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T01

Comparing the Ne-Profiles from the IRI2020, NeQuick2 and 3D EDD Models with the COSMIC2 Measurements over Europe

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Abstract:

Constructing the ionospheric electron density profile accurately is still a significant challenge for radio wave propagation research and space weather monitoring.

In this work, we evaluate the constructed electron density as obtained from the IRI2020 model, the standard NeQuick2 models, and the hybrid Nequick - TaD (TSM-assisted Digisonde) model reconstruction model provided in PITHIA-NRF eScience Centre (eSC), which is updated with the bottomside Digisonde vertical electron density profiles. .

To evaluate the performance of the models, we compare the resulting reconstructed profiles with independent datasets obtained from Radio Occultation profiles (COSMIC2).

Comparative evaluation under various ionospheric conditions provides insights into the accuracy of reconstruction models in describing the various ionospheric layers, particularly the F2 layer, with a realistic assessment of density gradients and thickness in both its bottomside and topside regions.

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T02

Identification of Ionospheric Anomalies Prior to Moderate and Shallow Earthquakes during Quiet Solar Conditions

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The aim of this work is the determination of seismo-ionospheric precursors during the preparation process of two moderate and shallow earthquakes happened at Greece on 09/22/2012 (M=5, depth = 10 Km) and 09/16/2013 (M=5.3, depth = 7.7 Km). For this purpose, we used the running median of the critical frequency of the F2 layer and the associated interquartile range. The methodology defines a confidence interval where foF2 varies. Any deviation of foF2 from this interval is considered an anomaly. Since the ionosphere is directly influenced by solar and geomagnetic activity, we also analyzed the Kp, Dst and Ap indices. This eliminates any ambiguity regarding the nature of the detected disturbances.

We successfully detected disturbances within the 10 days preceding the studied earthquakes. The advantage of the IQR method is that it provides the hour and date of the occurrence of the abnormal variability. However, it is important to define the source of the localized anomaly. Since both events occurred during quiet solar activity conditions, it would be difficult to distinguish between intrinsic ionospheric variability and that caused by the future earthquake. In order to answer this question, we carry out the same analysis on measurements taken at an ionospheric station located far from the epicenter. This second station must have the same or very close geographic longitude and geomagnetic latitude as the first ionospheric station. Thus, any anomaly detected at both stations is considered specific to the ionosphere and cannot be considered as a seismo-ionospheric precursor.

This procedure yielded excellent results in classifying the nature of the detected anomaly. However, it is interesting to consider several cases of earthquakes under different solar activity conditions. It would also be interesting to choose earthquakes occurring at the same or similar time period in order to better understand the nature of the anomaly.

T03

Optimizing GNSS Positioning by Integrating Regional Ionospheric Variability into Correction Algorithms

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Ionospheric mitigation for single-frequency GNSS is essential for achieving accurate positioning over a specific region, especially for low-cost mobile platforms like smartphones and tablets. Systems relying on Galileo are based on the NeQuick-G algorithm—an adaptation of the NeQuick ionospheric model—to correct ionospheric errors [1].

In this paper, we explore the concept of adjusting the NeQuick-G algorithm by integrating regional ionospheric characteristics derived from digital ionosondes and colocated GNSS receivers. This approach could facilitate local adjustments to the Committee Consultative for Ionospheric Radiowave Propagation (CCIR) coefficients, leading to more realistic TEC estimation and therefore enhanced positioning accuracy under quiet geomagnetic conditions [2, 3].

The approach optimizes the effective ionization parameter on a local scale, using a GNSS receiver collocated with an ionosonde to minimize discrepancies between model forecasts and measured Total Electron Content (TEC). Building on this, we will examine the possible extension of the approach across Europe, utilizing data from more European ionosonde stations. By incorporating autoscaled foF2 and M(3000)F2 characteristics, we will investigate the concept for improved single-frequency Galileo positioning on various time-scales to enhance GNSS positioning accuracy, offering significant benefits for navigation services across Europe.

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T04

The Impact of the Mother's Day Storm on Low-Latitude Ionospheric Irregularities and IRI 2020 model validation of Ionospheric storm conditions.

