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OBSERVATION OF ELECTRON DENSITY IN THE AURORAL IONOSPHERE—RESULTS OF THE ANTARCTIC ROCKETS S-310JA-11 AND -12

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Abstract: During the 26th Japanese Antarctic Research Expedition, measurements of electron density were carried out as a part of the coordinated rocket experiments (S-310JA-11 and -12) for wave-particle interactions in the auroral ionosphere. The two rockets were launched into the auroral arcs of different type on May 29, 1985 and July 12, 1985, at Syowa Station (69°00′S, 39°35′E). The electron density profiles show characteristic signatures corresponding to the auroral forms and activities. Especially low altitude ionospheric layer of high electron density was observed in a bright arc of the break up type aurora by S-310JA-12 during its ascending.

1. Introduction

Sounding rocket experiments into the aurora were carried out successfully on May 29 and July 12, 1985, during the 26th Japanese Antarctic Research Expedition (JARE-26), at Syowa Station, Antarctica. The experiments have a mission to clarify the wave-particle interaction in the auroral ionosphere. The details of the scientific aim and the experimental summary are described by YAMAGISHI and FUKUNISHI (1985) and EJIRI *et al.* (1988). Among the missions of the rocket experiments the impedance probe (NEI) provides the electron density along the rocket trajectory as one of basic parameters of the background ionosphere. In this report a brief description is given for the electron number density obtained by the Antarctic sounding rockets S-310JA-11 and -12 along the rocket trajectories. Discussions are given on several points of interest to be investigated in connection with other cooperative observations by the on-board instruments and the ground based equipments.

2. Instrumentation and Observation

The NEI system installed on the Antarctic rockets S-310JA-11 and -12 is basically the same that used during the IMS period (TAKAHASHI *et al.*, 1981). Impedance of the probe immersed in a plasma shows a frequency-dependent nature with various

Table 1. Instrumental parameters for the NEI system on board the sounding rockets S-310JA-11 and -12.

Sweep freq. (MHz)	Sweep time (s)	TM response (Hz)	Probe	Capacitance range (pF)
0.0–13.0	0.608	81	1.2 m whip	0.5–300

resonance effects. In the NEI system the electron density is determined by the upper hybrid resonance frequency (f_{UHR}) using the magnetic field strength obtained by the MGF system (TOHYAMA *et al.*, 1988). The instrumental parameters of the NEI system are summarized in Table 1. The main parameters were designed to be the same for the two experiments. Time resolution for the electron density measurement is decided by the frequency sweep time, namely, 0.61 s for both cases.

The measurements were carried out successfully with other on board rocket experiments. Figures 1a and 1b show the sequential swept frequency output of the NEI system for an initial portion of the flight paths of the S-310JA-11 and -12, respectively. The rocket altitude and the flight time after the launch are given for the several

