AOSWA 2023
Asia-Oceania Space Weather Alliance
MALAYSIA

NICT | KMITL King Mongkut's Institute of Technology Ladkrabang | THAI GNSS AND SPACE WEATHER THAI GNSS AND SPACE WEATHER INFORMATION DATA CENTER | ASEAN IVO

Statistics of the Equatorial Plasma Bubbles in February, March and May 2023 at CPN station, Thailand, and NUO station, Laos

By **Phimmasone Thammavongsy** (1), Pornchai Supnithi (2), Lin Min Min Myint (3), Donekeo Larkanchanh (4), Phosy Phanthongsy (5), Phouthong Southisombath (6), and Michi Nishioka (7)

(1,4,5,6) Electronic and Telecommunications Engineering, National University of Laos, Vientiane 4242, Lao P.D.R

(2,3) King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, THAILAND

(7) National Institute of Communication and Telecommunications, Koganei, Tokyo, 184-8795, JAPAN

National University of Laos

Outline

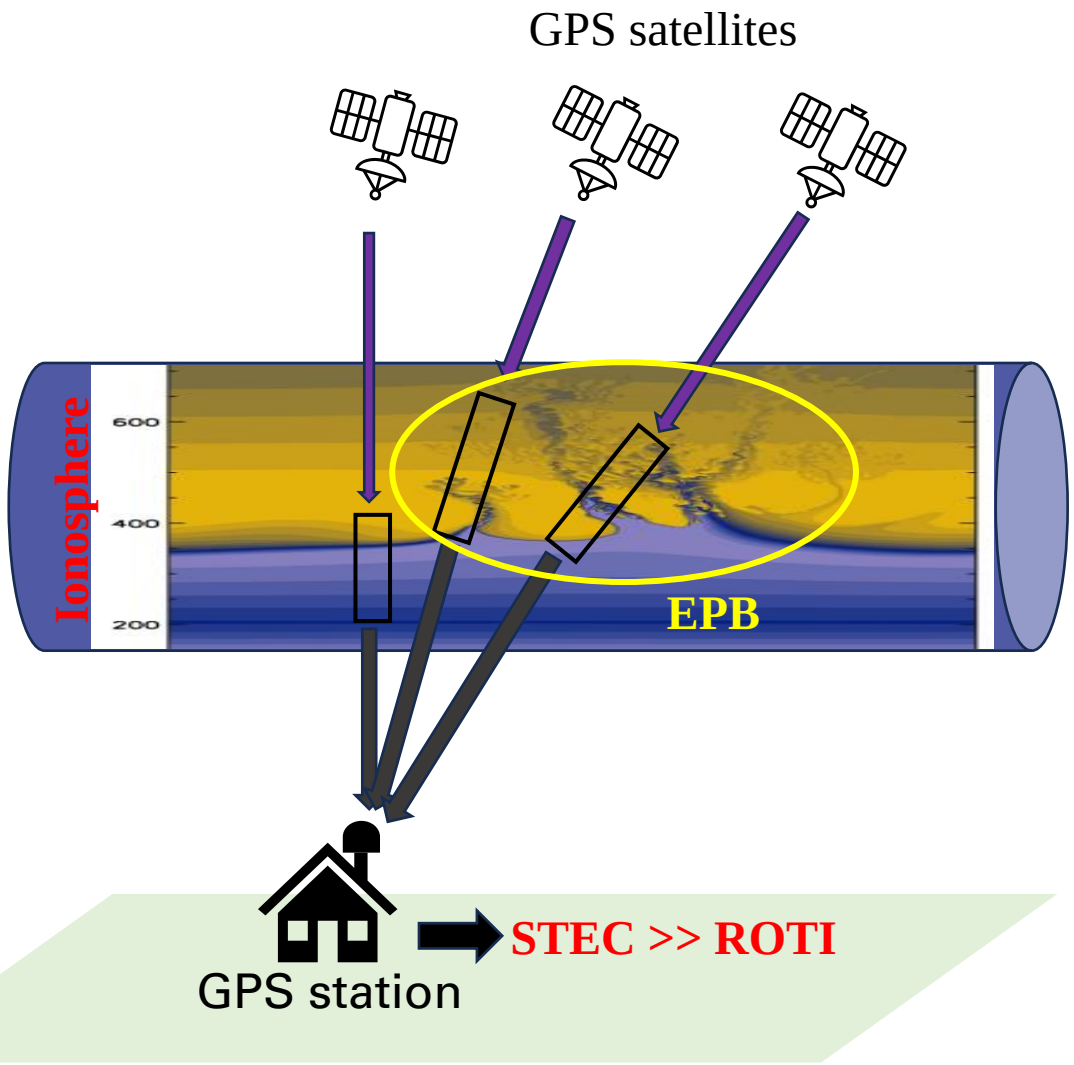
- Problem statements
- Related works
- Objectives
- Background theory
- Experimental setups
- Results
- Conclusions

