Earth, Planets and Space

16th International Symposium on Equatorial Aeronomy (ISEA-16), 2022

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The Seismological Society of Japan
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Yokoyama *et al. Earth, Planets and Space (2024) 76:115*
https://doi.org/10.1186/s40623-024-02052-1

PREFACE

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Special issue "16th International Symposium on Equatorial Aeronomy (ISEA-16), 2022"

Tatsuhiro Yokoyama[1*], Jeffrey Klenzing[2], Marco A. Milla[3], Claudia Stolle[4] and Duggirala Pallamraju[5]

The International Symposium on Equatorial Aeronomy (ISEA) has been held once in every 3 to 4 years since 1962. Researchers from the fields of atmospheric, ionospheric and magnetospheric sciences gather together during ISEA to share new findings, discuss the current status, and identify remaining key questions in equatorial and low-latitude aeronomy. The 16th ISEA (ISEA-16) was held from September 12 to 16, 2022 at the Research Institute for Sustainable Humanosphere, Kyoto University, Japan. Since the symposium period was close to the end of COVID-19 worldwide pandemic, it was held as a hybrid event (in-person and virtual participation). The symposium was successfully attended by 70 in-person (44 overseas) and 63 virtual (59 overseas) participants.

ISEA-16 consisted of 7 scientific sessions, a keynote lecture on the first day, and a closing lecture on the final day. The scientific sessions were: (1) Equatorial E- and F-region irregularities: cause and effects; (2) Longitudinal/hemispheric variation of equatorial electrodynamics; (3) Atmosphere-ionosphere vertical coupling at low- and mid-latitudes; (4) Space weather effects at low- and mid-latitudes; (5) Recent advances in instrumentation and observation; (6) Application of numerical techniques for aeronomy; and (7) Future trends, opportunities, and challenges in low-latitude aeronomy. Important scientific results presented in ISEA-16 are collected within the special issue, which includes one Frontier Letter (Hosokawa et al. 2023), two Express Letters (Kumar et al. 2023; Suclupe et al. 2023), and 12 full papers. In the following, we summarize the contents of papers in the special issue briefly.

One of the oldest topics in equatorial aeronomy is Equatorial spread F (ESF), or equatorial plasma bubbles (EPB) which was observed for the first time as abnormal ionogram more than 80 years ago. Understanding the day-to-day variability of ESF has been an important and long-standing issue for HF radio communication in the pre-space era and for satellite communication/navigation systems in the modern era. Hosokawa et al. (2023) conducted EPB monitoring by using VHF radio signals for the aeronautical navigation system. This technique has been shown to have large potential to continuously monitor EPBs in wide area even over the ocean where no local ground stations are available. Abadi et al. (2023) investigated new forecast techniques for ESF occurrence based on ionosonde observations in Southeast Asia. Figueiredo et al. (2023) studied secondary instability generated on EPB walls, and Rino et al. (2023) investigate stochastic structure inside EPBs based on a high-resolution EPB simulation model. New observation instruments were installed in various regions: an UHF radar in the Jicamarca Radio Observatory (Rodrigues et al. 2023), scintillation monitors in Thailand compared with LEO observations (Seechai et al. 2023), and HF Doppler receivers in Taiwan compared with airglow observations (Sejima et al. 2023).

Strong impacts on the upper atmosphere and the ionosphere after the huge volcanic eruption in Tonga in January 2022 were timely topics during ISEA-16. Choi et al. (2023) described an ionospheric density hole observed by COSMIC-2, ICON, Swarm, and

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ground-based TEC which was suggested to result from as an interplay between the EIA development and neutral wind disturbances due to the eruption. Nakata et al. (2023) investigated traveling ionospheric disturbances observed by a HF Doppler sounding system in Japan, while Pacheco et al. (2024) studied atmospheric and ionospheric impacts over Peru.

The application of machine learning technique has been a major topic in atmospheric and ionospheric sciences. Therefore, we organized Session 6 entitled "Application of numerical techniques for aeronomy" at ISEA-16 which presented several studies that used machine learning method. Two papers of this session are published in this special issue: (i) Thammavongsy et al. (2023) used artificial neural network and long short-term memory to forecast ESF occurrence by ionosonde data in Thailand, while (ii) Thanakulketsarat et al. (2023) developed models for classification of radar backscatter from EPBs using convolutional neural network and support vector machine techniques.

This special issue has also welcomed papers on recent subjects on low-latitude aeronomy which very well complement the presentations given during the conference. Kumar et al. (2023) studied the relation between the strength of the northern stratospheric polar vortex and the magnitude of solar and lunar tides detected in the equatorial electrojet. Based on a newly installed multistatic specular meteor radar, Suclupe et al. (2023) investigated the climatology of mesosphere and lower thermosphere diurnal tides in neutral winds over Jicamarca. Matamba et al. (2023) studied the response of the ionosphere over South Africa during a geomagnetic storm in November 2021.

All 15 papers in this special issue contribute to advance a variety of aspects of equatorial aeronomy. We anticipate that scientists from the aeronomy community will actively gather again in the next 17th International Symposium on Equatorial Aeronomy (ISEA-17), which will be held in Costa Rica in 2026.

Acknowledgements
We thank all participants of ISEA-16 in September 2022 and convey our appreciation to all the authors for contributing to this special issue. We are highly grateful to all the reviewers who served in evaluating the submitted papers and for giving helpful suggestions.

Author contributions
All the authors of this article served as guest editors for this special issue. TY drafted the manuscript. All the authors read and approved the final manuscript.

Availability of data and materials
Not applicable.

Declarations

Competing interests
The authors declare that they have no competing interests.

