GPS L1 scintillation detection using a novel 3-dimensional PFISR Mode

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Introduction

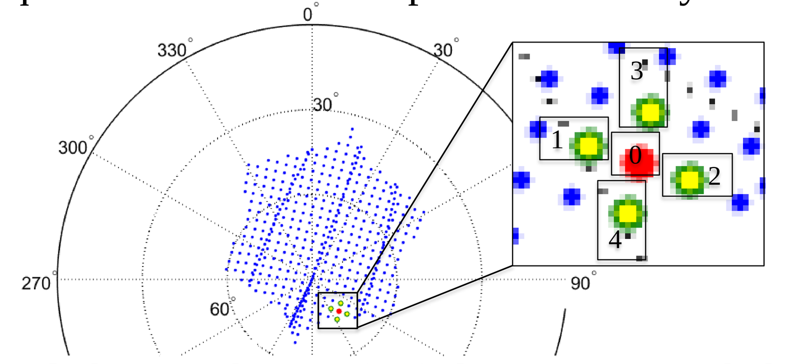
Scintillations on GPS L1 signals due to high-latitude ionospheric electron density gradients can be highly localized and difficult to attribute. Previous studies indicate that above Poker Flat Research Range (PFRR), scintillations are primarily the result of dynamic E region gradients produced by impact ionization during energetic auroral precipitation. Previous modes on the Poker Flat Incoherent Scatter Radar (PFISR) directed a single beam along the GPS line of site. Temporal and spatial resolution of at least 15 s and 24 km were achieved, but only along the GPS line of site. Little information was gained regarding the spatial context of the ionospheric structures [1,2].

Problem Statement

Design a multi-beam PFISR experiment mode that achieves appropriate temporal and spatial resolution to concisely attribute ionospheric scintillations on GPS L1 signals with context.

Materials and methods

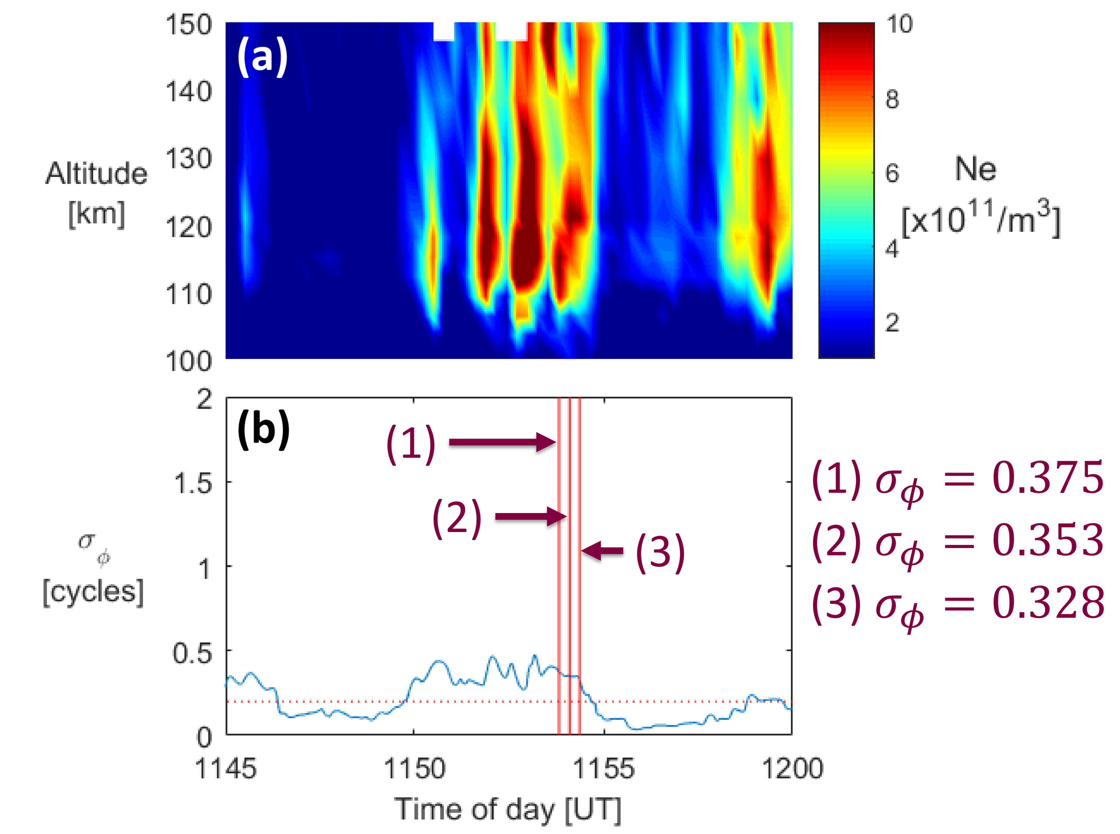
Experiments were conducted between February and May 2017, and from October 2017 to April 2018. Through the end of February 2018, over 550 multi-beam, interleaved coded pulse experiments were conducted on PFISR to target the E region ionosphere, yielding over 200 hours of data. In the figure below, the PFISR beam pattern is shown with the multi-beam mode sequence for the experiment presented in results. Beams were sensed in order according to 102304, with the central beam (0, along the GPS signal path line of site) sensed twice per sequence to decrease temporal uncertainty.



