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THE LUMINOSITY DYNAMICS AND PRECIPITATED PARTICLE FLUX CHARACTERISTIC DURING AN OPTICAL TOMOGRAPHY EXPERIMENT IN FEBRUARY 1999

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Abstract. Auroral tomography is an efficient method of investigation of ionosphere structure and ionospheric parameters' dynamics. An auroral tomography experiment was carried out in the Kola Peninsula on February 10, 1999, when a diffuse stable arc was registered. The volume emission rates and profiles of electron concentration were reconstructed by tomography method from measurements of 427.8 nm and 557.7 nm emissions, using a universal mathematical approach based on the theory of stochastic conversion. The distinguishing characteristics of two-dimensional distributions of 427.8 and 557.7 volume emission rate were explored. The particular feature of these distributions is a pronounced decrease tendency of altitude of the volume emission rate maximum inside the auroral form in the north-south direction. This consistent pattern is of a steady nature and remains persistent during stable auroral structures. The analysis of characteristics of precipitated electron energy spectra, obtained using tomography reconstruction of 427.8 nm volume emission rate, showed that the increase of average electron reached 2-4 keV. At the same time, the energy flux was characterized by a maximum in the center and a digression toward the confines of auroral form, which correlated with the emission intensity behavior.

Introduction

Tomograpic methods had first been tried to be applied for aurora studies (auroral tomography) as far back as over 10 years ago, using onboard satellite scanning photometers /1/, rocket photometers /2,3/ or ground based photometers /4,5/. Although there is being done an extensive amount of reseach in this field (ARIES, ALIS, COTIF projects) the results as such of tomographic studies are not numerous. It is mainly due to the instrumentation used, which is not perfect and another reason is the complexity of optical data processing. However, the interest in auroral tomography has ever been growing and besides polar regions it has been reaching as well the Earth's middle latitude zones. For instance, in the paper /6/ by Semeter et al. tomography reconstructions of a middle latitude SAR aurora have been carried out, according to meridional spectrographer chain data.

Among the methods of tomographic inversion in the auroral tomography the most spread are various iteration algorithms. Alternative approaches are represented by algorithms, based on the theory of stochastic inversion, developed for the satellite tomography of the reconstruction of the ionosphere electron density spatial distribution /7,8/. According to those methods the reconstruction is normally done without iterations, what's more they use regularization and error analysis, which iteration methods do not have. The algorithm and the corresponding software package, described in /8/ have been developed by PGI researhers jointly with a group of Finnish researchers. Inspite of the fact, that this package was originally developed for statellite tomography /9/, it can directly be used in the auroral tomography , since the tasks in both satellite and auroral tomography are almost identical. Because of different physical processes the reconstruction algorithm has undergone some software modifications, as, for instance, the application of the spatial grid of another type. Thus, an elementary cell of tomographic grid was diminished almost by an order, compared to the one, used in satellite tomography and its size step was equal to 2.5x2.5 km, which allowed us to reconstruct fine luminosity structures.

The first reconstructions of spatial distribution of the basic auroral emission luminosity intensity, based on the data of auroral photometric measurements, were obtained during the experiment in February-March 1999. The data were obtained, using 4- channel scanning photometers., registering the luminosity of 320.0 nm, 427.8 nm, 557.7 nm, 630.0 nm emissions. Devices were located almost along the geomagnetic meridian and were separated by distances of 93 km and 133 km along the north-south line at geographic positions of Apatity ($33^0$24',$67^0$34'), Verkhnetulomski observatory ($31^0$45',$68^0$35'), Korzunovo village ($30^0$59',$69^0$24'). The photometers had been calibrated and brought to the similar sensibility level prior to the experiment

The luminosity dynamics and precipitated particle flux characteristic

At the first stage the following tasks were set: a) studying typical features of the two-dimensional distribution of the emission volume intensity in the specific forms of auroras, such as bands, arcs or systems of bands / arcs, b) carrying out a quantitative and qualitative analysis of tomographic reconstructions of the electron density distribution, obtained using auroral tomography data.

