Investigating Electrodynamic Energy of the Pulsating Aurora

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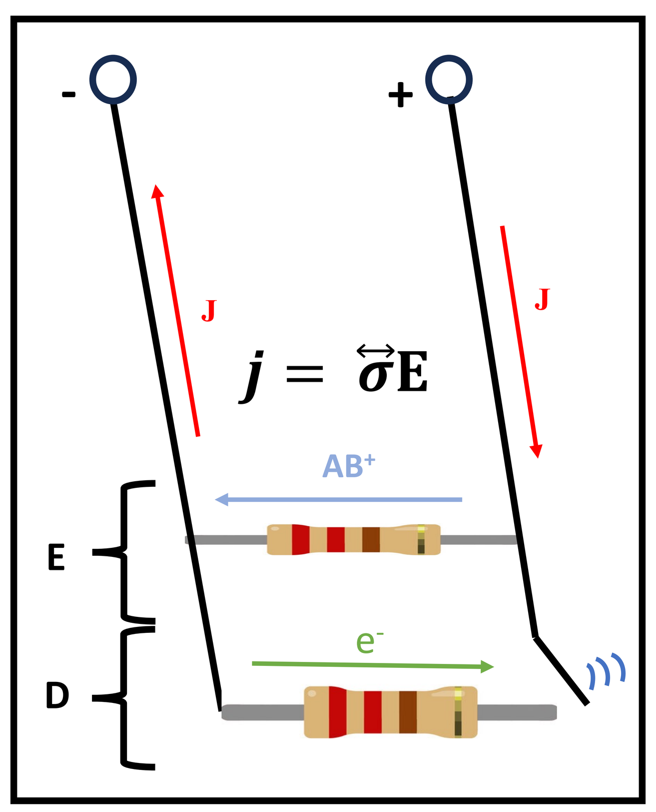
Abstract

Pulsating aurora are a common auroral subset characterized by an optical strobing effect of multiple small patches that are typically found in morning MLT sector and following substorm breakup. Pulsating aurora are attributed to higher energy particle precipitation than discrete aurora and penetrate to lower altitudes in the E-region and upper D-region. The strobing nature of the optical effect is reflected in high resolution electron density maps at these altitudes. This poster focuses on observational efforts to quantify the current systems associated with pulsating aurora. For this investigation, we will use pulsating aurora events captured on incoherent scatter radar and all-sky imagers during the Loss through Auroral Microburst Pulsations (LAMP) campaign. We quantify the contribution that D-region Pedersen conductivity enhancements have on the overall energy dissipation within an auroral event. We further present electric field measurements associated with these events to understand the interplay between the electric fields and the conductivities to effect heating.

Theory

Joule Heating (Q_j) is the rate of energy deposition from frictional heating that comes from the interaction of electrons, ions, and neutrals in Earth's ionospheric plasma. Full characterization of Joule Heating requires neutral wind data; however, it is a common and attainable tool to determine the Passive Joule Heating (Q_j^e) that only considers neutral collisions and not winds. This depends on the electric field (E) and the height integrated conductivity (conductance- Σ_P) of the ohmic plasma.

$$Q_j^e = \mathbf{J}_P \cdot \mathbf{E} = \Sigma_P \mathbf{E}_\perp^2$$



Conductivity has three-dimensional structure relative to magnetic field lines. Conductivity perpendicular to the magnetic field and parallel to the electric field is known as the Pedersen conductivity, which contributes to Joule Heating. Ionospheric conductivity is derived from the ion momentum equation with the assumption of negligible gravitational and pressure gradient forces. Current derived from this velocity expression is manipulated into the ohmic form. The resulting conductivity depends on electron density and collision frequencies.

$$\sigma_P = \frac{en_e}{B}\left(\frac{\Omega_i \nu_{in}}{\Omega_i^2 + \nu_{in}^2} + \frac{\Omega_e \nu_{en}}{\Omega_e^2 + \nu_{en}^2}\right)$$

Studies of discrete and diffuse aurora only calculate the Pedersen conductivity contribution from the demagnetization of ions that typically peaks at approximately 120km. High energy particle precipitation forming pulsating aurora has been shown to create a secondary peak at 70-90km tied to the demagnetization of electrons for short (5-20s) time periods.[1] This changes the typical analogy from a single resistor to two different resistors in parallel, as demonstrated in the diagram on the left.

