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Variations of the Magnetopause Position versus the Level of Geomagnetic Activity (according to Data of the *INTERBALL-1* Satellite for 1995–1997)

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Abstract—The variations in the deviation of the observed position of the magnetosphere boundary from its mean position predicted by the Shue at al., 1997 (Sh97) model [7] are studied as a function of the substorm activity level (the *AE*-index value) and magnetic storm intensity (the value of the corrected D_{st}^{*} index). The results obtained make it possible to state that the amplitude of motion of the magnetospheric boundary on the dayside and in the low-latitude tail is small. It is likely that the position of the boundary is either independent of the *AE* and D_{st}^{*} indices or this dependence is weak. At the same time, the boundary of the high-latitude tail shifts inward on the average by $1.5R_{\rm E}$ with an increase of the *AE*-index in the case of absence of magnetic storms (contraction of the magnetospheric tail). On the contrary, in the presence of magnetic storms, this boundary shifts outward by up to $3R_{\rm E}$ with an increase of the *AE*-index (inflation of the magnetospheric tail). It is also shown that the boundary of the high-latitude tail moves outward with an increase of the D_{st}^{*} index, both at low substorm activity and in periods of high substorm activity. The amplitude of the outward motion of the high-latitude tail of the magnetosphere is by a factor of two higher for moderate magnetic storms with strong substorms than for moderate magnetic storms with weak substorms.

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1. INTRODUCTION

It is widely known that the position of the magnetospheric boundary and the amplitude of its motion depend on external causes: variations in the solar wind pressure and orientation of the interplanetary magnetic field, the plasma pressure within the magnetic layer, reconnection of the magnetic field (flux transfer events, FTE), and Kelvin–Helmholtz instability (see [1, 2] and references therein). Parameters of the interplanetary medium (the dynamic pressure of the solar wind P_d and the B_z component of the interplanetary magnetic field (IMF)) are the principal parameters determining the localization of the magnetospheric boundary.

However, in addition to the external impact, internal processes occurring within the magnetosphere are able to influence the localization of the magnetospheric boundary. In particular, an increase of the ring current intensity related to magnetic storms can lead to the increase in magnetosphere dimensions [3]. The studies in the subsolar region of the magnetosphere showed that the ring current weakly influenced the boundary position [4]. At the same time, it was shown that the position of the dayside magnetopause depended on the value of the *AE*-index: the daytime magnetosphere was compressed during strong substorms ($AE > 100$) and expanded at low substorm activity ($AE < 100$) [5].

The investigations made at high latitudes in the vicinity of the cusp (the distance along X is up to $-5R_{\rm E}$) showed that the magnetospheric boundary shifts outward (the magnetosphere expands) with a decrease of the D_{st} index and increase of the *AE*-index [8].

Thus, the information available concerns very limited spatial regions of the magnetosphere (mainly the daytime magnetosphere at low, middle, and high latitudes). There is no information on the behavior of the magnetospheric boundary in the region of the near magnetospheric tail (up to $-19R_{\rm E}$).

The goal of this paper is to determine how the position of the magnetospheric boundary and amplitude of its motion change depending on the changes in geomagnetic conditions within the magnetosphere. We consider separately the high-latitude dayside magnetosphere and the near (up to $-19R_{\rm E}$) magnetospheric tail both at high and low latitudes.

2. METHOD OF PROCESSING AND ANALYSIS OF DATA

The crossings of the magnetopause at the dayside and in the tail (up to $-19R_E$) of the magnetosphere (1277 crossings) detected onboard the *INTERBALL-1* satellite within the time interval 1995–1997 [2] including multiple crossings for which the data on the solar wind were available are the initial data for the analysis. Each out of the multiple crossings of the magnetopause recorded at the flight across the magnetospheric boundary is considered as an independent event, that is, the multiple crossings are not averaged (unlike the previous publications, see [2]).

Due to the satellite orbit, about 70% of all analyzed crossings of the boundary are high-latitude crossings ($|Z| > 7R_E$). At the same time, about 75% of all analyzed crossings for which the data on the AE and D_{st} indices were available occurred at the night side of the magnetosphere or in the tail ($-19R_E < X < 0$). The geocentric solar–magnetospheric coordinate system [2] is used in this paper.

