GROSS FEATURES OF ELECTRON TEMPERATURE PROFILE OF POLAR IONOSPHERE

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Abstract: Six electron temperature profiles over Syowa Station are presented. Discussion is mainly concentrated on the energetics of the lower ionosphere.

At the heights above 120 km, particle precipitation seems to be enough for electron heating. Whilst, the observed electron temperatures at the heights of $\approx$100 km need excess energy sources besides the precipitating particle heat source.

The result shows that the biggest magnetic disturbance does not always give the highest electron temperature increase in the lower E region.

1. Introduction

Electron temperature in the polar ionosphere was successfully measured by means of six Japanese rockets which were brought to Syowa Station. The rockets which were launched in the past are shown in Table 1.

Geophysical conditions of these rocket launching days are briefly described in this report only when necessary because they are described by AYUKAWA and HIRASAWA (1980).

Table 1. List of the rockets launched in the past.

Rockets	Date of the experiments	Time of the experiments
S-310JA-2	10 Feb. 1977	03 22 50 LT (00 22 50 UT)
S-310JA-3	26 July 1977	18 35 29 LT (15 35 29 UT)
S-310JA-4	18 Aug. 1978	03 32 43 LT (00 32 43 UT)
S-310JA-5	10 June 1978	01 56 50 LT (22 56 50 UT)
S-310JA-6	28 Aug. 1978	00 56 00 LT (21 56 00 UT)
S-310JA-7	27 May 1978	22 15 50 LT (19 15 50 UT)

As the electron temperature profiles obtained are not fully understood yet, especially from the standpoint of lower ionosphere energetics, we only describe general features of the profiles.

2. Instrument

As the principle of the electron temperature measurement has been described several times (HIRAO and OYAMA, 1970), we describe it very briefly here.

Electron temperature can be obtained by detecting the floating potential shifts which are produced by applying two successive sinusoidal signals of small amplitudes. Although electron temperature probe is not influenced by electrode contamination, it is noted that our probe gives erroneous results when energy distribution of electrons is not maxwellian near floating potential. Non-maxwellian distribution of thermal electrons might not be unusual in the polar ionosphere where strong magnetic field and electric field exist. Electron temperature probe can give reliable data on the plasma density above 6×10^3 electrons/cm³. This means generally that our probe can work at the heights above 90 km.

3. General Features of Electron Temperature Profile

Upleg profiles are summarized in Fig. 1. All electron temperature profiles

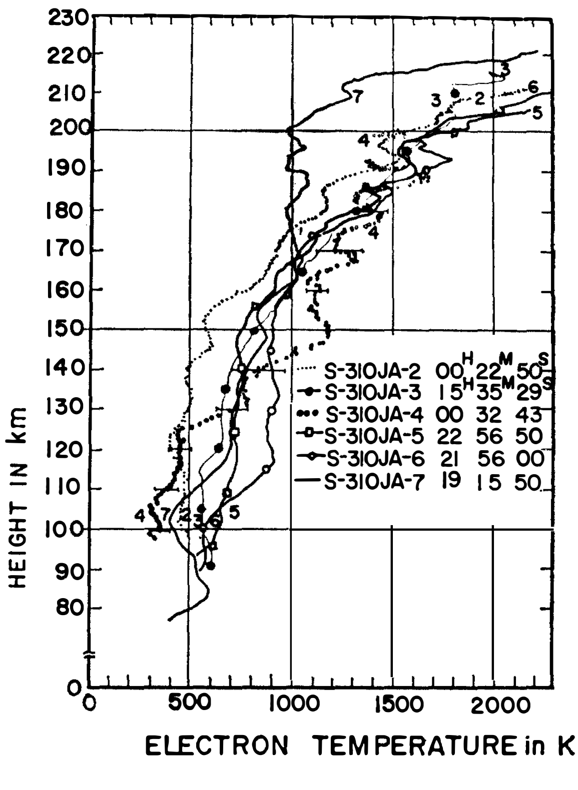

Fig. 1. Six electron temperature profiles obtained over Syowa Station. Numbers attached to the individual profiles correspond to rocket names.

present similar features between 100 km and 150 km. For example, S-310JA-6 profile, whose feature is prominent, shows electron temperature increase at the height of ≈ 100 km and T_e stops increasing at the height of ≈ 120 km, keeps constant value up to 150 km and finally starts increasing after 150 km.

Maximum electron density of the individual profiles appears to correspond to the height (≈ 120 km) where abrupt T_e increase stops as shown in Table 2. It might be noted that the electron temperature at the heights of ≈ 100 km in S-310JA-7 profile is not the heighest among 6 profiles, though the electron density is the highest among 6 profiles.

Table 2. List of the sounding rockets launched from Syowa Station.

