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The New Index of Geomagnetic Activity

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Abstract

Up-to-date indices of geomagnetic activity are widely used for scientific purposes. The indices D_{st}, K_p and AE characterize activity of geomagnetic field at low, middle and high latitudes, respectively. However, these indices do not characterize the energy injected into the magnetosphere by the solar wind, although the change of energy has an influence on the meteorological and biological Earth's processes. The AE index is the most suitable for this aim, but it is set too low for disturbed periods. We propose index $\Sigma(H-S_q)$. This index may be effectively calculated on middle latitude magnetic observatories data.

The index is determined as a daily sum of differences between mean hourly values of horizontal (H) component and corresponding mean hourly values of H on five international quiet days of the preceding month.

The new index corresponds to the standard AE index for quiet day periods and is better than AE′ for disturbed periods.

Key words: geomagnetic activity indices, internationally quiet days, magnetic storms.

The flow of charged particles from the Sun interacts with the Earth's magnetic field and creates several magnetospheric and ionospheric current systems. These systems disturb the main geomagnetic field by about 1-2%. To compare the intensity of the disturbances, several indices were adopted. The D_{st}, K_p and AE are the most often used indices for scientific and practical purposes.

Index D_{st} characterizes intensity of the magnetospheric ring current and currents of the magnetopause. The index is a deviation of the horizontal component (H) from its quiet time value, averaged over four low latitude observatories: Honolulu, San Juan, Hermanus and Kakioka. The D_{st}-index shows the value of geomagnetic field variations at low latitudes and do not express the variations induced by auroral zones ionospheric currents.

Index K_p is a mean standardized K-index from 12 observatories at middle and sub-auroral latitudes. The K_p-index has the longest row of meanings. But K_p and its equivalent ranges a_p and daily index A_p do not take into consideration full variation induced by magnetospheric ring currents.

A new definition of the K-index was proposed by Polish scientists (Reda, Jankowski 2004, Nowożyński 2006). The definition is based on the calculations of energy contained in irregular changes of components X and Y.

The AE-index was introduced by Davis and Sugiura in 1966 to measure global electrojets activity in the auroral zone. The AE-index derives from the horizontal component of geomagnetic variations observed at 12 observatories along the auroral zone (geomagnetic latitudes 60°-71°). Table 1 shows a list of these observatories.

Table 1

List of AE index observatories

No	Observatory	Geographical coordinates		Geomagnetic coordinates	
		φ	λ	Φ	Λ
1	Cape Chelyuskin	77.43	104.17	66.4	177.2
2	Dixon Island	73.32	080.33	63.1	162.3
3	Tixie Bay	71.35	129.00	60.7	192.4
4	Barrow	71.18	156.45	68.8	242.6
5	Abisko	68.21	018.49	65.8	115.7
6	Cape Wellen	66.10	180.50	62.1	238.5
7	College	64.51	147.52	65.0	258.1
8	Baker Lake	64.20	096.02	73.8	317.7
9	Reykjavik	64.11	021.41	80.9	072.2
10	Narsarsuaq	61.10	314.80	70.8	038.7
11	Fort Churchill	58.44	096.15	68.7	325.0
12	Sitka	57.03	135.20	60.2	277.1

The AE-indices allow to evaluate the values of energy injected from solar wind into the magnetosphere (Spiro *et al*. 1982, Feldstein 1992). The AE-indices have very essential drawback. They are underestimated during magnetic storms. It is so because the auroral electrojets (both westward and eastward) shift to the sub-auroral latitudes (Feldstein *et al*. 1999).

Figure 1 shows the position of the auroral westward electrojet during the magnetic storm at different universal times. The horizontal axis is the geomagnetic latitude and the vertical axis is disturbance of horizontal and vertical components. Position of electrojet is above the observatory where ΔX is maximal, and ΔZ is zero. One may see that the position of electrojet changes from latitude 65° to 56°.

