MAPPING OF 2D SPORADIC E STRUCTURE USING HIGH DENSITY GPS RECEIVERS IN SOUTH EAST ASIA

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DEDICATION

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ABSTRACT

Sporadic E (Es) is a cloud of intensified electron concentration that developed at the ionospheric E layer that might interrupt the pathway of radio communication. Despite the abundance of studies on Es have been carried out, equatorial Es was hardly highlighted. This investigation was executed with the intent of observing the Es events near equatorial South East Asia (SEA) region. Using well-established methods such as ionosonde and Equatorial Atmosphere Radar that set up at Kototabang, Indonesia, the E layer was simultaneously analysed to identify Es. Then, data from dense SEA Global Positioning System (GPS) network for 23rd June 2011 with measured critical frequency of Es (foEs) and virtual height of Es (hEs) provided by ionosonde dataset and Range-Time-Intensity plot were used to plot a detrended GPS Total Electron Contecnt (TEC) maps thus producing a 2-D equatorial Es map. From the TEC maps, the presence of Es frontal structure was identified with 50-500 km length and 10-30 km width and that is composed of smaller scale irregularities. Also, Es structure moves in the North-South direction, perpendicular with elongation azimuth. The findings disclose the morphology and dynamics of equatorial Es and initiate a geographically broad-scale Es observation using GPS TEC.

ABSTRAK

Sporadik E (Es) ialah satu kumpulan awan yang mempunyai ketumpatan elektron yang sangat tinggi yang terhasil di lapisan E ionosfera dan mampu mengganggu laluan komunikasi radio. Walaupun terdapat banyak kajian mengenai Es yang telah dilakukan, Es khatulistiwa adalah sangat kurang difokuskan dengan lebih mendalam. Kajian ini telah dilaksanakan untuk mengkaji peristiwa Es yang berlaku di sekitar garisan khatulistiwa Asia Tenggara. Teknik pemerhatian *ionosonde* dan *Equatorial Atmosphere Radar* (EAR) telah digunakan pada masa yang sama untuk mengenalpasti kehadiran Es di lapisan E. Maklumat foEs dan hEs yang didapati daripada *ionosonde* dan plot *range time intensity* (RTI) bertarikh 23 Jun 2011 kemudiannya digunakan untuk memplot peta GPS jumlah kandungan elektron (TEC) *detrended* 2-D Es khatulistiwa mengikut peristiwa berlakunya Es menggunakan data daripada rangkaian GPS yang padat. Berdasarkan peta-peta TEC, kehadiran stuktur hadapan dapat dikenalpasti, berkepanjangan 50-500 km dan berkelebaran 10-30 km. Struktur tersebut juga terdiri daripada gangguan yang lebih kecil dan bergerak pada arah Utara-Selatan, berserenjang dengan azimut pemanjangan. Hasil kajian membolehkan morfologi dan dinamika Es khatulistiwa dapat dikenalpasti dan memberikan pendedahan untuk melaksanakan pemerhatian Es berskala lebar dengan menggunakan GPS TEC.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AFSCN	-	Air Force Satellite Control Network
CORS	-	Continuously Operating Reference System
EAR	-	Equatorial Atmosphere Radar
EEJ	-	Equatorial Electrojet
Es	-	Sporadic E
GPS	-	Global Positioning System
GSI	-	Geographical Survey Institute
IGRF	-	International Geomagnetic Reference Field
IGS	-	International GNSS Service
IGS	-	International Ground Station
IPP	-	Ionospheric Piercing Point
JUPEM	-	The Department of Survey and Mapping Malaysia
LAPAN	-	National Institute for Aeronautics and Space
LOS	-	Line-Of-Sight
MF	-	Medium Frequency
MyRTKnet	-	Malaysia Real-Time Kinematics GNSS Network
NGA	-	National Geospatial-Intelligence Agency
RISH	-	Research Institute for Sustainable Humanosphere
SEALION	-	South East Asia Low Latitude Ionosphere Observation Network
SOPAC	-	Scripps Orbit and Permanent Array Center
SPS	-	Standard Positioning Service
STEC	-	Slant TEC
SuGAr	-	Sumatera GPS Array
TEC	-	Total Electron Content
UV	-	Ultra Voilet
VHF	-	Very High Frequency
VTEC	-	Vertical TEC

LIST OF SYMBOLS

ε_0	-	Permeability of Free Space, $8.854\times10^{-12}\ C^2/Nm^2$
θ	-	Elevation Angle
χ	-	Receiver's Zenith Angle
e	-	Electron Charge, $-1.602\times10^{-19}C$
f	-	Signal Frequency
f_p	-	Phase Frequency
f_1	-	GPS L1 Carrier Frequency
f_2	-	GPS L2 Carrier Frequency
h_m	-	Height of Ionosphere
n	-	Refractive Index
m_e	-	Electron Mass, $9.109\times10^{-31}kg$
N_e	-	Electron Density
R_E	-	Radius of the Earth

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Ever wonder how any wireless electronics operate? How does the information interchange between two distant devices occur within the thin air and not perceive with naked eyes? For instance, firing up the television by just pressing a button from its remote control, watching the news from the television or even some other Internet-connected devices while the filming is taking place in the studio. Owing to the advancement and modernisation of radio waves, sending command between gadgets without material contact is achievable.

Kellermann (2014) in an article suggested that the availability of radio-frequency spectrum for purposes such as communication, position and location also entertainment broadcasting might be most impactful technical development to the society. A simple at-home device such as television has evolved significantly from transmitting analogue to now digitally encoded signal besides travelling across the atmosphere to now reflected off of satellites to the users (Fisher, Fink, Fisher & Noll, 2020)

On top of leisure and pleasure, the operation of radio waves also contributes tremendously in military tasks. In Military Balance 2020 written by The International Institute for Strategic Studies (IISS), it is stated various application of this particular range of electromagnetic spectrum waves for instance hunting and identifying a target wherever it might be, interchange of situational information and instruction as well as navigation and timing via satellite signal.