For this aim we chose the period from 23:00 to 01:00 UT of February 10-11, 1999. From Fig. 1, which represents scanograms in the emissions of 427.8 nm and 557.7 nm, one can see, that during the given time interval (about 1,5 h), a relatively stable diffuse luminosity band was observed. The detailed inspection of TV-images, that give a better time resolution, than scanning photometers do, allows one to see a finer structure in the luminosity, which is an evidence of a system of two and more closely positioned bands. Fig. 2 provides examples of tomographic reconstruction of the 557.7 nm volume emission rate for the following time moments: 23:17, 23:19, 23:21, 23:50, 00:01, 00:15, 00:49, 00:54 UT. The tomographic reconstruction of the 427.8 nm volume emission rate is similar to 557.7 nm. In the figure, the zero of horizontal distance corresponds to Apatity, 133 km to Verkhnetulomski, 226 km to Korzunovo (marked with blue asterisks in the figure). The first thing to be mentioned, is that the chosen grid in the procedure of tomography reconstruction allows one to resolve at least two luminosity bands close one to another (23:17, 23:19, 23:21 UT). From 23:17 there were left just two luminosity bands with varying brightness and different height of the intensity maximum. With time, the two bands merge by 00:01 and after that we can observe one band with the volume velocity of the emission of 557,7 nm of about 300 cm^{-3} c^{-1}. However, the most typical feature of the obtained two-dimensional distributions is the markedly expressed tendency towards the decrease of localization size of both the lower edge and the maximum of volume intensity of the emission inside the form (or forms) directed from south to north, which is, first of all, an evidence of systematic increase of the hardness of the precipitated electron flux.

The spectra of precipitated electrons were computed from height profiles of the 427.8 nm volume emission rate, using the method, described in Sergienko et al /10/. Certain examples of the calculated spectra of auroral electrons are given in Fig.3. The same figure includes the altitude profiles of the volume emission rate, obtained from tomographic reconstruction and calculated using the reconstructed energetic spectra of precipitated electrons.

Let us consider variations along the meridian in south-north directions of some characteristics, which reflect both the basic features of the luminosity distribution structure and precipitated electron parameters, that form those features: a) the distribution along the meridian of the emission intensity integrated in the vertical column ($\mathbf{I_\lambda}$) as well as of the height of the intensity maximum localization (**Hmax**,) calculated from the data of tomographic reconstruction, b) the distribution of the energy flux magnitude (**Φ**) along the meridian as well as the magnitude of the mean energy of the flux precipitated electrons (**E**), calculated from the reconstructed differential energetic spectra. Fig. 4 gives examples, displaying the behavior of $\mathbf{I_\lambda}$, **Hmax**, **E** and **Φ** in the meridional direction during the period from 23:17 UT up to 00:54 UT, which spans over an extended phase of existance, relative to the quiet band of diffuse luminosity and the beginning of auroral activation. From figures one can clearly see an evident tendency of the decrease of Hmax from south to north, which correlates with an increase of the mean energy of the electron flux by 2-4 keV. At the same time, the energy flux, as one should have expected, is characterized by the maximum in the centre of the luminosity region and is decreased towards the edges of the band, correlating with the integrated emission intensity distribution. Fig. 5 presents a combined illustration, emphasizing the nature of the **Hmax** and **E** distribution for all the above considered cases.

Conclusion

Using the method of auroral tomography, there were reconstructed and first studied the characteristic features of the two-dimensional distribution of emission volume intensity in the band of an aurora in the emissions of 427.8 and 557.7 nm. One characteristic distinction of the given distribution is an evident tendency towards the decrease of the height of maximum of the emission volume rate inside auroral form in the south-north direction. The given regularity is characterized as stable and is preserved during the entire time period of the existance of quiet form of the aurora (in the considered case-study it makes about 1.5 hour) The analysis of characteristic features of precipitated electron flux energy spectra, reconstructed using data of tomography reconstrution of two-dimensional distributions of the 427.8 nm emission volume rate, displays the corresponding increase in the mean energy of the electron flux by 2-4 keV. At the same time, the energy flux is characterizied by a maximum in the center of luminosity region and it decreases toward the edges of the band, correlating with the distribution of the integrated emission intensity.

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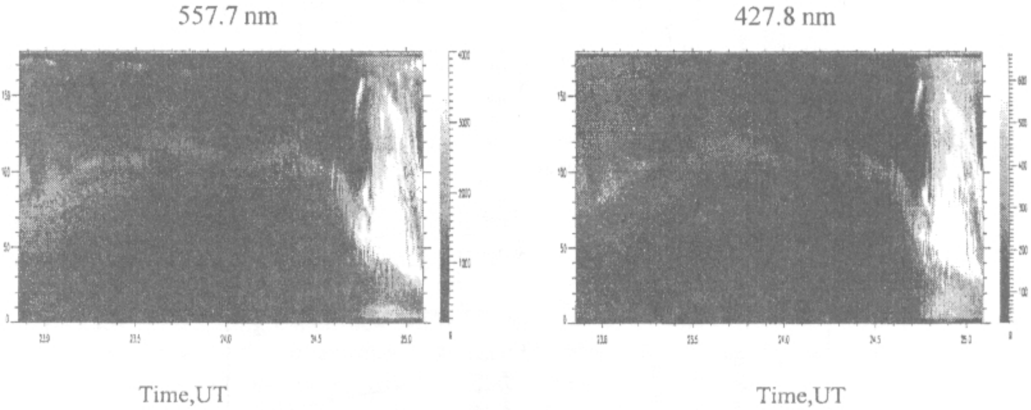