Received: 25 July 2024 Accepted: 30 July 2024
Published online: 02 September 2024

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Figueiredo CAOB, Miranda RA, Wrasse CM, Takahashi H, Barros D, Egito F, de Matos RG, Sampaio AHR (2023) Secondary instability generated on the equatorial plasma bubbles wall due to an interaction with midnight brightness wave. Earth Planets Space 75:141

Hosokawa K, Saito S, Nakata H, Lin C-H, Lin J-T, Supnithi P, Tomizawa I, Sakai J, Takahashi T, Tsugawa T, Nishioka M, Ishii M (2023) Monitoring of equatorial plasma bubbles using aeronautical navigation system: a feasibility study. Earth Planets Space 75:152

Kumar S, Siddiqui TA, Stolle C, Pedatella NM, Pallamraju D (2023) Impact of strong and weak stratospheric polar vortices on geomagnetic semidiurnal solar and lunar tides. Earth Planets Space 75:52

Matamba TM, Danskin DW, Nndanganeni RR, Tshisaphungo M (2023) Space weather impacts on the ionosphere over the southern African mid-latitude region. Earth Planets Space 75:142

Nakata H, Hosokawa K, Saito S, Otsuka Y, Tomizawa I (2023) Periodic oscillations of Doppler frequency excited by the traveling ionospheric disturbances associated with the Tonga eruption in 2022. Earth Planets Space 75:158

Pacheco EE, Velasquez JP, Flores R, Condori L, Fajardo G, Kuyeng K, Scipion D, Milla M, Conte JF, Poblet FL, Chau JL, Suclupe J, Rojas R, Manay E (2024) The impact of the Hunga Tonga-Hunga Ha'apai volcanic eruption on the Peruvian atmosphere: from the sea surface to the ionosphere. Earth Planets Space 76:79

Rino C, Yokoyama T, Carrano C (2023) A three-dimensional stochastic structure model derived from high-resolution isolated equatorial plasma bubble simulations. Earth Planets Space 75:64

Rodrigues FS, Milla MA, Scipion D, Apaza JM, Kuyeng KM, Sousasantos J, Massoud AA, Padin C (2023) On new two-dimensional UHF radar observations of equatorial spread F at the Jicamarca Radio Observatory. Earth Planets Space 75:120

Seechai K, Myint LMM, Hozumi K, Nishioka M, Saito S, Yamamoto M, Supnithi P (2023) Simultaneous equatorial plasma bubble observation using amplitude scintillations from GNSS and LEO satellites in low-latitude region. Earth Planets Space 75:127

Sejima S, Hosokawa K, Nakata H, Chum J, Lin C-H, Lin J-T (2023) Simultaneous observations of equatorial plasma bubbles with an all-sky airglow imager and a HF Doppler sounding system in Taiwan. Earth Planets Space 75:156

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Thammavongsy P, Supnithi P, Myint LMM, Hozumi K, Lakanchanh D (2023) Equatorial spread-F forecasting model with local factors using the long short-term memory network. Earth Planets Space 75:118

Thanakulketsarat T, Supnithi P, Myint LMM, Hozumi K, Nishioka M (2023) Classification of the equatorial plasma bubbles using convolutional neural network and support vector machine techniques. Earth Planets Space 75:161

Publisher's Note

FRONTIER LETTER **Open Access**

Monitoring of equatorial plasma bubbles using aeronautical navigation system: a feasibility study

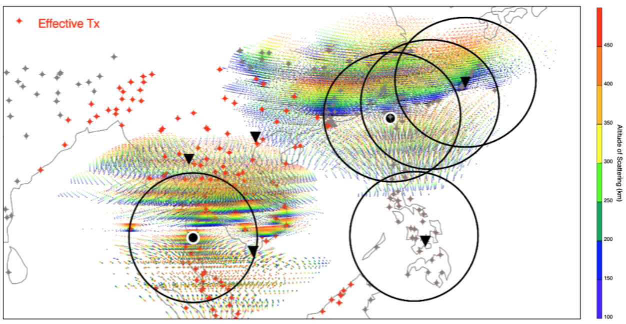
Keisuke Hosokawa*, Susumu Saito, Hiroyuki Nakata, Chien-Hung Lin, Jia-Ting Lin, Pornchai Supnithi, Ichiro Tomizawa, Jun Sakai, Toru Takahashi, Takuya Tsugawa, Michi Nishioka and Mamoru Ishii

Earth, Planets and Space 2023, **75**:152 DOI: 10.1186/s40623-023-01911-7
Received: 31 May 2023, Accepted: 21 September 2023, Published: 3 October 2023

Abstract

It has long been known that field-aligned irregularities within equatorial plasma bubbles (EPBs) can cause long-range propagation of radio waves in the VHF frequencies such as those used for TV broadcasting through the so-called forward scattering process. However, no attempt has been made to use such anomalous propagations of VHF radio waves for wide-area monitoring of EPBs. In this study, we investigated the feasibility of monitoring of EPBs using VHF radio waves used for aeronautical navigation systems such as VHF Omnidirectional radio Range (VOR). There are 370 VOR stations in the Eastern and Southeastern Asian region that can be potentially used as Tx stations for the observations of anomalous propagation. We have examined the forward scattering conditions of VHF waves using the magnetic field model and confirmed that it is possible to observe the EPB-related anomalous propagation if we set up Rx stations in Okinawa (Japan), Taiwan, and Thailand. During test observations conducted in Okinawa since 2021, no signal has been received that was clearly caused by anomalous propagation due to EPBs. This is simply because EPBs have not developed to high latitudes during the observation period due to the low solar activity. In March 2023, however, possible indications of EPB-related scattering were detected in Okinawa which implies the feasibility of observing EPBs with the current observation system. We plan to conduct pilot observations in Taiwan and Thailand in future to further evaluate the feasibility of this monitoring technique.