Final electron density (Ne) data were provided after being processed and fitted by SRI at 15 s cadence. CASES data shown here is at 100 Hz cadence, post-processed from raw data. [3]

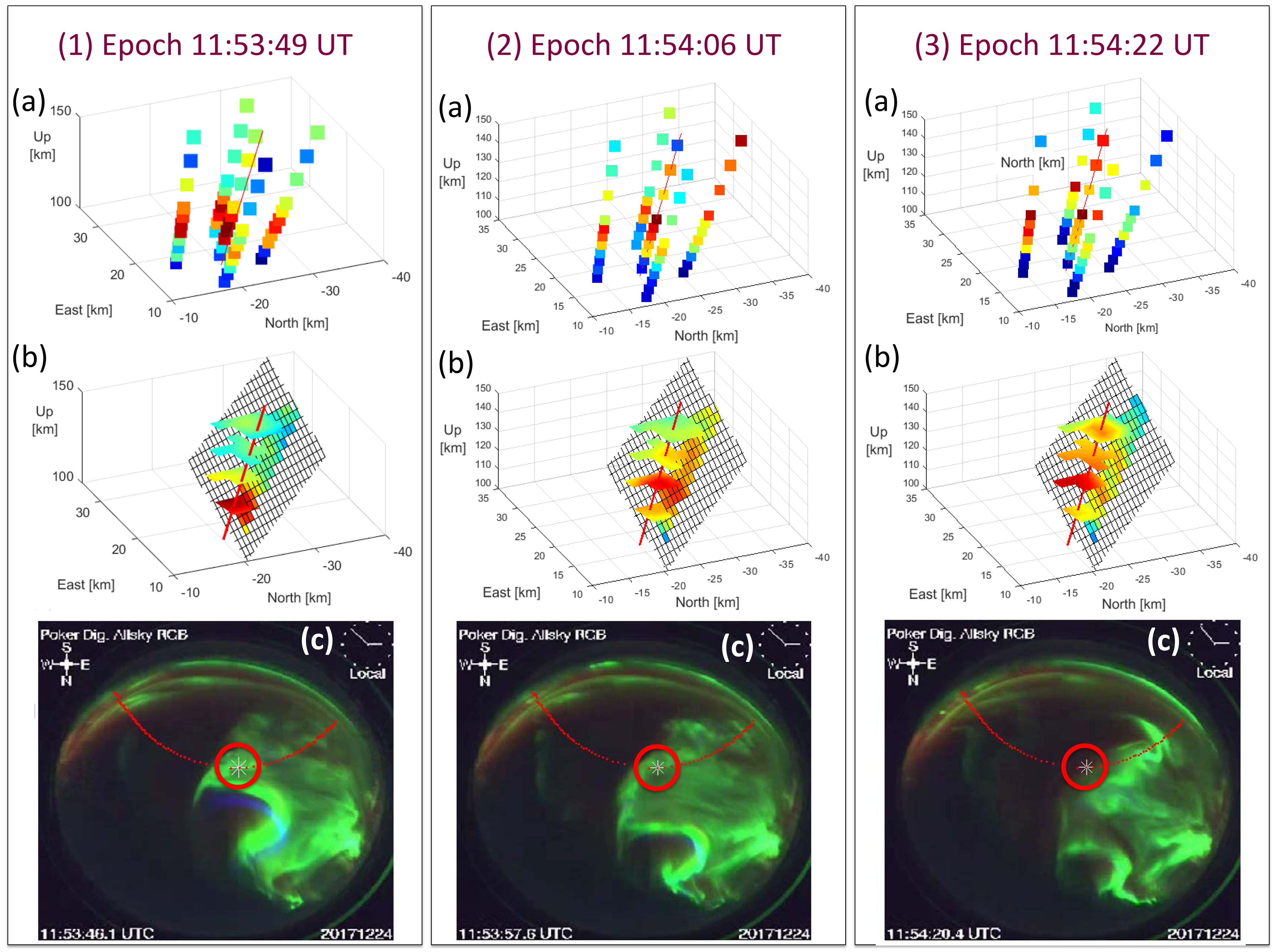
Results

Shown below are figures representing snapshots of a single experiment on December 24, 2017, 11:44:00-12:06:30 UT. During this time there were only minor fluctuations in storm indices (the DST dropped almost 20 points from +10 to -9, the Kp reached just over 3, and the AE was active, not shown). Local magnetometer data at PFRR shows magnetic field component fluctuations, an indicator of auroral activity (not shown).



Data displayed

1. Far right:
   (a) Color plot of electron density by altitude from PFISR beam 65468 (central beam, az 140.04º, el 75.29º) at 15 s cadence.
   (b) Phase scintillation index (σ_ϕ) over the corresponding time interval. Three vertical lines numbered (1) through (3) correspond to the radar and all sky imagery below.
2. At right: Radar and imagery data from the three epochs highlighted on the scintillation plot in 1(b) above. Each sub-figure is described below.
   (a) 3D scatter plot of fitted PFISR radar beams for the epochs indicated. A canted red line indicates the approximate GPS signal path at the time of the data.
   (b) 3D interpolated slices spread horizontally over 110-140 km and one diagonal slice. A red line indicates the GPS signal path at the time of the data.
   (c) PFRR DASC RGB overlay at the nearest image epoch prior to the radar epoch represented. The location corresponding to the PFISR experiment beams during is indicated by a red circle. The GPS location at the current epoch is indicated by a white asterisk. The red arc indicates the az/el locations over time for the GPS satellite.



Summary & Future Work

