On the Long-Term Consistency of the Magnetic H Component and K Indices at the Swider and Niemegk Observatories (1921-1975)

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The recently digitized hourly geomagnetic data of the Polish station Swider (geographical coordinates: $52^0 7'0$ N and $21^0 15'0$ E) for the whole interval of the registration (1921-1975) are compared with records of Niemegk and Rude Skov using the absolute values of the H component, Kp index and the local K and IHV indices derived from this component. Data of other stations as Wingst, Lovö, and Honolulu are also quoted. We apply the correlative analysis and the wavelet technique with establishing of the significance levels of the resultant power spectra. Generally our analysis of the H absolute values and IHV indices shows the good quality of the Swider H component registration that agrees with the results of other stations at that time. A small inconsistency in the registrations during 1927-1928 and 1933 should be corrected. The local K indices at Swider observatory should be recalculated in the periods 1940-1956.5 and 1964.3-1970. The long-time Potsdam/Seddin/Niemegk data set from the first half of 20th century collected in WDCs should be improved in order to resolve them to the same level of registration. The method of improvement is proposed.

Introduction

Nowadays old geomagnetic data sets from the time before the era of space flights are looked on with an increasing interest because of advanced discussions about past solar activity levels, climate changes and other different phenomena in our environment - the geosphere. Therefore an incorporation of every new geophysical data set from archive records to the electronic databases is very desirable.

Fig.1. Stanislaw Kalinowski

In this paper the recently digitized [1] H component of the geomagnetic field registered at Polish station Swider (SWI) [2, 3] during 55 years are examined and compared with records of Niemegk (NGK), Rude Skov (RSV) and other stations enumerated in Table 1. This observatory was established 25 km from Warsaw in 1910-1913 by Professor Stanislaw Kalinowski, a well known Polish magnetologist (see Fig.1). After his death in 1946 his daughter, Zofia Kalinowska took over the leadership of the observatory. The most part of station works and treatments of the records were done by both Kalinowski's daughters Zofia and Dr. Ewa Kalinowska-Widomska. Moreover, later they donated their freehold territory and buildings of the Swider station to the Geophysical Institute of Polish Academy of Sciences with a view to continuing scientific observations. The continuous registration was conducted since 1921 till 1975, with hourly tabular data of H, D, Z elements published till 1967 and 3-hour K indices calculated and published from 1937 till 1975 [3, 4]. Nowadays the atmospheric electric observatory is localized there. It belongs to the Institute.

The Eschenhagen-Schmidt variometers prepared by the company "O. Toepfel und Sohn" in Potsdam were the basic instruments for the horizontal component H and declination D of the geomagnetic field. The Z component was measured by Schmidt variometer constructed by the same company. They were used during the whole period of registration. The absolute measurement of the base-line was performed by means of Kew magnetometer No.169 produced in 1909 by Cambridge Scientific Instrument, and tested at Potsdam Observatory in 1910, Pavlovsk in 1912 and Seddin in 1930. Before 1950 these measurements were made every 2 weeks, since 1950 - once a week [5]. In fifties and sixties other magnetometers (Balance Magnetometer Zero (BMZ), Quartz Horizontal Magnetometers (QHM), Sartorius and Askania) were additionally used for base-line measurements to control the stability of the standard instrument levels [6]. More than ten direct comparisons of base-line levels were done between Swider and other European observatories. The first such measurement was performed by Dr. La Cour from Rude Skov in 1935 by QHM magnetometers. In fifties and sixties such comparisons were carried out between Swider and Niemegk, Krasna Pachra, Rude Skov, Prohunice and Hurbanovo (see [7-8] and references therein). These studies showed that the registration at Swider satisfied the standards adopted by the worldwide geomagnetic community. The errors of the hourly H and D means were estimated as 1 γ and 0.1', accordingly [6].