Figure 1. The experimental intensities of 557.7 nm and 427.8 nm emissions, obtained from Korzunovo.

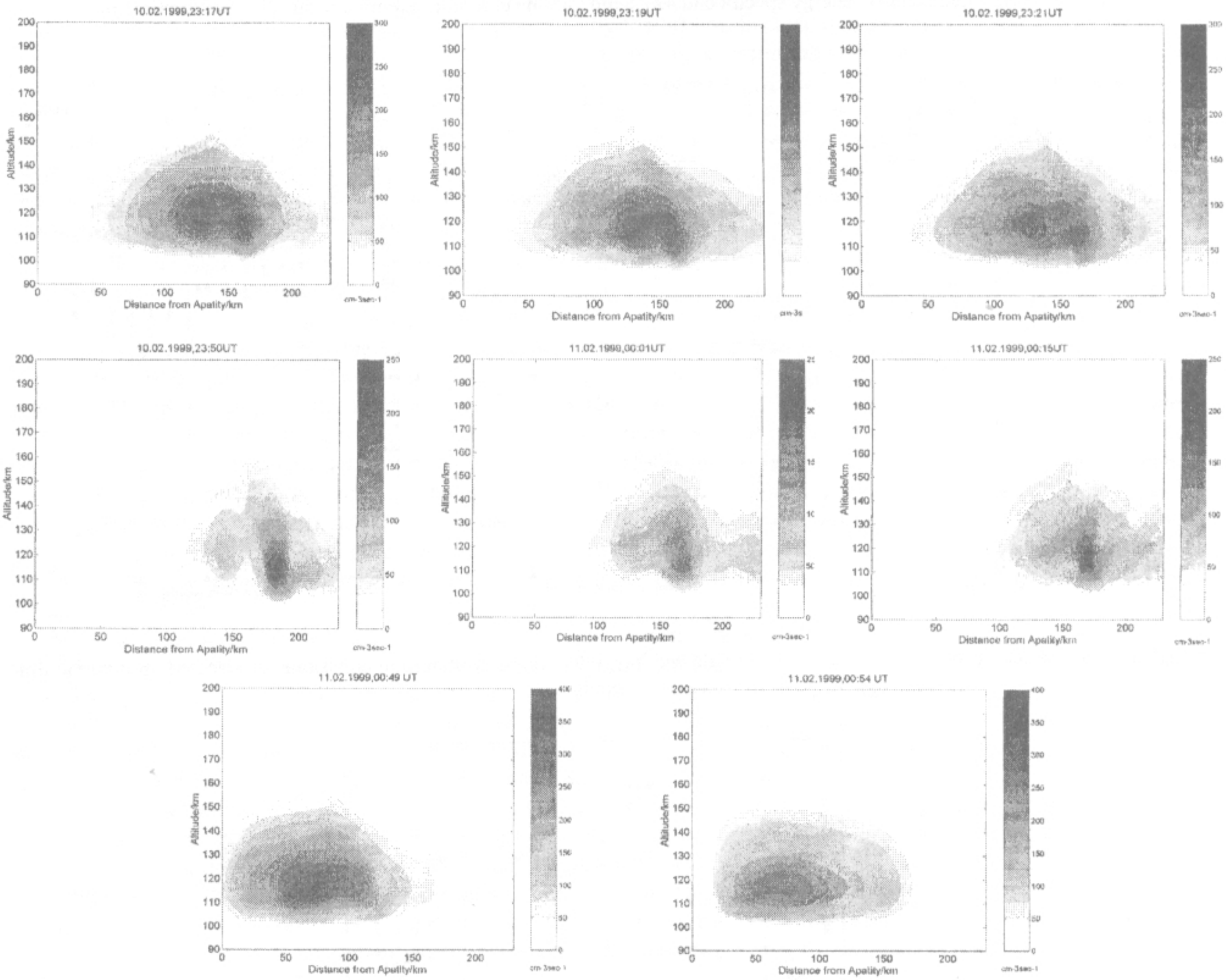

Figure 2 The tomography images for 557.7 nm emission intensity

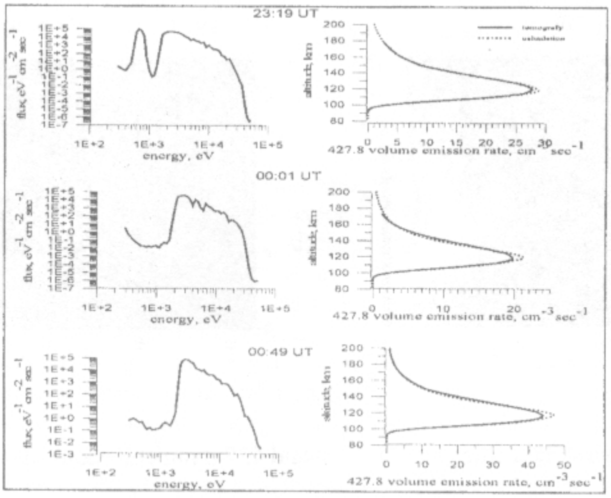

Figure 3. Precipitated electron energy spectra and 427.8 nm volume emission rate for various observation time periods.

