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MAGNETOSHEATH TURBULENSE AND LOW LATITUDE BOUNDARY LAYER (LLBL) FORMATION

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Abstract. Simultaneous observations of plasma parameters and magnetic field in the low latitude boundary layer (LLBL) measured by INTERBALL/Tail probe and in the magnetosheath measured by Geotail satellite are analyzed for the event of March, 2, 1996. The high level of magnetic field fluctuations is one of the main features of magnetosheath observations. It is shown that in the analyzed event the amplitude of such fluctuations is higher than the value of the magnetic field under the magnetopause. Results of observations show that fluctuations of the magnetic field in the magnetosheath can be an important factor of the magnetopause formation. Local disruptions of magnetopause pressure balance under the influence of such fluctuations can lead to magnetosheath plasma penetration inside the magnetosphere and formation of LLBL. The role of the magnetopause pressure balance disruption in the formation of reconnection events is discussed.

1. Introduction

The low latitude boundary layer (LLBL) is the region just earthward of the magnetopause where the magnetosheath-like and magnetosphere-like plasmas coexist. The solution of the problem of LLBL formation is connected with conditions of mass, momentum, and energy transfer between the magnetosheath and the magnetosphere. LLBL is formed due to the process of interaction between the turbulent solar wind and the Earth's magnetic field. Despite more than 25-year history of its study, many problems of LLBL formation are still open. The condition of stress balance on the magnetopause has not been properly studied so far. Therefore, the problem of the magnetosheath plasma penetration through the magnetopause has no definite solution. Changes in the observed LLBL properties are commonly explained as a result of changes in the conditions of magnetosheath plasma penetration through the magnetopause under different interplanetary magnetic field (IMF) parameters. However, the processes inside the magnetosphere can also influence the observed LLBL properties (Antonova, 2005).

In this paper we examine the results of simultaneous INTERBALL/Tail probe, WIND and Geotail observations of LLBL, solar wind and magnetosheath for the event of March 22, 1996 and try to show that fluctuations of magnetic field in the magnetosheath can be an important factor of magnetosheath plasma penetration inside the magnetosphere.

2. Results of observations

We use data obtained by the Corall low-energy ion experiment (Yermolaev et al., 1997), the Electron low-energy electron experiment (Sauvaud et al., 1997), and the MIF magnetic field instrument (Klimov et al., 1997) on board the INTERBALL/Tail spacecraft. The plasma moments such as the ion density, bulk velocity vector, ion temperature, etc. are computed on the basis of the Corall measurements. We also analyze data of solar wind observations on WIND spacecraft and magnetosheath observations on Geotail satellite (http://stp.isas.jaxa.jp/geotail/).

At the investigated period of time Geotail crossed the shock wave and was in the magnetosheath region and INTERBALL/Tail probe crossed the magnetopause at the same flank of the system magnetosphere-magnetosheath-shock wave during the investigated interval.

Fig. 1 presents the results of INTERBALL/Tail probe observations. Panel 1 shows the results of magnetic field observations by MIF instrument. Panel 2 shows energy-time spectrogram of Electron instrument. Density and temperature of ions are illustrated in the 3 and 4 panels. The results of Corall measurements are shown in the bottom panel 5 for the channel measuring ions at the angle of 65° relative to the Earth-Sun line. The intensity on the spectrogram is color-coded according to the logarithm of the measured count rate per sample as shown by the color bar on the right of the figure. The lower part of the Figure demonstrates the satellite coordinates in GSM system. Satellite INTERBALL/Tail probe from 03.30 UT till 05.30 UT March 2, 1996 crossed the magnetosheath, LLBL and then the plasma sheet. The satellite trajectory was localized on the evening flank of the magnetosphere. The satellite remained in the magnetosheath till 04.07 UT, from 04.07 UT till 04.33 UT and after 05.08 UT it was in the plasma sheet. LLBL was not observed from 04.07 UT, when the satellite went from magnetosheath to plasma sheet at Z ≈4.5 R_E. Distribution functions corresponding to simultaneous pretense of magnetosheath and plasma sheet are presented from 04.33 till 05.08 UT at Z ≈ 3 R_E which means the low latitude boundary layer crossing. The regions where hot and cold ion populations coexist simultaneously were crossed by the satellite at 04.33 - 04.43 UT and 04.55 - 05.01 UT. The analysis of LLBL crossing allows to select jet structures.

