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Comparison of annual variations observed in the earth's magnetic field at Tromsø, Ny-Ålesund, and Bjørnøya

STEINAR BERGER & ASGEIR BREKKE
The Auroral Observatory, University of Tromsø

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A comparison of the annual variations of the geomagnetic field at Tromsø, Bjørnøya and Ny-Ålesund is reported. It is found that the Z-component at all three places has increased by 35–45 γ/year for the last 10–15 years. The H-component has also increased during the same period except at Ny-Ålesund where it reached a maximum in 1975. The D-component, however, has gone through an oscillation and reached a minimum westward direction in 1971 at Ny-Ålesund and Tromsø, and in 1972–73 at Bjørnøya. The general agreement between the results found for these Arctic stations and the sub-Arctic station Nurmijärvi, all being close to the same magnetic meridian, indicates that the radial dipole model described by Nevanlinna (1978) is representative for the secular variations of the earth's geomagnetic field in this part of the Arctic.

S. Berger and A. Brekke, The Auroral Observatory, University of Tromsø, P.O. Box 953, N-9001 Tromsø, Norway.

INTRODUCTION

For almost 50 years the Auroral Observatory in Tromsø has been recording by standard magnetometers the daily variation of the three components H, D, and Z of the earth's magnetic field.

From these daily mean values, annual mean values of the earth's magnetic field at Tromsø have been derived and used to establish the difference between magnetic north and true north (declination) in the northern part of Norway for the last 30 years. At Bjørnøya, such observations have also been performed for the last 25 years to derive the declination angle in this important part of the Northern Sea, and finally for the last 12 years similar recordings have been made at Ny-Ålesund to yield the declination angle in the Spitsbergen area.

In this report we will present the first series of these annual mean values of the earth's magnetic field derived at Ny-Ålesund and Bjørnøya and compare them with the observations made at the well-established Auroral Observatory in Tromsø. A point of particular interest is the fact that these three stations are close to the same magnetic meridian (see Table I).

Annual variations of the magnetic field from this part of the Arctic have not previously been presented for extended periods, and will hopefully be a fruitful addition to the magnetic field data relevant to the long term (secular) variations of the earth's magnetic field on a global scale.

THE INSTRUMENTATION

At Tromsø, two variometer systems of the La Cour type are installed. The recordings of the high sensitivity system are used to derive the daily mean values during normal conditions. For stormy periods, however, the low sensitivity system has to be used. Both instruments are placed in an isolated house (rebuilt in 1968) 30 metres from the main observatory building. During a construction phase at the observatory site ending in 1971, the base line on the H-trace might have been changed by an unknown amount, resulting in an unknown relative uncertainty between the absolute values derived before and after this construction period.

At Bjørnøya, a normal sensitivity La Cour variometer is installed in a small hut about 75 metres from the nearest house. The instruments are mounted on the rock and are therefore very stable. In Ny-Ålesund, however, where also the normal sensitivity variometer is installed in a hut about 30 metres from the nearest building, the instruments are mounted on permafrost and are therefore less stable than on the two other stations.

THE DATA

Daily mean values for all quiet days are derived. A quiet day is defined as a period where the maximum variation in the H-trace is less than 15 γ.

The quiet daily means are used as a data base for the quiet yearly mean. At Bjørnøya and Ny-Ålesund, where the sensitivity is 10–13 γ/mm, the uncertainty in the yearly mean will be about $\pm$ 5 γ in H and Z and 2′ in D, respectively. For the Tromsø values, where the sensitivity on the normal variometer is 7–8 γ/mm, the uncertainty will be 2–3 γ in H and Z and about 1′ in D.

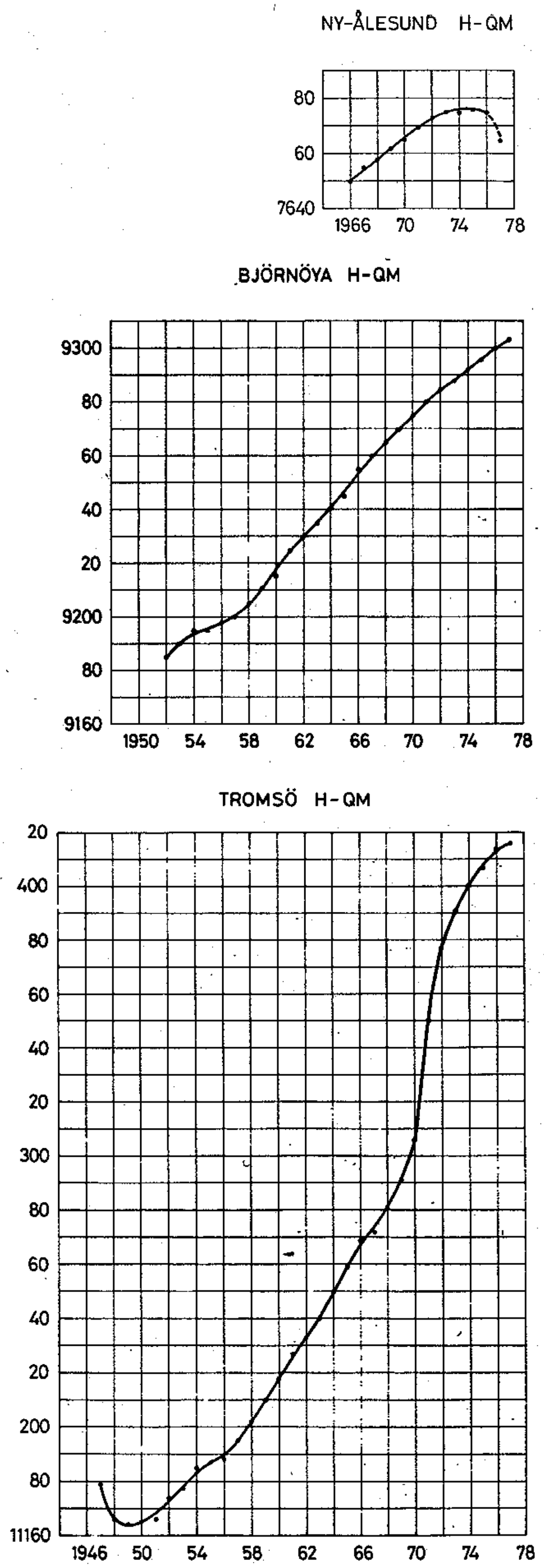

Fig. 1. Annual quiet mean values of the H-component of the geomagnetic field at Ny-Ålesund, Bjørnøya and Tromsø.

