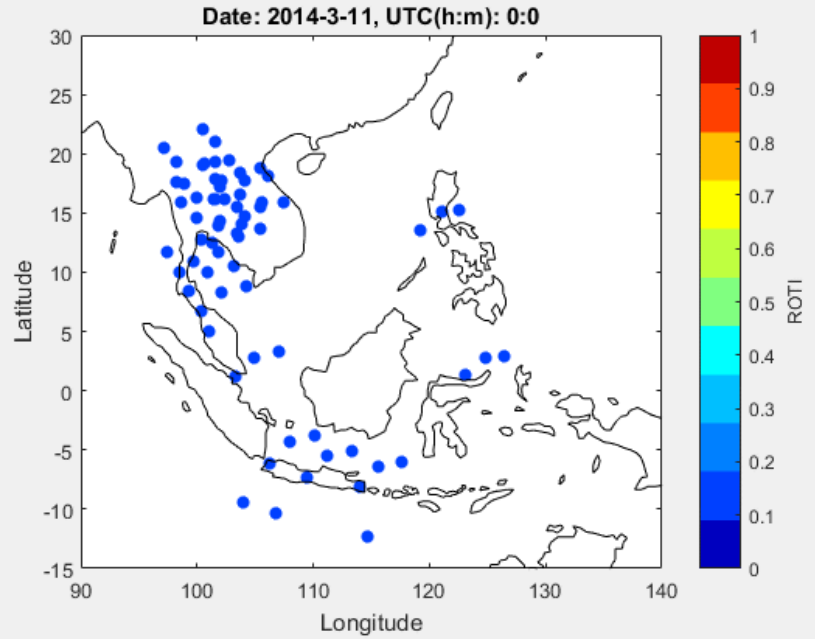
Project Title: Research and development for precise positioning with Artificial Intelligence (AI) during ionospheric disturbances in low-latitude region in ASEAN

Background :

Ionospheric irregularities such as equatorial plasma bubbles (EPB) in low-latitude regions in ASEAN countries often lead to degradation in precise positioning and navigation. To detect irregularity various sensors and data are typically utilized such as ionosonde, GNSS receivers, VHF (Very High Frequency) radar and LEO (Low Earth Orbit) satellite data. In addition, forecasting and mitigation of EPB effects on modern technology is needed for society at large. Importantly, as Solar cycle 25 is ongoing and will reach the solar maximum in 2024 or 2025, it is imperative to acquire more data and develop the warning capability.



Target :

1. To analyze the EPB statistics during the solar maximum and mitigate the EPB effects
2. To develop forecasting models for EPB occurrences
3. To demo RTK technology at local stations and utilize for various applications

Speaker: **Prof. Pornchai Supnithi**

School of Engineering and Excellence Center in GNSS and Space Weather
KMITL, Thailand

Project Title: Research and development for precise positioning with Artificial Intelligence (AI) during ionospheric disturbances in low-latitude region in ASEAN