TABLE 1
List of stations used and sources of data

station	IAGA abbr.	geog. lat.	geog. long.	mag. lat. */	period of data using	Source of data
Swider	SWI	52.12	21.25	50.43	1921-75	[2-4]
Potsdam/ Seddin/ Niemegk	POT/ SED/ NGK	52.38 52.28 52.07	13.06 13.01 12.68	52.11 52.02 51.88	1900-07 1908-31 1932-45, 1946-80	[21]
Rude Skov	RSV	55.85	12.45	55.53	1927-80	[21]
Lovo	LOV	59.35	17.83	57.90	1957-61	[21]
Wingst	WNG	53.75	9.07	54.12	1939-67	[21]
Honolulu	HON	21.32	202.00	21.64	1926-28	[21]

*/ Magnetic latitudes calculated using the IGRF 2000 model.

During the difficult time of the Second World War, when Poland was occupied, the observatory continued working. The electrification in 1936 of the nearby railway line, at the nearest point only 1 km away from the observatory, was additional impediment to the station's operation during 1936-1975. Artificial disturbances became even stronger after the electrification of the next part of the railway line in 1958-1961 and impeded especially Z component observations. The magnetic effect of the electric trains to the station records was carefully studied by Kalinowski and his coworkers and consulted with La Cour from Rude Skov, where a similar situation occurred [9]. An additional geomagnetic station in Glinianka, 16 km away from Swider, was established and operated in the period 1949-1954, with the aim to better determine differences between disturbed and undisturbed records. The conclusion of these studies was following: hourly means of H and D components in data tables of Swider observatory "can be considered to be unaffected by additional errors due to artificial disturbances caused by the train traffic" [6, 10].

We pay special attention to Swider records in order to emphasize that the long effort of Kalinowski's group of investigators gave a significant contribution to our knowledge of the magnetic field and its changes at this part of European area. However, not all Polish scientists share this appreciation. Our paper is an answer to Jankowski's negative view about the quality of Swider records which was published without any statistical analysis or comparisons with other records [11].

The K index is a quasi-logarithmic local index, firstly introduced in 1938 by Bartels [12] for the Niemegk magnetic observatory. It consists of an integer 0-9 for each 3-hour interval of universal time (UT). Local disturbance levels have been determined by measuring the difference between the highest and lowest values during three-hourly time intervals of the H component after the S_q variation has been removed. The conversion of disturbances to K indices includes some subjectivity onto the results, making them dependent on the observer. We should note that observers change during the long operating period of the observatory. The planetary Kp index is a global 3-hour mid-latitude index computed from the local K indices of 13 stations between 44 and 60 degrees of northern and southern geomagnetic latitude. We note that only 5 observatories were continuously operating since the start of Kp indices in 1932, others have been replaced [13].

The recently introduced InterHour Variability Index (IHV) [14] has no such subjectivity. It is defined as the sum of the absolute differences of hourly means of the H component from one hour to the next over a six-hour interval near local midnight where the S_q variation is absent or minimal. According to the authors "the index is objective in the sense that it is derived from simple hourly averages without any problematic attempt to eliminate the variations not caused by the solar wind."

In the next sections we compare daily means of H component registered in SWI, NGK and RSV, the daily local K indices derived from SWI and NGK H components with planetary Kp indices, and then we use daily IHV indices calculated by us from the hourly means of H component at these three stations to test the quality of SWI and in some manner NGK registrations. We have chosen the registrations at Niemegk and Rude Skov as because these stations are located not far from Swider (about 600 and 1000 km) and the difference in geomagnetic latitudes between them is small (about 50). Two other components (D and Z) will be studied in a further paper.

Method of data analysis

We use the correlation analysis and additionally the wavelet technique which lets to estimate the coherence between analyzed data.

The magnitude-squared coherence between two time series x(t) and y(t) at the frequency ω is defined as

$$C_{xy}^2(\omega) = |P_{xy}(\omega)|^2 / P_{xx}(\omega)\, P_{yy}(\omega),$$

where t is time, P_{xx} and P_{yy} are power spectral densities of the series, P_{xy} is the cross spectral density between these time series [15].

The wavelet transform describes filtration of an analyzed signal x(t) using real or complex-valued function $\psi(t,a)$, which is defined as

$$Wx(t,a)=(1/a^{-0.5})!\psi^*(\tau-t)/a)\cdot x(\tau)d\tau,$$

where * denotes complex conjugate, variable a and τ are the dilation (frequency) and translation (position) scaling factors.

