Auroral Observations in Finland—Visual Sightings during the 18th and 19th Centuries

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(Received April 7, 1995; Revised June 23, 1995; Accepted September 4, 1995)

Systematic naked eye sightings of northern lights started in Finland in 1748. Such observations were carried out for about 100 years at two places in Southern Finland. All observations were compiled and published by Hallström (1847). Auroral occurrence frequencies in this compilation obey well the semiannual variation and the 11-year sunspot cycle when compared with other coeval auroral and magnetic data available in Europe. In the middle of the 100-year auroral series there was an anomalous period of very low auroral occurrence, known as Dalton’s solar activity minimum, lasting about three decades from 1795 to 1825. As a signature of Dalton’s minimum, auroras were totally absent from the sky in Southern Finland for the 10 years 1806–1815.

1. Introduction

Appearance of aurora is a signature of solar particle emissions causing visible light in Earth’s polar atmosphere. In long-term time intervals the occurrence frequency of auroras are connected with the 11-year solar activity periodicity. In a short time scale, semiannual and 27-day recurrence of auroras are prevailing features of auroral occurrence. Basically, the aurora reflects disturbances which originate largely in the sun.

Documents of naked-eye observations of visual auroras exist already both in Occident and Orient over 2000 years (see Section 2 of Eather (1980)), but more continuing observations have been collected since the beginning of the 18th century. De Mairan (1733) was probably the first who systematically collected locations and dates of nights with auroras in Europe. Later Fritz (1873) published much more comprehensive lists of auroral recordings reported mainly in Europe but also including material from North America compiled by Lovering (1867). Rubenson’s (1879, 1882), and Tromholt’s (1902) catalogues cover auroral observations in Sweden and Norway for about 150 years since 1720’s containing some 8 000 auroral observation records. In a recent review article on secular trends of auroral occurrence, Silverman (1992) presented an extensive description of existing auroral catalogues, data bases since the 16th century, and a rather complete list of relevant references. He has combined auroral records into a large data base comprising about 45 000 individual visual observations for a period of about 500 years, from 1450 to 1948. Based on this compilation, Silverman was able to demonstrate how the auroral occurrence rate behaved during e.g. the Maunder and Dalton minima of solar activity in the 18th and 19th centuries, respectively. Thus, long time series of auroral observations from different locations world-wide give unique proxy information of periodic variations and secular trends of solar activity. Although individual observation sites are often suffering from local meteorological conditions and short summer nights at higher latitudes, the vast number of observations at different locations makes it possible to carry out statistical analyses of the time behaviour of auroral occurrence rate in a meaningful way.

The aim of this paper is to present some results based on naked-eye observations of auroras made in Finland and published during the 18th and 19th centuries. There are available some 1000 observations mostly made in Southern Finland (geographic latitude about 60°N). Some of these have already been included in Fritz’s (1873) catalogue but most of them appear only in the 19th century’s Finnish scientific annals that are not widely known in the international scientific community.

Scientifically the most interesting of the Finnish auroral records is the series compiled by Hallström
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(1847), which consists of relatively homogeneous and continuous set of 686 auroral observations carried out in Turku ($\phi = 60.5^\circ N, \lambda = 22.2^\circ E$) and Helsinki ($\phi = 60.2^\circ N, \lambda = 25.0^\circ E$) from 1748 through 1843. This interval includes the Dalton minimum of solar activity that occurred in the beginning of the 19th century during Carrington solar cycles 5 and 6.

The definition of auroral observations used in this study is simply the number of days during which the observer has seen auroral lights in the sky at a given place on a given day without reference to the nature of the aurora itself, or to the length of the time for which it is observed. Monthly and annual sums of such numbers give the seasonal and yearly variations of the occurrence rate of auroras. Series of auroral observations covering time intervals comparable in length with the 11-year sunspot cycle give information on the long-term trend of solar activity itself.

2. Visual Observations of Auroras in Finland 1748–1884

Reports on auroral occurrence in Europe during the 17th century are very scarce. The reason for that was the long-term decrease of solar activity, known as the Maunder minimum (e.g. Siscoe, 1980; Silverman, 1992), lasting almost the whole 17th century. Solar activity increased rather rapidly in the first two decades of the 18th century. As mid-latitude auroras were now seen more frequently than for decades, they became a scientific object again after being almost forgotten for about one hundred years. One of the greatest magnetic storms after the Maunder minimum, with accompanying auroral displays, seen even in South Europe occurred on March 15–17, 1716. It was reported in many scientific annals in Europe (see e.g. Fritz, 1873; Rubenson, 1882; Brekke and Egeland, 1983, 1994).