In Figure 1 the annual quiet mean H-component at all 3 stations is shown. The trend for the last 25 years in Tromsø has been a general increase in the H-component by more than 8 γ/year as an annual average rate. The H-component at Bjørnøya has also on the average increased for the last 16 years by more than 13 γ/year. In Ny-Ålesund, however, the H-component increased until 1975 by about 2.5 γ/year from 1966, and since 1975 the H-component has dropped by about 5 γ/year. It appears as if a maximum is about to be reached in Tromsø, at least if the trend during the last 5 years continues. There is a large jump in the H-component in Tromsø between 1970 and 1972 which can be related to the construction of the new observatory building only 30 metres away from the variometer house. From other observatories in the Scandinavian region like Dombås (62.07 N, 9.12 E) and Nurmijärvi (60.50 N, 24.60 E), however the increase in the H-component has also been exceptionally strong in this period (see Table II); therefore an increase appears to be a general feature in the H-component in Tromsø for the period 1952 to 1977.

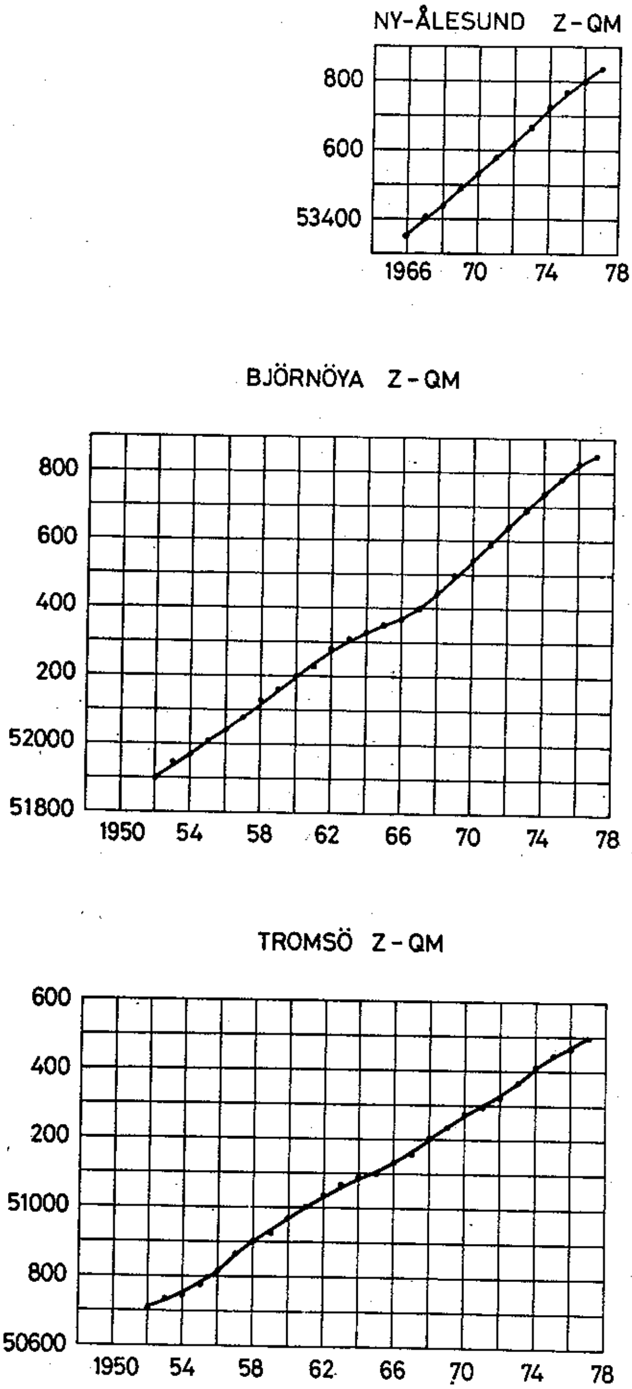

Fig. 2. Annual quiet mean values of the Z-component of the geomagnetic field at Ny-Ålesund, Bjørnøya and Tromsø.

In Figure 2 the annual quiet mean values of the Z-component at the 3 Arctic stations are shown. There is an increase in the Z-component at all 3 places and the increase appears even more uniform than for the H-component. At Tromsø the average increase is about 32 γ/year, at Bjørnøya the rate is 34 γ/year, and finally at Ny-Ålesund it is about 45 γ/year. The rate of change therefore increases slightly by latitude.

In Figure 3 the declination angle (D) for the three different observatories is presented. This parameter of the magnetic field appears to have varied quite uniformly in this part of the Arctic during the time period studied. For the period from 1952 to 1966, before the observations at Ny-Ålesund were started, the declination at Tromsø and Bjørnøya varied almost in parallel, and shifted towards east by about 1°. After 1966 an oscillation towards west occurred, but the minimum westward direction was reached in 1971 at Tromsø and Ny-Ålesund, and between 1972 and 1973 at Bjørnøya, as if a local phase shift were present. Since 1973 the declination at all 3 places has drifted towards east, and by the end of 1977 the declination is back to the same values as in 1966.

A closer look at the three different diagrams of the D-component reveals that the amplitude of the westward oscillation between 1966 and 1976 is largest at Ny-Ålesund (~ 22′) and smallest at Tromsø (~12′) with the amplitude at Bjørnøya in between (~19′).

Figure 3 also shows the variations in the D-component at Nurmijärvi in the period 1953–1976 according to the results derived by Nevanlinna (1978). Nurmijärvi is close to the same magnetic meridian as the Norwegian stations (see Table I) and the variations in D are very similar along this meridian chain. The amplitude of the westward excursion between 1966 and 1976 at Nurmijärvi is ~7′, less than on any of the higher latitude stations, as if the rate of change of D decreases by latitude.