In the case of one-dimensional original signal, the continuous wavelet transform generates a two-dimensional picture of the wavelet power (scalogram): $S_x(t, a) = |W_x(t, a)|^2$ [16]. The cross wavelet transform of two time series x and y is defined [17] as

$$S_{xy}(t,a) = W_x(t,a)\, W_y(t,a)$$

and the wavelet coherence (WTC) of two signals or time series is defined [18] as

$$C_{xy}^2(t,a)=|A(a^{-1}S_{xy}(t,a))|^2/(A(a^{-1}|S_x(t,a)|)\cdot A(a^{-1}|S_y(t,a)|)),$$

where A is a smoothing operator along time axis and scale axis. It is a complex function and is resembled the formula for correlation coefficient, $0 \le C_{xy}^2(t,a) \le 1$. When coherence values for two time series are close to one it can be concluded that both data sets are very similar in a wide range of frequencies. In the paper we use the package prepared by Grinsted et al. [17, 18], which employs the Morlet wavelet in order to evaluate WTC of two data sets.

The treatment of data gaps

For calculation of correlation coefficients gaps are omitted. For estimations of WTC, as this method needs equally sampled data, the short gaps in records (several hours to 1 day) were filled by interpolation, the longer gaps (1-20 days) were filled by series of hourly means of H component registered at the station RSV after adjusting the absolute levels of RSV records to the NGK or SWI levels, and only if the mean differences of variances for the nearby time interval with existing records were less than 30% of the mean value. After filling gaps the IHV indices were calculated. The longer gaps of daily sum of K for NGK or SWI were filed by Kp values. Such procedure seems to be better then a simple interpolation because it preserves the variability of registration at the station. There were such cases of gaps when magnetic disturbances occurred just in the time interval corresponding to the data gap. The long period without registration at NGK 1 January 1945 – 28 February 1946 had been eliminated from calculations.

The correction to calculated IHV indices for the change of the daily curves during the solar cycles, as proposed by Mursula et al. [19], is fairly small for the considered mid-latitude stations, and is neglected in this paper.

Data used

Data used are enumerated in Table 1. Time series of Adolf Schmidt Geomagnetic Observatory Niemegk collected in WDCs [21, 22] are assembled from records of Potsdam (1890-1907) and Seddin (1908-1931) normalized to NGK, and NGK from 1932 till present. Unfortunately, this normalization was incorrect. So, there are sudden changes of the mean H level of about several tens of nT on the turn of years: 1904/1905, 1907/1908, 1931/1932, as well as between 1944 and 1946 (Fig. 2). They would disturb the coherence between NGK (NGKorg) and other station data, so, we have prepared improved set (NGKimp) by addition or subtracting of the values quoted in Table 2 and Fig. 2. The secular trend of NGK improved H component in the period 1921-1967 can by described by the 5th degree interpolation polynomial.

TABLE 2
Correction to hourly and daily data of Niemegk H component

No.	1	2	3	4
time period	1.01.1900 – 31.12.1904	1.01.1905 – 31.12.1907	1.01.1908 – 31.12.1931	1.01.1932 – 31.12.1944
correction	- 39 nT	+ 81 nT	+ 46 nT	- 35 nT

NGK data brought some troubles in such analyses because of systematic practice to shut operation for several days in the beginning of almost every year (5th or 6th – 10th January), which occur from 1911 to 1986 which produces an additional incorrect variation as the result of an analyzing procedure. The other difficulty is the long break in registration (1945 - February 1946). From this point of view RSV and SWI data are better (Table 3).

TABLE 3
Quality of collected H component data

station	period	gaps > 2d	baseline incorrectness
POT/SED/NGK	1900-1986	70	4
	1921-1967	43	
SWI	1921-1967	7	0
RSV	1927-1980	0	0

