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SCIFER–Height measurements of the midmorning aurora

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Abstract. Dual–site ground–based optical observations were performed January 25, 1995 in support of the SCIFER rocket campaign (Sounding of the Cleft Ion Foundation Energization Region). Two Meridian Scanning Photometers (MSPs) were operative simultaneously at Ny–Ålesund (NYA) and Nordlysstasjonen in Adventdalen (LYR) 118 km apart in the geomagnetic meridian. The photometers at each station scanned approximately along the same geomagnetic meridian plane and measured the intensity of auroral wavelengths as a function of zenith angle and time. The principal wavelengths used in the present analysis were the green 5577 Å and the red 6300 Å emission lines of atomic oxygen. For the magnetospheric cleft auroral activity studied here at 10 hr magnetic local time (MLT), the luminosity maximum for the green line varied in altitude between 125 and 160 km. The red line maximum was in the range 200 to 220 km. The absolute intensity ratio and the height-luminosity profiles obtained using this method were consistent with the near simultaneous rocket measurement of the field-aligned electrons having a characteristic energy of 230 eV by the SCIFER experiment [*Lorentzen, et al.*, 1996]. Geomagnetic disturbance data obtained during the flight included an example of a magnetic impulse event (MIE) coinciding with a bright, discrete arc. The altitude of this arc was > 140 km, and it is doubtful that it produced an increase of conductivity in the E Region or developed a current system which could be associated with the MIE. It is proposed that the transient magnetic events were associated with the energetic pulsating aurora which was occurring equatorward of the zenith. In addition, the altitude of three poleward-moving auroral forms (PMAFs) was measured. Within the error of the observations, the PMAFs do not seem to change in altitude with increasing latitude. The sample is too small for a definitive conclusion, but the method shows promise.

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Introduction

Early auroral height measurements were made using the method of parallactic photography. The technique [*Størmer*, 1952;*Harang*, 1951;*McEwan and Montalbetti*, 1958; *Brandy and Hill*, 1964]. involves the superposition of two photographs taken from at least two sites separated by an appropriate distance. Several analyses of such photographic pairs [*Egeland and Omholt*, 1966; *Deehr*, 1983] have demonstrated the power of the method to show spatial and temporal changes in auroral particle precipitation which are unavailable to satellite and rocket studies. Previous observations of the dayside auroral altitude using all-sky cameras in Murchison Bay and Pyramiden on Svalbard and in Greenland during the International Geophysical Year were valuable to show the mesoscale differences between the dayside and nightside aurora [*Starkov*, 1968; *Lassen*, 1969]. The present study will show that higher time resolution yields valuable information on the smaller-scale temporal and spatial changes which are also not available in other methods.

In the early 60's it became obvious that the height of maximum luminosity was more related to the characteristic energy of the incoming particles than the lower border [*Rees*, 1963]. A general problem is the height/range ambiguity in the data. Discrete arcs are therefore most suitable for triangulation using scanning photometers [*Romick and Belon*, 1967 a, b]. An extensive series of auroral altitude measurements were made using two scanning photometers separated by 220 km in the magnetic meridian in Alaska [*Boyd et al.*, 1971] This series showed for the first time variation with time and latitude of the nightside aurora. Triangulation between Ny–Ålesund (NYA, 78.9° N, 11.9° E) and Nordlysstasjonen in Adventdalen (LYR, 78.2°N, 15.7° E) close to Longyearbyen has been conducted previously with special emphasis on nightside poleward expanding aurora [*Sandholt et al.*, 1982], and on the dayside arcs [*Deehr et al.*, 1980].

In order to estimate the geographical location and the spatial dimension of an auroral feature from a single all–sky camera and meridian scans from a single photometer, one has to make the assumption of a fixed emission altitude. The 5577 Å [OI] emission layer is often assumed to peak at 110 km in the E–region, while the 6300 Å [OI] emission intensities peak around 250 km in the F–region [*Moen et al.,* 1994]. Based on nightside auroral height measurements, the red line emission peak varies between 250–550 km. The objective of the current paper is to establish emission height profiles of the prenoon cleft aurora during the SCIFER overflight of Svalbard, and to use these measurements to determine variations of the altitude in local time and space of certain auroral forms characteristic of the dayside aurora.