For each crossing of the boundary, a mean (model) position of the magnetopause as a function of the state of the interplanetary medium, i.e., of the external conditions, was preliminarily determined. The mean position of the boundary was estimated using the Sh97 [7] model. The interplanetary medium parameters (the values of the dynamic pressure of the solar wind plasma and the B_z component of the interplanetary magnetic field) were determined from the solar wind data obtained onboard the *WIND* spacecraft [8, 9]. When determining the interplanetary medium parameters, the time lag caused by propagation of the solar wind from *WIND* to *INTERBALL-1* was taken into account.

We assume that the discrepancy between the measured boundary position and the mean position predicted by the model is determined by changes in the conditions within the magnetosphere, in particular, by the activity of substorms and intensity of magnetic storms.

The activity level of a substorm (the intensity of the auroral electrojet) is estimated from a value of the AE-index. One-minute values of the AE-index obtained at the moment of the magnetospheric boundary crossing are used [10]. The magnetic storm activity (the ring current intensity) is determined by the value of the D_{st}^* index (hourly averaged corrected D_{st}^* index) [11–13]. The corrected D_{st}^* index whose variations are caused by growth and decline of the ring current is used for the analysis. The correction of the D_{st} index measured on the ground for the contribution of the external parameter (dynamic pressure of the solar wind) was performed using the following relation: $D_{st}^* = D_{st} - a(nv^2)^{1/2} + b$, where $a = 0.02$ [nT/(cm^{-3} km^2/s^2)$^{1/2}$], $b = 20$ [nT], and v [km/s] and n [cm^{-3}] are the velocity and plasma density of the solar wind, respectively [13].

2.1. The Dependence of the Boundary Position on the AE-Index

The variations of the magnetopause position as a function of the AE-index value were estimated on the basis of 765 crossings of the boundary (no data on the AE-index are available for 1996). Out of these crossings, 557 are high-latitude ones ($|Z| > 7R_E$). Out of them, 183 and 374 events occurred on the dayside ($X > 0$) and nightside (or the tail) of the magnetosphere) ($-19R_E < X < 0$), respectively. The remaining 208 crossings refer to the low-latitude magnetosphere tail. In order to take into account the mutual influence of the AE and D_{st}^* indices, the analyzed crossings were split into two groups differing in the value of the D_{st}^* index. The events for which $D_{st}^* > -30$ nT were ascribed to the quiet time period without magnetic storms. The events for which the value of the D_{st}^* index was strongly negative, i.e., $D_{st}^* \le -30$ nT, were associated with the disturbed period of time with magnetic storms [14].

Figure 1 shows how the deviation D(Sh97) of the position of the real boundary from the Sh97 model prediction varies depending on the value of the AE-index in quiet time (Figs. 1a, 1c, and 1e) and during magnetic storms (Figs. 1b, 1d, and 1f). Points show the value averaged over the AE-index within the interval of 100 nT for the events without magnetic storms (Figs. 1a, 1c, and 1e) and within the interval of 200 nT for the events with magnetic storms (Figs. 1b, 1d, and 1f). Vertical lines passing through the points show the value of the error of the mean value (the root-mean-square deviation).

Positive values of the deviations of $D(\text{Sh97}) > 0$ correspond to the events when the real boundary is located closer to the Earth than the mean position (the magnetosphere is in a compressed state). Negative values of $D(\text{Sh97}) < 0$ correspond to the cases when the actually measured boundary is located farther from the Earth that it follows from the model predictions (the magnetosphere is in an expanded state).

One can see in Fig. 1 a difference in the character of the variations in deviations of D(Sh97) depending on the AE value corresponding to different magnetospheric regions and to periods of different degree of disturbance according to the D_{st}^* index.