Problem statements

- Bottom-side ionospheric irregularity occurs on time scale from few seconds to hours and length scales from centimeter to tens of kilometers (Woodman & La Hoz, 1976)

- Growth ionospheric irregularity to Plasma Bubbles can affect a radio wave signal
  - Scintillation of GNSS signals (Aarons, 1977)
  - Loss-of-lock in GNSS signals (Spogli, et al., 2016)
  - Signal outage of LF/HF/UHF communication (Kelly, et al., 2014)

ESF effects on radio wave propagation



Aarons, J., 1977. Equatorial Scintillation: A Review. IEEE Transactions on Antennas and Propagation, 25(5), pp. 729-736.
Kelly, M., Comberiate, J., Miller, E. & Paxton, L., 2014. Progress toward forecasting of space weather effects on UHF SATCOM after Operation Anaconda. Space Weather, 12(10), pp. 601-611.
Spogli, L. et al., 2016. Formation of Ionospheric Irregularities over Southeast Asia during the 2015 St. Patrick's Day Storm. Journal of Geophysical Research, 121(12), pp. 12211-12233.

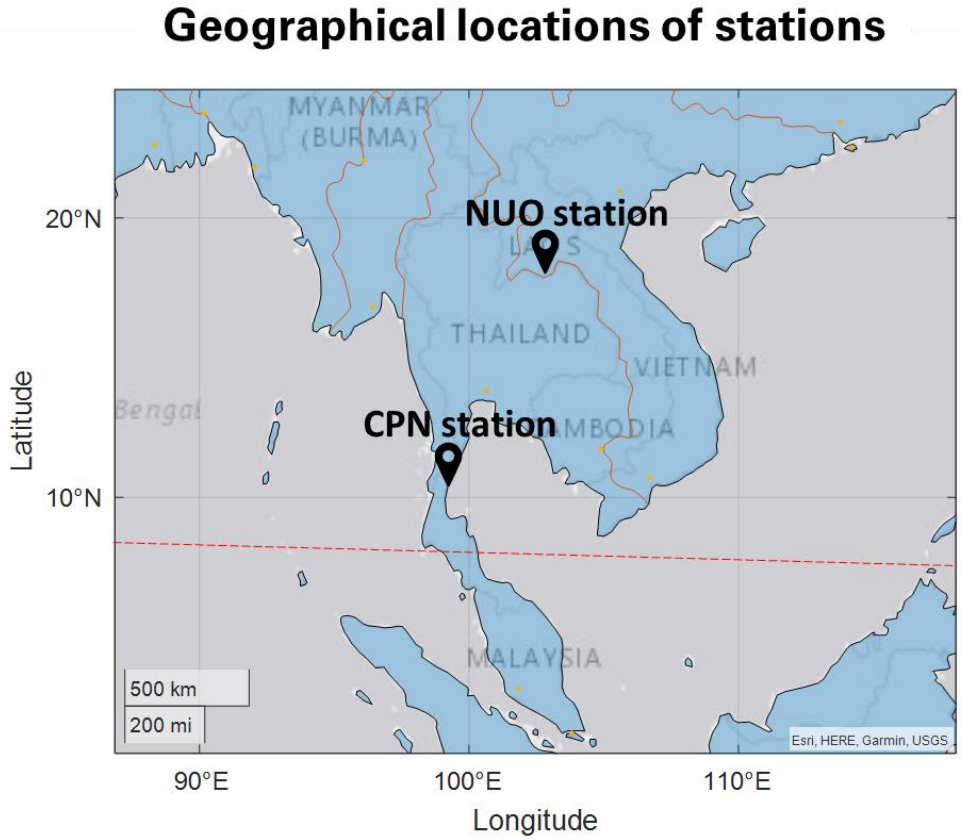
Related works

Studies of the EBPs in Southeast Asia regions

- **(D.N. Thanh et al., 2021):** Ionospheric irregularities at the equator-ward EIA are observed more often than at the magnetic equatorial regions

- **(A. Olla et al., 2019):** EPB occurrence rate and latitudinal extension over southward stations in Asia are positively related to strong PRE

- **(M. Pezzopane et al., 2013):** Ionospheric irregularities at CPN station, Thailand are reported with lower events than other longitude sectors