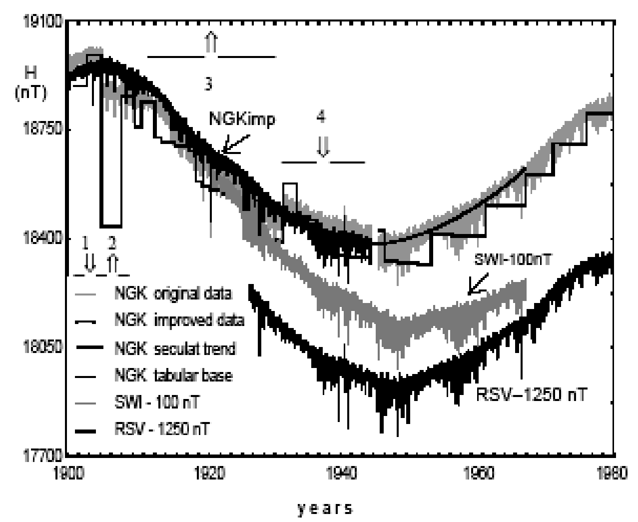

Fig. 2. Niemegk, Swider and Rude Skov daily means of H component. The improved data of NGK was prepared by changes of its registration basic levels in four time intervals indicated in Table 2 and on the picture (by subtracting or addition of the values quoted in Table 2). The original tabular bases of the NGK data are also presented. An idealized secular trend of NGK data was obtained by fitting the data by the 5th degree interpolation polynomial. For the clarity of the picture 100 nT was subtracted from the SWI records, 1250 nT was added to the RSV data.

Comparisons and conclusions

The course of the secular variation at an observatory and comparison with other observatories gives an idea of the registration stability of absolute measurements in a long time scale. It is seen from Figs. 2 and 3 that though the courses of secular variation somewhat differ in various observatories; the general trend in every mentioned station was similar.

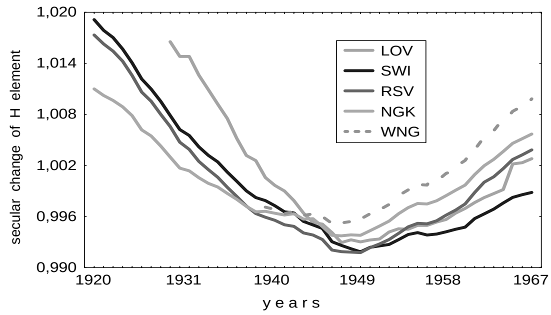

Fig. 3. Relative secular change of H component. Annual means have been divided by means of H component from whole showed period.

From direct comparisons of NGKimp, RSV and SWI H daily means by plots it has been seen that the coherence between these records in the whole studied period was good, except two short time intervals: 30 May – 9 July 1927 and 16 December 1927 till 25 March 1928 (Fig. 4). The level of registration at SWI was changed and some additional variations appeared.

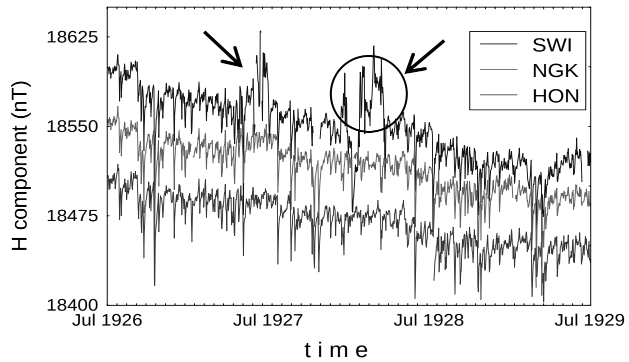

Fig. 4. Daily means of H component records at SWI, NGKorg and HON during period when the SWI time series and other data was not coherent. Arrows show supposed incorrect registration in SWI. For easy comparison data from Honolulu have been normalized to the mean level of 18480 nT.

As there were no similar changes at other stations we could assume that the effects at SWI were caused by incorrect registration or elaboration of records, and not by real geomagnetic changes. We find the reflection of these incorrect records in wavelet scalogram of IHV indices (Fig. 6, upper left) in the shape of the small area of incoherence. The next small area at this picture is caused by change of basic level of NGKorg data in 1931/1932.

Direct comparisons of NGKimp, SWI and RSV H components variability (Fig. 5 upper), correlation analysis (Table 4) and wavelet coherence of IHV indices show the good quality of the SWI and NGK data. NGKimp a few better correlates with other data than NGKorg.