For example, the dayside high-latitude magnetospheric boundary in the absence of magnetic storms ($D_{st}^* > -30$ nT) (Fig. 1a) on the average is located in the vicinity of the model boundary ($\langle D \rangle = 0.12 \pm 0.06$, the confidence interval for the root-mean-square error is $0.05 < \sigma < 0.07$ with a reliability of 0.95). With an increase of the AE value (up to 800 nT, only for two events), a tendency of the inward magnetospheric boundary motion by a distance D(Sh97) ~$1.2R_E$ closer to the Earth, that is, a compression of the dayside magnetosphere, is observed. In the period of magnetic storms ($D^*_{st} \leq -30$ nT) at the dayside of the high-latitude magnetosphere, only 7 crossings of the magnetopause (Fig. 1b) were recorded. They are characterized by the mean deviation of the boundary $\langle D \rangle = 0.52 \pm 0.45$ (the confidence interval for the root-mean-square error with a reliability of 0.95 is $0.28 < \sigma < 0.99$). One can see in Fig. 1b that with an increase of the AE-index ($AE > 400$), the dayside magnetopause can come to the Earth to 0.2–$2.5R_E$, however (because of a poor statistics of crossings during high values of AE-index and high error) one may only assume that there is a tendency of compressing of the dayside high-latitude magnetosphere with an increase of the AE-index value.

The behavior of the high-latitude tail of the magnetosphere (Figs. 1c and 1d) with a change of the AE-index value differs strongly in quiet period of time without magnetic storms ($D^*_{st} > -30$ nT) (Fig. 1c) and in the periods of magnetic storms ($D^*_{st} \leq -30$ nT) (Fig. 1d). First, the presence of magnetic storms (intensification of the ring current) leads to an expansion of the high-latitude tail of the magnetosphere. For example, in the absence of magnetic storms, the mean value of the deviation $\langle D \rangle = 0.45 \pm 0.06$, that is, the high-latitude tail is slightly compressed (Fig. 1c). With a confidence probability of 0.95 the root-mean-square deviation is within the confidence interval $0.05 < \sigma < 0.06$. In the presence of magnetic storms, the mean deviation $\langle D \rangle = -1.27 \pm 0.20$ (with a reliability of 0.95 the root-mean-square error is within the interval $0.17 < \sigma < 0.24$), that is, the high-latitude tail is expanded (Fig. 1d).

Second, as one can see in Fig. 1c, in the absence of magnetic storms the amplitude of the inward motion of the high-latitude tail boundary with an increase of the AE-index is 1–$1.5R_E$ (the amplitude of the compression of the high-latitude magnetospheric tail). In the presence of magnetic storms (Fig. 1d) the amplitude of the outward motion of the tail reaches almost $3R_E$ (the tail expansion) with the increase of the AE-index up to ~700. At further increase in the AE-index above 800 (very strong storms), the amplitude of the outward motion of the magnetopause decreases down to $-1.5R_E$, and the magnetospheric tail is even compressed (down to $+1R_E$). One can see in Fig. 1d that the errors in the deviations are high enough, and one can only assume that there is a tendency of compression of the high-latitude magnetospheric tail at very strong increase of the AE-index even during magnetic storms.

In the same way, the presence of magnetic storms increases the outward shift of the boundary (the tail expansion) as compared to the period without magnetic storms also for the low-latitude tail. For example, the mean deviation of the boundary of the low-latitude tail from the model prediction is $\langle D \rangle = -0.30 \pm 0.10$ (with a reliability of 0.95 the confidence interval for the root-mean-square error is $0.09 < \sigma < 0.11$) for the substorms in the absence of magnetic storms and $\langle D \rangle = -0.81 \pm 0.16$ (with a reliability of 0.95 the confidence interval for the root-mean-square error is $0.13 < \sigma < 0.19$) for the substorms in the presence of magnetic storms. During magnetic storms the low-latitude magnetospheric tail is in an expanded state ($\langle D \rangle = -0.5R_E$) even at a small value of the AE-index (AE ~ 120). With an increase of the AE value, the amplitude of the boundary outward motion at first increases up to $-1.5\ R_E$ and then at very high values $AE > 500$ decreases down almost to zero. In other words, during magnetic storms with strong substorms, a small compression of the low-latitude magnetospheric tail with an increase of the AE-index is apparently observed.