Finally Figure 4 shows the mean values of the total field strength (F) at the three different Norwegian stations deduced from Figures 1 and 2. As expected, the yearly variation in F closely follows the Z-component since this component is the dominating one for these high latitude stations.

CONCLUSION

The earth's magnetic field at the three Arctic stations Tromsø, Bjørnøya, and Ny-Ålesund has on the average increased by 35–45 γ/year in strength during the time interval from 1966 to 1977. Such an increase could take place either as a conse-

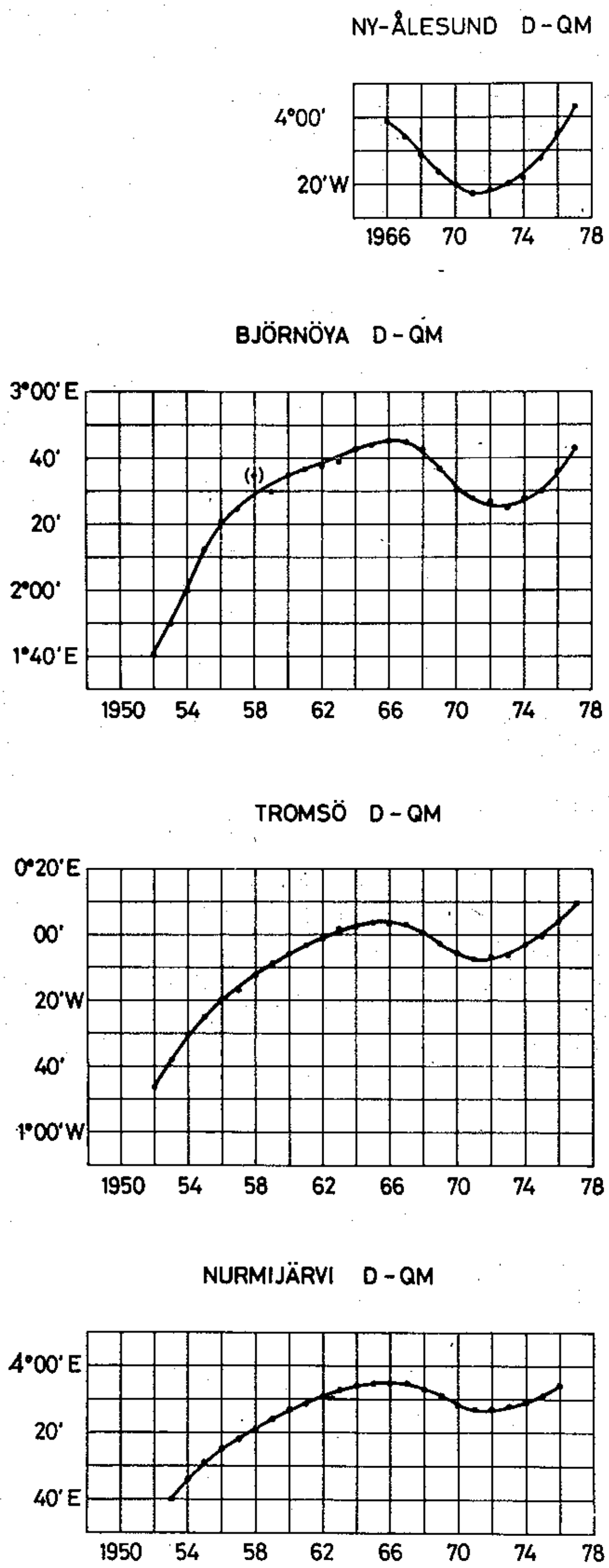

Fig. 3. Annual quiet mean values of the D-component of the geomagnetic field at Ny-Ålesund, Bjørnøya, Tromsø and Nurmijärvi. The latter curve is obtained from the work by Nevanlinna (1978).

