Geophysica (1998), 34(1-2), 39-50

Oulujärvi Magnetic Station

K. Pajunpää[1], J. Kultima[2], P. Posio[1], J. Tiikkainen[3] and J. Yliniemi[4]

[1]Finnish Meteorological Institute, Nurmijärvi Geophysical Observatory, FIN-05100 Röykkä, Finland
[2]Sodankylä Geophysical Observatory, FIN-99600 Sodankylä, Finland
[3]University of Oulu, Institute of Geosciences and Astronomy, FIN-90570 Oulu, Finland
[4]University of Oulu, Geophysical Observatory, FIN-90570 Oulu, Finland

(Received: June 1996; Accepted: November 1996)

Abstract

A new permanent magnetometer station was founded in 1992 on the shore of the lake Oulujärvi in central Finland. The location is only few hundred kilometers south of the auroral zone so that the substorm current systems frequently extend over the site. The station was named Oulujärvi and it is a variation station for ionospheric and magnetospheric studies as part of the IMAGE magnetometer network and it is also stabile enough for secular variation recording over years and decades. The data quality is high and reliable results of the secular variation are obtained. Consequently, the Oulujärvi magnetic station could serve as a magnetic observatory. Comparison of Ak-indices between Oulujärvi, Nurmijärvi and Sodankylä is also presented.

Key words: magnetic observatory, magnetometer station

1. Introduction

The Oulujärvi magnetic station was established in 1992. There was a need to have a permanent magnetic station in the central Finland between the two magnetic observatories at Nurmijärvi and at Sodankylä (NUR and SOD in Fig. 1) described by *Sucksdorff* (1952a, 1952b), *Sucksdorff and Haikonen* (1958) and *Kataja* (1973). It fills the gap between the auroral Sodankylä and the mid-latitude Nurmijärvi which mostly observe magnetically very different phenomena. Simultaneously, the IMAGE (International Monitor for Auroral Geomagnetic Effect) project described by *Lühr* (1994) was established and Oulujärvi (OUJ) together with Hankasalmi (HAN) and Nurmijärvi was a good extension to the magnetometer network having previously stations in the northern Finland and Norway.

When planning the location of the new magnetometer station, information was available about the induced magnetic field in the Oulu region. A magnetometer array

Published by the Geophysical Society of Finland, Helsinki

study by *Pajunpää et al.* (1983) had revealed a subsurface conductivity anomaly, called the Oulu anomaly. This anomaly causes strongly anomalous vertical and horizontal magnetic field variations and therefore the vicinity of the town Oulu was not suitable for a magnetic station. North and east of the Oulu anomaly, the magnetic field was known to be more uniform with regard to induced currents giving therefore better information of currents in the ionosphere and magnetosphere.