TABLE 4
Correlation coefficients between daily and Bartels rotation means of K_p and K sums in NGK and SWI (1937-1975), and between daily and Bartels rotation means of absolute H component values and IHV indices in NGK, SWI, RSV (1921-1975), n number of values */

			Bartels rotation means		Daily means	
No	item	correlation	coef	n	coef	n
1	K	SWI-Kp	0.780	527	0.921	10847
2	K	NGK-Kp	0.939	513	0.969	15626
3	K	SWI-NGK	0.775	513	0.926	10481
4	H comp.	SWI-RSV	0.785	422	0.797	10847
5	H comp.	SWI-NGKimp	0.678	408	0.757	16248
6	H comp.	SWI-NGKorg	0.623	408	0.677	16248
7	H comp.	RSV-NGKimp	0.915	652	0.992	9732
8	H comp.	RSV-NGKorg	0.881	652	0.990	9732
9	IHV	SWI-RSV	0.917	422	0.893	10847
10	IHV	SWI-NGKimp	0.955	408	0.961	15932
11	IHV	RSV-NGKimp	0.919	652	0.918	9732

*/ All coefficients have a significance level $p < 0.01$.

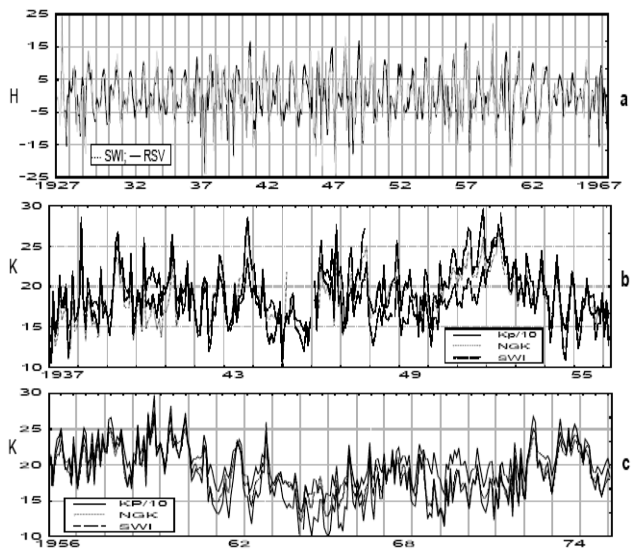

Fig. 5. Time variation of: (a) differences between Bartels rotation means of daily means of H component and secular trend determined as annual running means of this element data at SWI and RSV, (b, c) Bartels rotation means of daily Kp index divided by 10 and daily K indices at Swider (SWI) and Niemegk (NGK).

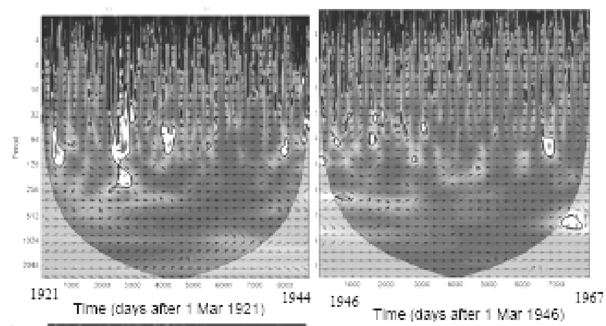

Fig. 6. Coherence between daily: IHV indices derived from original NGK data and SWI in the records in the period 1921-1967 (upper); K_p indices and sums of K at SWI (lower). Thick contours separate statistically significant regions (grey, dark grey) on the level of 95 % against red noise and designate cones of influence of edge effect. The relative phase relations between time series: arrows pointed right when time series are in-phase, pointed left in case anti-phase.

Notice the high correlation between NGK K local and Kp indices (Table 4 and Fig. 5). The general agreement of variations depicted by K indices derived from H component at NGK and SWI is noticeable. However, assuming that the level of Kp is correct, there are some periods where SWI K index was underestimated (October 1947-May 1952) or overestimated (February-September 1940, 1961-September 1962, 1965, 1969-1972). It is reflected in observed big areas of incoherent oscillations in the scalogram presented in Fig. 6 (down). Due to incorrect estimations of SWI K index the short term oscillations of this index better correlate with changes of

Kp and NGK K indices then Bartels averaged SWI K values (Table 4 and Fig. 6, down). Thus, the local K index at SWI should be recalculated in the periods 1940-1956.5 and 1964.3-1970.

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