In Nordic Countries systematic observations of auroras and geomagnetic variations were started in the 1720’s by A. Celsius at Uppsala University in Sweden. Together with his assistant D. Hiorter he found the well-known connection between the simultaneous appearance of northern lights and the enhanced geomagnetic activity as seen in rapid vibrations of compass needles. Probably by the initiative of Celsius, geophysical and meteorological observations were started in Finland at the Turku Academy which had close scientific connections with Uppsala University. J. Leche (1704–1764), a professor of medicine at the Turku Academy, started meteorological and auroral observations at Turku in 1748. He had been a student of Celsius, who suggested him to continue studies and observations of these topics at the Turku Academy (Simojoki, 1978). Before Leche, occasional observations of auroras together with meteorological ones has been made at Turku in the early 1730’s (see, Fritz, 1873).

Leche’s and his successors’ auroral observations were compiled and continued by Hällström (1775–1844). He was professor in physics at the Turku Academy and later in Helsinki University. His sphere of scientific interest comprised of collecting meteorological, climatological, hydrological and magnetic observations (for details, see Simojoki (1978) and Holmberg (1992)). These scientific disciplines, now included in geophysics, were quite new in Hällström’s time. In the 18th and 19th centuries auroral phenomena were regarded to be connected with meteorology and related with lightning. Some scientists believed also that meteorites and their burning dust may excite auroral lights. Hällström understood that in order to penetrate into unknown realms of geophysical phenomena, long-term continuous and careful observations were needed for serious scientific studies. Hällström’s work laid the foundations of later meteorological and geomagnetic observations and geophysical observatory practice in Finland.

Monthly values of Leche’s observations without dates were included Hällström’s (1847) list of auroras 1748–1844. The dates of individual observations for 1748–1828 were later published by Johansson (1911) in his study of Hällström’s unpublished scientific material. The later part of Hällström’s compilation of auroral observations were made by Hällström himself and by J. Argelander, a professor of astronomy. Argelander published much later his detailed description of auroral displays observed in Turku 1826–1832 and in Helsinki 1832–1836 (Argelander, 1867).

The whole city of Turku and the Academy buildings were badly destroyed in a fire in September 1827. This gave the reason for moving the Academy into Helsinki, which had been the capital of Finland since 1812. Argelander continued his auroral observations in the astronomical observatory of the Helsinki
university until his move to Bonn in Germany in 1836.

After Hällström, auroras were observed at the Helsinki magnetic-meteorological observatory where auroral sightings were part of the meteorological observations from July 1844 to February 1848. Magnetic and meteorological observations were carried out under the supervision of J. J. Nervander (1805–1848), the founder of the observatory. They were published posthumously after Nervander’s death in the meteorological yearbooks of the Helsinki observatory, and are also included in Fritz’s (1873) catalogue.

During the First Polar Year auroral observations were carried out in the Finnish Lapland at two places: at the Sodankyla observatory site (\( \phi = 67.4^\circ \text{N}, \lambda = 26.6^\circ \text{E} \)) and at a field station Kultala about 100 km north of Sodankyla. The observations were visual sightings and descriptions of the auroral forms were written down. This series of observations includes several hundreds of individual auroral cases with detailed descriptions covering the time period of two years from September 1882 to August 1884 (Lemström and Biese, 1887). The Finnish Polar Year auroral data set was a part of the extensive analysis of auroral occurrence frequencies in the polar cap area carried out by Vestine (1944).

Along with Hällström, the other notable scientist in the Finnish auroral research in the 19th century was physics professor S. Lemström (1838–1904). Lemström’s main achievement in auroral physics was his theory about the origin of northern lights which was published as a textbook (Lemström, 1886a, b). Lemström’s auroral theories, spectroscopic analyses, and his experiments for producing artificial auroras have been described in more detail by Brekke and Egeland (1983, 1994) and Holmberg (1992). He also organized and partly fulfilled visual auroral observation programme at the Sodankyla Polar Year station during 1882–1884.

