Near Real-time Equatorial Plasma Bubble Monitoring System using GNSS at the Low Latitude Region in ASEAN

N.Tongkasem (1), L.M.M. Myint* (1), P. Supnithi(1), K. Hozumi(2), D. Lakanchanh(3), and T. Nhem(4)

*** Presenter email:** linminmin.my@kmitl.ac.th

URSI GASS 2023
August 19(Sat)–26(Sat), 2023 SAPPORO, JAPAN

Introduction

- Monitor EPB occurrences using daily ionospheric total electron content (TEC) and rate of TEC change index (ROTI) map and keograms,
- Develop a near real-time EPB monitoring system using Global Navigation Satellite System (GNSS) data from the receiver stations in Thailand as well as the stations in Lao and Cambodia.
- Generate (every 15 minutes) 2D-maps (latitude and longitude) of TEC, ROTI covering the low latitude region from latitudes of N 0° from N 25°, and the longitudes from E 95° to E 110°.
- Detect the occurrence of EPB from the generated 2D-maps using image processing of AI in future.

Methods

TEC calculation

Ionospheric delay can be measured from **TEC**

$$d_{iono} = \frac{40.3}{f^2} TEC \quad (1)$$

TEC can be calculated from **pseudorange**, which recorded from **code or carrier phase measurement**.

1 Code pseudorange

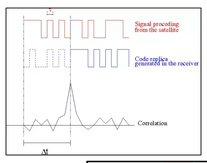


Fig. 1. The pseudorange is calculated from the delay time of the code signal correlation

$$P_1 = \rho + \frac{d_{iono}}{f_1^2} + c\left(b_{P1}^r + b_{P1}^s\right) + \varepsilon_{P1} \quad (2)$$

$$P_2 = \rho + \frac{d_{iono}}{f_2^2} + c\left(b_{P2}^r + b_{P2}^s\right) + \varepsilon_{P2} \quad (4)$$

(4)-(2) $TEC_P = K(P_2 - P_1) + Hardware\_delay + noise$

2 Carrier phase pseudorange

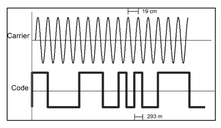


Fig. 2. The pseudorange is calculated from the carrier phase tacking

$$L_1 = \rho - \frac{d_{iono}}{f_1^2} + \lambda_1 n_1 + \varepsilon_{L1} \quad (3) \quad f_1 = 1.57542\ GHz$$

$$L_2 = \rho - \frac{d_{iono}}{f_2^2} + \lambda_2 n_2 + \varepsilon_{L2} \quad (5) \quad f_2 = 1.2276\ GHz$$

(3)-(5) $TEC_l = K(L_1 - L_2) + ambiguity + noise$

Parameters

d_{iono}	Ionospheric delay	$[s]$
TEC	The amount of electron density between the satellite and the receiver, expressed in TECu (1 TECu = 10^16 electrons/m2).	
ρ	real distance	$[m]$
b^r	receiver hardware delay	$[s]$
b^s	satellite hardware delay	$[s]$
c	light speed	$[m/s]$
$P_{1,2}$	recorded code pseudorange	$[m]$
$L_{1,2}$	recorded carrier-phase pseudorange	$[m]$
n	integer ambiguity	
λ	phase	$[m]$
ε	noise and multipath	$[m]$

$K = \frac{10^{-16}}{40.3}\left(\frac{f_1^2 f_2^2}{f_1^2 - f_2^2}\right) = 9.5196\ [m^{-1}TECu]$

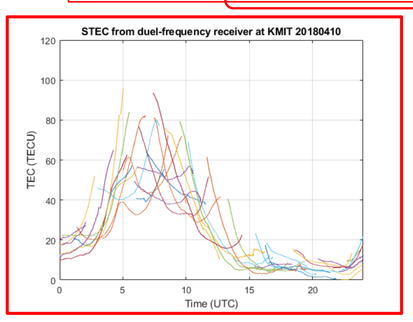


Figure. The observed TEC on 10/04/2018 at KMIT station.

