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SOLAR WINDS CONTROL OF MAGNETOSPHERIC ENERGETICS DURING MAGNETIC STORMS

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Abstract. The magnetospheric energy budget is calculated as $U_s = U_j + U_c + U_{DR} + U_T$ where $\underline{U_j}$ is Joule heating in the high-latitude ionosphere, U_c is the power of auroral precipitation, U_{dr} is the ring current energization, U_T is the plasma sheet energization. We have calculated the magnetosphere energy budget for four magnetic storms in 1998: on March 10-12 (Dst = -116 nT), May 02-07 (Dst = -205 nT), August 26-28 (Dst = - 205 nT), September 24-26 (Dst = -207 nT). Correlation between U_s, U_j , U_c , U_{DR} , U_T and the solar wind parameters are analyzed. To our knowledge, there is no adequate procedure of magnetospheric energy budget calculation yet. All known procedures are based on rough approximations, so that calculated U_j, U_c, U_{DR}, U_T, U_s may differ several times from the real values, and it is impossible to estimate calculation accuracy. It is nontrivial to establish the energy input for the magnetospheric budget. As no direct means to measure the energy input are known, various solar wind-derived proxies have been developed. U_j, U_c, U_{DR}, U_T, U_s equations contain quantities which are functions of solar wind parameters. Depending on the data sets used, the underlying assumptions, and also the time-scales under consideration, different functions turned out to have better or worse correlation in different events or under different statistical approaches. We have analyzed the most widely used energy input function, the so-called parameter of Akasofu ε, characterizing the power input to the Earth's magnetosphere from interplanetary medium. Based on the correlation of U_j, U_c, U_{DR}, U_T, U_s with solar wind parameters, we propose a new function ε' similar to ε. It is shown that ε' and ε have identical correlation properties with U_j, U_c, U_{DR}, U_T, U_s but ε' has more transparent physical meaning. As known now, geomagnetic activity is described by special geomagnetic indices, which quantify temporal scale of geomagnetic variation amplitudes only. But, in our idea, the real geomagnetic activity is described by the total energy of geomagnetic variations generated by magnetospheric and ionospheric current systems in the near-Earth space. To estimate magnetospheric current system activity, two following methods may be suggested: a) to estimate the energy of the magnetic field generated in near-Earth space with using the up-to-date models of the magnetospheric current systems, such as the paraboloid model, Tsyganenko model, Maltsev model etc.; b) to estimate the magnetic energy of the geomagnetic field variations on the ground from observations or model distribution of these variations (the IZMEM model). Then, it will be possible to introduce a geomagnetic activity index that is more precise than the classic ones and which can be used for more realistic classification of geomagnetic activity level. The energy of the ground geomagnetic variations during October and November, 2003 major magnetic storms has been estimated using the IZMEM model.

1. Introduction

Any large-scale physical phenomenon in the Earth's environment occurs either with energy injection or energy dissipation. The solar wind is the main energy source for the electromagnetic processes in the magnetosphere. The energy is delivered from the solar wind to the magnetosphere and distributed within different magnetospheric regions, providing the energetics of large-scale current systems in the Earth's magnetosphere. The magnetic fields of these current systems superposing on the geomagnetic dipole field cause the magnetosphere formation in the space region where there is geomagnetic field. Today it is generally recognized that the Bz component of the interplanetary magnetic field (IMF), to a large extent, controls the energy input to the magnetosphere. Once the IMF turns southward, the rate of reconnection at the subsolar magnetopause is enhanced, leading to an increase of open magnetic flux in the magnetosphere. This corresponds to more effective coupling of the magnetosphere to the solar wind dynamo and an increase in the magnetospheric electric field, driving a more intense convection. An increase in the lobe flux due to dayside magnetic field erosion leads to the development of a more tail-like magnetospheric configuration and to an increase of the cross-tail current. The surface currents on the magnetopause shield the space outside the magnetosphere from the magnetic fields of the dipole and all current systems. In the nightside, the magnetospheric magnetic field is stretched, forming a comet-like tail, the dawn-to-dusk current in the central part of the tail being closed via the magnetopause. On the magnetopause, a MHD-generator, which is the source of the large-scale field-aligned current system, arises as a result of the interaction of the solar wind plasma with the magnetosphere. The field-aligned currents flow from the magnetosphere into the ionospheric altitudes on the dawnside and out of the ionosphere on the duskside. During magnetic storms, the ring current generated by hydrogen and oxygen ions with energies of tens keV arises in the inner magnetosphere between the plasma sheet and plasmasphere due to solar wind energy input. Accelerated ions of both plasma sheet and ionospheric origin are sources of this current.