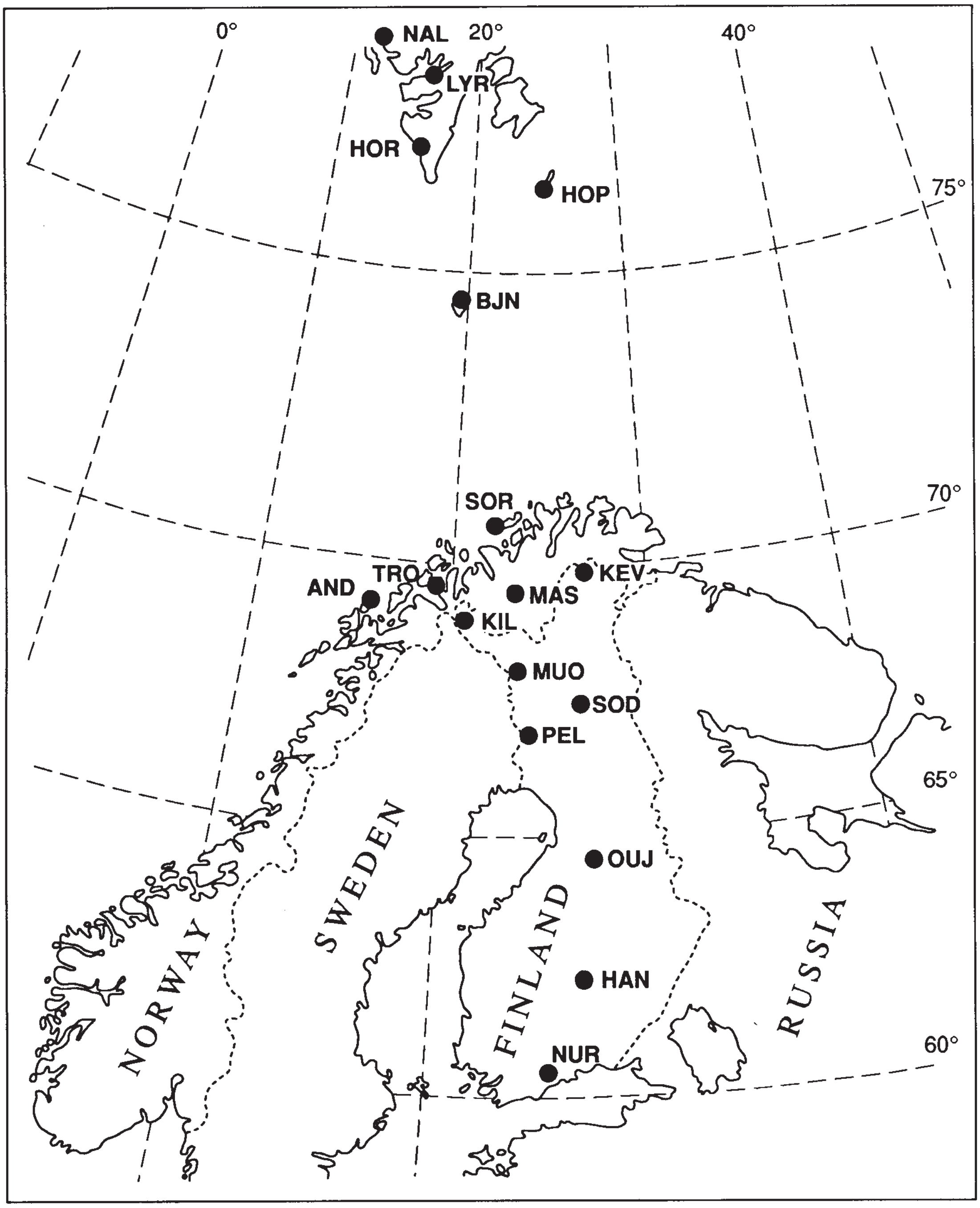


Fig. 1. The IMAGE magnetometer network in September 1996.

The geographical station of the Oulu University in the municipality of Vaala on shore of the Lake Oulujärvi was found to be the most suitable site for the magnetic station (Fig. 2). Its geographic coordinates are N 64.52° and E 27.23°, corrected geomagnetic coordinates are N 60.6° and E 106.9° and L-value is 4.3. A 20 kV power line 150 meters form the magnetomer site was the only worrying thing in the area. Geomagnetically induced currents (GIC) in 400 kV power lines have been measured in Finland. *Viljanen and Pirjola* (1994) reported that during big magnetic storms the current may exceed 200 A. We assume that the maximum current in a 20 kV line is 10 A, respectively. A line current model gives 13 nT field at the distance of 150 meters. This extreme current may occur during large magnetic variations. Thus we assume that the maximum error in the recordings of rapid magnetic variations due to the 20 kV power line is about one percent.

