PUBLS. INST. GEOPHYS. POL. ACAD. SC., C-99 (398), 2007

Long-Term Variation of the Geoelectric Activity Index T

Árpád KIS, András KOPPÁN, István LEMPERGER, Tímea PRODÁN,
Judit SZENDRŐI, József VERŐ and Viktor WESZTERGOM

Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences
9400 Sopron, Csatkai u. 6-8. Hungary
e-mails: lempi@ggki.hu; wv@ggki.hu

Abstract

We study the long-time behavior and variability of the Earth geomagnetic activity based on the uniquely long geoelectric field observations recorded at the Nagycenk Geophysical Observatory for the past five decades. According to our results there is no clear correlation between the solar activity (expressed in sunspot number) and the daily T index. On the other hand, we found an almost linear relation between the Ap and T indices.

1. Introduction

From the ground based magnetometer measurements, different activity indices are obtained. Some of them cover many solar cycles: The K index was introduced by Bartels in 1939, the Ap index is available since 1932. In the middle of 1800's Rudolph Wolf devised a daily method of estimating the solar activity by counting the number of individual sunspots and groups of spots on the solar disk. Geomagnetic activity is generated by the interaction between the solar wind and the magnetosphere. Many features of the geomagnetic and solar activity have been discovered by spectral and statistical analysis of the uninterrupted time series of indices. Besides the well known 11 year and annual cycle and the coronal holes related 27 days recurrence period, a 13.5 day period was found recently. The semi-annual and annual variabilities are related to the tilt of the Earth's orbit to the Sun's rotation axis. The 11 year variability of the geomagnetic activity is more or less correlated with the solar activity cycles, but in the geomagnetic activity three major peaks appear according to the dominance of different sources (solar eruptions and coronal holes). The largest one occurs 2-3 years after the solar maximum (Vennerstrom and Friis-Chistensen 1996).

The Nagycenk Observatory (IAGA code: NCK, L = 1.9, $\varphi = 47°38'$, $\lambda = 16°43'$, altitude = 153.70 m) has been providing a special activity index called T, hand-scaled from continuous telluric (geoelectric) recording. The telluric field is generated by the time variation of the geomagnetic field (curl $\mathbf{E} = - \partial B/\partial t$), therefore T characterises the higher frequencies in comparison with the magnetic range indices (since $\mathbf{E}$ is proportional to the angular frequency of the geomagnetic variation). Statistical analysis of T confirms the main characteristics of geomagnetic activity known from numerous former studies (e.g. Schreiber 1998), but slight differences are found due to the dominating higher frequency variations like giant pulsations.

2. T Index Data Series at Nagycenk Geophysical Observatory

The high time resolution Earth current measurements started in 1957 at the Nagycenk Geophysical Observatory (NGO). From the beginning it was decided to focus on certain spectral indices from the records, like the hourly averaged amplitude in the time periods of 0-2, 2-6, 6-12, 12-24, and 24-60 minutes and the value of the T index. The 3 hour T index is scaled from 0 to 9 characterizing the geoelectric activity during 3 hour intervals corresponding to the largest range covered by the variation of Ex and Ey. The (daily) T index is the sum of the corresponding three hour T index values. The ten classes of the range are scaled with a linear step of 1.8 mV/km. Before the digital recording, i.e from 1957 to the early nineties, the data series of the T index were obtained from the so-called normal run Earth current recordings (25 mm/hour). To ensure continuous digital data for almost five decades, the earlier data has been carefully transformed to digital format by hand. This way we obtained a uniform (digital) data series for the past 48 years. The daily variations were eliminated from the T indices for the whole available time period. A 3-hour interval proved to be adequate to indicate any geomagnetic transient event and to provide a suitable time resolution as well.

Like any other geoelectric and geomagnetic indices, the T index also has its limitations. The activity level is strongly affected by the local time, by the geomagnetic latitude and by the local geological structure (i.e., the spatial distribution of the conductivity); the latter can strongly influence the electric field. From the point of view of the geological structure, the location of the observatory is optimal. According to earlier investigations (Ádám and Verő 1967, 1981), the observatory lies on the slope of a local crystalline basement. The thickness of the conductive sediment is about 1500 m. This fact implies that the periods of the variations shorter than 8 min lie in the magnetotelluric (MT) S-interval, i.e. in the increasing branch of MT sounding curves, which represent the high-resistivity basement. This means that the phase shift between the electric and the magnetic field is close to zero and the surface impedance is nearly constant.

Corresponding to the outlined conditions, the magnetic and electric variations expressed in nT and mV/km, respectively, have the same numerical value during normal (i.e quiet) daily variations. The numerical values of electric variations are about 2-5 times larger than the corresponding magnetic ones in the period range of substorms and about 100 times larger in the scale frequency of pulsations. Slight anisotropy is caused by regional effects. The transfer function between the magnetic and electric field components is routinely determined in order to check the scale value of the measurements in the observatory.