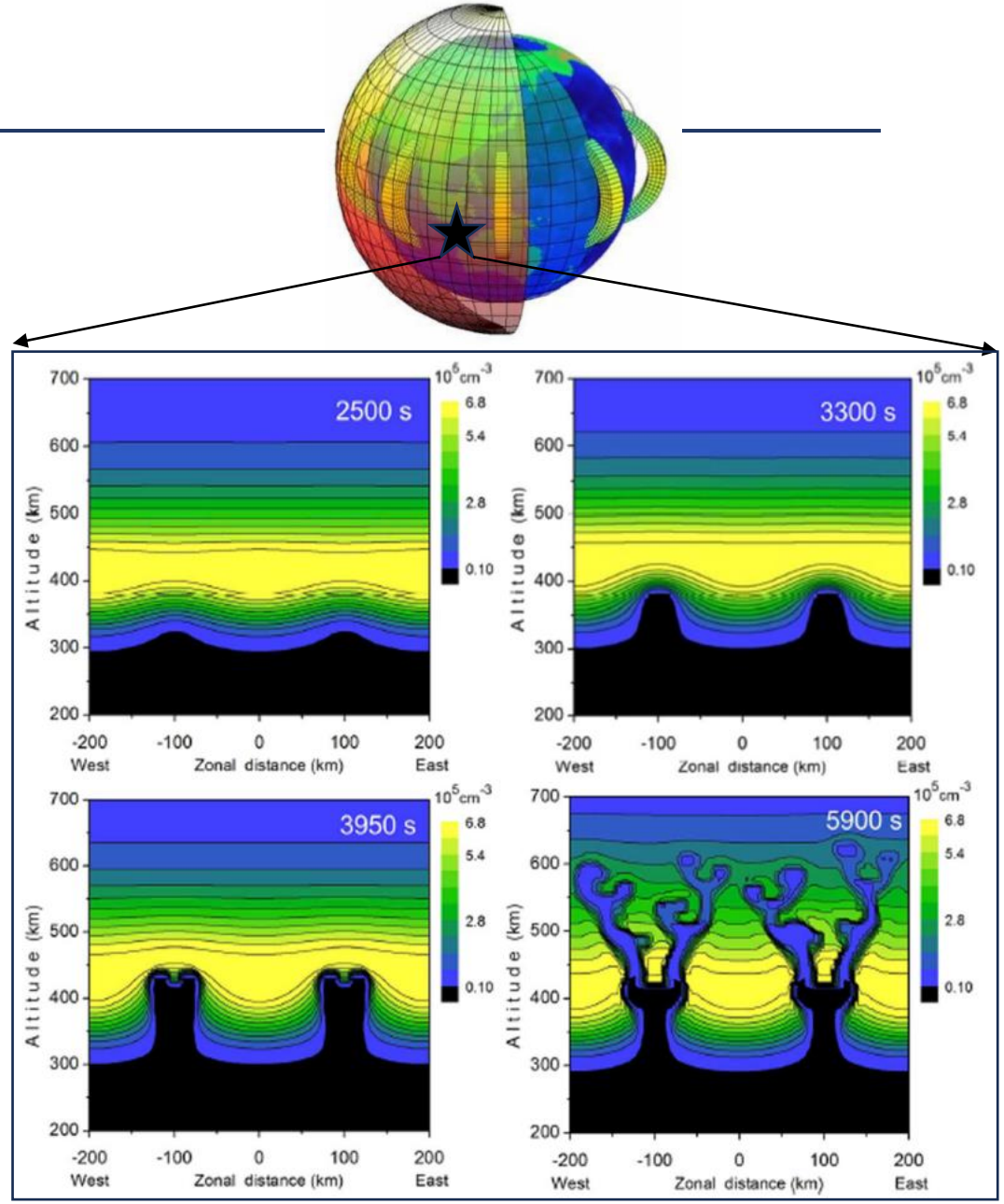
- The study of the EPBs between CPN station and NUO station had not been studied

Objectives

- To observe statistical characteristics of the Equatorial Plasma bubbles (EPBs) on the function of local time and month between CPN station, Thailand and NUO station, Laos

Background theory

- The plasmasphere instability process is interpreted by a theory of a **Rayleigh-Taylor instability** (Sultan, 1996)
- 4-time simulated result **of Equatorial Plasma Bubble** (EPB) structure (Carrasco et al, 2020)
- **Trends to move eastward** and sometime, its movement direction is reserved
- **Scale sizes** from tens of centimeters to 100s of kilometers (Booker et al., 1997)
- The EBPs in **day-to-day variability** are not fully understood



(Carraso et al., 2020)

Sultan, P., 1996. Linear theory and modeling of the Rayleigh-Taylor instability leading to the occurrence of equatorial spread F. Journal of Geophysical Research, 101(A12), pp. 26875-26891.
Carrasco AJ, Pimenta AA, Wrasse CM, Batista IS, Takahashi H (2020) Why do equatorial plasma bubbles bifurcate? J Geophys Res Space Phys 125(11):1–11.

