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Geomagnetic Observations at Sodankylä During the First International Polar Year (1882-1883)

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Abstract

*Sodankylä was one of the 11 stations that were in operation during the First International Polar Year 1882-1883. In this study we re-analyze the magnetic observations carried out in Sodankylä. Observed were, on hourly basis, declination (*D*), horizontal (*H*) and vertical (*Z*) components of the geomagnetic field. There are available altogether 28512 magnetic observations for the period August 21, 1882 – August 31, 1883. The quality of magnetic observations of* D *and* H *is high but* Z *is less reliable. Local geomagnetic activity indices (*K, Ak*, and* SS*) were derived from the hourly values. A comparison between local daily indices (*Ak*) and global* aa *showed a high correlation (*r *= 0.88). Sodankylä Polar Year data is thus reliable and usable for studies of time variations of the geomagnetic activity. The Polar Year period was magnetically exceptionally disturbed. One of the greatest (eighth strongest according to the* aa*-statistics 1844-1998) magnetic storm occurred in November 1882.*

Key words: Geomagnetic observations

1. Introduction

In the early 19th century first magnetic observatories in the modern sense were established in several countries. The scientific impetus of founding such observatories was H.C. Örsted's (1777-1851) innovation (1820) of the physical connection between magnetic field and electric currents. This new concept was adopted to geomagnetism where Earth currents were assumed to be the cause of the regular diurnal variation of the geomagnetic field, hitherto an unexplained phenomenon. Because of the similarity between daily air temperature and diurnal magnetic variation curves, it was believed that the heat radiated from the Sun generates thermoelectric currents in the Earth that produce the observed smooth changes in the geomagnetic field. However, transient magnetic variations during geomagnetic storms, superposed to regular diurnal variation, could not be explained by Earth currents. In order to get more systematically geomagnetic variation data, especially from the northern latitudes, Gauss and Weber in Göttingen organised a world-wide co-ordinated observation programme of geomagnetic variations. This organisation was called “Der magnetische Verein” ("Göttingen Magnetic Union") and it was in operation from 1836-1841 during which some tens of geomagnetic observatories were running more or less continuously.

The International Polar Commission started an important international effort in geophysics during the Second Polar Conference held in Bern in 1880. It was decided to organize an extensive programme of co-ordinated geophysical observations in the northern and southern Polar Regions under the name "First International Polar Year". There were 11 participating countries and 13 observatories were set up from which two were located in the Southern Hemisphere.

The leading figure of the Finnish Polar Year activities was Selim Lemström (1838-1904) who was Professor of Physics at the University of Helsinki. His main interest in the Polar Year programme was studies on auroral lights, especially active experiments for producing artificial auroras. More details are given by *Simojoki* (1978) and *Holmberg* (1992). In Finland there was in operation a full-scale magnetic-meteorological observatory in Helsinki already since 1838. Geomagnetic observatory routines and other geophysical activities carried out at the observatory and in the university were at high level and it was thus natural that Finland was a participant in the Polar Year programme.

The motivation to choose Sodankylä (Lat. = 67° 25'N; Lon. = 29° 36'E) as one of the 11 stations was its geophysical suitable situation inside the Arctic Circle where occurrence of auroras and magnetic storms are frequent. Sodankylä was also in the north-south line of two northern Polar Year stations, namely Bossekop in Norway near the coast of Arctic Ocean, and the Swedish Polar Year site in Spitzbergen. The meteorological conditions in Sodankylä are continental whereas the climate in Bossekop and Spitzbergen is dominantly oceanic. It was thus expected that the planned meteorological observations would give interesting comparisons between these two types of climatological conditions.

According to the Polar Year's programme the geophysical phenomena to be observed were (*Lemström*, 1885):

- Geomagnetic variations (three components)
- Earth currents
- Atmospheric electricity
- Meteorological parameters

In addition, astronomical observations were needed for time determinations. The official Polar Year observation period lasted 13 months from August 1, 1882 to August 31, 1883 but at Sodankylä the observations started delayed on Aug 21, 1882.

The Polar Year programme was a big task for the Finnish scientific community but it also meant a new active and more international era in geophysics. The responsibility of the fulfilment of the programme was shared by the Finnish Society of Sciences, Central Meteorological Institute, and University of Helsinki. The project was financed by a state grant of 100 000 FIM (which corresponds to about 1,000,000 FIM or 200 000 USD in present day money) for the two year period 1882-1884. This allowance was divided so that Sodankylä observatory together with Kultala auxiliary station got 85 000 FIM and the Meteorological Institute in Helsinki 15 000 FIM.