The energy of the large-scale current system, stored in the magnetic fields generated by the currents, dissipates through upper atmosphere Joule heating by the ionospheric currents, energetic charged particles injections, ejection of plasma, energetic particles and magnetic field via the remote part of the magnetotail to the solar wind, charge-exchange interaction of the ring current ions with the neutral particles of the exosphere, energetic ions ejection across the dayside magnetopause in the course of the curvature/gradient drift around the Earth.

In this paper we estimate the accuracy of computational procedures for calculation of magnetospheric energy budget taken in the form $U_s = U_j$ (Joule heating in the high-latitude ionosphere) + U_c (power of auroral precipitation) + U_{DR} (ring current energization) + U_T (plasma sheet energization). Besides, we present the results of our budget calculations for four magnetic storms in 1998: on March (Dst = -116 nT), May (Dst = -205 nT), August (Dst = -205 nT), September (Dst = -207 nT). After that, we discuss the most widely used energy input function, the so-called ε parameter of Akasofu, characterizing the power incoming to the Earth's magnetosphere from interplanetary medium. Based on the correlation of U_j, U_c, U_{DR}, U_T, Us with solar wind parameters, we propose a new function ε' which is similar to ε, but has a more transparent physical meaning.

2. Calculation of magnetospheric energy budget for magnetic storms

The global energy deposition during magnetic storm has previously been investigated in many studies [*Perreault and Akasofu, 1978; Akasofu*, 1981; *Ahn et al.*, 1983; *Monreal Mac-Mahon and Gonzales*, 1997; *Cooper et al.*, 1995; *Lu et al.*, 1998; *Feldstein et al.*, 2003 and references therein]. We show some examples of these investigations, with concentrating on computational procedures used in calculations of the magnetospheric energy budget. Possible errors of these computational procedures are discussed.

2.1. Computation procedures for the energy budget

Through solar wind-magnetosphere-ionosphere interaction, a part of incoming solar wind energy is released in Joule heating U_j of the high-latitude ionosphere, auroral precipitation U_c, ring current energization U_{DR} in the inner magnetosphere, plasma sheet particle heating U_T, plasmoid ejection in the magnetotail U_{PL}.

2.2.1. Computation of U_j

The current system connecting the Earth's ionosphere with space consists of the magnetospheric currents, field aligned currents (FACs), and closure currents in the ionosphere. The distributions in time and space of these currents depend not only on FAC driving mechanism but also on the ionospheric conditions, particularly on the ionospheric conductivity. A change in the conductivity may be caused by the electric current as well as by other parameters such as the electric field. Therefore, the ionosphere conductivity and the electric field are related to each other in various current systems. The FACs are a part of the system which transfers the energy and momentum from the magnetosphere to the ionosphere. While it is clear that the system is driven ultimately by the solar wind, the direct physical mechanism providing energy and momentum and initiating their transfer into the ionosphere is still not well understood. Nor we have detailed knowledge as to whether and how these driving physical mechanisms are influenced by ionospheric conditions, which are variable in time and in space.