Transmission of radio waves may be via one or more modes namely free space propagation, ground wave propagation, ionospheric propagation, tropospheric propagation and scatter propagation (Holker, 1993). For more than 50 years, the ionosphere has been studied extensively due to its significant influence in aiding long-distance radio communication (Dabas, 2000) that Goodman (2005) has categories radio systems depending on the effect of the ionosphere on them. Category 1 associates with systems that include the ionosphere as a part of its structure and category 2 associates with systems that found the ionosphere is a bit of an inconvenience.

From the name itself, the ionosphere is made up of ions and free electrons induced by solar radiation, which varied along with the altitude (Poole, 1999). This layer acts like a mirror in the sky that reflects radio signals off, taking the responsibility for over-the-horizon travelling of the wave. The ions and free electrons in the ionosphere are highly affected by any changes in near-Earth magnetic and/or electric field. The disruption created within ionospheric layers or at outer space will lead to unpredicted scattering of radio signal thus not entirely delivered to the receiver end.

For example, Australian radio listeners reported in 2016 that the usual radio station they tuned in was interfered by signals from the other side of the country. A website for radio industry broadcast professionals, radioinfo, recorded this event and turn to several experts in hope to find an explanation. It is said that the very distant radio reception due to an ionospheric irregularity known as Sporadic E (Es), which commonly occurred during summertime. Arras (2000) stated that Es is an intensified electron density comprises within a thin layer observed at the lower of ionospheric E region.

Based on the report mentioned, the issue might not be as severe as it seems if there is any irregularity presents in the ionosphere since the radio broadcast is to fulfill hobby reason. However, if any aircraft or military radio communication were to be intercepted by an ionospheric disturbance, the mishap might cost the security of a nation and even innocent lives. For example, the National Oceanic and Atmospheric Association (NOAA) reported in 2003 the occurrence of one of the most intense outbreaks of solar activity that disturb communications between aircraft and air traffic control centre also lead to Federal Aviation Administration suggesting airlines to fly at lower altitudes when travelling beyond 35-degree latitude north and south.

Recently, Pinholster (2019) reported that a group of space and atmospheric researchers, led by Dr Barjatya, plan to launch two rockets from a northeast island of Papua New Guinea, utilizing the fund granted by NASA. It is believed that the rockets together with other observation instruments will benefit fellow enthusiast to understand space weather and the Earth's atmosphere particularly the ionospheric E and F-layers. The activities within these layers are believed might influence systems operating by radio waves.

On top of that, Friedlander (2019) stated that two NASA rockets are already launched from Marshall Island to gather data in the ionosphere. The project's lead investigator said that the aim is to measure, understand and eventually anticipate a kind of space weather that is common at low magnetic latitudes. Scientists suggested that the layer close to the equator impair radio and radar signals more than the rest.

1.2 Problem Statement

Many characteristics of Es has been brought to light as a result of immense amount of interest and effort has been put in investigating this daytime ionospheric irregularity. Though, there is a huge disproportion between the number of studies taken place in the midlatitude region and the equatorial region. Had there been investigations near equatorial area, the common countries would be India and Brazil. Only recently, observations in South East Asia (SEA) started to be taken place. Therefore, this study will contribute to the growth of Es investigation over SEA region in the future. On top of that, researchers had proposed a different mechanism of development of Es near equatorial region than that in midlatitude region, and therefore called for extended studies on equatorial Es.

Moreover, investigation on Es generally conducted by operating only one method at a time. Side by side comparison as done by Resende et al. (2018) or Lee et al. (2000) is not yet a common practice. Each of the observation method is limited by spectral and spatial coverage. Ionosonde is operating at widest frequency range, between 2 - 30 MHz, (high spectral coverage) but the observation is limited to one point (small spatial coverage). Global Positioning System (GPS) observations at L-band frequencies between 1200 and 1500 MHz (small spectral) covers 3000 km (largest spatial coverage) in zonal (East-West) direction, however no altitude information is provided. Equatorial Atmosphere Radar (EAR) working at 47 MHz (small spectral) with 300 km in zonal direction (medium spatial coverage). Simultaneous observation between ionosonde, EAR and GPS would enhance the spectral and spatial resolution of Es. It is expected that these observations will aid in visualizing the evolution of Es layer with time from various observation that might lead to understanding the mechanism of the development of Es layer.

1.3 Research Objectives

The objectives of the research are:

(a) To observe equatorial Es using ionosonde, EAR and GPS.

(b) To construct two dimensional (2D) structure of Es with high spatial and temporal resolution.

1.4 Research Scope

The data analysed for this study is restricted to a selection of date and time with the presence of Es. From a dataset containing parameters obtained from the ionogram, any Es event was first identified. Then, the critical frequency of the Es (foEs) is extracted and arranged with the day with the highest foEs to be prioritised.

The EAR data for the selected date with relatively high foEs is retrieved from its source. However, due to unavoidable reason, there are some days that the EAR is not operating and no observation was made. Thus, dates without EAR plot is eliminated from the list due to data unavailability. The chosen event used in this study will be from the remaining dates that have both ionogram and EAR data, as data from GPS is attainable throughout any year.

Also, since the ionosonde and EAR are stationed near the equatorial, the Es observation produced is naturally an occurrence of equatorial Es. GPS data plotted is focused around 10ºN and 10ºS to ensure any Es event is indeed within the equatorial region.

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