Lemström and *Biese* (1887) have published the scientific results of the geophysical observations carried out at Sodankylä during the First Polar Year and its extension (1883-1884) in three vast volumes. Magnetic data collected from Polar Year stations, Sodankylä observatory included, increased much the knowledge of basic features of geomagnetic storm behaviour. It was found that magnetic storms begin nearly simultaneously all over the Earth, and that storm reduces the daily mean value of the horizontal intensity. Although magnetic results of Sodankylä Polar Year observatory has been already published quite thoroughly in form of tables and diagrams, the data is now available in electronic form (*Nevanlinna*, 1998) and can be used in various studies of geomagnetic field variations as will be demonstrated in this study.

2. *Magnetic observations at Sodankylä*

At Sodankylä observatory there were in operation two independent variometers recording variations in the horizontal (*H*), vertical (*Z*), and declination (*D*) components of the geomagnetic field vector (see Fig. 1). In addition absolute measurements were made on a regular basis several times per month. All observations were visual recordings aided with a telescope. Each component was observed according to the following scheme:

Component	**Time (*T*)**
H	*T* - 01m 30s
D	*T* - 01m 00s
Z	*T* - 00m 30s
	T
Z	*T* + 00m 30s
D	*T* + 01m 00s
H	*T* + 01m 30s

where *T* refers to the full hours 1 … 24 h. The time used in observations was Göttingen mean time which is 1h 6m ahead of the Universal Time (UT). The final adopted (and printed in the yearbook) value was the mean of the two values corrected by the temperature changes. On special days, the first and fifteenth of the month, observations were made every 5 minutes. These “terminal days” observations have not been included in this study. The magnetic data analyzed here were taken from the printed tables of the Polar Year yearbook (*Lemström* and *Biese*, 1887). The data is now completely in electronic form. The total number of observations is 9504 per component distributed over the time interval of 12 month and 9 days from August 21, 1882 to August 31, 1883.

Fig. 1. Observatory buildings of the Sodankylä Polar Year station. The hut in the front was the "absolute house" for determining the absolute level of variometer readings. The farthest building in the middle was a variometer hut for Lamont-variometers, and the hut in the right was for Wild-type magnetometers. Meteorological equipment was in the hut on the left.

Hourly values (24-hour running means) of *D*, *H* and *Z* are shown in Figs. 2, 3, and 4, respectively. Fig. 5 depicts daily activity indices *Ak* and *aa*. The former index was calculated from *H* and *D*-observations at Sodankylä applying the so-called FMI-method for determinations of three-hour *K*-values (*Sucksdorff et al.*, 1991). The activity indices as well as the hourly mean values for 1882-1883 can be obtained from the Internet address (ftp://geo.fmi.fi/pub/data/sodankyla_1882-83/) and in printed form in the publications series of the Sodankylä geophysical observatory (*Nevanlinna*, 1998). The *aa*-index is the global geomagnetic activity index by Mayaud (see *Menvielle and Berthelier*, 1991). *aa*-indices can be found through Internet (e.g. ftp.ngdc.noaa.gov /STP/SOLAR_DATA/ RELATED_INDICES/AA_INDEX/).

The polar year period 1882-1883 was very disturbed which is the reason why *H*- and *D*-curves in Figs. 1 and 2 show so many spikes. They are signatures of geomagnetic storms, not due to instrument failures. Sodankylä *Ak* and global *aa* activity index curves (Figs. 5 and 6) are similarly spiky.

One of the greatest magnetic storm since 1844 occurred during that period. This storm took place on November 15-25, 1882 and the highest daily value of *aa* was 305 (20th Nov) being the eighth highest recorded during the period 1868-1998. November 1882 was the most disturbed (as measured by the *aa*-index) month for 75 years and only three times since that the monthly *aa*-value has been greater. The storm period can be seen in Figs. 2 and 3 very clearly (days 319-329). The lowest *H* reading during the storm was 12 200 nT (mean value for the year was 13 340 nT). The corresponding values for *D* was - 6.8°E (mean *D* = - 1.5° E).

