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GPS Radio Occultation for Global Scintillation Specification

Ronald G. Caton[1], Keith M. Groves[2] and Charles S. Carrano[2]

[1] Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM, USA.

[2] Boston College, Institute for Scientific Research, Chestnut Hill, MA, USA

ABSTRACT

Current state-of-the-art models providing specification of the equatorial ionospheric scintillation environment utilize near real-time data streams from ground-based sensors at locations of opportunity. While this technique provides highly accurate regional nowcasts and short-term forecasts of anticipated scintillation activity, it suffers from a reliance on climatology to fill the large gaps in denied regions such as over the vast ocean areas. Use of space-based receivers onboard Low Earth Orbiting (LEO) spacecraft capable of high-rate recordings of signals from occulting GPS satellites provides the opportunity to expand of our knowledge of the ionospheric scintillation environment to a global scale. Doing so, however, requires sophisticated algorithms for accurate geolocation of the ionospheric irregularities resulting in scintillated signals during GPS radio occultations (RO).

As depicted in Figure 1, the geometry of an RO event as recorded from a LEO spacecraft can result in long path links through the ionosphere. Here, the sub-satellite position of GPS PRN 23 during is shown in green (over Eurasia) during an RO event recorded on the Communication/Navigation Outage Forecasting System (C/NOFS) Occultation Receiver for Ionospheric Sensing and Specification (CORISS) whose sub-satellite position is shown as a red solid line. Black lines connecting the C/NOFS position to GPS 23 represent lines of the setting occultation. The solid blue line represents the occultation tangent point while the orange shading represents regions where the lines of occultation penetrate select ionospheric altitude ranges. The inset window on the bottom right shows the decimated signal-to-noise on L1 at 10 s (blue) and 1 s (red) cadences, the tangent height altitude, a pseudo-S_4 based on the 1 s data samples, and finally the SNR as a function of tangent height altitude.

Typical methods for using GPS RO to characterize the scintillation environment involve use of the tangent point for geolocation of the turbulent ionospheric regions. During the period in which the scintillation is observed on the GPS RO event in Figure 1, the tangent point is well below the F peak, an indication that the use of such techniques would not provide precise specification. For this particular event, the occultation geometry is such that one might be able to better geolocate the scattering region and by assuming the turbulent regions giving

rise to scintillation are within magnetic anomaly belt and ignoring the orange shaded regions at 20^o to 30^o MLAT.

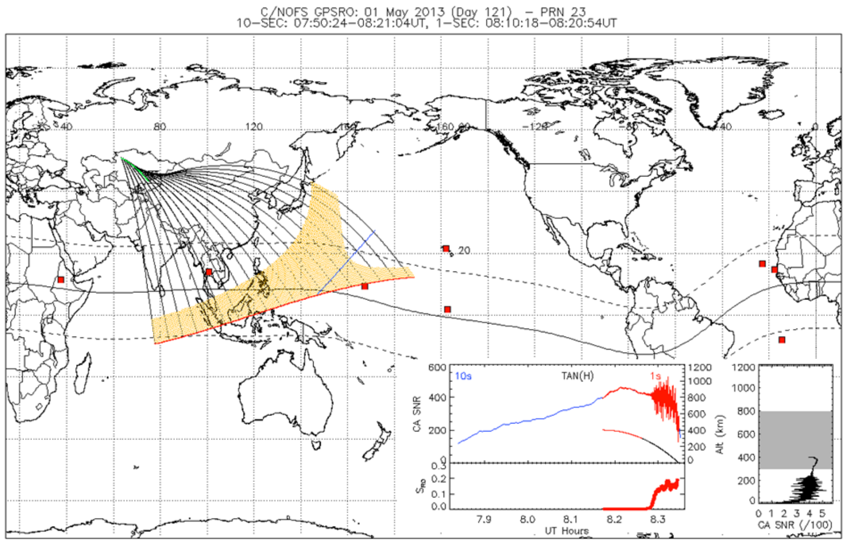

Figure 1. A depiction of the geometry from a GPS Radio Occultation (GPSRO) event as recorded on the C/NOFS Occultation Receiver for Ionospheric Sensing and Specification (CORISS) sensor near 08:00 UT for PRN 23 on 01 May 2013.

The RO event presented in Figure 1 began at 08:10 UT. With its ~90 minute orbit, the C/NOFS satellite recorded a subsequent occultation with the same PRN beginning at approximately 09:34 UT. As the GPS satellite continued its southward trajectory, the sub-satellite points during this event place PRN 23 over the Indian Ocean. Summary data from this occultation are presented in Figure 2 where the lines of occultation are observed to span thousands of kilometers at ionospheric height making precise geolocation of the scattering structures a complex and difficult task.

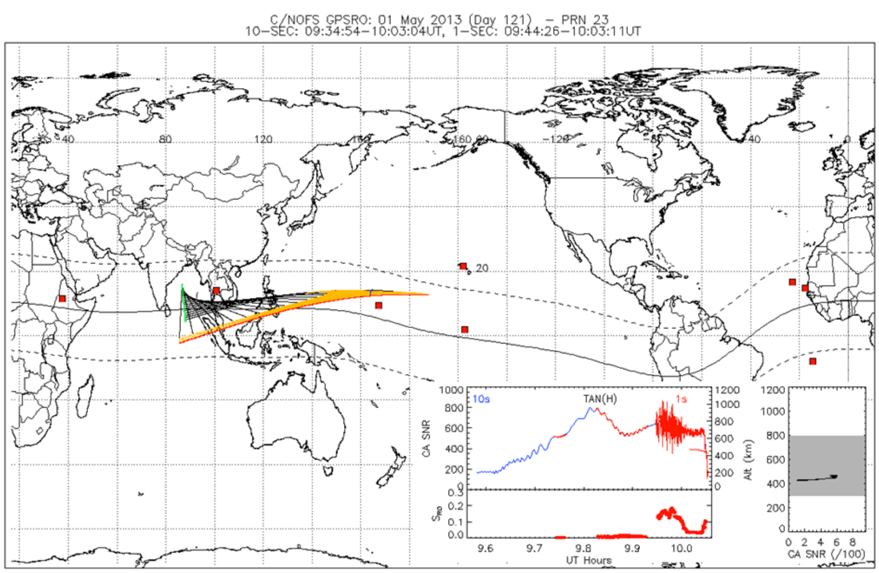

Figure 2. A depiction of the geometry from a GPS Radio Occultation (GPSRO) event as recorded on the C/NOFS Occultation Receiver for Ionospheric Sensing and Specification (CORISS) sensor near 09:30 UT for PRN 23 on 01 May 2013.

In this paper, we will report on a current effort focused on the development of techniques allowing for the use of GPS RO signals for accurate specification of the global ionospheric scintillation environment and present results from a comparison of CORISS GPSRO observations with ground-based measurement from the global Scintillation Network Decision Aid (SCINDA). We will analyze various methods for precise geolocation of scintillation on GPS RO signals paying specific attention to the occultation geometry and its role in determining the appropriate techniques.

Key words: GPS Radio Occultation, Equatorial Ionosphere, Scintillation, COSMIC-2