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CORRECTION OF THE AURORAL ELECTROJET INDICES ON THE BASIS OF THE HIGH LATITUDE GEOMAGNETIC VARIATION MODEL

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Abstract. Auroral activity indices AU, AE, AL are being investigated using of IZMIRAN electromagnetic model. The result of investigation allows us to figure out the coefficients to correct the indices for different UT hours and Dst index values.

Introduction. The "auroral electrojet" indices AE, AL, and AU have been introduced to quantify geomagnetic activity in the auroral oval, that is, in the regions between 60°–70° corrected geomagnetic (CGM) latitude where *aurora borealis* is observed most often [9]. Currently these indices are also used for quantitative assessment of the energy downloaded into the ionosphere from the magnetospheric tail during geomagnetic substorms. But nearly every article points to limitations of indices: their dependence of AE-stations location at any UT hour (UT variation) and level of magnetic activity. The UT dependence could be illustrated by the next simple example. Let in high latitude ionosphere exist one stationary current system. The location of AE-observatories will differ in different the UT hour with respect to those current system and stations will fix the different maximal and minimal magnetic perturbations from the current system and so will different indices values. Could there exist a limited number of current systems and ways to know what a system presents at every moment then we could construct a UT variation of indices for all systems and correct maximum and minimum values. However the spatial distribution of electric fields and conductance in the high latitude ionosphere are very variable and it is impossible to make an ideal correction. But we can do it approximately using of some model construction if such a model includes information about magnetic fields at the points of real AE-stations location. In this work we use the IZMIRAN's electromagnetic model (IZMEM) [16, internet site http://www.sprl.umich.edu/MIST/) This model has proved qualitative and reliable through many years of usage [15]. IZMEM was made on the basis of regression analyses and it gives magnetic perturbation vectors at any point of high latitude. So it allows let us to simulate different current systems and to figure out corrections of AE (AU, AL) indices. Different methods for indices improvement were suggested earlier [3,12] but those methods are reduced to the attraction of additional magnetic information from other (non AE) stations. In this article we suggest an other approach (developing the ideas of [11]), which gives a key to correct AE, AU, AL indices for every moment now, in past, in future when Bz and By components of the IMF and Dst values are available.

UT variation of AE-indices. In our work we used the next procedure for indices correction. We have taken some By, Bz values and let them remain unchanged 24 hours long. The AE-stations [4] complete the full cycle under a stable current system. At any UT hour the H-component of the magnetic field are registered at points of stations location. The maximum and minimum values of it's magnetic field give AU and AL indices values respectively. Because of differences in stations coordinates the values will differ and should be normalized for maximum magnitude. The hour mean values and CGM coordinates for AE-stations [1] were used as in the IZMEM. The local geomagnetic time (MLT) was calculated using the graph from [18].

The on tire unlimited amount of current systems. We separated into 14 classes according the interrelations between model coefficients. The names of classes and appropriate IMF values are presented in table 1. For classes m5-0 and p5-0 in case of By exceeds the table value one needs to take coefficients for m3-* and p3-* classes respectively with the maximum By values (taking into account the right sign).

Dst dependence. Beside the UT effect the location of auroral electrojets depends on the global magnetic activity [12]. In the paper [10] one can find the graph for distribution of eastward and westward electrojets centers as a function of the Dst value. Basing on the data from that paper we can figure out equations for eastward and westward electrojets centers latitudes as a function of the Dst value. Supposing that the electrojets centers are situated at 67° CGM latitude when Dst=0 we can write down respectively for eastward and westward electrojets:

$$\Phi'_{AU} = 49° + \frac{1800}{100 - Dst} \quad (1)$$

$$\Phi'_{AL} = \frac{1}{3}\left(124° + \frac{30800}{400 - Dst}\right) \quad (2)$$

where Dst is in nanoteslas. In our calculations we simulated the shift of electrojet such a way that stations coordinates changed poleward when electrojets shifted equatorward with growing of Dst magnitude with respect to entire current system.

The current systems for different IMF combinations are very asymmetric and Dst dependence is rather complex. Not only the magnitude of indices changes, but the MLT hours of maximums and minimums differ. So we separated all Dst values into 5 classes 0, -20, -60, -120, -250 for Dst >-10; -

40>Dst>-80; -80>Dst>-120; -120>Dst>-250 respectively.

