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EVOLUTION OF THE ENERGETIC ELECTRON FLUX OBSERVED BY ARASE SATELLITE AND SIMULTANEOUS AURORA IN THE CASE OF MARCH 31, 2017, 00-01 UT

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Abstract. The data of simultaneous observation of the energetic electron flux by ARASE satellite and aurora by ground-based all-sky imager in Murmansk region (Russia) have been analyzed for the time interval 00:00-01:00 UT on March 31, 2017. The energy spectra of middle-energy (7-90 keV) electrons observed by MEPe detectors in and near the loss cone have been used for simulation of the auroral emissions in the atmosphere. The temporal evolution of the simulated emission intensity has been compared with the observed emission in the magnetic field-aligned footprint point for the satellite. It was found that the projection along magnetic field has been distorted by the developing disturbance.

Introduction

Dynamics of the magnetospheric plasma and its manifestation in the auroral activity have been studied for recent decades. However, the plasma processes extend in so broad range of scales in space and time, that each new experimental equipment open up opportunities for new findings. The ARASE (ERG) satellite is operating from the beginning of 2017 and is aimed mainly for studying the wave-particle interactions in the radiation belts. The satellite is equipped by several particle and field detectors useful for these studies. The mission has a broad international ground based support over the world, especially in the Fenno-Scandinavian region.

Here we analyze one of the first intervals of simultaneous magnetically conjugate observation of the ARASE satellite [*Miyoshi et al.*, 2018a] and the ground-based all-sky imager in Murmansk region (Russia) [*Kozelov et al.*, 2012]: the time interval 00:00-01:00 UT, March 31, 2017. Recently this interval was studied in [*Kawamura et al.*, 2019] for tracking the region of high correlation between pulsating aurora and chorus VLF waves. It was found that this region jumps near the satellite projection along the magnetic field line to the ionosphere. Propagation of the VLF waves in a plasma from the region of their generation and the structure of this region in the magnetosphere are the problems still under discussion. But here our investigations aim to other side of the problem, i.e., to the energetic particles interacting with these waves and precipitating in the loss cone. According to theory [*Trakhtengerts*, 1999; *Trakhtengerts et al.*, 2004] it should be electrons with energies in the range of tens of keV. The energy spectrum of the electrons in this range is observed by MEP-e detectors of the ARASE satellite. Precipitation of the energetic electrons should lead to auroral emissions in the ionosphere at the same magnetic field line.

Taking into account the evolution of the measured spectrum of the energetic electrons we estimate the possible auroral response in the green (557.7 nm) and blue (427.8 nm) lines by a model of *Dashkevich et al.* [2017]. Then as a first approach we try to compare these estimations with the auroral intensity observed by Apatity all-sky imager along the track of the magnetic field-aligned footprint point for the satellite.

Observations

Figure 1 presents the relative positions of the ground- based all-sky camera and the satellite track during the events under consideration. The keogram in Figure 2 presents the evolution of aurora in the North-South cross section of the field of view of Apatity all-sky camera during the interval 00:00-01:00 UT on March 31, 2017. We can see the wide band of pulsating aurora during the entire time interval with decreasing activity after 00:50 UT. From 00:24 to 00:34 UT the activation of aurora at the poleward boundary of the band is observed, and the boundary moves fast to the South, followed by slow backward motion.

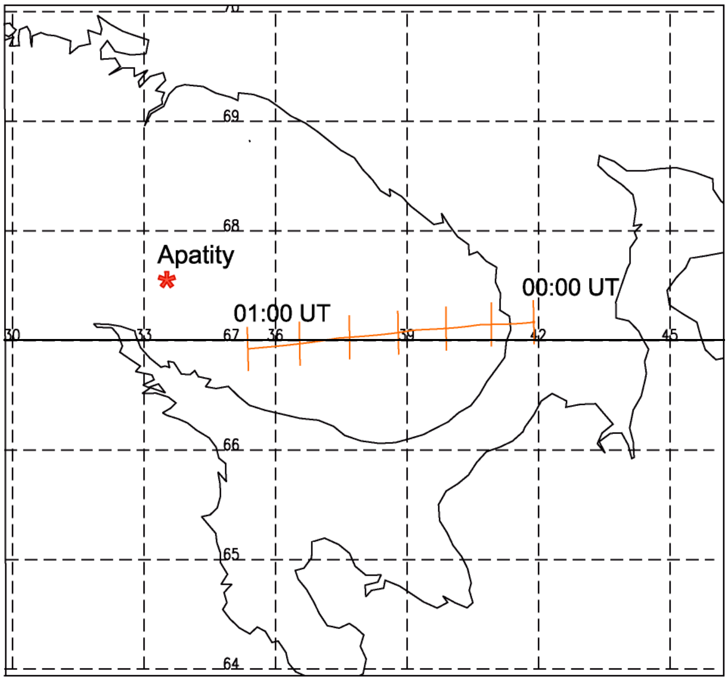

Figure 1. Projection of the ARASE satellite position along the magnetic field line during the interval 00:00-01:00 UT, March 31, 2017. Tsyganenko-89C magnetosphere model used.