Keywords: Equatorial plasma bubbles, Radio propagation, Airglow observation



Graphical abstract

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FULL PAPER **Open Access**

A three-dimensional stochastic structure model derived from high-resolution isolated equatorial plasma bubble simulations

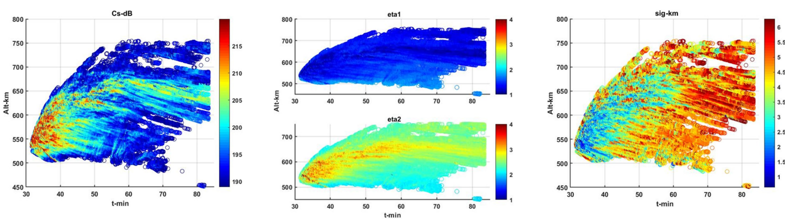
Charles Rino*, Tatsuhiro Yokoyama and Charles Carrano

Earth, Planets and Space 2023, **75**:64 DOI: 10.1186/s40623-023-01823-6
Received: 14 December 2022, Accepted: 15 April 2023, Published: 28 April 2023

Abstract

Ionospheric structure is characterized by the space–time variation of electron density. However, our understanding of the physical processes that initiate and sustain intermediate-scale structure development does not relate directly to statistical measures that characterize the structure. Consequently, high-resolution physics-based equatorial plasma bubble simulations are essential for identifying systematic relations between statistical structure measures and the underlying physics that initiates and sustains the structure evolution. An earlier paper summarized the analysis of simulated equatorial plasma bubble (EPB) structure initiated with a quasi-periodic bottom-side perturbation that generated five plasma bubbles. The results are representative of real environments. However, the association of the structure development with individual EPBs was difficult to ascertain. This paper summarizes the analysis of new results from single isolated EPB realizations with varying parameters that affect the structure development. The evolution of the single isolated EPB realizations reveal what we have identified as a canonical structure evolution pattern manifest in the space–time development of four quantitative spectral parameters. The onset of structure occurs when the plasma bubble penetrates the F-region peak. The parameter evolution from the initiation point have a fish-like appearance. The three-dimensional structure model can be used to interpret in situ and remote diagnostic measurements as well as predicting the deleterious effects of propagation disturbances on satellite communication, navigation, and surveillance systems.

Keywords: Equatorial Spread F, Power-law ionospheric structure, Convective plasma instability, Structure characterization



Graphical abstract

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FULL PAPER **Open Access**

Equatorial spread-F forecasting model with local factors using the long short-term memory network

Phimmasone Thammavongsy, Pornchai Supnithi*, Lin Min Min Myint, Kornyanat Hozumi and Donekeo Lakanchanh

Earth, Planets and Space 2023, **75**:118 DOI: 10.1186/s40623-023-01868-7
Received: 21 March 2023, Accepted: 30 June 2023, Published: 4 August 2023

Abstract

The predictability of the nighttime equatorial spread-F (ESF) occurrences is essential to the ionospheric disturbance warning system. In this work, we propose ESF forecasting models using two deep learning techniques: artificial neural network (ANN) and long short-term memory (LSTM). The ANN and LSTM models are trained with the ionogram data from equinoctial months in 2008 to 2018 at Chumphon station (CPN), Thailand near the magnetic equator, where the ESF onset typically occurs, and they are tested with the ionogram data from 2019. These models are trained especially with new local input parameters such as vertical drift velocity of the F-layer height (Vd) and atmospheric gravity waves (AGW) collected at CPN station together with global parameters of solar and geomagnetic activity. We analyze the ESF forecasting models in terms of monthly probability, daily probability and occurrence, and diurnal predictions. The proposed LSTM model can achieve the 85.4% accuracy when the local parameters: Vd and AGW are utilized. The LSTM model outperforms the ANN, particularly in February, March, April, and October. The results show that the AGW parameter plays a significant role in improvements of the LSTM model during post-midnight. When compared to the IRI-2016 model, the proposed LSTM model can provide lower discrepancies from observational data.

Keywords: Equatorial spread-F, Equatorial spread-F forecasting model, Artificial neural network, Long short-term memory, IRI-2016 model

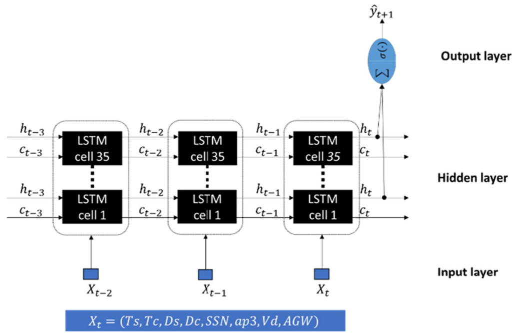

Fig. 2

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FULL PAPER **Open Access**

On new two-dimensional UHF radar observations of equatorial spread *F* at the Jicamarca Radio Observatory

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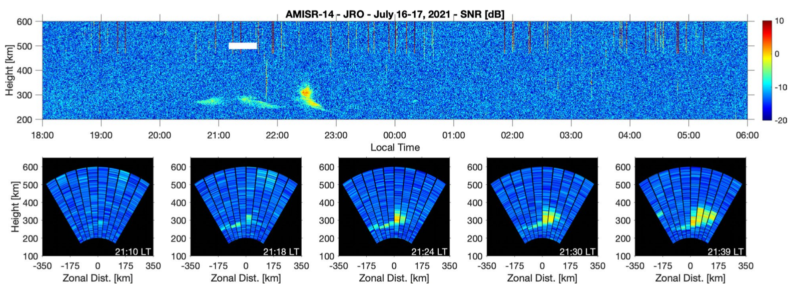
Earth, Planets and Space 2023, **75**:120 DOI: 10.1186/s40623-023-01876-7
Received: 24 April 2023, Accepted: 30 July 2023, Published: 9 August 2023

Abstract

We describe a mode for two-dimensional UHF (445 MHz) radar observations of *F*-region irregularities using the 14-panel version of the advanced modular incoherent scatter radar (AMISR-14). We also present and discuss examples of observations made by this mode. AMISR-14 is installed at the Jicamarca Radio Observatory (JRO, 11.95°S, 76.87°W, ~0.5° dip latitude) in Peru and, therefore, allows studies of ionospheric irregularities at the magnetic equator. The new mode takes advantage of the electronic beam-steering capability of the system to scan the equatorial *F*-region in the east–west direction. Therefore, it produces two-dimensional views of the spatial distribution of sub-meter field-aligned density irregularities in the magnetic equatorial plane. The scans have a temporal resolution of 20 s and allow observations over a zonal distance of approximately 400 km at main *F*-region heights. While the system has a lower angular and range resolution than interferometric in-beam VHF radar imaging observations available at Jicamarca, it allows a wider field-of-view than that allowed with the VHF system. Here, we describe the mode, and present and discuss examples of observations made with the system. We also discuss implications of these observations for studies of ESF at the JRO.



