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SCINTILLATION DETECTION AND MONITORING WITH SPACE- BASED GPS OCCULTATION SENSOR TECHNIQUES

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Abstract. AFRL has investigated the potential to utilize GPS occultation sensor (GPSOS) data to detect, locate and specify ionospheric irregularities. A limited study comparing GPSOS results with high-resolution profiles from the ALTAIR radar shows remarkably good agreement, indicating that GPSOS techniques may be effective in monitoring ionospheric scintillation.

1 INTRODUCTION

AFRL has performed statistical studies analyzing more than 200 GPS occultations from COSMIC satellites in the vicinity of SCINDA sites for periods in 2008 and 2009. Due to solar minimum conditions, only SCINDA VHF data are suitable for such comparisons. While the results overall show a positive correlation of scintillation detection with space-based GPS occultation techniques, a large number of inconsistencies between the ground- and space- based data were discovered. The unexpected findings can be explained by a number of factors, such as spatial and/or temporal separations between the sampled regions, instrumental artifacts and lack of high rate (50 Hz) GPS data from COSMIC for tangent point altitudes above 120 km.

Fundamentally, these studies suffered from an inability to adequately determine ionospheric parameters along a given occultation path. This limitation has been largely overcome in the results reported here where the ALTAIR UHF/VHF radar located at Kwajalein Atoll, Marshall Islands, was used to monitor ionospheric density profiles and the precise locations of irregularities in regions where GPS occultations occurred recorded by the CORISS GPS receiver on-board the C/NOFS satellite. AFRL compared ALTAIR radar observations with CORISS occultation data nightly for the period 21 April to 01 May 2009.

2 APPROACH AND RESULTS

During the 10 day period a total of 49 post-sunset GPS occultations in the vicinity of Kwajalein were recorded by CORISS. It is worth noting that this corresponds to nearly five occultations per night suggesting that the regional GPSOS coverage from a single low-inclination satellite is quite good; most evenings proximal occultations occurred nearly every orbit, a refresh rate of approximately 100 minutes. Of the 49 total occultations, 27 occurred within the effective field-of-view (FOV) of the ALTAIR radar while the radar was operating. Effective FOV refers to observations on a common magnetic field line; the data from both CORISS and ALTAIR have been mapped along magnetic field lines to the magnetic equator, to their so-called apex altitudes, to provide a common frame of reference for the radar and GPS observations, as illustrated in Figure 1.

The CORISS GPSOS was 100evenings of the campaign. Considering individual occultations, 26 of the 27 cases showed perfect agreement between the radar and the GPS receiver. Irregularities were accurately detected by both sensors on 15 of those cases and the remainder correctly diagnosed an absence of scintillation. Moreover, as can be seen in the example shown in Fig 1, the occultation technique appears to localize the longitude of the irregularities within about 100 km or approximately 1, a somewhat unexpected result given the extended horizontal slant path typical of occultation geometries. This is a preliminary result based on a handful of observations and further study is required before firm conclusions can be reached, but the future application of GPSOS observations for meaningful scintillation products appears promising.

Careful consideration of the singular case where the agreement between ALTAIR and CORISS app ears imperfect indicates that even this event is consistent when properly understood. In this case the occulting tangent point entered the radar FOV at 500 km altitude approximately 200 km east of ALTAIR and descended to the east, terminating at about 300 km altitude. Despite apparently passing through a region of strong radar irregularities, the occultation SNR shows no evidence of scintillation. The details of the occultation geometry and the radar scan are show that the occultation tangent point is approximately 10 N Mlat when it maps into the radar FOV at an apex altitude of some 500 km. Because it is some 1000 km north of the magnetic equator, the actual tangent height is quite low at this point, well below the F-region of the ionosphere.

In fact, all points on the occultation raypath that are actually sampling the low latitude F- region for this case map to apex altitudes well above the irregularities and their meridional extent. The points that map into the radar FOV are well below the F region and are actually only sampling the neutral atmosphere below the ionosphere. This case illustrates that caution must be used in understanding what regions are effectively monitored by a given occultation and places constraints on future GPSOS-based scintillation products. These occultation observations do not truly map into the radar FOV at all and should not be considered a valid case for comparison of the ground- and space-based techniques.

3 CONCLUSION

The correlation between space- and ground-based observations investigated in this limited study is very high, indicating that the GPSOS technique can provide a reliable indicator of equatorial scintillation activity. Much more modeling is required to develop quantitative products based on these data, but with the dataset being acquired by the CORISS receiver on C/NOFS researchers should have sufficient information to do so in the near future. Surprisingly, the GPSOS observations appear to resolve the locations of the irregularities regions with an accuracy approaching 100 km. This may be a result of the localized nature of bubbles during solar minimum. Further comparisons with a much larger set of ground-based scintillation observations are planned to better characterize the statistical reliability of the GPSOS technique and to evaluate the efficacy of on-board S4 or other indices calculations for scintillation prediction. The use of ndices rather than raw data is important because of limitations in real-time satellite telemetry, particularly for a constellation of satellites such as the planned COSMIC II mission. The use of space-based ndices to effectively monitor disturbed regions would greatly reduce the requirements for data transfer from the space platform. The use of GPSOS data to quantitatively model turbulence strength for estimating scintillation activity on non-occultation link geometries (e.g., space-to-earth SATCOM) requires further investigation and more detailed modeling.

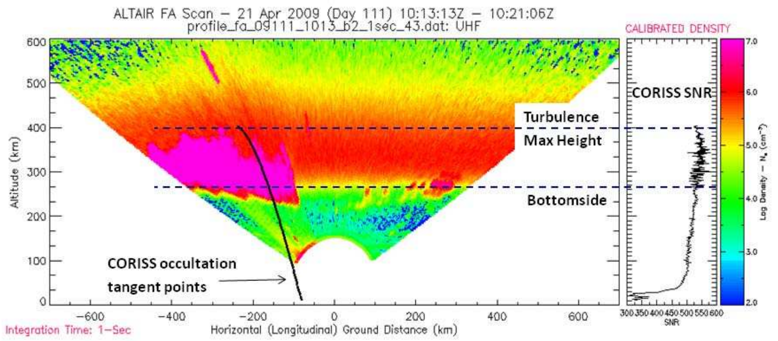

Figure 1: Indicates where occultation tangent point maps into the radar field-of-view in the magnetic equator reference frame. The raypath appears to intersect a region of strong irregularities as detected in the ALTAIR radar scan (magenta echoes). The received power of the occulting ray exhibited scintillations as the tangent point passed through the irregularities.