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Abstract for the International Reference Ionosphere and NeQuick – Improving the Representation of the Real-Time Ionosphere

Comparison of IRI Model TEC and GNSS-Derived TEC over Kenya During Quiet and Storm Conditions in 2025

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The International Reference Ionosphere (IRI) model plays a critical role in providing global climatological estimates of ionospheric parameters. However, its performance in equatorial regions—particularly during geomagnetically disturbed periods—remains an area that requires further investigation. This study compares the Total Electron Content (TEC) values derived from the IRI model with those obtained from ground-based GNSS receiver in Kenya during both geomagnetically quiet and storm periods in 2025.

Kenya, being located near the magnetic equator, is characterized by dynamic ionospheric conditions influenced by the equatorial ionization anomaly (EIA) and post-sunset irregularities. We use dual-frequency GNSS data from receivers stationed at the Kenya Space Agency headquarters in Nairobi, supplemented with geomagnetic indices (Kp) to identify quiet and disturbed intervals. IRI model outputs for corresponding dates and locations were generated using the IRI-2020 model via the IRI Web Interface.

The comparative analysis reveals that while IRI-derived TEC values generally align with GNSS-derived TEC during quiet periods, significant deviations emerge during geomagnetic storms. In particular, the IRI model tends to underestimate the magnitude and timing of TEC enhancements and depletions observed in GNSS data during storm-time ionospheric responses. This discrepancy is particularly pronounced in the post-sunset hours and at times of maximum EIA development.

Our results emphasize the need for real-time data assimilation into empirical ionospheric models to enhance their accuracy in low-latitude regions during disturbed conditions. This study also accentuates the critical role of local GNSS infrastructure in validating and improving global ionospheric models such as IRI, especially for regions like equatorial Africa where ground-based observations have historically been sparse.

Keywords: IRI model, Total Electron Content, GNSS, Equatorial Ionosphere, Kenya, Geomagnetic Storms, Space Weather, Model Validation

P02

ATRIO-Antarctic Thermosphere Retrieved from Ionospheric Observations

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ATRIO – Antarctic Thermosphere Retrieved from Ionospheric Observations project, funded by National Program of Antarctic research, aims to apply a novel method, THERION, THERmospheric parameters from IONosonde observations [1], for retrieving key thermospheric parameters—such as atomic and molecular oxygen and nitrogen concentrations, exospheric temperature, and meridional wind velocity—using ground-based ionosonde observations in the sunlit Antarctic region. This approach aims to improve understanding of atmospheric drag effects on polar-orbiting satellites and enhance upper atmosphere modeling, especially through comparison with empirical models and satellite-based neutral gas measurements. Considering that hundreds of communications and navigation satellites orbiting around the Earth cross the polar area being subjected to atmospheric drag which affects their orbital characteristics, the development of methods to monitor atmospheric drag effects on satellites is a very actual problem, The present-day knowledge of the Antarctic thermosphere is very limited. Direct observations of the thermosphere are technically very complicated and expensive. The idea is to solve an inverse problem of aeronomy to retrieve the main thermospheric parameters using a method based on the analysis of the bottom-side electron density profiles, Ne. The AUTOSCALA code [2] developed at INGV is applied for ionogram reduction to produce real Ne(h) profiles. Electron density profiles are produced also with NeQuick model [3]. The method is supposed to be applied both for historical and current ionosonde observations. The retrieved thermospheric parameters will be compared to modern empirical thermospheric models.

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P03

Neural network modelling of the topside ionosphere based on 4 solar cycles of measurements and its connection to plasmasphere

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The Earth's ionosphere influences the propagation of signals from Global Navigation Satellite Systems (GNSS). The topside ionosphere contains a significant fraction of the total electron content and is therefore important for both scientific and operational applications. A major challenge for modeling the topside ionosphere has been the limited data availability, with most observations coming from in-situ measurements along satellite trajectories that are temporally constrained and lack full three-dimensional coverage. In the last twenty years, a substantial volume of radio occultation (RO) electron density profiles has become available, providing a valuable resource for improving our modeling approaches. In this work, we utilize RO, in-situ, and digisonde measurements, in combination with historical data from topside sounder missions, to produce an enhanced version of the Neural Network model of Electron density in the Topside ionosphere (NET). The improved model is trained on a data set covering roughly four solar cycles, encompassing a broad spectrum of solar and geomagnetic activity. We assess the model's performance using measurements from several key ionospheric missions and show that it generalizes effectively to new data, with about 90% of its predictions falling within a factor of two of the observed values. We explore the model's scientific potential during geomagnetic storms by examining the topside ionosphere's response in the equatorial dawn and dusk regions both in NN outputs and through statistical findings from the superposed epoch analysis. We also discuss the real-time version of the NET model that is already running at GFZ Potsdam. It provides 24-hour forecasts of electron densities in the topside. Last but not least, we use data from the recently launched Arase mission to establish a connection of the model to the plasmasphere by quantifying scale height profiles in the transition region. We show that Arase measurements can serve as a basis for extending ionospheric models to higher altitudes and can help improve our understanding of the ionosphere-plasmasphere as a coupled system.

P04

Stochastic Analysis of Ionospheric and Magnetospheric Activity Indices

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We explore the statistical behaviour, over several solar cycles of the ground-based ionospheric and magnetospheric indices relevant to space weather. We demonstrate the conditions when these data consistently follow statistics of a Levy alpha-stable and other processes. We model the system responses by driving a fractional stochastic differential equation with an alpha-stable noise parametrized by our data.