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OF THE ACTIVE FRENCH-SOVIET
ARAKS EXPERIMENTS

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Strong wave-particle effects during downward energetic electron injections into the ionosphere

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ABSTRACT. – *In this paper we describe some strong wave-particle effects observed for downward energetic electron injection into the ionosphere under locally disturbed conditions during the second Araks experiment.*

RESUME. – *Dans cet article, on décrit les effets ondes-particules importants observés lors de l'injection vers le bas d'électrons énergiques dans l'ionosphère, lors de conditions géophysiques localement perturbées, pendant la seconde expérience Araks.*

Introduction

This article discusses some results from the data analysis obtained by wide-angle electron detectors (Volvok *et al.*, 1978 ; Gringauz *et al.*, 1980) in the second Araks experiment (Cambou *et al.*, 1980) during gun pauses after pulses of downward electron injection into the ionosphere under disturbed conditions : in "downward" injections the beam makes a 140° angle with the rocket axis. Data from wide angle electron detectors situated on the rocket were compared with wave emission data in the $\omega < \Omega_e$ frequency band (Ω_e being the local electron cyclotron frequency) obtained by a broad band wave receiver (Gusev *et al.*, 1978) that was installed on the nose cone.

The broad band wave receiver was used to measure wave emissions (electric component) for the $f = 0.1$-5 MHz range. Data on wave emission for $\omega < \Omega_e$ (whistlers) were selected by filter (Δf = 300 kHz) whose central frequency was adjusted to the maximum amplitude frequency f_c for the $\omega < \Omega_e$ band ($f_c \sim 650$ kHz for this flight).

We describe below some effects that were observed by the broad band wave receiver in the whistler range and by wide angle electron detectors during downward pulsed electron injections into the ionosphere under conditions locally more disturbed than the first flight in which these effects were not observed. It is necessary to note also that during the second flight we had much larger variation in the pitch angle of downward injections (107-173°) than for the first flight (133-147°).

Particle and wave observations during pauses after the downward pulses of electron gun for the second Araks flight

Figure 1 shows wide angle electron detector data for the first series of pulses injected downward. The energy threshold of a detector is ≃ 8 keV, its field of view ± 45° ; the detectors were installed on the rocket and directed upward. The black area gives the intensity of the injected electron beam ; the effect of injections is clearly seen on the detector, depending on the emission pitch angle θ_0. It is also evident that electron fluxes measured during pauses can be very high and varying with θ_0. It appears that maximum amplitude of electron fluxes during gun pauses is observed for the smaller initial pitch angles of downward injected electrons of preceding pulses.

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Figure 1 is characteristic of particles measured during pauses by wide electron detectors.

1) After the pulses, if electrons are injected downward (the range of initial pitch-angles θ_0 of injected electrons is 107-173°) large electron fluxes were observed ($10^5 - 10^9$ cm^{-2} sec^{-1}).

2) These electron fluxes were not observed during pauses for the upward and middle electron injections (Cambou *et al.*, 1980).

3) The amplitude of fluxes during pauses was dependent on the initial electron pitch-angle θ_0 for preceding electron gun pulses. The amplitude is larger for θ_0 close to 107° and the minimum values of amplitude were observed for θ_0 close to 173°.

4) This effect is always present for downward 27 keV injections but is decreasing with time and/or altitude. The effect disappears when the gun is emitting 15 keV electrons and with the cesium plasma sources on. These 2 parameters cannot be separated because they are effective near the same time when the injections are not downward.

We have compared the data obtained by wide angle electron detectors with the data from a broad band wave receiver for the region of whistlers (electromagnetic emission in $\omega < \Omega_e$ frequency band). The maximum amplitudes of whistlers were expected to appear in $\omega \lesssim \Omega_e/2$ frequency region according to estimates (Alekhin *et al.*, 1971).

Comparisons of data from a wide angle electron detector with the data from the broad band receiver are shown in Figures 2 and 3. In the lower part of the Figures the changing of initial pitch-angle of the injected electrons is shown. The data obtained by the wide angle detector appear in the middle part of Figures 2 and 3 ; in the upper part the data from the broad band wave receiver are shown ($f = f_c = 650$ kHz, $\Delta f = 300$ kHz). In these figures the black area corresponds to gun pulses of 20 msec duration and the very thin black area to short occasional gun pulses. Signals represented by dashed figures correspond to measurements of electron fluxes and wave emissions between pulses of the electron gun.

