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TRIANGULATION OF AURORAL STRUCTURES IN BARENTSBURG, THE FIRST DATA OF THE SEASON 2018-2019

B.V. Kozelov, A.V. Roldugin, S.V. Pilgaev, V.F. Grigoriev

Polar Geophysical Institute, Murmansk-Apatity, Russia

Abstract. The precipitations of energetic electrons observed at the Spitsbergen latitude, which manifest themselves in the optical range as auroras, differ in their origin and morphology from the precipitations in other regions of the auroral zone. The electron energy determines the height of the auroral luminescence, which in the experiment can be determined from triangulation observations. In 2018, optical devices of the Polar Geophysical Institute on the Spitsbergen archipelago were supplemented with an additional camera. The camera is installed in the Barentsburg settlement, 4 km southern of the main optical pavilion and has a field of view of about 30 degrees. In patrol mode, the camera is directed to the zenith, which allows, together with the data of the all-sky camera, located in the main optical pavilion, to obtain information about the height of the observed structures of auroras in the vicinity of the zenith. The report contains the parameters of the optical system used for triangulation and examples of the registration of auroral structures.

Introduction

The aurora phenomenon is the most obvious manifest of the magnetosphere-ionosphere interaction. Statistically, the main region of aurora forms oval structure (auroral oval) and beyond this structure the aurora observations are less probable. The Barensburg observatory of Polar Geophysical Institute is located at 78°N and in the night time it typically placed inside the auroral oval. However, aurora during magnetospheric disturbances is usual event there and it observation is limited mainly by cloudiness of the sky.

The auroral structures observed at the latitudes of Barentsburg are corresponds to the poleward boundary of the auroral oval, and it typically contains more rayed structures produced by precipitated electrons. The characteristics of these particles precipitation in their spatio-temporal dynamics are not fully investigated.

Ground-based optical observation is the most informative source for study of the spatio-temporal dynamics of aurora. By triangulation of the aurora luminosity it is possible to estimate their altitude [1] and to deduce the energy of the precipitated particles [2]. However, the all-sky cameras (ASC), usually used for auroral observations, have large distortions and small spatial resolution. Location of the cameras at large distances complicates the structure identification needed for the triangulation.

Previously in [3] was reported the observational complex aimed at investigating spatial structure of the aurora, its scaling properties, and vertical distribution in the rayed forms. The precisely synchronized identical cameras were installed in auroral zone, in Apatity, with distance of 4 km between them, so the cameras can be used as a stereoscopic system for the triangulation.

In 2018, optical devices of the Polar Geophysical Institute on the Spitsbergen archipelago were supplemented with an additional camera. The camera is installed in the Barentsburg settlement, at 4 km distance of the main optical pavilion and has effective field of view about 30 degrees. In patrol mode, the camera is directed to the zenith, which allows, together with the data of the all-sky camera, located in the main optical pavilion, to obtain information about the height of the observed structures of auroras in the vicinity of the zenith. The report contains first examples of the registration of auroral structures by this optical system and results of their analysis.

Equipment and methods

The schema of optical observations in Barentsburg during the winter season 2018-2019 is shown in Fig.1. Here we use the data of all-sky camera (ASC) located in the main optical pavilion of PGI observatory and the data of auroral camera with narrow field of view (NAC), placed 4 km southern in the Barentsburg settlement. Both cameras based on cooled color RGB CMOS ZWO astro-cameras. ASC gives images of practically all sky of 274×390 pixels. The NAC registries in image of 450×350 pixels the sky region near zenith with effective field of view about 30 degrees. The time resolution is 1 frame per second for ASC and 1 frame per 2 seconds for NAC. The angular resolution of the

NAC is 0.0837 degrees (~5 angular seconds) per pixel. For the same region the ASC has angular resolution on factor 5.6 lower. All orientations, scaling factors and positions in the data images were obtained by stars.

