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# LONGITUDINAL DRIFT AND PRECIPITATION OF THE ENERGETIC ELECTRONS DURING THE SUBSTORM

A.A.Lubchich[1], A.G.Yahnin[1], E.E.Titova[1], V.Yu.Trakhtengerts[2], A.G.Demekhov[2], R.D.Belian[3], J.Manninen[4], T.Turunen[4], R.Rasinkangas[5]

[1]*Polar Geophysical Institute, Apatity, Russia*
[2]*Institute of Applied Physics, Nizhny Novgorod, Russia*
[3]*Los Alamos National Laboratory, Los Alamos, NM, USA*
[4]*Geophysical Observatory, Sodankyla, Finland*
[5]*Department of Physical Sciences, University of Oulu, Oulu, Finland*

***Abstract.*** Anisotropy of the drifting energetic electron cloud injected during a small isolated substorm is studied on the basis of data from several high altitude satellites spaced in longitude. It is shown that at 03-08 MLT the expected growth in anisotropy ceases and the isotropisation occurres. Comparison with ground-based data confirms the suggestion that the cyclotron wave-particle interaction is a mechanism of isotropisation.

## 1. Introduction.

In this paper we consider the geosynchronous satellite energetic electron observations made during the small substorm occurred at 02:10 UT of 17 December 1990. The ground-based observations during the event has been recently described by *Manninen et al.* [1996]. In particular, it has been demonstrated that the substorm was followed by the strong impulsive energetic electron precipitation and enhanced VLF emissions registered in the morning sector. Usually such a precipitation is explained as a result of the cyclotron wave-particle interaction occurring in the morning sector when the eastward drifting electrons meet the region of the enhanced level of the wistler-type waves scattering the particles into the loss cone. The detailed analysis of the instability requires some characteristics of the particle anisotropy and some other parameters of the drifting electrons (see, for example, *Demekhov et al*., this issue). For the considered event the data of energetic electron measurements made onboard the LANL geosyncronous satellites and onboard the CRRES satellite (see the description of the satellite instrumentation in *Belian et al*.[1978]) allowed us to study the electron anisotropy variations along the longitude in the equatorial plane. Some conclusion on the anisotropy behaviour can be also obtained from a simple model of the particle drift in the dipole-like magnetic field. The comparison between model calculations and observations confirms the suggestion on the particle scaterring and on the cyclotron instability as a scaterring mechanism.

## 2. Results (Verification of the model).

For the event under study the data from three LANL spacecraft were available. The spacecrafts 097, 129, and 046 measured electrons with energies >30 keV at 03-04, 07-08, and 16-17 MLT, respectively. The CRESS was close to midnight.

For modelling of the energetic electron drift we use the dipole magnetic field model. In this field the drift velocity is

$$\left\langle \mathbf{V_{DR}} \right\rangle = \frac{6 \cdot \mathbf{E}}{\mathbf{q} \cdot \mathbf{B}_0 \cdot \mathbf{R}_0} \cdot \left(0.35 + 0.15 \cdot \sin \alpha_0\right) \qquad (1)$$

where E is the particle energy, $\alpha_0$ is pitch-angle, $B_0$ and $R_0$ are local magnetic field and geocentric distance, respectively.

Firstly, we must verify the validity of the used model, which, of course, can not be applied for every case because of its simplicity. For example, *Shukhtina and Sergeev* [1991] have shown that for the interpretation of the observed particle anisotropy the account of the L-shall splitting, which is an intrinsic feature of the motion of particles in the real magnetosphere, is very important. In our case, however, there are some arguments to confirm the applicability of the simple model. The effect of cross-tail currents, which are the main contributor into the night-day asymmetry of the magnetic field, should be more significant in the night sector, at the location of the CRRES satellite. Nevertheless, the difference between the dipole magnetic field and that measured onboard the CRRES is rather small (not larger than 10%). We explain this by the fact that the pre-substorm conditions were rather calm, there were no signatures of a strong growth phase. Thus, we do not expect intensive currents in the magnetotail. Moreover, the substorm related current disruption produced additional dipolarization of the magnetic field. We can

