# 2022 Workshop: Equatorial Ionization Anomaly (EIA) and ionospheric irregularities

Long title

Recent advances in the understanding of Equatorial Ionization Anomaly (EIA) and ionospheric irregularities (e.g., Scintillations, Equatorial Plasma Bubbles, Spread-F) over low and mid latitudes using ground and satellite measurements and modelling studies

Conveners

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Description

This session invites presentations related to space and ground-based measurements and modeling efforts that contribute to a better understanding of the development and variability of EIA and ionospheric irregularities (e.g., Scintillations, Equatorial Plasma Bubbles, Spread-F) over low and mid-latitudes.

Agenda

1. [13:30 - 13:35] - "Welcome and Introduction"

2. [13:35 - 13:50] - **Richard W. Eastes** - “What Controls the Nighttime Equatorial Ionization Anomaly (EIA) Crests’ Latitudes? (in 2020 GOLD Mission Observations)”

3. [13:50 - 14:00] - **Brians Chinonso Amadi** - “Impact of collisions on equatorial plasma bubble (EPB) development during the 02 -06 February, 2022 geomagnetic storm”

4. [14:00 - 14:15] - **Fabiano Rodrigues** - “Low-cost sensors for distributed ionospheric observations: Description and examples of application in low to mid latitude studies"

5. [14:15 - 14:25] - **Ercha Aa** - “Pronounced Suppression and X-Pattern Merging of Equatorial Ionization Anomalies after the 2022 Tonga Volcano Eruption”

6. [14:25 - 14:40] - **Joe Huba** - “SAMI3/HIAMCM simulations of the Tonga event”

7. [14:40 - 14:50] - **Aaron Bukowski** - “Vertical Behavior of TADs/TIDs near the Topside Ionosphere using SAMI3 driven by GITM”

8. [14:50 - 14:55] - **Enrique Rojas** - “Fluid simulation of the Farley-Buneman instability”

9. [14:55 - 15:05] - **Sevag Derghazarian** - “Lower hybrid waves in high altitude echoes of the inner plasmasphere: Simulations and new experimental results”

10. [15:05 - 15:15] - **Anastatia Newheart** - “Observations of Night-Time Equatorial Ionosphere Structure with the FPMU on board the International Space Station”

11. [15:05 - 15:30] - Discussions and Future Thoughts

Justification

Equatorial Ionization Anomaly (EIA) and ionospheric irregularities (e.g., Scintillations, Equatorial Plasma Bubbles, Spread-F) have been a major focus of the low and mid-latitude ionospheric research community. The behavior of the IT system is influenced by the solar forcing from above, wave activities from below, traveling atmospheric/ionospheric disturbances (TADs/TIDs) from mid/high latitudes, and the equatorial dynamo process. These factors along with the dynamic processes manifest various thermospheric and ionospheric irregularities (e.g., Scintillations, Equatorial Plasma Bubbles, Spread-F). Further, the geometry (such as magnetic declination angle, terminator alignment), geomagnetic activities, and other conditions (e.g. winds and wave activity) regulate the morphology and variability. Determining these conditions and understanding their interactions have challenged the research community for decades. New satellite measurements (GOLD, ICON, COSMIC) and modeling approaches have revealed several new, interesting characteristics about the EIA variability and ionospheric irregularities.

Summary

**Attendance:** ~30 participants

**1.0. "Welcome and Introduction" -** By Dr. Deepak Karan

The session started about 13:30 with a welcome note from Dr. Deepak Karan, during which he emphasized the impact of equatorial irregularities on technological systems and the need for continuous studies so as to enhance our understanding of their evolution towards accurate prediction.

**2.0. “What Controls the Nighttime Equatorial Ionization Anomaly (EIA) Crests’ Latitudes? (in 2020 GOLD Mission Observations)” -** By Dr. Richard W. Eastes

Using 135.6 nm radiance data from the Global-Scale Observation of Limb and Disk (GOLD) satellite, Dr. Eastes discussed the longitudinal variation of the EIA crests locations at different seasons. The EIA crest locations show different behavior to the east and west of the longitude where the geomagnetic and geographic equator cross. To understand the mechanism behind this, he considered meridional winds, declination angle-solar terminator alignment, and the position of the subsolar point from the geomagnetic equator. In conclusion, the sub-solar point, meridional winds, and the declination angle-solar terminator alignment are discussed to have a mixed influence on the EIA crests' locations.

**3.0. “Impact of collisions on equatorial plasma bubble (EPB) development during the 02 -06 February 2022 geomagnetic storm” -** By Amadi Brians Chinonso

During the 4th February 2022 geomagnetic storm, several Starlink satellites were lost. Amadi Brians observed the suppression of EPB using GOLD electron density data. To ascertain the possible driver of this suppression, he computed the ion-neutral collision frequency (a factor that suppresses RTI growth and in turn, EPB development) using neutral gas density from the MSIS model and collision coefficients. He showed that days of high ion-neutral collision frequency were characterized by EPB suppression. He also observed that the high collision frequency is due to geomagnetic disturbance dynamo that drives charged particles into the South-American sector of the low-latitude region; characterized by particle precipitation through the low magnetic field strength region called the South Atlantic Magnetic Anomaly (SAMA). In conclusion, geomagnetic disturbances can suppress EPB development via driving a high ion-neutral collision frequency that suppresses RTI growth.