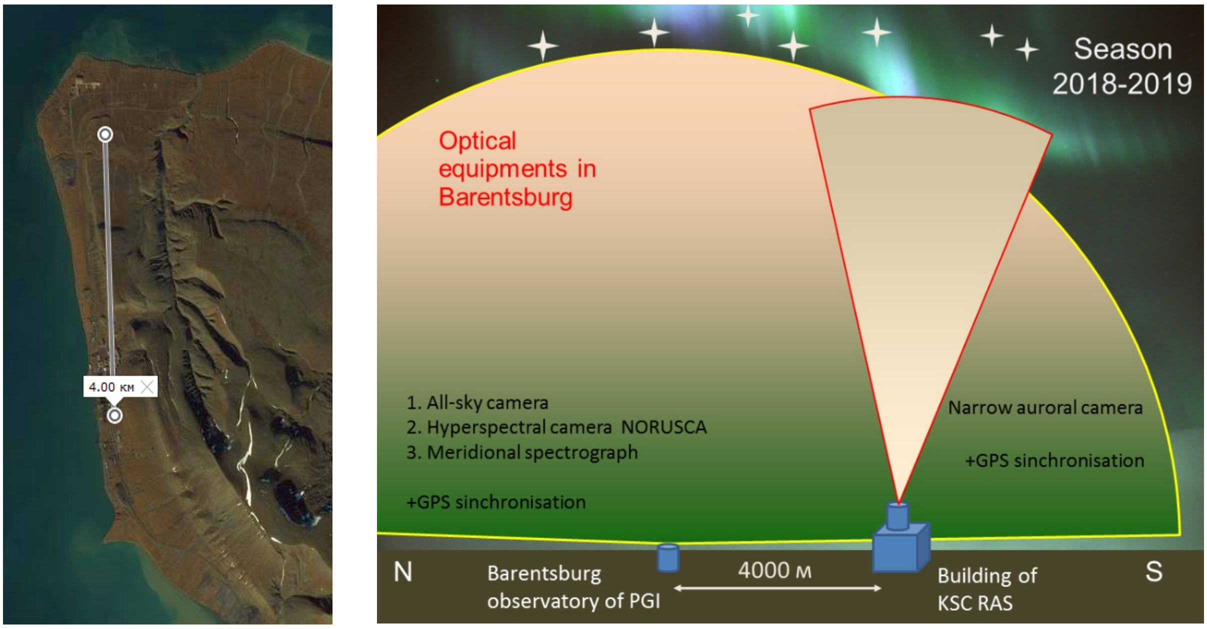

Figure 1. Schema of optical observations in Barentsburg.

The auroral structures in the images were extracted by Sobel filtering [4, 5]. Technically, it is a discrete differentiation operator, computing an approximation of the gradient of the image intensity function. The Sobel operator is based on convolving the image *I(x,y)* with a small, separable, and integer-valued filter in the horizontal and vertical directions. Convolution is the process of adding each element of the image to its local neighbors, weighted by the kernel. These horizontal and vertical filters are:

$$X_{mask} = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

$$Y_{mask} = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \qquad (1)$$

Then the horizontal and vertical gradient approximations are

$$G_x = \text{convol}\,(I(x,y), X_{mask})$$

$$G_y = \text{convol}\,(I(x,y), Y_{mask}). \qquad (2)$$

The x-coordinate is defined here as increasing in the "right"-direction, and the y-coordinate is defined as increasing in the "down"-direction. At each point in the image, the resulting gradient approximations can be combined to give the gradient magnitude and the gradient's direction:

$$A = \sqrt{G_x^2 + G_y^2}$$

$$\varphi = \operatorname{atan}\left(\frac{G_y}{G_x}\right) \qquad (3)$$

By scaling the filter matrixes in both directions by s times we can analyze the gradients at larger scales (here s – spatial scale).

Examples of the data analysis

During evening on 8 February 2019, the magnetic activity started in Scandinavian sector after 19 UT, Fig. 2. However, the bright aurora structures were occurred in sky over Spitsbergen only after the auroral breakup and following poleward expansion after 21:30 UT. The weather conditions were well satisfied for aurora observations and we take several minutes of the data from Barentsburg's ASC and NAC for the analysis.

Fig. 3 presents an example of simultaneous images registered by ASC and NAC and their transformation according the method described above for spatial scale s=8. For visualization of the filtering results according (3) we use the following color representation: (R,G,B)= (G_y, G_x, G_x). One can see that the spatial structures are well visually recognized in both images. The displacement of the structure found by best-fit correlation of the filtered images give us the estimation of the average altitude of the structure. In this case the best-fit displacement is 17 pixels that corresponds altitude ~160 km.