In early investigations the relationship U_j = const×(AE-index) was suggested for computation of Joule heating. In [*Akasofu*, 1981], const = 2 for U_j in Watts and AE in nT. It is obvious, that the accuracy of such a relationship is not high enough. The discrepancies in estimating of U_j taken in this form by different authors can be attributed to several causes: a) not the same AE index is used in different studies, i.e. the utilization of AE(12 stations), AE(10), etc. can lead to a discrepancy of factor ~ 1.5;

b) AE index is different in the northern and southern hemispheres which is likely to cause differences in the estimates as high as ~ 1.5 times;

c) the relation between AE and various electrodynamic quantities is nonlinear, and the cross-polar cap potential drop tends to saturate the estimates for AE > 1000 nT. The power function fits of AE versus U_j are a significant improvement over the linear fitting in terms of reducing the standard deviation. In other words, calculation of $U_j = U_j(\mathrm{AE})$ is not accurate and the difference between the estimates obtained and real values may be as large as an order.

Another method of calculation uses the relation of U_j to the ionospheric electric field E and ionospheric conductivity Σ in the form $U_j = (\mathbf{JE}) = (\Sigma p)\mathbf{E}^2$, where $J = \Sigma\mathbf{E}$ is the ionospheric current, Σ is the tensor of integral conductivity of the ionosphere and Σp is Pedersen part of this conductivity. In [*Manreal Mac-Mahon*, 1997] the relationship $U_j = \iint \Sigma p \mathbf{E}^2 (Re + h)^2 \mathrm{Sin}\vartheta d\vartheta d\lambda$ was used for this aim, where ϑ changes from 0° to the geomagnetic colatitude for the equatorward boundaries of the auroral zone and λ is the geomagnetic longitude. The auroral zone boundaries were determined using the database on the total energy flux of electrons from the NOAA satellite. The electric field in the polar ionosphere was estimated in a sort of hybrid way using both ionospheric and interplanetary (ISEE-3 satellite) data. This method was used in [*Lu et al.*, 1998], where the electric potential φ ($\mathbf{E} = -\nabla\varphi$) and Σp were calculated by AMIE procedure [*Richmond and Kamide*, 1988; *Richmond et al.*, 1990] on the basis of geomagnetic data and 5-min snapshots, auroral electron energy flux derived by combining various observations (DMSP F10, F12, F13; NOAA12 and 14 satellites, auroral UVI images from the Polar satellite, ion drift measurements from 6 SuperDARN radars, Millstone Hill and Sonderstrom radars; 119 ground magnetometers). Such an approach was also used in [*Feldstein et al.*, 2003], where φ and $\mathbf{J}$ were obtained from the IZMEM model which gives these values for high latitudes as a function of solar wind parameters [*Feldstein and Levitin*, 1986].

The discrepancies in the estimates of U_j by these methods can be attributed to several causes (in addition to those mentioned above). First of all, when calculating the height-integrated Joule heating rate $Q = \Sigma p\mathbf{E}^2$, there is an error associated with the estimated large-scale electric field E at each grid point. This error depends on the manner of calculation of the electric potential φ from geomagnetic field variations and conductivity of the ionosphere. When using geomagnetic variation, it is necessary to set a basic level but actually this level is not known, especially in the period of magnetic storm. The points of registration of geomagnetic variations are not uniformly distributed over the surface, so that using spherical harmonic presentation for geomagnetic disturbances may be incorrect. As for the ionospheric conductivity, it is known very poorly in the period of storms. Secondly, some postulates using for calculation of the high-latitude current system from geomagnetic data (such as equipotentiality of geomagnetic field lines, the condition $E = -\nabla\varphi$, etc.) can be violated [*Feldstein and Levitin*, 1986].

Therefore, any method for U_j calculation contains non-controllable errors, so that the differences between the estimates and real values can reach an order of magnitude.

2.2.2. Computation of U_c

In early investigations to calculate the power of auroral precipitation U_c the following expressions were used: $U_c = 10^8$AE [*Akasofu*, 1981] and $U_c = [1.75\times(AE/100 + 1.6]\times10^{10}$ [*Spiro et al.*, 1982], where Uc is in Watt and AE is in nT. Some other relationships were also proposed: $U_c = 1.610^8\times AL$; $U_c = (4.4\times AL^{1/2} - 7.6)\times10^9$. It is clear that for the reasons mentioned in 2.2.1 these expressions can also lead up to an order of magnitude discrepancy between the estimates and real values.

