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Comparison of E layer critical frequency over the Thai station Chumphon with IRI

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Abstract

In this research, as a part of working towards improving the IRI over magnetic equatorial region, the critical frequency of E layer in the ionosphere (*fo*E) derived from the ionogram at Chumphon station (10.72°N, 99.37°E), Thailand, during 2005–2008 is analyzed. The Chumphon station is located in the magnetic equatorial region at the magnetic latitude of 3.22°N. The seasonal variation of the *fo*E measurements is compared to the IRI *fo*E predictions with the optional input in the sunspot number (Rz12) and the solar radio noise flux (F10.7). For a declining phase of the solar cycle 23 during the year 2005–2008, the study shows that the IRI *fo*E prediction is similar to the *fo*E observation during the period of 2005–2008. The maximum differences between the IRI *fo*E prediction and *fo*E observation are about 500 kHz during daytime period of 2007.

Keywords: E layer; Critical frequency of E layer; Equatorial ionosphere; IRI-2012 model; Sunspot number; Solar flux index

1. Introduction

The critical frequency of E layer (*fo*E) is an important ionospheric parameter which directly affects the radio wave propagation through the ionosphere. It changes dramatically with the time of the day, month, season and variation in solar activity. Previous works reported the ionosphere responds to the solar extreme ultraviolet (EUV) irradiance. The solar EUV ionizes the neutrals and thus forms the ionosphere which happens to be correlated to the solar radio noise flux index (F10.7). Some researchers investigated the daily variability of critical frequency of E layer in the ionosphere (Kouris and Muggleton, 1973a,b; Rastogi and Mullen, 1981; Yamamoto et al., 1991, 1992). Abe et al. (2013) examined the variability of *foE* in the equatorial ionosphere with solar activity within the equatorial ionospheric anomaly region. The study revealed that the *fo*E increases as the solar intensity increases. While *fo*E increases with solar activity as expected, they find that the relative variability of *fo*E decreases with increasing solar activity.

*fo*E measurements in the equatorial region assist in the development of ionospheric models such as the International Reference Ionosphere (IRI) (Bilitza, 2001; Bilitza and Reinisch, 2008; Bilitza et al., 2011). Some studies in the literature report the measured *fo*E data obtained from different techniques at various locations (Kouris and Muggleton, 1973a,b; Yamamoto et al., 1991, 1992; Schlegel and Haldoupis, 1994).

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There were also many local and regional ionospheric models related to the E-layer critical frequency. Kouris and Muggleton (1973a, 1973b) used *fo*E data over a period of 11 years of many ionosonde stations all over the world to obtain the dependence of *fo*E on latitude, season, solar flux and local time. Zolesi et al. (1993) developed a regional ionospheric model by using Fourier analysis on the monthly median values of ionospheric characteristics including *foE* from seven ionospheric stations in Europe. McKinnel and Poole (2003) established a local *E*-layer critical frequency model over Grahamstown, South Africa, by using neural networks. However, there were a few regional models related to Chumphon station, Thailand, at the equatorial region where is influenced by the equatorial ionization anomaly (EIA) phenomenon. In an effort to improve the IRI model, the comparison of the *fo*E measurement and the IRI-2012 *fo*E prediction is made in this work.

Despite the series of studies on the dependence of the ionospheric characteristics on the solar activity, a few attention is given to the E-region of the equatorial ionosphere especially in South East Asia location. The monitoring Chumphon station is a part of the South East Asia Low Latitude Ionosphere Observation Network (SEALION) (Maruyama et al., 2007). SEALION aims to observe, monitor and forecast the ionospheric variation in the Asia Pacific region near the magnetic equator. It is a joint project among the following institutions and countries: National Institute of Information and Communications Technology (NICT), Japan, King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand, Chiang Mai University (CMU), Thailand, National Institute of Aeronautics and Space (LAPAN), Indonesia, Hanoi Institute of Geophysics (HIG), Vietnamese Academy of Science and Technology, Vietnam, Center for Space Science and Applied Research (CSSAR), Chinese Academy of Sciences, China, and Kyoto University, Japan.

2. Observation methodology

The critical frequency of the ionosphere is a function of many variables: local time; geographical coordinate; season; magnetic and solar activity. Good knowledge of this parameter is greatly essential for ionospheric researchers and users. The physical nature and dependence of the ionospheric characteristics on solar activity still remains the subject of study and investigation. The purpose of this research paper is to study the variation of *fo*E at equatorial latitude station, Chumphon, Thailand, and to compare the *fo*E measurement obtained from the ionograms with the *fo*E prediction extracted from IRI2012 model. The period of study is divided into 4 seasons; September equinox, December solstice, March equinox, and June solstice.

2.1. foE measurement data

The *fo*E measurements are made at Chumphon campus, KMITL, located at the geographic longitude 99.37°E and latitude 10.72°N, Thailand. The magnetic latitude for Chumphon station is 3.22°N, close to the equatorial magnetic latitude. The *fo*E values are measured from the frequency-modulated continuous wave (FMCW) ionosonde with transmitting power at 20 watts and the repletion period of 5 min. The ionosonde continuously transmits radio waves from 2 to 30 MHz and receives echoes from the ionosphere to provide the ionogram profile at every 15 min. The ionogram data are automatically uploaded to KMITL in Bangkok to be analyzed. The observation parameters are summarized in Saito and Maruyama (2006). The seasonal variations of *fo*E are measured for 2005–2008. Sporadic E occurs frequently in the low latitude region. We removed such erroneous data by using the median value of *fo*E.

2.2. Rz12. and F10.7 data

The data of the sunspot number (Rz12) and the solar radio noise flux (F10.7) are from the Space Weather Prediction Center (SWPC). SWPC is one of the National Weather Service which is a component of the National Oceanic and Atmospheric Administration (NOAA). NOAA is an Operating Unit of the U.S. Department of Commerce. The daily F10.7 index and the 81-day average F10.7 index are entered into the IRI model. The data can be accessed at http://legacy-www.swpc.noaa.gov/ftpdir/warehouse/.

2.3. IRI foE prediction data

The International Reference Ionosphere (IRI) project was initiated by the Committee on Space Research (COSPAR) and by the International Union of Radio Science (URSI) in the late sixties (Bilitza and Reinisch, 2008). With the objective of establishing an international standard for the specification of ionospheric parameters based on all available worldwide data from ground-based stations as well as satellite observations, the IRI model is continually upgraded as new data and new modeling approaches become available and, consequently, this process has resulted in several major milestone editions of IRI (Rawer et al., 1978a,b, 1981; Bilitza, 1990, 2001; Bilitza and Rawer, 1996; Bilitza and Reinisch, 2008; Bilitza et al., 2011) progressing from a set of tables for typical conditions, to a global model for all phases of the solar cycle. More information about the IRI project including the information on the IRI Newsletter and the IRI electronic mailer can be found on the IRI homepage at http://www.irimodel.org/.

In the CCIR model for *fo*E (CCIR, 1973) the critical frequency at the peak of the E-layer is given as (Kouris and Muggleton, 1973a; Kouris and Muggleton, 1973b)

$$foE^4 = A \bullet B \bullet C \bullet D \quad \text{(MHz)} \tag{1}$$