The precision of the method is limited mainly by the precision of the obtaining of the reference positions of the stars. Taking into account the sub-pixel approximation for ASC images and integration the information during several nights, we estimate the precision of the method as ±2 pixels on NAC image.

Variation of the average altitude of the auroral structure over Barentsburg in the interval from 21:41 to 21:44 UT is shown in Fig. 4. The structures were sets of rayed arcs and individual rays. The average altitudes in the range 150-200 km are typical for such structures.

Discussion and conclusions

Triangulation with different fields of view and camera parameters is more complicated than with the same. The first conclusions from the processing of available data obtained in winter season 2018-2019 at Barentsburg observatory are:

1. Careful spatial reference is required for all-sky camera images. It is possible by accumulation of information about star positions during several successful nights.
2. It is necessary to check the coincidence of time for pairs of images. Some breaks of synchronization and lost frames were founded in the data set.
3. To match the observed structures, is necessary to use the same exposure times.

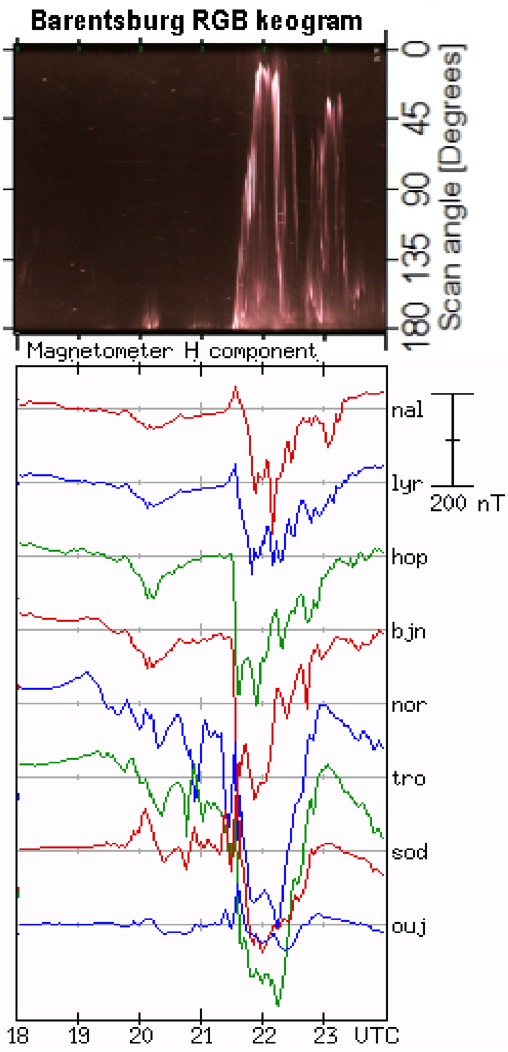

Figure 2. Magnetic and auroral activity in Scandinavian sector on evening 8 February 2019.

In general, the experience of such type of observation and data analysis is successful. The typical average altitudes in the range 150-200 km are obtained for auroral structures contained of rayed arcs and individual rays. The algorithm of analysis should be improved to characterize the individual structure elements.