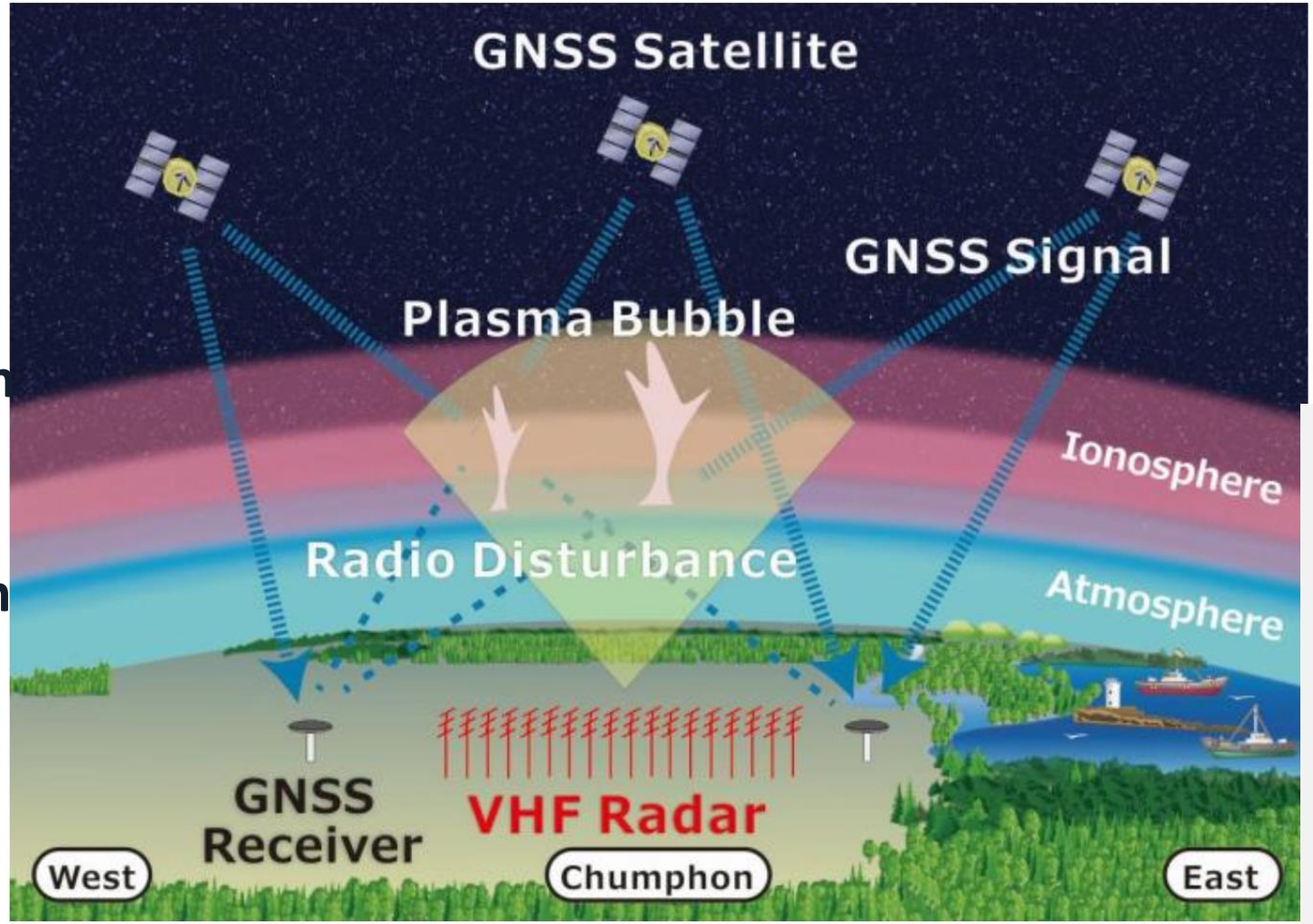
Project Members : (9 institutes)

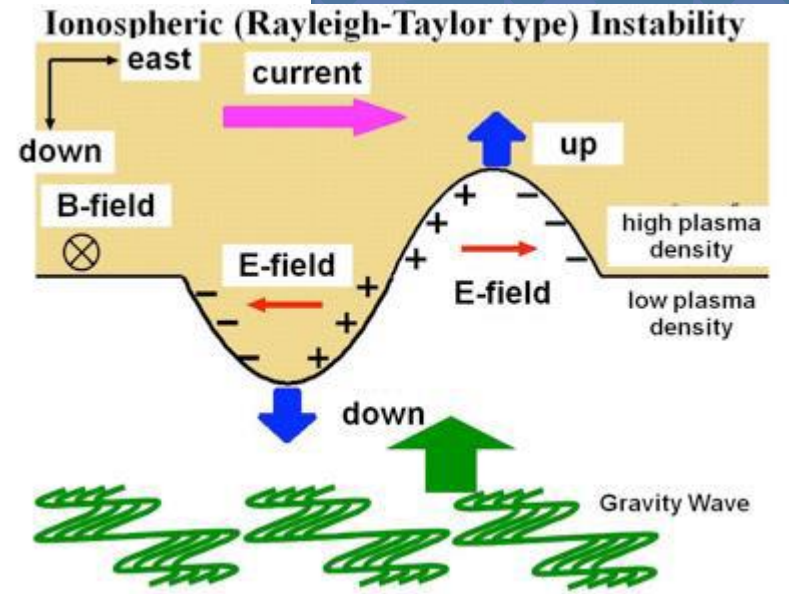
(KMITL, Thailand) P. Supnithi, P. Jamjureegulgarn, P. Kenpankho, K. Sepsirisuk , Lin Min Min Myint, Jirapoom Budho, S. Sophan, T. Thankulketsarat, N. Tongkasem,
(CMU, Thailand) Tharadol Komolmis, Witsarut Achariyaviriya, Prayoonsak Praychan
(KMUTT, Thailand) Alisa Kongthon
(NUOLS, Laos) Phosy Phanthongsy, Phimmasone Thammavongsy, Tick Sengthipphany, Phouthong Southisombath
(IGP, Vietnam) Le Truong Thanh, Dung Nguyen Thanh, Mai Thi Nguyen, Thanh Ha Nguyen
(LQDTU, Vietnam) Hoang Van Phuc, Nguyen Van Trung
(ITC, Cambodia) Sainglong Kaing
(CADT, Cambodia) Phutphalla Kong, Soklay Heng
(NICT, Japan) Michi Nishioka, Takuya Tsugawa, Septi Perwitasari

