Comparative Hypothesis Testing of Auroral L-Band Scintillation Layer

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Introduction

Motivation: Scattering layers of GNSS (Global Navigation Satellite System) are normally hypothesized using case studies

Objective: Determine the layer where scintillation will likely occur using a survey of scintillation events

Background

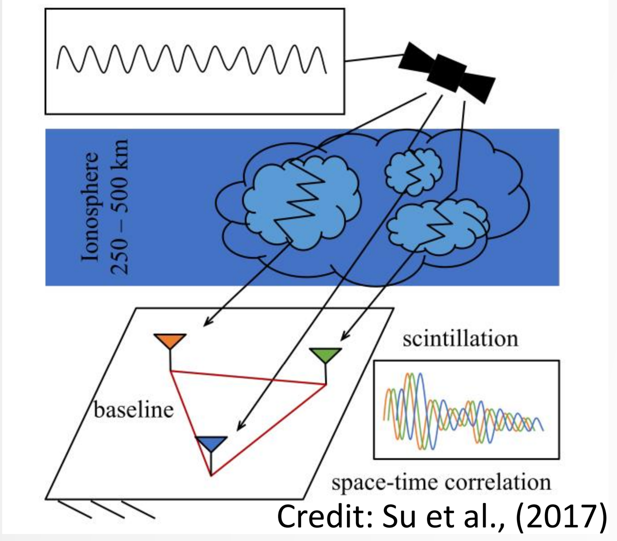

Fig 1.) Image describing scintillation

- Scintillation Auroral GPS Array (SAGA) is used to detect when scintillation occurs (Sreenivash et al., 2020)
- ~ 5,000 scintillation events analyzed in this study
- Sreenivash et al. 2020 hypothesize where peak electron densities occur is where the scattering layer is likeliest to be
- Ratios of auroral light emission can also be used to predict the scattering layer
- Multi-instrument study used to hypothesis layers

Instrumentation

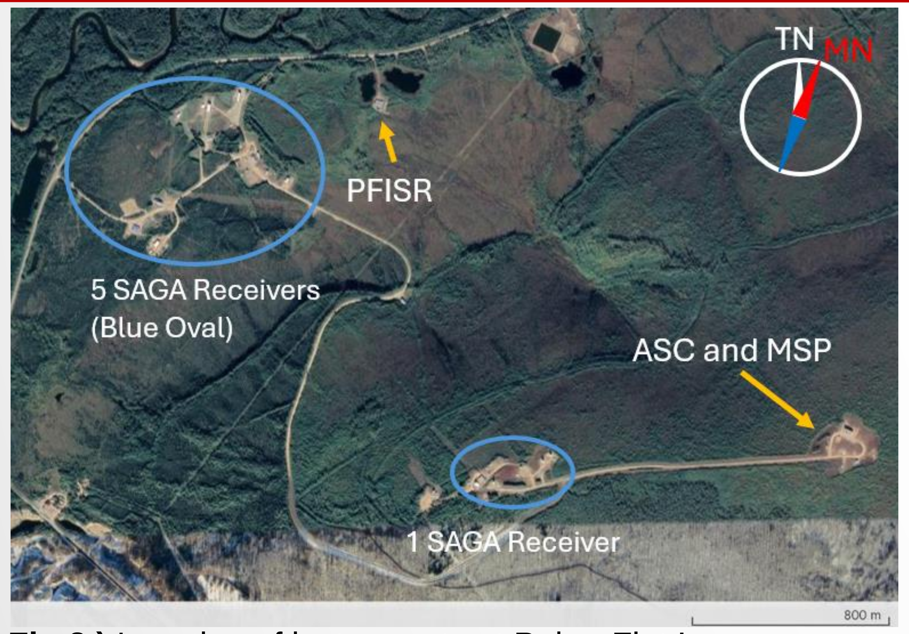

Fig 2.) Location of instruments at Poker Flat Image Modified from Google Earth

- Instruments located at Poker Flat Research Range
  - (66.1^{0}N magnetic)
- Poker Flat Incoherent Scatter Radar (PFISR) measures electron densities
- All-sky Cameras (ASC) measure emission related to particle precipitation

PFISR

- Southward facing, anti-parallel to local magnetic field line (205.7º az, 77.5º el) beam used
- Two types of electron density data used
  - Long Pulse (LP) (above 195 km)
  - Alternating Code (AC) (below 195 km)