Two periods of scintillation appear in this window. The first, with a peak σ_ϕ of 0.471 cycles, is linked to a period of electron density variation that changed slightly over 16 seconds. By contrast, the second, with a peak σ_ϕ approaching more than 2 cycles just after the experiment window, shows a much greater electron density variation over two similar intervals. In agreement with previous experiments, GPS L1 scintillations during this window appear to be linked to fluctuating E region electron density gradients that resulted from impact ionization due to auroral particle precipitation. Higher σ_ϕ values appear correlated with faster changing gradients. Future work includes maturation of the 3D visualizations and interpolation schemes, fitting of PFISR data for plasma velocities, and running correlation analyses between σ_ϕ and any or all of vertical and lateral spatial gradients, plasma velocities, and particle energies [4].

Acknowledgments

- The Poker Flat Incoherent Scatter Radar (PFISR) is operated by SRI International on behalf of the US National Science Foundation under NSF Cooperative Agreement AGS-1133009. All PFISR processed data is available via amisr.com/database, and raw data is available upon request to roger.varney@sri.com.
- ASTRA staff were supported by NSF Grant PLR 1243225. CASES data available upon request to gcrowley@astraspace.net.
- Optical imagery data provided by D. Hampton at the Geophysical Institute, UAF, PFRR.
- DST, Kp, and AE Indices downloaded from WDC for Geomagnetism, Kyoto.
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Abbreviated Reference List*

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[4] Rees, M. H., and D. Luckey (1974), Auroral Electron Energy Derived From Ratio of Spectroscopic Emissions 1. Model Computations, Journal of Geophysical Research, 79 (34), 5181{5186, doi: 10.1029/JA079i034p05181.

* Abbreviated, full list provided upon request

Further information

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