Results of AU and AL indices correction. In fig. 1 we show an example of AL index absolute value dependence on the UT hour. There was the "m3-0" class IMF and class –60 of Dst for 24 hour long. The shown dependence which derived from model calculations is extremely similar to curves in plate 1 in [3], which were obtained on the huge experimental material. On the one hand this fact gives an additional argument for our calculations correctness, and on the other hand it shows the actuality of correction itself.

To obtain the corrected values of any of the indices one needs to multiply the published index value by tabular coefficient according UT hour, the season of year, IMF and Dst classes. In table 2 we present an example of correcting coefficients for AU, AL, AE indices (Kau, Kal, Kae respectively) for equinox, IMF class m5-0, and two Dst classis as 0 and –60. In fig. 2 we also show the behavior of coefficients for AL index for the winter season, m3-p class IMF and different Dst classes.

To test the quality of correction we choose the real data for 1979, for which there is a relatively good set of IMF data. As the input parameters we used hour mean values of Bz and By components of IMF, and Dst and AU/AL indices. The data were separated for different seasons of year. In table 3 we present linear correlation coefficients between AU/AL indices and Bz*V combination for Bz<0. Comparing coefficients for AL index before and after correction we can say that modifications are insignificant. There is an improvement in summer and in equinox and deterioration in winter season. On the contrary the improvement for AU index is rather large. The mean value of correlation coefficient increased from 0.45 to 0.58; from 0.49 to 0.59; and from 0.58 to 0.61 for winter, equinox and summer seasons respectively. The most significant improvement are in those hours when according to the IZMEM the real AU index can be calculated with the largest error, i.e. for 0-3 and 11-13 UT. The obtained result could be explained from a widely accepted point of view about direct driving and loading-unloading processes [13]. The AU index reflects the direct driving mechanism and the significant improvement of the AU confirms our assumption that diurnal variation of this index depends on IMF and Dst. On the other hand the weak improvement of the AL index shows the greater dependence of index on internal (magnetospheric) processes then on the IMF.

Summary and conclusion. In this work we show using model calculations that auroral activity indices AE, AU, AL can change the magnitude in two times and more because of different location of the AE-stations only depending on the UT hour. Using the correcting coefficients obtained using of the IZMEM model as a function of IMF parameters and Dst variation we can improve correlation coefficients AE, AU, AL indices with IMF parameters. For the improvement of quality of indices, the authors of paper [3] suggest to establish some additional AE-stations. It can make the indices better but such a variant is impossible to apply to the data obtained in the past. The method presented in this article is more "universal" and does not need a large expenses. More over the described approach lets one to calculate the corrected values of indices obtained on the basis not only of 12 AE-stations but on the basis of 11 or 8 stations (http://swdcdb.kugi.kyoto-u.ac.jp/). For this purpose we need to take the other stations' coordinates in the computer program only.

In addition, because of the existing of the IZMEM model for southern hemisphere there is a possibility to obtain and to correct southern auroral indices which otherwise have significant limitations [17]. In such a way one can correct hemispheres asymmetry for more precise energy balance calculation.

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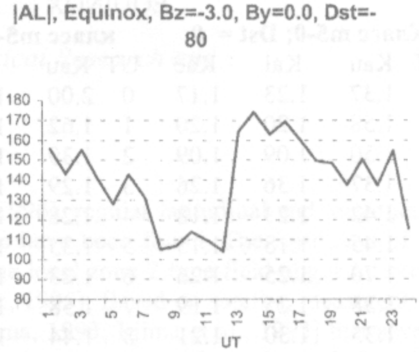

Fig.1. Dependence of absolute value of *AL* index on UT hour for next stable conditions: Bz=-3.0 nT, By=0.0 nT, Dst=-80 nT

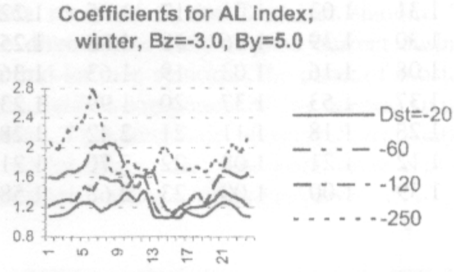

Fig. 2 Diurnal variation of *AL* index coefficients in winter season for class m3-p IMF and different Dst classes.

Table 1.