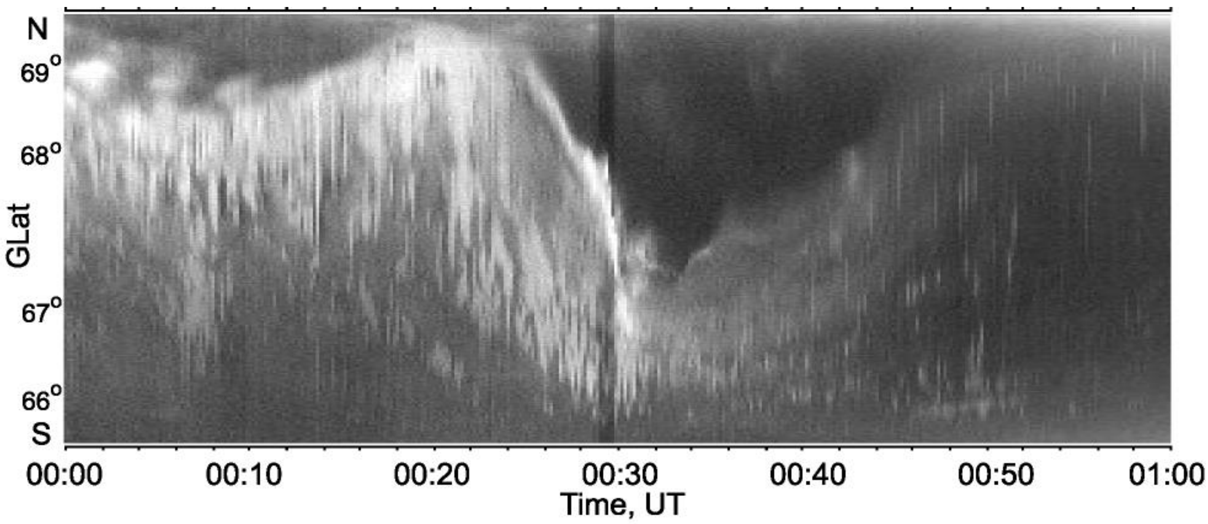

Figure 2. North-South keogram of aurora evolution observed by Apatity all-sky camera during the interval 00:00-01:00 UT on March 31, 2017. In the interval 00:29-00:30 UT the intensity decreased due to the auto gain control.

Figure 3 presents the evolution of energy spectrum of electrons in the range from 7 to 90 keV obtained by MEPe detectors onboard ARASE [*Kasahara et al.*, 2018]. We calculate the particle flux for the pitch-angles in loss cone [*Matsuoka et al.*, 2018], taking into account its changes along the satellite track. During the first 20 minutes of the considered interval we can see relatively high electron flux for the energy below 30 keV with a fast drop the flux above 50 keV. At 00:23 UT we can see the start of an injection with dispersion from ~70 keV, which develops to at least 00:36 UT with a decrease in energy to ~10 keV. After 00:23 the flux at energy above 50 keV increases up to more than an order of magnitude. During the entire interval simultaneous fast pulsations of the particle flux in a wide range of energies were observed. They indicate local wave-particle interactions in the magnetic flux tube crossed by the spacecraft.