Background theory

- **TEC**: **T**otal **E**lectron **C**ontent in an area (electrons/m^2)
- **S**TEC: Electron density along the **slant** path
- **R**OTI: **Rate** of TEC change index
- **ROTI index** is widely used to indicate the ionospheric irregularities such as the EPBs

$$STEC = \int_S N_e ds \qquad (el/m^2)$$

N_e : Electron density (electrons/m^2)

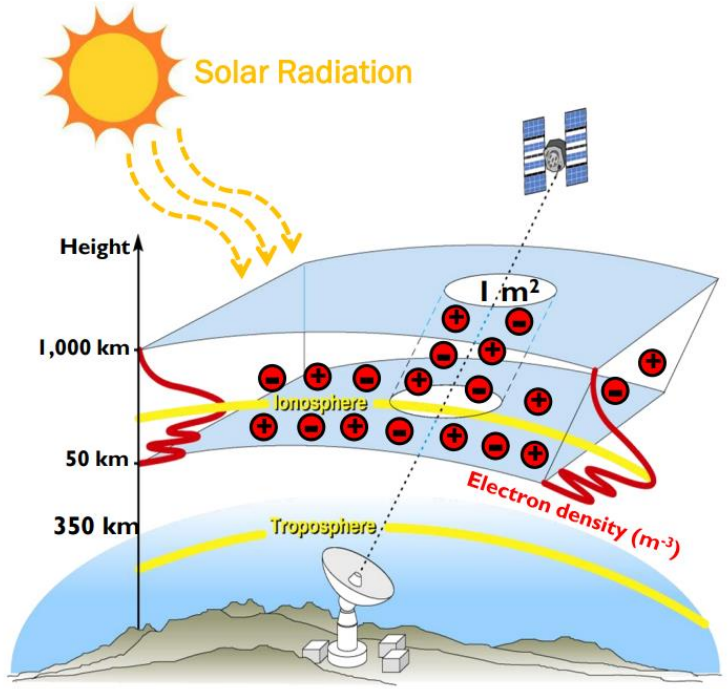
S : Distance along the slant path)

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

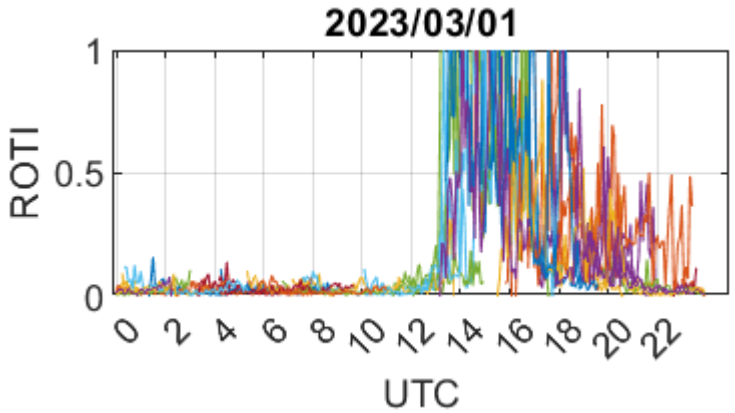
$$ROTI = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(ROT(i) - \overline{ROT})^2}$$

i: index of time

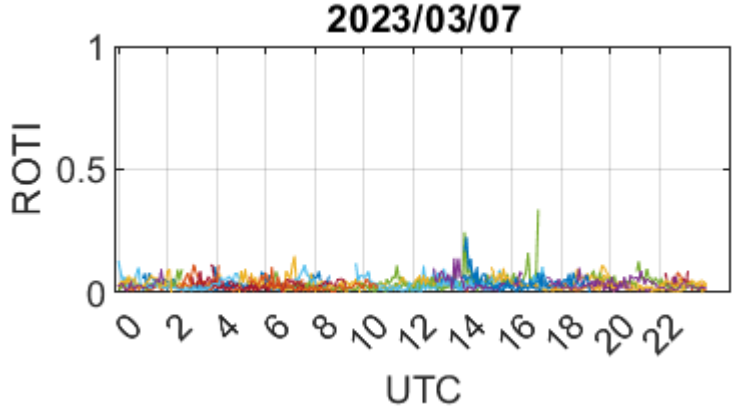
N: Window time (minute)