Instrumentation

The two meridian scanning photometers (MSPs) operated simultaneously at NYA and LYR have 4 and 6 channels, respectively. Each channel consists of a cooled photomultiplier tube with a telescope and a narrow band interference filter. A mirror in front of the parallel aligned assembly of photometers scans the sky from north to south in the geomagnetic meridian plane (45° W of N). The MSP located at NYA has a scan period of 18 seconds. The field of view of each photometer is 2° and circular. The MSP located at LYR has tilting filters in order to subtract background light from peak transmissions [*Romick* 1976]. Two individual peak and background scans are averaged before recording the data, resulting in a time resolution of 16 seconds for each scan of the processed data. The field of view is 1° and circular. In addition we have in situ information on the particle fluxes measured by the SCIFER rocket [*Lorentzen et al.,* 1996]. The two stations cross geomagnetic local noon at ~08:30 UT, so the data of interest were taken near 10 MLT (06:30 UT).

Experimental technique

The height of maximum luminosity was calculated by the same method as described by *Boyd et al.* [1971]. The data reduction technique is as follows:

1. Choose an isolated auroral form. This is done by selecting a minimum of 3 scans of data including an auroral form known to be the same from each station. Thus, the structure must be distinguishable from other auroral forms as seen from both sites.
2. Mark peak zenith angles and the minimum angles where the intensities blend into the background. Assuming that the auroral form is aligned with the geomagnetic field, the above angles locate the boundaries of the arc. The height of maximum intensity is then simply

$$h_m = \frac{D \tan\alpha_m \tan\beta_m}{\tan\beta_m - \tan\alpha_m} \qquad (\alpha \neq \beta), \qquad (1)$$

where α_m and β_m are the zenith angles of maximum intensity from LYR and NYA, respectively. D=118 km is the distance between the two sites. Note that if $\alpha_m = \beta_m = 45°$ then $h_m = \frac{D}{2} \tan\alpha_m$. When $\beta_m = 90°$ then $h_m = D \tan\alpha_m$.

3. Subtract the background intensities from the auroral luminosity defined in Step 2 at each station. This is done by fitting an intensity versus zenith angle curve to the data points representing the background at each station. This correction removes light contamination seen with the aurora and scattered from other parts of the sky.
4. Since the magnetic field makes an angle of $\phi = 8.2°$ to the south of the vertical, the corrected intensity versus zenith angle seen from LYR is easily converted to intensity versus height,

$$h(\alpha) = h_m \tan\alpha \left(\frac{1 + \tan\alpha_m \tan\phi}{1 + \tan\alpha \tan\phi} \right). \qquad (2)$$

It must be emphasized that these selecting criterias restrict us to focus only on auroral forms which are relatively narrow in latitudinal extent. [*Belon et al.,* 1966].

Optical observations

A general overview of the auroral activity during the SCIFER flight is given by *Lorentzen et al.* [1996]. The auroral intensity as a function of elevation angle from N and Universal Time (UT) provided by the MSP is shown in Fig. 1. Four auroral forms indicated in Fig. 1 were selected for photometric triangulation. The UT and the Mission Elapsed Time (MET), in seconds for the SCIFER flight is also marked for each event in Table 1. Fig. 2 shows the resulting emission height profiles during the four periods marked in Fig. 1. One expected result obtained by triangulation, is that the 6300 Å [OI] profile is always situated higher in altitude than the corresponding 5577 Å [OI] (Panel 1). These emission are transitions from metastable states, ^1D and ^1S respectively, of atomic oxygen. The [OI] ^1D state is susceptible to collisional quenching below ~200 km, while quenching of the ^1S state only occurs below ~90 km, resulting in a higher–altitude peak for the red emissions.

The measured heights of maximum intensity are shown in Table 1, along with the estimated characteristic energy. The vertically integrated λ 6300/λ 5577 intensity ratio and the volume emission ratio were found using a N–S arc thickness of 15 km. According to *Rees and Luckey,* [1974], the characteristic electron energy, E_c, of the primary particles was estimated from the observed red to green intensity ratio to be 0.3 – 0.6 keV. This is consistent with the altitude of maximum emissions also given in Table 1. In addition, the altitudes found using the method in this work are in agreement with previous measurements of the dayside aurora [*Starkov,* 1968; *Lassen,* 1969; *Deehr et al.,* 1980].