2.1 Long-term variations in the auroral occurrence

Figure 1 (top and middle panels) shows the annual numbers of auroras according to Hällström’s and Fritz’s compilations and the sunspots in 1748–1843. As can be seen, the highs and lows in the auroral number curves follow reasonably well each other. A conspicuous feature is the anomalously low sunspot and auroral numbers for about 30 years from 1794 to 1824 during Dalton’s solar activity minimum. Practically no auroras were observed at all for 12 years since 1805. However, a few auroras were seen during the peak years of the Daltonian sunspot maxima at 1804 and 1816 indicating that the 11-year solar cycle was working although its amplitude was on an anomalously low level. The length of the cycle during the Dalton minimum seems to be some years longer than the average 11 years as demonstrated by the power spectrum analysis by Silverman (1992). An FFT-analysis of Hällström’s annual auroral occurrence numbers yielded major spectral peaks at 18, 13, and 9 years, differing not too much from those obtained by Silverman (1992). Dalton’s minimum ended in the middle of the 1820’s. The numbers of observed auroras increased rapidly since 1825 and peaked in the sunspot maximum year in 1830 attaining for the first time as high values as 43 years earlier.

Figure 1 (bottom panel) depicts the annual variation of the sunspot number together with the yearly mean values of the daily amplitude (range) of declination as observed at several European magnetic observatories since 1781 according to Wolf’s (1884–1887) compilation taken from February 1884 issue LXI of Astronomische Mittheilungen (Table 3, p. 11). Daily range values are combined and smoothed values from eight mid-latitude European observatories. Because the mean daily range reflects the total amount of ionization in the ionosphere, year-to-year changes in the annual range tell about corresponding changes in the sun’s average UV-radiation intensity and maybe even about the general activity level of the sun. The effect of low solar activity during the Dalton’s minimum period can be clearly seen in the range curve which shows a pronounced decrease in the mean diurnal declination amplitudes during solar cycles 5 and 6 with sunspot maxima in 1804 and 1816, respectively. Anomalously low values of auroras and daily amplitude of declination indicate a low efficiency of solar-terrestrial relationship during Dalton’s minimum for about three decades in the beginning of the 19th century.

As pointed out by Oguti (1993a, 1993b) the occurrence of auroras at a given observation site depends also on the distance of the observation point to the auroral zone. He did demonstrate how e.g. the Northern UK was in the auroral zone some 300 years ago due to the slow movement of the zone caused by decreasing
Fig. 1. Top: Relative number of yearly observations of visual auroras in Turku and Helsinki in 1748–1843 according to Hällström (1847) compilation. Middle: Relative numbers (circles) of auroral sightings in Europe and North America between latitudes 58°N and 65°N taken from Fritz’s (1873) catalogue. Bottom: Relative range of mean diurnal variation of geomagnetic declination according to Wolf’s (1884–1887) compilation. Year-to-year changes in the range is a measure of corresponding changes in the solar radiative output. Shadowed area in all panels shows annual sunspot numbers.
Earth’s geomagnetic dipole field intensity and location of the geomagnetic pole. This secular trend may seen in the present auroral data series which should be investigated in future studies. However, our interpretation of the cause of low auroral occurrence rate during the Dalton’s minimum is the temporary decrease in the solar activity during the first decades of the 19th century.

2.2 Seasonal variation of auroras 1748–1843

The seasonal bias in the occurrence frequency of auroras has already been recognized by de Mairan (1733) and later mentioned by several workers in the 19th century (see e.g. Silverman, 1992 and references therein). Auroral activity maximizes near March and September equinoxes and minimizes near solstices in June and December. However, as early as in mid-19th century there were observations that a secondary maximum appears near July especially in middle latitude auroral recordings. Eklöf (1847) analyzed 12 data sets from different locations in Europe from the 18th century and noted the July-August maximum in some mid-European data series. His object was to confirm Marain’s law of equinoctial maxima by using harmonic analyses of monthly recordings of auroras in Europe.

Figure 2 depicts a comparison between the monthly occurrence percentage of Hällström’s and Rubenson’s data from Sweden. The latter data base comprises about 4 300 observations covering the latitudinal belt 58.5°N–61.5°N for the time interval 1720–1877. Monthly percentages in the Hällström’s compilation differ only slightly from those calculated from the Swedish data indicating that the Finnish data set of 686 observations reasonably well represents the seasonal variability of northern lights.

