DMSP satellites in the upper (~840 km) ionosphere. On the nightside for $1.4<L<2.8$, plasmaspheric temperatures were found to be quite close to ionospheric electron temperatures. At $L=2.5$–2.8, ion temperatures in the plasmasphere were close to electron temperatures in the upper ionosphere everywhere except for the noon-to-dusk MLT sector. At higher L ($L>3$), the plasmasphere-to-ionosphere temperature ratio was greater than 1, and there was also an increase in the 12–20 MLT sector. Apparently there is a heating source at high L that is strongest in the noon-to-dusk MLT sector.

It was revealed that during moderate magnetic storm development, nighttime ion temperature was depressed in the storm main phase, but exceeded quiet time values in the storm recovery phase. Possible reasons of such temperature behavior are briefly discussed.

Keywords: Plasmasphere; Ion temperature; Electron temperature; Magnetic storm

1. Introduction

For many years of plasmasphere study the plasma density distribution was examined quite thoroughly because this parameter was obtained in almost any measurement in the plasmasphere. By contrast, the ion temperature is measured only in direct plasma measurements and the temperature database is rather limited. The most informative data on the plasmasphere thermal structure were obtained by the retarding ion mass-spectrometer RIMS on the DE-1 satellite (Comfort, 1986, 1996). The temperature data were examined in the dawn and dusk sectors of the plasmasphere from low and high altitudes within the same flux tube. In particular, it was shown that plasmaspheric ion temperatures are higher than those in the

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ionosphere and on average temperature increases along the magnetic field with the gradient of ~0.05–1.0 K/km. However, Comfort (1986) mentioned that in the morning sector the field-aligned temperature gradient was observed only in the outer part of the plasmasphere at $L > 3.0$.

DE-1/RIMS data were used to examine the effect of magnetic activity on plasmaspheric ion thermal structure and this effect differed for morning and evening sides. On the morning side below $L = 3.0$, the magnetic activity produced almost no effect on ion temperatures. On the evening side for the range $2 < L < 3$, low and moderately disturbed periods also showed similar mean temperatures, while the highest levels of magnetic activity were associated with lower temperatures. In the outer plasmasphere the increased magnetic activity was associated with higher temperatures. Meanwhile, Comfort (1996) pointed out that "if a source of heat associated with magnetic activity becomes suddenly available the plasma can respond within minutes to hours" and hence it is probably more fruitful to find detailed mechanisms in case studies than to examine the average values using a global index.

Here we used the INTERBALL 2 (1996) and MAGION 5 (1999–2001) data to compare the ion temperatures in the plasmasphere with ionospheric temperatures along the magnetic field lines. Temperature variations during magnetic storm developments were also analyzed.

2. Sources of experimental data

INTERBALL 2 AURORAL and its subsatellite MAGION 5 were launched on August 29, 1996 into an elliptic orbit with an apogee of 20,000 km, an inclination of 65° and an orbital period of ~6 h. After only 1 day of operation Magion 5 ceased to transmit telemetry data. It was successfully reactivated on 7 May, 1998 after 20 months in space but at the time when INTERBALL 2 finished its active life. On board INTERBALL 2, thermal plasma measurements were made by the ALPHA 3 instrument including modulating potential analyzer PL-19. Energy spectra were measured during 2 s once per ~15 or 280 s depending on the telemetry mode. The data from four orbits per day were very suitable to examine the magnetic activity effect on plasmasphere characteristics.

On MAGION 5, plasmaspheric plasma data were obtained by the retarding potential analyzer PL-48. Energy spectra were measured during 0.4 s every ~8 s. For different reasons the MAGION 5 data were mostly available on one plasmasphere pass (mainly inbound) per day. The data were acquired in all MLT sectors at low geomagnetic latitudes.

Earlier the PL-48/ALPHA 3 data obtained by INTERBALL 1 were compared with DE-1/RIMS data (Kotova et al., 2002). Good agreement of these data confirmed the reliability of INTERBALL data.

We analyzed the data of INTERBALL 2 obtained in 1996 during the solar activity minimum and the data of MAGION 5 collected in 1999–2001 in the maximum phase of solar cycle.

For comparison, the data on electron and ion temperature obtained in the high-altitude ionosphere by the DMSP F12, F13 and F15 satellites were used. These are polar orbiting satellites at an altitude of about 840 km. For thermal plasma measurements, the spacecraft flew the Special Sensors-Ions, Electrons, and Scintillation (SSIES) thermal plasma analysis package. The package includes a Retarding Potential Analyzer (RPA) and a Langmuir probe, which provide ion and electron temperature data, respectively (http://cindispace.utdallas.edu/DMSP/).

3. Comparison of ion temperatures in the plasmasphere to ionospheric electron and ion temperatures

To estimate experimentally the temperature gradient along the magnetic lines, measurements in the plasmasphere and ionosphere were compared. The data obtained under low and moderately disturbed ($K_p < 5$) magnetic conditions were analyzed.

We chose one typical measurement of ion temperature on every available pass of the INTERBALL 2 or the MAGION 5 satellite across the plasmasphere and compared it to the DMSP data. The latter were taken exactly at the same invariant latitude (or L) where plasmaspheric data were obtained, the difference in MLT was at least less than 120 min, the maximum difference in UT was 50 min (the average difference in MLT and UT between the INTERBALL/MAGION and DMSP measurements was 54 and 24 min, respectively); no distinction between the Southern and the Northern Hemispheres was made. If more than one ionospheric point was found within these criteria, the closer in time and space to field-aligned projection of the plasmaspheric measurement was preferred.