Items \ Rockets*	S-310JA-3**	S-310JA-4	S-310JA-5	S-310JA-6	S-310JA-7
Height where T_e increase starts (km)	115	120	100	95***	102
Height where abrupt T_e increase stops (km)	122	130	120	118	122
Height where T_e increases again (km)	135	140	150	150	135
Height of N_e maximum (km)	105	122	112	109	118
Maximum N_e at 100–130 km (/cm^3)	3×10^5	10^5	2.7×10^5	5×10^5	5×10^5

* S-310JA-2 is not listed because the density profile was not obtained.

** Electron density profile by this rocket is similar to midlatitude nighttime profile. Therefore, this profile may be excluded from other four profiles.

*** Not clear.

The above description might be considered as one of the main features of polar ionospheric electron temperature. In mid-latitude electron temperature is almost equal to neutral temperature at the height of 90 km, shows a slight increase around the height of 100 km, approaches neutral temperature at the height of 130 km and finally starts increasing (OYAMA *et al.*, 1980).

4. Energetics of the Lower Ionosphere

As shown in Fig. 1 electron temperature is higher than neutral temperature at all the heights. Can these electron temperature deviations from neutral temperature be explained by energetic particle precipitation?

Heating of the electron gas by precipitating particles can be estimated from a steady state continuity equation (BANKS, 1977)

$$Q_p = \varepsilon \alpha_{eff} N_e^2$$

where N_e is the electron density, α_{eff} is the effective recombination coefficient which was given by WICKWAR *et al.* (1975), and ε is between ≈ 0.623 and ≈ 2.0 eV (WALKER and REES, 1968) in the altitude range of 100–120 km. For example in the case of S-310JA-4, if we take $N_e = 8 \times 10^4$ electrons/cm^3 and $\alpha_{eff} = 4 \times 10^{-7}$ cm^3/s, $Q_P \approx 2.56 \sim 4 \times 10^3$. While, the cooling rate due to rotational excitation by N_2 which is a main cooling factor is described by;

$$L_{en} = N_e \{3.1 \times 10^{-14} [N_2](T_e - T_n) T_e^{-1/2}\} \text{eV/cm}^3 \cdot \text{s}.$$

If we take $[N_2] = 4 \times 10^{11}$/cm^3, $T_e - T_n = 100$ K and $T_e = 400$ K in the above equation, we get;

$$L_{en} \approx 5 \times 10^3 \text{ eV/cm}^3 \cdot \text{s}$$

which is nearly equal to particle energy input. The above calculation shows that electron temperature at the heights of 110–120 km could be roughly explained by particle bombardment.

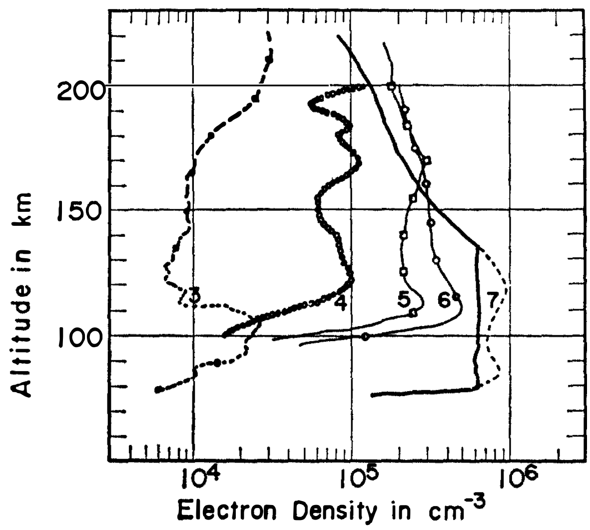

Fig. 2. Electron density profiles obtained by means of Gyro plasma probe and retarding potential analyzer (S-310JA-7) (by courtesy of TAKAHASHI, OYA, MIYAZAKI, MORI and OGAWA).

While at the height of ≈ 100 km, $Q_P = \varepsilon \alpha_{eff} N_e^2 \approx 4 \times 10^2$ eV/cm$^3 \cdot$s even when we assume that $T_e - T_n = 10$ K. This energy input is much smaller than electron loss rate. That is, particle heating is not enough for electrons to deviate even 10 degrees in Kelvin from neutral temperature. The same discussion holds for other five profiles. To explain the deviation of electron temperature from neutral temperature, some other heat sources must be found out.

SCHLEGEL and ST-MAURICE (1980) observed anomalous electron temperature enhancement around the heights of ≈110 km with a Chatanika IS radar. They attributed this enhancement to unstable plasma heating (Joule heating was not sufficient for the observed electron temperature). Their theory seems to explain the departure of electron temperature itself very well. However, more detailed study must be done in the future.

5. Concluding Remarks

Our Observation shows that

(1) the biggest auroral event does not always produce the highest electron temperature,

(2) excess energy which raises electron temperature above neutral temperature is not clearly identified yet at the height of ≈100 km.

In order to have a clear understanding of the energetics of the lower ionosphere, we need well-organized rocket experiment. The experiment should include the measurements of energetic particles of wide energy ranges, magnetic and electric field, ion and electron temperatures, energy distribution of very low energy electrons, and plasma irregularities.

Acknowledgments

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