Graphical abstract

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FULL PAPER Open Access

Simultaneous equatorial plasma bubble observation using amplitude scintillations from GNSS and LEO satellites in low-latitude region

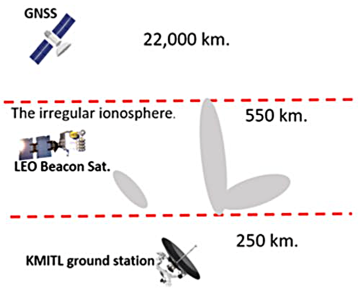
Khanitin Seechai, Lin Min Min Myint*, Kornyanat Hozumi, Michi Nishioka, Susumu Saito, Mamoru Yamamoto and Pornchai Supnithi

Earth, Planets and Space 2023, **75**:127 DOI: 10.1186/s40623-023-01877-6
Received: 13 May 2023, Accepted: 30 July 2023, Published: 23 August 2023

Abstract

This study estimates the scale sizes of the plasma density irregularities and the longitudinal width associated with equatorial plasma bubbles (EPBs) in equatorial and low-latitude regions. By analyzing amplitude scintillation S_4 indices and total electron content (TEC) measured from low earth orbit (LEO) satellite's beacon signals with 400 MHz and Global Navigation Satellite System (GNSS) L1/E1 signals with 1575.42 MHz, recorded by receivers at the KMITL station in Bangkok, Thailand (geographic; 13.73° N, 100.77°E, magnetic: 7.26°N), we investigate the characteristics of these irregularities. We collected data of 154 LEO satellite pass events during nighttime on 21 disturbed days in four equinoctial months in 2021. Based on the presence or absence of the scintillation effects on GNSS and LEO beacon signals, the events are categorized into four classes to estimate the scale size of the plasma density irregularities. The analysis suggests that events with both GNSS and LEO scintillations, as well as events with GNSS scintillation alone, occur predominantly before midnight assuming the presence of the small-scale size of the irregularities within EPB. However, events with only LEO scintillation occur throughout the whole night and some events are observed before the events with both GNSS and LEO scintillations. Post-sunset LEO scintillation alone may be attributed to the onset of EPBs developing at low altitude, while post-midnight LEO scintillation events near the magnetic equator, observed during periods of low GNSS Rate of TEC Index (ROTI) values, are associated with bottom-side ionospheric irregularities but are not linked with EPB. The findings are consistent with previous researches on the generation and decay of electron density irregularities within plasma bubbles. However, this study provides new insights by using specific data sets and analysis techniques, offering a more comprehensive understanding of the association of LEO scintillations with bottom-side ionospheric irregularities near the magnetic equator, not observed in the ROTI map.

Keywords: Space weather, Global Navigation Satellite System, Low earth orbit satellites, TEC, Ionospheric irregularity, Equatorial plasma bubble, Amplitude scintillation index



Graphical abstract

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FULL PAPER Open Access

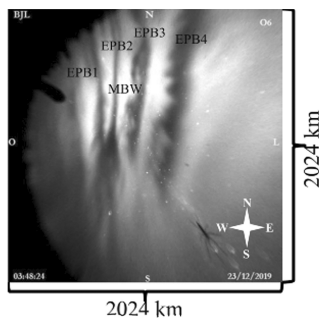
Secondary instability generated on the equatorial plasma bubbles wall due to an interaction with midnight brightness wave

Cosme Alexandre Oliveira Barros Figueiredo*, Rodrigo A. Miranda, Cristiano Max Wrasse, Hisao Takahashi, Diego Barros, Fábio Egito, Geângelo de Matos Rosa and Antonio Hélder Rodrigues Sampaio

Earth, Planets and Space 2023, **75**:141 DOI: 10.1186/s40623-023-01892-7
Received: 31 March 2023, Accepted: 26 August 2023, Published: 15 September 2023

Abstract

Interaction between Equatorial Plasma Bubbles (EPBs) and midnight Brightness wave (MBW) was observed over Bom Jesus da Lapa (13.3° S, 43.5° W; Quasi-Dipole geomagnetic latitude of 14.1° S), using OI 630 nm all-sky images. On the night of December 22nd, 2019, an EPB was seen propagating eastward in its fossil stage until it interacted with an MBW. After the interaction, the west walls of EPBs generated secondary instabilities that can be associated with gradient drift instability (GDI) and/or Kelvin–Helmholtz instabilities (KHI). We suggest that the MBW contributed to generate a shear in the EPBs walls due to changes in the thermospheric dynamics, such as neutral wind in the F layer height. Furthermore, spectral analysis of the all-sky images suggests that GDI and/or KHI generated turbulence and helped to dissipate the EPBs.