(P. Supnithi, 2022)



Day with ***EPB presence***

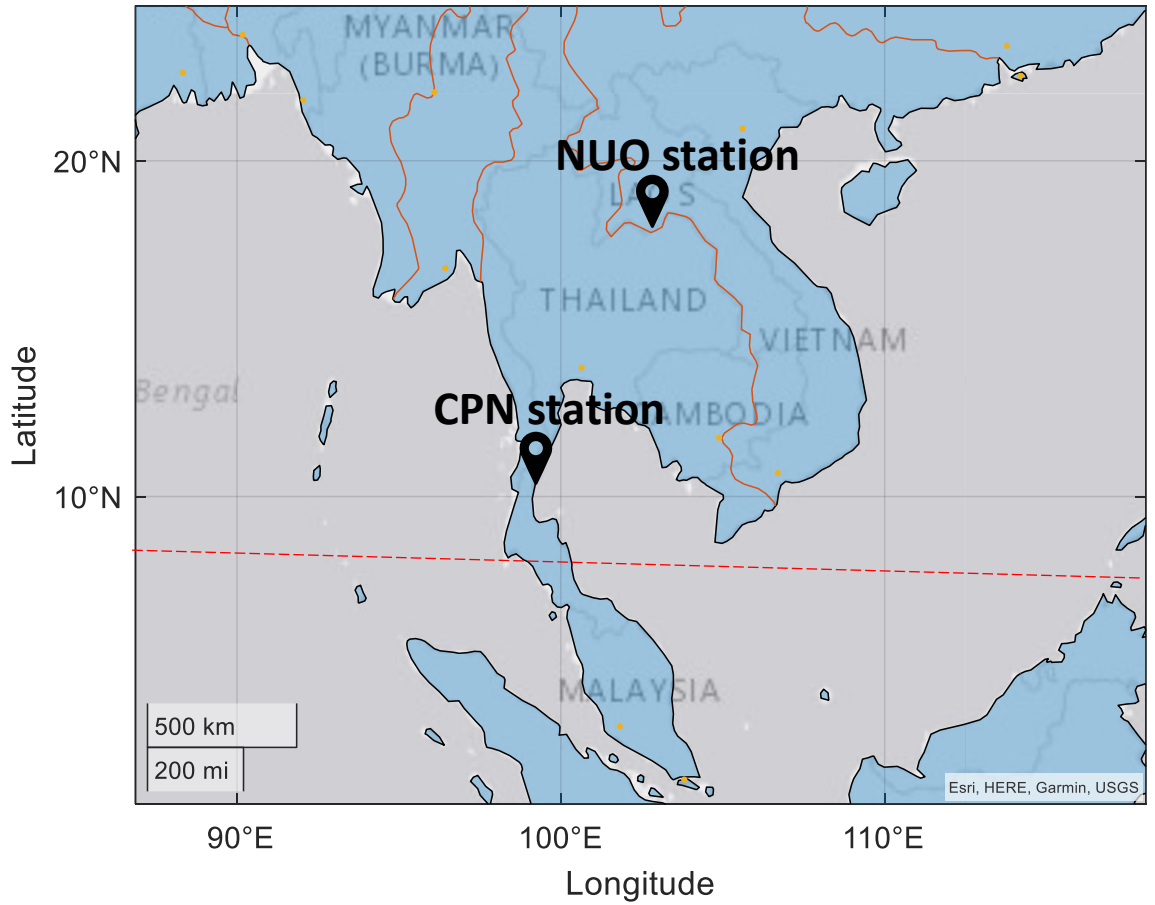


Day with ***EPB absence***

Experimental setups

- **We exclude** an analysis in **January**, **April**, and **June** due to scanty data
- **5-minute of window time** is determined for calculating the ROTI index
- Day with high ROTI at **least four satellites** is considered
- **Receiver cycle slips** are removed (Horvath and Crozier, 2007)
- **0.5 of the ROTI** value is used as threshold for determining EPB presence and absence
  - ROTI >= 0.5 indicates EPB presence
  - ROTI < 0.5 means to EPB absence
- **Statistics of the EPBs** are analyzed as
  - Occurrence rate (percentage)
  - Durations (hour)

