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Location # 41

Pulsating Aurora: the Equatorial Source Population & Local Morphological Interplay with Diffuse Aurora

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Abstract

Pulsating aurora (PA) is a common ionospheric phenomenon and as such offers a unique opportunity to study the source of the precipitating particle populations. Whistler-mode chorus waves are naturally occurring magnetospheric plasma waves that are distinguished as a discrete superposition of quasi-monochromatic emissions and it is thought that they are the mechanism for pitch angle scattering of energetic electrons into the loss-cone. The dominant source of loss-cone scattering for energetic equatorial electrons, which can then precipitate as PA, has been explored, but not yet clearly identified. Here we use simultaneous satellite- and ground-based data to show that there is a direct correlation between frequencies of equatorial electron flux pulsations and PA luminosity in the corresponding ionospheric magnetic footprint. We computed an array of the correlation coefficients between the pixel luminosity for each individual pixel of the ASI images and the flux measurements at the satellite. The results show regions of very strong correlation between the luminosity fluctuations on the ground and particle pulsations in space.

Observations of a dynamic pulsating aurora event were taken with a pair of colocated allsky imagers at Poker Flat, one filtered at 4278 (blue) and one at 5577 (green). Here we show preliminary results of differences in the energy channels and the structure that appears and disappears as pulsating starts and stops.

Background

It is generally believed that pulsating aurora is caused by energetic electrons [1,2], precipitated by pitch angle diffusion in the vicinity of the equatorial regions of the magnetosphere [3,4,5], a result based on velocity dispersion analyses of sounding rocket observations of energetic electrons in conjunction with pulsating aurora [6,7]. These studies have consistently concluded that the electron populations must originate from geosynchronous orbit, perhaps as a result of scattering via VLF "chorus" or hiss.