Graphical abstract

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FULL PAPER **Open Access**

Space weather impacts on the ionosphere over the southern African mid-latitude region

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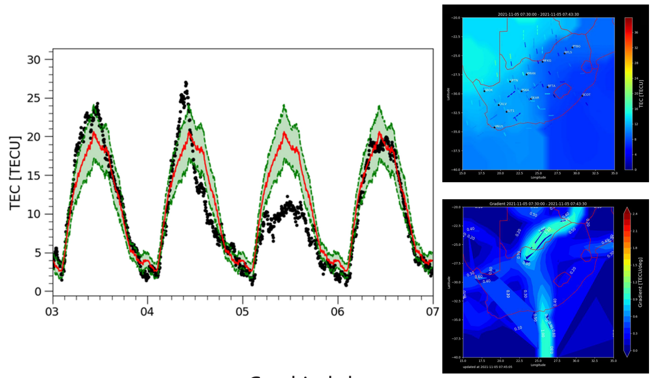
Earth, Planets and Space 2023, **75**:142 DOI: 10.1186/s40623-023-01894-5
Received: 22 May 2023, Accepted: 1 September 2023, Published: 19 September 2023

Abstract

The ionosphere suffers major perturbations during severe space weather events such as Coronal Mass Ejections (CMEs), solar flares, high-speed streams, and Corotating Interaction Regions (CIRs). The ionosphere can experience depletions or enhancements in Total Electron Content (TEC) during severe space weather conditions. The South African National Space Agency (SANSA) near-real-time (NRT) TEC maps were used to show the ionospheric variability during the geomagnetic storm of 3–8 Nov 2021 over the southern Africa mid-latitude region. The ionosonde TEC, NRT TEC, and the quiet-time AfriTEC model were compared during the 6-day period. A negative ionospheric response was observed during the main and recovery phases of the geomagnetic storm (4–5 Nov 2021). The changes to neutral composition O/N_2 was one of the physical processes attributed to the decrease in TEC over the mid-latitude region. The GPS TEC maps showed a very good agreement with ionosonde measurements and the AfriTEC model. A strong east–west TEC gradient was observed occurring between two ionosonde stations.

Keywords: Ionospheric storms, Geomagnetic storms, Ionosphere, Total electron content, TEC gradient



Graphical abstract

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FULL PAPER **Open Access**

Simultaneous observations of equatorial plasma bubbles with an all-sky airglow imager and a HF Doppler sounding system in Taiwan

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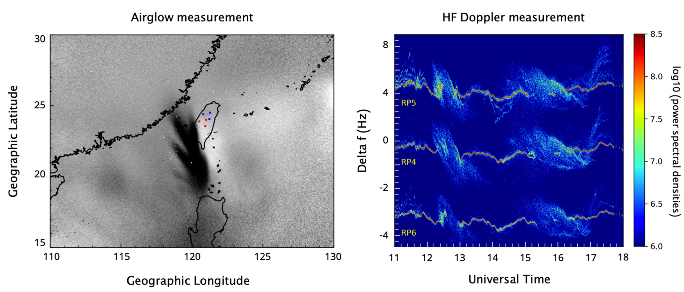
Earth, Planets and Space 2023, **75**:156 DOI: 10.1186/s40623-023-01908-2
Received: 9 May 2023, Accepted: 21 September 2023, Published: 10 October 2023

Abstract

High-Frequency Doppler (HFD) sounders at low-latitudes often detect characteristic oblique spreading Doppler traces in the spectrogram, known as Oblique Spread Structure (OSS). OSS has been expected to be generated by the dispersion of radio wave reflection due to equatorial plasma bubbles (EPBs). However, it has not yet been confirmed whether OSS is surely a manifestation of EPB by conducting simultaneous observations of EPB and OSS with different observational techniques. Additionally, it remains unclear what kinds of properties of EPB are reflected in the fine structure of OSS. In this study, we investigated three cases of OSSs and EPBs simultaneously observed by a HFD sounding system and an all-sky airglow imager in Taiwan. For the three cases presented here, the timing of OSS occurrence in the HFD data well coincided with that of the EPB appearance in the airglow data. The frequency shift of OSS is quantitatively explained assuming a radio wave reflection at 250–300 km altitudes. These results strongly indicate that OSS is formed by electron density variations at F-region altitudes accompanying EPB; thus, OSS is a manifestation of EPB in the HFD observations. Furthermore, it was suggested that the fine structure of OSS reflected the branching structure of EPB when the multiple branches of EPB reached the intermediate reflection point of the HFD observation. The detection of EPB occurrence and its fine structure using HFD observation enables monitoring of EPB regardless of weather conditions, which will contribute to monitoring the space weather impact of EPBs, for example, on GNSS navigation, in a wide area.

Keywords: Equatorial plasma bubbles, Radio propagation, Airglow observation



Graphical abstract

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FULL PAPER **Open Access**

Periodic oscillations of Doppler frequency excited by the traveling ionospheric disturbances associated with the Tonga eruption in 2022

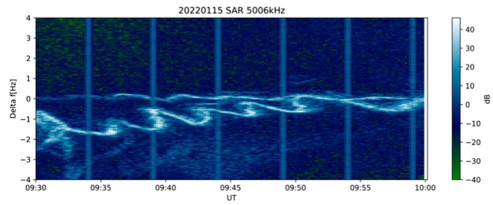
Hiroyuki Nakata*, Keisuke Hosokawa, Susumu Saito, Yuichi Otsuka and Ichiro Tomizawa

Earth, Planets and Space 2023, **75**:158 DOI: 10.1186/s40623-023-01914-4
Received: 31 May 2023, Accepted: 27 September 2023, Published: 10 October 2023