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This study investigates the impact of the 10–11 May 2024 G5 geomagnetic storm (Kp ~9), on ionospheric irregularities. Using ground-based GNSS receivers across the East African region, specifically at Mbarara, Uganda (Lat 0.60°S, Lon 30.74°E, Mag. Lat 10.22°S), Malindi, Kenya (Lat 2.99°S, Lon 40.19°E, Mag. Lat 12.42°S), Addis Ababa, Ethiopia (Lat 9.03°N, Lon 38.77°E, Mag. Lat 0.18°N) and Arusha, Tanzania (Lat 2.73°S, Lon 35.95°E, Mag. Lat 13.5°S), we analyse both the amplitude scintillation (S4) and Rate of Total Electron Content (ROTI) indices to assess ionospheric irregularities. Additionally, the performance of the IRI 2020 model in reproducing storm-time ionospheric TEC during this period will be evaluated. The storm, characterised by a Sudden Storm Commencement (SSC) at 17:00 UTC on 10 May 2024 (20:00 EAT), resulted in a notable suppression of ionospheric irregularities during its main phase on 10 May at all four stations. This suppression is attributed to the timing of the storm's main phase, with the maximum negative DST excursion occurring around 23:00 EAT. At this time, the pre-reversal enhancement (PRE) of the eastward electric field, which is critical for the development of equatorial plasma bubbles (EPBs) that cause irregularities, would have already diminished [1]. On 11 May, still within the main phase, no ionospheric irregularities were detected at any of the four stations. This absence is primarily attributed to a negative ionospheric storm observed during the daytime. During the recovery phase, preliminary analysis of the ionospheric response at the selected locations reveals differing patterns in the generation and inhibition of ionospheric irregularities during post-sunset hours. Despite being in the same time zone, this variation suggests a latitudinal influence, which will be further examined by investigating how the Equatorial Ionisation Anomaly (EIA) response to the geomagnetic storm affects the ionospheric behaviour at these locations, particularly in relation to their proximity to the EIA crest and trough regions [2]. This observation underscores that local time alone is not sufficient to explain storm-time ionospheric dynamics. Preliminary validation of the IRI 2020 model during this storm period at one of the stations suggests that, while the model generally captures the TEC reduction during the main phase, it does not reflect the multiple peaks of TEC enhancements and reductions observed on 11 May. A final analysis incorporating data from all stations will be conducted, including an examination of latitudinal variations in the storm-time ionospheric response as reproduced by the IRI 2020 model using the fof2 storm option, as outlined in [3]. These findings contribute to a deeper understanding of the electrodynamics associated with low-latitude ionospheric phenomena during geomagnetic storms and provide insight into the IRI 2020 model's storm-time performance, highlighting areas for improvement.

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T05

Evaluating Long-Term Ionospheric Model Performance at Mid- and High-Latitudes Using foF2 Observations from 1950 – 2022

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Accurate modelling of the high-latitude ionosphere-thermosphere system is critical to understanding the impacts of space weather on modern technology, such as communications and navigation systems. At low and mid latitudes, both physics-based and empirical models are well-developed and capture the variability of the ionosphere to a good degree of accuracy. At high latitudes, however, the complex chemistry and dynamics due to interactions with the solar wind and magnetosphere, added to lack of observations, presents challenges to such models. This study evaluates the climatological performance of the Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM), the Whole Atmosphere Community Climate Model with thermosphere and ionosphere extensions (WACCM-X), and the Empirical Canadian High Arctic Ionospheric Model (E-CHAIM) for the period 1950 – 2022. Model outputs are compared to observational foF2 data from the high-latitude Resolute Bay ionosonde and the mid-latitude Chilton ionosonde to assess the limitations of models in reproducing the variability of the high-latitude ionosphere. Preliminary results from TIE-GCM and WACCM-X exhibit strong winter anomaly behaviour at all times of day at high latitude, which is not present in observational data. An equinoctial asymmetry is also present, with elevated electron densities in March compared to September, even during low solar activity. In contrast, E-CHAIM shows significantly better agreement with observations, more accurately reproducing seasonal and solar cycle trends. These findings highlight the need for improved representation of high-latitude processes in physics-based models.