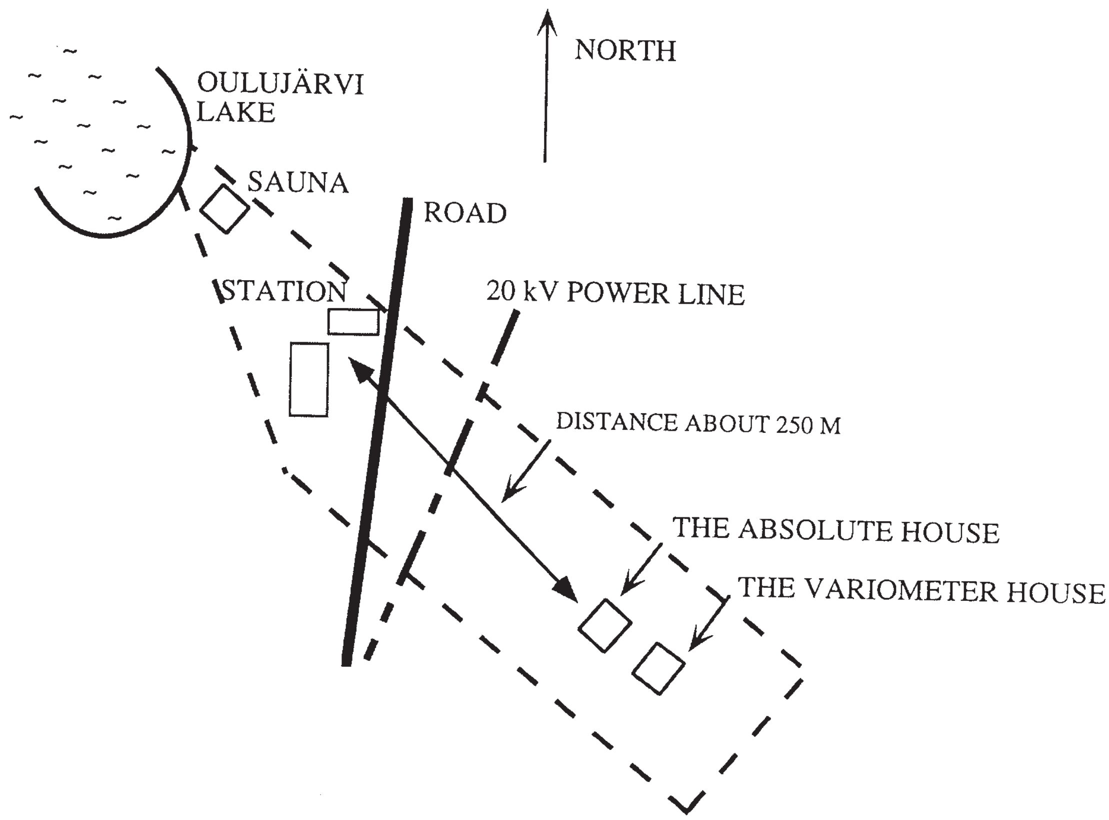


Fig. 2. Location of various buildings at the Oulujärvi station.

Two magnetic buildings, a variation house and an absolute house shown in Figure 3, were built in the forest some 250 meters south-east of the station building. An azimuth mark was erected and an open line for sight was cut in the forest. The building started in 1991 and was finished in 1992. Both houses are 2.5 x 2.5 square meters and have a pillar in the center of the building. Electric heating was originally installed only in the roof of the houses but it was soon realized that the power was not enough to keep the temperature constant during the cold season. Additional heaters were installed on the walls. A thermostat is controlling the temperature in both houses. The variation house is connected to the school house with underground cables. In addition to instrumentation cables there are optical cables which can be used for safe data transmission from the variometer to the computer in the station.

Fig. 3. Absolute and variation houses.

2. Instrumentation

In 1992 a three component fluxgate magnetometer model FGE described by *Rasmussen* (1990), was purchased from the Danish Meteorological Institute. The magnetometer has fixed sensors mounted on a marble cube (see Fig. 4) and its drift according to the manufacturer is less than 3 nT/year. The magnetometer was calibrated at the Nurmijärvi Geophysical Observatory. The error of the orthogonality of the sensors was measured to be 3’ (minutes of arc) between X and Y, 7’ between Y and Z and 3’ between X and Z. The largest error due to the misalignment of the sensors can thus be e.g. 2 nT in a 1000 nT variation. The total measuring range of the magnetometer is +/- 5000 nT. The data is recorded with a 0.1 nT resolution but the accuracy of the magnetometer when recording 10 second mean values is about +/- 0.2 nT.

Fig. 4. The Danish FGE magnetometer on the pillar in the variation room. The pillar is made of glass bricks and a marble plate.