##	Class name	Bz IMF value	By IMF Value
1	m5-0	Bz< -4.7	|By|<2.5*|Bz|
2	m3-m	-4.7 < Bz< -2.5	By< -3.2
3	m3-p	-4.7 < Bz< -2.5	By> 3.5
4	m3-0	-4.7 < Bz< -2.5	-3.2 <By< 3.5
5	m1-m	-2.5 < Bz< 0	By< -3.0
6	m1-p	-2.5 < Bz< 0	By> 3.3
7	m1-0	-2.5 < Bz< 0	-3.0 <By< 3.3
8	p1-m	0 < Bz< 2.7	By< -3.0
9	p1-p	0 < Bz< 2.7	By > 3.0
10	p1-0	0 < Bz< 2.7	-3.0 <By< 3.0
11	p3-m	2.7 <Bz< 5.0	By< -5.0
12	p3-p	2.7 <Bz< 5.0	By> 5.0
13	p3-0	2.7 <Bz< 5.0	-5.0 <By< 5.0
14	p5-0	5.0 <Bz	|By|<2.7*|Bz|

Table 2

Correcting coefficients for different UT hours

EQUINOX

Класс m5-0; Dst = 0				класс m5-0; Dst= -60			
UT	Kau	Kal	Kae	UT	Kau	Kal	Kae
0	1.37	1.23	1.17	0	2.00	1.21	1.29
1	1.58	1.20	1.20	1	1.62	1.32	1.30
2	1.50	1.09	1.09	2	1.39	1.20	1.15
3	1.37	1.36	1.26	3	1.29	1.25	1.16
4	1.42	1.23	1.18	4	1.28	1.41	1.27
5	1.45	1.18	1.15	5	1.33	1.28	1.19
6	1.70	1.25	1.26	6	1.23	1.33	1.20
7	1.38	1.25	1.19	7	1.58	1.59	1.49
8	1.35	1.30	1.21	8	1.44	1.67	1.49
9	1.27	1.29	1.18	9	1.86	1.51	1.50
10	1.21	1.34	1.20	10	2.03	1.54	1.57
11	1.24	1.36	1.22	11	1.64	1.70	1.58
12	1.00	1.27	1.08	12	1.46	1.16	1.14
13	1.38	1.06	1.05	13	1.61	1.20	1.20
14	1.12	1.41	1.21	14	1.70	1.14	1.17
15	1.38	1.33	1.24	15	1.50	1.29	1.25
16	1.42	1.20	1.16	16	1.69	1.17	1.20
17	1.31	1.03	1.01	17	1.95	1.22	1.29
18	1.30	1.39	1.26	18	1.88	1.25	1.30
19	1.08	1.16	1.03	19	1.63	1.36	1.33
20	1.37	1.53	1.37	20	1.99	1.23	1.30
21	1.28	1.18	1.11	21	2.42	1.28	1.41
22	1.12	1.21	1.08	22	2.70	1.21	1.37
23	1.39	1.00	1.00	23	2.68	1.58	1.70

Table 3

Correlation coefficients as function of UT hour for initial (r) and corrected (r_{cor}) indices

AU, Winter, Bz < 0				AL, summer, Bz < 0			
UT	r	r_{cor}	number. of points	UT	r	r_{cor}	umber of points
0	-.31	-.45	63	0	.66	.71	62
1	-.19	-.51	57	1	.68	.67	50
2	-.36	-.61	61	2	.60	.51	55
3	-.53	-.76	51	3	.49	.51	62
4	-.53	-.54	56	4	.51	.54	56
5	-.67	-.82	52	5	.51	.52	50
6	-.61	-.73	57	6	.34	.34	52
7	-.49	-.67	67	7	.50	.43	54
8	-.42	-.56	56	8	.37	.32	54
9	-.54	-.59	57	9	.34	.32	65
10	-.56	-.53	61	10	.52	.55	52
11	-.51	-.77	56	11	.51	.59	56
12	-.35	-.61	60	12	.81	.85	57
13	-.55	-.64	58	13	.55	.61	66
14	-.78	-.84	61	14	.71	.70	59
15	-.68	-.72	62	15	.65	.66	55
16	-.46	-.51	62	16	.61	.57	66
17	-.39	-.58	59	17	.62	.68	65
18	-.57	-.73	58	18	.60	.63	61
19	-.50	-.63	63	19	.67	.65	61
20	-.44	-.60	62	20	.70	.71	64
21	-.38	-.52	59	21	.58	.65	55
22	-.22	-.38	60	22	.69	.69	55
23	-.07	-.33	61	23	.70	.70	55
mean	-.45	-.58	1419	mean	.60	.62	1387