Discussion and Future Work

In this ongoing work we demonstrate that the secondary peak in conductivity formed by electrons during pulsating aurora has a lasting impact on the state of the ionosphere beyond the period of "on" pulsation. During the LAMP mission, electron mobility represented an average of 11.1% of the total height integrated conductance.

The passive Joule heating on the night of the LAMP sounding rocket launch peaked at **67.9 mW/m²** and averaged **3.18 mW/m²** . The electron mobility contribution to Joule heating averaged **10.3%** but was consistently elevated as the pulsating aurora continued past dawn.

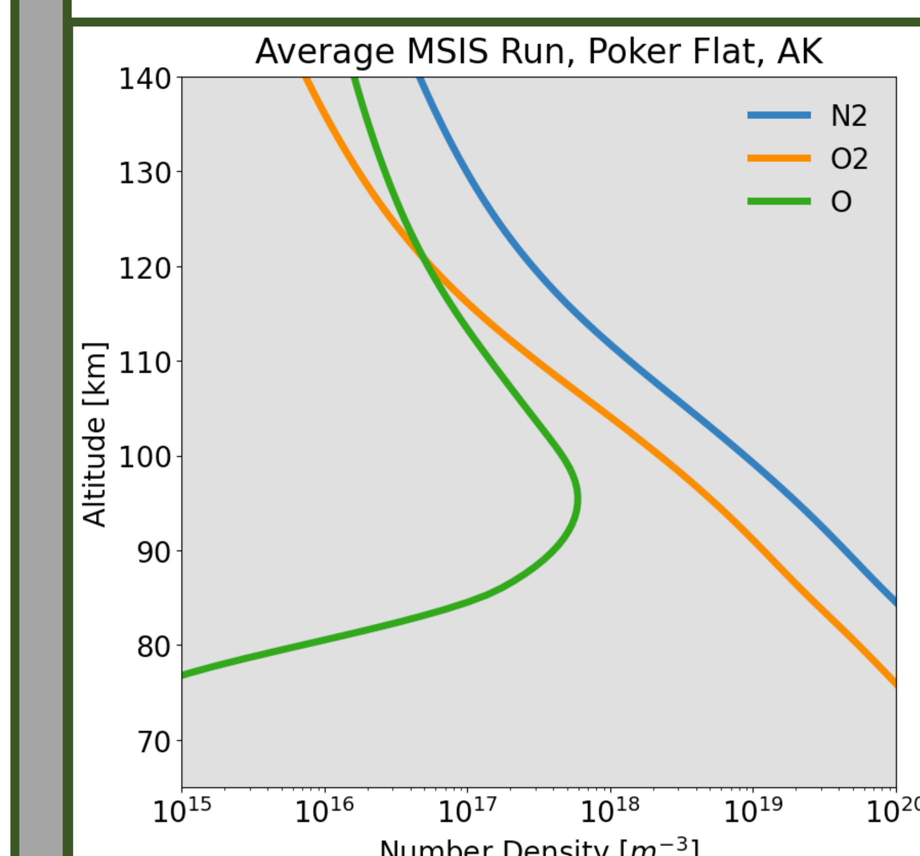
Future work on this project will incorporate more pulsating aurora events captured by PFISR both in the LAMP campaign and in the MSWINDS dataset for statistical analysis. We will also seek methods to improve electric field time resolution and re-examine the formulation and assumptions of collision frequencies under strong pulsating aurora conditions.