T06

Integration Magnetospheric, Ionospheric and Ground station data for Geomagnetic Storm Case study event: 01 January 2025

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Abstract

Geomagnetic storms, driven by solar wind interactions with Earth's magnetosphere, can significantly impact both space and ground-based systems **[1]**. This study proposes an integrated framework for monitoring and analysing geomagnetic storms 01 January 2025 through the synergistic use of magnetospheric data, ionospheric data, and ground station measurements. Magnetospheric data, including particle flux and field intensity from satellite-based instruments such as **GOES**, offer insight into solar wind dynamics and magnetospheric disturbances **[2]**. Ionospheric data, including Total Electron Content (TEC) and ionospheric irregularities, provide essential information about storm-induced ionospheric anomalies, which are crucial for understanding radio wave propagation and GPS signal degradation. We used Swarm satellite data and different models such as **IRI, NeQuick, IONOLAB-TEC** during this storm **[3,4 and 5]**. Ground station data, encompassing geomagnetic field variations, complement these datasets by providing real-time, high-resolution measurements of geomagnetic disturbances at specific locations such as **INTERMAGNET Data [6].** The integration of these datasets allows for a comprehensive understanding of storm impacts, facilitates early warning systems, and enables the development of predictive models to mitigate storm effects on communication, navigation, and power grid infrastructure. This approach enhances the quality and applicability of space weather forecasting, offering a more holistic view of the complex interactions between the magnetosphere, ionosphere, and Earth's surface during geomagnetic storms.

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T07

Study of Ionospheric Total Electron Content over Thailand Using BeiDou Satellites

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Abstract

This study aims to analyze the Total Electron Content (TEC) in the ionosphere over Thailand using BeiDou satellite signals received by GNSS receivers [1, 2]. Data were collected in the year 2025 from six monitoring stations: Bangkok, Chiang Mai, Chumphon, Nong Bua Lam Phu, Phuket, and Ubon Ratchathani, respectively, covering the pentire region of Thailand. The analysis and results revealed that Nong Bua Lamphu recorded the highest average at 77.94 TECU, followed by Chiang Mai with 73.55 TECU. Ubon Ratchathani had an average of 65.81 TECU, while Phuket recorded 59.54 TECU, closely followed by Bangkok with 59.22 TECU. Chumphon had the lowest average maximum value at 45.00 TECU, respectively. This study indicate an improvement knowledge reflecting the success of the potential for applying the BeiDou satellite system in future ionospheric TEC studies.

Keywords— BeiDou, Ionosphere, BD TEC

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T08

Assessment of improvement of the IRI model over Kenya for the modeling of the variability of TEC during the period 2020 – 2024

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This paper discusses the monthly and seasonal variation of the total electron content (TEC) and the improvement of performance of the IRI model in estimating TEC over Kenya during the onset of solar cycle 25 for the period 2020-2024. The GPS derived TEC data used in the study was obtained from three IGS stations across Kenya region namely mal2 (40.1°E, 2.9°S), moiu (35.3°E, 0.3°N) and rcmn (36.89°E, 12°S). The results reveal that the highest peak GPS-derived diurnal VTEC is observed in the March equinox in 2024 over from all the stations. Moreover, both the arithmetic mean GPS-derived and modelled VTEC values, generally, show maximum and minimum values in the equinoctial and June solstice months, respectively for the entire period of study. However, in 2024, the minimum and maximum arithmetic mean GPS-derived values are observed in the March equinox and December solstice, respectively. The equinoxes show a higher variability in VTEC as compared to Solstice. Towards the peak of the solar cycle in 2024, the December solstice also showed higher TEC variability. The results also show that, even though overestimation of the modelled VTEC has been observed on most of the hours, the IRI models used are generally good to at reproducing both the monthly and seasonal diurnal hourly VTEC values, especially in the early morning hours (00:00 - 03:00 UT or 03:00-06:00 LT). The models also do not capture the diurnal variability in VTEC, none of the versions of the IRI model used was able to capture the effects of geomagnetic storms.
Keywords: GPS-TEC; IRI-TEC; TEC over Kenya; TEC during solar maximum

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T09

Latitudinal Signatures of Ionospheric TEC Disturbances During Intense Geomagnetic Storms in the Ascending Phase of Solar Cycle 25 Over Thailand