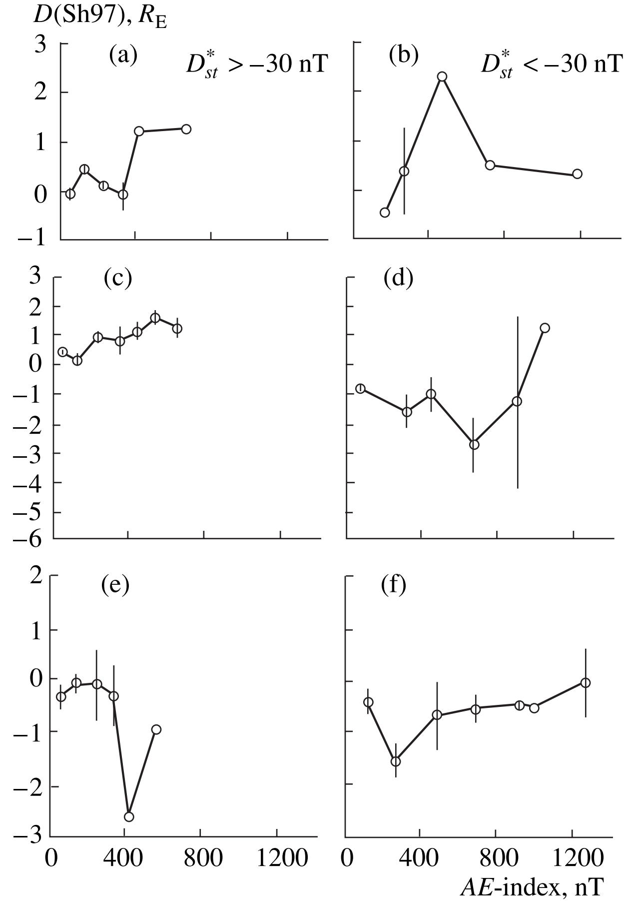

Fig. 1. Deviations D(Sh97) of the real magnetopause from the model prediction [7] as a function of the AE-index value: (a) for high-latitude ($|Z| > 7R_E$) crossings on the dayside ($X > 0$) in the absence of magnetic storms; (b) during magnetic storms; (c) in the tail ($X < 0$) of the magnetosphere in the absence of magnetic storms; (d) during magnetic storms; (e) for low-latitude crossings of the magnetopause in the magnetospheric tail ($|Z| < 7R_E$, $X < 0$) in quiet time; and (f) during magnetic storms.

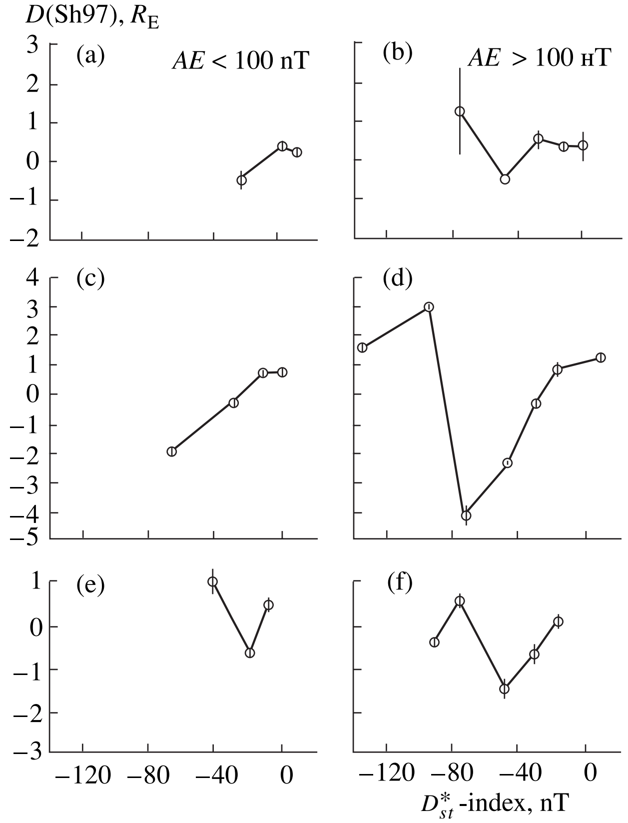

Fig. 2. Deviations D(Sh97) of the magnetopause position from the model prediction [7] as a function of the value of the D^*_{st} index: (a, b)on the dayside and high latitudes ($X > 0$, $|Z| > 7R_E$); (c, d) in the magnetospheric tail at high latitudes ($X < 0$, $|Z| > 7R_E$); and (e, f) in the tail at low latitudes ($X < 0$, $|Z| < 7R_E$).