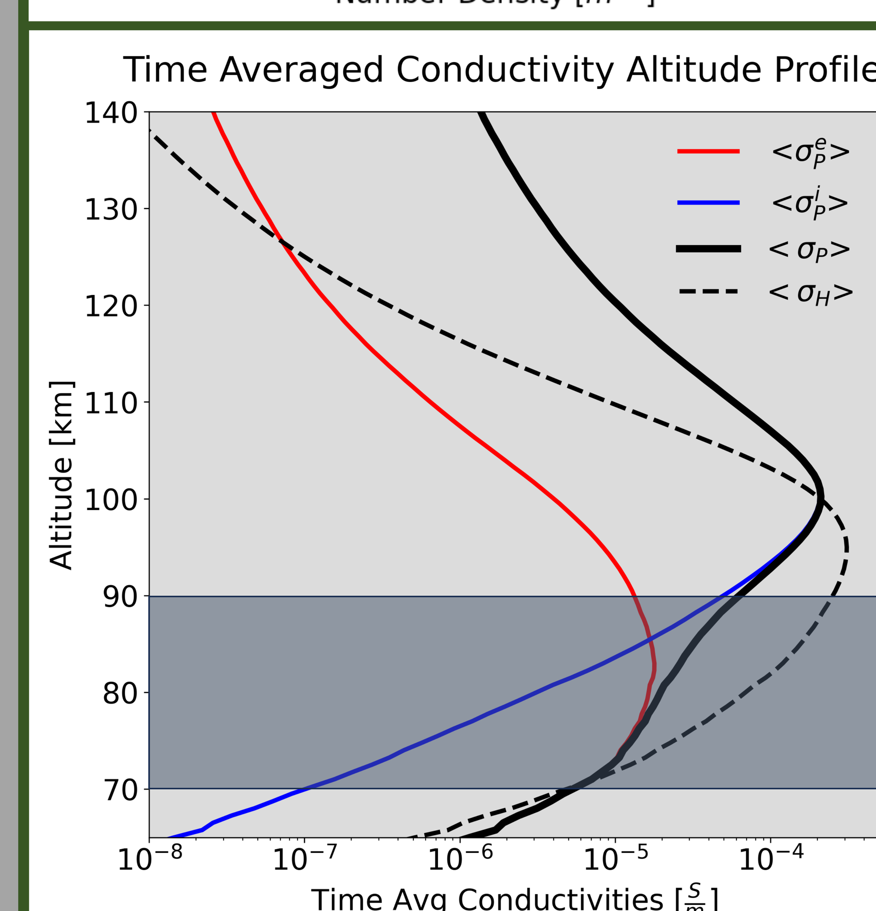
Methodology

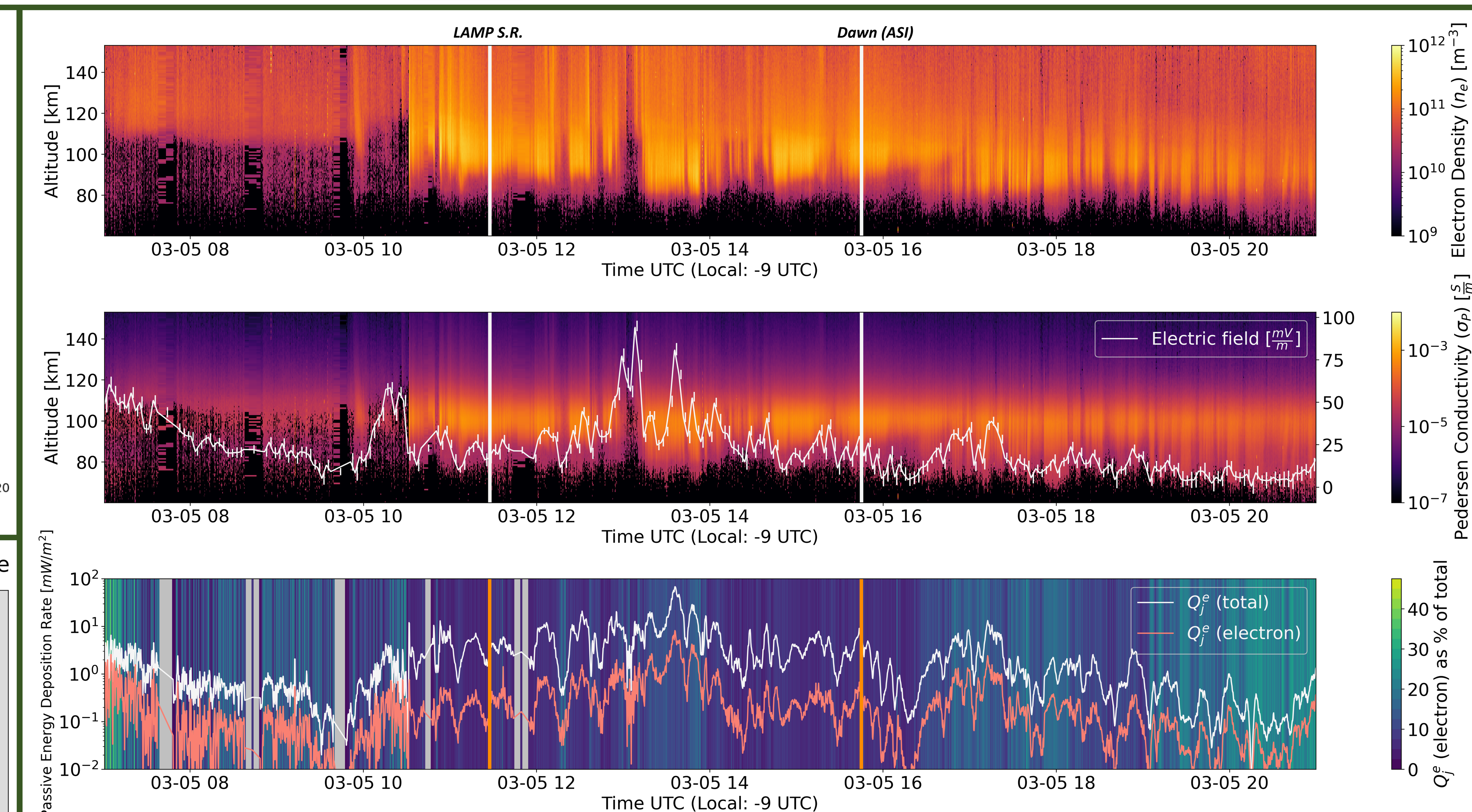
- Electron density and electric field data were taken from the Poker Flat Incoherent Scatter Radar (PFISR) during a six-beam mode that combined Barker code, alternating code, and long pulse transmissions. Barker code data was used for vertical 15 second resolution electron density measurements at 70-150km. Long pulse data produced F-region electric fields (assumed to map downward) using the Heinselman and Nicolls Bayesian reconstruction method.
- Collision frequencies were calculated by the formulas presented below.[2] Concentrations were modeled using MSIS 2.0 each hour and the electron temperature was assumed to be equal to the neutral temperature. Ion-electron collisions were considered negligible, and collisions were considered non-resonant.

$$\nu_{in} = k_{N_2} \cdot [N_2] + k_{O_2} \cdot [O_2] + k_O \cdot [O] \qquad \nu_{en} = 5.4\times10^{-10} n_n \cdot T_e^{\frac{1}{2}}$$

Results







(Upper Left) Average of MSIS 2.0 runs for species N_2, O_2, and O initialized every hour. These runs were used to model collision frequencies for the conductivity calculation. **(Lower Left)** Conductivity height profile averaged over the pulsating aurora data collection time. The solid and dashed black lines are the Pedersen and Hall conductivities respectively, and the red and blue lines show the individual contributions from the electron and ion mobility terms. Note the shoulder enhancement that forms in the Pedersen profile from 70-90km. **(Upper Right)** PFISR Electron density plot from 03-05-2022 LAMP campaign. High resolution measurement taken with Barker code pulse compression. **(Middle Right)** Pedersen conductivity calculation from Barker code data with overplotted electric fields determined by Heinselman and Nicolls Bayesian reconstruction from F region long pulse data under a vertical mapping assumption. **(Lower Right)** Joule heating calculation disregarding neutral winds. White line represents the total and red represents the contribution of the electron mobility term. The colormapped background depicts the percentage contribution of the electron term to the total passive energy deposition rate.

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2. Brekke, A. (2013). *Physics of the Upper Polar Atmosphere* (2nd ed.). Springer.