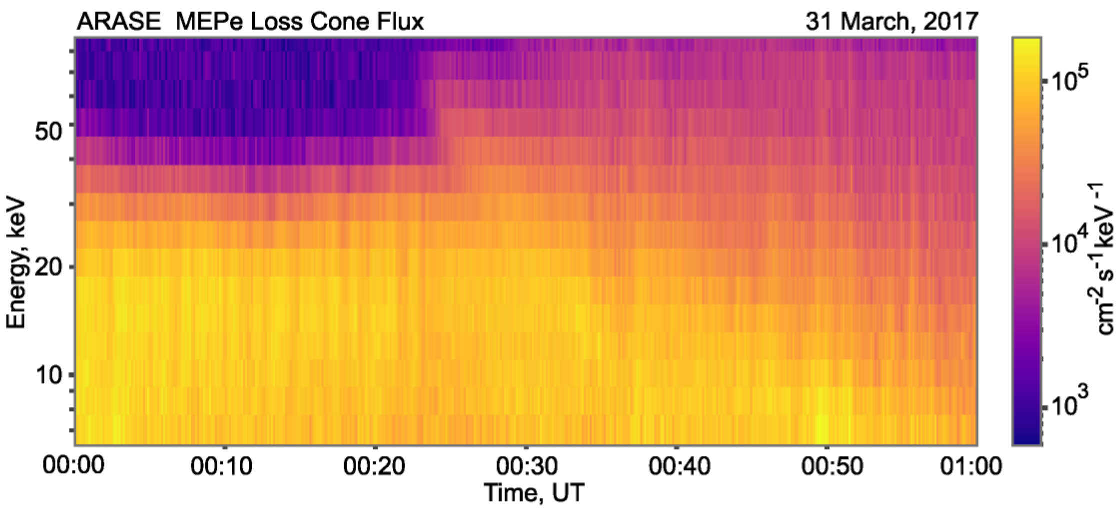

Figure 3. Evolution of the energy spectrum of electrons obtained by MEPe detectors onboard ARASE.

Discussion

By using the measured spectrum of energetic electrons and the physical-chemical model of the ionosphere [*Dashkevich et al.*, 2017] we estimate possible auroral response in the green (557.7 nm) and blue (427.8 nm) lines. The temporal evolutions of the intensities are shown in Figure 4. The sum of these two lines gives 90% of the aurora intensity in the blue-green range of the visual spectrum. Also we calculate the altitude of the maximum in the altitude profile of these emissions. We found that during this event the altitude is falling down from 101 km to 99 km for 557.7 nm and from 100 km to 97 km for 427.8 nm. This corresponds to the observed hardening of the electron energy spectrum.

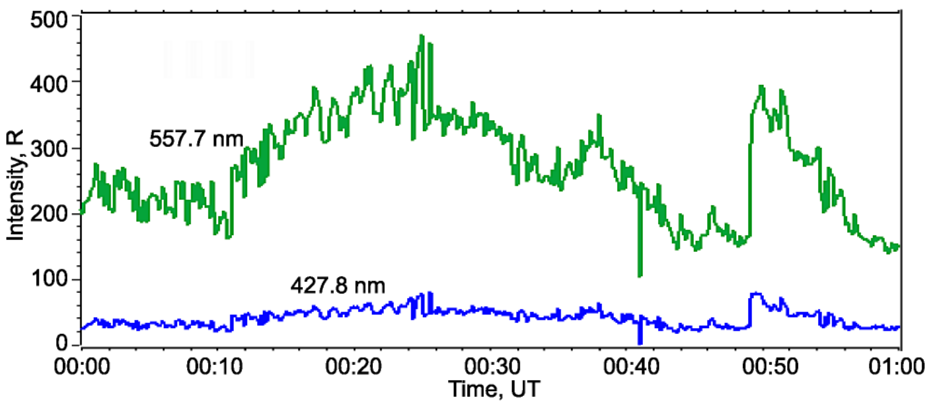

Figure 4. Theoretical estimation of 557.7 nm and 428.7 nm lines intensities calculated by MEPE electron flux spectrum in the loss cone.

To compare these results with the calculated estimations of the aurora intensity, as a first approach, we construct the keogram by the North-South cross section of the all-sky images through the moving projection of ARASE satellite position, see Figure 5. The latitude of satellite projection is marked by dotted line; the images are mapped onto the height 100 km. The evolution of the intensity along the satellite projection is presented in Figure 6.

The evolution patterns shown in Figures 4 and 6 differ considerably from each other. This could mean that the particle precipitation occurs not exactly in the expected points, which can be due to an imperfect field line mapping under disturbed conditions. Figure 7 shows three examples of all-sky images at different stages of the considered event. The satellite position mapped by an average model of the magnetic field is marked by star. One can see that in the beginning of the event (the first image at 00:01 UT) the strong East-West auroral band is located northward of the satellite. The band is strongly distorted due to local ionosphere-magnetosphere currents (the second image at 00:30 UT). These conditions are visually different for the field line mappings.

Another support of our suggestion about the imperfect field line mapping is shown in the third image of Figure 7 at 49:39 UT. Nearby the satellite projection we can see a big auroral patch. The life-time of this patch corresponds well to local pick in the theoretical intensity near 00:50 UT in Figure 4. So, detailed correlation analysis of the auroral patches in images and the evolution of theoretical auroral intensity obtained from the electron spectra can help to map the region of the particle precipitation more precisely to the magnetosphere.