ASC

- 2-D image from white light camera
- Two physical filters
  - 428 nm (blue) filter (excitation of N_2^+ - E Region)[7]
  - 630 nm (red) filter (O(1D) - F Region)[7]

$$M_{\lambda,ij}(t) = (S_{\lambda,ij}(t) - \beta_\lambda)(\frac{k_\lambda}{\tau_\lambda})$$

-The corrected photon flux M (Rayleighs) at wavelength λ, (i,j) are the pixel indices
-S is the raw sensor image (camera counts)
-B_λ is a constant bias (camera counts)
-k_λ is a camera response per exposure time
$-\tau$ is the camera exposure time

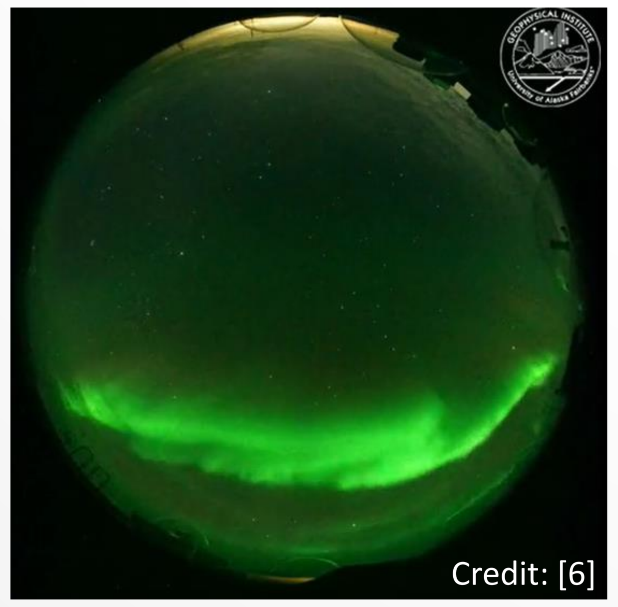

Fig 3.) Image using an all-sky imager

Method

Density-based hypothesis:

PFISR electron density data used to find peak electron densities

Step 1.) Check if at least 80% of AC data and 80% of LP data is available during scintillation

Step 2.) Filter out data points if $DNe > \frac{Ne}{3}$ (LP data), $DNe > Ne$ (AC data) (gray oval Fig. 5)

Step 3.) Find maximum electron densities for each time step PFISR outputs data (red oval Fig 5)

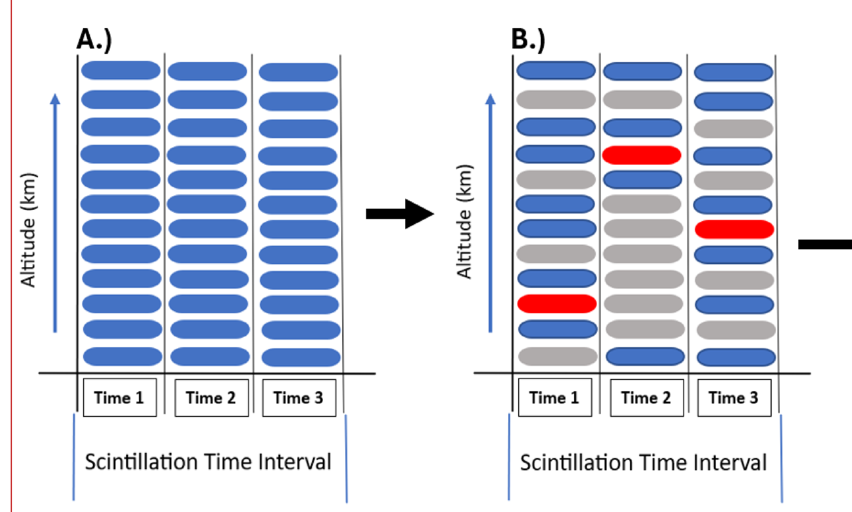

Fig 4.) Cartoon of data filtering due to uncertainty criteria. Red ovals (max densities), gray ovals (data filtered out due to large uncertainties)

