Ground-based optical observations during the Cascades-2 rocket

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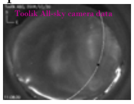
Introduction

The Cascades-2 (The Changing Aurora: In Situ and Camera Analysis of Dynamic Electron Precipitation Structures) sounding rocket was successfully launched into dynamic and rayed aurora over Alaska on 20 March 2009. Ground-based observations of the aurora were carried out with optical instruments located in Kaktovik, in Toolik Lake and at Poker Flat. The instrumentation consisted of all-sky cameras as well as narrow field imagers. Thin, tall auroral rays are seen at the rocket footprint, and their properties are investigated further.

Ground-based instrumentation

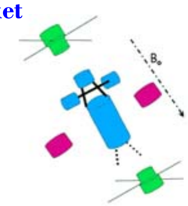
All-sky cameras as well as narrow FOV imagers were positioned at Toolik Lake Field Station, Kaktovik and at Poker Flat.
Two AVT Guppy cameras, FOV: 24.4° × 31.6°, were tracking the rocket footprint from Toolik:
-Guppy1: Filter: 6300 Å, 4 s exposure times
-Guppy2: Filter: RG645 cutoff, 2 fps



Cascades-2 rocket

Sounding rocket with multi-point measurements

-Two free-flying subpayloads along B_0, with
* wire-boom E-field probes, magnetometers and GPS
-Two free-flying particle detectors across B_0 with
* electron detectors, magnetometers and GPS
-Main payload with
* ion detector, electron detectors, magnetometers, imager and GPS



Launched from Poker Flat into rayed aurora on 20 March 2009, through events of Polar Boundary Intensifications (PBIs).
Apogee: 564 km
PI: Kristina Lynch, Dartmouth
Collaborators: Dartmouth, Cornell, UNH, UAF, KTH, and UC Berkeley

For more information on the rocket and rocket data analysis, see presentation by P. Kintner!

Analysis of auroral rays

Height extent

During the rocket TOF auroral rays were observed from the side. The 100 km to 200 km footprint of the rocket is marked with white dots in Fig.1. The images indicate that there are two layers of rays, one layer (yellow arrow in Fig.1) closer to the camera and another layer further away (orange arrow in Fig.1). From the auroral features detected in the *in-situ* data we can assume that the rays seen at the footprint take place at the known distance of 580 km between Toolik Lake and the rocket footprint. Their height extent is then 130 km. Fig.3 shows a keogram made from cuts along the rocket footprint. The altitude extent of the rays is fairly constant with time.

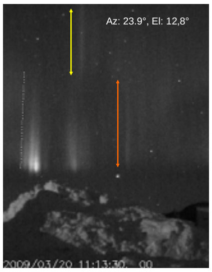


Fig.1: Guppy2 image showing two layers of rays, marked in yellow and orange. The rocket footprint (100 – 200 km extension) is shown as a dotted line.

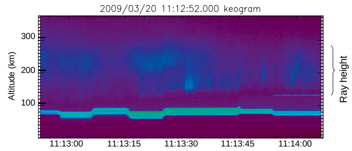


Fig.2: Keogram from vertical cut along rocket footprint, where the rays are seen as light blue. The green line shows the top of the snow pile. The jumps are due to the motion of the tracking camera.

Motion of rays

The time series of guppy images (Fig. 3) show the evolution of auroral rays during an interval of 1min 10s. The auroral drapery is characterized by dynamic and rapid rays moving in opposite directions, with a lower boundary at about 100 km altitude.

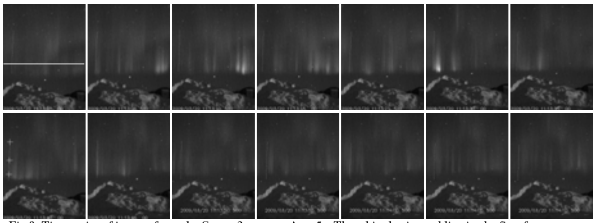


Fig.3: Time series of images from the Guppy2 camera. Δt = 5s. The white horizontal line in the first frame illustrates the position of the cut to create the keograms in Fig.4 and 5.