The magnetometer was installed in the variation room of the Oulujärvi station in November 1992. The X-Y-Z orientation (geographic North, East and down) of the sensor was chosen. Accurate directing of the sensor was done in May 1993 when first azimuth direction was measured using the Sun and then absolute measurements were made at the absolute pillar using DI-fluxgate and a proton magnetometer. The magnetometer sensor was turned until the Y-component was the same as on the absolute pillar some 20 meters from the variation house. The recording system was first installed in the absolute house and consisted of a PC having a 22-bit A/D converter card inside. Two 7 Ah batteries provided power during blackouts of the mains. Accurate timing was based on an Omega receiver. This first recording system served for many years first as the only system and later as a valuable backup.

In summer 1993 another data acquisition system was brought to the station. A stand-alone A/D-converter card was installed in the variation room close to the magnetometer electronics and the computer was installed in the station building some 200 meters from the sensor. Since then data have been transmitted from the variation room in a digital serial line using either a twisted pair or optical fibres. Difficulties were soon met with the software when using the optical fibres. Better data coverage was obtained with twisted pair cables when an asynchronous short range modem was connected at both ends of the cable. Another data acquisition computer and an uninterruptable power supply (UPS) was installed in the station building in 1993. Data transmission from Oulujärvi to the Nurmijärvi observatory was arranged first by diskettes and since summer 1993 by modems and telephone lines.

In the beginning of 1996 Jouni Rynö from the Geophysics Department of FMI wrote a new data acquisition software using ERLANG language developed at Ericson Ab, Sweden. In February 1996 the operating system of the two computers was changed to LINUX and the new data acquisition software was installed. A new GPS receiver for timing and the modem were connected to one of the computers. Ethernet line between the two computers enables time synchronization and also access of the data from the second computer through the first one. This reform improved the reliability of the system and, as a detail, the optical cable between the variation room and the station building could be utilized again.

3. Data quality

The Oulujärvi magnetic station was designed to record high quality data both for ionospheric-magnetospheric studies and for secular variation studies. Although data for these tasks can be collected using the same instrumentation, specially the secular variation measurement needs a high stability of the equipment and absolute measurements for verifying the long time stability. The main factors for the long time stability are the pillar and the magnetometer. If the pillar is tilting because of frost in the soil during the winter, the base line drift of the horizontal components can be several tens of nanotesla during one year according to *Rasmussen* (1990). The pillar as well as the magnetometer can be affected by the temperature but this problem can be resolved with a temperature controller and a non-magnetic heater. At Oulujärvi the temperature is varying between about 15 and 20 °C. According to the manufacturer, the Danish FGE magnetometer has the temperature drift of less than 0.3 nT/°C and therefore the instrumental drift due to temperature can be up to +/- 1 nT. The long time drift of the magnetometer as well as the stability of the pillar can basically be measured only by absolute measurements.

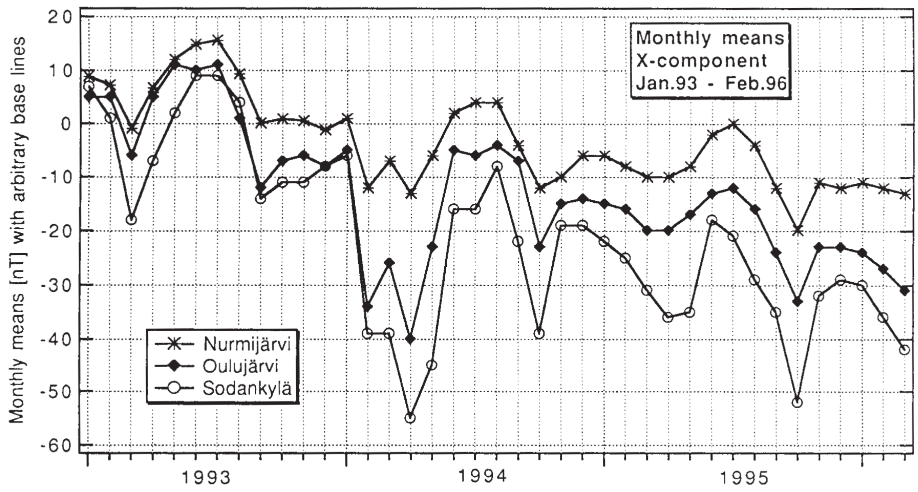
Until the end of 1995 absolute measurements were done only in the summer seasons and the results are given in Table 1. In February 1996 the measurement was done for the first time during the winter. The base line values measured in summer show that the long time drift at the station is small (< 5 nT/year). However, the last values are clearly different in February 1996. A question arises whether the base line had been different during all the cold seasons and what is the reason for the latest result? Information from the two other magnetic observatories in Finland have been used to answer this question.

