VARIATION OF GEOMAGNETIC ACTIVITY — A STUDY BASED ON 50 YEARS TELLURIC OBSERVATIONS AT NAGYCENK OBSERVATORY

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Introduction

From the ground based magnetometer measurement different activity indices are obtained. Some of them cover many solar cycles: K index was introduced by Bartels in 1939, Ap index is available since 1932. Many features of the geomagnetic and solar activity have been discovered by spectral and statistical analysis of the uninterrupted time series of indices. Beside 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.

Nagycenk Observatory has been providing a special activity index called T 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 with 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.

T index data series

The high time resolution Earth current measurements started in 1957 at Nagycenk Geophysical Observatory (NGO). 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 a 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 3-hour interval proved to be an adequate indicator of geomagnetic transient events 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. According to the 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 value of electric variations are about 2–5 times larger than the corresponding magnetic ones during 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 preserves the observation site from the man-made disturbances. 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.

Analysis of the T index

Fore some reasons the geoelectric field is seldom measured continuously and its nature is much less known than the characteristics of the geomagnetic field. 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. 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.

Fig. 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. 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.

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 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

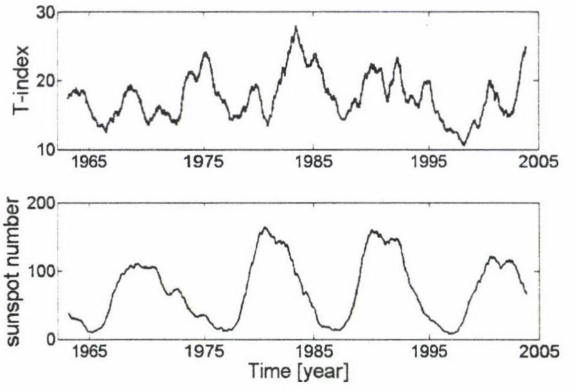

Fig. 1. Fifty years of T index (top) and sunspot number (bottom) data smoothed with one year running average are plotted

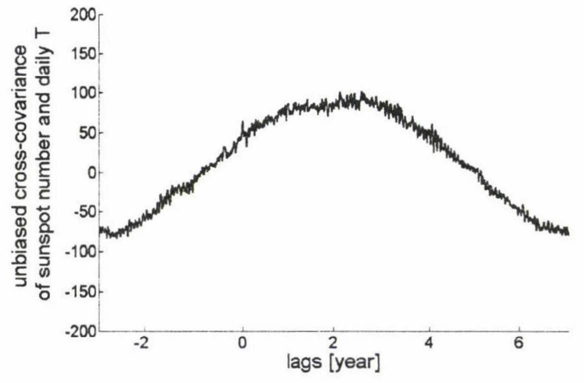

Fig. 2. Unbiased cross-covariance between sunspot number and T index

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.

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 maximums 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.

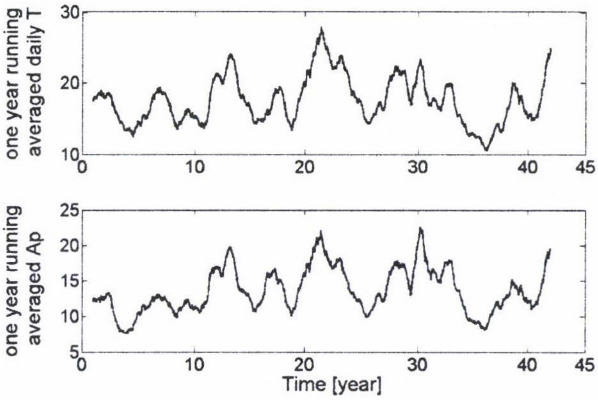

Fig. 3. One year running average smoothed T (top) and Ap (bottom) indices

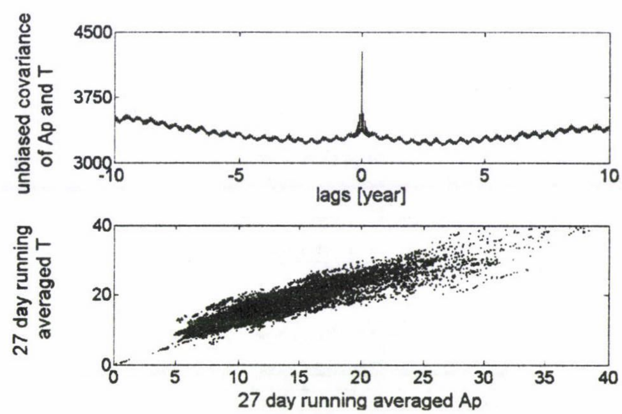

Fig. 4. Unbiased covariance of Ap and T indices (top), 27 day running average smoothed T versus Ap (bottom)

In the power spectrum of daily T sums shown Fig. 6 a significant peak occur 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 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).

The next higher frequency group of peaks belongs to the 27-day rotation of the Sun together with its second and third harmonics moreover as rather small peak at about 28 days might be due to the influence of the Moon. The 13.5 day

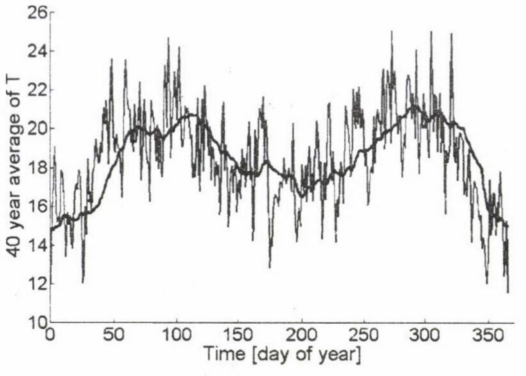

Fig. 5. Forty year average of daily T index at each day of year and its 27-day running average curve

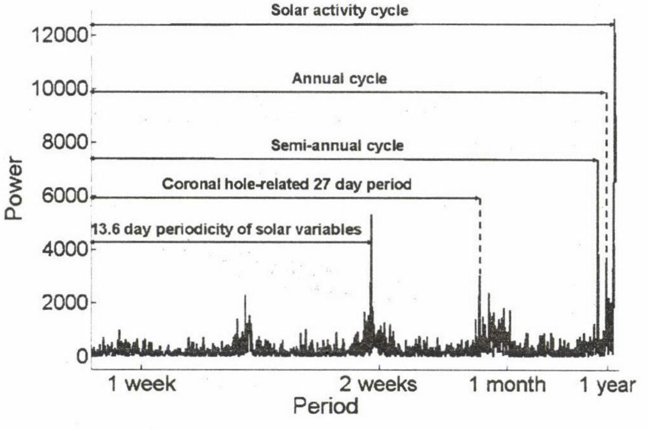

Fig. 6. The well known spectral peaks are indicated on the spectra of the T index. (The 11 year solar cycle is the outside right peak)

quasy- periodicity peak also clearly appears on the spectra produced by two-stream structures (Mursula and Zieger 1996).

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 earth-current (telluric) activity index T with sunspot number and geomagnetic Ap indices. 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 turn correlated with 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. It is tried to identify such differences between the two time series and also in the 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.

References

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

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

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

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

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

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