2.2.3. Computation of U_{DR}

According to the Dessler-Parker-Schopke relationship [*Sckopke*, 1966], $\Delta\mathbf{B}/\mathbf{B}_0 = -K_R/K_M$, where $K_M = 8\times10^{24}$ ergs, the total energy of the particles of the ring current being equal to $K_R = 4\times10^{20}\times D$, where D is the pressure-corrected Dst index in nT (Dst*). The energy injection rate is obtained from the energy balance equation: $U_{DR} = 4\times10^{24}(dDst^*/dt + Dst^*/\tau)$, where τ is the particle lifetime in the ring current. The magnitude of the ring current energy rate strongly depends on τ parameter. Several models were proposed to estimate this parameter. In earlier studies the same τ for all possible Dst values was assumed [*Buton et al*., 1975]. Later, the necessity to introduce different values of τ for different Dst ranges was emphasized [*Prigancova and Feldstein*, 1992; *Feldstein*, 1992]. In [*Feldstein et al*., 2003], the equation $U_{DR} = -0.74\times10^{10}(dDR/dt + DR/\tau)$ was used for DR, which is the ring current magnetic field on the Earth's surface determined by AMPTE/CCE ion measurements in the magnetosphere.

The τ values are often chosen to provide the overall balance between the input solar wind energy and total magnetospheric energy consumption. Since the real τ is unknown, U_{DR} estimates can differ from the real values by factor 2 - 5 or by an order of magnitude.

2.2.4. Computation of U_T

U_T computation is a very hard task and the accuracy of U_T calculation can not be determined at present. In [*Feldstein et al*., 2003] U_T was calculated with the use of the paraboloid model [*Alexeev and Feldstein*, 2001] according to the relation $U_T = E_T/dt - E_T/\tau$, in which the tail energy $E_T = (E_{T1})\exp\{(t - t1)/l_T,$ where

$$E_{T1} = (2F_0^2/\pi\mu R_1) \times A\times B;\ \ A = (2R_2/R_1 + 1)^{1/2};\ \ B = Ln[2R_k/R_1 + 1)^{1/2}/(2R_2/R_1 + 1)^{1/2}],$$

R_1 being the distance to the magnetopause subsolar point, R_2 the distance to the inner edge of the current sheet and R_k = 60Re.

What is the accuracy of such an approximation? U_T estimates can differ from the real values by factor 2 - 5 or up to an order of magnitude, as it is for U_j, U_c and U_{DR}.

2.2.5. Computation of U_P

Computation of U_P is also very difficult. In [*Leda et al*., 1998], based on statistical analysis of plasmoid evolution, it was suggested that the energy carried by each plasmoid is $\sim2\times10^4$ J in the middle tail, and this energy is lost on the way from the middle to the distant tail. This value was derived for the plasmoid dimensions of 10Re(length)× 40Re(width)×10Re(height). Accordingly, the energy, ejected tailward in the course of substorm, was roughly estimated to be 10^{15} J. It is comparable to the energy released to the auroral region and to the ring current.

It is unclear what the accuracy of such an approximation is. The estimates for U_P can differ from the real values by factor 2 - 5 or up to an order of magnitude, as it is for U_j, U_c and U_{DR} and U_T.

Thus the estimates for the sum $U_s = U_j + U_c + U_{DR} + U_T + U_P$ can from 2 to 5 times (or up to an order of magnitude) differ from the real values.

Energetics of the solar wind

At present, there are no direct observational means capable to determine the energy transfer from the solar wind into the magnetosphere. In fact, we do not even know the details of how and where the transfer takes place. It is known that the efficiency of transferring is strongly coupled to the IMF southward component.