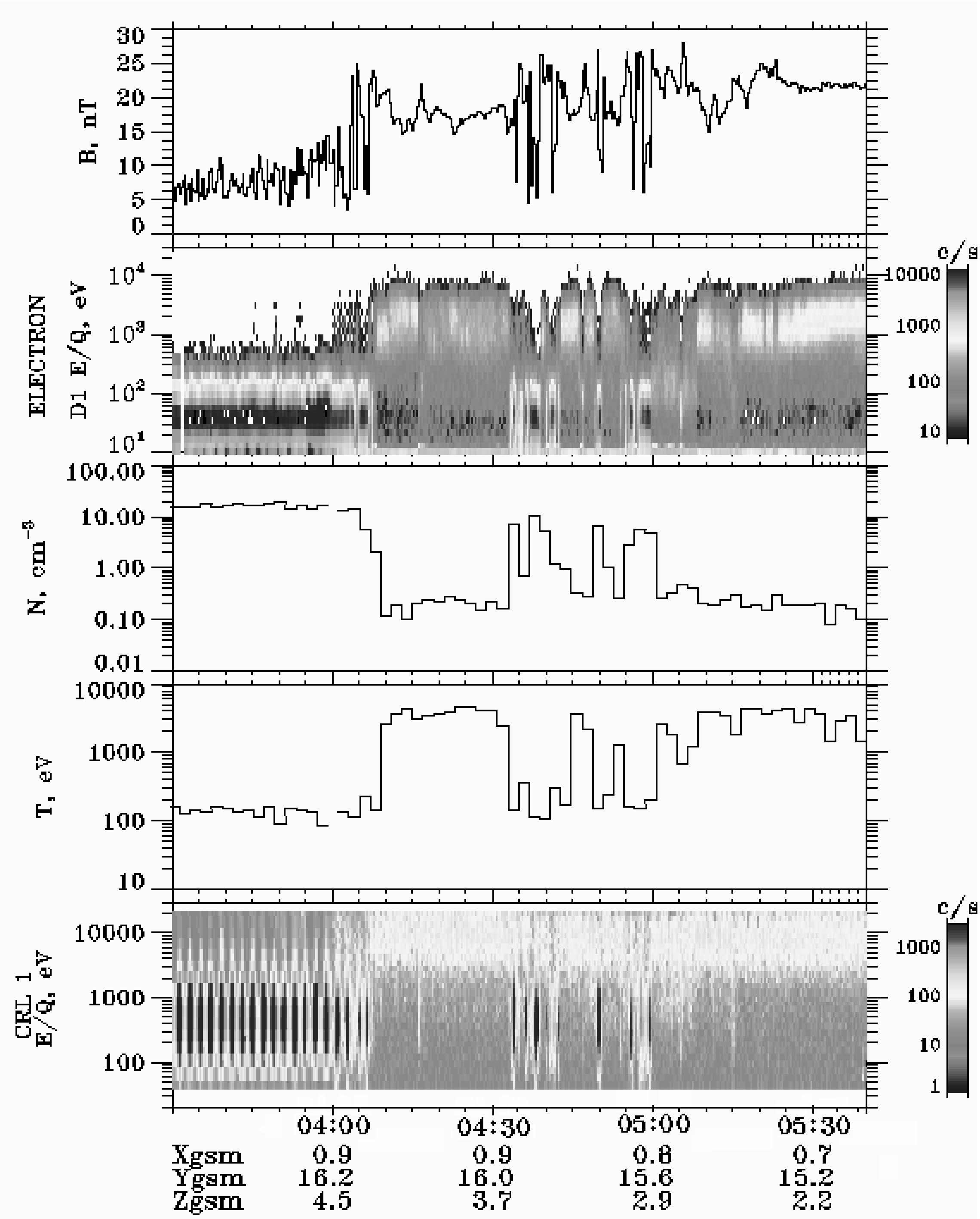

Figure 1. The results of observations of March 2, 1996 on board satellite INTERBALL/Tail probe

Fig. 2 shows WIND measurements of the solar wind velocity V (1 panel), density (panel 2) and IMF value (panel 3) on March 2, 1996. Solar wind velocity, as shown in Fig. 2, was practically unchangeable and constituted ~335 km/s. Solar wind magnetic field was nearly stable and increased from 2.4 nT to 4.2 nT.

Fig. 3 shows the results of Geotail observations of V (1 panel), density (panel 2) and magnetic field (panel 3). The Geotail satellite was in the same flank of the magnetosphere as INTERBALL/Tail when INTERBALL/Tail probe crossed LLBL, but it was nearer to the Sun in the magnetosheath region. It is possible to select in Fig. 3 typical for the magnetosheath magnetic field, velocity and density fluctuations.

