frontiers | Frontiers in Astronomy and Space Sciences

TYPE Editorial
PUBLISHED 10 May 2023
DOI 10.3389/fspas.2023.1211582

OPEN ACCESS

EDITED AND REVIEWED BY
Joseph E. Borovsky,
Space Science Institute, United States

*CORRESPONDENCE
Andres Calabia,
andres@calabia.com,
a.calabia@uah.es

RECEIVED 24 April 2023
ACCEPTED 04 May 2023
PUBLISHED 10 May 2023

CITATION
Calabia A, Lu G and Bolaji OS (2023), Editorial: Advances on upper-atmosphere characterization for geodetic space weather research and applications.
Front. Astron. Space Sci. 10:1211582.
doi: 10.3389/fspas.2023.1211582

Editorial: Advances on upper-atmosphere characterization for geodetic space weather research and applications

Andres Calabia[1]*, Gang Lu[2] and Olawale S. Bolaji[3,4,5]

[1]Department of Physics and Mathematics, University of Alcala, Alcalá de Henares, Spain, [2]High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO, United States, [3]Department of Physics, University of Lagos, Lagos, Nigeria, [4]Department of Mathematics and Physics, University of Tasmania, Hobart, TAS, Australia, [5]Department of Physics and Solar Energy, Bowen University, Iwo, Nigeria

KEYWORDS

space weather, space geodesy, solar-terrestrial interactions, near-Earth environment, upper atmosphere, magnetosphere-ionosphere-thermosphere coupling

Editorial on the Research Topic
Advances on upper-atmosphere characterization for geodetic space weather research and applications

Predictive space weather modeling is a burgeoning field that aims to expand our knowledge of how space weather impacts our environment and how we can better anticipate and prepare for its effects. Scientists use a variety of sources, including information gathered by satellites and ground-based instruments, to better understand the behavior of solar wind, solar radiation, and cosmic rays, and how these phenomena interact with near-Earth space. These data are then used to model and predict space weather patterns that help decisions and actions to reduce risks and ensure safety. There are numerous areas where data on space weather plays a critical role in decision-making. These include aviation and spaceflight, military operations, emergency management and natural disasters preparedness, health and safety, environmental protection, global transportation, energy production and distribution, and more. By leveraging geodetic data from ground-based and Earth-orbiting satellites, as well as other types of instrumentation, scientists and decision-makers can monitor and predict the effects of space weather events to inform practical applications.

On 22 April 2017, the Focus Area on Geodetic Space Weather Research (FA GSWR) was established in Vienna within the Global Geodetic Observing System (GGOS) of the International Association of Geodesy (IAG). Figure 1 provides a visual representation of the FA-GSWR organizational structure, illustrating the space-geodetic observation techniques in orange and the solar observations in blue. To address the challenges associated with the coupled magnetosphere-ionosphere-thermosphere (MIT) system, significant progress must be made in geodetic observations of plasma and neutral density, compositions, and velocities, as well as observations of energetic particles and magnetic field perturbations both in space and on the ground. Moreover, advanced theoretical and numerical modeling capabilities are necessary to support these

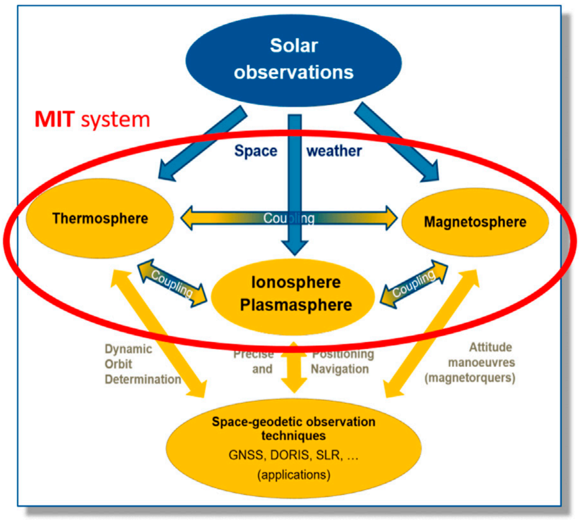

FIGURE 1
Structure of the IAG GGOS Focus Area on Geodetic Space Weather Research including the components Magnetosphere, Plasmasphere, Ionosphere and Thermosphere. Source: https://ggos.org/about/org/fa/geodetic-space-weather-research/objectives/.

observations (Heelis and Maute, 2020). The establishment of the FA GSWR within the GGOS represents an important step forward in the study of space weather.