Table 1. Base line values for the magnetometer at Oulujärvi as calculated from the absolute measurements.

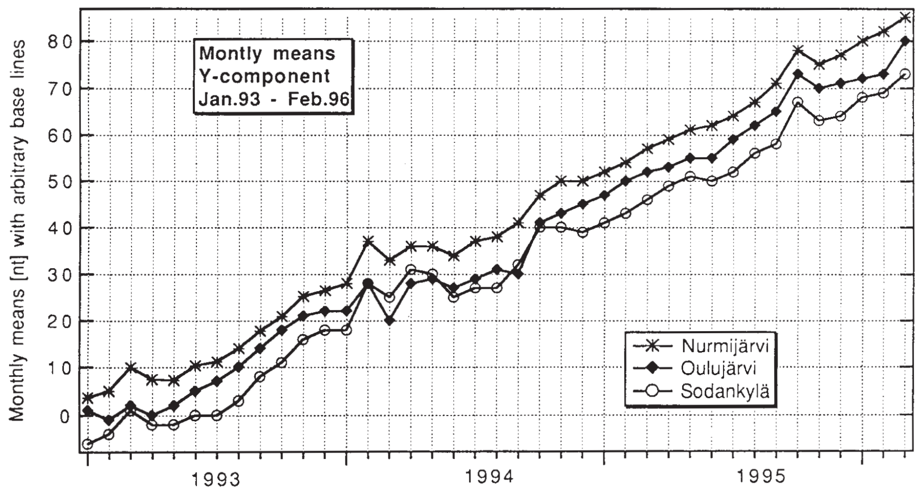
Day	X [nT]	Y [nT]	Z [nT]
1993-05-05	12945,3	1847,2	50639,4
1993-07-25	43,9	45,8	39,9
1993-07-25	43,3	46,6	40,0
1994-06-16	45,6	51,4	40,8
1994-06-16	45,0	50,0	41,2
1994-08-24	45,7	50,1	39,4
1994-08-24	45,6	49,8	39,4
1995-05-10	42,0	48,7	38,8
1995-06-13	42,1	48,8	39,5
1995-08-17	42,9	47,9	39,3
1996-02-27	47,3	62,3	37,6

The monthly mean values of the Nurmijärvi, Oulujärvi and Sodankylä observatories in January 1993 - March 1995 are plotted in Figure 5. At Oulujärvi the base line values for all the components were constant until January 1996. Thereafter the base lines were corrected to the values obtained in the absolute measurement in February 1996. The correlation of the three curves is best for the Y-component which is least affected by the eastward and westward electrojets in the auroral zone. The X-component is most affected by these disturbances as can be seen specially in the spring 1994 (see also Fig. 6). Based on these curves, no base line variation can be observed at Oulujärvi. Therefore the base line drift at Oulujärvi is less than 5 nT for all the components until the end of 1995, and the pillar has been stabile during cold seasons, respectively. In February 1996 the pillar has tilted about one minute of arc to west and a quarter of minute to the south that corresponds to the observed base line changes. By comparing the daily mean values of Oulujärvi and Nurmijärvi, it can be seen that the change occurs gradually during the month. The explanation for this could be a different frost thickness in the soil at the station when compared to the previous winters. The base line drift due to pillar tilting could be avoided only by using a suspended magnetometer as shown by *Rasmussen* (1990).

