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Northern Light Studies and Geomagnetic Observations in Finland in the 19th Century

Abstract

Due to Finland's northern position the Aurora Borealis (Northern Lights) phenomenon is well-known to most people in the country. The studies of Northern Lights follow the general pattern of scientific methodology in the 19th century. At first only the occurrences of Northern Lights were recorded as is demonstrated in the articles by G.G. Hällström[1] and J.H. Eklöf.[2] Later a more thorough study of the phenomenon took place: theories were put forward, apparatuses were constructed and controlled experiments were performed (S. Lemström, 1870-1900).

Parallel to Aurora Borealis research geomagnetic observations were performed. Hällström, Professor of physics, suggested that a magnetic observatory should be founded in Helsinki. The plan was realized and the magnetic observatory was built and J.J. Nervander was appointed its first Director. The geomagnetic field, as well as the occurrence of magnetic storms, was at the beginning recorded at ten minutes intervals starting in 1844. These intervals grew longer as the years passed, but the recordings were made until electric tram traffic in the 1910s made the measurements unreliable. These early recordings have only recently been analyzed by Nevanlinna et al.[3,4,5,6,7,]and *aa*-indexes have been calculated (1992-9). Thus the great project started 150 years ago by Nervander[8] has finally come to an end.

1. Introduction

Due to Finland's northern position Aurora Borealis, i.e. the northern lights, can be observed all over the country. Most frequently they are observed in Lapland, but also in southern Finland one can occasionally see them. Green and red are the

[1] HÄLLSTRÖM (1847).
[2] EKLÖF (1847).
[3] NEVANLINNA (1994)
[4] NEVANLINNA, KETOLA, and KANGAS (1992a).
[5] NEVANLINNA, KETOLA, VILJANEN, HÄKKINEN and IVORY (1992b).
[6] NEVANLINNA and KETOLA (1993).
[7] NEVANLINNA and KETOLA (1994).
[8] NERVANDER (1850).

dominating colours and it is a fascinating phenomenon when the northern light rays are drawn over the dark winter sky like curtains. Earlier it was believed that northern lights were a sign in the sky and that spirits were dancing in the sky.

There are long traditions of northern lights research in Finland. At the beginning one only noticed the occurrence of the northern lights and tried to vividly describe them. During the second half of the 19th century the problem was approached in a more scientific manner. Selim Lemström, professor of physics in Helsinki, took part in the international geophysical year 1882-3 with an expedition to Sodankylä in northern Finland. He had constructed a "discharge" apparatus to be put up on hill tops for observing the bursts of the northern lights. The "discharges" were detected by a sensitive electric measuring device. He was convinced that some kind of electric discharge took place to produce the northern lights, and he also tried to measure spectral lines from the northern lights. However, it was not possible for Lemström to come up with a final explanation of the Aurora Borealis phenomenon. In the 19th century the knowledge in physics and geophysics were not yet enough.

Today we know a lot more. The Earth is surrounded by a magnetic field, reaching far out into space. The magnetic field lines origin from a region close to the South Pole and are brought back to the Earth at a point near the geographical North Pole. The sun does not only send out visible light, but a small portion of the total energy consists of charged particles, mainly electrons and protons. When this solar wind comes into the magnetic field of the Earth, the particles start to move in spiral orbits in the main direction of the magnetic field. The particles are trapped in the magnetic field. As the electrons in the polar regions move deeper into the atmosphere, they collide with the molecules in the thin air. These molecules are then excited and send out mainly green light (from oxygen) and red light (from nitrogen). These processes occur at a height of 100-150 km. The charged particles in the solar wind can be trapped and stay for some time in the magnetic field, and occasionally sudden bursts of particles may occur in the polar regions, followed by strong northern lights. Simultaneously it is observed that magnetic storms, i.e. fast changes in the magnetic field of the Earth, occur.

Already the brief example given above from the field of geophysics in the 19th century, indicates that Finnish scientists (physicists) were working hard on their research projects and that their results had an international interest. Of course scientists were well-motivated. They all had the wish to find the clues to the problems they were dealing with. In the background, however, also another reason can be found, namely that of making an academic career, with its positive and negative sides. Finally there was Finland on the political scene. Being a Grand Duchy in the Imperial Russian empire it was essential that also Finland took part in international projects, and in this way projected herself onto the political map. These different aspects of motivation will come out in the following paragraphs dealing with research in Finland on northern lights and geomagnetism.