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This study investigates the signature variations of Total Electron Content (TEC) in response to geomagnetic storms at low latitudes over Thailand during the ascending phase of Solar Cycle 25. Ten intense geomagnetic storm events between 2021 and 2024 were analyzed, with Dst values ranging from –96 nT to –412 nT and Kp indices from 7 to 9. A nine-day analysis window was applied to each event, three days before and five days following the storm peak. TEC data were obtained from GNSS receiver stations located in Chiang Mai (MAIG: 19.21°N, 99.12°E, 9.96°N dip), Bangkok (THBK: 13.73°N, 100.78°E, 4.82°N dip), and Chumphon (THCP: 10.72°N, 99.38°E, 1.85°N dip). The results reveal distinct latitudinal differences in ionospheric responses to geomagnetic activity. At the THCP station, near the magnetic equator, TEC exhibited marked increases, reaching up to 45 TECU, highlighting the region's heightened sensitivity. In contrast, the upper low-latitude MAIG station frequently experienced TEC depletions. The THBK station displayed enhancements and suppressions, likely influenced by preceding moderate storms. Statistical analysis confirmed that many TEC values significantly deviated beyond the typical range during storm periods, with positive anomalies prevailing near the equator and negative deviations occurring at higher latitudes. Furthermore, the study observed that nighttime geomagnetic storms tended to produce weaker TEC enhancements compared to daytime events. The findings underscore the influence of geomagnetic storm intensity, particularly Dst and Kp indices, on ionospheric TEC variations at low latitudes and highlight the necessity of localized monitoring for improved understanding of space weather effects in equatorial and sub-equatorial regions.

Keywords— Intense geomagnetic storm, TEC, Low latitude, Solar Cycle 25

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T10

Temporal Variations in Nighttime Scintillation Near MUF Communication Link at the Equatorial Region

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ABSTRACT

Scintillation of long distance HF communications signals near the MUF band is influenced by the ionospheric dynamics and electrodynamics, particularly from post-sunset to midnight. This effect is particularly pronounced at the equatorial region due to the Equatorial Ionization Anomaly (EIA) and at high latitudes due to auroral activities. This study examines the relationship between the Maximum Usable Frequency (MUF) and scintillation (S4) index to assess the potential correlation between these parameters over time. The analysis reveals weak and inconsistent correlations, with alternating negative and positive values showing monthly, seasonal and annual variations. Despite the presence of some seasonal or temporal trends, the low R-squared and correlation values suggest that other factors significantly influence the variations in MUF and S4. In relation to solar flux, there was an increasing trend between MUF and Solar flux while S4 does not show strong correlation with solar flux at nighttime. This implies that while MUF depends significantly on solar flux, scintillation (S4) is not strongly linked to MUF. These findings highlight the complexity of ionospheric dynamics and underscore the need for further research incorporating additional data and parameters to better understand the interplay between MUF and scintillation.

KEYWORDS: Equatorial region; Scintillation; MUF; seasonal trends; solar flux; R-squared correlation.

T11

Towards a Global Climatological Spread F Model

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Spread F (SF) is an ionospheric phenomenon characterized by the spreading of the ionospheric F traces along the frequency band (FSF) and/or height range (RSF)[1]. These distortions result from irregularities in electron density that scatter radio waves, leading to signal loss, phase shifts, and amplitude fluctuations. Such disruptions are significant for communication, navigation, and positioning systems. SF has been studied across different latitudes. In equatorial regions, the Rayleigh-Taylor (R-T) instability [2] is considered the primary instability mechanism, while at midlatitudes, the Perkins instability dominates [3]. At high latitudes, large-scale travelling ionospheric disturbances (LSTIDs), typically driven by auroral electrojet, are key drivers [4]. SF has also been linked to medium-scale TIDs (MSTIDs) [5, 6], sporadic E layers (Es), and F-region uplifts under both geomagnetically quiet and active conditions [3]. Paul et al. (2018) [1] identified an inverse relationship between solar activity and SF occurrence rates, with notable differences between low and high midlatitudes.

Climatological SF studies have been carried out since the 1960s. Empirical models such as the International Reference Ionosphere (IRI), updated to IRI-2020 [7], provide global monthly averages of ionospheric parameters. Abdu et al. (2003) [2] proposed a probability model for SF occurrence using long-term data from Brazilian stations, now integrated with IRI. Artificial neural networks (ANNs) have also been used; for instance, McKinnell et al. (2010) [8] developed an ANN-based model using Brazilian data and multiple ionospheric parameters. Despite progress, existing models apply to a limited regional scope. To address these challenges, we have [9] used real-time data from the FastChar database (https://giro.uml.edu/didbase/scaled.php) hosted on the DIDBase platform to develop a preliminary climatological SF model over Europe based on data over a full solar cycle.