A



B



C

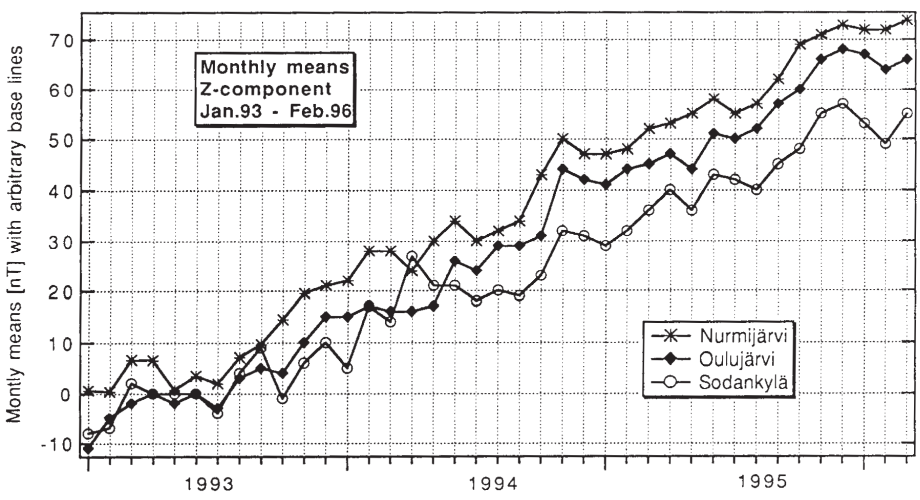


Fig. 5. Monthly mean values of the magnetic field components at Nurmijärvi, Oulujärvi and Sodankylä: (a) X-component, (b) Y-component and (c) Z-component.

The absolute measurements together with the comparison with Nurmijärvi and Oulujärvi observatories prove that the Oulujärvi station can be used as a high quality magnetic observatory giving reliable secular variation data provided that absolute measurements are done in warm and cold seasons every year. The annual mean values of the Oulujärvi station for the first three years are printed in Table 2.

Table 2. Annual mean values [nT] in 1993-1995 at Oulujärvi.

Year	**North X**	**East Y**	**Down Z**
1993	12971	1912	50591
1994	12953	1935	50616
1995	12951	1963	50642

Data coverage is another essential measure of the quality. At Oulujärvi the annual numbers of the data coverage are given in Table 3 and the longest data gaps can be seen in Figure 6. The numbers reveal that about 10 % of data was lost during these three years, which can be regarded as only tolerable. The station is only part-time manned and specialists from the Oulu University have visited the station usually once a month. In this respect the station can be regarded as fully automatic. The data gaps occur mostly during summer and their main reason has been lightning which has destroyed twice the modem and I/O-card of the computer. Protection has been improved by an on-line UPS and protecting elements in the telephone lines. Software problems have been another reason for the gaps. The first software was unreliable and due to the lack of people at the station, the computer could not be rebooted as frequently as was needed. This problem was overcome by the new software in February 1996.

Table 3. Data coverage in 1993-1995 at Oulujärvi.

Year	**Data coverage**
1993	95 %
1994	91 %
1995	89 %

4. K-values

The K- and Ak-values for the Oulujärvi station were computed from 10 second data using the “FMI” -method developed by *Sucksdorff et al.* (1991) at the Finnish Meteorological Institute. After comparing in 1994 the K-values of Oulujärvi to those of Nurmijärvi and Sodankylä during one year (Dec. 92 - Nov. 93) the limit for K = 9 was chosen to be 950 nT. Daily Ak values from Oulujärvi in 1993 - 1995 are plotted in Figure 6. High activity in February - April, 1994 is clearly seen.