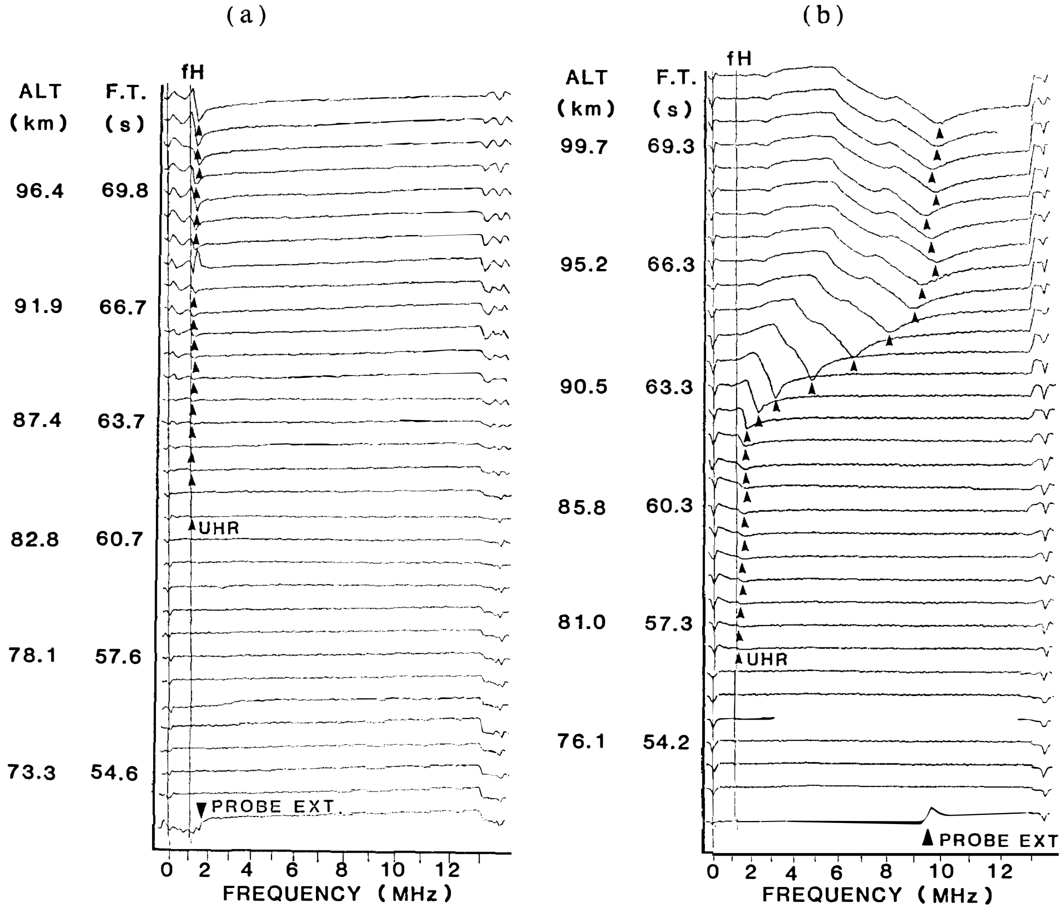

Fig. 1. (*a*) *Sequential sweep output wave form of the impedance probe (NEI) after the probe extention for the S-310JA-11 sounding rocket. Small triangles show the upper hybrid resonance from which the electron number density is determined. Positions of zero frequency and the gyro-frequency are also indicated with solid lines.*

(*b*) *Same as Fig. 1a for the NEI on board S-310JA-12.*

sweep data in the figures. Small triangles in the figure indicate the observed frequencies of the upper hybrid resonance. In the figures zero frequency and the electron cyclotron frequency calculated from the MGF data are also indicated by solid lines. The trends of the UHR frequency converge to the gyro-frequency in the lower altitude, reflecting a smaller value of the electron density at a lower altitude. From the above fact we can verify that the system provides us with correct values of the electron number density in the auroral ionosphere. However, the error of the obtained electron number density become large in a low density region, because the electron density is calculated from the difference of the measured UHR frequency and the gyro frequency. In these systems, the relative errors are about 25, 12, 7 and 4% for density values of 5×10^3, 10^4, 2×10^4 and 5×10^4 cm^{-3} respectively. For the density values greater than 10^5 cm^{-3}, the error of the measurement is less than 3%. Reflecting the different auroral conditions for the two occasions, a drastic difference between two height profiles of the UHR frequency is observed in the two rocket flights.

