

Experience with New Geomagnetic Activity Index E Based on Power Spectra

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Abstract

Properties of classical magnetic activity indices K and new indices E based on power spectra are described. Relation between the two indices and magnetic activity is discussed. A comparison of correlation of planetary indices Ep and Kp with solar wind parameters is made.

Key words: geomagnetic activity, geomagnetic indices.

1. Introduction

The magnetic activity indices are used to characterize the magnetic activity in local, regional and global scales. The most widely used measure of magnetic activity is the 10-digit K scale. The K index was designed by Bartels *et al.* (1939). The K index determination consists in finding the maximum amplitude of irregular changes of horizontal components X(H) or Y(D) of geomagnetic field variations in the three-hour time interval and in ascribing to these amplitudes an integer between 0 and 9. The K index is a local index, characterizing the field activity in a specified place. In order to describe the state of activity of the whole Earth, there were introduced planetary indices Kp. The Kp index is an arithmetic mean of standardized indices Ks from the selected thirteen observatories in middle geomagnetic latitudes. The Kp indices provide information on global energy supplied to the magnetosphere (Menvielle *et al.* 1991)

The K indices have many advantages and therefore are widely used. First of all, they can be very easily determined from analog recording that is still in use in some observatories. However, they also have very serious drawbacks, the major being the following:

1. The K index is determined from the maximum amplitude of one component, which is not precise, since the K index depends not only on amplitude of irregular variations but also on polarization direction. The K index determined from components X and Y may differ from that determined from H and D.
2. The K index does not depend on the number of occurrences of irregular disturbances in the three-hour interval. The K index is the same if the disturbance of a certain amplitude occurred once or more often.
3. The K index is determined from the maximum amplitude of irregular variations of just one horizontal component. When, for instance, $K_x = 3$ and $K_y = 0$, the K index will be the same as for $K_x = 3$ and $K_y = 3$.

It seems that the main idea of those who invented the K-indices was the simplicity of determination. The physical sense of the definition was taken into account to a lesser extent.

2. The E Index Based on Power Spectra

Because of various shortcomings of the K-indices, postulates for developing new indices, whose physical meaning would be more fit to the present knowledge of the mechanisms that produce magnetic disturbances, have already been put forward in the past (Pirjola *et al.* 1991). Even earlier, Lanzerotti and Surkan (1974) had proven that there exists a statistical dependence between the K indices and the power spectrum of irregular magnetic variations. They also stated that further exploration of the possible use of an index based on the actual geomagnetic power seems to be required.

Reda and Jankowski (2004) proposed a definition of a new index E, based on the calculation of energy contained in irregular variations of the horizontal geomagnetic field components. The definition is the following:

The E index is a digit from the interval 0-9 proportional to the logarithm of energy of two horizontal components variations in the interval of 3 hr. The number is normalized so that the observatories situated in moderate geomagnetic latitudes have similar activity indices and the new indices are similar to the K indices.

The E indices, like the K indices, can be calculated by a computer from the digital recording of a given observatory. The first step in the E index determination procedure is to eliminate the regular variations S_R . For this purpose, the adaptive smoothing method (ASm) (Nowożyński *et al.* 1991) was applied.

3. Relation of the E and K Indices to the Geomagnetic Activity

The E indices determined according to the above definition do not depend on the choice of components (X and Y or H and D). In both cases the indices are identical, since the energy used for the E index determination is calculated as a sum of energies of both horizontal components. As we know, the energy is additive, so the energy-derived indices must in both cases be the same. Needless to say, the geomagnetic energy is one, regardless of the choice of coordinate system in which the geomagnetic

field is observed. The definition of K indices contradicts this obvious fact, and the differences in magnetic indices determined in XY or HD systems may be considerable, notably in observatories in which the declination value is large (e.g., in excess of 10 deg).

At the beginning, the K indices were determined from three components, i.e., the vertical component Z was used too. Such an approach turned out to be improper since changes of this component, in particular at moderate geomagnetic latitudes, are mainly a result of induced electric currents flowing in upper layers of the Earth's crust. The error was corrected in 1963, when IAGA decided that the Z component should not be used for K index determination (IAGA Bulletin 19, 1963, p. 359, resolution 4). In practice, this change does not much affected the K index determination since the irregular disturbances of the Z component are, as a rule, much smaller than the horizontal component disturbances.

The notion of magnetic activity is a collective notion, referring to many geomagnetic phenomena. Therefore, it should take into account various phenomena to a possibly equal degree (Kraiński 1968). It is worth to realize that the K index somewhat discriminates in favor of bay-type disturbances. Such disturbances attain large amplitudes and therefore bring the main contribution to the K index estimation, while the Pc3, Pc4 and Pi pulsations have small amplitudes and their share in the K index determination is almost negligible. Instead, the E indices take into account not only the large-amplitude disturbances, but all disturbances whatsoever, since these indices are calculated on the basis of the energy of all irregular variations.

The procedure proposed by Reda and Jankowski (2004) for calibration of the E indices on the basis of the K indices makes it possible to treat the former as a continuation of the latter. The differences between the K and E indices were shown to be not large (only in about 0.1% of cases did they exceed 1), but clearly noticeable.