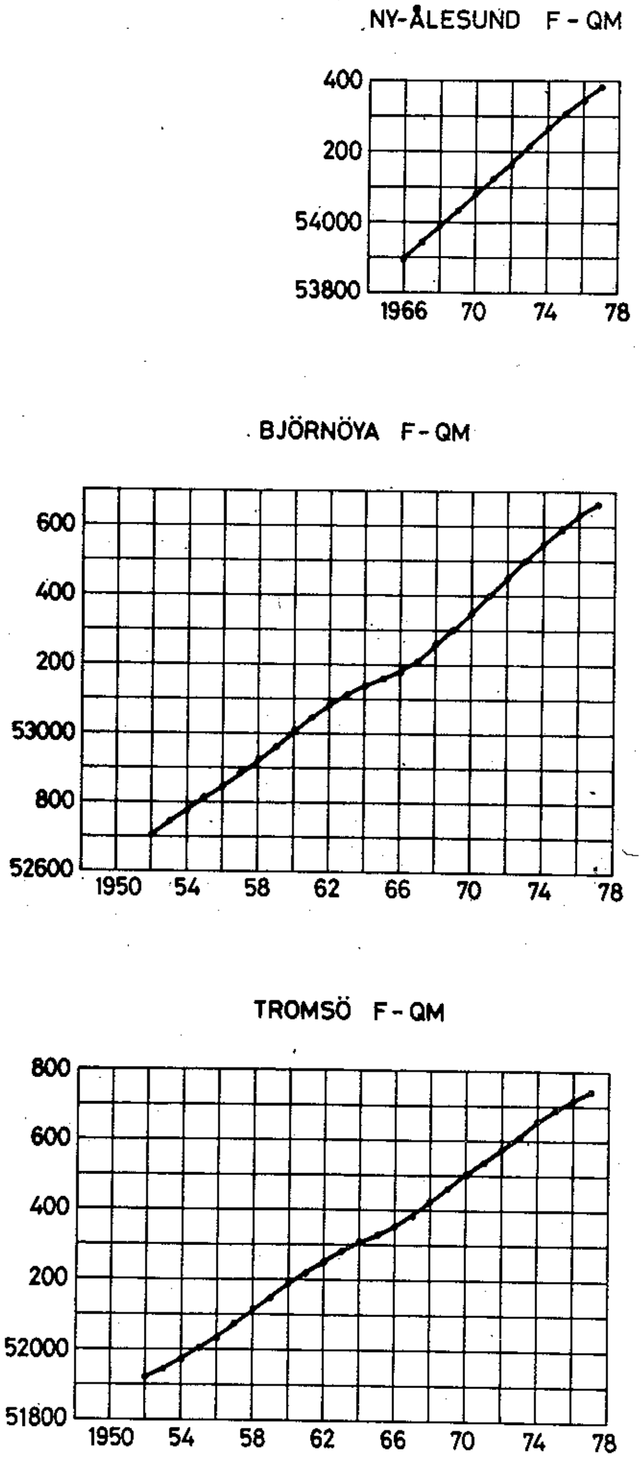

Fig. 4. Annual quiet mean values of the total geomagnetic field strength at Ny-Ålesund, Bjørnøya and Tromsø.

quence of a general growth of the earth's magnetic field strength, or as a drift of the geomagnetic north pole towards this region, or as an increase in a local region of the magnetic field.

According to results derived by McDonald & Gunst (1967), the global average magnetic dipole moment is decreasing and has decreased by as much as $6 \times 10^{22} \gamma \, cm^3$ in the last 170 years; therefore it is not likely that the results derived for these stations can be explained by the general variation in the strength of the earth's magnetic dipole moment.

It has also been found that the drifting part of the secular variations (Yukutake & Tachinaka 1968) has a global average westward drift of 0.2 degrees/year (Bullard et al. 1950; Yukutake 1962). The westward drift in Tromsø and Bjørnøya of about 0.07 degrees/year until 1966 is in the right sense compared to the global average value, although a little less in magnitude. The oscillation back eastward between 1966 and 1976 at all three Arctic stations and also at Nurmijärvi is not in accordance with this global average drift of the drifting part of the secular variations.

It is therefore likely that some local variations in the earth's magnetic field are present; particularly the tendency of an increasing amplitude by latitude in the oscillation of the D-component between 1966 and 1976 supports this hypothesis.

Nevanlinna (1977 and 1978) finds that the secular variation in the Scandinavian part of the Eurasian region can be explained by variations in position and strength of a radial dipole (or current loop) situated close to the focus of the Asian regional anomaly. The general agreement between the results obtained at the three different Arctic stations and the sub-Arctic station in Finland therefore indicates that the variations found in the Scandinavian Arctic sector also are in reasonable good agreement with this theory.

A closer examination of the D-components observed in this work, however, reveals that the variations are not in phase at all three stations as the minimum in the D-component at Bjørnøya appears to be lagging behind the minimum in the D-component at other stations by one to two years, the minimum at the other stations being all in phase and occurring in 1971. This time difference, if real, cannot be in accordance with the theory of Nevanlinna (1978), as one would expect the variations at all stations to be in phase. One might therefore infer that an additional source is contributing to the variations at Bjørnøya and most likely this will be a very localized one.

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The assistance of Mrs. Liv Larssen and Mr. Petter Brochmann in preparing this report is gratefully acknowledged.

Table I.

Station	Geographic		Geomagnetic	
	Lat.	Long.	Lat.	Long.
Ny-Ålesund	78.9 N	11.9 E	75.4 N	131.3 E
Bjørnøya	74.5 N	19.1 E	71.1 N	124.5 E
Tromsø	69.6 N	18.9 E	67.1 N	116.8 E
Nurmijärvi	60.5 N	24.6 E	57.8 N	112.9 E

Table II

Mean yearly variation in H measured in γ.

Year Station	1969–70	70–71	71–72	72–73	73–74
Rude Skov	21	26	23	20	17
Lovö	18	18	20	17	16
Nurmijärvi	15	19	15	11	10
Dombås	17	20	18	18	15
Sodankylä	14	13	12	4	5
Kiruna					
Abisko	17	14	10	11	11
Tromsø	15	44	27	14	9
Bjørnøya	5	6	5	3	4
Ny-Ålesund	3	5	3	2	1

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Optical auroral research expedition to Ny-Aalesund, Svalbard

K. HENRIKSEN & M. KRISTENSEN
The Auroral Observatory, University of Tromsø

Henriksen, K. & Kristensen, M. Optical auroral research expedition to Ny-Aalesund, Svalbard. *Geophysica Norvegica*, Vol. 32, No. 1, pp. 7-13, 1980.

During the auroral expedition to Ny-Aalesund, January 1978, observations of the aurora were made by optical instruments operating 24 hours per day. The polar night, clean air, and location within the dayside auroral oval are the main advantages of Ny-Aalesund as a research site for optical aeronomic studies. Preliminary results indicate that the sodium D lines are enhanced during aurora; the atomic nitrogen ^{2}D line at 5200Å is an inherent feature in faint aurora and nightglow; the Li 6708Å emission is distinct in twilight; conspicuous variations appear in the ratio of the intensities of the auroral green/red lines; and an intensity enhancement is observed on the wavelength of the HeI 5876Å emission, correlated with visible aurora.

K. Henriksen and M. Kristensen, The Auroral Observatory, University of Tromsø, P.O. Box 953, N-9001 Tromsø, Norway.

INTRODUCTION

Even though the spectroscopic investigation of the aurora started more than 60 years ago (Vegard 1961), the great spectral variations exhibited by the aurora are incompletely studied and justify intensified research (Sivjee & Romick 1976). Recent measurements from satellites find distributions of heavy ions in the magnetosphere comparable with the distribution of protons (Young et al. 1977), and the possible termination of such ions in the upper atmosphere can be investigated by spectrometric methods.

At Ny-Aalesund spectrometric measurements can be performed continuously for more than two months around winter solstice without the interruption of daylight (Henriksen et al. 1978a). The unique position for observing the dayside aurora has been established by former expeditions (Berkey & Harang 1976).

