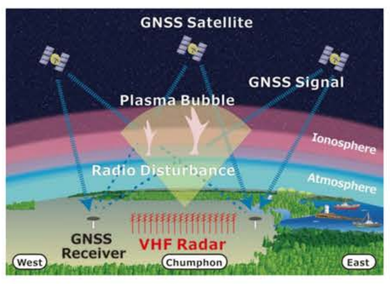
Equatorial plasma bubble detection and analysis using 2-D ROTI map and VHF radar images during the upcoming solar maximum

P. Supnithi[1], L.M.M. Myint[1], N.Tongkasem[1], T.Thanakulketsarat[1] and M. Nishioka[2]
[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

Introduction

- Equatorial plasma bubbles (EPB) refers to ionospheric irregularity which often occurs after sunset and may last until early morning [Kelly et al. 2014]
- Both local condition and global condition (geomagnetic storm) may cause EPB [Abdu et al. 2000, Otsuka et al. 2018]
- Various sensors can be used to study the EPBs such as GNSS receivers, VHF radar, ionosonde, etc.

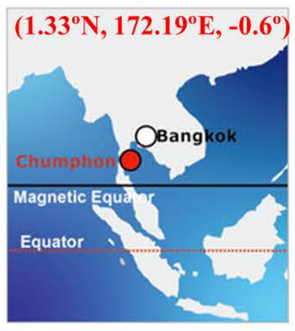


Objectives

- To compare the ionospheric irregularities as detected by rate of TEC change index (ROTI) maps, and VHF radar images
- To analyze the EPB occurrence statistics
- To analyze the ionospheric irregularities during the recent May 2024 solar storms

Data and Methodology

Chumphon VHF radar station



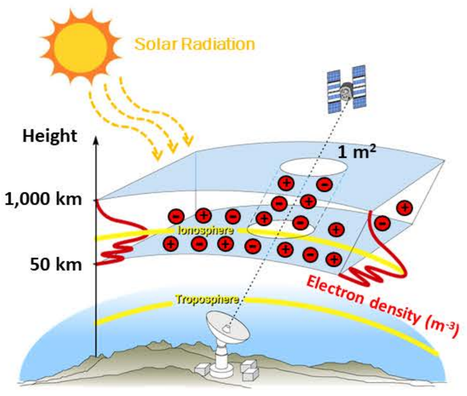
Ionosonde station

Item	Description
Frequency	39.65 MHz (25 kHz BW)
$P_{transmitter}$	1.1 kW per module for 20 kW peak power
Antenna	18 Yagi-antennas, 130-m separation, 9 beams ±60° (azimuth), off-zenith pointing angle = 8.3°
Range	1000 km (Latitudinal coverage up to ~20ºN)
Beam cycle	Scanning in geomagnetic E-W direction, the range of zenith angle 0º to 28º

Item	Description
System	FM/CW with pseudo-random Tx/Rx switching
Frequency	2-30 MHz
$P_{transmitter}$	20 W (Max.), 10 W (Avg.)
Antenna	Delta antenna (tower height 27 m)
Sweep rate	100 KHz/sec
Sweep Period	5 min

GNSS receiver

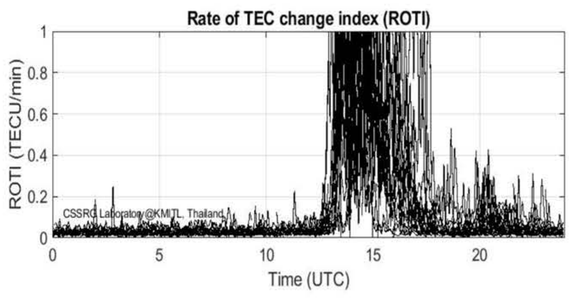
Slant TEC = slant total electron conteny (el/m^2)



Rate of TEC Change Index (ROTI)