Project Duration : 24 months (1st April 2023 - 31st March 2025)

Project Budget: (Year 1) $39,700 (Year 2) $39,700

Equatorial Plasma Bubbles (EPB)





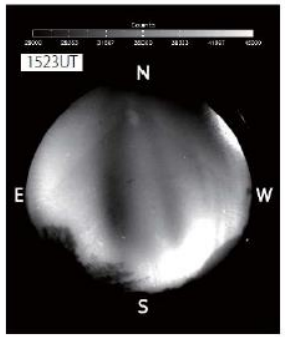
Local ionospheric disturbance

- local irregularity
- occurs after sunset, near magnetic equator, then expand (West-> East), high latitudes
- also driven by global disturbance (e.g. magnetic storms)

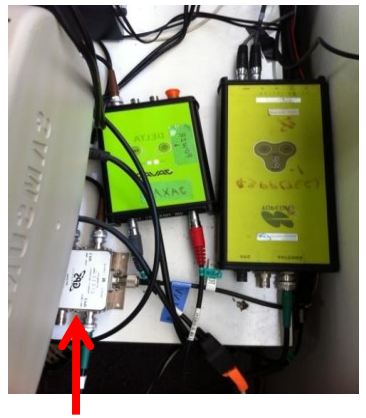
Instrument for EPB observation

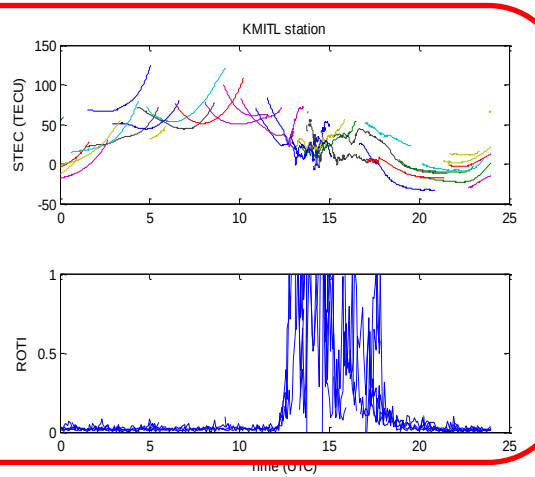
GNSS = Global Navigation Sateliite System (ex: GPS)