2. Gustaf Gabriel Hällström and Johan Jakob Nervander

Gustaf Gabriel Hällström was born in 1775. His first education was given at home by private teachers but later he attended the school in Vasa and was a registered student at the academy in Turku in 1792. Hällström made a fast academic career and at the age of only 25 he was appointed professor of physics. As a scientist Hällström was very active and he published papers on several fields of physics; a total of 57 academic papers in physics and mathematics appeared in the *Acta series of the Finnish Society of Sciences and Letters*. Several of them were translated and appeared in international journals. Among the more important articles can be mentioned papers dealing with the temperature for the highest density of water, night frosts in Finland, the northern lights, and still 21 more original papers for European journals. Three of the works were awarded prizes.

The scientific merits, many of them achieved already in early years, gave Hällström the academic position as professor. His further success was due to his ability to organize and make clever decisions. Therefore, Hällström was considered a valuable person for the university and he sat on in many committees and working groups. Several times he was appointed rector for the university, one period being the stressing three-year period 1829-1832 when the university, after the great fire in Turku, was reestablished in Helsinki.[9]

During the first half of the 19th century Finland saw an other excellent scientist and poet.[10] In 1805 Johan Jakob Nervander was born. His parents were Johan Nervander, a pharmacist in Nystad, and his wife Beata Bergbom. The family had been well off, but the father's speculations in ships and import business brought the family to economic ruin. It was, however, possible for young Nervander to attend school and in 1820 he became a student at the academy in Turku.

Johan Jakob Nervander was a brilliant student. At the beginning of his studies he concentrated on the humanities and his wish was to become a poet. His good friend J.L. Runeberg was studing at the same time at the Academy in Turku. J.L. Runeberg was a talented poet, and it is said that Nervander considered Finland too small to host two grat poets. Nervander therefore turned his interests to science and physics. In 1827 he finished his studies and obtained 30 marks out of a maximum of 33. That was a record never beaten, as long as there were 11 subjects in the exam.[11,12,13,14]

During the period 1832-1836 Nervander had an oppurtunity to make a long journey to central and southern Europe, as he was the first recipient of the main scholarship for travelling awarded by the university. During this journey he met many of the famous physicists in Europe. He also spent a few weeks in Italy but on

[9] HOLMBERG (1992).
[10] STEINBY (1991)
[11] BORENIUS (1848).
[12] CYGNAEUS (1848).
[13] CHYDENIUS (1860).
[14] KERÄNEN (1955).

his return journey back north he spent only one night in Como. He also constructed and described the "tangentbussol", a sensitive instrument for measuring weak electric current.[15] This invention made him a well-known physicist. After returning from his long journey Nervander eagerly wanted to make an academic career. He considered himself competent for a professorship in physics, and he was impatient as the old professor Hällström did not show any sign of retiring. Nervander's writings to the university with plans how the problem could be solved, were not very nice and he was considered a bothersome person by many members of the University Council. In these efforts Nervander had no success. Hällström's scientific competence and excellent ability to organize university affairs was a firm ground and nothing could remove him.[16]

Even if Nervander had difficulties in Helsinki, he met a more understanding atmosphere in the scientific circles in St. Petersburg. He often visited this metropolis and published many of his articles in the series of the Imperial Academy[17] and he held a high reputation as a scientist. At the same time he made important contacts. As an example of that is the correspondence between him and the academician A.J. Kupfer.[18] Nervander's idea to have a magnetic observatory established in Helsinki was supported in St. Petersburg and soon the new, necessary houses were built in Kaisaniemi park, Helsinki, and Nervander was appointed the first director and extra ordinary professor.

When the professorship in physics became vacant after Gustaf Gabriel Hällström Nervander applied for the position, and in 1846 he finally reached his goal and was appointed professor. However, there was not very much time for him to act as professor. In 1848 he fell ill with smallpox and, although the physicians were positive, Nervander died in 1848.

3. Early Aurora Borealis Research in Finland

In December 1842 Johan Henrik Eklöf, then a student at the university in Helsinki, gave a lecture at the meeting of the Finnish Society of Sciences and Letters, on the annual periodicity of the northern lights at different sites in Europe.[2] Eklöf applied the following function to the observational material from different sites

$$P = 8{,}33 + u'\sin(m\text{x}30^{\circ} + U') + u''\sin(m\text{x}60^{\circ} + U'') + u'''\sin(m\text{x}90^{\circ} + U''')$$

Here P gives the occurrence (in per cent) of the northern lights in the m:th month (starting from January). The results showed the same pattern for all sites, namely the maxima usually occurring at the equinoxes and the minima at the summer and winter solstices.