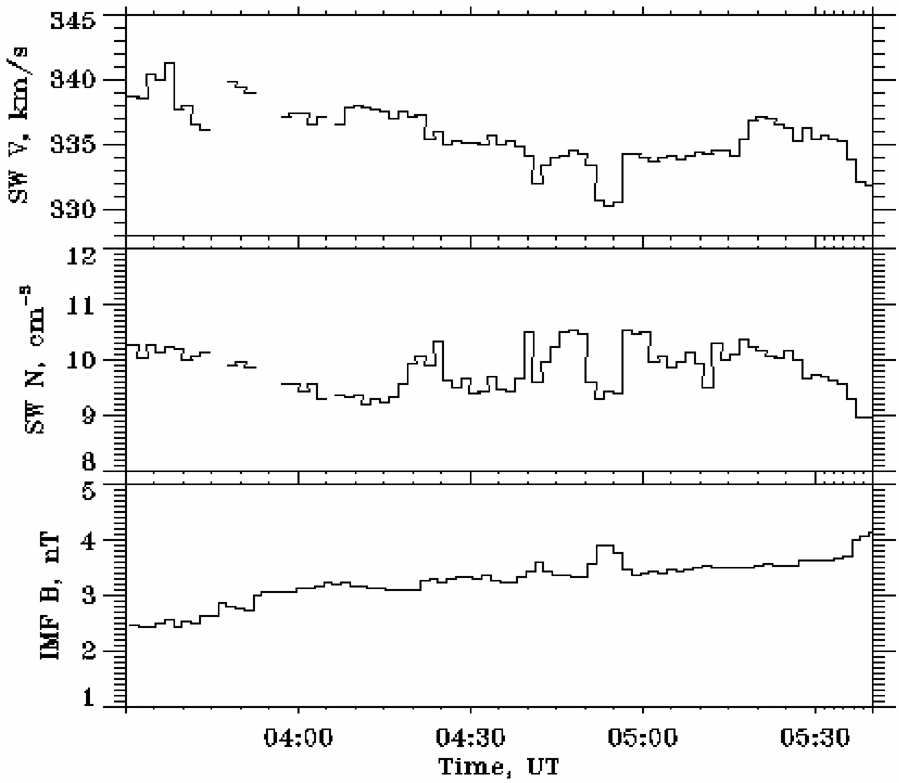

Figure 2. Interplanetary magnetic field parameters in accordance with WIND data

The Geotail satellite crossed the magnetosheath during time intervals 03.50-04.23 UT, 04.34-04.45 UT and 04.57-05.14 UT which is possible to see due to the measured values of velocity, density and magnetic field (see Fig.3).

4. Results of the analysis

It is possible to see from Fig. 1-3 that solar wind conditions were comparatively stable: fluctuations of the solar wind velocity did not exceed 5 km/s and fluctuations of magnetic field – 1 nT. The density of the solar wind fluctuated by 1 cm^{-3}. Simultaneous variations of magnetosheath velocity components constituted ± 100 km/s and the amplitudes of magnetic field fluctuations ~30 nT (see Fig. 4). Density of plasma measured on Geotail satellite had fluctuations of about 20 cm^{-3}. Values of magnetic field measured by MIF on INTERBALL/Tail probe in the magnetosheath constituted 6-12 nT which corresponds to values under the shock wave. The magnetic field is increased till ~15-24 nT in LLBL region.

The amplitudes of fluctuations of the magnetic field and plasma flow parameters in the magnetosheath exceed the same fluctuations in the solar wind. Plasma jets, formed under these conditions, should penetrate the magnetosphere and produce substantial distortion of the magnetic field in the magnetopause region.

The amplitude of magnetic field fluctuations in the magnetosheath can exceed the value of the magnetic field under magnetopause in the near cusp region, which is seen in the analyzed event. The configuration of plasma in the magnetosheath varies all the time even under stable solar wind conditions. Magnetopause position as it is well known is determined by the condition of plasma and magnetic field pressure balance inside and outside the magnetosphere. Magnetic field in the magnetosheath and its fluctuations is obviously an important factor determining the conditions of plasma penetration inside the magnetosphere when the value of magnetic field under the magnetopause is comparable with the value of magnetic field and its fluctuations in the magnetosheath. Jets of magnetosheath plasma can penetrate different places of magnetopause inside the magnetosphere due to the local pressure disbalance. These jets form LLBL and plasma mantle. The reconnection processes will appear as a consequence of the discussed penetration. If the level of fluctuations in the magnetopause is high, plasma forming the LLBL can consist of jets situated on the closed or opened magnetic field lines.