In [*Feldstein et al.*, 2003] a quantitative estimation is presented of the energy transferred by the plasma flux and solar wind electromagnetic field into the magnetosphere with a cross section S. The rate of kinetic energy transfer is Ukin(W) = 8.35×10^{-7}N(particles cm^{-3})×(V(km s^{-1})/100)^3×S, while the rate of electromagnetic energy transfer onto the surface S is Uemag = 7.9×10^{-8}[V(km s^{-1})/100]×[B(nT)]^{2}xS. The cross section along the dawn-dusk meridian of the magnetopause with the paraboloid shape can be found as $S = \pi(1.5R_1)^2$, where R_1 is the distance to the magnetopause subsolar point.

For quantitative description of solar wind energy input into the magnetosphere Akasofu compiled a so-called *ε*-function: $\varepsilon = VB\sin^4(\vartheta/2)x(L_0)^2$ [*Perreault and Akasofu*, 1978; *Akasofu*, 1981]. This function has identical correlation properties with respect to the Uj, Uc, Udr, Ut, as well as to the U_s. The parameter L_0 = 7Re enables to calibrate *ε* to the order of U_s magnitude (for *ε*-function relation to the Poynting flux see [*Kan and Akasofu*, 1982]).

While in practice it has been shown that *ε* is a very useful parameter, there is no convincing evidence of its superiority over other known coupling parameters. We have performed correlation analysis of the amplitudes of U_j, U_c, U_{DR}, U_T and of their sum for four magnetic storms with the solar wind parameters. Depending on the dataset used, underlying assumptions, and time-scales considered, different functions turned out to exhibit better or worse correlations in different events or under different statistical approaches. The parameter *ε* is one of the proper parameters (along with B_s, VB_s etc.) that exhibit a good correlation with U_j, U_c, U_{DR}, U_T and with their sum. But the physical meaning of *ε* is questionable. As a new energy input parameter, we propose $P = V(Bs)^2\times S$, where Bs = 0.5 for Bz > 0, Bs = -Bz for Bz < 0, $S = \pi\,(1.5R_1)^2$, and R_1 is calculated using the paraboloid model [*Dremukhina et al.*, 1999; *Alexeev and Feldstein*, 2001].

In Tables 4-7 the coefficients of Uj, Uc, Udr, Ut and U_s correlation with different combinations of IMF components and solar wind parameters are presented.

3. Calculation of energetics for particular magnetic storms

To study the magnetospheric energy budget, four magnetic storms of 1998 were selected. Table 1 shows the main characteristics of the storms.

Table 1

Characteristics of the magnetic storms

N	Date	Dst minim, nT	Main phase: day, UT	Recovery phase: day, UT
1	March, 1998	-116 nT	10.03, 13 – 10.03, 22	10.03, 23 – 11.03, 09
2	May, 1998	-205	04.05, 00 – 04.05, 05	04.05, 06 – 05.05, 00
3	August, 1998	-155	26.08, 08 – 27.08, 14	27.08, 15**Ошибка! Ошибка связи.**28.08, 12
4	September, 1998	-207	25.09, 00 **Ошибка! Ошибка связи.** 25.09, 09	25.09, 10 **Ошибка! Ошибка связи.**25.09, 19

3.1. Computation of the magnetospheric energy budget for four magnetic storms

For each of the storms we calculated $U_s = U_j + U_c + U_{DR} + U_T$, in which $U_c = 2\times\{4.4(AL)^{½} - 7.6)\}\times10^9$; $U_{DR} = -0.74\times10^{10}(dDR/dt + DR/\tau)$, where $\tau = 2.4 \text{ x } \exp\{9.74/(4.69 + V\times Bs)\}$ and Bs = -Bz for Bz < 0, Bs = 0.5 for Bz ≥ 0 [*O'Brain and McPherron*, 2000].

To calculate Joule heating, we used the relation $U_j = U_j$(steady-state current) + U_j(substorm), in which U_j(substorm) = 0.32×10^9(AE) [*Baumjohann and Kamide*, 1984]. In calculating U_T, we used the relations from [*Feldstein et al.*, 2003] presented in section 2.2.4.