Remove: Hardware delay, ambiguity and noise

$(STEC)$

Slant Total Electron Content

ROTI calculation

the slant differential TEC or rate of TEC, ROT in (6) is determined by calculating the change of slant TEC between consecutive intervals time 1 minute.

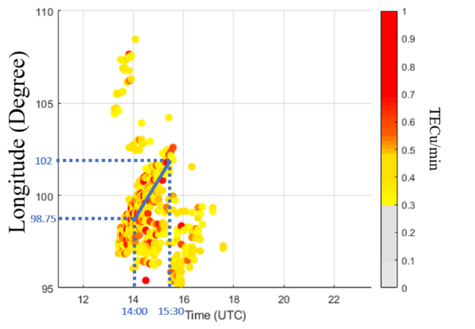
$$ROT_{r,k}^s = \frac{sTEC_{r,k}^s - sTEC_{r,k-1}^s}{(t_k - t_{k-1})} \quad (6)$$

The ROTI in unit of TECu/min is computed from the standard deviation of ROT

$$ROTI_{r,k}^s = \sqrt{\frac{\sum_{n=0}^{N-1}\left(ROT_{r,(k-n)}^s - ROT_{r,k}^s\right)^2}{N}} \quad (7)$$

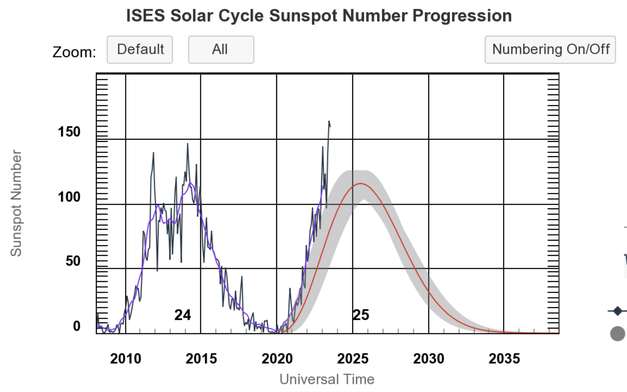
EPB speed estimation

The direction and speed of the EPBs can be estimated using the zonal drift velocities of the EPBs shape of ROTI keogram.



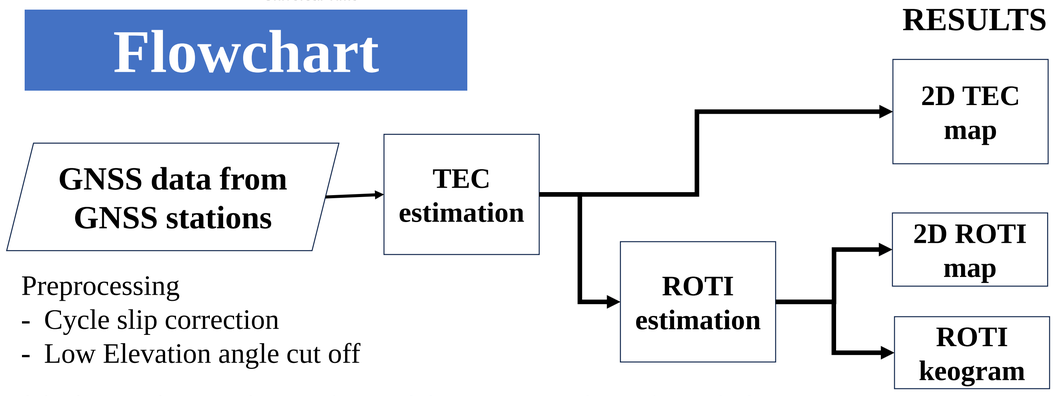
Solar 25

[space weather prediction center, NOAA]



The ascending phase of the Solar Cycle 25 are higher than the predicted sunspot number value (SSN), and higher than the peak of SSN in Solar Cycle 24.

