Formation of continuum emission structures associated with the aurora

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I. Background & Motivation

Recently developed ground-based auroral imagers have facilitated observations[1] of **continuum emission structures** that appear to be tied to the dynamic aurora.

- 'Grey-toned' structures
- Spectrally like STEVE*
- Embedded in or alongside the aurora
- Evolve on timescales of minutes

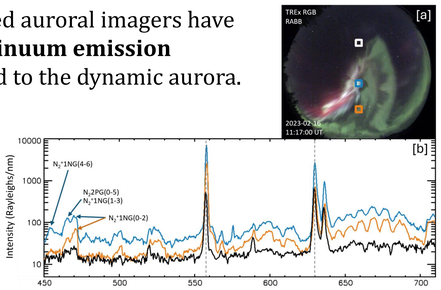

Fig 1. *Example structured continuum emission event.* [a] *TREx-RGB all-sky image.* [b] *Spectra for the locations indicated in the ASI image.*

Goal of this study:
Characterize the geomagnetic conditions associated with the occurrence of these structures.

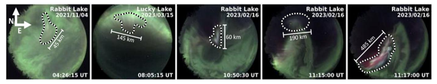

Fig 2. *Images of structured continuum events and associated aurora.*

* Strong Thermal Emission Velocity Enhancement

II. Datasets

Events

Database of 52 events, identified visually in TREx RGB and confirmed with TREx Spectrograph

Global Conditions

Planetary K (Kp) Index[2]

Disturbance Storm-Time (Dst) Index[2]

Local Conditions

TREx RGB[3]

TREx Spectrograph[4] + TREx NIR[5] → TREx ATM[6,7,8] (Auroral Transport Model) → REGO[9] + TREx Blueline[10]

III. Methodology

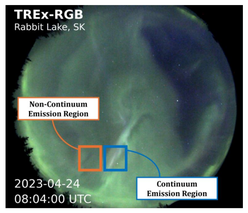

Fig 3. *TREx-RGB image, with "continuum" and "non-continuum" regions indicated.*

1. Superposed epoch analyses of the Kp and Dst indices to quantify global conditions from a statistical perspective.
2. Superposed epoch analyses of TREx RGB data to investigate patterns of luminosity in the local ionosphere.
3. Together, TREx Spectrograph + TREx NIR instruments provide absolute intensity of four common auroral emissions. These emissions are then used as inputs to TREx ATM to model energy flux, quantifying the continuum structures' association with precipitation for a subset of 32 events.
4. For one event with coverage from TREx RGB, TREx NIR, TREx Blueline and REGO, four necessary emissions were obtained for a large spatial extent within the ASIs' field-of-views. Using these as inputs into TREx ATM and georeferencing the outputs allows for a spatially resolved map of energy flux.

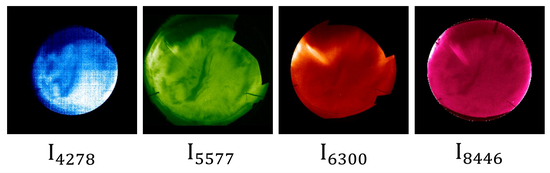

Fig 4. *Absolute intensities of four common auroral emissions for an overlapping field-of-view. These 'emission images' are used as inputs to the auroral transport model to map precipitating energy flux.*

IV. Results

Global Conditions

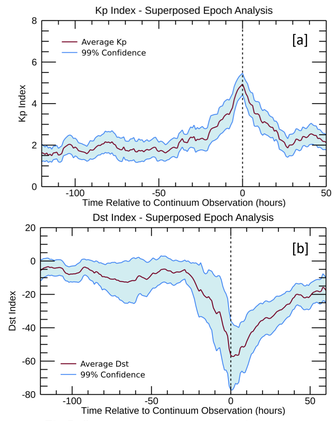

Fig 5. *Superposed epoch analyses of global geomagnetic indices.* [a] *Planetary K (Kp) Index.* [b] *Disturbance Storm-Time (Dst) Index*

- Kp is substantially elevated at the time of structured continuum observation.
- Kp increases from ~ 2 to 4.5 over the 24 hours preceding emission onset.
- Kp index reaches its **peak value at t_0.**

- Trend in Dst agrees, showing an average decrease of ~ 50 nT over 30 hours prior to continuum observation.
- Structured continuum emissions occur near **minimum Dst**, consistent with strongest, storm-time conditions.