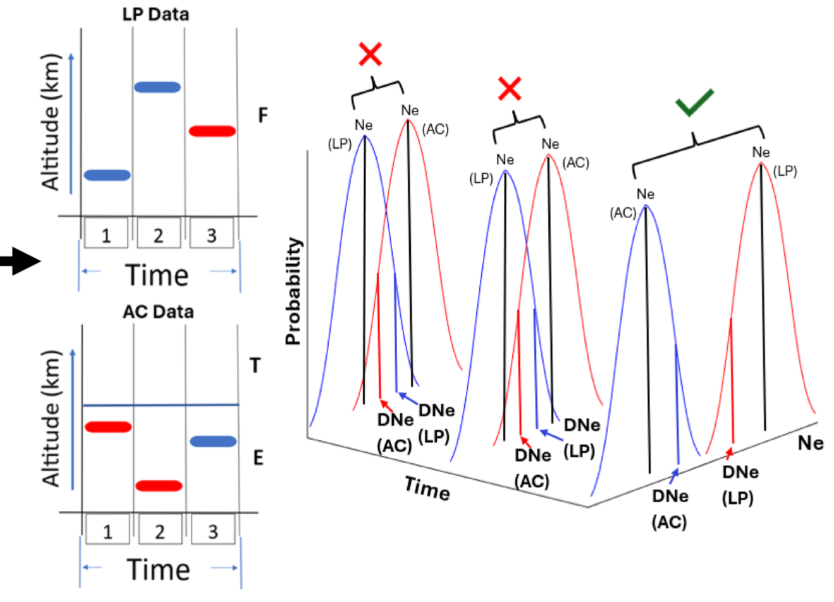

Fig 5.) Process showing when measurement uncertainties overlap

Step 4.) At time t let Ne_1 be the greater density measurement ($Ne_1 > Ne_2$) if $Ne_1 - DNe_1 < Ne_2 + DNe_2$ the measurements fall within each others uncertainty and all data is removed at that time step

Step 5.) Compare remaining peak densities from AC data to LP data

Energy-based Hypothesis:

ASC is used to measure emissions of aurora

Step 1.)

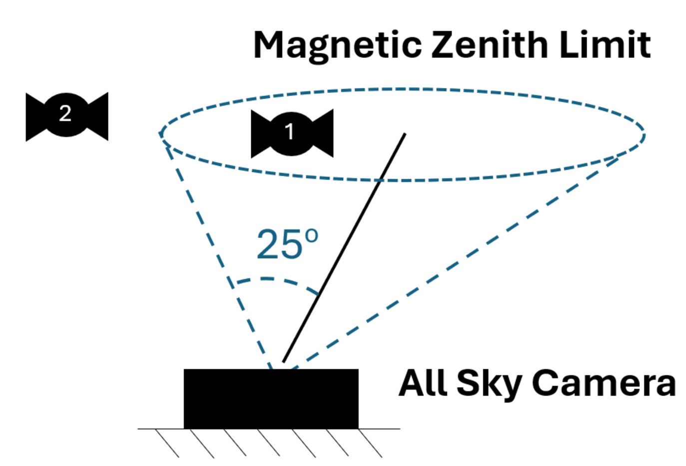

Fig 6.) Remove satellites not within magnetic zenith limit

Step 2.)

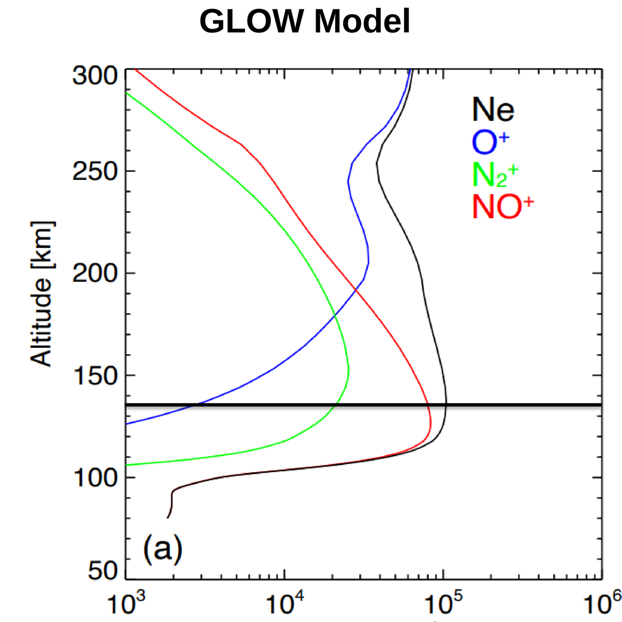

Fig 7.) GLOW model Output: Image Credit: Dr. Nishimura

Step 3.)

$$\rho_{630/428}(t) = \frac{M_{630.0}}{M_{428.0}}$$

- Use the ratio of the ASI red image (630.0 nm) pixel intensity to the blue (428.0 nm) pixel intensity
- Red/Blue ratio of 1.35 corresponds to E/F region cutoff of 135 km

Step 4.)