However, in both cases the statistics of the events with high values of the *AE*-index is too poor (while the errors are large), so one can only assume that the boundary of the low-latitude tail of the magnetosphere either does not depend on the *AE*-index value, or the dependence is very weak.

2.2. Dependence of the Magnetopause Position on the D^*_{st} Index

We used 1201 events for studying the dependence of the magnetopause position on the value of the corrected D^*_{st} index. Out of them 793 events are high-latitude crossings (202 events at the dayside and 591 evens in the tail) and 408 events are low-latitude crossings in the magnetospheric tail. In order to reduce the influence of the *AE*-index, all the crossings were split into two groups depending on the value of the substorm index *AE* [5]. The events with $AE < 100$ nT correspond to weak substorm activity or quiet time. The events with $AE > 100$ nT correspond to a strong substorm activity.

Figure 2 shows how the deviation D(Sh97) of the magnetopause position from the mean position varies depending on the value of the D^*_{st} index at various levels of substorm activity and in different spatial regions of the magnetosphere.

One can see in Fig. 2 that the analyzed crossings of the magnetosphere occur mainly in quiet time in the absence of magnetic storms ($D^*_{st} > -30$ nT) or during weak magnetic storms ($-50 < D^*_{st} \le -30$ nT). Only a small number of crossings correspond to the period of moderate ($-100 < D^*_{st} \le -50$ nT) and strong ($D^*_{st} \le -100$ nT) magnetic storms. It is worth noting that strong and moderate magnetic storms occurred when the satellite was crossing the boundary of the magnetospheric tail mainly at high latitudes (see Fig. 2).

On the dayside of the magnetosphere under weak substorm activity ($AE < 100$ nT), the amplitude of the outward motion of the boundary (expansion of the magnetosphere) becomes small with a decrease of D^*_{st} and is less than $0.5R_E$ (see Fig. 2a), this value being within the existing error (see Fig. 2a). Therefore, one may assume that at weak substorm activity ($AE < 100$), the position of the high-latitude boundary of the dayside magnetosphere either does not depend on the value of the D^*_{st} index (within the D^*_{st} range from 0 to −30 nT) or the dependence is weak. However, at strong substorms ($AE > 100$) with the decrease of D^*_{st} down to −70 nT, this boundary shifts inward by $\sim 1R_E$ (the magnetosphere is compressed), the latter value being only slightly higher than the observational error (see Fig. 2b). The tendency of compression of the high-latitude magnetosphere in the periods of magnetic storms with strong substorms can bear witness of the prevailing influence of the substorm activity over the activity of magnetic storms (the compression caused by the strong auroral electrojet prevails over the expansion caused by the ring current). However, because of the poor statistics for the events with high values of the D^*_{st} index and high errors, one may only assume that the position of the high-latitude dayside magnetopause either weakly depends on the value of D^*_{st} or the dependence is absent.

The mean value of the deviation of the magnetopause of the high-latitude tail is $\langle D \rangle = 0.45 \pm 0.05$ (with a confidence probability of 0.95 the confidence interval for the root-mean-square error is $0.045 < \sigma < 0.055$) under weak substorm activity (the compression of the tail). Under strong substorm activity (the expansion of the tail), this value is $\langle D \rangle = -0.18 \pm 0.15$ (with a confidence probability of 0.95 the confidence interval for the root-mean-square error is $0.13 < \sigma < 0.17$) (see Figs. 2c and 2d). One can see in Fig. 2c that at $D^*_{st} \sim 0$ the boundary of the high-latitude tail is located by ~$1R_E$ closer to the Earth, however, at the decrease of D_{st}^* down to –70 nT it shifts from the Earth by ~$2R_E$.