3. Electron Density Profiles

3.1. Result of S-310JA-11

The sounding rocket S-310JA-11 was launched at 0059:00 UT on May 29, 1985

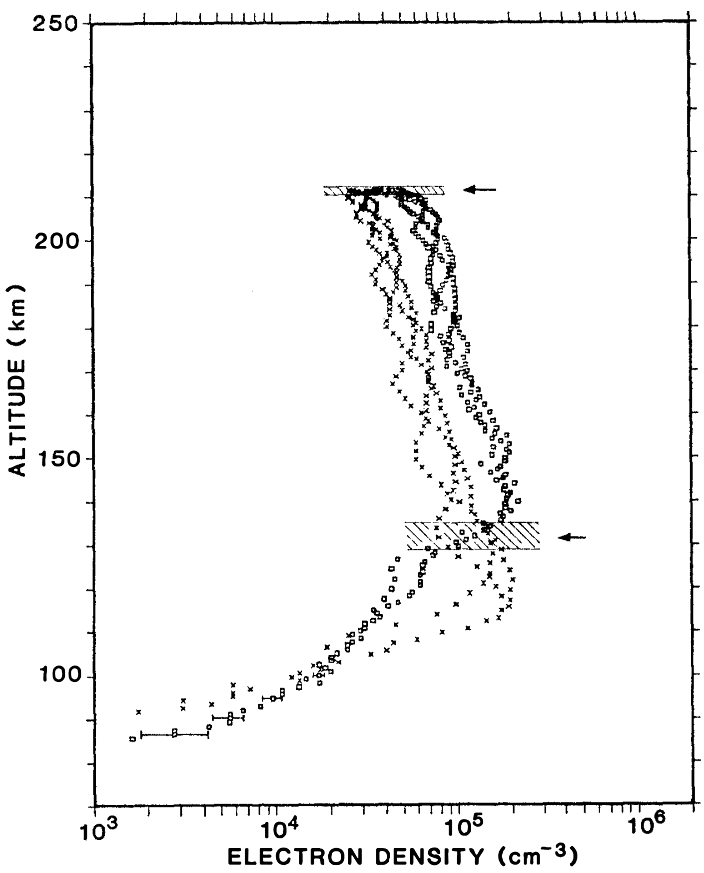

Fig. 2. Electron density profiles observed during the ascending period (squares) and the descending period (crosses) of the S-310JA-11 rocket flight.

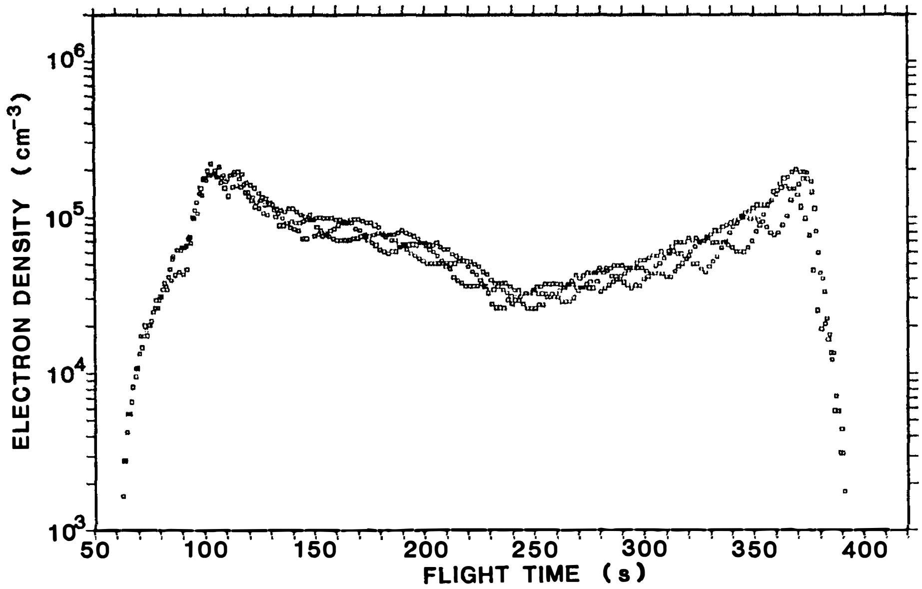

Fig. 3. Electron density profiles vs. flight time of the S-310JA-11 rocket.