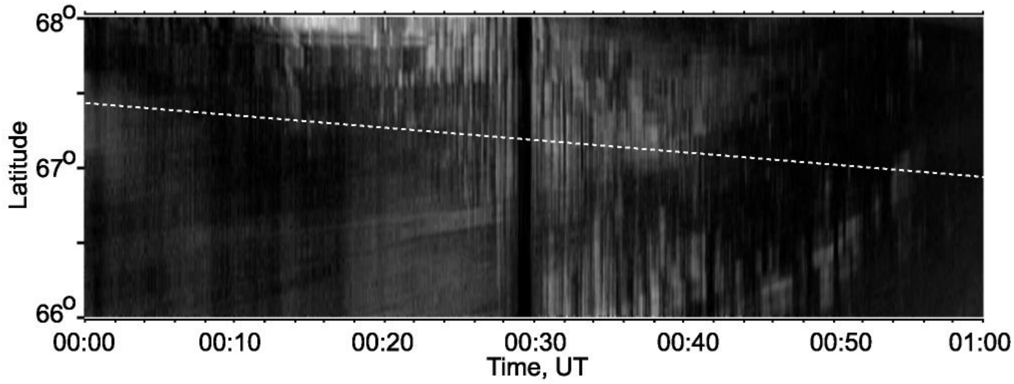

Figure 5. North-south keogram by Apatity all-sky images crossed through the projection of ARASE position. The projection of the satellite latitude is marked by a dotted line; the images are mapped at a height of 100 km.

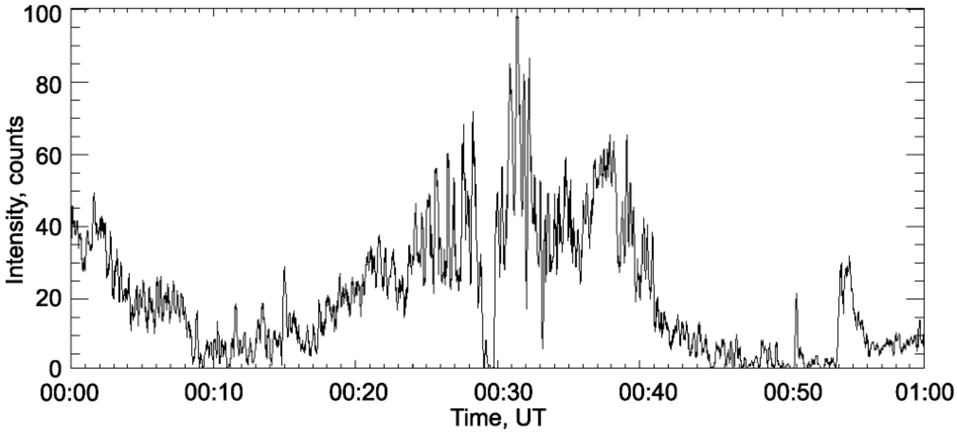

Figure 6. Evolution of the aurora intensity observed by the all-sky camera at the magnetic field line crossed by ARASE at a height of 100 km.

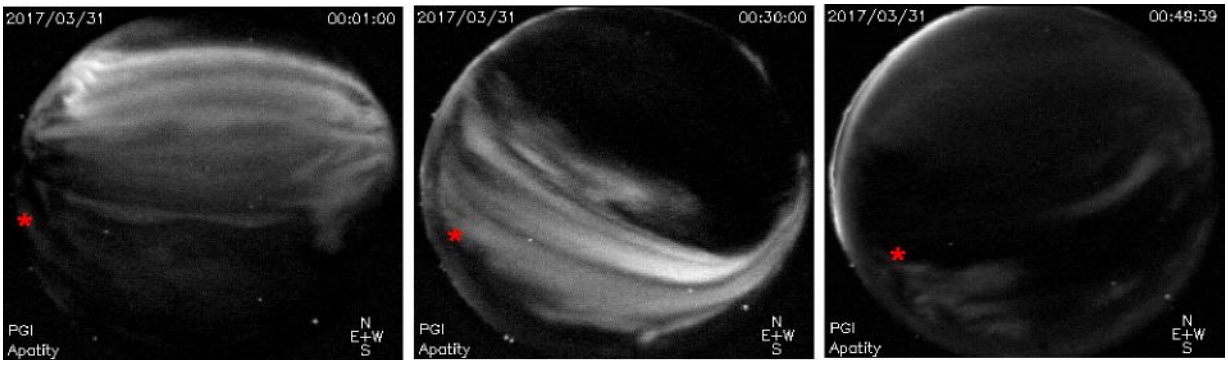

Figure 7. Examples of Apatity all-sky images with the projection of ARASE position along the magnetic field line (marked by a red star).

Results

We have analyzed an interval of simultaneous observations by the ARASE satellite and the ground-based all-sky imager. The energy spectra of middle-energy electrons observed by MEPe detectors in and near the loss cone have been used for simulations of the aurora emissions in the atmosphere. The temporal evolution of the simulated emission intensity has been compared with the observed emission in the magnetic field-aligned footprint point for the satellite. It was found that the evolution patterns differ considerably from each other. We deduce that the projection along magnetic field has been distorted by the developing disturbance.

Detailed correlation analysis of the auroral patches in images and the evolution of theoretical auroral intensity obtained from electron spectra can help one to find exactly the position of the particle precipitation region in the magnetosphere.

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