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A Community Wide Ionosphere/Thermosphere Modelling Test

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ABSTRACT

This paper describes an open coordinated ionospheric model testing scenario. There are a wide range of ionospheric models in active use and development around the globe, utilizing a number of modelling techniques. The models are split into three categories: empirical, data assimilation and physics-based. The ability of these models to provide electron density profiles below the peak of the F2 layer, and the total electron content (TEC) is compared. The developed scenario is a month-long extremely quiet solar period. Previous coordinated test scenarios include *Shim et al.* [1] and *Feltens et al.* [2]. However these test scenarios were for relatively short time periods. The advantage of using a longer time period is to provide a more robust statistical analysis.

Empirical, data assimilation and physics-based models have been tested. A short description of each model and a reference for more information can be found below:

- **IRI:** The International Reference Ionosphere (IRI) is an empirical monthly median model, widely used due to relative ease, speed and generally acceptable level of validity [3].
- **IRTAM:** The IRI Real-Time Assimilative Mapping (IRTAM) is a data assimilation model which assimilates Digisonde data into IRI in real-time [4].
- **NeQuick:** NeQuick is a quick-run empirical model, able to represent the median conditions of the ionosphere and particularly designed for trans-ionospheric propagation applications [5].
- **NeQuick Data Ingestion (DI):** NeQuick DI is a modified version of NeQuick which assimilates Global Navigation Satellite Systems (GNSS)-derived TEC data and profile peak parameters from ionosondes [6].
- **EDAM:** The Electron Density Assimilative Model (EDAM), which assimilates GNSS TEC and ionosonde information into an IRI-2007 background model [7].
- **TIE-GCM:** The Thermosphere Ionosphere Electrodynamics General Circulation Model (TIE-GCM) is a non-linear 3D physics-based thermosphere/ionosphere model which solves the continuity, energy and momentum equations at each time step [8].
- **GITM:** The Global Ionosphere Thermosphere Model (GITM) is a physics-based 3D global thermosphere/ionosphere model that solves the full Navier-Stokes equations for density, velocity and temperature for a number of components at each time step [9].

- **CTIPe:** The Coupled Thermosphere Ionosphere Electrodynamics (CTIPe) model solves the non-linear primitive equations of momentum, energy, and continuity on a 3D spherical polar grid rotating with the Earth [10].
- **SAMI3:** Is a physics-based ionospheric model which relies upon an empirical neutral density model. The model calculates the plasma and chemical evolution of seven ion species [11].
- **AENeAS:** The Advanced European electron density (Ne) Assimilation System (AENeAS) is a data assimilation model that assimilates GNSS TEC data into a physics-based background model (currently provided by TIEGCM).
- **UPC TOMION:** The Universitat Politècnica de Catalunya TOmographic Model of the IONosphere (UPC TOMION) is an assimilative TEC model, combining voxel-based ionospheric tomography with Kriging interpolation [12].
- **USU-GAIM:** The Utah State University Global Assimilation of Ionospheric Measurements (USU-GAIM) Model is a physics-based data assimilation model. The model assimilates bottom-side electron densities from ionosondes, slant TEC, in situ measurements of electron density and line-of-sight UV emissions [13].

The analysis interval for the study was from the 8th December 2008 to January 7th 2009. Data from the ionosonde stations at Chilton, Juliusruh and Pruhonice and a selection of European GNSS stations is assimilated (Figure 1). The models' profiles are then compared with the Dourbes ionosonde in Belgium; the TEC is compared with the closely located (~40 km) GNSS station at Redu. The data from both the Dourbes ionosonde and Redu GNSS receiver are not assimilated into the models. This particular time range was chosen to coincide with very quiet solar conditions. Across the whole month the F10.7 only varies between 68 and 71 flux units and the largest spike in Ap was 22, which is considerably lower than the storm threshold value of 29. The average sunspot number for the period was 1.0.

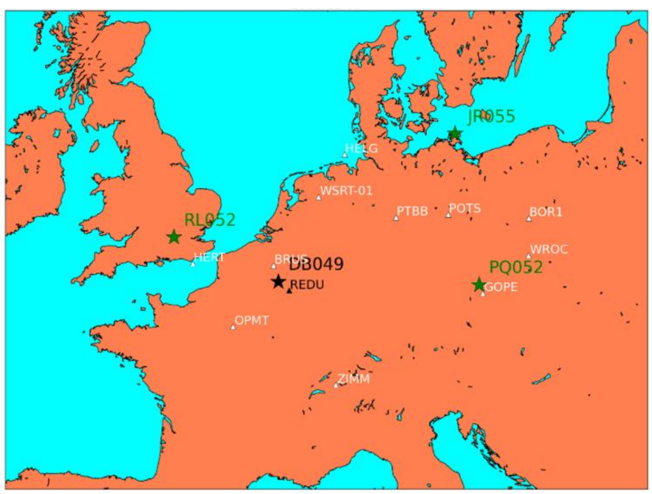

Figure 1. Map of the test scenario. Stations in green are the ionosondes to be assimilated (if applicable to a particular model). Stations in white are GNSS stations to assimilate, and the two stations in black are the stations where the comparisons are made, Dourbes (DB04) for the 3D profile information and Redu (REDU) for the TEC.

This paper will present the results of the study, comparing and contrasting how the various modelling types and techniques perform.

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Key words: Ionosphere, Model Validation, Comparisons, Testing

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