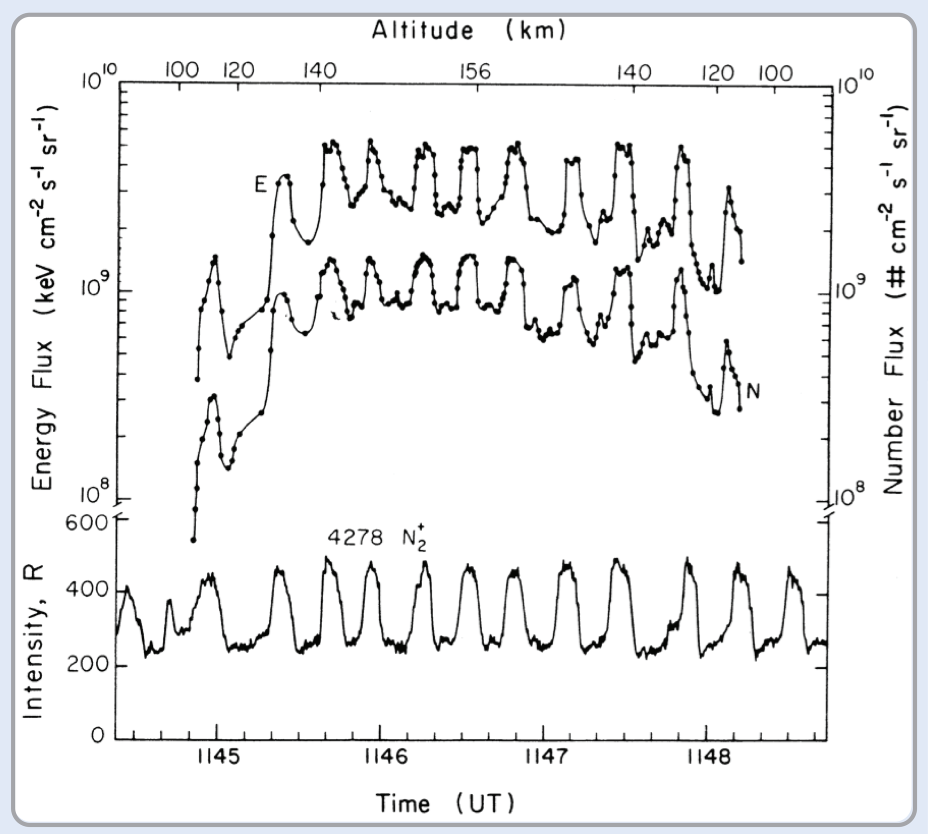


Fig. 1 - Electron fluxes observed from a sounding rocket (upper two traces) plotted with ground-based optical data (lower trace) [2]. Eleven pulsations are clearly shown in all traces.

Whistler-mode chorus waves are generated near the magnetic equator [9,10, 11, 12], and it is thought that they are the mechanism for pitch angle scattering of energetic electrons into the loss-cone [13, 14, 15]. This dominant source of loss-cone scattering for energetic equatorial electrons, which can then precipitate as PA, has thus far only been inferred through rocket observations since the 1960's, until now.

In this study, we use simultaneous satellite- and ground-based data to show, for the first time using in-situ data, that there is a one-to-one response between frequencies of electron flux pulsations in space and PA luminosity in the corresponding magnetic region of the ionosphere . This identifies a source region for the origin population of pulsating aurora.

GOES 13

MAGnetospheric Electron Dectector (MAGED) on GOES 13 satellite

- Geosynchronous orbit near magnetic equator at ~6.6 RE
- 9 SSD telescopes in crossed-fan arrangement (Fig. 2)
- FWHM of 20 degrees each
- Each telescope measures electron fluxes in five energy channels: 30-50 keV, 50-100 keV, 100-200 keV, 200-350 keV and 350-600 keV
- Center pitch angles derived from GOES Magnetometer data
- GOES13 can fly in upright or inverted position, with T7 and T9 typically being nearest to a = 0 in each respective position
- Obtain time-varying pitch angle and magnetic measurements concurrently with particle fluxes

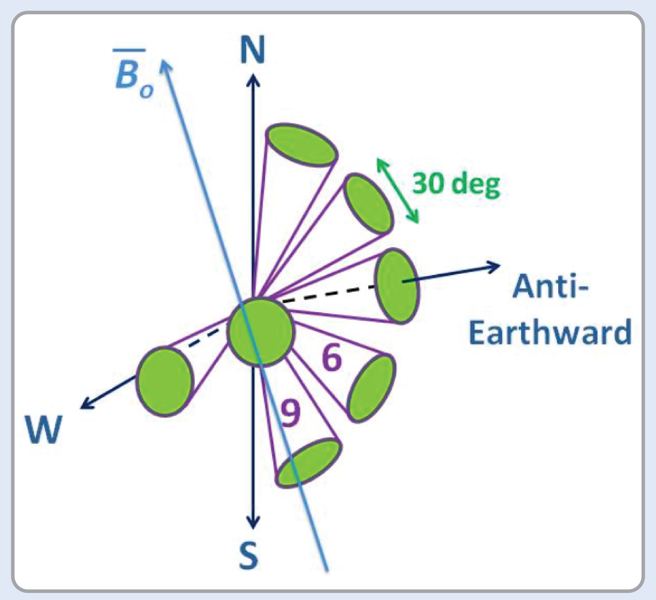
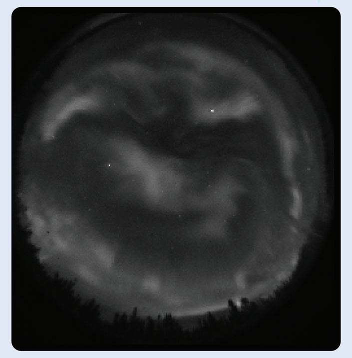