$$ROTI = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(ROT(i) - ROT)^2}$$

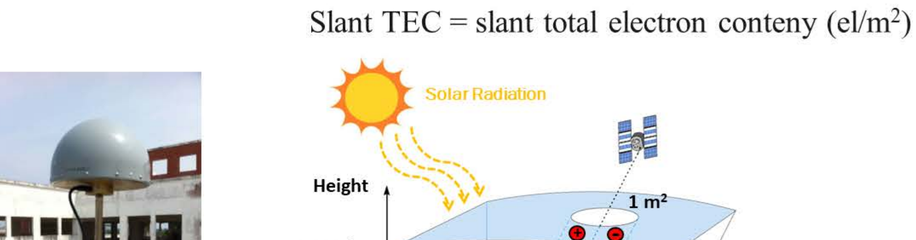
$$ROT(i) = STEC(i+1) - STEC(i)$$



Results and Discussions

March 18th , 2020 – Max. Kp = 3

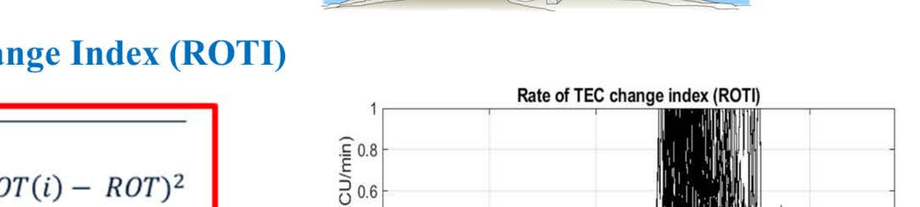
ROTI map



* **Fd3** as an overhead beam

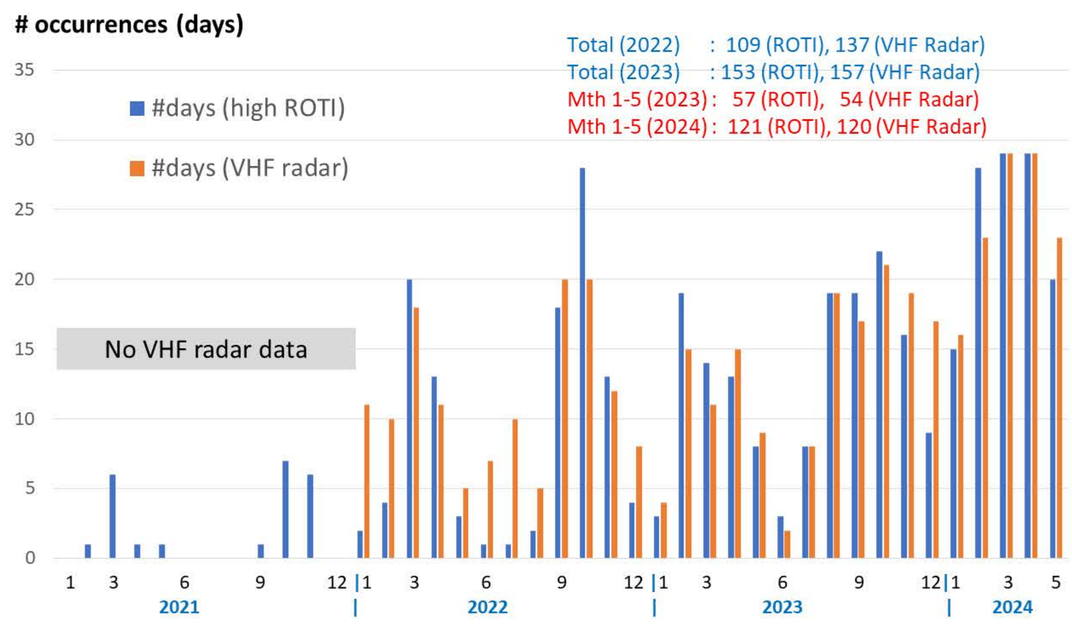
VHF Radar

Ionogram (QL)



The graph shows the detected signals and images from ROTI maps (only the IPPs (ionospheric piercing points) with high ROTI are shown), VHF radar images (FD3 beams), and ionograms (Quick look) on March 18th, 2020. The irregularities are seen from around 13:30 hr to 15:00 hr. The EPB tends to move from West to East. From VHF radar images, the irregualrities are detected from around 250 km and reached up to 750 km. The ionograms also showed the spread F traces from 250 km up to around 400 km.

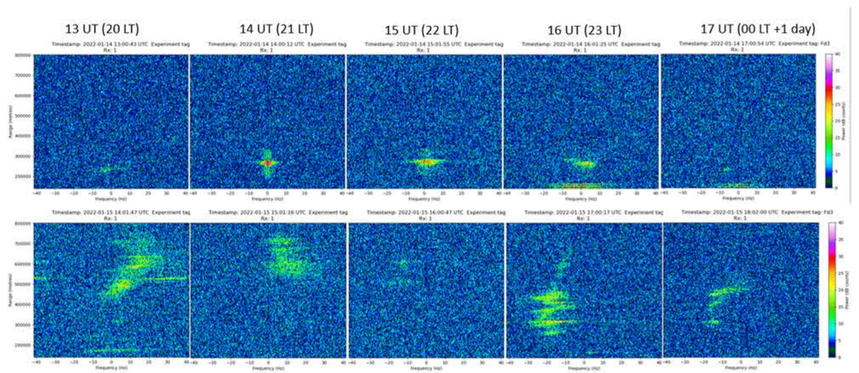
Month statistics of ionospheric irregularities (2021-2024)



