With the continuing reduction in seasonal Arctic sea ice extent, increase in ship traffic above the Arctic Circle is expected, and will increase the overall communication and navigation footprint in the region. Ionospheric behavior in the polar regions can significantly impact Ultra High Frequency (UHF) transmissions including degradation of Global Positioning System (GPS) positions and communications interruptions. To address these operational concerns, a need arises to identify and understand the location of the scattering region and its variability, which is a key component of the ionospheric scintillation phenomenon. The Poker Flat Incoherent Scatter Radar (PFISR) provides a significant dataset of ionospheric disturbances and their impact on GNSS signals. In this project, GPS data was obtained over a two-year period with a focus on the month of March which shows high seasonal Arctic sea ice extent and increased communication and navigation footprint.

Introduction

With the continuing reduction in seasonal Arctic sea ice extent, increase in ship traffic above the Arctic Circle is expected, and will increase the overall communication and navigation footprint in the region. Ionospheric behavior in the polar regions can significantly impact Ultra High Frequency (UHF) transmissions including degradation of Global Positioning System (GPS) positions and communications interruptions. To address these operational concerns, a need arises to identify and understand the location of the scattering region and its variability, which is a key component of the ionospheric scintillation phenomenon. The Poker Flat Incoherent Scatter Radar (PFISR) provides a significant dataset of ionospheric disturbances and their impact on GNSS signals. In this project, GPS data was obtained over a two-year period with a focus on the month of March which shows high seasonal Arctic sea ice extent and increased communication and navigation footprint.

Daily ionospheric electron density (Ne) variations are known to occur due to day-to-day photoionization. Irregularly occurring enhancements due to high geomagnetic activity can also impact the ionospheric scintillation and other known phenomena. This is evident in the color plots in Figure 6, covering the timeframe 6-20 March 2013, for both the zenith and field-aligned beams at PFISR. To determine the relative contributions of effects above PFISR during this timeframe, a baseline was formed at each altitude. An example site at 36.3 km altitude (zenith beam) and 35.7 km (field-aligned beam) are also shown in Figure 6. Local midnight is indicated with black dashed lines. The daily photoionization peaks (occurring following local noon) and the irregular night time substorms (occur quasi-regularly just after local midnight). Examples of each are highlighted on the altitude slices in Figure 6. An easy way to differentiate between solar driven geomagnetic storms and substorms is to look at the peak photoionization Ne levels and see that they drop during the period of substorms (highlighted with a red box in Figure 6) and recover back to normal levels following.

In order to determine which GPS signals pierced the PFISR beam at any given altitude, the geometry of the situation was revisited. As the earth is not flat and distances between sites varied from 200 to 600 km, a flat earth approximation was not appropriate to determine the path. An Earth Centered Earth Fixed (ECEF) coordinate frame, common amongst GPS users, was used to determine at what corresponding latitude and longitude (lat/lon) GPS signals pierced a specific altitude above PFISR. Performing this calculation for all GPS signals received at a given site is computationally intensive, as an iterative solution is required (Figure 8a). In order to minimize required computations, GPS data was first screened based on local site visibility criteria by limiting azimuths to those surrounding the beam from each site to PFISR, then by using a flat earth approximation to limit the possible elevation angles of the received signals (Figure 8b). This process of ionosphere location of the observed beams is presented in Moore and Enge. Shown in Figure 11 are the final latitude coordinates associated with the ground below the Sub-Ionospheric Pierce (SIP) point at 147.24 km for GPS signals received over a 24-hour period at the indicated locations. Overlaid is a Mercator projection presented in Moore and Enge. Additionally, the GPS constellation was designed to allow each satellite to roughly repeat the same ground track over a site daily. This allows us to assume the time windows for pulling scintillation data will be roughly constant over the 6-20 March 2013 timeframe.

Where do GPS Signals Pierce the PFISR Beam?

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The PFISR is an incoherent scatter radar (ISR) with an electronically steered beamformer array located at Poker Flat Research Range, 147° 24'W, 66° 36'N, Alaska. It has a northward oriented bore site, tilted 16° from zenith and aligned to a 15° bearing from each site to PFISR, then by using a flat earth approximation to limit the possible elevation angles of the received signals (Figure 8b). This process of ionosphere location of the observed beams is presented in Moore and Enge. Additionally, the GPS constellation was designed to allow each satellite to roughly repeat the same ground track over a site daily. This allows us to assume the time windows for pulling scintillation data will be roughly constant over the 6-20 March 2013 timeframe.

Preliminary Results for 16-18 March over various altitudes

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The Way Ahead

1. Evaluating measurements during a ‘normal’ geomagnetic storm could lead to insight into Auroral behaviors and mapping of ionospheric/substorm boundaries.
2. A ‘quiet’ ionospheric baseline above a sensor can be determined and used for normalizing raw data to remove contributions from known aperiodic phenomena.
3. The GPS SIP concept presented in Misra and Enge can be expanded to account for signals piercing various altitudes above the PFISR footprint.
4. There does appear to exist a correlation between Ne above PFISR and phase scintillation in GPS signals that pierced PFISR. The data presented here could be many reasons for this which have yet to be evaluated.

The Connected Autonomous Space Environment Sensor (CAGES), developed by ASTRA, Cornell and UT Austin, is deployed at each of the locations in Figure 1. The focus of the experiment is to acquire data while monitoring in many forms including signal phase scintillation data (σΦ) calculated over a continuously updated 100 second running average.

References