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THE VLF AND ULF RELATED PARTICLE PRECIPITATIONS AND COLD PLASMA STRUCTURES IN THE EQUATORIAL MAGNETOSPHERE

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1. Introduction

Cyclotron wave-particle interaction is expected to produce precipitation of energetic charged particles from the radiation belt into the ionosphere. Specific, isolated patterns of energetic (>30 keV) ion (EI) and electron (EE) precipitation related, respectively, to ULF and VLF waves were, indeed, revealed using low-altitude satellite observations (Titova et al., 1998; Yahnina et al., 2003). It was suggested that the wave-particle interaction producing these evening-side precipitation patterns takes place in regions where the energetic particles drifting around the Earth contact with the cold plasma structures forming so-called "plasmaspheric tail" or "plasmaspheric plume". Energetic electrons should precipitate on the western flank of the cold plasma plume, while energetic protons should precipitate from the eastern flank.

Plasmaspheric plume signatures are often seen on geosynchronous orbit. Geosynchronous investigation has shown that the plume has a fine structure – small-scale (<1 MLT in longitude) enhancements of cold plasma density (Moldwin et al., 1994). In such case one may expect that sometimes the EI and EE precipitation are weakly separated. To verify this suggestion the observations of EI and EE precipitation should be compared with measurements of the plasmaspheric plasma. In this paper we present the results of such a comparison based on simultaneous measurements of energetic electrons and ions at low altitudes (~ 800 km) and cold ions at geosynchronous orbit (6.6 R_E). For this aim we used the data of the Medium Energy Proton and Electron Detector (MEPED) instrument measuring particles with energies >30 keV onboard the low-altitude satellites NOAA-12 (Hill et al., 1985) and data obtained from the Magnetospheric Plasma Analyser (MPA) instrument onboard the geosynchronous LANL spacecraft (McComas et al., 1993). The MEPED instrument has two detectors. At high latitudes (L>3) the orientation of the detectors enables to observe particles both within the loss cone (precipitating particles) and outside the loss cone (locally trapped ones). The MPA instrument measures electrons and ions with energies 1 eV < E < 40 keV. Here the density of protons with energy lower that 10 eV will be considered to retrieve the information on cold plasma distribution along the geosynchronous orbit.

2. Observational results

From the two-year (1996-1997) data set, we selected those NOAA-12 orbits at which both EI and EE precipitation events were observed. In all, 51 events of nearly simultaneous observations of EI and EE precipitation were found. Further, those events were selected for which one of the LANL geosynchronous spacecraft was in the vicinity (within a few MLT hours) of the EI/EE precipitation MLT sector. Only 16 such events were found. The events are listed in the Table. The entries in the Table are the NOAA-12 orbit number, type of the particle burst (EE or EI), UT and MLT, distance of equatorial projection of the particle burst from the Earth, and plasma density measured by LANL spacecraft. All of the particle events are within total distance 4.25 – 7.20 R_E from the Earth. In most cases of the LANL/NOAA comparison (15 from 16 events) the observations of EE and EI precipitation at low altitude are associated with the cold plasma enhancements at geosynchronous orbit. A few EE/EI cases are mapped close to geosynchronous orbit, so we have a chance to make a direct comparison of the EE/EI location with peculiarities of the cold plasma distribution along the LANL orbit.

An example of the EE/EI precipitation is presented in Fig. 1. The thin and thick lines show, respectively, the trapped and precipitating fluxes intensity. The regions of isotropic and anisotropic fluxes are clearly seen in the data. Within the anisotropic zone sharp enhancements of precipitating fluxes are seen at 12:52 - 12:53 UT in the evening MLT sector. More detailed data for time interval 12:51 - 12:53 UT are shown in two bottom panels.