[15] HONKANEN (1986).
[16] AUTIO (1981).
[17] IMPERIAL ALEXANDER UNIVERSITY (1836-1848).
[18] KLADO (1962).

In April 1843 professor Hällström presented a continuation to Eklöf's work. The northern lights observations in Turku for the period 1748-1828, and in Helsinki 1829-1843, were analyzed, the total number of the northern lights being 682. Hällström also recalculated the results for Uppsala, now for a longer period than that used by Eklöf.[1] It might be of interest to compare the *P*-functions obtained by Eklöf

$$P = 8{,}33 + 5{,}42 \sin(m\text{x}30^{\circ} + 101^{\circ}\,48') + 3{,}94 \sin(m\text{x}60^{\circ} + 283^{\circ}\,24') + \\ + 0{,}94 \sin(m\text{x}90^{\circ} + 281^{\circ}\,22')$$

to that by Hällström

$$P = 8{,}33 + 5{,}126 \sin(m\text{x}30^{\circ} + 116^{\circ}\,31') + 5{,}580 \sin(m\text{x}60^{\circ} + 303^{\circ}\,12') \\ + 11{,}242 \sin(m\text{x}90^{\circ} + 319^{\circ}\,15').$$

Both functions show the same pattern, however, a small change in input data affects the values of the parameters to be calculated. Therefore a close analysis of the results cannot be performed.

Throughout the 19th century there was continuous great interest in the northern lights and several observational notes were published in the series of the Finnish Society of Sciences and Letters.[19] [20] [21]

4. The Magnetic Observatory in Helsinki

Nervander's interest in the Earth's magnetism grew stronger during his grand tour in Europe and he worked hard for the idea of having a magnetic observatory founded in Helsinki. It should be of the same type as those already established in Russia, and thereby the total area covered by magnetic observations would be enlarged when Helsinki, in the western part of the Russian empire was included.

In April 1838 an Imperial letter was read at the meeting of the University Council, saying that a magnetic observatory was to be established in Helsinki (Imperial Alexander University in Finland 1836-1848). The planning of the observatory now proceeded very quickly and in November 1839 the new buildings were completed.[3]

From the very beginning Nervander wanted to secure the future activity of the magnetic observatory by connecting its observations to international projects. In 1841 his plans were accepted in St. Petersburg and it was decided that the observations should be performed according to a certain schedule during the timeperiod of the simultaneous British South Pole expedition.

The magnetic observatory, and the observations made, was a great project in the Finnish university world. To understand correctly the dimensions of this project one has to compare it to other projects physicists in general were dealing with at the university in Helsinki. The professor of physics (Hällström) had only a few rooms

[19] KRUEGER (1872).
[20] LEVÄNEN (1873).
[21] FELLMAN (1874).

(together with the chemists) at his disposal in the southern part of the university main building, and the personnel consisted of a lecturer, a docent and occasionally an assistant.

Director Nervander held also the position as extra ordinary professor of physics, and in Kaisaniemi park relatively large buildings were at his disposal. The magnetic observatory was not only designed for observational purposes. The director with his family was also living there, and one room was reserved as a resting room for the assistants working at the observatory. When the observations started (they were performed day and night at ten minutes intervals) Nervander had 12 assistants at his disposal. The project obtained big resources and it was a part of an international network. It was really big science at that time.

5. Selim Lemström and his Research

Karl Selim Lemström (1838-1904) is today remembered as one of the founders of modern laboratory-based physics in Finland and his research was typical of the orientation towards northern exploration in late 19th century Scandinavian science.

After having graduated from the university in Helsinki 1862, Lemström contacted Adolf Erik Nordenskiöld, the Finnish scientist and explorer who lived and worked in Stockholm. In 1867 Nordenskiöld managed to find for his compatriot a research position in Stockholm in the laboratory of the well-known professor of physics, Erik Edlund, at the Swedish Academy of Sciences. In the next year Lemström was appointed physicist on Nordenskiöld's expedition to Svalbard (Spitsbergen). During that journey Lemström was in charge of the physical apparatus and performed regular magnetic measurements and the northern lights observations. This expedition to Arctic waters and the panorama of the colourful Aurora Borealis illuminating the dark sky aroused in Lemström a strong desire to investigate the phenomenon more closely.