Fig. 2 - Schematic of GOES 13 MAGED telescope array

THEMIS allsky



- GOES 13 footpoint maps well to the THEMIS ASI at The Pas, Manitoba (designated TPAS)
- Several periods of significant fluctuations in equatorial particle flux were seen with MAGED on 15 March, 2008
- The most notable period, from 1100-1140 UT, corresponds with ASI pulsating aurora
- Positioned at 105.3 W, with local midnight occuring at 0700 UT
- GOES 13 was flying in the inverted configuration during this event

Results

- Analysis focused on the 30-50 keV channel of Telescope 9, as that channel had the most intense pulsations
- Telescope 9 was the MAGED telescope most closely field-aligned during this time

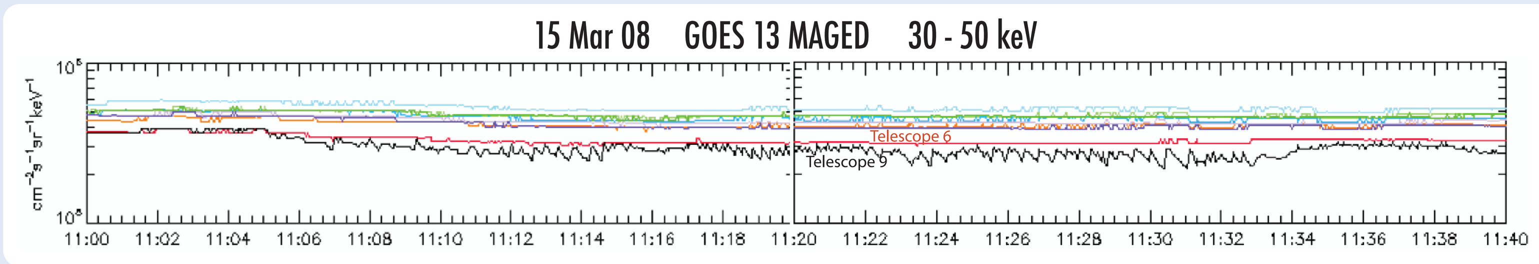


Fig. 3 - GOES 13 electron flux pulsations for 1100-1140 UT, energy channel (30-50 keV) used for correlation. Black trace is the most closely field-aligned Telescope 9. Red trace is Telescope 6.

- The average periods are similar with values of ~24 seconds for the PA pixel luminosity and ~26 seconds for the GOES flux measurements.
- For this plot, the pixel sampled is the one that has the highest correlation with the flux data over the full 30 minute period.
- Contour plots of the correlation coefficients for each time duration are shown below in Fig. 5. Contours are plotted over a single allsky image.

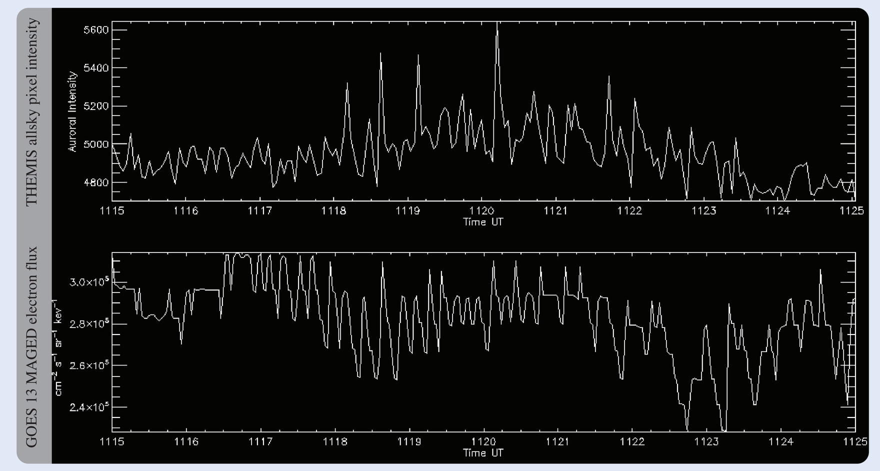


Fig. 4 - Concurrent time series of pixel intensity and electron flux.