Flowchart

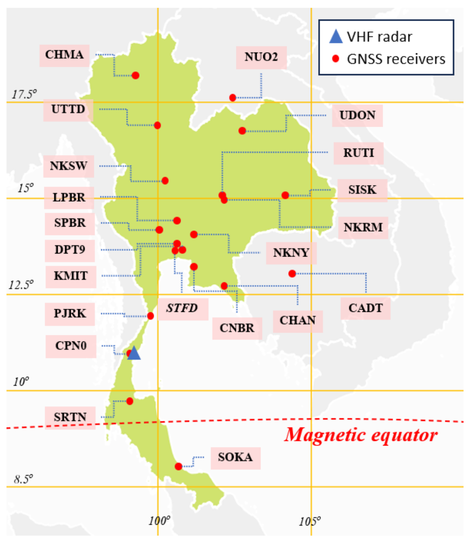


Publish on the Website: http://iono-gnss.kmitl.ac.th/

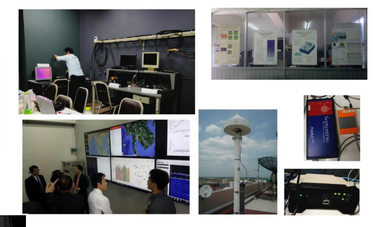
Data sources and Results

Data source

20 GNSS stations on the Thailand region and nearby



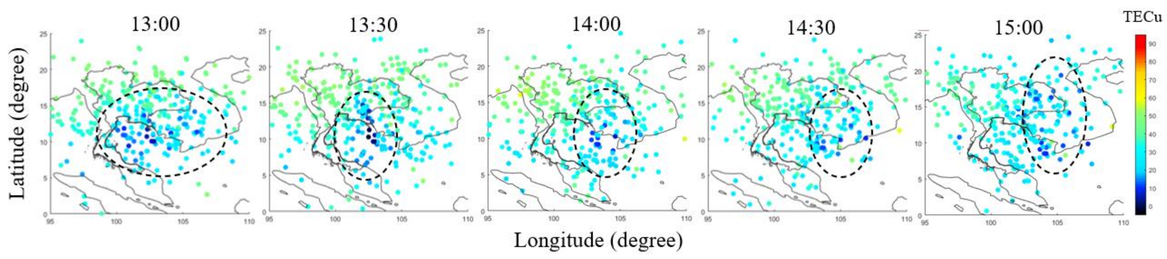
King Mongkut institute of Technology Ladkrabang (KMITL)



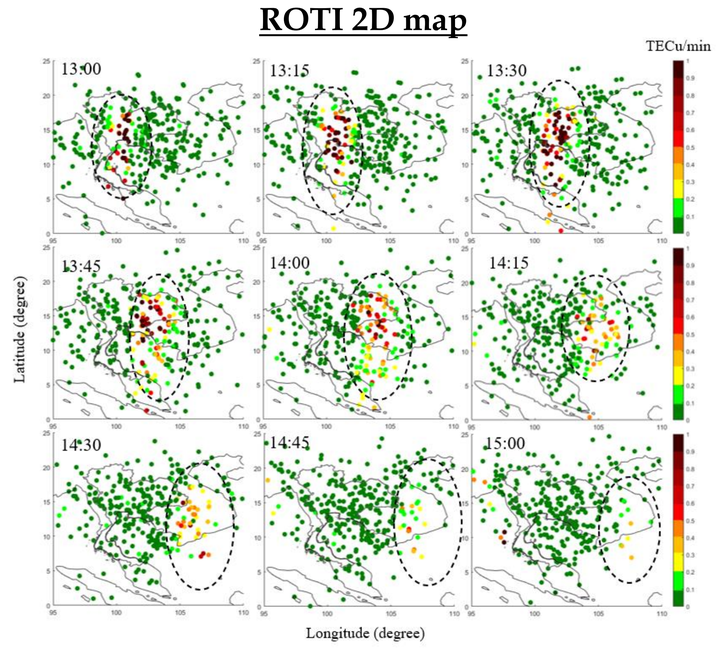
Cambodia Academy of Digital Technology (CADT)

University of Laos (NUO2)