The motion of the rays can be seen from keograms made by a horizontal cut in the images (Fig. 4 and 5). From the slope of the structures the velocity is determined to 13 km/s both for westward and eastward moving rays.

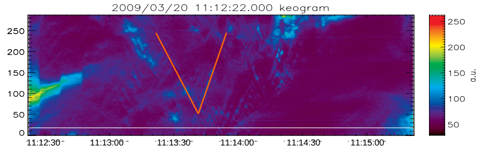
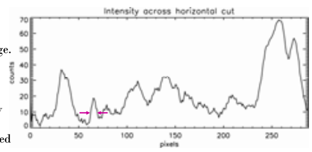


Fig.4: Keogram from a cut made at y=180 in the images. The motion of rays in different directions is seen as lines with positive and negative slopes for eastward and westward motion, respectively. Red lines are put on the keogram to mark typical velocities. The white line near the bottom shows the position of the rocket footprint.

The individual widths of the rays vary, with values down to 5.5 km as seen from the side (Fig. 6). The rays merge and split continuously, with a typical distance between the rays of 15 km, and about 10 individual rays observed simultaneously.



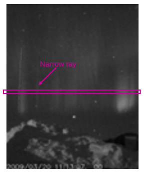


Fig.6: Left: Plot of the intensity through a horizontal cut of an image. The widths of the narrowest rays is determined, by fitting a Gaussian to the intensity peak.
Right: Image with marked cut and narrowest ray.

The large scale picture

All-sky data from Kaktovik (Fig. 7) show the band of rays that the rocket passsed through. Fig. 8 is spectrograph data from Kaktovik. The rocket passed through the poleward onset of a PBI at the time of the observed rays.

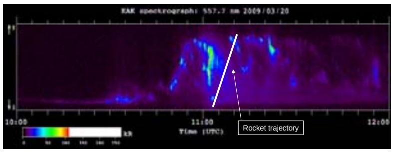


Fig. 8: Spectrograph data from Kaktovik: the rocket passed through poleward onset of PBI at time of the guppy observations.

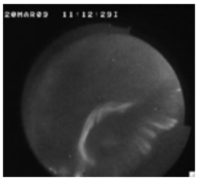


Fig. 7: Kaktovik All-sky camera data

Electron data (Fig. 9, 10) show that the rays are caused by mainly electrons with energies of less than 1 keV. The dispersion seen in electron data is a signature of Alfvén waves. Fig. 10 (top) shows the altitude variation in intensity, with maximum intensity measured at 150 km.

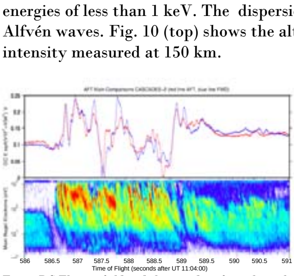


Fig. 9: DC Electric field and electron data from the rocket.

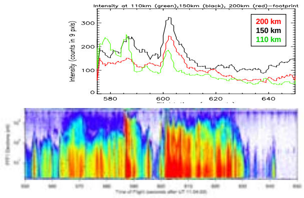


Fig. 10: The correlation between emission intensity in the footprint at 110 / 150 / 200 km altitude (top) and precipitating electron energy (bottom) indicates that the observed rays are the ones seen by the rocket.

Discussion and Conclusions

Auroral rays have been investigated during the flight of the Cascades-2 rocket. First preliminary results show widths of down to 5 km, height extension of 130 km with sharp lower border and motions of the rays in eastward and westward directions simultaneously, with velocities of up to 13 km/s. Rocket data indicates <1 keV electron precipitation and Alfvén wave signatures at the time of the rays. The rays are brightest at ~150 km altitude.

This study will continue by a more detailed analysis of the many data sets (ground based and *in-situ*) available.

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