Geographical locations of stations



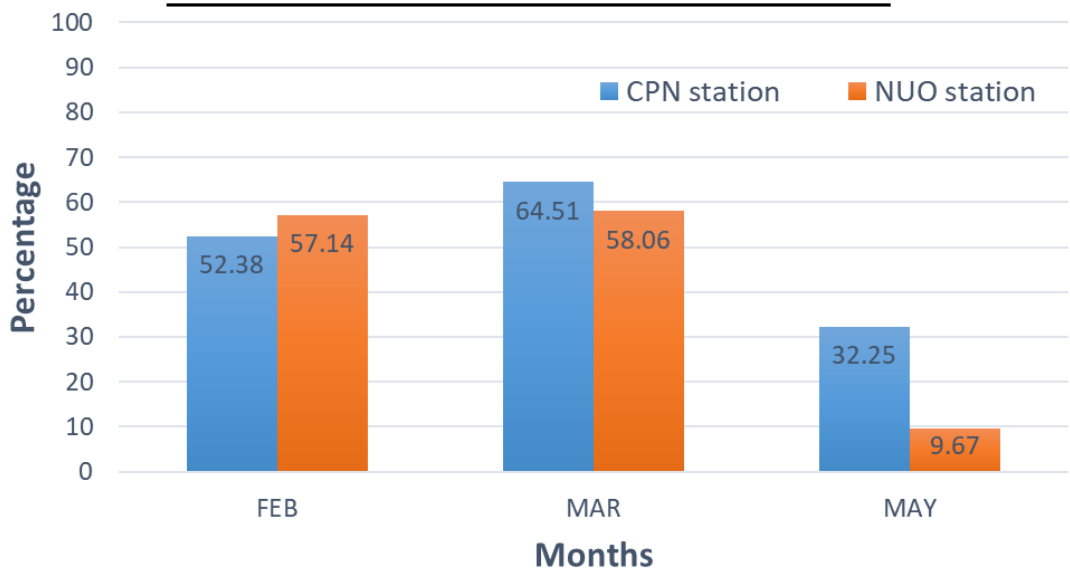
- CPN station (Lat: 10.72°N, Lon: 99.37°E), Thailand
- NUO station (Lat: 17.93°N, Lon: 102.62°E), Laos

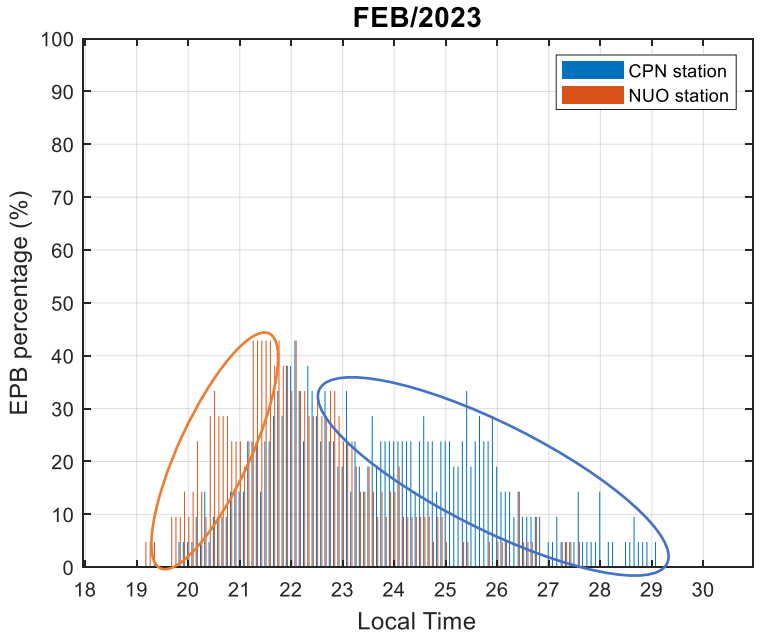
I. Horvath and S. Crozier, Software developed for obtaining GPS-derived total electron content values. RADIO SCIENCE, VOL. 42, RS2002, doi:10.1029/2006RS003452, 2007.
STEC and ROTI calculassions software developed by Thai GNSS and Space Weaather at https://github.com/cssrg-kmitl/TEC-calculation-MATLAB