The thick conductive sediment prevents the observation site from the man-made disturbances. In addition, the NGO is situated in a natural park, as far as possible from settlements. General analysis of the man-made ULF noise was carried out by Villante et al. (2004) at NGO and other observatories. From this analysis it was concluded that the man-made noise amplitude at NGO is orders of magnitude lower than the variations caused by natural effects, however the spectral analysis of long time data series might be influenced by working days of stronger effects and reduced weekend noise levels. To conclude, the T index determined from records at NGO is minimally distorted and it can be regarded as a valuable and representative indicator of geomagnetic induction.

Statistical and Spectral Analysis of the T Index

For some reasons the geoelectric field is seldom measured continuously and its nature is much less known than the characteristics of the geomagnetic field. However, this tendency is about to change. The knowledge of the long term characteristics of the geoelectric field is of increasing importance in several space weather applications, especially in geomagnetic risk assessments (see Boteler and Pirjola 1998, Pirjola and Viljanen 1998). This fact also increases the value of the T index data series.

In our study we present a statistical analysis of the T index for the recent 47 years and its correlation with solar activity and the Ap index.

Figure 1 presents, from top to bottom, the T index and the sunspot number versus time for the time period under investigation. Both the T index and the sunspot number data series were smoothed with a 1-year running average in order to filter out the high-frequency fluctuations and to be able to study the long-term variations. The sunspot number variation, which reflects the changes in solar activity, seems to have minimal effect on the T index variation, i.e on the geoelectric activity.

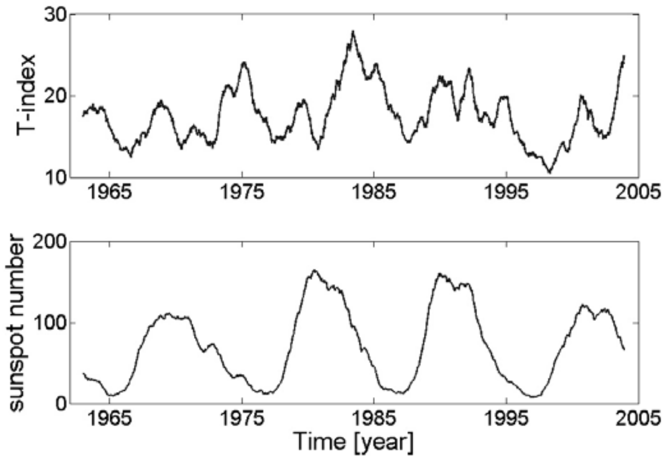

Fig. 1. Fifty years of T index (top) and sunspot number (bottom) data smoothed with one year running average.

Figure 2 presents the unbiased covariance value between the T index and the total sunspot number. As it can be seen, the unbiased covariance does not have a maximum value at year 0, instead it has a local maximum at ~2.7 years.

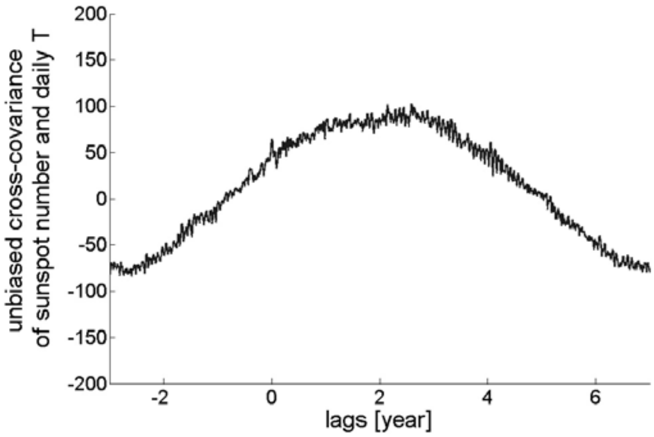

Fig. 2. Unbiased cross-covariance between sunspot number and T index.

Figure 3 presents the Ap index versus the T index. Both the Ap and the T indices were one year averaged. It can be seen that the Ap and the T indices are almost linearly correlated. This is clearly demonstrated on the upper panel of Fig. 4, where the unbiased covariance between the 27 day averaged T and the Ap indices is shown. The lower panel in Fig. 4 presents the T index versus the Ap index. The occurrence of high geomagnetic activity and its coincidence with a high value of the induced electric fields shows that the Ap and the T indices reflect essentially the same geoelectromagnetic activity. The almost linear relation between the Ap and the T indices suggests that the Ap indices can be calculated from the T indices. However, some differences might result between the observed and the calculated Ap indices, since the T index is influenced by the pulsation activity.