One characteristic spectral feature of the high-latitude aurora is that the auroral red line at 6300Å is generally stronger than the auroral green line at 5577Å (Henriksen et al. 1978b). The bright parts of the dayside auroral displays are less intense and appear to have smaller dimensions than those on the nightside. The nightside poleward-expanding aurora reaches Ny-Aalesund and constitutes the brightest displays. During weak and moderately disturbed conditions, Ny-Aalesund is a polar cap station on the nightside and within the polar cleft on the dayside.

A great advantage in Ny-Aalesund is that the amount of man-made light can be controlled and decreased as much as it is necessary. The air is clean, and a large percentage of clear weather, about 50%, makes this station, Figure 1, naturally suited for optical aeronomic observations.

Spectrometric measurements were performed during January 1978, using two Littrow spectrometers, SP3 and SP4 (Stoffregen et al. 1966; Stoffregen et al.

1971). The spectral resolution of SP3 was varied between 2Å and 5Å, whereas SP4 had a fixed value of 30Å. Both spectrometers were directed towards zenith and had a rectangular field of view $\sim 0.3° \times 3°$. The data were recorded simultaneously on digital tape and by a chart recorder. The sensitivity threshold of the analog recordings of SP3 and SP4 were of the order of 10R and 100R, respectively. Doing signal averaging with an on-line signal averager, the limiting intensity of an emission to be identified by SP3 was reduced to about 1R. The total amount of spectrometric data from this expedition exceeded 400 hours.

The research program was designed to investigate the following subjects:

1) The diurnal variation of the auroral green/red line intensity ratio.
2) The intensity of the sodium doublet emission from the dark ionosphere in the absence of moonlight.
3) The behaviour of the $N(^2D)$ 5200Å emission during quiet ionospheric conditions.
4) The lithium emission at 6708Å, originating from the upper atmosphere during twilight.
5) A search for the HeI emission at 5876Å.

In the next section illustrative examples of observations will be presented and shortly discussed. All the data will be analysed and reviewed in future reports.

PRELIMINARY RESULTS

1) Both the auroral green and red lines are significant features of the auroral spectrum, as shown in Figure 3. The elec-

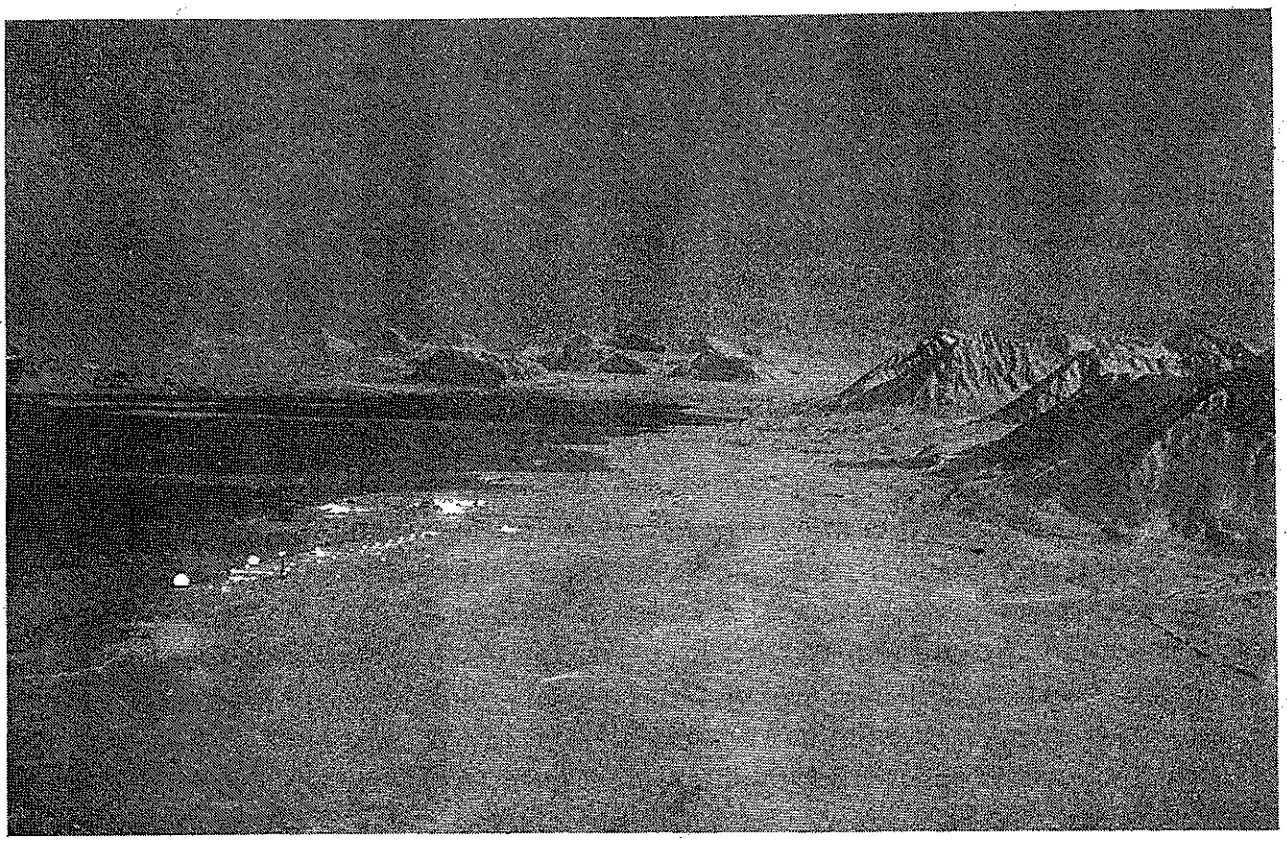

Fig. 1. Ny-Aalesund on the south-western side of Kongsfjorden during full moon midwinter. (Photo: Jens Angard).