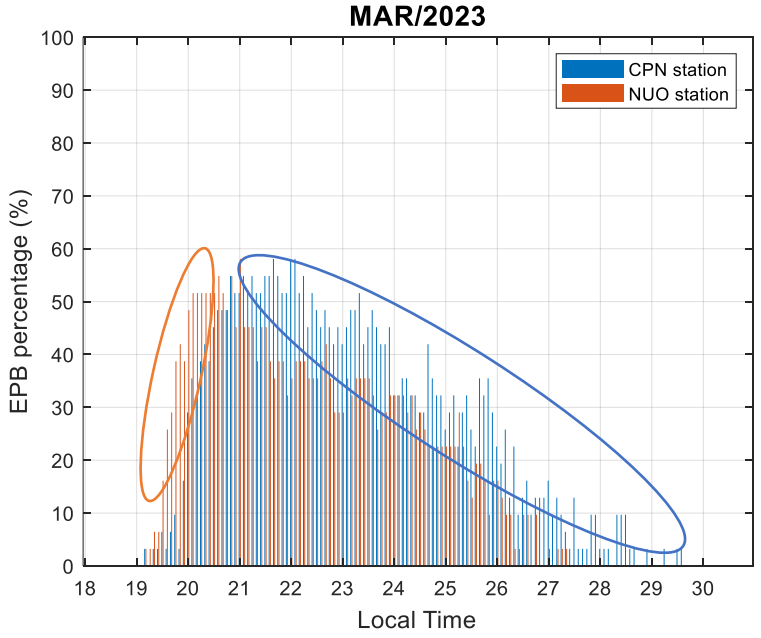
Results

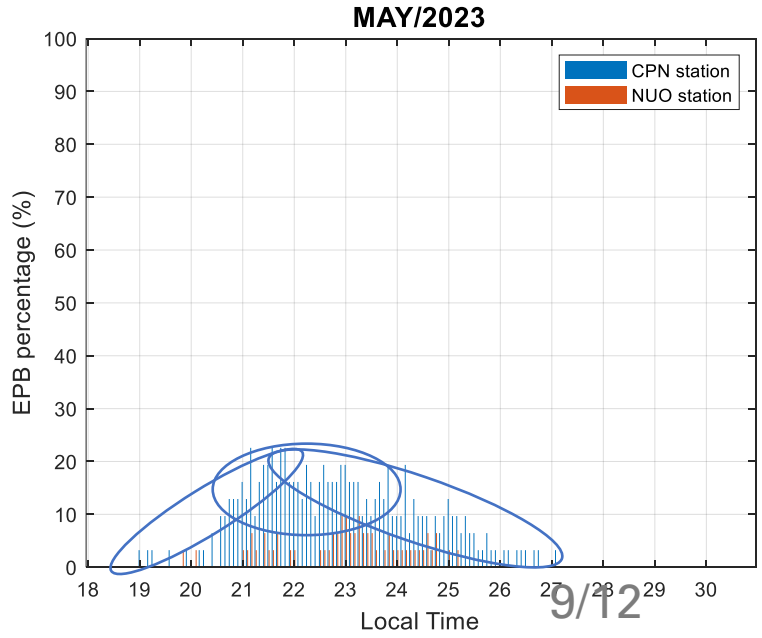
- Occurrence rate of the EPBs are seen less than 65% in each month at both stations
- **High percentage of the EBPs** is around 21:00 – 22:00 LT for both sites
- **High EPB occurrences** are seen during post-sunset at NUO station and post-midnight at CPN station