Abstract

The explosive eruption of the Hunga Tonga-Hunga Ha'apai volcano on 15 January 2022 generated atmospheric waves traveling around the Earth, which caused ionospheric disturbances on various spatio-temporal scales. A HF Doppler sounding system in Japan detected characteristic ionospheric disturbances showing periodic oscillations in the Doppler frequency with a period of ~ 4 min. In this study, such periodic oscillations were examined by comparing Doppler frequency data with Total Electron Content data obtained by Global Navigation Satellite System. The observed periodic oscillations in the Doppler frequency were characterized by a sawtooth or S-letter shaped variation, implying the passage of the traveling ionospheric disturbances through the reflection points of the HF Doppler sounding system. It was also found that the periodic oscillations occurred prior to the arrival of the tropospheric Lamb wave excited by the Tonga eruption. From the total electron content data, the traveling ionospheric disturbances causing the periodic oscillations were excited by the tropospheric Lamb waves at the conjugate point in the southern hemisphere, namely, the electric field perturbations due to the Lamb waves in the southern hemisphere mapped onto the sensing area of the HF Doppler sounding system in the northern hemisphere along the magnetic field lines. The periodic oscillations were observed only in the path between Chofu transmitter and Sarobetsu receiver, whose the radio propagation path is almost aligned in the north–south direction. This suggests that the traveling ionospheric disturbance has a structure elongating in the meridional direction. The variation in the Doppler frequency was reproduced by using a simple model of the propagation of the traveling ionospheric disturbances and the resultant motion of the reflection point. As a result, the vertical motion of the reflection point associated with the periodic oscillations was estimated to be about 1 km. It is known that 4-min period variations are sometimes observed in association with earthquakes, which is due to resonances of acoustic mode waves propagating between the ground and the lower ionosphere. Therefore, a similar resonance structure in the southern hemisphere is a plausible source of the traveling ionospheric disturbances detected in the northern hemisphere.

Keywords: HF Doppler (HFD) sounding, Total electron content (TEC), Traveling ionospheric disturbances (TIDs), Volcanic eruption, S-shaped variation



Graphical abstract

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FULL PAPER **Open Access**

Classification of the equatorial plasma bubbles using convolutional neural network and support vector machine techniques

Thananphat Thanakulketsarat, Pornchai Supnithi*, Lin Min Min Myint, Kornyanat Hozumi and Michi Nishioka

Earth, Planets and Space 2023, **75**:161 DOI: 10.1186/s40623-023-01903-7
Received: 2 June 2023, Accepted: 12 September 2023, Published: 16 October 2023

Abstract

Equatorial plasma bubble (EPB) is a phenomenon characterized by depletions in ionospheric plasma density being formed during post-sunset hours. The ionospheric irregularities can lead to disruptions in trans-ionospheric radio systems, navigation systems and satellite communications. Real-time detection and classification of EPBs are crucial for the space weather community. Since 2020, the Prachomklao radar station, a very high frequency (VHF) radar station, has been installed at Chumphon station (Geographic: 10.72° N, 99.73° E and Geomagnetic: 1.33° N) and started to produce radar images ever since. In this work, we propose two real-time plasma bubble detection systems based on support vector machine techniques. Two designs are made with the convolutional neural network (CNN) and singular value decomposition (SVD) used for feature extraction, the connected to the support vector machine (SVM) for EPB classification. The proposed models are trained using quick look (QL) plot images from the VHF radar system at the Chumphon station, Thailand, in 2017. The experimental results show that the combined CNN-SVM model, using the RBF kernel, achieves the highest accuracy of 93.08% while the model using the polynomial kernel achieved an accuracy of 92.14%. On the other hand, the combined SVD-SVM models yield the accuracies of 88.37% and 85.00% for RBF and polynomial kernels of SVM, respectively.

Keywords: Equatorial plasma bubble, Support vector machine, Convolutional neural network, Singular value decomposition

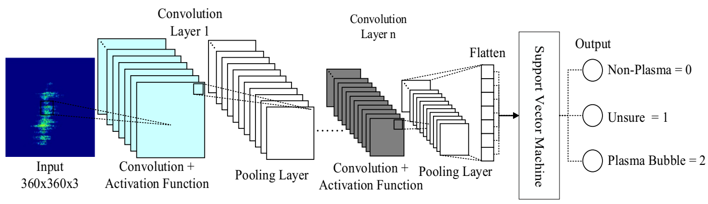

Fig. 7

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FULL PAPER **Open Access**

Giant ionospheric density hole near the 2022 Hunga-Tonga volcanic eruption: multi-point satellite observations

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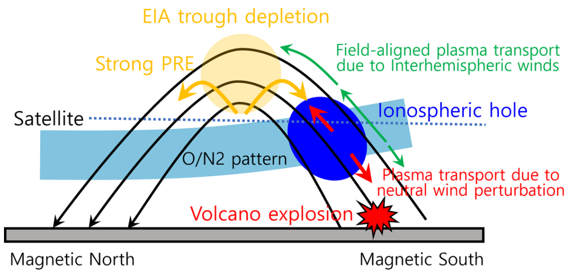
Earth, Planets and Space 2023, **75**:184 DOI: 10.1186/s40623-023-01933-1
Received: 31 March 2023, Accepted: 9 November 2023, Published: 8 December 2023

Abstract

A giant ionospheric hole was simultaneously detected in the in situ measurements of FORMOSAT-7/COSMIC-2 (F7/C2), Ionospheric Connection Explorer (ICON), Swarm missions, and ground-based total electron content (TEC) by global navigation satellite system receivers, and F7/C2 Global Ionosphere Specification (GIS) data near Tonga, following the explosive volcano eruption on 15 January 2022. The TEC maps displayed the huge depletions that developed near Tonga after the eruption and gradually evolved. The ICON IVM, F7/C2 IVM and Swarm-LP detected large depletions not only near Tonga, but also in the EIA trough region. The GIS observations clearly show the ionospheric hole that extends spatially near Tonga, especially strongly south/southward. The simultaneous observations showed that the ionosphere hole near Tonga combined with the EIA trough and finally evolved into a giant ionosphere hole around 07 UT. The ionospheric hole, which occurred at 05 UT near Tonga, extended over a wide area of 160°-200°E and 25°S-20°N and lasted for about 11 h. The F7/C2 and ICON satellites overpasses showed large ion density depletions by the hole at orbit altitudes, accompanied by enhancements in ion temperature and field-aligned and perpendicular ion drift. Such a long-lasting giant ionospheric hole by a seismic event has not been reported earlier, creating a unique ionospheric environment near Tonga after the eruption. The strong successive impulses by multiple volcano eruptions, together with O/N_2 decrease in the summer hemisphere, interhemispheric wind, and water vapor injection into high altitudes apparently yielded such a giant ionospheric hole, 4–6 times larger than that observed during the Tohoku earthquake.