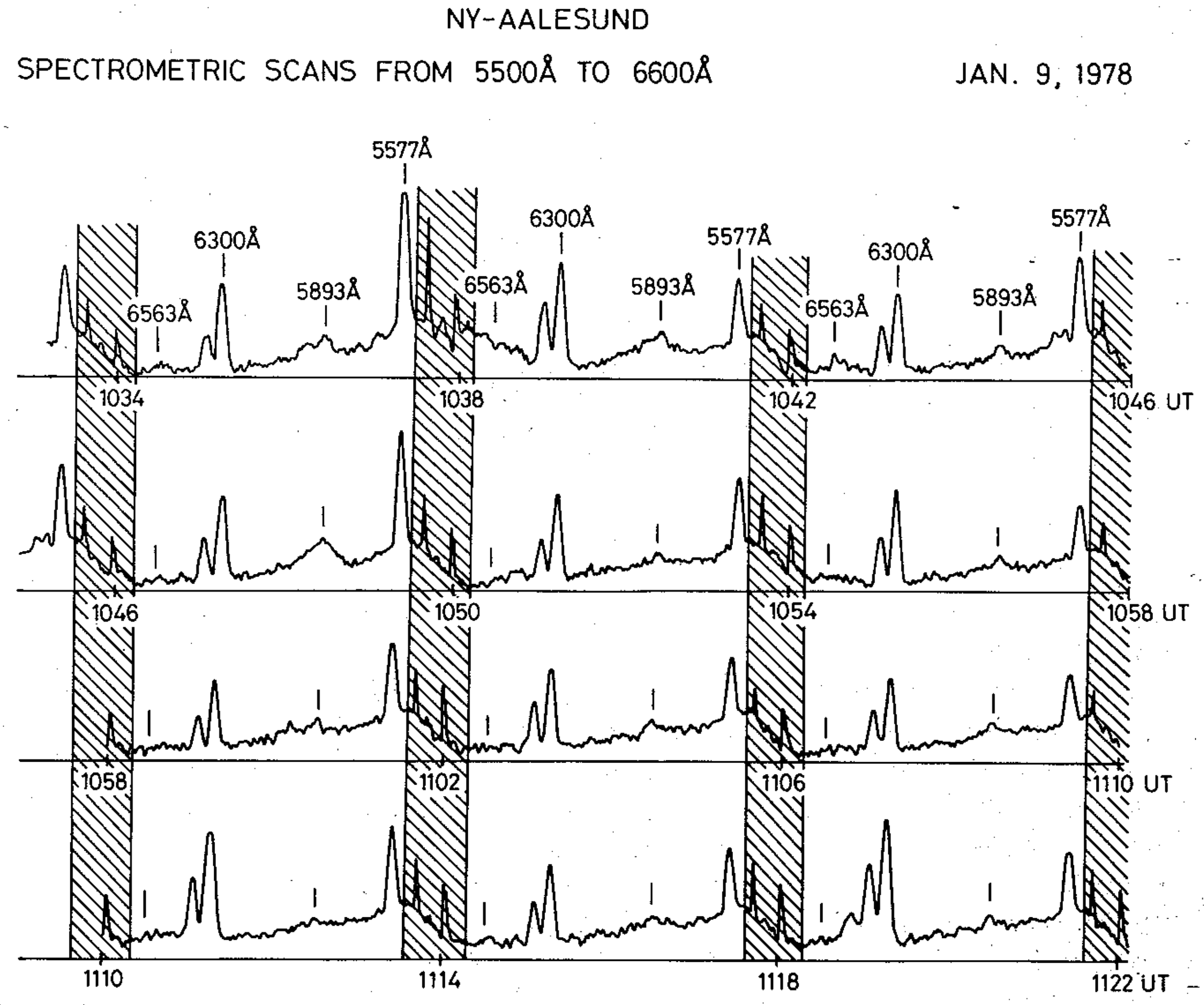

Fig. 2. Spectrograms of the wavelength region from 5500Å to 6600Å with 30Å resolution and 4 min. scanning time during weak dayside aurora. Return part of each spectrogram is cross-hatched. The intensity is not calibrated in absolute units, but varies linearly with the observed emissions. The sensitivity of the spectrometer increases with a factor of two from 6300Å to 5577Å. The auroral green and red lines at 5577Å and 6300Å and the sodium doublet at 5893Å are clear in all the twelve spectrograms.

tron precipitation at high geomagnetic latitudes has high fluxes with energy between 10 eV and 100 eV (Doering et al. 1976), producing most aurora above 200 km (Rees 1963). Occasionally, the intensity of the red line sinks below the threshold of detectability of SP4, and this decrease can be due to harder auroral particle precipitation, generating the aurora below 150 km. At these altitudes collisional deactivation is the main loss of the red line, causing the suppression. Within the auroral zone the particle precipitation is generally harder, and the red line suppression is characteristic of that region (Omholt 1971).

Our observations will continue with SP4 at Tromsø, to get a relevant comparison of the diurnal variation of the green/red line intensity ratio from the polar cap/cleft and the auroral zone. Preliminary results indicate in accord with previous investigations (Eather & Mende 1972; Peterson & Shepherd 1974) that the

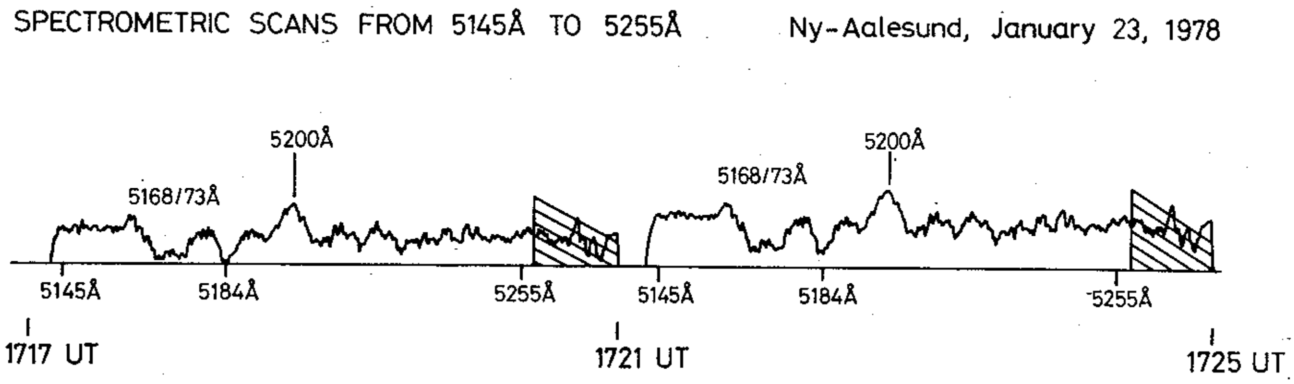

Fig. 3. Two succeeding spectrograms obtained with Nuclear Data Enhancetron signal averager. The observed wavelength region is from 5145Å to 5255Å with 5Å resolution and 4 min. scanning time. Return part of each spectrogram is cross-hatched. The vertical scale is linear, but not calibrated in absolute units. Auroral activity is low, and no aurora detectable by eye. The measurements are carried out in bright moonlight one day before full moon, and the Fe and Mg Fraunhofer lines are distinct together with the NI(^{2}D) 5200Å emission.

red line is relatively stronger to the north of the auroral zone.