In the above paper it was also demonstrated, on the basis of ample statistical material, that the E indices for a given observatory better correlate with the solar wind parameters than the classical K indices. The analysis concerned the following parameters: (a) vertical component B_z, i.e., the component Z of the interplanetary magnetic field (IMF) in the geocentric solar magnetospheric coordinates, (b) plasma temperature T_p, and (c) solar wind speed V. However, scientists and people solving practical tasks prefer to use the planetary index K_p. Therefore, of utmost interest was to examine whether the E indices derived from the E indices would better correlate with the solar wind parameters than the K_p indices. Such an analysis is one of the objectives of the present study. Prior to statistical analyses, we converted the K_p and E_p indices to the equivalent amplitudes a_K expressed in nanoteslas. Such an approach is justified by the fact that the K_p and E_p indices are just the codes (Mayaud 1980). An analysis was made for the whole year 1999 except of the periods when the E_p indices could not be calculated because of gaps of data in some observatories or the lack of magnetospheric indices B_z, T_p or V. The planetary indices E_p were calculated from data of the same 13 observatories whose data were used to calculate the planetary indices K_p. For the needs of the present study, the E_p indices were calculated in a simplified manner, omitting the stage of E index standardization; while in the case of

the Kp indices calculation the standardization was applied. The correlation analysis was made in two variants:

- (a) for cases when the Kp indices differed from the Ep indices; the results are shown in Fig. 1
- (b) and for all cases ($K_p = E_p$ and $K_p > E_p$) ; the results are in Fig. 2.

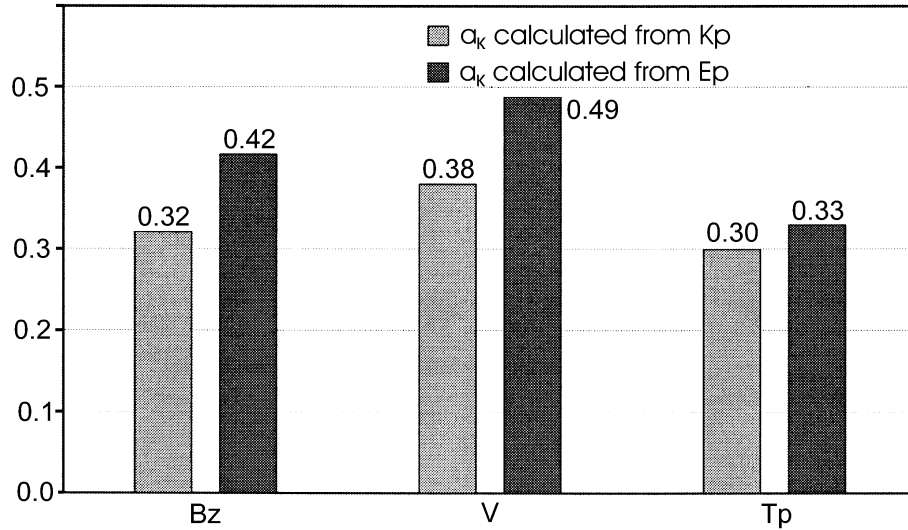


Fig. 1. Correlations of the Kp and Ep indices with the solar wind parameters for cases when $K_p > E_p$.

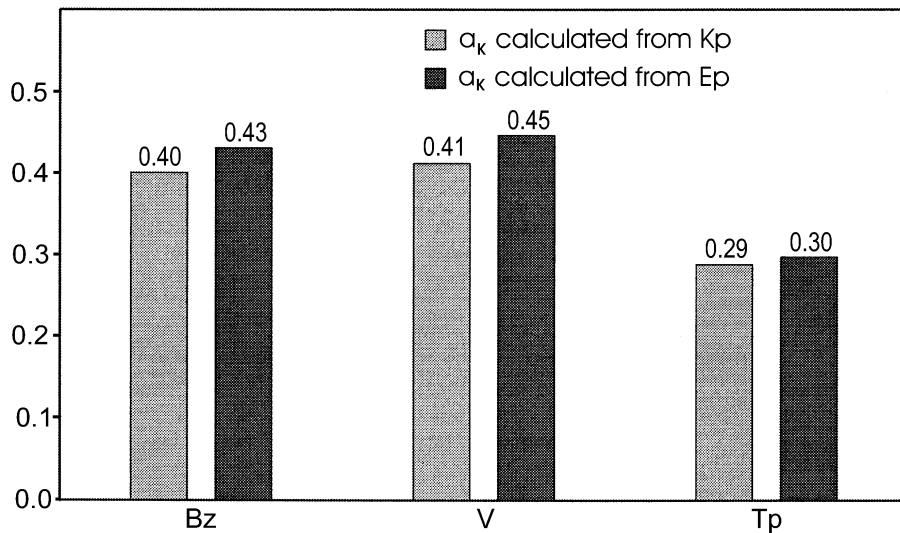


Fig. 2. Correlations of Kp and Ep with the solar wind parameters for all cases ($K_p = E_p$ and $K_p > E_p$).