Diurnal variations of cold (<10 eV) ions along the geosynchronous orbit are presented in Fig. 2. Several strong enhancements exhibiting a small-scale plume structure are seen at ~11:30-15:30 UT (16.5-20.5 MLT). The regions of enhanced cold plasma density along the geosynchronous orbit are marked in Fig. 3 by the thick line. Fig. 3a shows the locations of the EE/EI precipitation (triangle/circle, respectively) mapped onto the equatorial plane. Coordinates of the projections are X=-6.13 R_E, Y=1.09 R_E and X=-6.72 R_E, Y=1.31 R_E, respectively. The equatorial projection of the NOAA-12 trajectory crossed an isolated cold plasma structure at MLT=17.2 close to the time when geosynchronous spacecraft 1991-080 entered this region of the dense plasma. It is clear that the EI/EE precipitation occur in the immediate vicinity of the cold plasma enhancement. A possible location of the cold plasma structure is displayed in Fig. 3b. Note, that the oblongness of the cold plasma structure was selected to ensure the proton precipitation to occur poleward of the electron precipitation (see, Fig. 1). Indeed, if a plasma inhomogeneity were elongated in orthogonal (compared to the above structure) direction, energetic protons scattered at the plasma inhomogeneity would precipitate equatorward of electrons. The oblongness shown in Fig. 3b seems to be typical for the events under study. To demonstrate this, all 51 cases of joint EI and EE precipitation observations are displayed in Fig. 4 in co-ordinates MLT - CGLat. Except 4 cases, the EE precipitation is situated equatorward of the EI precipitation.

Table

№	Data	Orbit of the NOAA-12	Type of burst	UT	MLT	Distance (Re)	N (cm^{-3}) (LANL)
1	11.02.96	24544n	EE	13:15:14	17.82	4.91	60
			EI	13:16:02	17.72	5.83	
2	26.02.96	24755n	EE	09:27:04	17.00	6.35	45
			EI	09:27:36	16.82	7.20	
3	14.03.96	24997n	EE	09:55:40	17.41	4.81	25
			EI	09:57:18	16.96	6.89	
4	17.07.96	26775s	EI	12:17:38	18.62	5.99	35
			EE	12:18:12	18.60	5.18	
5	17.07.96	26776n	EE	12:52:10	17.23	6.25	35
			EI	12:52:34	17.17	6.88	
6	01.08.96	26987n	EE	09:01:42	16.77	5.70	40
			EI	09:02:24	16.54	6.68	
7	01.08.96	26988n	EE	10:43:08	16.94	6.07	40
			EI	10:43:34	16.82	6.71	
8	21.01.97	29449s	EI	13:49:10	18.09	5.85	60
			EE	13:49:22	18.10	5.58	
9	27.01.97	29535n	EE	13:52:22	17.56	6.13	30
			EI	13:52:36	17.54	6.49	
10	30.01.97	29581s	EI	20:30:52	18.35	6.18	25
			EE	20:31:20	18.33	5.60	
11	23.04.97	30755n	EI	09:07:24	16.56	6.59	5
			EE	09:07:42	16.45	7.07	
12	18.09.97	32860n	EE	10:02:02	17.20	4.56	20
			EI	10:02:48	17.04	5.34	
13	08.10.97	33145n	EE	11:05:06	17.24	5.99	20
			EI	11:05:36	17.13	6.70	
14	04.11.97	33534s	EI	20:38:16	18.75	6.09	35
			EE	20:39:12	18.69	5.04	
15	04.11.97	33536s	EI	23:59:32	20.74	5.90	45
			EE	23:59:54	20.63	5.49	
16	11.12.97	34056n	EE	12:39:26	17.69	4.25	40
			EI	12:39:52	17.64	4.63	

3. Discussion and Conclusion

We showed that nearly simultaneous EE and EI precipitation observed at low altitudes in the evening sector correlate with signatures of the detached plasma (plasmaspheric plume) at geosynchronous orbit. The result agrees with the suggestion that specific, isolated EE and EI precipitation related to VLF and ULF cyclotron waves (Titova et al., 1998; Yahnina et al., 2003) are generated at the flanks of the region of the enhanced cold plasma density forming the plasmaspheric plume. Moreover, the generation is evidenced at the edges of the small scale structure within the plume. Since the plume has multiple small scale structure, one may expect multiple generation regions. Such multiple sources of precipitation and waves within the plume were, indeed, recently observed by Yahnin et al (2002). The oblongness of the cold plasma structures deduced from the low altitude observations of energetic particles agrees with elongation of the plasmaspheric plume predicted by the theory (e.g. Grebovsky, 1970) and directly observed (Spasojevic et al., 2003).

Finally, we conclude that presented results confirm the idea that EI/EE precipitation patterns observed onboard low-altitude satellite can be used for diagnostics of the detached cold plasma in the equatorial magnetosphere.

