2021 Workshop: Space Weather at Midlatitudes

Long title
Space Weather impacts on GNSS applications at Mid-latitudes
Conveners
Sebastijan Mrak
Larisa Goncharenko
Toshi Nishimura
John Retterer
Charles Carrano
Jade Morton
Keith Groves
Description

GNSS signals are subject to propagation effects as they traverse the ionosphere. Positioning errors in single-frequency systems are constrained by a model and/or satellite-based augmentation data, while dual-frequency receivers are able to correct errors for the ionosphere under nominal conditions. The presence of ionospheric structure or small-scale (sub-km) irregularities cause amplitude and phase fluctuations of GNSS signals. These temporal variations, which may be due to refraction, diffraction (i.e., scintillation), or both, can stress signal tracking loops in GNSS receivers resulting in increased errors, cycle slips, and complete loss-of-lock. A key application recently embraced by meteorologists is the use of GNSS radio occultation (RO) data for terrestrial weather forecasting and climate studies. The propagation effects on RO geometries are greatly amplified due to extended ionospheric path lengths relative to typical overhead GNSS applications. Thus, even modest ionospheric disturbances may pose a risk for the RO performance. The statistical occurrence of mid-latitude irregularities is low; however, sporadic observations show irregularities form during geomagnetically disturbed times, but it is not well understood how do they form, what is their density spectrum, background density, flow structure, etc.

The climatology of the irregularity environment is relatively well understood at all latitudes, but the morphology of sporadic mid-latitude activity associated with geomagnetic storms is not captured by any of the existing models. This proposal is motivated by the 2019 Living With a Star Institute: “Space Weather Impacts on

GNSS Radio Occultations at Mid-Latitudes” to explore the impacts of space weather on mid-latitude GNSS applications, and we aim at extending the discussions with the CEDAR community. We will report the institute’s activities, solicit science highlight presentations, and foster a discussion to promote innovative observations and modeling capabilities to characterize mid-latitude space weather.

Agenda

(1) Keith Groves et al., NASA Living With a Star Institute "Space Weather impacts on GNSS applications at mid-latitudes": A Report

(2) Anthea Coster, "Space Weather at mid-latitudes a historical perspective: SED, SAPS, Gradients, Impacts on the FAA"

(3) Qian Wu, "COSMIC2 Observations"

(4) Dominic Fuller-Rowell, "SWPC Operations, products, future needs and directions"

(5) Aramesh Seif “Sporadic-E, COSMIC RO,”

(6) Nathaniel Frisell, "Sources of Large Scale Traveling Ionospheric Disturbances Observed using HamSCI Amateur Radio, SuperDARN, and GNSS TEC"

(7) Fabiano Rodrigues, "The properties of and ionospheric conditions associated with a moderate-to-strong scintillation event observed in Dallas, TX"

(8) Cheng Sheng, “Magnetic ground perturbations due to neutral wind-driven current at mid-latitudes.”

(9) Shweta Dutta, “Neural Network Model of the topside ionosphere”

(+1) Xiaoqing Pi

Justification

In this workshop we seek to understand: (1) What is the state of the mid-latitude ionosphere under which irregularities, scintillations, and TEC gradients develop? (2) What are the physical processes responsible for the mid-latitude density structures and irregularities? (3) What is our ability to model those processes? (4) How can we improve our ability to monitor the environment? (5) What radio communication systems are affected, to what extent, and can we mitigate the impacts?

This workshop will: (1) Review past and current capabilities to characterize ionospheric irregularities at mid-latitudes, (2) present the most recent and relevant observations and modeling advances, and (3) discuss pathways to overcome current observational and modeling limitations.

These objectives are aligned with the CEDAR Strategic Thrust #1: Encourage and Undertake a Systems Perspective to Geospace, Strategic Thrust #2: Explore Exchange Processes at Interfaces and Boundaries, and Strategic Thrust #4: Develop Observational and Instrumentation Strategies for Geospace System Studies.

Summary

The session featured 10 scheduled talks and 1 commentary at the end of the session which lasted for 135 minutes. The 1st talk was a report on the NASA Living With a Star Institute on TEC and scintillations given by the institute leader and all working group heads. The following presentations were: (1) a review talk on TEC and scintillation impacts on GNSS applications by Anthea Coster, 8 research talks. Six research talks were focused on the mid-latitude ionospheric space weather observed by ground- and space-based observations, and 3 talks were focused on modeling perspective.

We report that ionospheric space weather at mid-latitudes was observed used GNSS platforms (ground- and space), HF-radios (HAM-radio bands, SuperDARN), and in-situ measurements. The presentations reported the mid-latitude space weather impacts radio/GNSS applications by virtue of density irregularities, scintillations, traveling ionospheric disturbances, TEC gradients, and sporadic E-layers. The presenters repeatedly emphasized the need for more dedicated observations of small-scale ionospheric irregularities at mid-latitudes. The final commentary was given by Xiaoqing Pi (JPL). He discussed storm-time events from solar cycle 23, that produced mid-latitude irregularities observed by GNSS receivers.

The modeling presentations focused on overlooked mid-latitude features: neutral-wind-driven currents, climatology of the top-side electron density, and operational data products at NOAA SWPC. The operational needs were presented at aiming to better specify ionospheric irregularities at a variety of spatial scales and filling the gaps over oceans to reduce the model uncertainty over these under-sampled regions. The operational products feature GloTEC; an assimilative model of ionospheric electron density, and ROTI maps; a measure of ionospheric irregularities.

We had >100 participants throughout the session with a peak of>120 participants. This is almost twice the expected audince. The talks were given by senior researchers, early career researchers, and one graduate student. An extraordinary response to the session calls for a continuation of mid-latitude space weather discussions in the forthcoming years.

View PDF