Correlation Coefficients

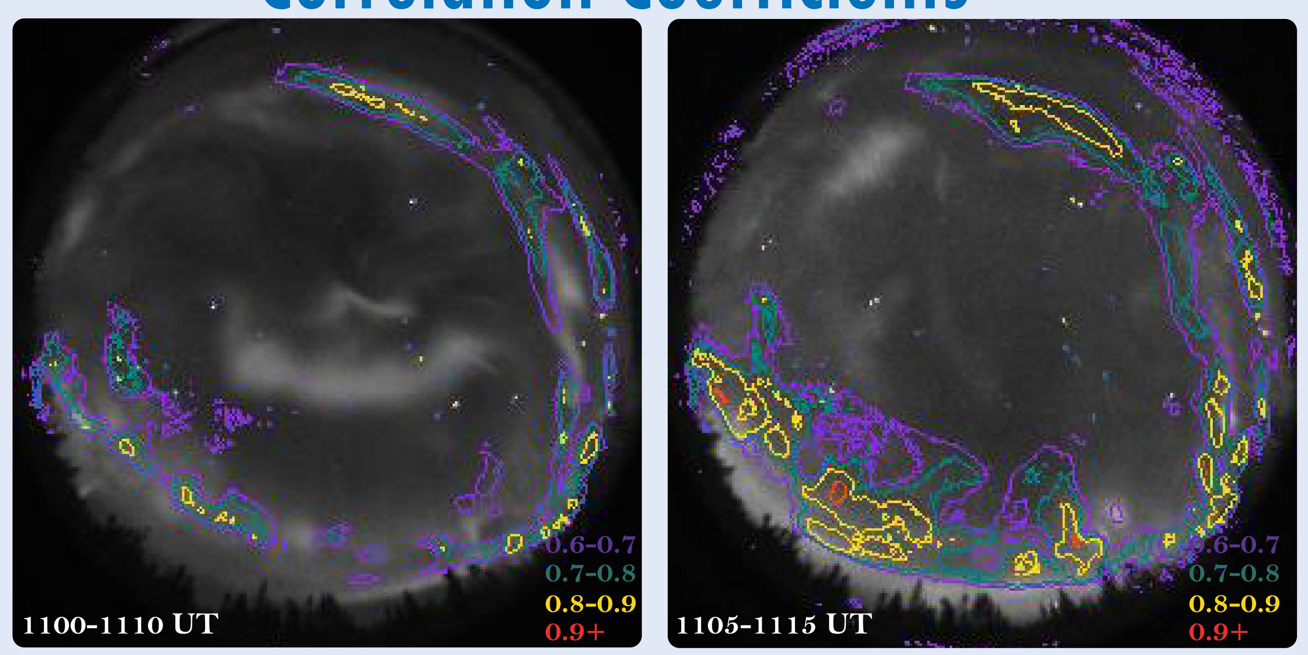


Fig. 5 - Contour plots of correlation coefficients for two 10 minute intervals. Left shows a more quiet time in pulsations. Right shows interval when pulsations intensified.

The location of GOES 13 was traced to 100 km altitude using the TS05 model with OMNI solar wind data as input. Figure 6 shows the Northern hemisphere footprint of the satellite between 0700 and 1500 UT, on 15 March 2008. These locations lie in the northwest quadrant of the field-of-view of the THEMIS all-sky imager at TPAS. There was a dramatic shift in footpoint location (white trace on figure) from 1115-1130, during the time of high pulsations. This is also when the correlations drop off in the allsky analysis.