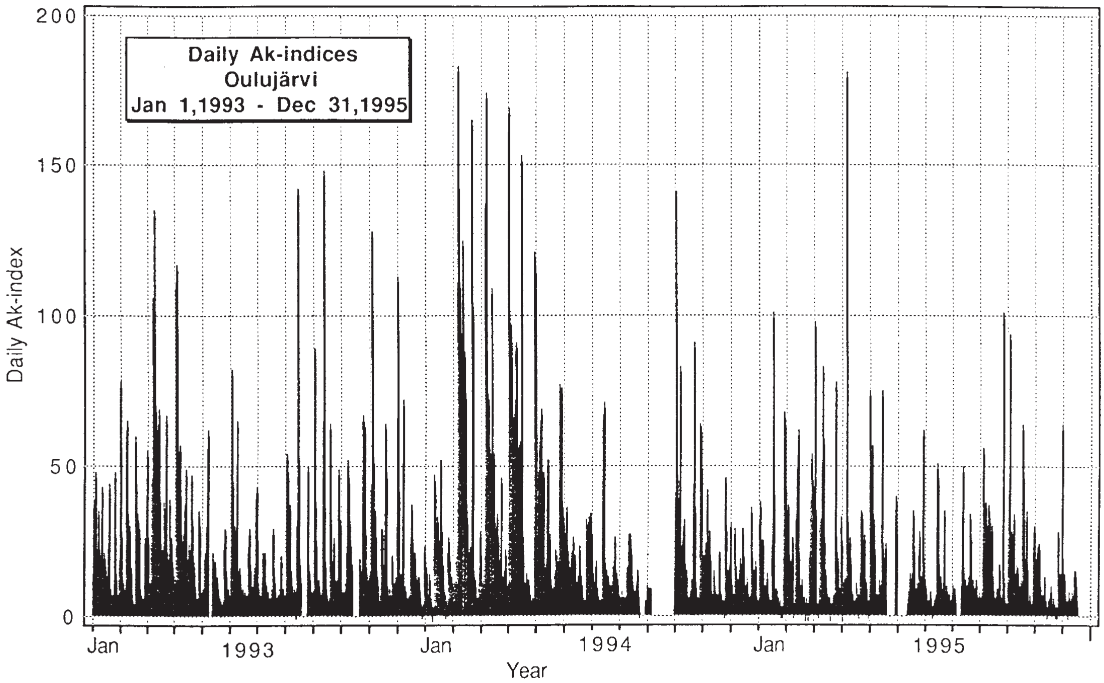


Fig. 6. Daily Ak-indices of the Oulujärvi observatory in 1993 - 1995.

Comparison of the Oulujärvi Ak-indices with those of Nurmijärvi and Sodankylä is presented in Figure 7. At Nurmijärvi the K-values were computed from 10 second data using the "FMI"-method but at Sodankylä they were manually read from analog LaCour recordings. Comparison with Nurmijärvi (K=9: 750 nT) shows that the Oulujärvi Ak values are clearly higher. Relative to the Sodankylä (K=9: 1500 nT) values the balance is

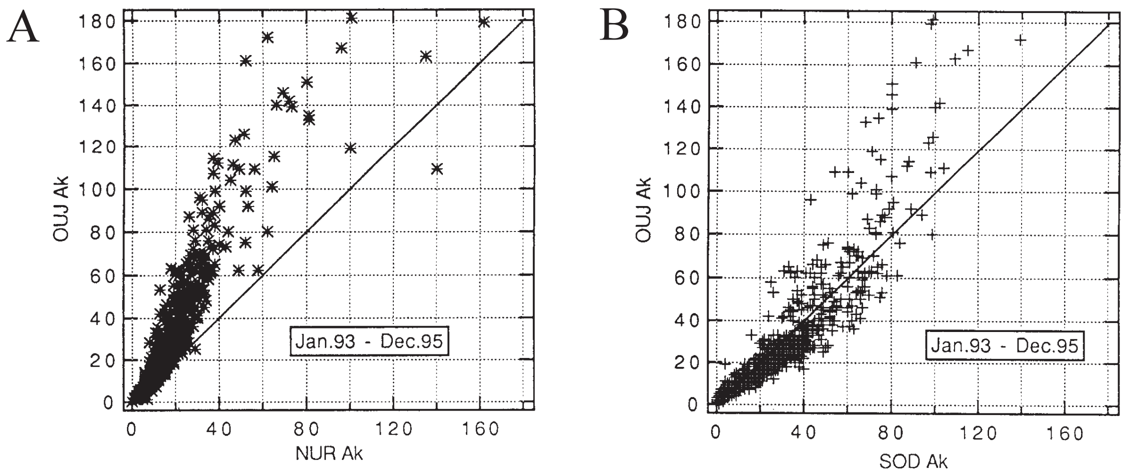


Fig. 7. Oulujärvi Ak-indices plotted with regard to Ak-indices of (a) Nurmijärvi and (b) Sodankylä observatories.

much better although the small values are now lower whereas the high values are clearly higher than those of Sodankylä. Sodankylä is located on the southern edge of the auroral zone. Nurmijärvi is about 800 km south of Sodankylä and can mostly be regarded as a mid-latitude observatory. Oulujärvi is clearly a sub-auroral station, so the substorm current system often expands to the south above Oulujärvi. Because the limits for high K-values are lower at Oulujärvi compared to the those of Sodankylä high K-values are more often measured at Oulujärvi.