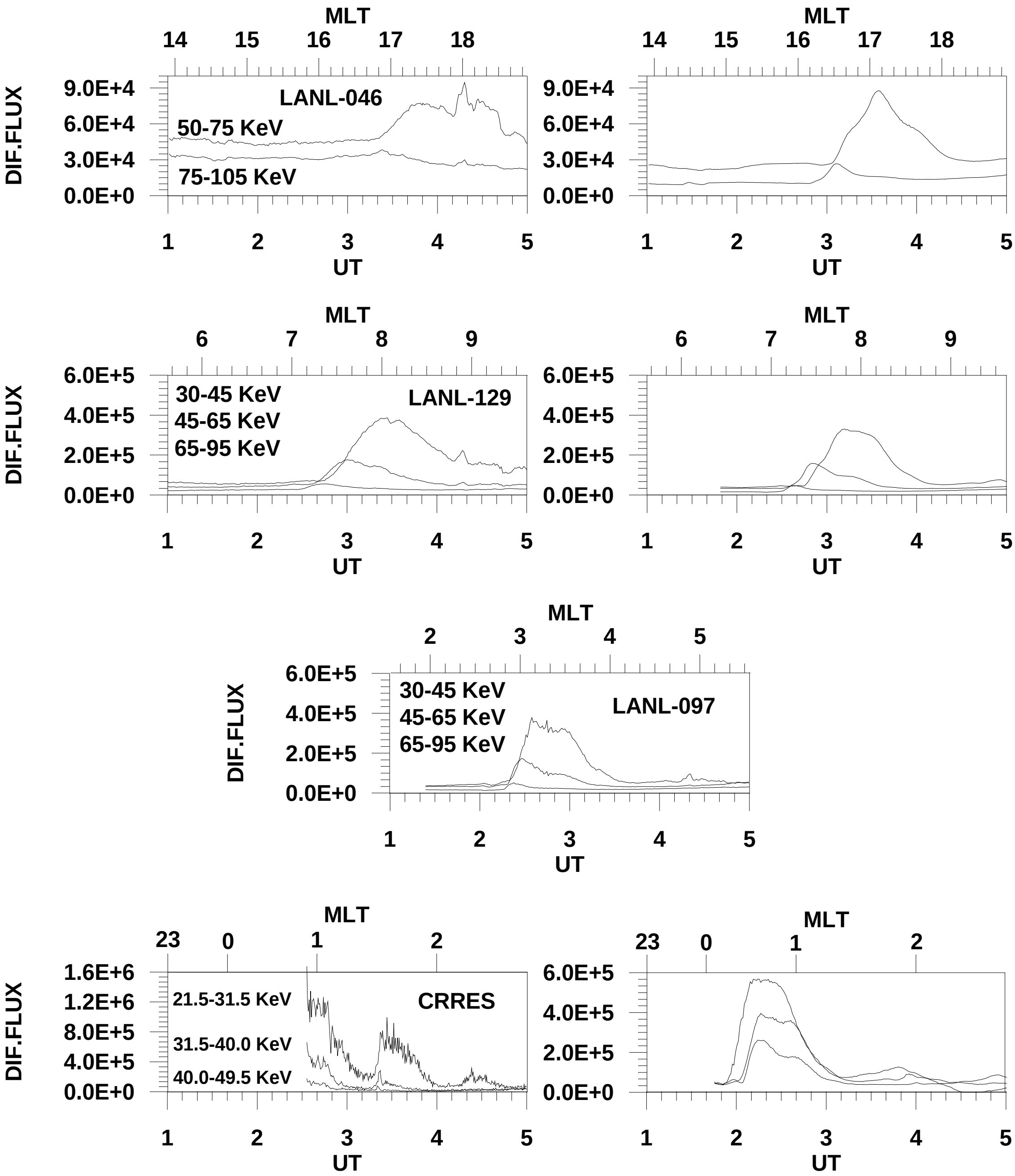


Fig. 1

also directly check the model by comparison of measured and calculated fluxes at different locations. Using the above formula the fluxes measured onboard the LANL 097 satellite were traced forth and back along the longitude. The result of the tracing is shown in the right column of the Fig.1 whereas the left column presents the measured fluxes. Rather good coincidence of the calculations and measurements is seen. (Note, that it is not related to the spike around 04:15 UT seen at every locations. This spike is produced by the SI, and not related to the particle drift).