into a stable auroral arc during a quiet condition of geomagnetic activity. Figure 2 shows the electron density profiles observed during the ascending (squares) and descending (crosses) periods of the rocket flight. The error of the measurement discussed in the previous section is shown with error bars in the figure for several data in the low altitude region of the ascending period. Peculiar beat patterns in the altitude profile are considered as the electron density depression due to crossings of the probe in rocket wake where the electron density is considerably reduced. Figure 3 shows the electron density *vs.* flight time. From these results several characteristic signatures of the auroral ionosphere can be pointed out. As indicated with arrows in Fig. 2, a steep gradient of electron density were observed in the ascent profile near 130 km altitude and the apex. Considering the crossing of an auroral arc in the ascending period (EJIRI *et al.*, 1988), the steep structure may be ascribed to the traversing of a local enhancement area produced by precipitating particles. During through the descending period the rocket encountered another arc of less intensity. The relatively simple structure of the profile with its peak near 115 km may be considered just as the height profile of the ionospheric structure produced by auroral particles. The ionization level in the low altitude below 100 km is considerably higher during the rocket ascent than the descent. It is considered that there was a noticeable high energy particle precipitation into this region during the ascending period.

3.2. *Result of S-310JA-12*

The sounding rocket S-310JA-12 was launched at 1935:39 UT on July 12, 1985 into a strong auroral breakup. During the ascending period the rocket passed through a strong auroral arc of 14 k*R* brightness. As shown in the height profiles given in Fig. 4 the ionization level in the ascending period showed a considerably large value in comparison with the case of S-310JA-11. The peak density reached 1.2×10^6 cm^{-3} and the altitude of the peak was as low as 101.5 km. The profile during the descent

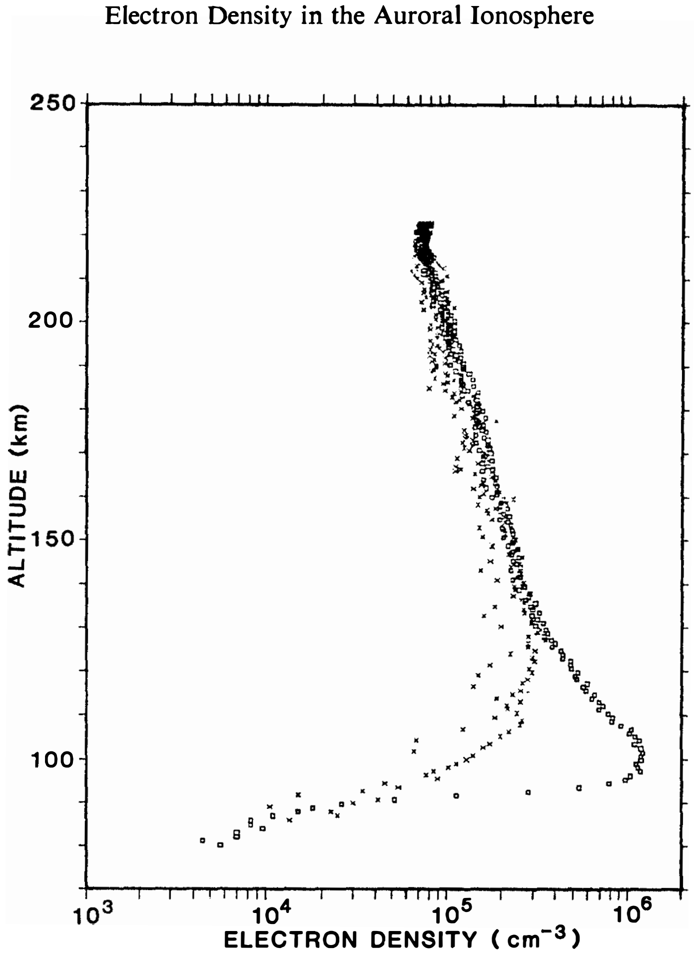

Fig. 4. Electron density profiles observed during the ascending period (squares) and the descending period (crosses) of the S-310JA-12 rocket flight.