Rocket observations

The SCIFER rocket measured differential energy electron fluxes during its flight. At about 710 sec flight time, corresponding to 74.7° ILAT (approximately magnetic zenith from LYR), a sharp transition boundary was seen in the electron spectrogram [*Lorentzen et al.,*

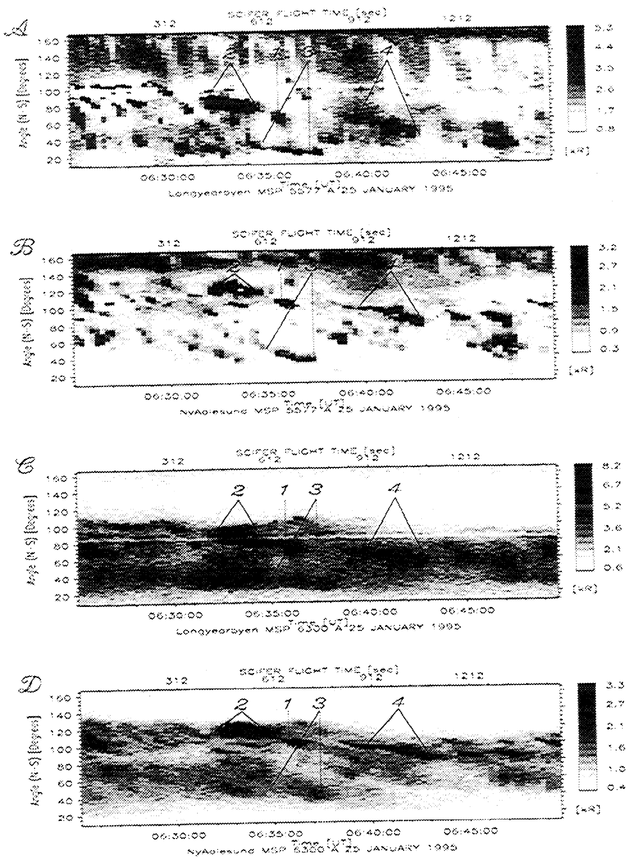

Figure 1. MSP grayscale intensity plots for 25 January 1995 from Nordlysstasjonen in Adventdalen and Ny–Ålesund. Intensities are plotted as a function of time and elevation angle from N horizon. The SCIFER flight time is also given in seconds in each panel. Panels (A) and (C) show the auroral [OI] 5577 Å and [OI] 6300 Å emission intensities from Adventdalen, respectively. Panel (B) and (D) show the [OI] 5577 Å and [OI] 6300 Å emission intensities from NYA, respectively. The time intervals used for triangulation listed in Table 1 are marked (1), (2), (3) and (4) in panel (A). Intensity bars to the right indicate the intensities in kR. The extent of the PMAFs used in the calculations are indicated with lines from the numbers.

1996]. Equatorward of this boundary, a diffuse electron flux was measured, which resulted in pulsating aurora described by *Lorentzen et al.* (1996). (These auroras are not amenable to triangulation.) Immediately poleward of this boundary, there was a structured population of soft (few hundred eV) electrons likely of magnetosheath origin. Farther poleward, during 835–875 sec (75.2°–75.6° ILAT) and 950–1000 sec (76.2°–76.5° ILAT) intervals of the flight, two regions of accelerated electron fluxes (anticorrelated with ion precipitation) were detected, each of which was associated with a discrete auroral form typical of dayside aurora. The former of these precipitation regions was traversed by SCIFER slightly to the east of our scanning meridian, and the corresponding auroral feature has been indicated by a cross in panel (A) of Figure 1. During the 835–875 sec interval of flight time, SCIFER measured strong electron fluxes (inverted V signature) with energies in the ~1 keV range, and energy fluxes of 3–5 ergs/cm^2 sec. The latter flux will produce approximately 3 kR of 5577 Å [OI] emission [*Dalgarno et al.*, 1965]. Arnoldy (Private communications, 1995), calculated the E$_c$ from the rocket particle data to be 275 eV which agrees well with our estimates from the emission rate in Table 1.

