Rocket Observations of Plasma Density Irregularities in the Polar *E* Region

Hirotaka MORI*, Tadahiko OGAWA* and Shigeru MIYAZAKI*

電離層プラズマのゆらぎ

森 弘隆*・小川忠彦*・宮崎 茂*

要旨: 高度 90～120km の電離層領域で変動周波数 10～100 Hz 程度の電離層プラズマのゆらぎが観測された．観測はラングミュアプローブで行われ，そのゆらぎの変動は，周囲の平均的な電子密度量に対して，数 %～10% 程度の振幅を有する変動で，この変動が観測される領域は，オーロラ発光領域と密接に関係している．

Abstract: Low frequency (10～100 Hz) electron density irregularities were observed in the height range of 90 to 120 km in the polar ionosphere by Langmuir probes on board sounding rockets launched at Syowa Station in 1972–1973. Preliminary analysis shows that the irregularities have relative amplitudes with respect to the ambient average electron density of a few to 10% and that the irregularity region seems to be closely related with optical aurora.

1. Introduction

Cylindrical Langmuir probes on board six sounding rockets launched at Syowa Station succeeded in obtaining electron density profiles in the antarctic *E* layer, together with data on low frequency density irregularities. The details of the electron density profiles are given in this issue by S. MIYAZAKI.

The density irregularities, with which we are concerned here, were detected in the height range of 90 to 120 km, more or less, in all rocket experiments. Preliminary results are presented on some characteristics of the observed irregularities, including the frequency spectrum and the height variation of their amplitudes. Also, the relation between the irregularity regions and optical aurora is briefly discussed. The generation mechanism of irregularities is not clear. More detailed analysis is now in progress.

2. Observations

Table 1 lists the ionospheric conditions during each flight. To illustrate the detailed profiles of the observed density irregularities, the Langmuir curves obtained

* 郵政省電波研究所. Radio Research Laboratories, Nukuikita-machi, Koganei-shi, Tokyo.

Table 1. Ionospheric conditions during rocket experiments.

Rocket	Date	Time (45 EMT)	Geomag. H-component (γ)	CNA (db)	Ionogram
S-210JA-8	Aug. 11, 1972	0401	−450	−2.6	Blackout
-9	May 14, 1972	0213	−290	−1.3	Blackout
-10	May 16, 1972	0202	−200	−0.3	Spread F
-16	Feb. 15, 1973	0245	−300	−1.5	Sporadic E
-17	Apr. 23, 1973	0254	−750	−5.0	Blackout
-18	Aug. 23, 1973	0353	− 50	−0.5	Unstable

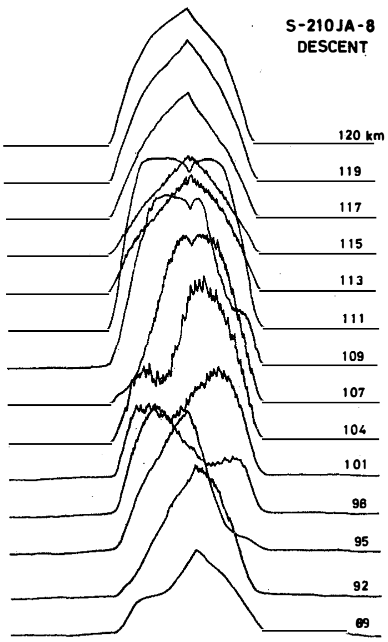

Fig. 1. Langmuir probe data at each height measured by S-210JA-8. Small irregularities exist at the saturation level of the probe current.

by the rocket JA-8 are shown in Fig. 1. Since in this experiment the probe voltage was swept triangularly from −8.2 to +7.8 volts in one second, the full length of the abscissa in each record corresponds to one second. In Fig. 1, small amplitude fluctuations are seen in saturation regions of the electron current. As the probe current in this region is directly proportional to ambient plasma electron density, the current fluctuations observed are considered to be due to plasma density irregularities. Figure 2 shows the electron density profile and the height variation of the relative amplitudes of the irregularities observed by JA-8. Here the relative amplitude is defined as the ratio of an irregularity amplitude to the ambient average electron density. The irregularities have amplitudes of a few to 10% and exist at about the same height in both the ascent and the descent.