The K-values were developed for mid-latitude stations, first for Niemegk by *Bartels et al.* (1939). At auroral and sub-auroral stations the magnetic disturbances are dominated by auroral substorms. Therefore, the K-values derived at Sodankylä and Oulujärvi stations are not directly comparable with those of lower latitude stations.

5. Data dissemination

Since the software reform in February 1996, data have been recorded and transferred to Nurmijärvi as 10 second and 60 second mean values. The system has also the readiness to record 1 second data. At Nurmijärvi the minute data are processed and checked and thereafter sent to the Sodankylä observatory where they are combined with data from three other magnetic stations in Finland (NUR, HAN, SOD) and plotted as daily magnetograms for monthly bulletins. The magnetograms can be seen also through the World Wide Web system.

Since its beginning Oulujärvi has belonged to the IMAGE magnetometer network extending from Nurmijärvi in southern Finland up to Ny Ålesund in Svalbard (see Fig. 1). The 10 second data from Oulujärvi is checked and corrected when necessary at Nurmijärvi. Thereafter it is sent to Helsinki to be combined with data from other IMAGE stations. Data of the IMAGE network is frequently used together with data from radars and satellites. Oulujärvi is capable for near real-time data access thus enabling quick-look type use of the station.

Data of the Oulujärvi station can be requested from the Oulu University and from the Finnish Meteorological Institute. Although a yearbook has not yet been published, all the usual values from a magnetic observatory are or can be calculated starting in 1993.

6. Summary

The Oulujärvi magnetic station was established in 1992 as capable for producing high quality data of the secular variation of the Earth's magnetic field as well as of ionospheric and magnetospheric currents. The first target has well been achieved by proper variation and absolute houses together with stabile magnetometer and recording systems. Although the station is practically unmanned, the data stability is at a high international level and as to the data the station can be regarded as a magnetic observatory. The second target of producing good variation data has slightly suffered from data gaps due to lightning and software problems. These problems should mainly be fixed by the new software. Since the beginning Oulujärvi has been one station of the

IMAGE magnetometer network and is an almost real-time station for satellite and radar campaigns.

Acknowledgements

Building of the Oulujärvi magnetometer station was financed by the Oulu University. Support for equipment and operation has been given by the Finnish Meteorological Institute. We wish to thank Prof. S.-E. Hjelt and Dr. H. Nevanlinna for their remarkable contribution to the development of the station.

7. References

Bartels, J., N.H. Heck and H.F. Jonston, 1939. The three-hour-range index measuring geomagnetic activity, *J.Geophys.Res.,* **44**, 411.

Kataja, E., 1973. The Sodankylä Geophysical Observatory in 1973, *Veröff. geophys. Obs. finn.Akad. Wiss.* 56/1, p. 23-58.

Lühr, H., 1994. The IMAGE Magnetometer Network, *STEP International,* **4**, N:o 10, 4-6.

Pajunpää, K., J. Heikka and T. Korja, 1983. Magnetometer array studies in Finland, *J. Geomag. Geoelectr.,* **35**, 543-553.

Rasmussen, O., 1990. Improvements in fluxgate magnetometers at Danish Meteorological Institute's magnetic observatories, *Proceedings of the International Workshop on Geomagnetic Observatory Data Acquisition and Processing, Nurmijärvi, Finland, May 15-25, 1989,* pp 93-102.

Sucksdorff, E., 1952a. The geophysical observatory Sodankylä, *Geophysica*, **5**, N:o 1, 17-47.

Sucksdorff, E., 1952b. The magnetic observatory Nurmijärvi, *Geophysica*, **5**, N:o 1, 1 p.

Sucksdorff, C. and T. Haikonen, 1958. The Nurmijärvi geophysical observatory, *Geophysica*, **5**, N:o 4, 203-215.

Sucksdorff, C., R. Pirjola and L. Häkkinen, 1991. Computer production of K-indices based on linear elimination, *Geophys. Trans.,* **36**, 333-345.

Viljanen, A. and R. Pirjola, 1994. Geomagnetically induced currents in the Finnish high-voltage power system, *Surveys in Geophysics,* **15**, 383-408.