Fig. 2. Hourly values (running averages of 24 hours) of declination (*D*) recorded at the Sodankylä Polar Year observatory Aug 21, 1882 - Aug 31, 1883. Exceptional series of severe magnetic storms occurred during Nov 15 - 25, 1882. On the Nov 20, 1882 (day number 324) there was the eighth strongest magnetic storm recorded since 1868.

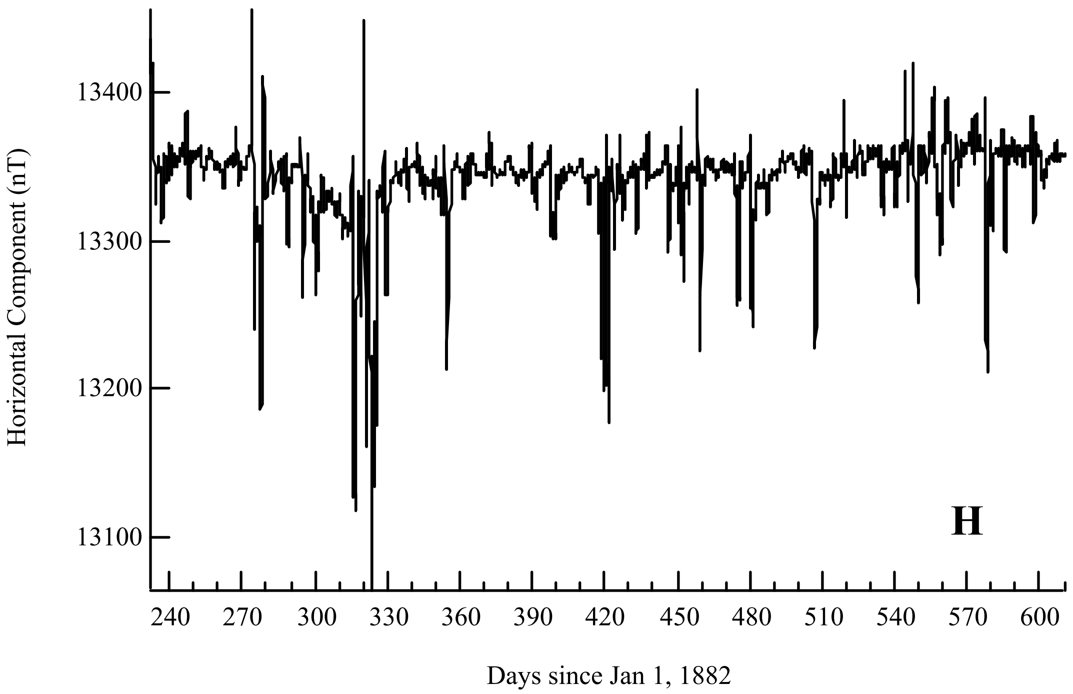

Fig. 3. Hourly values (running averages of 24 hours) of the horizontal component (*H*) recorded at the Sodankylä Polar Year observatory Aug 21, 1882 - Aug 31, 1883. Spikes with amplitudes up to several tens of nanoteslas are signatures of substorm activity.