Optical Sky Images

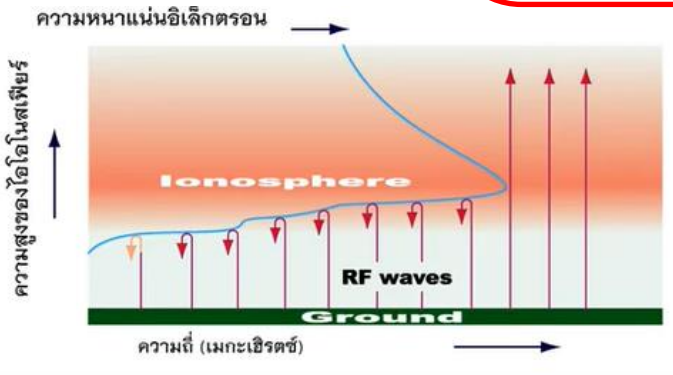


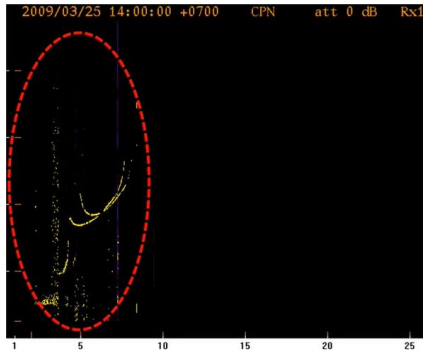
GNSS receivers





Ionosonde system

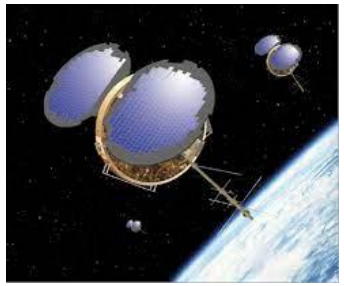


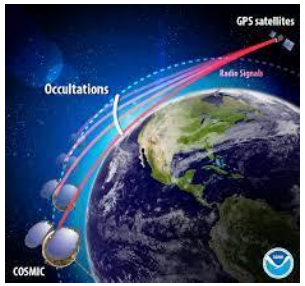


Received signal of 2 freq.
➔ Total Electron Content (TEC), Unit: el/m²

can detect iregularity EPB

Sateilites





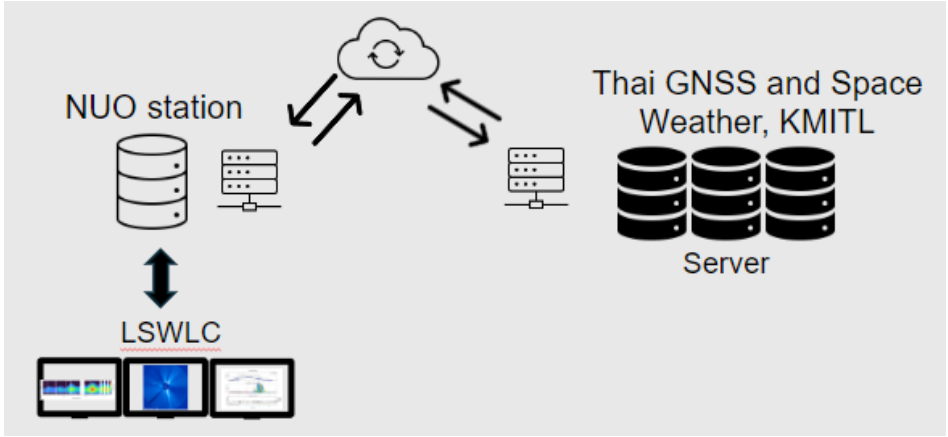
VHF radar

Project Activities: NUOL Space Weather

Dr. Donekeo Lakachan (NUOL, Laos)

LSWLC has been approved on **January 8th, 2024** under the ASEAN-IVO project

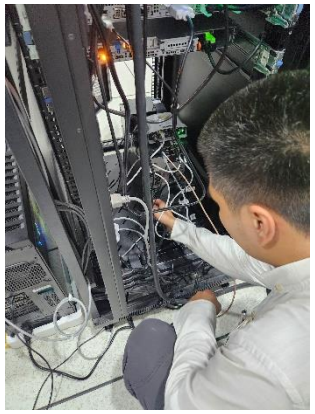
1. To enhance awareness and prevention of space impacts to society and industry
2. To develop observational center of Space Weather in Laos
3. To open space research gate in Laos



Project Activities: CADT VISIT

Prof. Pornchai Supnithi, Dr. Lin MM Myint (KMITL, Thailand)
Dr. Sovuthy, Dr. Kong (CADT, Cambodia)

- Inspect the GNSS receiver

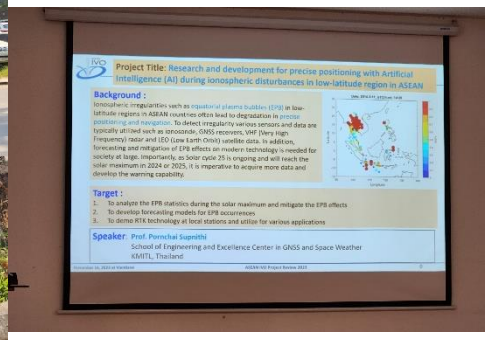


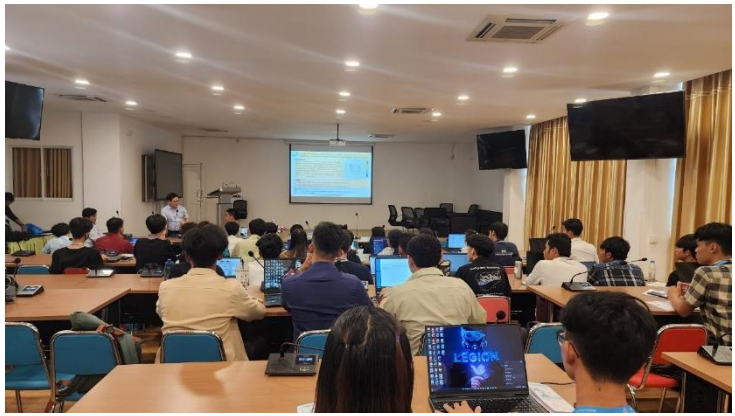
Project Activities: RTK Training at ITC

January 2024

Prof. Pornchai Supnithi, Dr. Lin MM Myint (KMITL, Thailand)
Dr. Sainlong (ITC, Cambodia)

