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IONOSPHERIC MODELS IN THE EQUATORIAL REGION: GPS TEC ASSIMILATION STUDY WITH ALTAIR

Benjamin N. Heruska*, Keith M. Groves*, Stephen M. Hunt†, Gregory P. Ginet† and Dale Sponsellerº

[*] Space Weather Center of Excellence
Air Force Research Laboratory
Hanscom AFB, MA 01731 USA
[†] Lincoln Laboratory
Massachusetts Institute of Technology
244 Wood Street Lexington, MA 02420 USA
º Kwajalein Range Services, LLC
Reagan Test Site
US Army Kwajalein Atoll (USAKA)
Kwajalein Atoll, Marshall Islands

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Summary: This study compares the performance of modern assimilative ionospheric models with a PRISM-based operational model designed to provide range corrections for a UHF/VHF radar by assimilating GPS TEC observations.

1 INTRODUCTION

This study compares absolute slant TEC values generated by the ARPA Long-Range Tracking and Instrumentation Radar (ALTAIR) with various ionospheric models and reports the results. The principal purpose of this study was to compare modern assimilative models with the current operational model used at the ALTAIR Radar, located at the Kwajalein Atoll in the Marshall Islands. The operational model, known as the Ionospheric Effects Correction Model (IECM), was derived from the USAF Parameterized Real-time Ionospheric Specification Model (PRISM) originally developed nearly 20 years ago. Operationally, IECM ingests TEC data from a single GPS receiver co-located with the ALTAIR radar. Biases for the dedicated GPS receiver are determined and maintained by routine comparisons with TEC measurements from ALTAIR. The model then provides range delay estimates in real-time for arbitrary radar pointing angles.

2 APPROACH

For this study, a field campaign was conducted at Kwajalein Atoll from 14-29 September 2008. Four Scintillation Network Decision Aid (SCINDA) GPS receivers were deployed at each of the following islands: Roi-Namur, Kwajalein, Meck, and Wotje as shown in Figure 1. The receivers were dual-frequency NovAtel GPS receivers that recorded L1 data at a rate of 50 Hz. Calibrated slant and vertical TEC were calculated at a 1 Hz rate. The ALTAIR radar on Roi-Namur was used to perform numerous tracks of two satellites over the course of the campaign: the Communications/Navigation Outage Forecasting System (C/NOFS) satellite and a 1.1-meter diameter calibration sphere (object #5398) in a low earth polar orbit. During these tracks dual frequency VHF and UHF data were recorded and subsequently processed to retrieve the absolute slant TEC which served as the ground truth in the study.

3 METHODOLOGY

A blind study was conducted using several modern assimilative ionospheric models. The modelers each received a copy of the calibrated TEC output from the four GPS receivers including location and timing information. The modelers were then asked to assimilate the data into their models and produce output for 12 test cases defined by actual satellite tracks performed by the ALTAIR UHF/VHF radar. The differential range measured by the UHF and VHF waveforms enables the radar to estimate absolute TEC to the satellite altitude with an error of less than 0.1 TEC unit. The test cases were generated by extracting the overflight geometries from the calibration sphere and C/NOFS tracking data for a number of nearly-overhead passes. The cases were then presented to the modelers with a request for slant TEC outputs calculated precisely along those tracks up to the satellite altitude.

4 RESULTS

For each of the 12 satellite tracks the assimilative models' slant TEC data were compared with the ALTAIR "truth" TEC data. Sample data from a calibration sphere track on 29 September are shown in Figure 2. Models B, C and D are modern assimilative models while Model A is a pure climatological model, the International Reference Ionosphere (IRI) - 2007 (green trace). Note that IRI significantly overestimates the background TEC for these conditions and exhibited a similar bias consistently throughout the campaign period indicating that it is ill-equipped to handle the extreme equatorial solar minimum environment present in Sep 2008. Despite the unstructured environment with little to no gradients present, the models show surprising variability. Comparisons between data assimilation models, the PRISM-based model, and the climatological model will be presented.

Figure 1: Map of Kwajalein Atoll showing relative placement of GPS sensors (red dots) used in the study.

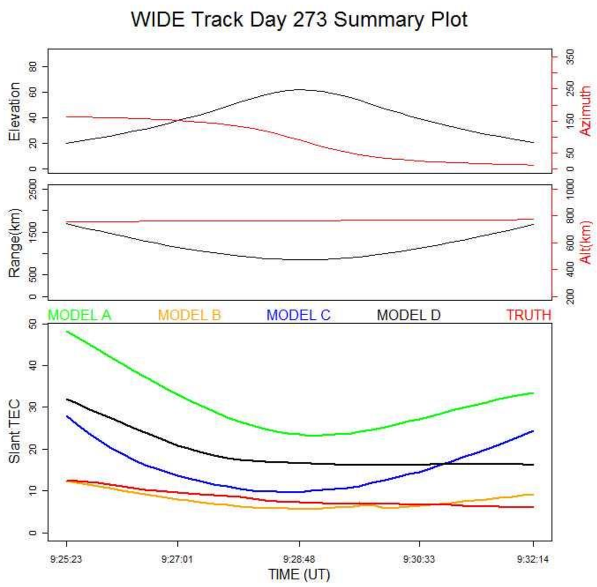

Figure 2: Example slant TEC results from a calibration sphere pass on Day 273 (29 Sep) 2008. Model A represents the IRI-2007 model while Models B-D are modern data-assimilation models. “Truth” is derived from the ALTAIR radar track data.