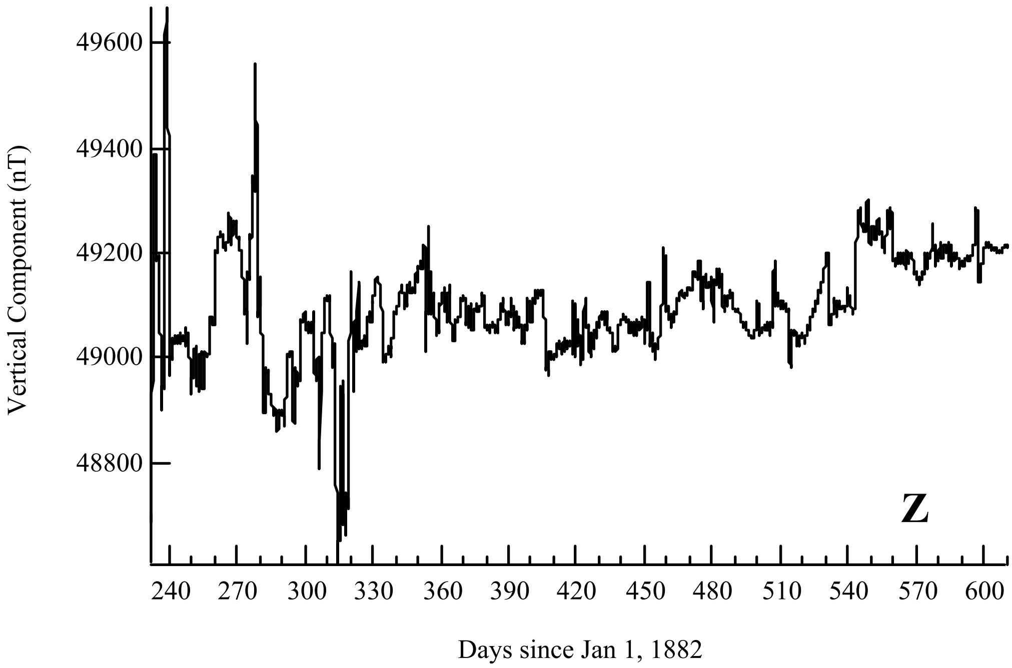

Fig. 4. Hourly values (running averages of 24 hours) of the vertical component (Z) recorded at the Sodankylä Polar Year observatory Aug 21, 1882 - Aug 31, 1883. Note the unstable character of Z variations, which is mostly due the calibration failure of the Z-variometer.

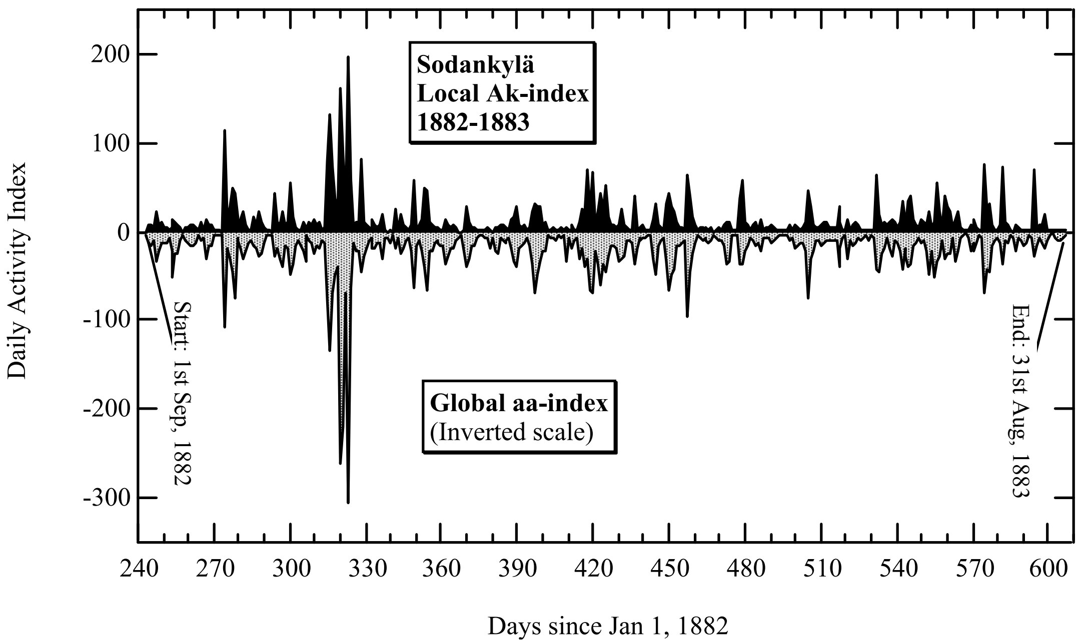

Fig. 5. Daily values of Sodankylä *Ak*-index and corresponding global index *aa* Sep 1, 1882 – Aug 31, 1883. For a better visual comparison of the two indices *aa*-values have been inverted to negative values and one can see how well the peaks in the activity curves correspond to each other.