### 3. Results (Anisotropy behaviour)

After this verification, which allows, in our opinion, to rely upon the applicability of the simple model in this particular case, let us compare the modeled anisotropy dynamics with the observations. Fig. 2 (left column) shows how a monoenergetic, isotropic particle cloud injected around midnight will disperse when it arrives to 04 MLT. (We suggested the injection started at 0010 UT and its duration of about one hour). The solid line corresponds to the integral flux, and the dashed line shows the flux of particles with the pitch angle of 45 degrees. Fig. 2 (right column) presents the anisotropy function calculated according to the formula

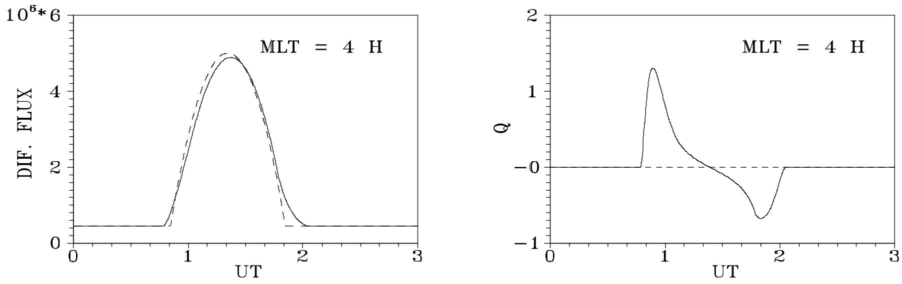


Fig. 2.

$$Q(t) = \frac{\int J(\alpha_0, t) \cdot \sin^3 \alpha_0 \cdot d\alpha_0}{\int J(\alpha_0, t) \cdot \cos^2 \alpha_0 \cdot \sin \alpha_0 \cdot d\alpha_0} - 1 \qquad (2)$$

This parameter Q characterizes the relation of particles moving along and across the magnetic field. In a point in the morning sector the anisotropy parameter increases for a short time, and then decreases. If no scaterring mechanism is taken into account the peak value will increase further to the east (it will increase twice from 04 to 12 MLT). The anisotropy was also calculated from the particle measurements onboard three spacecraft CRRES, LANL-097, and LANL-129 (Fig.3). The anisotropy near midnight is small (this fact supports our above mentioned suggestion on the isotropy of the injected particles), and the increase in the anisotropy is seen on the location of LANL-097 (03-04 MLT) in agreement with the model calculation. Anisotropy dynamics exhibited a tendency to depend on the particle energy: the maximal values of the anisotropy was registered earlier for more energetic electrons (not shown). At 07-08 MLT the anisotropy diminishes again. It means that, indeed, some mechanism scattered the particles somewhere between 03 and 08 MLT. Mind that just in this region the enhanced VLF waves and precipitation were observed by the ground-based instruments the cyclotron interaction seems to be the most appropriate candidate for this scaterring mechanism.

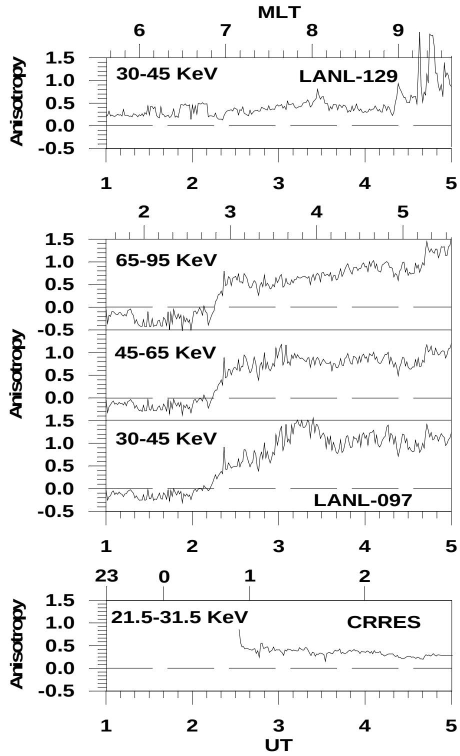


Fig. 3.

In the conclusion we would like to note that the time-depended anisotropy of the energetic electrons agrees with the dynamics of the precipitation particle energy estimated from the EISCAT electron density measurements. Indeed, the interaction with the anisoropic particle cloud will decrease the anisotropy. As a sequence, decrease in the wave frequency and an increase of the precipitating particle energy will occur. Another regime of interaction will start when the particles having moderate anisotropy will arrive. In such a case the particles having small pitch-angles will interact with the waves more effectively, and the anisotropy will grow. As a result the wave spectral density maximum will shift to the higher frequencies and the energy of the precipitating particles will decrease. It is this behaviour of the precipitating electron energy what has been deduce from the radar observations (Manninen et al., 1996).

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