Keywords: Ionospheric hole, EIA trough depletion, Plasma transport, F7/C2 IVM, ICON, F7/C2 GIS



Graphical abstract

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FULL PAPER **Open Access**

Assessing the potential of ionosonde for forecasting post-sunset equatorial spread F: an observational experiment in Southeast Asia

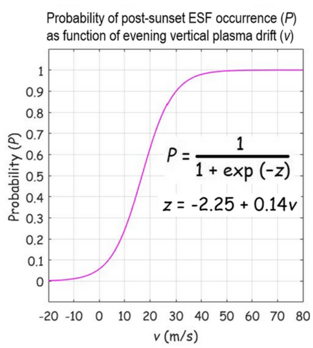
Prayitno Abadi, Umar Ali Ahmad*, Yuichi Otsuka, Punyawi Jamjareegulgarn, Alif Almahi, Septi Perwitasari, Slamet Supriadi, Wendi Harjupa and Reza Rendian Septiawan

Earth, Planets and Space 2023, **75**:185 DOI: 10.1186/s40623-023-01941-1
Received: 25 May 2023, Accepted: 1 December 2023, Published: 13 December 2023

Abstract

The occurrence of equatorial spread F (ESF) has the potential to detrimentally impact space-based technological systems. This study investigates the utility of ionosondes in forecasting the incidence of post-sunset ESF in the zonal direction, utilizing observational data obtained from four ionosondes located near the magnetic Equator in Southeast Asia. Data were collected during the equinox seasons (March–April and September–October) between 2003 and 2020. To establish a relationship between the probability of post-sunset ESF occurrence and the evening vertical plasma drift (v), a logistic regression model was employed. Post-sunset ESF occurrence is defined as the presence of ESF during the time window between 19:00 and 21:00 LT, while v is derived from the average time derivative of virtual heights during the interval from 18:30 to 19:00 LT. Results indicate that the probability of post-sunset ESF occurrence approaches zero, signifying that ESF is unlikely to develop when v is negative. Conversely, when v exceeds 30 m/s, the probability of post-sunset ESF occurrence surpasses 0.87, indicating that ESF occurs almost invariably. The likelihood of post-sunset ESF occurrence reaches 1 when v equals or exceeds 40 m/s. Utilizing this model, the study determined that a single ionosonde positioned at the Equator can effectively forecast the incidence of post-sunset ESF up to a longitudinal distance of 30° from its location. The accuracy of ionosondes in predicting post-sunset ESF occurrence above their respective locations is approximately 0.80, with a 10% decrease in accuracy when forecasting ESF occurrence at longitudinal distances of 30°. In conclusion, this study enhances our understanding of the link between the evening vertical plasma drift and the manifestation of post-sunset ESF by leveraging ionosonde data. Furthermore, it provides valuable insights into the recommended coverage range of ionosondes for predicting post-sunset ESF occurrence in the zonal direction, which can be employed to fortify regional space weather services.

Keywords: Equatorial spread F, Ionosonde, Logistic regression, Space weather services, Observational study



Graphical abstract

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FULL PAPER Open Access

The impact of the Hunga Tonga–Hunga Ha'apai volcanic eruption on the Peruvian atmosphere: from the sea surface to the ionosphere

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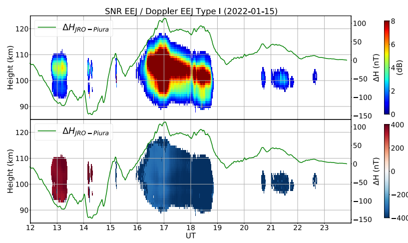
Earth, Planets and Space 2024, **76**:79 DOI: 10.1186/s40623-024-02022-7
Received: 31 May 2023, Accepted: 30 April 2024, Published: 28 May 2024

Abstract

The eruption of the Hunga Tonga Hunga Ha'apai volcano on 15 January 2022 significantly impacted the lower and upper atmosphere globally. Using multi-instrument observations, we described disturbances from the sea surface to the ionosphere associated with atmospheric waves generated by the volcanic eruption. Perturbations were detected in atmospheric pressure, horizontal magnetic field, equatorial electrojet (EEJ), ionospheric plasma drifts, total electron content (TEC), mesospheric and lower thermospheric (MLT) neutral winds, and ionospheric virtual height measured at low magnetic latitudes in the western South American sector (mainly in Peru). The eastward Lamb wave propagation was observed at the Jicamarca Radio Observatory on the day of the eruption at 13:50 UT and on its way back from the antipodal point (westward) on the next day at 07:05 UT. Perturbations in the horizontal component of the magnetic field (indicative of EEJ variations) were detected between 12:00 and 22:00 UT. During the same period, GNSS-TEC measurements of traveling ionospheric disturbances (TIDs) coincided approximately with the arrival time of Lamb and tsunami waves. On the other hand, a large westward variation of MLT winds occurred near 18:00 UT over Peru. However, MLT perturbations due to possible westward waves from the antipode have not been identified. In addition, daytime vertical plasma drifts showed an unusual downward behavior between 12:00 and 16:00 UT, followed by an upward enhancement between 16:00 and 19:00 UT. Untypical daytime eastward zonal plasma drifts were observed when westward drifts were expected. Variations in the EEJ are highly correlated with perturbations in the vertical plasma drift exhibiting a counter-equatorial electrojet (CEEJ) between 12:00 and 16:00 UT. These observations of plasma drifts and EEJ are, so far, the only ground-based radar measurements of these parameters in the western South American region after the eruption. We attributed the ion drift and EEJ perturbations to large-scale thermospheric wind variations produced by the eruption, which altered the dynamo electric field in the Hall and Pedersen regions. These types of multiple and simultaneous observations can contribute to advancing our understanding of the ionospheric processes associated with natural hazard events and the interaction with lower atmospheric layers.