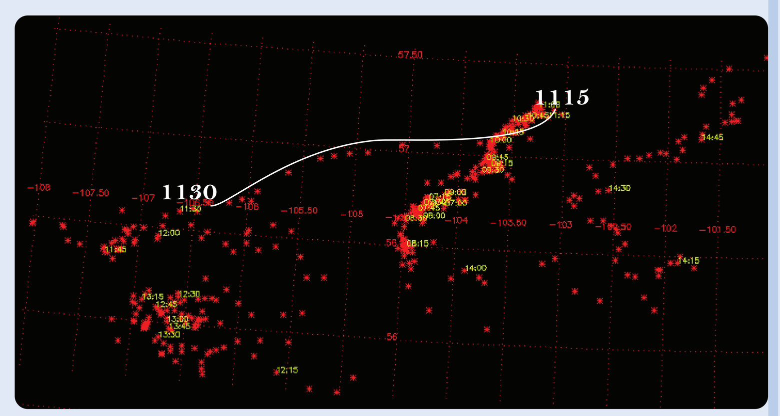


Fig. 6 - GOES 13 footprint mapped in Northern hemisphere

PA & Diffuse

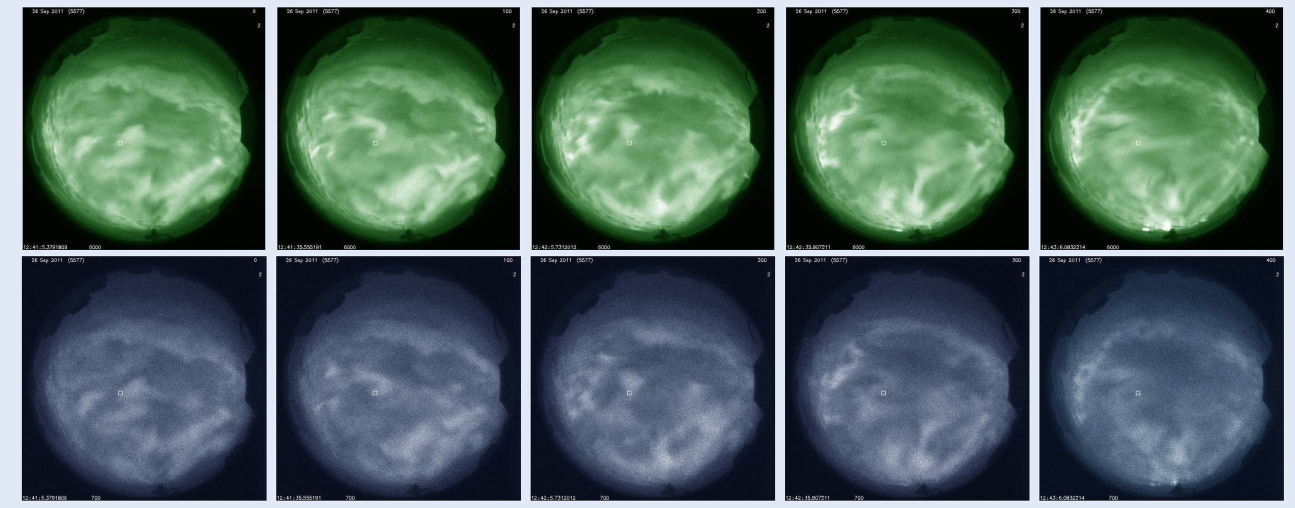


Fig. 7 - Series of raw images in each energy channel, spanning about 2.5 minutes, false color added for effect

Two allsky imagers at Poker Flat take simultaneous images of two distinct energy emissions: 5577 (green) and 4278 (blue) at a 3.3 Hz frame rate, run by the SwRI team. Data shown is from a dynamic pulsating aurora event observed on September 26, 2011.

Early results are shown in Fig. 8. The green and blue traces represent the green and blue emissions. Although the scaling is not accurate, clear pulsations can be seen in the green for some of the time interval, while the blue is more ambiguous, but does seem to become structured from frames 50 - 80. Bottom panel has the blue emission scaled by a constant in order to see relative differences.

This plot is for one pixel defined in Fig. 7 with a white bounding box.