Local Conditions

- Increased brightness in both ASI regions signifies consistent association with enhanced auroral dynamics.
- Peak luminosity, which occurs when the structure enters the region of interest, is substantially higher where continuum is observed.

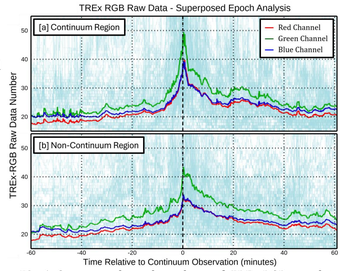

Fig 6. *Superposed epoch analyses of TREx RGB raw data channels.* [a] *Region of continuum structure observation.* [b] *Non-continuum region.*

- Continuum region reaches an average peak energy flux exceeding 10 erg/cm^2/s.
- Narrow peak in continuum region suggests that structures themselves are consistently associated with enhanced local energy input from magnetosphere.

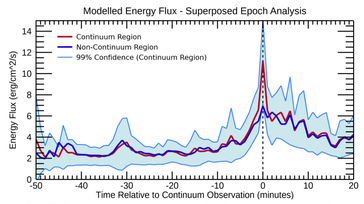

Fig 7. *Superposed epoch analysis of modelled energy flux.*

Case Study

Maps of modelled energy flux alongside TREx RGB show a spatially coherent structure evolving over time, with enhanced energy deposition, that tracks the structure itself.

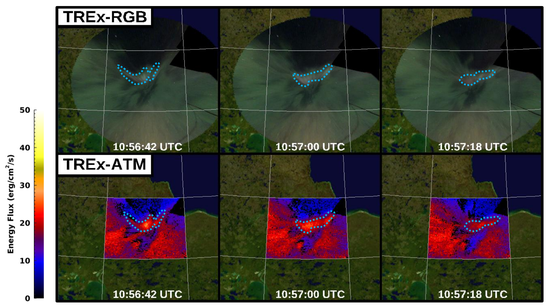

Fig 8. *Maps of modelled energy flux surrounding a structured auroral continuum emission. The top three panels show TREx RGB all-sky image data, projected onto a geographic map, in which a grey-toned continuum structure can be seen evolving over time. The bottom three panels show the corresponding maps of energy flux, obtained via an auroral transport model. This event occurred at Gillam, MB, on 2023-02-16.*

CEDAR-GEM Joint Workshop 2025
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Additional Information

V. Conclusions

Global Conditions

Structures consistently occur during periods of elevated geomagnetic activity, alongside significantly enhanced Kp and storm-time levels in Dst.

Superposed epoch analysis of Kp and Dst indicate a clear association between structured continuum emissions and **peak** geomagnetic disturbance.

Local Conditions

Auroral brightness in the local ionosphere observed but structures themselves peak higher than surrounding aurora.

Statistically, modelled energy flux indicates **a direct association between the structures and precipitation (MIT Coupling)**.

Precipitation enhancement is spatially coherent and aligns with visible continuum structures.

- Structures occur preferentially during periods of maximum geomagnetic disturbance.
- Modelled energy flux is spatially coherent with structures, indicating MIT coupling as a driver.

VI. Future Steps

- Similarity of spectral properties to STEVE warrants a comparison between the two – conjunctions with spacecraft will be used to explore the possibility of fast flows / sub-auroral ion drifts.
- One proposed mechanism[11] for STEVE's brightness is an NO_2 continuum arising from nitric oxide produced via vibrational excitation of N_2. Future work could aim to model these structure to determine validity of this mechanism.
- Utilizing SuperDARN data to further study the ionospheric environment (e.g. convection) could help connect these structures to known magnetospheric phenomena.

VII. Acknowledgements

This research was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada, and by the Canadian Space Agency (CSA).

The Transition Region Explorer is a joint Canada Foundation for Innovation and Canadian Space Agency project developed by the University of Calgary. The TREx RGB and Spectrograph instruments are operated and maintained by Space Environment Canada with the support of the Canadian Space Agency (CSA) [23SUGOSEC].

VIII. References

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