In recent decades, the negative effects of space weather conditions on modern technologies have become a significant concern. As our reliance on satellite communications, Positioning-Navigation-Timing (PNT), Global Navigation Satellite Systems (GNSS), Earth observation and forecasting through *in situ* and remote sensing, and countless other applications continues to grow, mitigating the impacts of space weather has become a critical priority. It is essential to understand the complex interplay between the Sun, Earth's atmosphere, and space weather to protect the technological infrastructure that we rely on daily. By studying the thermosphere, ionosphere, and their interactions with the Sun and lower atmosphere, we can develop better models for predicting and mitigating the effects of space weather. This will help ensure the continued functionality and reliability of critical technologies that are essential to our modern way of life.

The primary objective of this Research Topic is to showcase the latest advancements in algorithms, methodologies, and techniques for characterizing the upper atmosphere in the context of geodetic space weather research and applications. The Research Topic includes five manuscripts that focus on a range of research topics related to this field. This Research Topic brings together the work of leading researchers in the space weather community who are dedicated to advancing our understanding of the upper atmosphere and its relationship with space weather. Each manuscript highlights the latest developments in upper atmosphere characterization and presents new and innovative approaches to addressing key research questions. We believe that the research presented in this Research Topic will be of great interest to researchers, practitioners, and decision-makers in the field of space weather.

First, we would like to introduce the instrumental advances on new GNSS technologies done by Zhao and Lei, where the authors show the *effects of ionosphere dispersion on wideband GNSS signals*. This work shows the effects of the ionosphere dispersion on the tracking of various wideband GNSS signals during quiet and active ionosphere conditions. It shows that ionosphere dispersion may cause correlation power loss and carrier-phase offsets in the phase locked loop (PLL) output for wideband GNSS signal tracking but would not result in an additional delay in the estimated code delay if techniques for ionosphere dispersion compensation in receivers were not implemented. The *relationship between geomagnetic storms and occurrence of ionospheric irregularities in the west sector of Africa during the peak of the 24th solar cycle* is investigated in Ondede et al. This study focuses on the relationship between geomagnetic storm occurrence and ionospheric irregularity occurrence over the West African sector. Their results showed that irregularities do not depend only on geomagnetic storms, and there are other causes of ionospheric irregularities. Moreover, a "*Regional classification of time spectral amplitudes in total electron content (Southeastern United States during solar cycle 24)*" is presented in Burkholder et al. This study analyzes the spectral properties in the calculated TEC at a cluster of GNSS receivers in and around Florida to investigate the meso-scale structure of the ionosphere at mid-latitudes. They suggest that spatio-temporal variations of spectral amplitudes in the mid-latitude ionosphere are not dominated by a single process, and the amplitudes of diurnal, seasonal, and solar rotation signals are well ordered by magnetic latitude, which are superposed with meso-scale deviations between stations separated by ~100 s of km. Finally, we would like to highlight the emerging interest on investigating the lithosphere-ionosphere coupling, and its implications on the prediction and characterizations of future seismic events (e.g., Shah et al., 2020). There are 2 additional papers along this line of study. Khan et al. present the "*Possible seismo-ionospheric anomalies associated with the 2016 Mw 6.5 Indonesia earthquake from GPS TEC and Swarm satellites.*" This paper presents a statistical analysis of the TEC data from GNSS ground receivers and Swarm satellites to determine seismo-ionospheric anomalies associated with the Mw 6.5 Sumatra earthquake that occurred in Indonesia on 6 December 2016. The study provides validation of a new statistical analysis method, and proposes to implement such methods along with more satellite data to forecast future earthquakes. Cahyadi et al. in their paper entitled "*Three-dimensional tomography of co-seismic ionospheric disturbances following the 2018 Palu earthquake and tsunami from GNSS measurements*" analyzes the 3D tomography of the ionospheric electron density anomalies of the 2018 Palu Earthquake using the GNSS-TEC data.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Funding

The authors acknowledge the support of Frontiers to cover the APCs of this article.

Acknowledgments

The authors acknowledge the support of all the members of the Join Study Group 1: "Coupling processes between magnetosphere, thermosphere, and ionosphere" of the International Association of Geodesy Global Geodetic Observing System Focus Area Geodetic Space Weather Research (https://ggos.org/about/org/fa/geodetic-space-weather-research/groups/jsg1-coupling-processes/). Special thanks are given to all colleagues who have participated in this Research Topic.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

Heelis, R.A., and Maute, A. (2020). Challenges to understanding the earth's ionosphere and thermosphere. *J. Geophys. Res. Space Phys.* 125, e2019JA027497. doi:10.1029/2019JA027497

Shah, M., Ahmed, A., Ehsan, M., Khan, M., Tariq, M. A., Calabia, A., et al. (2020). Total electron content anomalies associated with earthquakes occurred during 1998 – 2019. *Acta Astronaut.* 175, 268–276. doi:10.1016/j.actaastro.2020.06.005