The hourly values of U_j, U_c, U_T, U_{DR}, Us, as well as their maximum values, are presented in Table 2 (for the storms in March and in May) and in Table 3 (for the storms in August and in September). As the storm in May included two disturbed periods, all data in Table 2 are given for two days: May, 2 (the first disturbance), and May, 4 (the second disturbance).

Table 2

Hourly means and maximum values of U_j, U_c, U_T, U_{DR}, Us for the magnetic storms in March and in May

	March storm, mean (W)	March storm, max(W)	May storm, mean (W)		May storm, max (W)	
			May, 02	May, 04	May, 02	May, 04
U_j	20 – 30	45	20 – 40	60	50 **Ошибка!**	
U_c	10 – 15	20	15 – 20	25	**Ошибка связи.** 60	
U_T	40 – 60	100	40 – 80	145	100	
U_{DR}	20 – 30	45	20 – 30	35	20 – 30	35
U_s	120	190	100 – 150	240	150 – 200	380
ε	170	275	150 –180	240	40 – 60	90
					150 – 300	480
					900	2000

Table 3

Hourly means and maximum values of U_j, U_c, U_T, U_{DR}, U_s for the magnetic storms in August and in September

	August storm, mean (W)	August storm, max (W)	September storm, mean (W)	September storm, max (W)
U_j	30 – 50	75	40 – 60	85
U_c	15 – 20	30	15 – 25	30
U_T	120 – 150	220	100 – 150	410
U_{DR}	30 – 50	60	40 – 50	65
U_s	150 – 450	370	150 – 250	565
ε	200 – 260	340	350 – 400	520

The coefficients of correlation between the hourly values of U_j , U_c, U_T, U_{DR}, U_s and ε , Bs, VBs, $BsNV^2$, Bs/B, B_T/B for the main phase of the storms (for all four magnetic storms) are presented in Table 4. Here V is the solar wind velocity, N is the solar wind density, B is the IMF magnitude, $B_T = [(Bz)^2 + (By)^2]^{1/2}$. The same correlation coefficients for the recovery phase are presented in Table 5.

Table 4

Main phase of the storms. Correlation coefficients between hourly means U_j, U_c, U_T, U_{DR}, U_s and ε , Bs, VBs, BsNV2, Bs/B, B_T/B.

	ε	Bs	Bs×V	$Bs \times NV^2$	Bs/B	B_T/B
Uj	0.64	0.54	0.55	0.51	0.37	0.12
Uc	0.55	0.50	0.51	0.43	0.40	0.16
U_T	0.60	0.51	0.55	0.62	0.31	0.09
U_{DR}	0.47	0.54	0.59	0.43	0.47	0.09
Us	0.72	0.65	0.69	0.68	0.45	0.08

Table 5

Recovery phase of the storms. Correlation coefficients between U_j , U_c, U_T, U_{DR}, U_s and ε , Bs, VBs, $BsNV^2$, Bs/B, B_T/B.

	ε	Bs	Bs×V	$Bs \times NV^2$	Bs/B	B_T/B
U_j	0.74	0.78	0.81	0.56	0.58	0.64
U_c	0.67	0.75	0.77	0.50	0.59	0.64
U_T	0.60	0.31	0.27	0.18	0.50	0.37
U_{DR}	0.57	0.34	0.37	0.53	0.05	0.09
U_s	0.54	0.67	0.66	0.50	0.64	0.56

As one can see, ε, VBs and Bs have identical correlation properties with respect to U_j, U_c, U_{DR}, U_t. Good correlation of ε with the parameters of geomagnetic activity is due to the term $V \times [\mathrm{Sin}(\vartheta/2)]^4$, which is proportional to VBs.