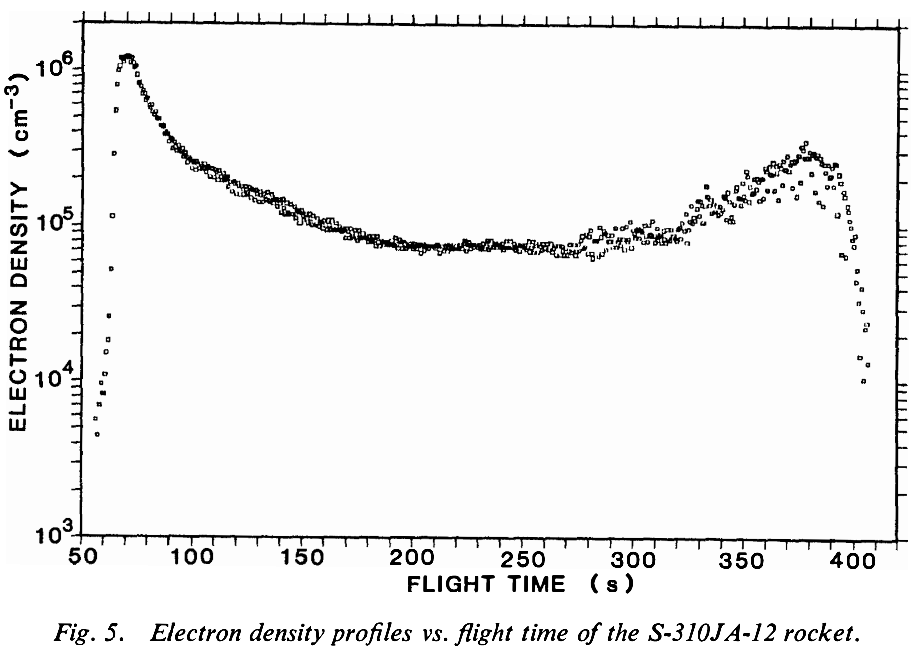

Fig. 5. Electron density profiles vs. flight time of the S-310JA-12 rocket.

showed a rather broad peak near 120 km altitude. It is interesting to note that the peak observed near 100 km in the ascending period entirely disappeared in the descending period. The disappearance may correspond to the softening of the precipitating particles as well as a smaller flux of the precipitating particles during the descent.

The bottom side densities showed a rather high value in low altitude in both of ascent and decent in comparing with the results of S-310JA-11. It is shown that the altitude of $10^4\ cm^{-3}$ density was about 86 km in the ascent, whereas the altitude was about 95 km for the case of the ascent of S-310JA-11. It is interesting that in the descending period the bottom side ionization level showed similar values for the profile of descending period, in spite of the large difference of the profiles near the peak altitudes.

The electron density profile *vs.* flight time is also given in Fig. 5 for S-310JA-12. Although precise descriptions will not be given in this brief report, it is pointed out here that small scale irregularities (several km in their dimension) of the electron density were observed around the region 150–200 km during the descent (300–360 s of the flight time).

4. Discussion

Precise descriptions of the spatial and temporal characteristics of the electron density within auroral arcs, particle precipitation and the critical discussions concerned will be given elsewhere; here we will mention several points of interest to be clarified in future. The dependence of the electron density distribution on the auroral arc luminosity is an interesting subject connected with the ionospheric structure produced by precipitating particles. In this sense we could find a significant relationship between the auroral arc and the local enhancement of the ionosphere, for the period of the flight time of S-310JA-11 from 90 to 230 s and the enhanced ionization peak near 100 km in the ascending period of S-310JA-12. Quantitative investigation is desirable on the ionospheric structure using also the observation by the ESP instrument. Some other points to be investigated in relation to the other on-board instruments are:

(1) Various modes of plasma emission are strongly observed in the region of especially enhanced ionization peak during the ascending period of S-310JA-12. The ionospheric condition to produce the strong emission must be investigated.

(2) The interrelations between a steep gradient of the background ionospheric structure and the small scale structures observed by the PWN instrument.

(3) Precise examination of the irregularity structure around the region of field aligned currents observed by the MGF.

Above may be clarified with the analyses including the wave form of the sweep frequency output of the NEI system, because it contains various information on plasma such as the electron temperature, small scale fluctuations, and the charging up effects due to precipitating charged particles.

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