**4.0. "Low-cost sensors for distributed ionospheric observations: Description and examples of application in low to mid-latitude studies" -** By Dr. Fabiano Rodrigues

To obtain a complete view of equatorial irregularities, there is a need for both ground- and space-based sensors to measure at least an aspect of these irregularities. One challenge to this quest is the cost of sensors which has significantly retarded advancement in atmospheric and space science research. In his presentation, Dr. Fabiano presented low-cost sensors, their uses, and capabilities relative to standard sensors. One of the sensors he presented is the ScintPi. This sensor is a robust but simple yet cost-effective sensor able to detect scintillations and also measure Total Electron Content (TEC) from GNSS signals. There are three versions of this sensor that can be purchased from Amazon. To get more information on this, you can reach Dr. Fabiano via Fabiano@utdallas.edu. Dr. Fabiano also demonstrated good agreement between ScintPi and conventional commercial GNSS receivers with respect to measuring S4 (an index for scintillation) and TEC. Additionally, he showed that ScintPi is able to observe all GNSS constellations (GPS, SBAS, GAL, GLO, Bei) as well as reduced downtime. In conclusion, scintillations are attenuations in amplitude and phase amplitude, and thus can be used as proxies for irregularities and plasma variations. Hence, cost-effective sensors will enhance our understanding of irregularities and the global response of the ionosphere to forcing since we can then have more receivers distributed over wider latitudes and longitudes.

**5.0. "Pronounced Suppression and X-pattern Merging of Equatorial Ionization Anomalies after the 2022 Tonga Volcano Eruption" -** By Dr. Ercha Aa

The distance between the EIA crest (see section 2.0) and the geomagnetic equator vary with time, longitude, season, forcing from below and above as well as wind dynamics. During the Tonga volcanic eruption, Dr. Ercha observed the collapse of the EIA crests, at the longitude where geomagnetic and geographic equators cross each other. To the west and east of GGE, the crests diverge from the geomagnetic equator, thus forming an X-like structure. Using TEC keogram and ICON wind data, Dr. Ercha showed that the enhanced zonal wind speed of up to 200 m/s may have influenced the formation of X-structure since they seem to be in phase with the EIA crests' collapse. A consequence of these winds was a possible westward zonal electric field that suppressed evening time enhancement of E x B drift. He confirmed this hypothesis using Digisonde drift data. This result showed a downward drift of plasma from about 500km to 260 km. In conclusion, the formation of the EIA crest requires an uplift of plasma and subsequent poleward drift along magnetic field lines by gravity and pressure forces. To lift plasma, sufficient E x B is required. The downward drift as shown by the digisonde data implies a suppression in E x B and thus, a collapse in EIA leading to the formation of X-structure.

## 6.0. "SAMI3/HIAMCM simulations of the Tonga event" - By Dr. Joe Huba

SAMI3 is a physics-based 3-dimensional global model that solves the ion continuity, momentum, and temperature equations for ionospheric ions while HIAMCM (High Altitude Mechanistic General Circulation Model) is a spatial resolution model that extends from the surface to about 500 km and simulates gravity waves over the whole range. Thus, coupling SAMI3 and HIAMCM can be used to study the influence of lower atmospheric forcing on the evolution of ionospheric irregularities. Dr. Huba used this coupled model to simulate the effect of massive Tonga-volcanic-eruption-induced waves on TEC and the evolution of EPBs. The global simulated TEC showed depletions that indicated the effect of upward propagating waves associated with the Tonga event. These waves also modified the zonal neutral wind and E x B which may have likely influenced the evolution of bubbles. In conclusion, Tonga-induced waves acted as seeds to enhance the initiation and evolution of EPBS. This was made possible via the modification of neutral wind and subsequently, E x B drift.

## 7.0. "Vertical Behavior of TADs/TIDs near the Topside Ionosphere using SAMI3 driven by GITM" - By Aaron Bukowski

The goal of the presentation is to study the storm time large-scale traveling atmospheric disturbances (LSTIDs) using SAMI3 and GITM. A comparison of the two models is discussed. The propagation of the LSTIDs at three longitudes is investigated. Through model simulation, it was observed that the TIDs seeded at the high latitudes and propagate towards low latitudes. The obtained velocities are compared to the data. In future work, the investigation will continue using a fully coupled SAMI3 and GITM.

## 8.0. "Fluid simulation of the Farley-Buneman instability" – By Enrique Rojas

The presentation started with a quick background and goals. Then the fluid simulation model was discussed in detail. The presentation was concluded with the potential of the fluid model and the future plan.

**9.0. “Lower hybrid waves in high altitude echoes of the inner plasmasphere: Simulations and new experimental results”-** Sevag Derghazarian

This presentation started with a review of the equatorial high latitude echoes in the plasmasphere. Echoes exhibit strong sidebands at the lower hybrid frequency at very low solar flux was proposed to be a new phenomenon. LH waves in echoes from ISR data were investigated. The possible mechanisms and hypotheses for the formation of the LH waves were discussed.

**10.0. “Observations of Night-Time Equatorial Ionosphere Structure with the FPMU on board the International Space Station”** – By Anastatia Newheart

In this presentation, the author discussed the EIA crests electron density variations using in-situ measurements from the ISS platform. The data were compared with the SWARM and TEC measurements.

**11.0. Discussions and Future Thoughts**

The session ended with a discussion about the need for more ground and space-based observations and model simulations for in detail investigation and understanding of the EIA and plasma irregularities.

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Keywords
Ionospheric irregularities, low and mid latitude ionosphere, Equatorial Ionization Anomaly
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