EPB occurrence rate on function of local time and month in 2023





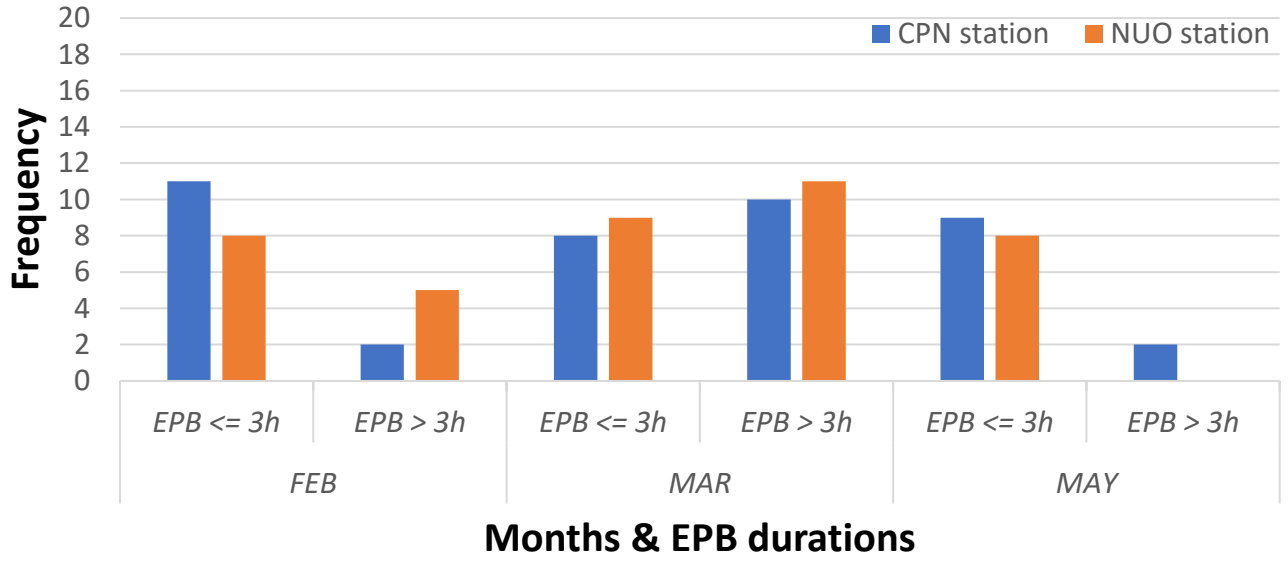




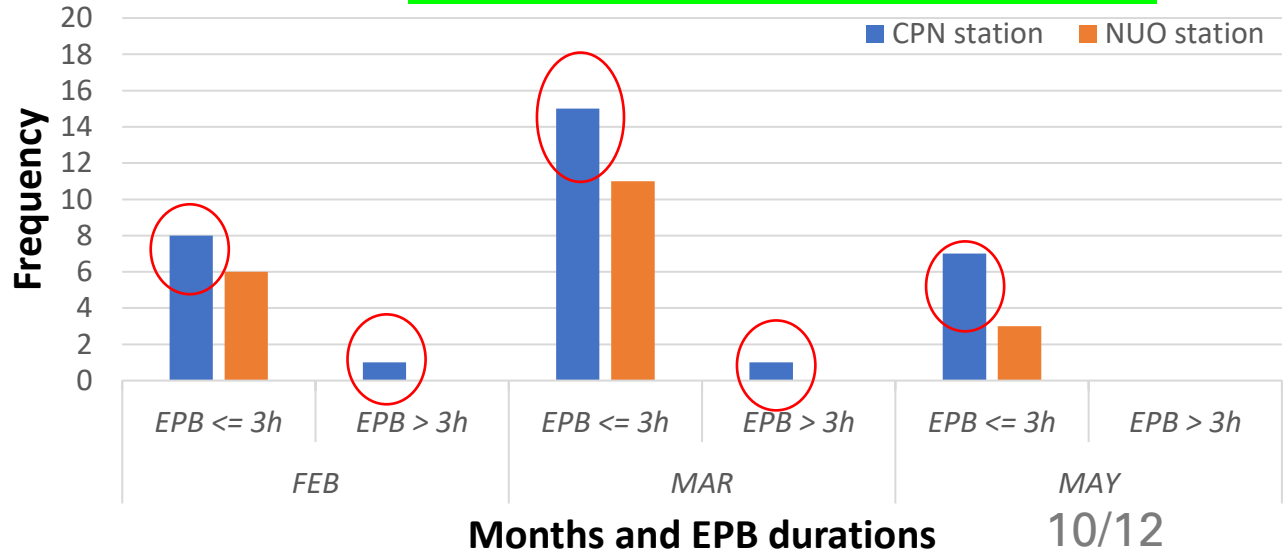
Results

- **Durations of the EBPs** during post-sunset at both stations are consistent
- **Long durations** of the EPBs are seen in MAR for two stations
- **Short durations** of the EBPs are dominant in all months at both stations
- **During post-midnight**, the durations of the EPBs at CPN station are higher than at NUO station for every months

Post-sunset (18:00 - 23:55) – 6h



Post-midnight (00:00 - 06:00) – 6h



Conclusions

- The EPBs' characteristics are importantly characterized on the function of time and months between CPN and NUO stations
- Higher EPBs during post-sunset at NUO station and higher EPBs during post-midnight at CPN station, these are caused by their own localization
- The EBPs' durations during post-midnight at CPN station are clearly seen higher than at NUO station

Future works

- We will figure out mechanisms of the different EPB characteristics at these two station

- Prediction of the EPBs is also one of our near future goals for mitigation purpose

Acknowledgement

AOSWA 2023
Asia-Oceania Space Weather Alliance
MALAYSIA

NICT

KMITL King Mongkut's Institute of Technology Ladkrabang

ASEAN IVO

THAI GNSS AND SPACE WEATHER
THAI GNSS AND SPACE WEATHER INFORMATION DATA CENTER

STEC and ROTI calculations software:

Thank you for your attention
(Q & A)