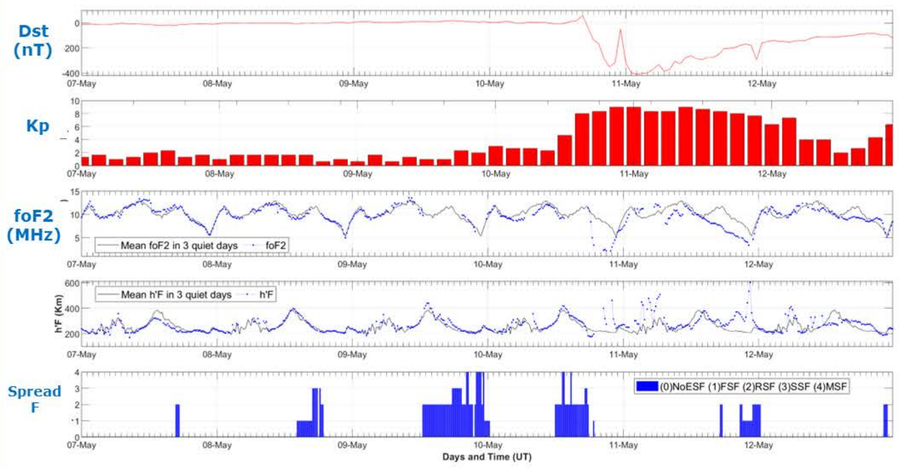
The graph shows the monthly statistics of ionospheric irregularities as analyzed from number of days with high ROTI (ROTI > 0.5) and VHF radar images
2021 - Lack of VHF radar data
2022-23 - High occurrences of ionospheric irregularities during equinocial months
2024 - Higher occurrences than 2022-23

14/02/2022
ROTI - No
VHF Radar - Yes

15/02/2022
ROTI - Yes
VHF Radar - Yes

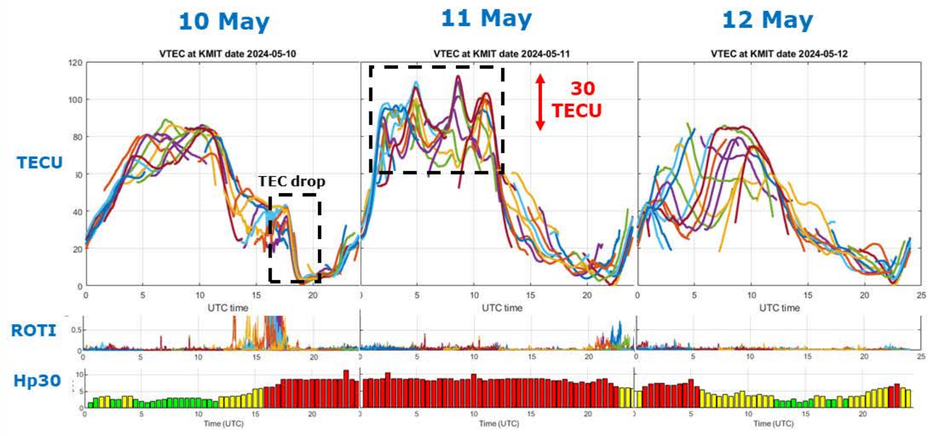


May 10-14, 2024 storms

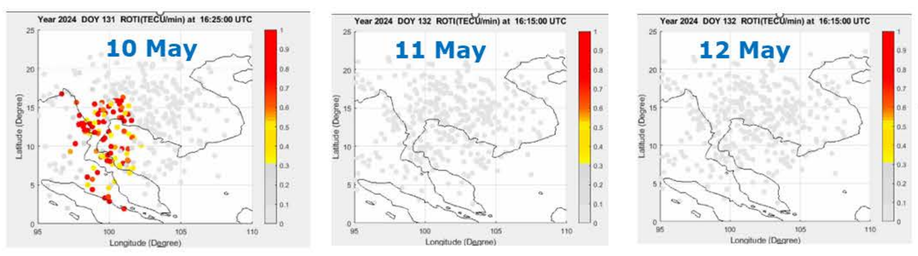


Dip in foF2 on 10-12 May

Some spread F events on 9-10, 12 May
No spread F event on 11 May



10 May – nighttime TEC fluctuation
11 May – daytime TEC fluctuation
12 May – None



10 May – high ROTI as seen on ROTI map
11 May – quiet
12 May –

Conclusions

- We find increasing ionospheric irregularities from 2021 to 2024
- ROTI map, VHF radar images, ionograms agree on the ionospheric irregularity occurrences
- During the recent May 2024 storms, TEC fluctuations and foF2 depressions are found.

Acknowledgement

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