- Training on the basics of GNSS receiver
- Training on the use of RTK system

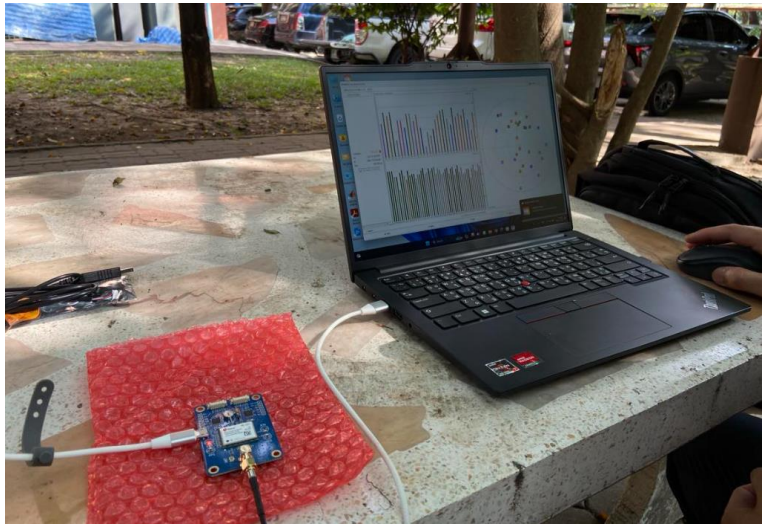




Project Activities: RTK Training at KMITL

Dr. Lin MM Myint, Dr. Jirapoom Budtho (KMITL, Thailand) - October 4th, 2024

- Training on the basics of GNSS receiver
- Training on the use of RTK system



Project Activities: **AOSWA 2024 Workshop**

Asia-Oceania Space Weather Alliance (AOSWA)

Oct. 8-11, 2024 in Bangkok, Thailand

ASEAN IVO Members (8)

(KMITL, Thailand) P. Supnithi, L. M.M.Myint, J.Budho, P. Jamjareegulgarn, P.Kenpankho

(CADT, Cambodia) Dr. Cheab Sovuthy

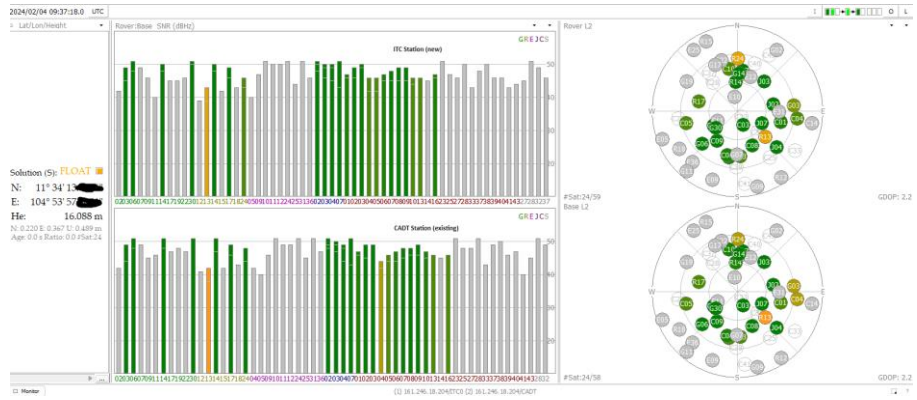
(IGP, Vietnam) Dr. Minh Le Huy

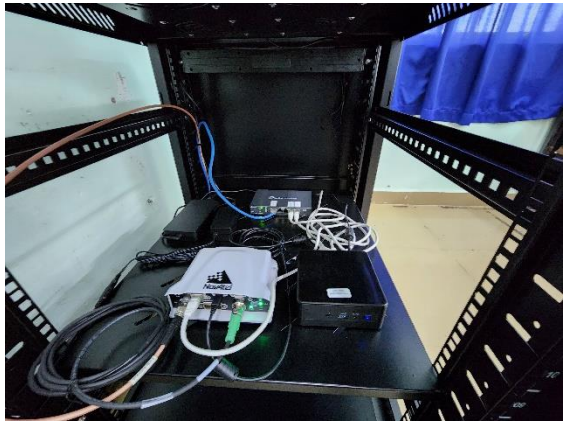
(NICT, Japan) S. Perwitasari, T. Tsugawa