The intensity ratio I(6300)/I(5577) decreases with increasing auroral brightness which can evidence a similar relation between energy and flux of precipitated particles in the polar cap/cleft and the auroral zone.

2) Between the auroral green and red lines conspicuous intensity enhancements occur on the wavelength of the sodium doublet at 5890/96Å, Figure 2. The sodium content of the upper atmosphere is located in a layer stretched from 80 km to 100 km. The excitation and possible enhancement of the sodium emission during aurora have become a controversial problem (Hunten 1955; Derblom 1964; Rees, Romick & Belon 1975). Intensity variations as in Figure 2 often occur and may indicate that the enhancement is caused by direct auroral impact excitation of sodium atoms or sodium oxides (Henriksen & Derblom 1978). The observations are performed when the solar depression angle is more than 20°, and accordingly the intensity variations are not caused by solar photoresonance excitation. Due to low resolution the sodium doublet is not resolved and separated from nearby emissions, and therefore these measurements do not conclusively demonstrate intensity enhancements of the sodium emission correlated with aurora. In the recent work of Henriksen & Derblom (1978), additional experimental evidence for enhancements is given.

Sodium light from populated areas is a considerable source of error in auroral sodium investigations. At Ny-Aalesund, however, this disturbance does not exist. Because of the ambiguity imposed by the low spectral resolution, future observations of the sodium doublet will be performed from Ny-Aalesund.

3) The atomic nitrogen emission of 5200Å is continuously occurring. It can be detected even during quiet ionospheric conditions close to full moon. In Figure 3 two spectrograms of the wavelength region from 5145Å to 5255Å are reproduced, showing the N(^{2}D) emission and the prominent solar Fe and Mg Fraunhofer lines at 5168Å, 5173Å, and 5184Å, when the aurora was faint and subvisual. This recording is almost identical with the night-

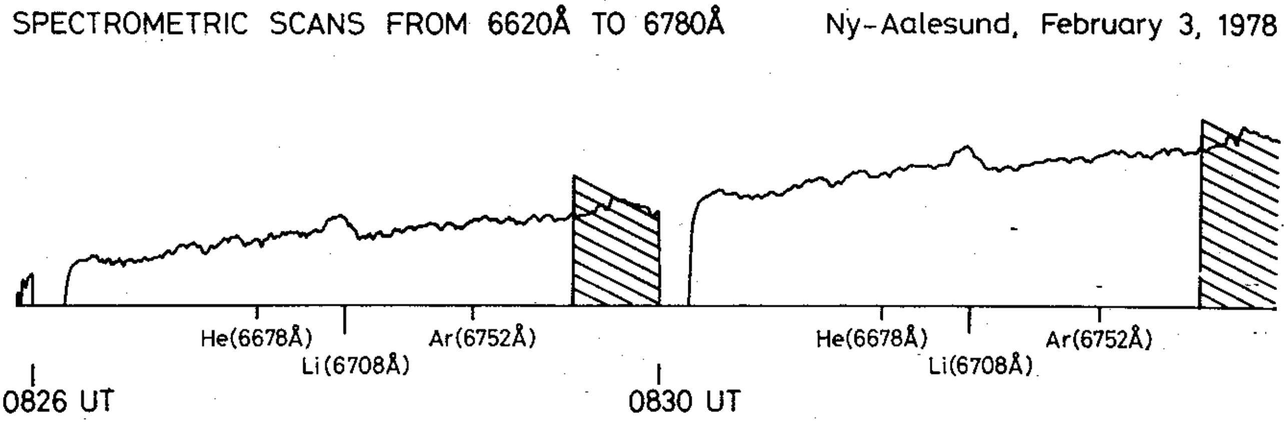

Fig. 4. Two succeeding twilight spectrograms obtained by the same technique as the spectrograms in Figure 3. Spectral resolution is 8Å and scanning time 4 min. No absolute calibration of intensity scale is performed. The He and Ar calibration lines are marked, and the Li 6708Å emission is distinct.

glow spectrum obtained by Henriksen (1978a) in the auroral zone. The nearby N_2^+ band at 5228Å is absent.

The absence or relatively low intensity of the N_2^+ bands is characteristic of the auroral spectra obtained at Ny-Aalesund. This can be another consequence of low-energy particle precipitation, producing aurora above 200 km where the N_2 density is relatively low. Intensity enhancement of the 5200Å line correlated with the visible aurora and particle precipitation is experimentally documented by Shepherd et al. (1976) in a rocket flight from Cape Parry.

4) The lithium emission at 6708Å is clear in spectra obtained during quiet conditions when the geometric solar shadow height is below 90 km. Our preliminary observations indicate that a major part of the lithium atoms is located within 10 km of the mesopause, in agreement with previous observations (Sullivan & Hunten 1964). A typical recording is shown in Figure 4. The observations continued throughout spring 1978, to get more information about the intensity, the height distribution, and a possible excitation due to auroral particle precipitation. Sunlit aurora were monitored to search for possible auroral enhancement. Due to long twilight periods the observation of sunlit aurora is relatively easy at Ny-Aalesund.

Lithium is a minor constituent of the upper atmosphere, and may find its origin mainly in meteors (Sullivan & Hunten 1964). Comparison of measurements from Tromsø and Ny-Aalesund indicates that the lithium content is increased by a factor of two in the polar regions.