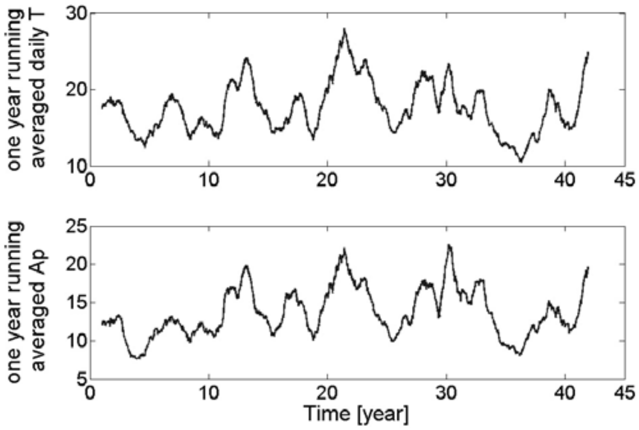

Fig. 3. One year running average smoothed T (top) and Ap (bottom) indices.

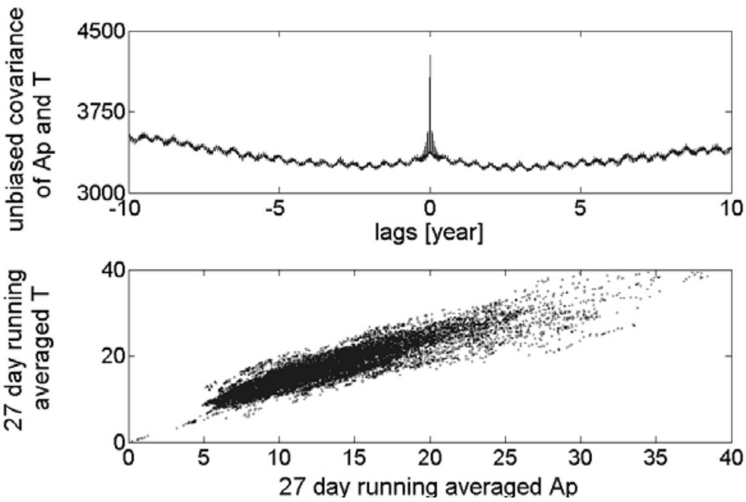

Fig. 4. Unbiased covariance of Ap and T indices (top), 27 day running average smoothed T versus Ap (bottom).

In order to study the average variation of the T index, we superposed and normalized the T index values for each year beginning with the year 1957 up to 2005. As it can be observed in Fig. 5, the yearly averaged T index presents two maxima during one year time period. This yearly average wave has a clear six-month periodicity. Both equinoctial maxima are roughly of the same level, however the summer values are slightly higher than the winter ones. This deeper winter activity in our opinion might be connected to the winter anomaly, which is a decrease of the pulsation activity in high solar activity years.

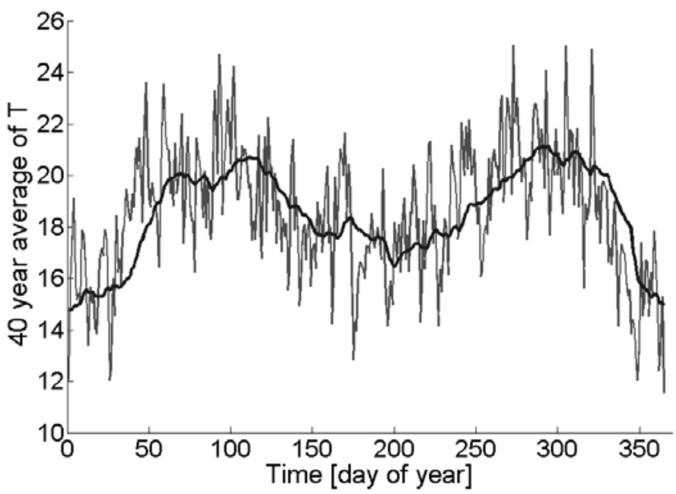

Fig. 5. Forty year average of daily T index at each day of year and its 27-day running average curve.

In the power spectrum of daily T sums shown in Fig. 6, a significant peak occurs at 11 years which can be related to the solar cycle. At shorter periods there is a lot of peaks between 1 and 11 years, possibly resulting from the irregular form of the solar cycle wave. The well known half-year wave of geoelectromagnetic activity is the strongest in its period range but there is also a yearly wave which can be due to a change in the direction of the geomagnetic disturbance vectors as the resistivity tensor of the Nagycenk Observatory is slightly elongated towards E-W (or ENE-WSW).