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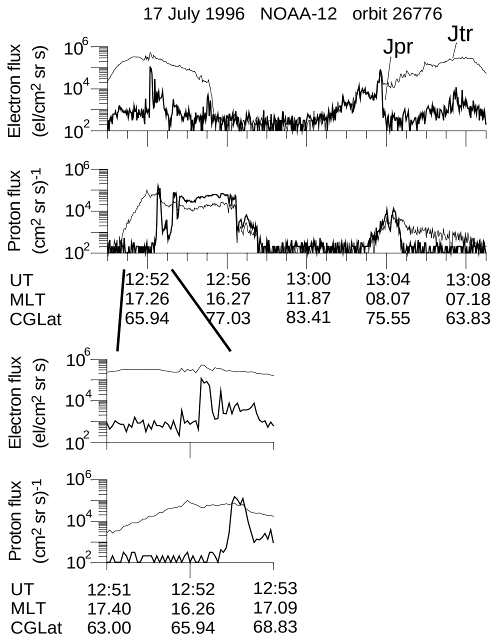

Fig. 1.

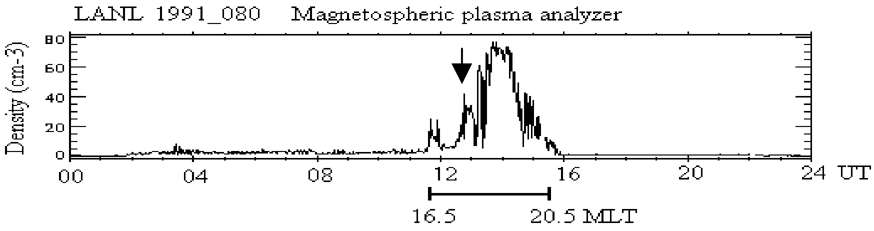

Fig. 2.

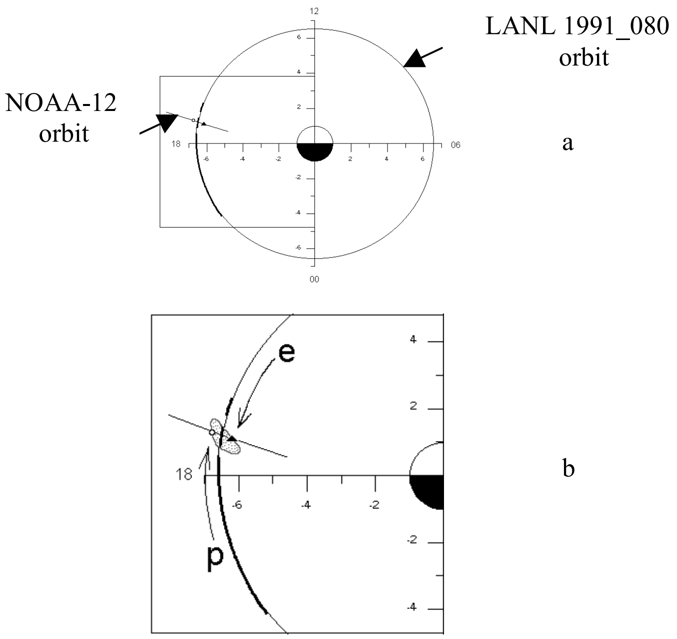

Fig. 3.

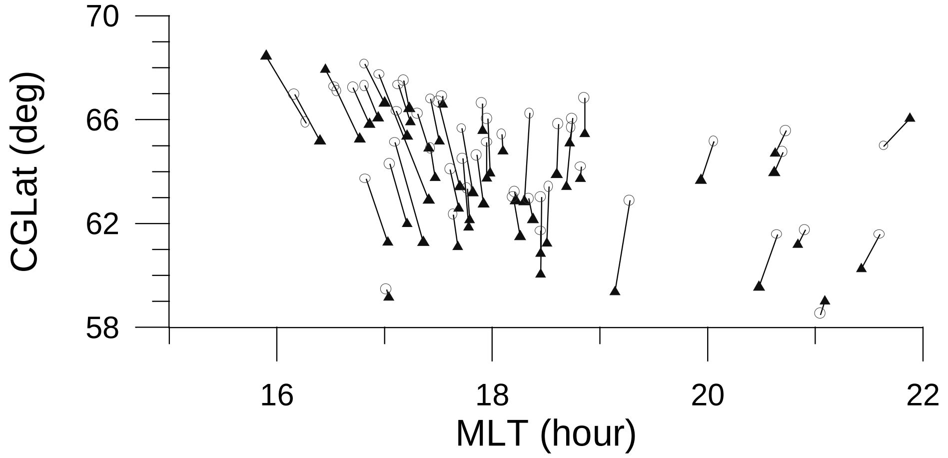

Fig. 4.

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