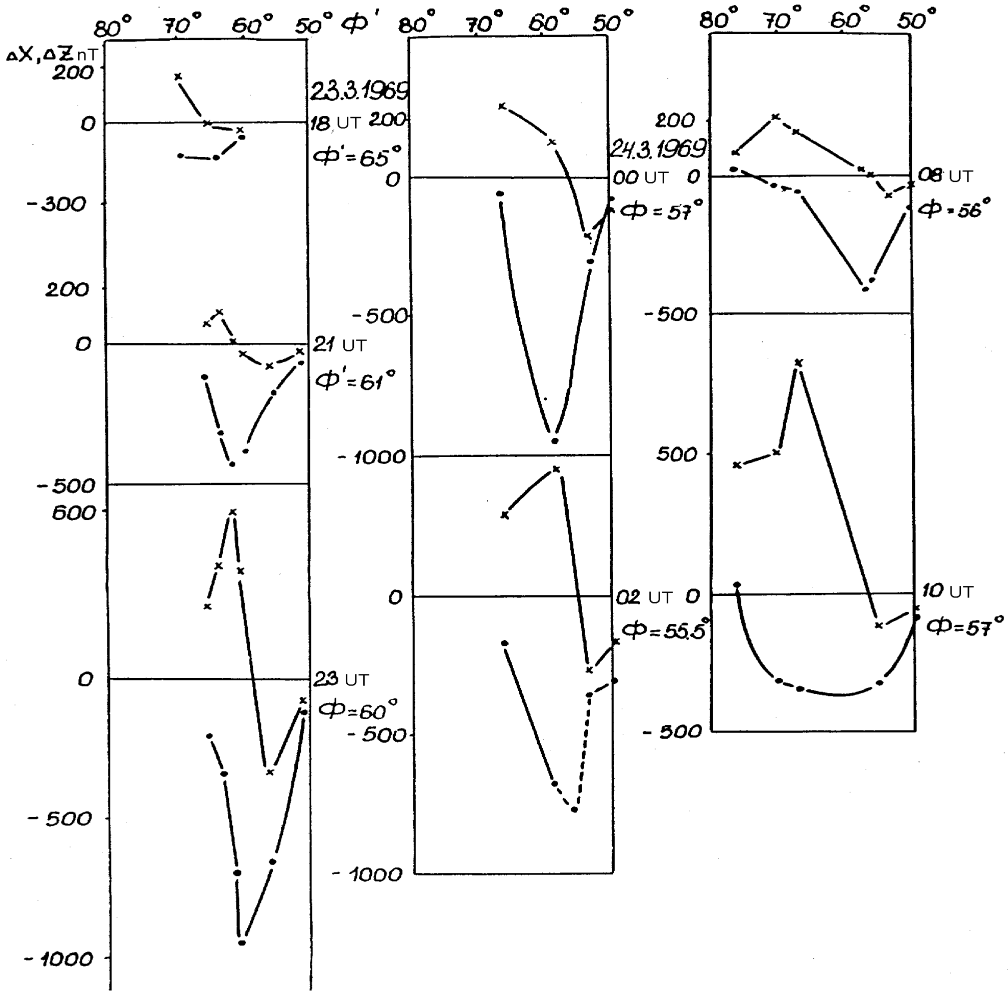

Fig. 1. Position of the auroral westward electrojet during the magnetic storm.

Thus, the chain auroral zone magnetic observatories do not register the maximal variations created by auroral electrojets. It is necessary to use data of sub-auroral observatories to correct AE. Figure 2 shows the understated AE and corrected AE′ for 22-23 March 1969 magnetic storm (the corrected AE′ are marked by the dotted line). To correct AE it is necessary to use data of sub-auroral observatories. Table 2 shows the list of these observatories. Correction of AE is a difficult job.

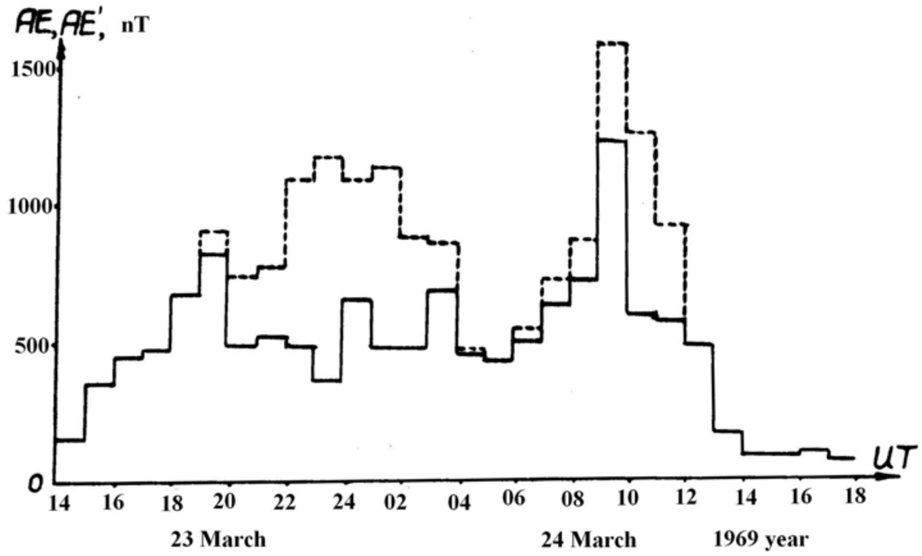

Fig. 2. Underestimated AE (solid line) and corrected AE′ (dotted line) during magnetic storm.