We performed a spectral analysis of the fluctuations observed by JA-8 to find the frequency spectrum of the density irregularities; the results are shown in Fig. 3.

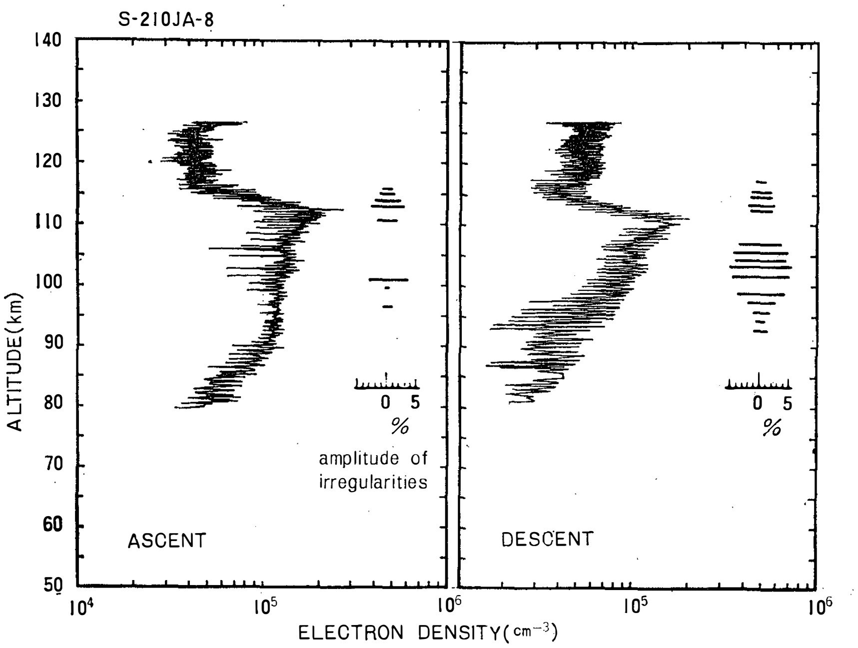

Fig. 2. Electron density profile and height variation of irregularity amplitude during the ascent and the descent of S-210JA-8.

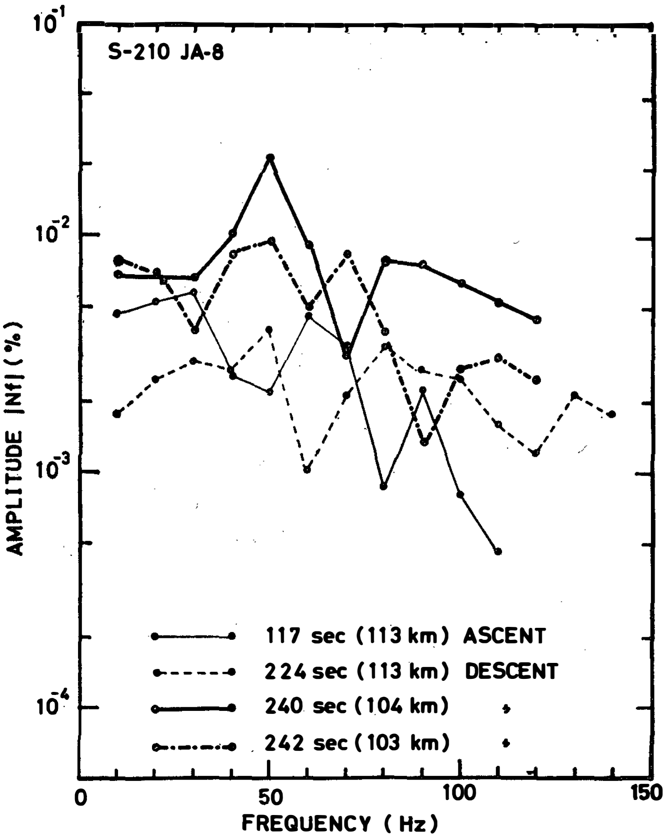

Fig. 3. Typical frequency spectrum of the irregularities detected by S-210JA-8.