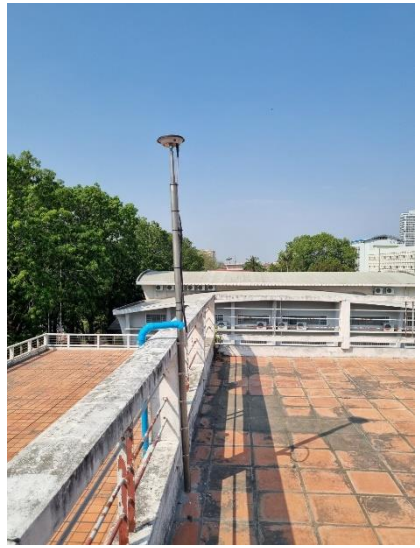
R&D results: **GNSS installation and test at ITC (Cambodia)**

Mr. Sainglong Kaing (ITC, Cambodia)

- tested the new GNSS receiver (**1-2 February, 2024**)





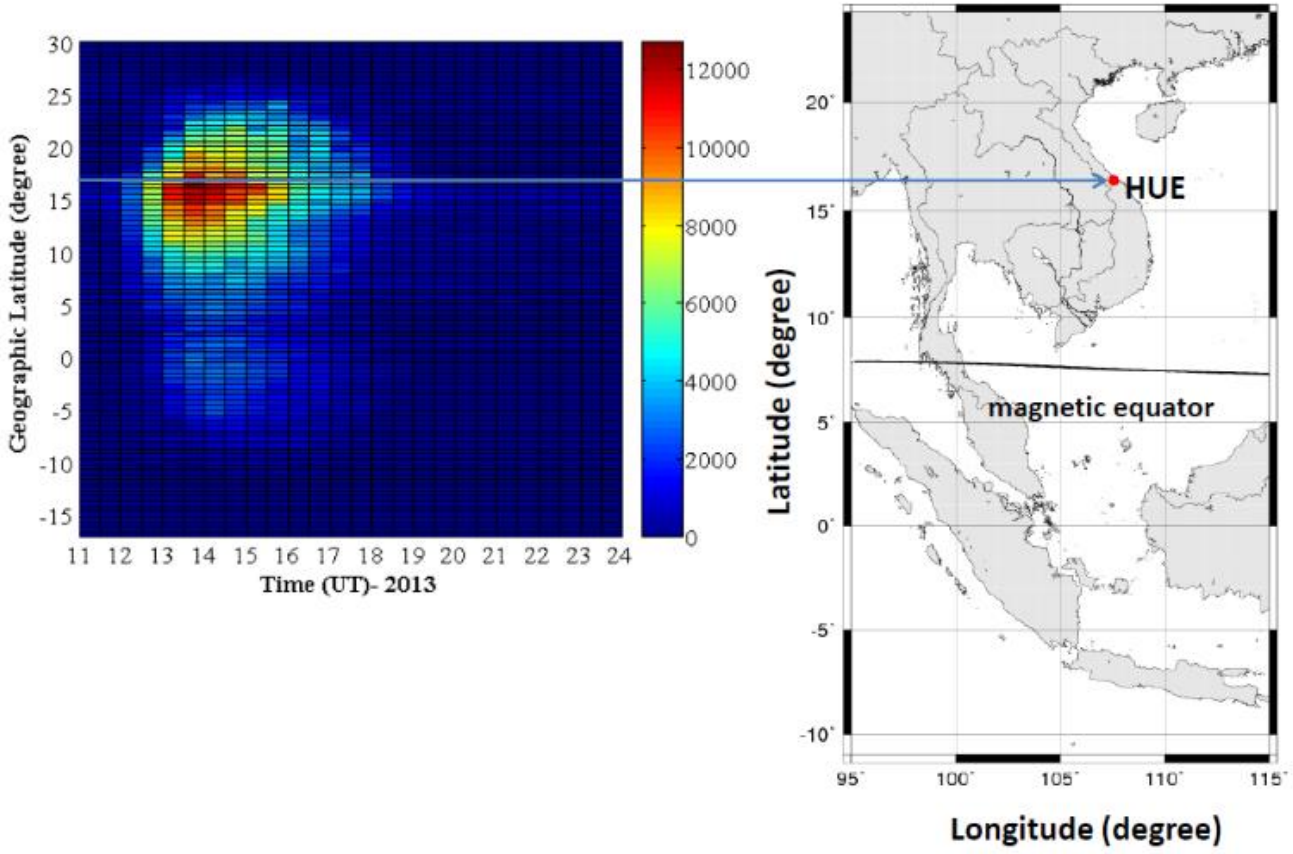


R&D results: **Plan for GNSS installation at IGP (Vietnam)**

Dr. Thanh Dung Nguyễn, Dr. Ha Thanh Nguyen, Dr. Le Truong thanh (IGP, Vietnam)