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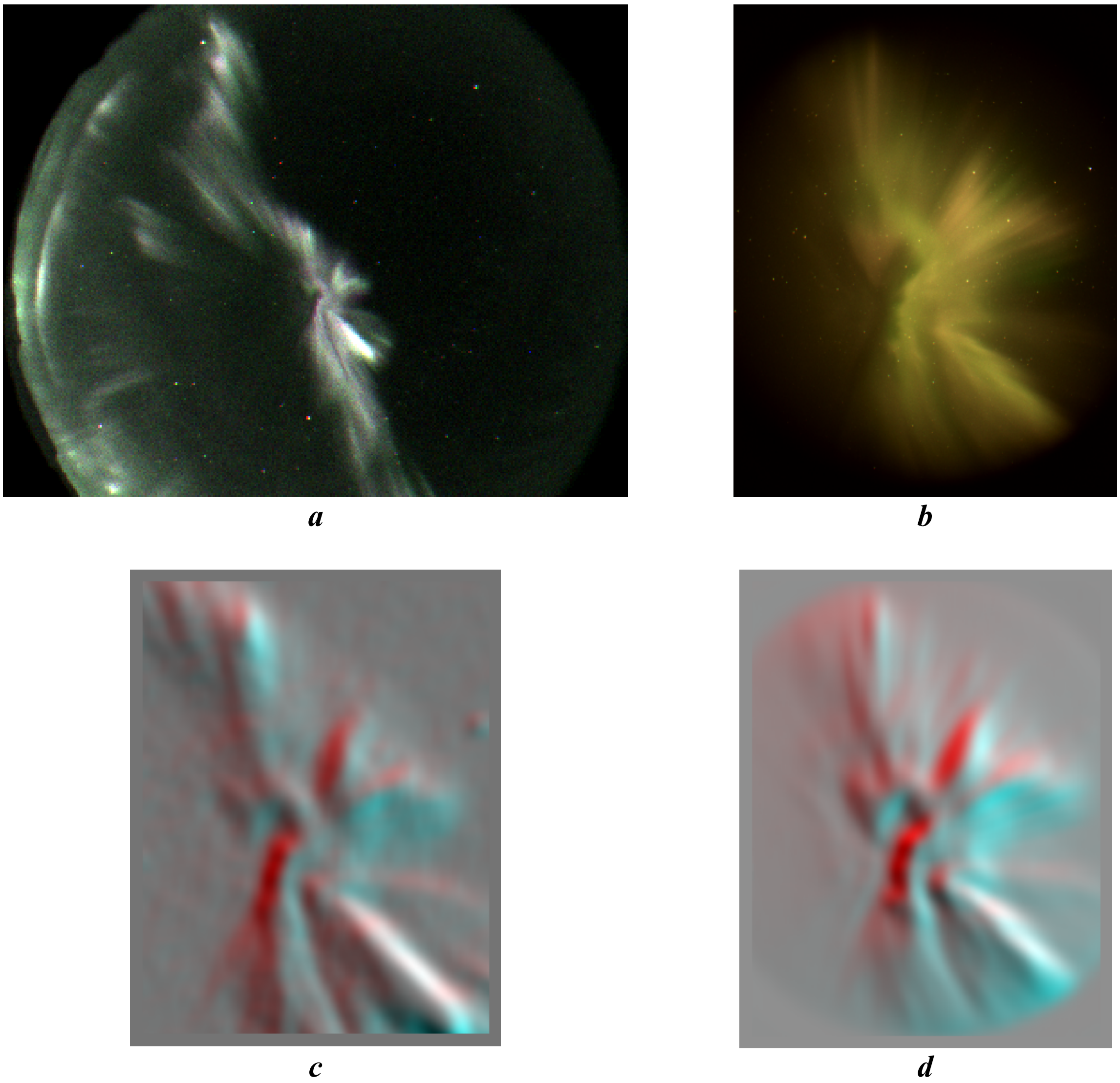

Figure 3. An example of the auroral structure observed by Barentsburg's cameras on 8 February 2019, 21:41:11 UT: ***a*** – all-sky camera (ASC) image; ***b*** – narrow field of view camera (NAC); ***c*** – filtering of the auroral structure on central part of ASC image (scaled up 5.6 times); ***d*** - filtering of the auroral structure on NAC image.

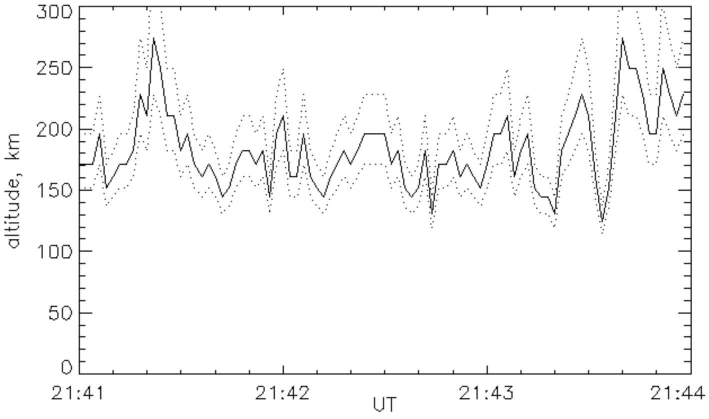

Figure 4. Variation of the average altitude of the auroral structure over Barentsburg in the interval from 21:41 to 21:44 UT on 8 February 2019. The dotted lines correspond to ±2 pixels errors in the obtained displacement.