The common theory of reconnection of the Earth's magnetic field and IMF does not explain the LLBL thickness dependence on the IMF orientation. The northward IMF orientation leads to the reconnection poleward from the cusp, with the southward IMF it should take place lower from the cusp. In accordance with this theory the thick IMF should be formed under the southward IMF orientation and the thin – under the northward one, not corresponding to the experiment. The observed regularity can be explained taking into account the plasma transport inside the magnetopause and its dependence on IMF orientation, as it was done in (Antonova, 2005). The results of the work (Antonova, 2005) and our analysis can help explain the formation of LLBL and its thickness dependence on the IMF orientation.

5. Conclusions

The conducted analysis of the results of simultaneous observations on satellites INTERBALL/Tail probe, WIND and Geotail supports the results obtained earlier on the existence of high level fluctuations of plasma and magnetic field parameters in the magnetosheath under comparatively stable solar wind parameters and requires the building of a new model of LLBL formation.

The picture of plasma and magnetic field parameter changes in the magnetosheath considerably differs from the picture of plasma and magnetic field distribution near the magnetopause postulated in models of magnetic reconnection on the magnetopause. The amplitude of magnetic field fluctuations in the magnetosheath can exceed the value of the magnetic field under magnetopause in the near cusp region. That is why the existence of such fluctuations should be taken into account in the analysis of the magnetopause formation processes.

The jets of magnetosheath plasma can penetrate inside the magnetosphere due to the absence of pressure balance in spite of the high level of fluctuations in the magnetosheath. Such a process can lead to the magnetic field lines reconnection and to the LLBL formation.

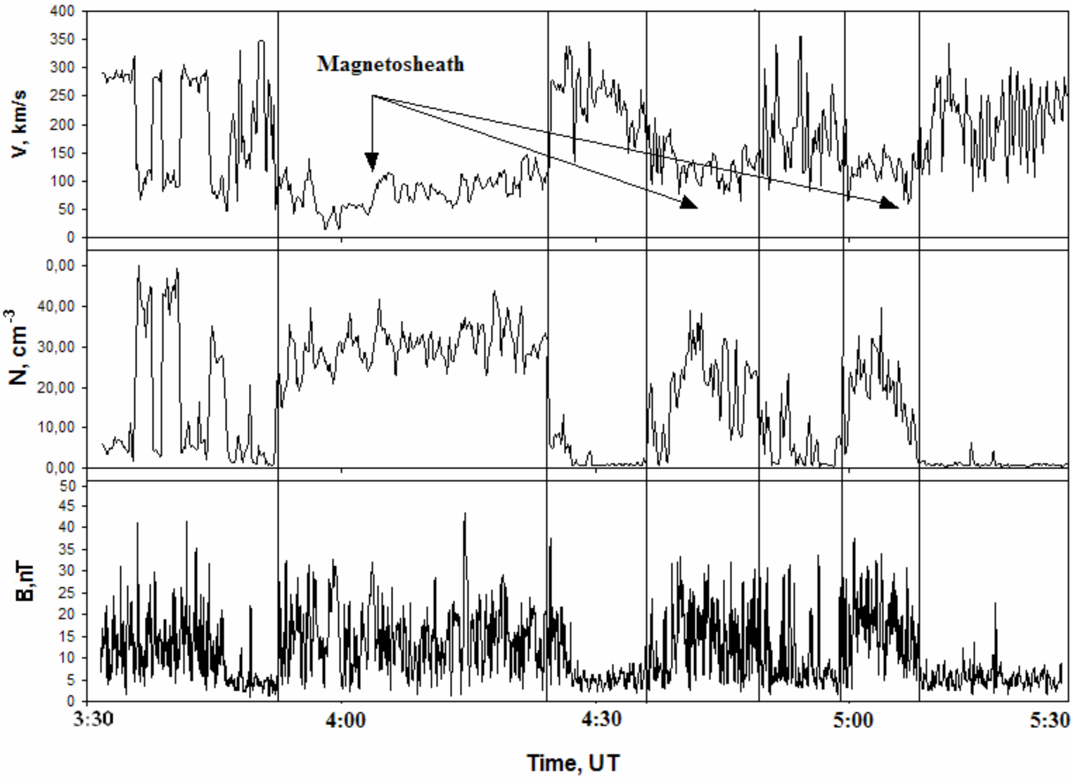

Figure 3. Magnetosheath plasma parameters in accordance with Geotail data

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