At the same time, during strong substorms, the amplitude of the outward motion of the boundary of the high-latitude tail of the magnetosphere at the same value $D_{st}^* \sim -70$ nT reaches more than $4R_E$. That is, in the period of strong substorms at the changes of D_{st}^* from 0 to –70 nT, the maximum amplitude of the motion of the high-latitude boundary of the magnetospheric tail is $5R_E$ (see Fig. 2d). The latter value is almost twice higher than in the case of low substorm activity. Four crossings of the high-latitude boundary of the magnetospheric tail observed at very high value $D_{st}^* < -90$ nT should be specially discussed. In these events the tail boundary approached the Earth as close as by $2–3R_E$, that is, the high-latitude tail was compressed (see Fig. 2d). Unlike the other events, these 4 crossings correspond to the period of a strong magnetic storm ($D_{st}^* < -138$ nT in the minimum) on October 11, 1997 (see below the discussion of results).

The boundary of the low-latitude tail of the magnetosphere is characterized by the mean value of the deviation $\langle D \rangle = -0.34 \pm 0.09$ (with a confidence probability of 0.95 the confidence interval for the root-mean-square error is $0.08 < \sigma < 0.1$) in the period of weak substorms and $\langle D \rangle = -0.55 \pm 0.12$ (with a confidence probability of 0.95 the confidence interval for the root-mean-square error is $0.10 < \sigma < 0.14$) during strong substorms (Figs. 2e and 2f). In other words, one may assume that on the average the low-latitude tail of the magnetosphere is slightly expanded relative to the model prediction, but the amplitude of the outward motion of the boundary is slightly higher for the period of magnetic storms with strong substorms than for the periods of magnetic storms with weak substorms.

One can see in Fig. 2e that in the period of magnetic storms with weak substorms, the amplitude of the low-latitude boundary motion does not exceed $1R_E$, the latter value being within the limits of the observational error. For the events in the period of magnetic storm with strong substorms, the amplitude of the outward motion (expansion) of the low-latitude tail reaches $1.5R_E$, the latter value slightly exceeding the error. Therefore, one may assume that the amplitude of the motion of the low-latitude magnetospheric tail either depends weakly on the D_{st}^* index, or does not depend on it at all.

3. DISCUSSION OF RESULTS

The value of the D_{st}^* index is a good measure of the intensity of the ring current flowing within the inner magnetosphere [11, 12, 16–21]. The substorm activity index AE characterizes the level of short-term magnetic disturbances occurring in the polar region mainly due to the increase in the ionospheric currents flowing in the auroral region [10, 22]. Both types of geomagnetic disturbances (magnetic storms and substorms) are able to occur simultaneously [23]. Though polar substorms more often occur during magnetic storms, they appear also in quiet time, when there are no magnetic storms. At the changes in geomagnetic activity, not only the ring current changes, but the currents of other current systems of the magnetosphere change as well. The latter include the cross-tail currents of the tail and also partial ring current and the current of zone 2 both flowing within the night side of the magnetosphere and being closed in the ionosphere by the field-aligned currents [20].

However, in this paper we interpret the geomagnetic activity indices AE and D_{st}^* as indicators of the level of the intensity of the auroral electrojet and ring current, respectively. In the absence of magnetic storms, not only weak substorms ($AE < 100$), but sometimes very strong substorms as well with the AE-index reaching 700 nT (see Fig. 1) are observed in the magnetosphere. During magnetic storms, the number of very strong substorms with the value of AE up to 1300 increases, while the number of weak substorms with $AE < 100$ decreases.

It is worth noting that the analyzed time period 1995–1997 falls into the solar activity minimum. The small statistics of the events with high AE and D_{st}^* indices and large uncertainty of the amplitudes of the motion of the magnetospheric boundaries make it possible to state only that there is a tendency of the suggested dependence of the magnetospheric boundary position on the level of geomagnetic disturbances. The most favorable situation with the event statistics takes place for the high-latitude tail of the magnetosphere (Figs. 1c and 2c), because in periods of strong substorms and magnetic storms the satellite was located in this very region of the magnetosphere.