Keywords: Volcanic eruption, Hunga Tonga–Hunga Ha'apai volcano, Tonga, Equatorial ionosphere, Tonga eruption effects, Peruvian ionosphere, Barometer, Magnetometer, Coherent radar, Perturbation waves, Equatorial electrojet, 150-km echoes, Plasma drifts, Ionosonde, GNSS-TEC



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EXPRESS LETTER Open Access

Impact of strong and weak stratospheric polar vortices on geomagnetic semidiurnal solar and lunar tides

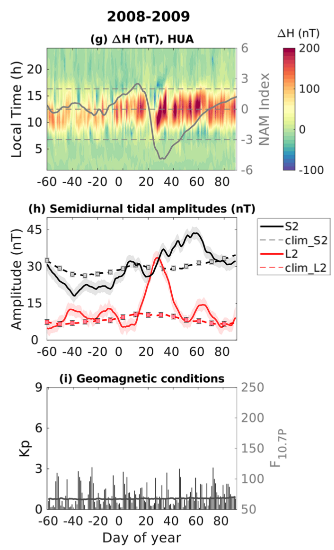
Sunil Kumar, Tarique A. Siddiqui*, Claudia Stolle, Nicholas M. Pedatella and Duggirala Pallamraju

Earth, Planets and Space 2023, **75**:52 DOI: 10.1186/s40623-023-01810-x
Received: 20 January 2023, Accepted: 21 March 2023, Published: 10 April 2023

Abstract

The impact of strong and weak stratospheric polar vortices on geomagnetic semidiurnal solar and lunar tides is investigated during Northern Hemisphere (NH) winters using ground-based magnetic field observations at the Huancayo (12.05° S, 284.67° E; magnetic latitude: 0.6° S) equatorial observatory. We analyze the periods between December 15 and March 1 for 34 NH winters between 1980 and 2020 and find that the response of semidiurnal solar and lunar tides as seen in geomagnetic field depends on the strength of the stratospheric polar vortex. During weak polar vortex events, geomagnetic semidiurnal solar and lunar tidal amplitudes show an average enhancement by ~ 25% and ~ 50%, respectively, which is consistent with the known results during sudden stratospheric warmings. When the stratospheric polar vortex is strong, geomagnetic semidiurnal solar and lunar tidal amplitudes decline on an average by ~ 15% and ~ 25%, respectively, during weak polar vortex events. Our results also reveal that the response of the geomagnetic semidiurnal solar tidal variations to strong and weak polar vortex conditions is delayed by approximately 10 days while the response of geomagnetic semidiurnal lunar tidal variations do not show a time delay. These results provide observational evidence that along with weak polar vortices in the Northern Hemisphere, the strong stratospheric polar vortices also have pronounced effects on the equatorial ionosphere.

Keywords: Strong polar vortex, Weak polar vortex, Stratospheric Sudden Warming, Solar semidiurnal tide, Lunar semidiurnal tide, Equatorial electrojet, Northern Annular Mode, Ionosphere, MLT



Graphical abstract

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EXPRESS LETTER **Open Access**

Climatology of mesosphere and lower thermosphere diurnal tides over Jicamarca (12°S, 77°W): observations and simulations

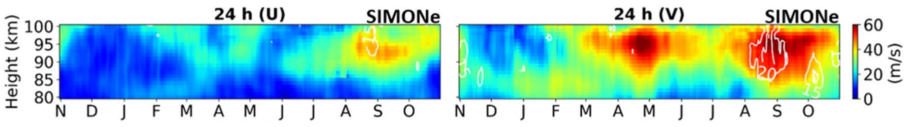
Jose Suclupe*, Jorge L. Chau, J. Federico Conte, Marco Milla, N. M. Pedatella and K. Kuyeng

Earth, Planets and Space 2023, **75**:186 DOI: 10.1186/s40623-023-01935-z
Received: 30 May 2023, Accepted: 9 November 2023, Published: 14 December 2023

Abstract

This work shows a 3-year climatology of the horizontal components of the solar diurnal tide, obtained from wind measurements made by a multistatic specular meteor radar (SIMONe) located in Jicamarca, Peru (12°S, 77°W). Our observations show that the meridional component is more intense than the zonal component, and that it exhibits its maxima shifted with respect to the equinox times (i.e., the largest peak occurs in August–September, and the second one in April–May). The zonal component only shows a clear maximum in August–September. This observational climatology is compared to a climatology obtained with the Whole Atmosphere Community Climate Model with thermosphere and ionosphere extension (WACCM-X). Average comparisons indicate that the model amplitudes are 50% smaller than the observed ones. The WACCM-X results are also used in combination with observed altitude profiles of the tidal phases to understand the relative contributions of migrating and non-migrating components. Based on this, we infer that the migrating diurnal tide (DW1) dominates in general, but that from June until September (November until July) the DE3 (DW2) may have a significant contribution to the zonal (meridional) component. Finally, applying wavelet analysis to the complex amplitude of the total diurnal tide, modulating periods between 5 and 80 days are observed in the SIMONe measurements and the WACCM-X model. These modulations might be associated to planetary waves and intraseasonal oscillations in the lower tropical atmosphere.

Keywords: Climatology, Diurnal tide, Low latitude, Tidal modulation, Meteor radar, GCM



Graphical abstract

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A Grant-in-Aid for Publication of Scientific Research Results (24HP2006) from Japan Society for the Promotion of Science is used for printing.

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Cover image: Equatorial Atmosphere Radar, Indonesia (Research Institute for Sustainable Humanosphere, Kyoto University)