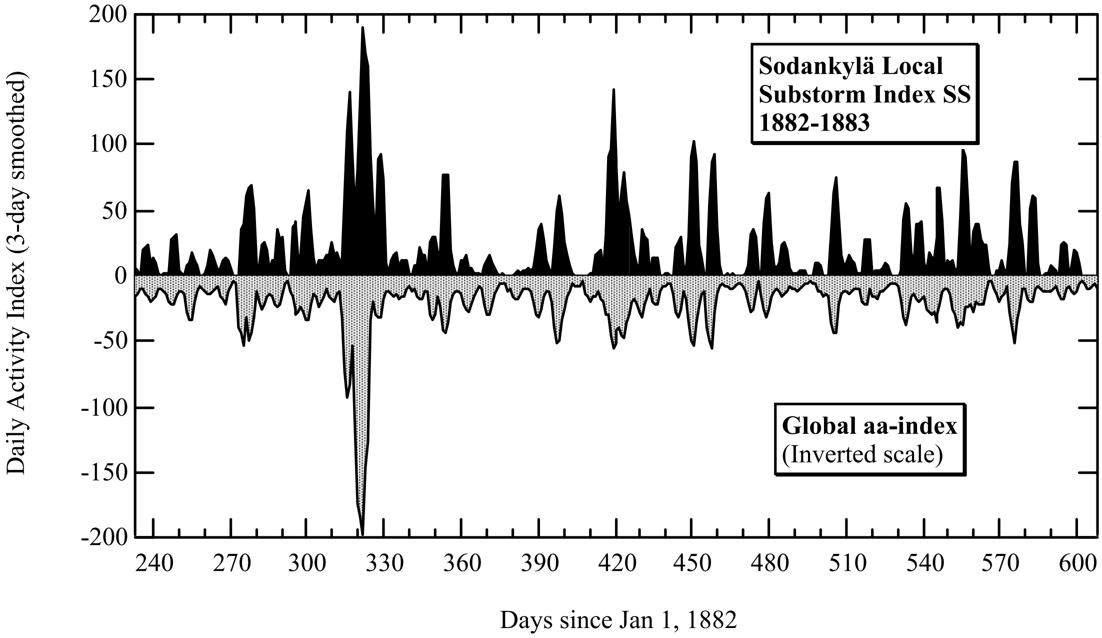

Fig. 6. Daily values (3-day smoothed) of substorm strength index (*SS* divided by the factor 5) and corresponding global-index *aa*. Note the great magnetic storms in November 1882 (day 320).

Due to the slow secular variation the present day values of *D* and *H* in the Sodankylä area are appreciably different from the Polar Year level. Declination has turned eastwards about 10° and the horizontal field has weakened more than 1000 nT during the 115 years elapsed since the First Polar Year until present.

The variometer for observations of the vertical field (*Z*) (Lloyd's pivoted *Z*-balance) has been rather unstable because *Z*-values change unrealistically rapidly during short time and are not well correlated with simultaneous changes in *D* and *H*. It is recommended not to use *Z* in scientific analysis.

Fig. 5 shows the daily values of the local *Ak*-index and the global *aa*-values. The correlation between the two indices is very high: the linear correlation coefficient is 0.88. *Ak*-values are systematically lower than daily *aa*'s which is due to the somewhat arbitrarily selected minimum *H*-range (550 nT) for the $K = 9$ disturbances. The linear relationship between daily *aa* and *Ak* is

$$aa = 6.1 + 1.14\, Ak$$

Another reason for differences between *Ak* and *aa* is naturally that Sodankylä is an auroral zone observatory but *aa* is based on magnetic variations at mid-latitudes from a different local time zone. However, for studies of geomagnetic activity it is perhaps more important that the time behaviour of different indices is mutually consistent as is the case with *aa* and *Ak* in Fig. 5.

Fig. 6 shows a comparison between the daily (3-day running mean) substorm strength index (*SS*) and the global *aa*-values. *SS* is essentially the product of the substorm duration in hours and the depth of substorm bay in nanoteslas (for further details, see *Nevanlinna* and *Pulkkinen*, 1998). One can see the high correlation between *SS* and *aa* during the great November storm in 1882. There have been many minor storms later that have been locally very strong (like in February 1883) having great *SS*-values but intermediate *aa*-values representing typical auroral zone substorm activity.

3. Conclusions

The hourly readings of *D*- and *H*-component of the geomagnetic field during the First International Polar Year at Sodankylä reveal reliably the basic features of time variations of transient geomagnetic variations. Variations of the *Z*-component are contaminated by artificial changes due to the unstable variometer calibrations. Comparison between local magnetic activity indices (*Ak* and *SS*) and global *aa*-values showed a good mutual correlation indicating that the Sodankylä Polar Year data is very suitable for studying geomagnetic activity in the time-scale of day or more.

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