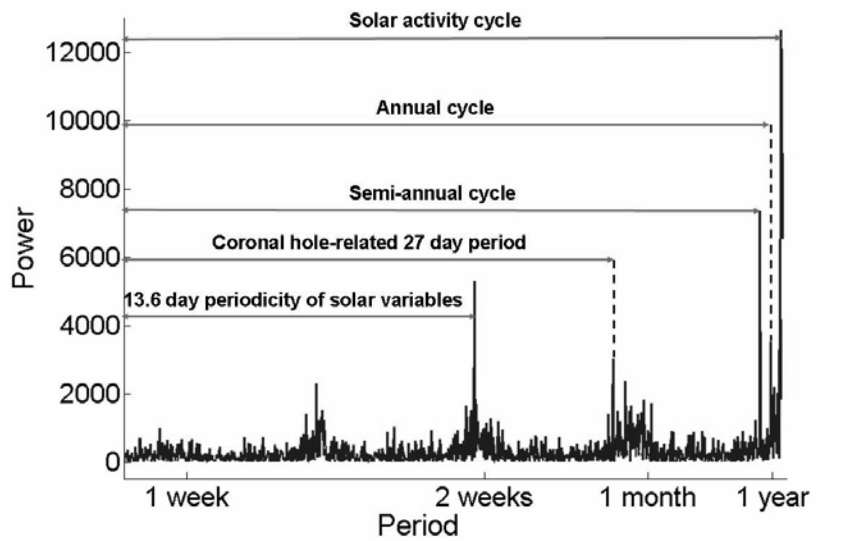

Fig. 6. The well known spectral peaks are indicated on the spectra of the T index. (The 11 year solar cycle is the outside right peak.)

The next higher frequency group of peaks belongs to the 27-day rotation of the Sun together with its second and third harmonics; moreover, a rather small peak at about 28 days might be due to the influence of the Moon. The 13.5 day quasi-periodicity peak also clearly appears on the spectra produced by two-stream structures (Mursula and Zieger 1996).

3. Conclusions

Nearly fifty years long time series of the NCK observatory is a representative, homogeneous and unique data set for statistical analysis of the long-term variation of the geomagnetic induction effect.

The present study compared the earth-current (telluric) activity index T with sun-spot number and geomagnetic Ap indices. The occurrence of high geomagnetically induced electric fields and their coincidence with the phases of solar activity is less clear than that of maximum magnetic activity but it was shown that Ap and T indices reflect essentially the same geoelectromagnetic activity which is, in turn, correlated with the sunspot number. As the weights of variations with different periods are rather different in geomagnetic and earth-current indices, there are also differences between the two kinds of activities. An attempt was made to identify such differences between the two time series and also in connection with solar activity time series. Several kinds of differences result from the influence of the pulsation activity on the T index. With the help of a polynomial connection between Kp and T indices, expected values can be computed from Kp for T. The difference of the observed and computed T indices may contain information about the effect of changing spectrum of geoelectromagnetic activity on these indices.

Several features of the geomagnetic activity have been confirmed and some further information has been obtained which we believe to be of importance.

References

Ádám, A., and J. Verő, 1967, *Latest results of electromagnetic measurements in Hungary* (in Hungarian), Geofizikai Közlemények **16**, 25-52.

Ádám, A., and J. Verő, 1981, *The geophysical observatory near Nagycenk, Electromagnetic measurements and processing of data*, Acta Geod., Geoph. Mont. Hung. **16**, 331-351.

Boteler, D.H., and R. Pirjola, 1998, *Modelling geomagnetically induced currents produced by realistic and uniform electric fields*, IEEE Trans. Power Delivery **13**, 17-27.

Mursula, K., and B. Zieger, 1996, *The 13.5-day periodicity in the Sun, solar wind, and geomagnetic activity: The last three solar cycles*, J. Geophys. Res. **101**, 27077-27090.

Pirjola, R., and A. Viljanen, 1998, *Complex image method for calculating electric and magnetic fields produced by an auroral electrojet of finite length*, Ann. Geophys. **16**, 1434-1444.

Schreiber, H., 1998, *On the periodic variations of geomagnetic activity indices Ap and ap*, Ann. Geophys. **16**, 510-517.

Vennerstrom, S.M., and E. Friis-Chistensen,1996, *Long term and solar cycle variation of the ring current*, J. Geophys. Res. **101**, 24727-24735.

Viljanen, A., H. Nevanlinna, K. Pajumpää and A. Pulkkinen, 2001, *Time derivative of the horizontal geomagnetic field as an indicator*, Ann. Geophys. **19**, 1107-1118.

Villante, U., M. Vellante, A. Piancatelli, A. Di Cienzo, T.L. Zhang, W. Magnes, V. Wesztergom and A. Meloni, 2004, *Some aspects of man made contamination on ULF measurements*, Ann. Geophys. **22**, 1335-1345.

Accepted February 26, 2007