- Plan to install the GNSS receivers at Hue, Vietnam, **in December 2024**

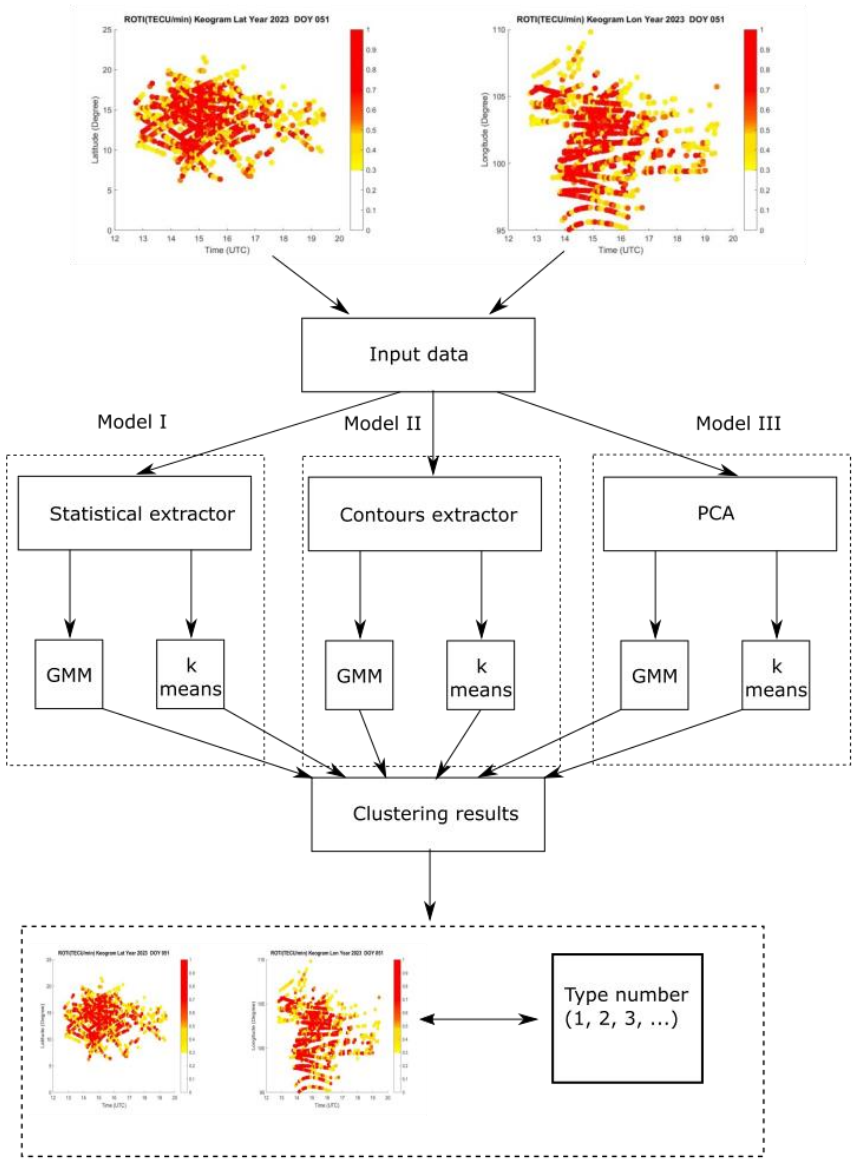
IGP's seismic station
Hue, Vietnam



Multi-frequency, multi-constellation GNSS receiver system set

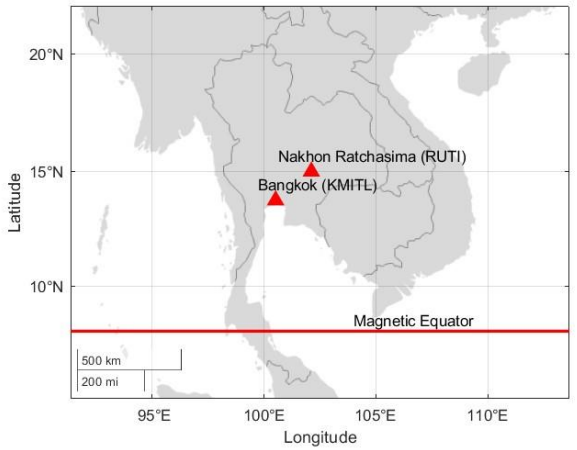
1. NovAtel PwrPak7 GNSS Receiver
2. NovAtel GNSS-850 GNSS Antenna
3. GNSS Low-loss Cable 15 meters
4. GNSS Antenna Stand (Pole)
5. Mini PC MSI for data collecting and sending to database server
6. VPN Router