We analyzed a multi-parameter correlation assuming $U = U_0 + K_{B\varepsilon} \times(\varepsilon) + K_{Bs}\times(Bs) + K_{BsV}\times(BsV) + K_{BsNV2}\times(BsNV^2)$. Table 6 (Table 7) presents correlation coefficients (R) and parameters for the main phase of the magnetic storms (for the crecovery phase).

Table 6

Main phase of the storms. Correlation coefficients R and parameters U_0, K_ε, K_{Bs}, K_{BsV},KB_{sNV2}.

U	R	U_0	K_ε	K_{Bs}	K_{BsV}	K_{BsNV2}
Uj	0.66	26.23	0.11	1.44	- 0.33	-0.12
Uc	0.57	15.95	0.03	0.41	- 0.06	-0.16
U_T	0.63	34.39	0.10	0.23	- 0.20	0.65
U_{DR}	0.64	12.05	-0.07	-1.44	0.73	0.01
Us	0.73	88.62	0.17	0.63	0.13	0.49

Table 7

Recovery phase of the storms. Correlation coefficients R and parameters U_0, K_ε, K_{Bs}, K_{BsV},KB_{sNV2}.

U	R	U_0	$K_{B\varepsilon}$	K_{Bs}	K_{BsV}	K_{BsNV2}
Uj	0.81	12.26	0.04	-0.60	0.53	- 0.41
Uc	0.77	10.23	0.01	0.27	0.12	- 0.21
U_T	0.47	23.91	-0.23	2.01	0.47	1.54
U_{DR}	0.68	19.97	0.10	3.21	-0.73	0.28
Us	0.68	66.37	- 0.08	4.90	0.39	1.21

The correlation coefficients of multi-parameter regression for the main phases of the storms are equal to those in Tables 4 and 5 but for the recovery phases the correlation coefficients of multi-parameter regression are larger than in Tables 4 and 5. One can see that the correlation coefficients of U_s with the solar wind parameters are equal to ~ 0.7.

The new parameter that we propose ($P = V(Bs)^2S$, where $S = \pi(1.5R_1)^2$ and $Bs = -Bz$ for $Bz < 0$ and $Bs = 0.5$ for $Bz \geq 0$) has more transparent physical meaning than ε. It can be interpreted as a product of the electric field $E = VBs$ and vertical component of the interplanetary magnetic field Bs. S is the area of the section of the magnetosphere of the paraboloid form. It is equal to the area of the circle with the radius of $1.5R_1$, where R_1 is the distance to the magnetopause subsolar point. We calculated R_1 using the paraboloid model [*Alexeev and Feldstein*, 2001]. The coefficient of correlation of the new parameter P with ε for the four storms chosen is equal to 0.91 for the storm main phases and 0.81 for the recovery phases. The coefficient of P to U_s correlation is equal to 0.66 for the main phases of the storms (the coefficient of ε to U_s correlation is 0.72 for the storm main phases) and 0.54 for the recovery phases (the same coefficient for ε is equal to 0.54). But, unlike ε calculating, it is not necessary to introduce $L_0 = 7Re$ for calculating P.

4. Summary

The adequate calculation of the magnetospheric energy budget has not been accomplished yet. All known calculation procedures are based on rough approximations, so that the reported estimations of U_j (Joule heating in the high-latitude ionosphere), U_c (power of auroral precipitation), U_{DR} (ring current energization) and U_T (plasma sheet enegization) may differ several times from the real values. All the equations for U_j, U_c, U_{DR}, U_T contain terms parameterized by the solar wind parameters, therefore, they correlate rather well with the main geoeffective parameters such as Bs, VBs, etc.. Accordingly, a number of expressions similar to that for ε have been proposed. Those correlate with U_j, U_c, U_{DR}, U_T quite well (the correlation coefficients are about 0.7). Parameter ε is not really a measure of energy input into the magnetosphere, and we have proposed a new function ε' similar to ε. The new parameter ε' and ε of Akasofu have identical correlation properties with respect to the U_j, U_c, U_{DR}, U_t, U_s but ε' has more transparent physical meaning.

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