During the next years Lemström finished his experiments on Volta induction current under Edlund's supervision. This work was published in 1870 and served to establish Lemström professionally at the University of Helsinki. In 1878 he was appointed professor at the university in Helsinki and in this position he was very active in several fields of physics. Lemström was an excellent experimentalist and he devoted himself to finding applications of physics in every-day life. He therefore moved the education and examinations at the university towards the experimental field and greatly increased the amount of experimental physics required in the degree program. These changes demanded more space and for many years Lemström worked to establish a new laboratory, which was finally built after his death.

Throughout his life Lemström was interested in the polar light phenomena. When the international geophysical year 1882-3 was planned there was world wide interest for the project. Finally eleven countries took part and 14 special stations were established, 12 of them being on the northern hemisphere, as far north as possible. Lemström worked hard to see Finland taking part in this international project, and he

was successful in his efforts. Accordingly, a special station for observations was built in Sodankylä, in northern Finland. The routine work at the station was exhausting. More than 700 readings were recorded every day all year round, and on certain days, assigned to especially intense observations - more than 4000 readings were taken. To study the polar lights effectively, Lemström constructed a large apparatus with a very sensitive galvanometer to be put up on top of the hills in Lapland. He thought he could actually record the bursts of the polar lights with his huge electric device, but his reports of the measurements were heavily criticized.

The Finnish results of the polar year were published in three large foliovolumes (1886, 1887 and 1898). From a scientific point of view the geophysical year had been a success. All the participants, including Lemström, had worked very hard, putting a lot of time and even money into the project. Afterwards the expedition to Sodankylä was, however, criticised for careless spending of the supported funds. This was of course stressing news for Lemström, but he eagerly continued his efforts at investigating the northern lights phenomenon. Still in 1899 he put up the "discharge" apparatus at the roof of the laboratory building in Helsinki. He also used the church tower of the Nikolai-dome in Helsinki for this purpose. Lemström presented the results of the phenomenon in a lecture given in Como 1900 at the centennial world exhibition dedicated to Volta's birth. On this occasion he was awarded the "Diploma di Benemerenza".

6. Magnetic Observations after Nervander

The magnetic observatory, with Nervander as its first director, was from the very beginning equipped with high level apparatuses and the results received were recognized abroad. Nervander collected the first results of the observations into large tables in four volumes. This work was published after his death and it was also awarded a prize from the Academy in St. Petersburg. After Nervander's sudden death in 1848 Henrik Gustaf Borenius continued as director at the observatory. Borenius was married to a daughter of Nervander and in many respects he had close relations with his father-in-law. The activity at the observatory continued, for many years, according to the routines and schedules already set up by Nervander.

When the meteorological observational system was reorganized in Finland the magnetic (meteorological) observatory, until then under the rules of the university, was taken over by the Finnish Society for Sciences and Letters. Borenius had been its director since 1848, but when he retired in 1880, it was considered a suitable time to carry out the reorganization.

When Nervander started the observations instrument readings were put into the journals every ten minutes. This very demanding schedule was followed during the years 1844-1856. After that (1857-1897) the readings were performed once an hour, and finally 1898-1911 three times a day. During the last year there was only one notation per day. After that the electric tram traffic close to the observatory was

disturbing the sensitive magnetic measurements and the results became unreliable. As a consequence the measurements were stopped.

The magnetic declination was measured, as well as the intensity of the horizontal component of the Earth magnetic field. During the very first period also the vertical component was noted. Nervander's collection of magnetic data from the period 1844-1848 was published posthumously in 1850.[3] Originally planned to appear in four volumes it now appeared in one tome, with an introduction by Borenius, dated April, 1852. The very first measurements were taken on July 1, 1844, at 0^h 0', followed by tables of readings every ten minutes. The fourth volume ends at February 29, 1848, at XXIIIh 50'.

After Nervander's death in 1848 observations were only made, but fortunately the original notebooks are still available at the bookshelves at the modern Finnish Meteorological Institute in Helsinki. Recently Heikki Nevanlinna *et al*. have carefully analyzed this material with the aid of computers. As a result the complete period 1844-1911 is now published in electronic form. Thus the work started by Nervander 150 years ago, and continued by several directors at the magnetic observatory, has come to an end. The notations of the magnetic declination (some 1 010 000 readings) cover a time period of five suncycles: it is thus almost two periods longer than the so far longest series of data giving the activity index (*aa*).[2,2,4,5,6,7]

[22] MENVIELLE and BERTHELIER (1991).

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