Table 2

List of AE′ index observatories

No	Observatory	Geographical coordinates		Geomagnetic coordinates	
		φ	λ	Φ	Λ
1	Cape Chelyuskin	77.43	104.17	66.4	177.2
2	Dixon Island	73.32	080.33	63.1	162.3
3	Tixie Bay	71.35	129.00	60.7	192.4
4	Barrow	71.18	156.45	68.8	242.6
5	Abisko	68.21	018.49	65.8	115.7
6	Cape Wellen	66.10	180.50	62.1	238.5
7	College	64.51	147.52	65.0	258.1
8	Baker Lake	64.20	096.02	73.8	317.7
9	Reykjavik	64.11	021.41	80.9	072.2
10	Narsarsuaq	61.10	314.80	70.8	038.7
11	Fort Churchill	58.44	096.15	68.7	325.0
12	Sitka	57.03	135.20	60.2	277.1
13	Yakutsk	62.01	129.40	51.2	194.9

Table 2 (continuation)

No	Observatory	Geographical coordinates		Geomagnetic coordinates	
		φ	λ	Φ	Λ
14	Nurmijarvi	60.30	024.39	57.7	113.5
15	Lerwick	60.08	001.11	62.2	089.6
16	Meanook	54.37	113.20	62.0	303.0
17	Ottawa	45.24	075.45	56.7	353.4
18	Agincourt	43.47	079.16	55.0	348.8
19	St. Johns	47.36	052.41	58.2	023.0

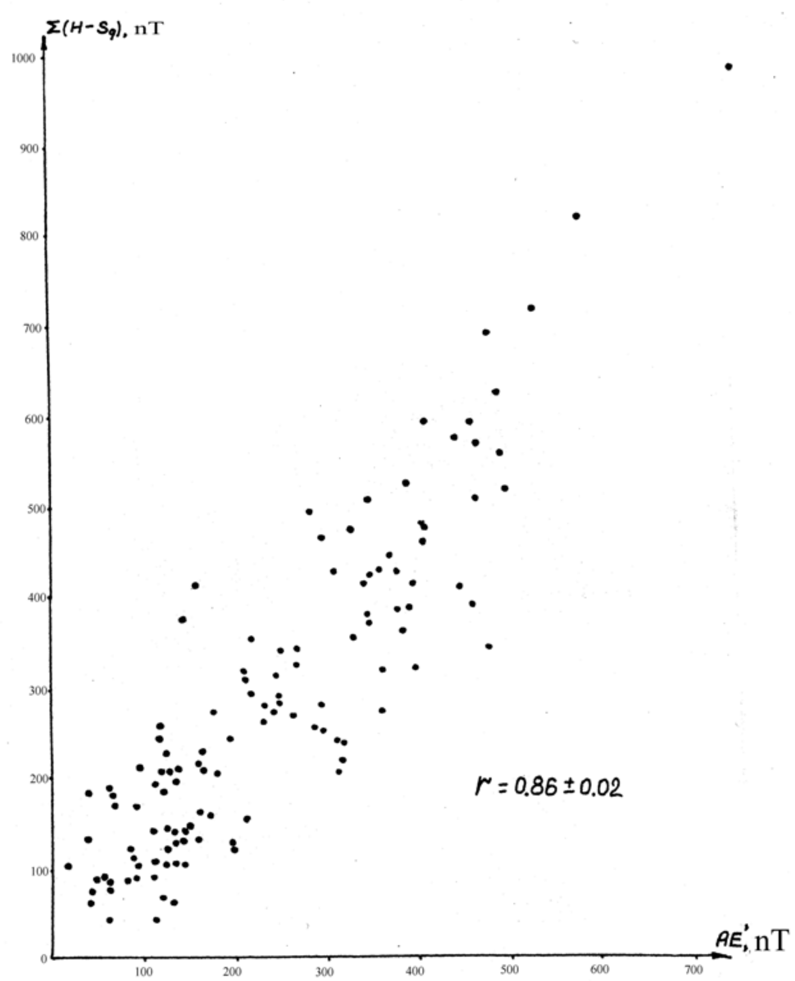

Fig. 3. Correlation between $\Sigma(H{-}S_q)$ and AE′ for 1980 at the magnetic observatory Lviv.

We propose a new index $\Sigma(H-S_q)$, i.e., a daily sum of differences between the mean hourly values of horizontal component at middle latitude observatory and the corresponding mean month values of the same component on five international quiet days of the preceding month. Coefficients of correlation between these values and corrected AE-indexes are high for disturbed and quiet time intervals.

The correlation coefficient is 0.86 and its dispersion is 0.02 (see Fig. 3). That is to say that the dependence is almost functional. Figure 3 shows dependence of $\Sigma(H-S_q)$ at the Lviv Magnetic Observatory on corrected AE′ index for 1980 year of high solar activity.

Thus, it is possible to use $\Sigma(H-S_q)$ as a geomagnetic activity index. The advantage of the index is that it may be calculated immediately. It may be used to evaluate the quantity of energy injected into the magnetosphere. The drawback of our index is that it has only daily interval values. The proposed index may be operatively calculated on the data of any middle latitude observatory.

Conclusions

A new geomagnetic activity index $\Sigma(H-S_q)$, is presented. The index is a daily sum of differences between the mean hourly values of horizontal component at middle latitude observatory and the corresponding mean monthly values of the same component on five international quiet days of the preceding month.

The index has only day interval time values. The correlation between $\Sigma(H-S_q)$ and corrected AE′ indices is high.

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