The results of the analysis show that in the absence of magnetic storms, the magnetospheric tail is compressed with an increase of the AE-index (intensity of the auroral electrojet). The maximum amplitude of the compression reaches $1.5R_E$. With an increase of the AE-index, a tendency of the compression by $1.2R_E$ of the dayside high-latitude magnetosphere is also observed. At the same time, the low-latitude tail of the magnetosphere apparently either does not depend on the AE-index value, or the dependence is weak.

The compression of the subsolar magnetosphere at an increase of the AE-index value was earlier reported in [5]. It was stated in [5] that the dayside magnetosphere is in an expanded state at low values $AE < 100$ (the absence of substorms according to the author's terminology) and it is compressed with an increase of the AE-index ($AE > 100$). The compression of the high-latitude magnetosphere with an increase of the *AE*-index agrees with the results obtained in [5] for the dayside magnetosphere at low and middle latitudes.

However, the situation changes in periods of magnetic storms (that is, at an increase of the ring current). The tail of the magnetosphere mainly expands with an increase of the *AE*-index. The amplitude of the outward motion is $3R_E$ at high latitudes and lower (up to $1.5R_E$) at low latitudes. The observed expansion of the magnetospheric tail with an increase of the *AE*-index in the period of magnetic storms agrees with the results obtained in [6]. It is stated in [6] that the boundary of the high-latitude magnetosphere in the vicinity of the cusp (up to $-5R_E$) is shifted outward with an increase of the *AE* and D_{st} indices. According to [3, 6] the cause of such a motion of the magnetospheric boundary is the increase of the magnetic pressure inside the magnetospheric tail (due to the increase in the intensity of the ring current and magnetic flux inside the tail at high values of the *AE*-index).

While interpreting the dependence of the magnetopause position on the *AE*-index, one should bear in mind that the values of the *AE*-index is not a good indicator of the beginning of substorm activity. According to [25] about 17% of substorm events do not reveal themselves in the value of the *AE*-index. This fact can partly explain the compression of the magnetosphere sometimes observed at small values of the *AE*-index. On the other hand, the events having the same values of the *AE*-index may be related to different phases of a substorm. According to [26] the tail of the magnetosphere expands at the growth (before the onset) phase of a storm and is compressed at the expansion (after the onset) phase. It is possible that just the influence of the substrom phase is able to explain the scatter in the magnetosphere boundary motion (inward, outward) almost at any value of the *AE*-index. For the clarification of the situation, an analysis of the amplitude of the boundary motion as a function of the substorm phase is required. This analysis will be performed in the paper to follow.

According to the data of the *INTERBALL-1* satellite, the influence of the D^*_{st} index (the ring current) on the position of the magnetopause (the outward shift) is best pronounced in the motion of the boundary of the high-latitude magnetospheric tail. In the case of magnetic storms with weak substorms ($AE < 100$), a decrease in the D^*_{st} index is accompanied by an expansion of the high-latitude tail of the magnetosphere (the amplitude of the outward motion is $-2R_E$). During magnetic storms with strong substorms, the expansion of the high-latitude tail increases (the amplitude of the boundary outward motion is $-4R_E$). The obtained result on the expansion of the high-latitude and low-latitude tail of the magnetosphere with a decrease of the D^*_{st} index agrees with the conclusions of [4, 6] and supplements them, since the events we have analyzed are related to the region of the near tail (up to $-19R_E$) and not only to low latitudes, but to high latitudes as well. The outward shift of the magnetopause with a decrease of the D^*_{st} index may be explained by the fact that the high negative values of D^*_{st} are related to a strong ring current. This increases the magnetic pressure outside the ring current and hence pushes the magnetopause outwards, which is in agreement with the observations [4, 6].