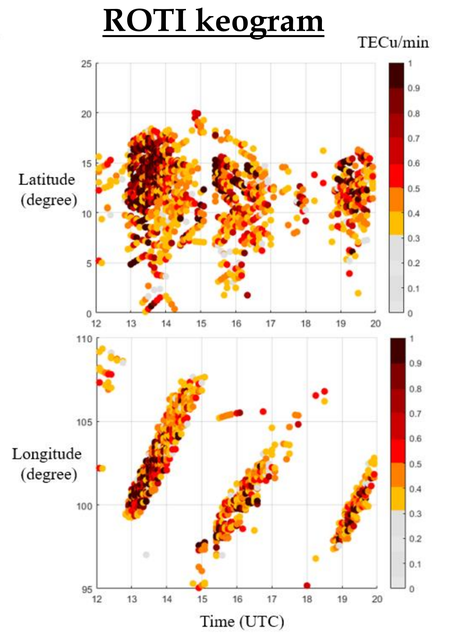
TEC map



ROTI 2D map

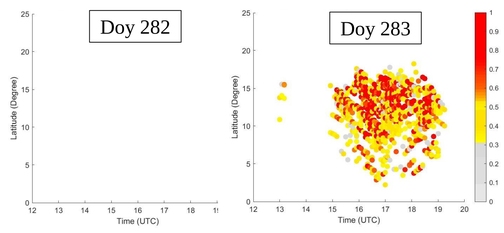


ROTI keogram

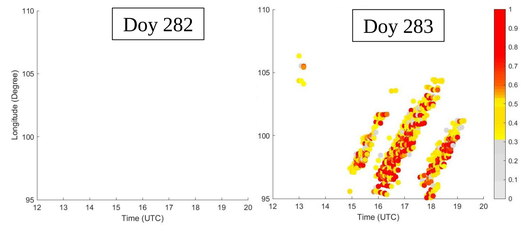


Quiet vs Disturb

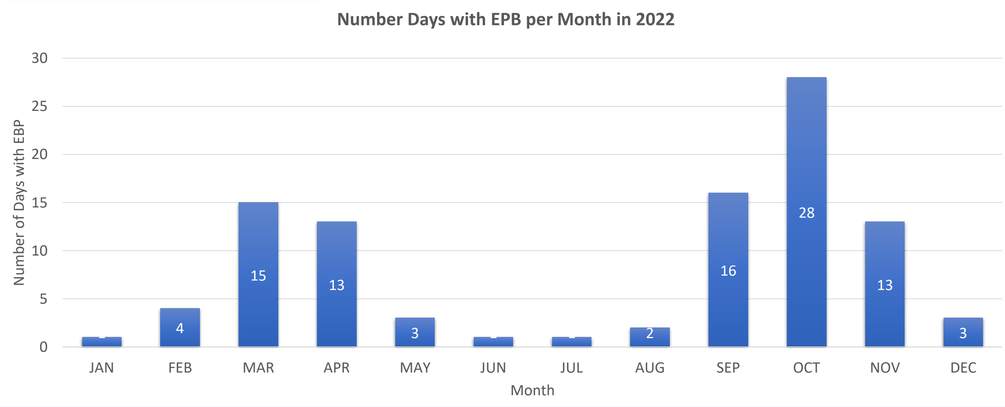
ROTI **latitude** keogram



ROTI **longitude** keogram



EPB Statistics in 2022



Conclusions

- In this study, we examine the spatial and temporal changes of EPBs using the spatial ROTI map, latitudinal/longitudinal keogram plots developed from the GNSS receiver network in ASEAN's northern hemisphere low latitudes.
- According to the results, the location of the EPB can be detected by the spatial ROTI maps and their spatial-temporal variation is monitored using the keogram plots for forecasting their occurrence and movement.

(1) School of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
(2) National Institute of Information and Communications Technology, Koganei, Tokyo, 184-8795, JAPAN
(3) Faculty of Engineering, National University of Laos, Lao PDR
(4) Institute of Digital Research and Innovation, Cambodia Academy of Digital Technology, 12252, Cambodia

Acknowledgement

The ASEAN IVO (http://www.nict.go.jp/en/asean_ivo/ index.html) project, [GNSS and Ionospheric Data Products for Disaster Prevention and Aviation in Magnetic Low- Latitude Regions (Phase II)], was also involved in the production of the contents of this work and financially supported by NICT (http://www.nict.go.jp/en/index.html).