From Figures 2 and 3 it is possible to see that electron fluxes during gun pauses correlate with bursts of wave emission. It can also be seen that the amplitude of the wave bursts during pauses is dependent on the initial pitch-angles of injected electrons, but this dependence on wave emissions is not so clear than

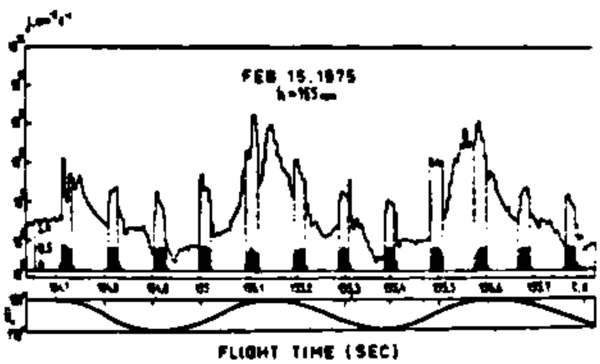

Fig. 1

Variation of the electron fluxes as a function of time during the first series of downward gun injections on Feb. 15, 1975. The black region gives the intensity of the gun current ; the bottom curves shows the direction of the gun with respect to the magnetic field. During the injections, this direction is the initial pitch angle of the electrons.

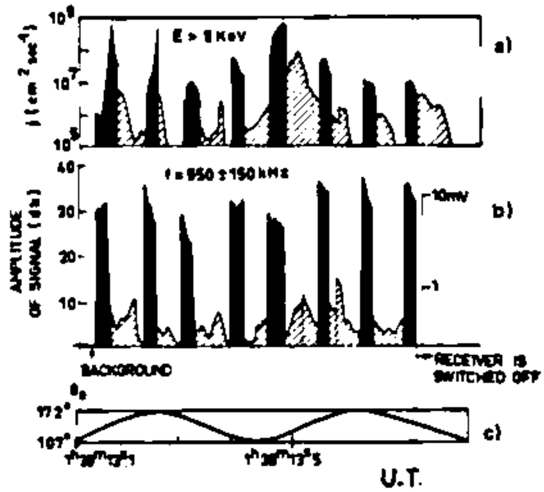

Fig. 2

Variation of the electron fluxes (curve a), of the amplitude of whislter waves (curve b) and of θ_0 (curve c) as a function of time between 193.1 and 193.9 seconds after launch on Feb. 15, 1975.

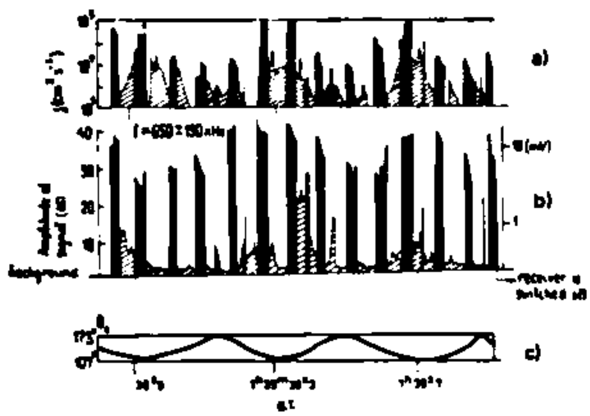

Fig. 3

Variation of the electron fluxes (curve a), of the amplitude of whistler waves (curve b) and of θ_0 (curve c) in function of time between 218.8 and 220 seconds after launch on Feb. 15, 1975.

for particles probably because the signals during pauses are modulated due to rotation of the nose cone ; indeed the same modulation is observed for signals measured during electron gun operation and it is superimposed over the modulation due to the change of initial pitch-angles of injected electrons by rocket rotation. The dependence of measured wave amplitude on the nose cone rotation may be caused by polarization of wave emission.

This question has not yet been answered and investigations are being carried out.

Large electron fluxes and wave bursts during pauses were observed only for series of downward electron injections with initial parameters $E_0 \cong 27$ keV, $I_0 \approx 0.5$ A (E_0 is the initial energy of electrons, I_0 is the intensity of pulse current). As for electron fluxes, wave bursts during the pauses decrease with time and/or altitude for 27 keV electron injections.

Discussion and conclusion

The effect thus detected is very strong, since the electron fluxes detected during the pauses are very high (one order of magnitude over those detected during the gun emissions, cf. Fig. 1).

No definitive conclusion is currently possible as to the origin of this physical phenomenon observed by two different experiments located several kilometers apart.

The following possible hypothesis may be cited :

– A local effect corresponding to a pseudo-trapping in the vicinity of the rocket where the plasma conditions are abnormal (e.g., halo phenomenon, plasma beam discharge). These energetic electrons, pseudo-trapped over times on the order of about 100 msec, may be responsible for the whistlers recorded simultaneously on the nose cone.

– The precipitation of magnetospheric electrons is stimulated by the whistler generated during the downward electron injection into the ionosphere under locally disturbed conditions in this case. By linking the electron fluxes and the whistler waves to each preceding injection of the gun, we can estimate that the region of wave-particle interaction is located below an altitude of about 2,000 kilometers and the length is about several hundred kilometers. Furthermore, the process of decay of whistlers generated during electron pulse injections seems to occur in the same region ($h < 2{,}000$ km).

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