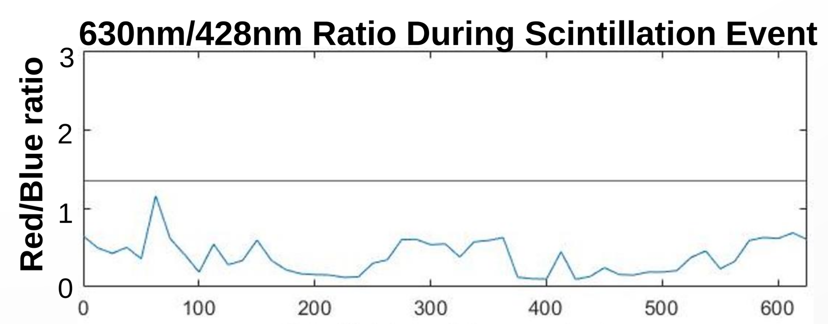

Fig 8.) 630nm/428nm ratio during scintillation event occurring on 03/18/2015.

Results

Density Method Layer

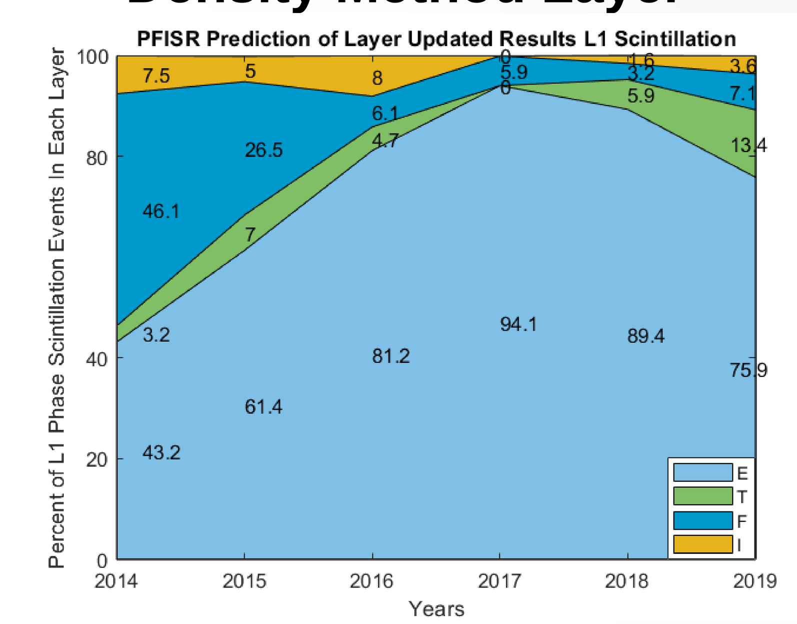

Fig 9.) Results of density-based method as a percentage year-by-year

Energy Method Layer

L1

Year	E	F	Total
2014	53	15	68
2015	13	6	19
2016	11	2	13
2017	5	0	5
2018	6	0	6
Total	88	23	111

L2C

Year	E	F	Total
2014	28	6	34
2015	9	5	14
2016	8	0	8
2017	5	0	5
2018	2	0	2
Total	52	11	63

Table 1.) Results of energy-based method: most layers are categorized as E events

Comparison of Density to Energy Based Method

Total Events =174 Layer Designation		Density Based E	Density Based F
Energy Based	E	114 (65%)	26 (15%)
Energy Based	F	19 (11%)	15 (9%)

Table 2.) Comparison of density-based method to energy-based method

- Survey 174 events from 2014-2018
- PFISR ASI Agree 74% and disagree 26%
- Majority of scintillation occurs in E region

Conclusion

- Updated the density-base method to more accurately predict irregularity layers
- Used the all-sky imager to predict irregularity layers due to precipitating electrons
- **Scintillation likeliest to occur in E region**
- **Future Work:**
  - Case study analysis of events when the density-based and energy-based methods disagree

Acknowledgments

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PFISR Data Accessed: http://cedar.openmadrigal.org/, https://data.amisr.com/database/
ASI Data Accessed: ftp://optics.gi.alaska.edu/PKR/

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Scintillation data for saga can be found at: http://apollo.tbc.iit.edu/~spaceweather/live/?q=SAGA
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