We see from the above figures that the E_p indices correlate with the solar wind parameters better than the K_p indices. An improvement of correlation is more distinctive than that reported by Reda and Jankowski (2004) for a single observatory. For parameters B_z , V and T_p , the improvement of correlation for the calculations according to the second variant (e.g., for all the cases) is 8%, 9% and 3.5%, respectively.

4. Fourier Analysis of K and E Indices

The Fourier analysis is a method widely applied in different fields of science. In the present work, it has been used to investigate phenomena of periodic occurrence in geomagnetic activity. To compare the spectral characteristics of K indices with those of newly proposed E indices, there has been carried out a Fourier analysis of amplitude equivalents of both types of indices. For this comparison, there has been selected a 10-years-long period from 1 January 1990 until 31 December 1999 from Belsk data. The results are presented in Figs. 3 and 4. This analysis allows to state that the spectra in both cases are almost identical. This means, amongst other things, that the new E indices are just as sensitive to periodic phenomena of geomagnetic activity as the K indices are. Hence also from this point of view it follows that the E indices can be regarded as a continuation of the actually applied K indices.

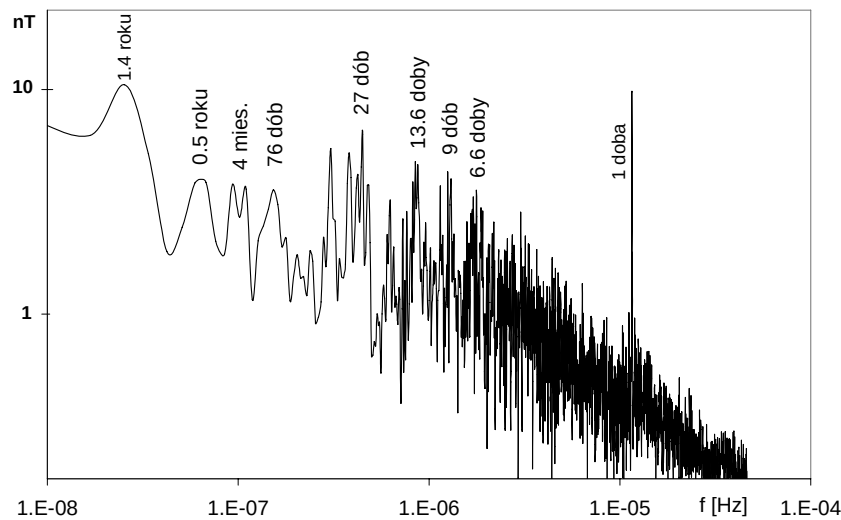


Fig. 3. Spectrum of amplitude equivalents of K indices from Belsk for 1990-1999; indices calculated with the ASm method.

5. Conclusions

The main advantage of the E indices is the fact that they are calculated on the basis of energy contained in irregular geomagnetic field variations. Therefore, the planetary indices E_p calculated from them better correlate with solar wind parameters B_z , V and T_p than the K_p indices. This is in accordance with expectations since it is the solar

wind energy transfer to the magnetosphere that decides upon the intensity of irregular variations observed at the Earth's surface. Furthermore, the E indices can be regarded as a continuation of the actually applied K indices from a spectral analysis point of view as well.

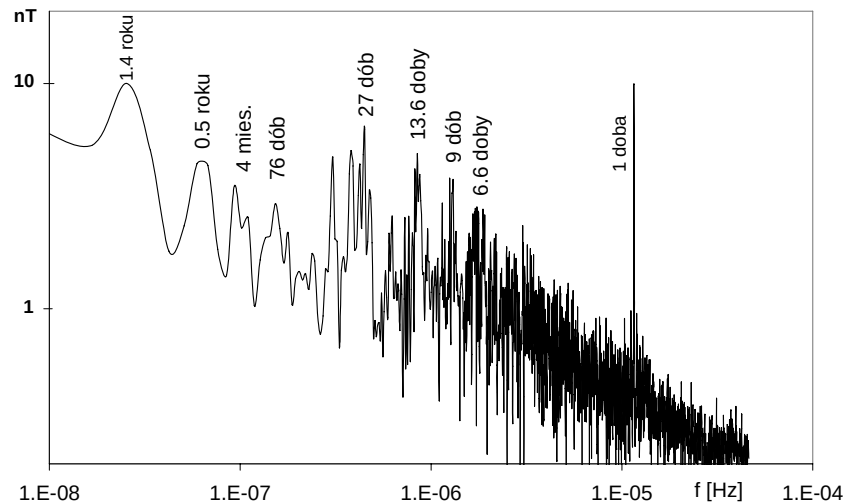


Fig. 4. Spectrum of amplitude equivalents of E indices from Belsk for 1990-1999.

Acknowledgments. The geomagnetic data from the Canberra, Lerwick, Wingst and Belsk observatories were taken from the CD-ROM 1999 issued by Inter-magnet. The magnetospheric data were taken from the http Server NSSDC (National Space Science Data Center, <ftp://nssdcftp.gsfc.nasa.gov/spacecraft/data/omni/>).

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