Since the frequency bandwidth of the data telemetry was about 100 Hz, the frequency spectrum is meaningless above 100 Hz. It is seen in Fig. 3 that the relative amplitudes are 1-0.1% in the frequency range of 10-100 Hz and decrease as a rule with increases in frequency.

Irregularity regions observed by each rocket are shown in Fig. 4, together with some electron density profiles, in which we can immediately see that the irregularities are found to exist more or less in all rocket experiments and in a restricted height range of 90 to 120 km. Amplitudes of irregularities are between a few to 10% for all cases. Except for the two rockets JA-9 and -18, the irregularities were observed in both the ascent and the descent. On viewing the electron density profiles and the all sky camera records, it is inferred that JA-9 and -18 passed through auroras in the descent and in the ascent, respectively, and that the irregularities are observed only during the passage through the aurora.

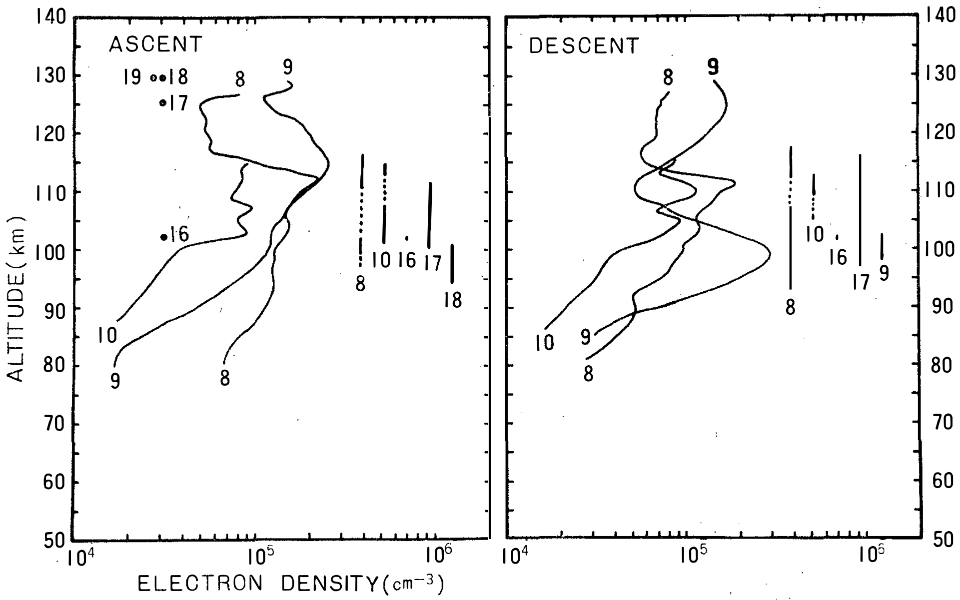

Fig. 4. Electron density profiles and altitude ranges of irregularities observed by six rockets. Number on the figure represents rocket name.

3. Discussion and Conclusion

Although the ionospheric conditions were different during each rocket flight as is seen in Table 1, it is remarkable that irregularities were observed in all rocket experiments. Further investigation is required to clarify the generation mechanism of such density irregularities, so that we cannot say more in this paper concerning this matter.

Here, let us discuss briefly the relationship between the aurora and irregularity