In the present study, we will discuss these shortcomings in the context of developing a comprehensive SF prediction model across the globe.

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T12

Evaluating the Performance of IRI and NeQuick Models in HF Ray Tracing for Real-Time Ionospheric Representation

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With the growing dependence on space-based technologies, the accurate and timely characterization of the ionosphere has become essential, particularly for applications such as satellite communication, navigation, and HF radio propagation [1]. The ionosphere, due to its variability and complexity, introduces significant propagation errors, making it critical to employ realistic models that can predict electron density profiles in real-time [2]. We present a ray tracing program to simulate the propagation of HF radio waves through the ionosphere using electron density inputs from the International Reference Ionosphere (IRI) and NeQuick models. The program used Appleton-Hartree equation to compute complex refractive indices and applies Snell's law to calculate 2D ray trajectories. To evaluate the performance of the two ionospheric models, we estimated HF transmission ranges using a 6.957 MHz signal transmitted from Abuja (7.38°N, 8.99°E) towards Lagos (6.52°N, 3.38°E), Nigeria. Results show that signals transmitted at incidence angles above 30° experience limited refraction and often escape into space, whereas those below 30° achieve greater transmission ranges. NeQuick predicted a greater transmission distances in the postmidnight period, while IRI outperformed during the postsunset period; both models provided comparable results during midday and midnight periods. Despite seasonal and solar-induced variations in the height of reflection and transmission distances, both models proved effective in representing ionospheric conditions for HF radio propagation. This research demonstrates how the established ionospheric models like IRI and NeQuick can be integrated into real-time ray tracing tools for improved forecasting and mitigation of ionospheric effects in data sparse areas.

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T13

Although the climatology of sporadic E (Es) layers has been studied with Radio Occultation (RO) and ionosonde techniques, detailed comparisons between the findings of these two different methods remain limited. The present study uses 11 years of COSMIC mission and ionosonde observations to investigate diurnal and annual variations in the intensity and height of midlatitude Es layers, providing a comprehensive comparative analysis. RO observations show regular diurnal and annual variations in Es layer intensity and height. The $S4_{max}$ index, which has been identified with the Es intensity, takes maximal values before local noon and later in the day near sunset. In addition, the RO Es layer heights (hEs_{RO}) are found to be higher near sunrise and late afternoon hours. The ionosonde critical frequencies ($foEs$) exhibit a broad maximum at prenoon, but not a second peak later in the day. The virtual layer heights ($h'Es$) maximize at the same time as it happens in RO observations, taking, however, values that are distinctly higher than the corresponding hEs_{RO} ones. Given that $foEs$ and $h'Es$ overestimate the layer intensities and heights during daytime, recent studies proposed methods to correct these ionosonde-measured parameters and thus replace them with the layer critical metal ion reflection frequency ($fo\mu Es$) and the real height (hEs). By adopting these methodologies in the present analysis, the agreement between the diurnal mean variations, obtained separately from RO and ionosonde measurements, was improved significantly. In addition, the yearly RO observations showed that Es layers intensify enough to become detectable at higher altitudes at sunrise and maximize during daytime. This supports a recent proposition where metal atom photoionization (MAP) plays a key role in shaping the sporadic E diurnal cycle.

T14

Evaluating the NeQuick model and IRI-2020 hmF2 model options with Digisonde, COSMIC-2 over South Africa during solar cycle 25

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This study investigates the performance of NeQuick and three IRI-2020 height models: AMTB-2013, CCIR-M3000, and Shubin2015 in estimating the ionospheric F2-layer peak height (hmF2) over South Africa[1]. The hmF2 parameter is crucial for applications such as high-frequency (HF) communication, satellite navigation, and accurate ionospheric modeling[2].

In this work, the outputs of the models are compared with both ground-based digisonde measurements and space-based COSMIC-2 (Constellation Observing System for Meteorology, Ionosphere, and Climate) observations during solar cycle 25. By evaluating the consistency and deviations of these models with actual observations, the study provides valuable insights into the spatial and temporal performance of NeQuick[3] and IRI-2020 height model components.

This comparative evaluation provides significant insight into the spatial accuracy of NeQuick and IRI-2020 height models and highlights the importance of regional validation when utilizing global ionospheric models.

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