5) Recent rocket observations find high fluxes, exceeding 10^7 $(cm^2 \text{ sec sr})^{-1}$, of precipitating He atoms during bright aurora (Bühler et al. 1976). Interactions between these energetic particles and the upper atmosphere will generate helium emissions, and Stoffregen (1969) has observed intensity enhancement on the wavelength of the HeI 5876Å emission in aurora. However, lack of doppler shift in the measurements of Stoffregen has been criticized and made them doubtful as identification of precipitating helium atoms (Vallance Jones 1974).

We have repeated the measurements of Stoffregen and used a signal averager in the data recording to improve the signal

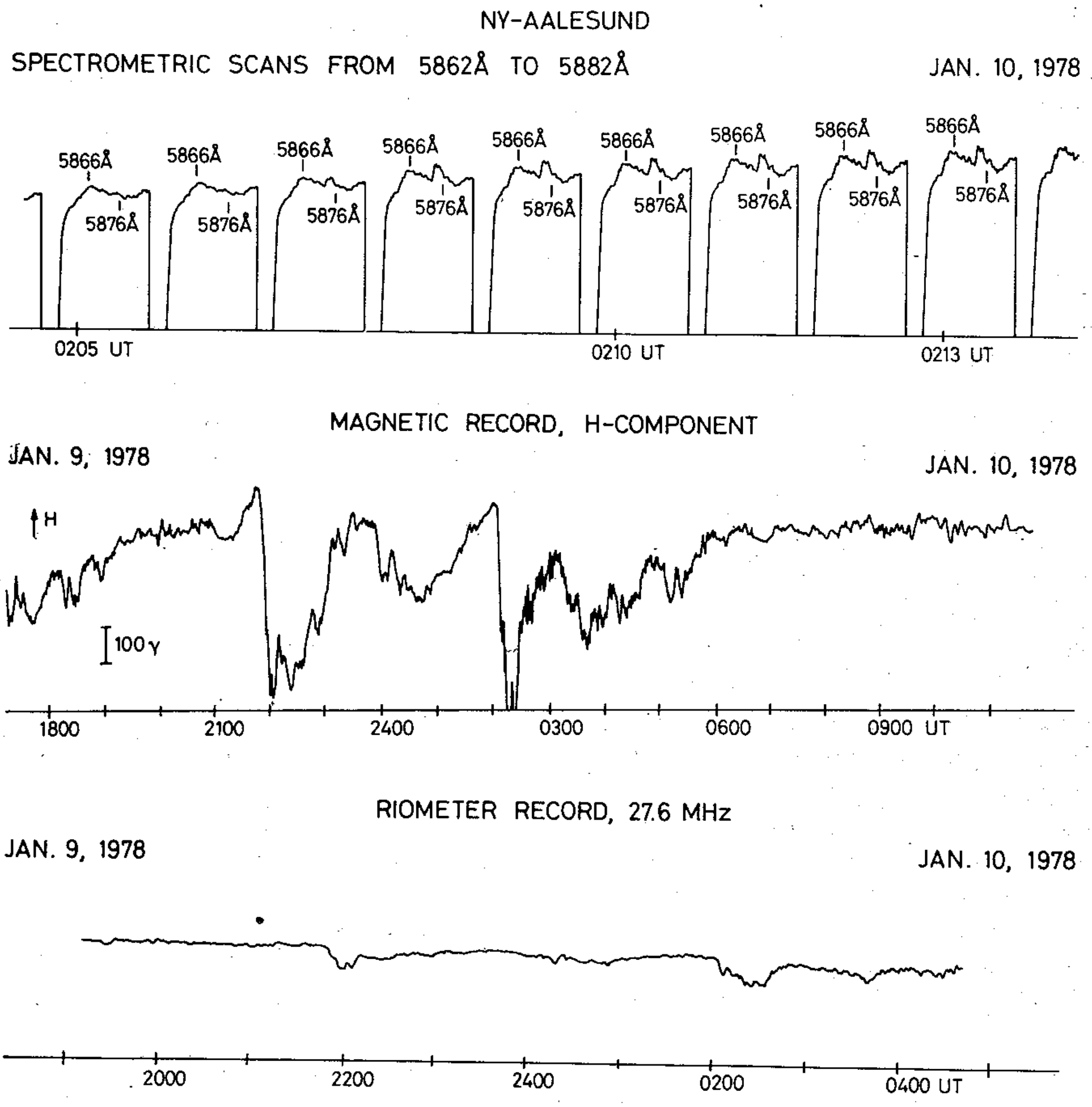

Fig. 5. Spectrograms covering the region from 5876Å to 5882Å, upper panel, when a bright arc passed zenith. The aurora was associated with a strong negative magnetic bay and riometer absorption (the two lower panels), indicating a westward auroral electrojet and precipitation of energetic particles generating ionization below 100 km. The emission at 5876Å increased and became distinct during the interval from 0206 UT to 0208 UT.

to noise ratio. In Figure 5 an intensity enhancement is obvious, shifted about one Ångström to the blue side of the HeI 5876Å emission. This observation was made during an auroral absorption substorm with the spectrometer pointing towards magnetic zenith. An auroral arc passed zenith around 0207 UT Jan. 10, and the enhancement appeared in the spectrogram. The intensity of this emission was weak with a magnitude of the order of a few Rayleigh. The source of the emission is likely to be auroral helium ions, originating in the solar wind (Henriksen 1978b). Wavelength calibration is carried out by helium and neon spectral lamps, and the accuracy is better than one Ångström.

CONCLUDING REMARKS

Our observational period at Ny-Aalesund shows that a large amount of data can be acquired in a relatively short time. This is due to the polar night, high probability of clear weather, and absence of city light. In addition, the location in the regions of the polar cleft during moderately disturbed conditions is unique and should be taken advantage of.

As shown in this report, several features of the polar cap/cleft aurora are considerably different from the auroral zone aurora. Intensified observational programs are necessary before the nature of high-latitude aurora and the physical consequences of the low-energy particle precipitation into the polar atmosphere can be satisfactorily explained.

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