Discussion

An important feature of the dayside discrete aurora is the poleward–moving auroral form (PMAF) [*Fasel*, 1995]. PMAFs are E–W aligned auroral arcs which form, move poleward, and disappear or linger near the poleward edge of the precipitation region between approximately 10 and 14 hrs MLT. They are related to magnetospheric flux transfer events (FTE) by their timing [*Fasel*, 1995] and their morphology [*Sandholt, et al.*, 1986; *Fasel, et al.*, 1993]. The extent of the PMAFs are indicated in Fig. 1 by the lines pointing from the numbers to the events. The altitude of the PMAFs in the four measurements are given in Table 1, and shown in their time development in Fig. 2. The possible exception is panel 3 in Fig. 2 where the general altitude is lower then the others. It should be noted, however, that the height measurements are most accurate when the arc is in the magnetic zenith of the poleward station, and the apparent lower altitude in Panel 3 may be an error associated with the distance from the station. (See error estimates in Table 1.)

Another dayside phenomenon of interest is the magnetic impulse event [*Lanzerotti*, 1987]. One of these events occurred at about 06:33 UT as recorded by the LYR magnetometer. These events have been associated with the bright, impulsive discrete arcs in the dayside aurora [*Sandholt, et al.*, 1982]. Panel 2 of Figure 2 is a series of height measurements on the arc associated with the impulse. It is evident that the altitude of the maximum luminosity associated with this event is at or above 140 km. It is therefore doubtful that there was enough Hall current in the E region associated with this arc to have generated the observed pulse. Indeed, the more energetic pulsating aurora to the equatorward of

Table 1. Heights of maximum auroral emission and estimates of initial electron energy, E$_{\mathrm{ini}}$, for the four examples given in figure 1. Also given, estimated height of the 5577 Å [OI] emission line, measured by hand from the data in Fig. 1., and the estimated characteristic energy, E$_c$, using the 6300 Å/5577 Å emission ratio at LYR.

Time [UT]	*MET [s]*	*Index mark*	*Max 6300 Å height [km]*	*Max 5577 Å height [km]*	*E*$_{\mathrm{ini}}$ ~ keV	*Mean 5577 Å height [km]*	E$_c$ ~ keV
06:35:28	656	(1)	200	160	1	180 ± 30	0.3
06:33:30	522	(2)	200	150	2	130 ± 25	0.6
06:36:30	702	(3)	220	125	3	130 ± 50	0.3
06:41:30	1002	(4)	210	130	4	120 ± 20	0.6

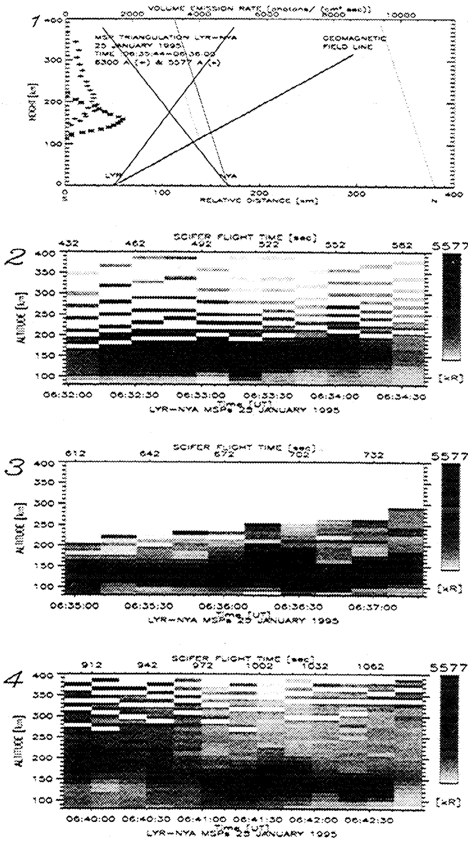

Figure 2. Emission height profiles obtained on 25 January 1995 from Ny–Ålesund and Nordlysstasjonen in Adventdalen. Panel 1 shows the volume emission rate as a function of altitude. The [OI] 6300 Å is plotted as (+) and the [OI] 5577 Å as (*). Panel 1 shows the geometry of triangulation. Panels (1), (2), (3), and (4) corresponds to the time intervals reported in Table 1. Intensities are given in Rayleighs for panels 2–4, which shows the time development of the auroral altitude. The plane of the diagram is the vertical plane containing the geomagnetic meridian through LYR and NYA. The boundaries of the auroral arc are drawn from where the 5577 Å intensities blend into the background in the intensity versus zenith angle traces from LYR.

the zenith could easily have been responsible for significantly changing the conductivity in that region, since its altitude was at or below 110 km according to the particle data from SCIFER [*Lorentzen, et al.*, 1996].

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