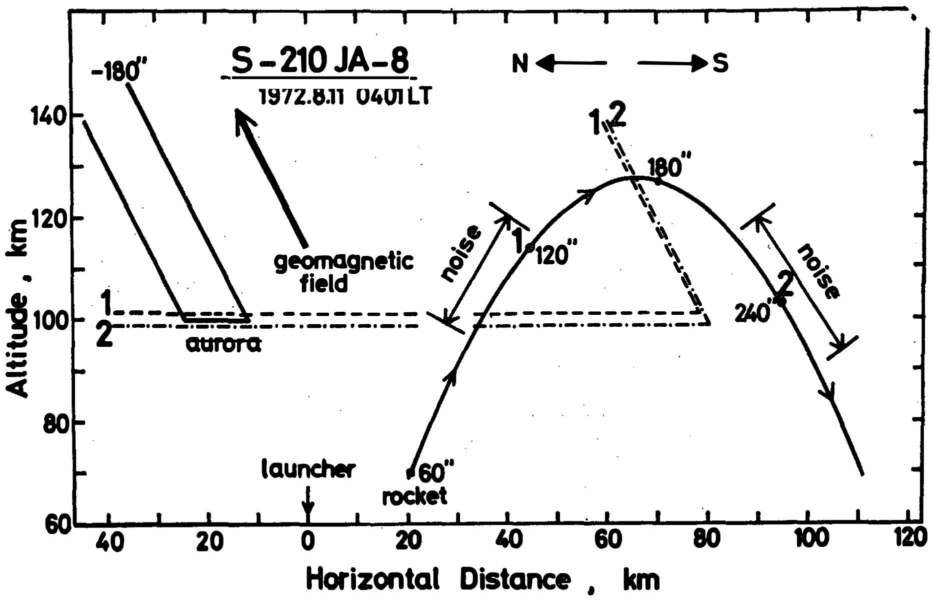

Fig. 5. Sketch of the rocket trajectory of S-210JA-8 and time evolution of the optical aurora.

regions observed by JA-8. Figure 5 sketches the trajectory of JA-8 and the time evolution of the auroral form obtained by all-sky camera photographs; it is assumed that the aurora is field aligned and has its lower border at approximately the 100 km altitude. The aurora which was clearly seen in the northern sky at 3 minutes before the rocket launching was expanding toward the southern direction during the flight as is depicted in Fig. 5. Since the all-sky photographs during the flight were not very clear, it is difficult to define the exact auroral location, and therefore to see whether the rocket passed through the aurora or not. However, as is shown in Fig. 2, there existed sharp peaks in the electron density profile near the altitude of 110 km in both the ascent and the descent paths. This fact suggests that the rocket may have passed through the aurora which expanded over large regions including the rocket trajectory. If this was the case, Fig. 5 indicates that the irregularities are generated near the boundaries of the optical aurora, i.e., near the lower border and side edges. In fact, the JA-18 rocket which passed through the southern edge of optical aurora in its ascent detected irregularities only when the rocket was situated near the lower border. Thus, co-ordinating the data of the optical aurora location, rocket trajectory and irregularity region location may give a clue to the generation mechanism of irregularities.

Recent observations of polar ionospheric irregularities by rocket (Kelley and Mozer, 1973) and by auroral radar (Balsley and Ecklund, 1972; Balsley *et al.*, 1973) suggest that irregularities are produced by plasma instabilities such as the two-stream and the cross-field instabilities, respectively. However, it is not clear whether our observations are explained by either of these instabilities or both, or by another different mechanism.

In conclusion, the density irregularities with relative amplitudes of a few to 10% were observed in the altitude range of 90 to 120 km by Langmuir probes on board six rockets. The generation mechanism of the observed irregularities could not be determined because the equipment on board the rockets did not originally aim to measure density irregularities. Therefore, it is necessary to improve the equipment to investigate the characteristics of the irregularities in more detail.

Acknowledgments

We wish to thank Dr. T. HIRASAWA and K. AYUKAWA of the National Institute of Polar Research for their helpful suggestions and for kindly providing us the all-sky camera photographs. These rocket experiments were supported by the National Institute of Polar Research.

References

BALSLEY, B. B. and W. L. ECKLUND (1972): VHF power spectra of the radar aurora. J. Geophys. Res., **77**, 4746–4766.

BALSLEY, B. B., W. L. ECKLUND and R. A. GREENWALD (1973): VHF doppler spectra of radar echoes associated with a visual auroral form: Observations and implications. J. Geophys. Res., **78**, 1681–1687.

KELLEY, M. C. and F. S. MOZER (1973): Electric field and plasma density oscillations due to the high-frequency hall current two-stream instability in the auroral E region. J. Geophys. Res., **78**, 2214–2221.