The anomalous behavior of the boundary of the high-latitude tail (the compression by (1.7–3) R_E instead of expansion) was observed during a strong magnetic storm on October 11, 1997 ($D^*_{st} < -138$ nT in the minimum of the D^*_{st} index reduction) accompanied by very strong substorms ($AE = 400$–1000 nT). The substorms continued permanently from the beginning of the magnetic storm for more than 10 h. The considered events (4 crossings) occurred during the period of the main phase and beginning of the recovery phase of a strong magnetic storm. One may assume that the behavior of the high-latitude tail during strong magnetic storms with a high level of substorm activity differs from the tail behavior during weak and moderate magnetic storms. The anomalous behavior of the boundary can be related to the influence of high level of the substorm activity pertaining for a very long time prior to the boundary crossings and during the crossings. This fact may show that the interrelation between magnetic storms and substorms (especially during strong magnetic storms with strong substorms) is not simple. It is widely known that during magnetic storms not only the ring current is increased, but the currents of the tail at distances outside $-12R_E$ as well [20, 16]. During the main phase of a magnetic storm, the disturbance of the magnetic field at the Earth surface caused by the current system of the tail is comparable with the contribution of the ring current [20]. The electric field of the magnetosphere which can vary during the substorm expansion phase influences formation of the ring current. This influence is nonlinear in its character. A mechanism of back influence of the increased ring current on the substorm dynamics is possible [14].

One may assume that there exists some threshold value of the ring current intensity (magnetic storm intensity) below which joint influence of the ring current and auroral electrojet leads to an expansion of the high-latitude magnetospheric tail. However, when the ring current intensity exceeds this threshold value (for strong magnetic storms), the influence of the intense auroral electrojet prevails and the high-latitude tail is compressed in the same way as in the case of substorm activity in the absence of magnetic storms. In any case, additional studies of the possible impact of strong magnetic storms on the magnetosphere behavior are required.

4. CONCLUSIONS

In this paper the dependence of the magnetospheric boundary position on the values of the *AE*-index (intensity of the auroral electrojet) and corrected D_{st}^* index (intensity of the ring current) is studied. About 1300 crossings of the magnetopause detected onboard the *INTERBALL-1* satellite during 1995–1997, that is, in the vicinity of the minimum activity of the solar cycle, are used for the analysis. The results of the analysis make it possible to assume that the magnetospheric boundary in some spatial regions depends on the values of the *AE*- and D_{st}^* indices.

1. In the case of substorms developing in the absence of magnetic storms, a tendency of a compression of the high-latitude dayside magnetosphere (by $1R_E$) and the high-latitude magnetospheric tail (by $1.5R_E$) with an increase of the *AE*-index is observed.

2. In the presence of magnetic storms, instead of a compression of the high-latitude magnetosphere with an increase of the *AE*-index value an expansion of the high-latitude tail of the magnetosphere by $3R_E$ is observed, this phenomenon being caused by the influence of the ring current.

3. In the period of weak substorm activity ($AE < 100$), an intensification of the ring current (a decrease of the D_{st}^* index) leads to an expansion of the high-latitude magnetosphere. At the dayside, the high-latitude magnetopause is shifted outwards with an amplitude of $< 1\ R_E$ upon a decrease of the D_{st}^* index. At the night side the amplitude of the motion of the high-latitude magnetospheric boundary reaches $2R_E$.

4. In the periods of strong substorm activity ($AE > 100$), an increase of the ring current is evidently accompanied by a compression of the dayside high-latitude magnetosphere by $\sim 1R_E$ and by an expansion of the nightside high-latitude magnetosphere. The amplitude of the outward motion of the boundary of the high-latitude tail reaches $\sim 4R_E$ (that is, by a factor of 2 larger than in the period of weak substorm activity).

5. Due to large errors, one cannot reveal the dependence of the dimensions of the low-latitude tail of the magnetosphere on values of the *AE*- and D_{st}^* indices.

Thus, the position of the magnetospheric boundary on the dayside and in the tail depends on values of the *AE*- and D_{st}^* indices. The dependence on the *AE*-index is different in different regions of the magnetosphere. An increase of *AE* compresses the low-latitude magnetosphere (the dayside and tail), but probably it does not influence the low-latitude tail. The presence of magnetic storms increases the magnetosphere dimensions. In the case of weak and moderate magnetic storms, the amplitude of the expansion of the high-latitude tail of the magnetosphere with a decrease of the D_{st}^* index is higher in the presence of strong substorms than during weak substorms or in their absence.

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