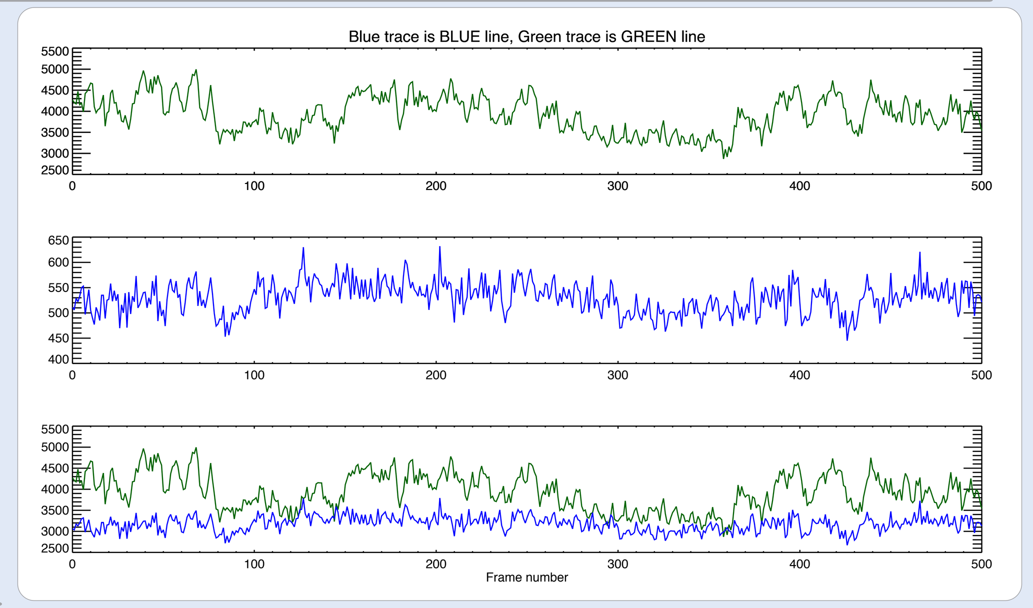


Fig. 8 - Pixel values for each emission, with bottom panel showing scaled data plotted together

Further work is being done with the data, to determine what role the local ionosphere may have on two distinct particle populations, diffuse and pulsating aurora. A good schematic to conjure is shown in Fig. 9. When the pulsating patches turn on and off, what is happening to the diffuse aurora above (or, from the ground-based perspective, "behind")? Studying this interplay with local conditions more closely may develop understanding behind auroral processes. There is interplay between these two fundamentally different populations, with distinct source regions!

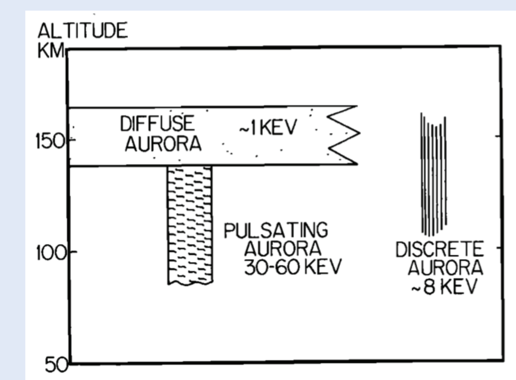


Fig. 9 - Schematic reproduced from Brown et al. 1976 [16]

Conclusions

- Pulsating aurora offers a unique opportunity to study the source of the precipitating particle populations, as we have done in this first study
- Geosynchronous observations of electron fluxes and pitch angles in the equatorial region can be measured with the GOES 13 MAGED telescope array
- In the event presented, we see a clear correlation between pulsating aurora modulations and electron flux pulsations at GOES 13 while it is located along a field line over a region of widespread and persistent pulsating aurora on the ground
- The data from the GOES 13 satellite shows, for the first time, occurrences of electron fluctuations at geosynchronous orbit that coincide with ground observations of pulsating aurora
- Pulsating and diffuse aurora may often interact with local ionospheric conditions in similar ways, affecting precipitation and morphology - this behavior and its implications begs further study

References:

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