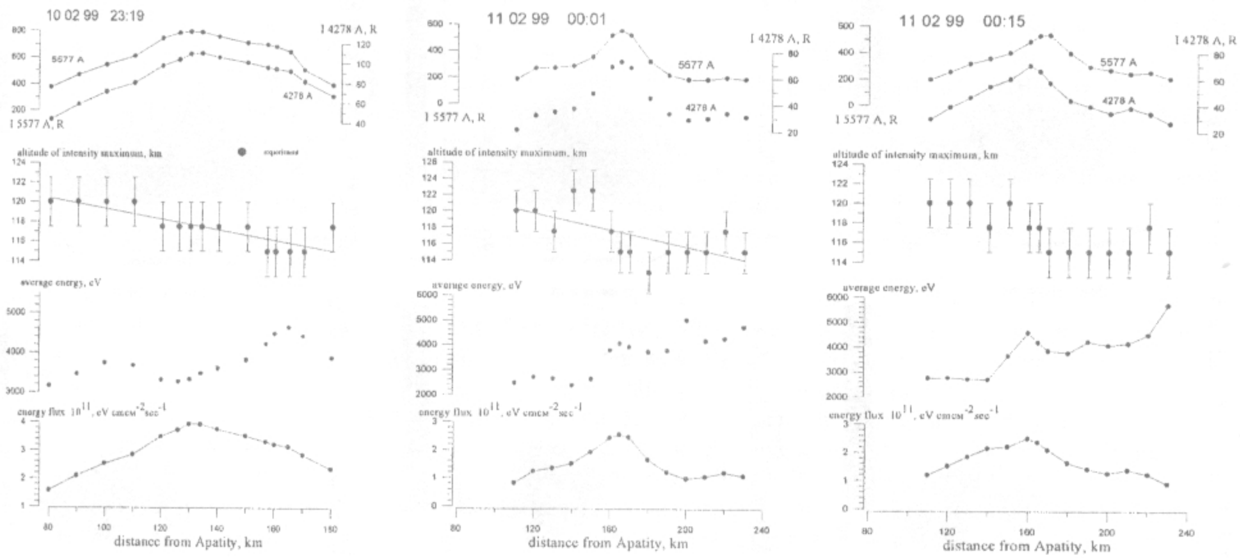

Figure 4. The variations of electron flux characteristic and integrated intensity of auroral emissions for selected observation time eriods.

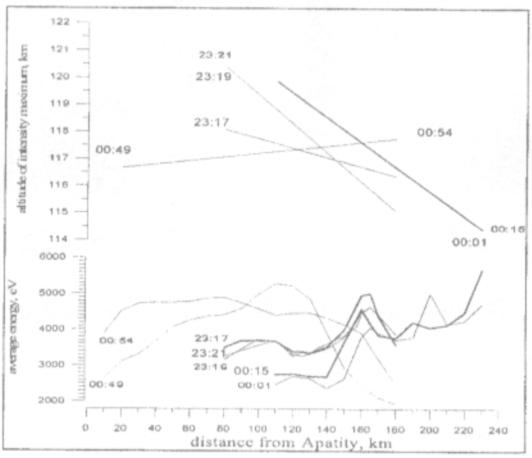

Figure 5. The variations of both electron average energy and altitude in 427.8 nm intensity maximum across auroral bands.