Hällström (1847) analyzed in more detail the seasonal variation of auroral occurrence during 1784–1843. He applied a Fourier-wave fit to the mean monthly occurrence percentages \( A \) of the total annual occurrence in order to determine the dates of auroral minima and maxima. The least-squares fit consisted of the sum of the annual wave, its second (semiannual) and third (4 months) harmonics as follows:

\[
A(n) = 8.33 + a_1 \sin(30°n + \phi_1) + a_2 \sin(60°n + \phi_2) + a_3 \sin(90°n + \phi_3),
\]

where \( A(n) \) is the percentage for month \( n \) (January = 1) and 8.33 (=100/12) is the mean monthly occurrence.

![Graph showing seasonal variation of auroras](image)
The Fourier-wave amplitudes \( (a_i) \) obtained by Hällström were 5.4, 5.0, and 0.8. The phase angles \( (\phi_i) \) were 99.7°, 285.7°, and 211.8°, respectively. Putting these in Eq. (1) yields March 1 and October 11 as equinoctial maxima and corresponding solstitial minima at June 25 and December 20 (see Fig. 2). Using the same three-wave harmonic fit, Hällström analyzed Celsius' auroral series from 1723–1756 obtaining maxima at March 6 and October 12, minima at June 21 and December 29. Hällström did take into account that in the early 18th century the Julian calendar was still in use in Sweden (where the Gregorian calendar was introduced in 1753) and in other non-catholic countries, a fact that Eklöf (1847) had ignored. The time discrepancy between the Julian and Gregorian systems was 11 days and Eklöf's results for maxima and minima were behind the correct ones.

2.3 Occurrence of auroras and geomagnetic activity

Great auroral displays are often accompanied by enhanced geomagnetic disturbances. This correlation was already known by Celsius. To check this correlation in the Finnish data, not much usable magnetic observations exist before 1843 simultaneously with the documented auroral sightings. However, magnetic and auroral observations carried out later in the 19th century provide a good database for determining statistical correlations between northern lights and magnetic variations in various time scales (e.g. Legrand and Simon, 1987; Silverman, 1992, and references therein). Usually magnetic indices have been used for describing geomagnetic variations and activity. Mayaud's \( aa \) indices have been utilized for long-term correlation between geomagnetic and auroral activities. Mayaud's \( aa \) index series is the longest global index available since 1868. An extension of an equivalent \( aa \) index series was published by Nevanlinna and Kataja (1993) using declination readings from the Helsinki magnetic-meteorological observatory from 1844 through 1880 thus providing a continuation of the \( aa \) series for more than two solar cycles. Figure 3 shows the equivalent Helsinki \( aa \) indices 1844–1880 versus the auroral occurrence (from the latitudinal belt 55°–65°N) numbers compiled by Fritz (1873). A least-squares fit yields the relationship

\[
AN = 13.2 + 4.3aa 
\]  

(2)
where $AN$ is the annual number of auroral nights. The correlation coefficient is 0.75. Legrand and Simon (1987) made a similar comparison for the time period 1883–1906 and the relationship between $AN$ vs. $aa$ was almost exactly the same as found for the period 1844–1880 using the Helsinki equivalent $aa$ indices.

3. Conclusions

The hundred-year (1748–1843) series of naked eye auroral observations collected in Southern Finland (Hällström, 1847) reveals both long-term and short-term time characteristics of auroral variability. The periodic waxing and waning of the occurrence of northern lights during the 11-year solar cycles as well as semiannually is clearly seen in the Finnish auroral data set.

Comparisons of the Finnish database with relevant data sets from other sites in Europe (Fritz, 1873) and the neighboring country Sweden (Rubenson, 1882) proves that Hällström (1847) compilation represents a reasonably homogeneous and reliable time series of auroral occurrences. An interesting feature was the anomalously low level of auroral occurrence period lasting three decades 1794–1823. During that time period (Dalton’s minimum) the highest annual numbers of auroral occurrence were typically at least 80% lower than the highest maxima in the years before and after the anomalous period. For 10 years from 1806 to 1815 there was a total lack of auroras in Southern Finland. The situation has been similar in central Europe as can be deduced from the auroral catalogue by Fritz (1873). However, as demonstrated by Eather (1980, p. 80), auroras were reported from Northern Norway even during the lowest activity period around 1805. This indicates that although auroral signatures were very weak in mid-latitudes and subauroral zones, auroral processes were not totally stopped but they restricted only on high latitudes.

Sun’s ionizing radiation has been on a significantly lower during the first two decades of the 19th century. Wolf’s (1884–1887) data of the daily range of declination variation (that is proportional to the sun’s ionizing radiation) shows a decrease of about 50% in the maximum annual means of range values at sunspot peaks around 1804 and 1816.

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