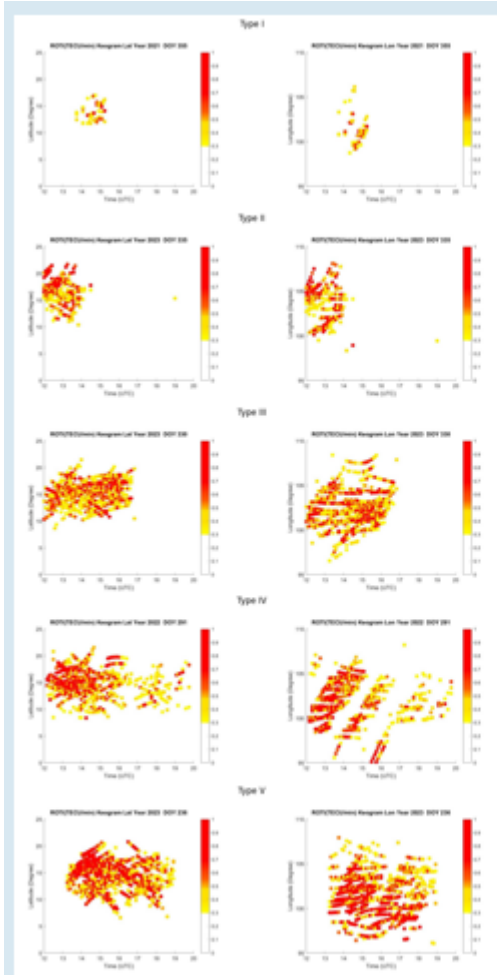
R&D results: **AI for ROTI map prediction**



(KMITL)
Dr. Lin M.M.Myint

Methods: K-Mean , Gaussian Mixed Models (GMM)





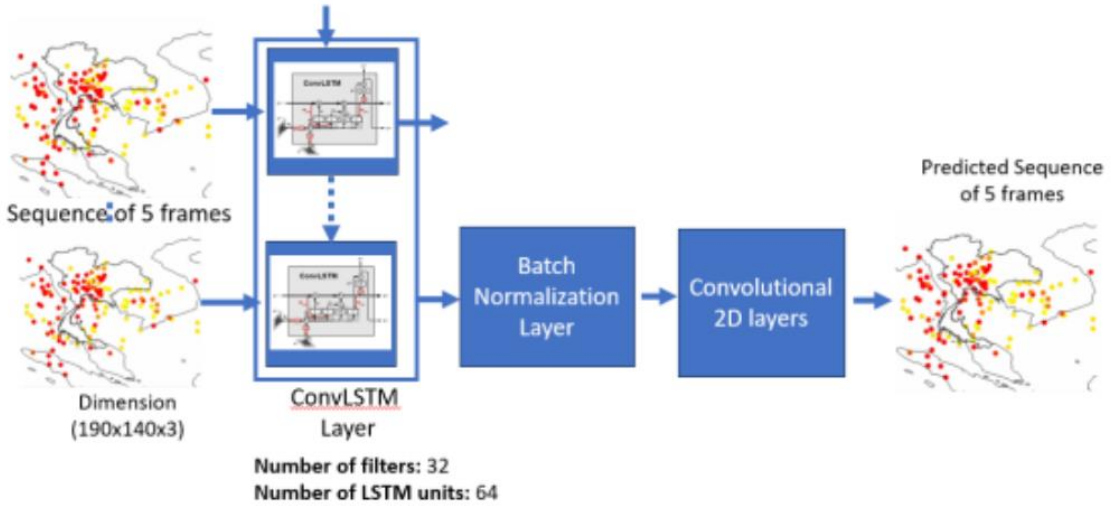
- Type I.
  - Small scale (less than 5 degrees)
  - Short duration (not more than 2 hours)
- Type II.
  - Size from 5 to 10 degrees
  - The duration can reach 3 hours.
- Type III.
  - Size is around 10 degrees
  - The duration takes values from 5 to 10 degrees)
- Type IV. Multistride irregularity. Looks like two or more small/moderate-scaled irregularities
- Type V. Extensively significant irregularity. Similar to Type III, but the duration can be more than 8 hours

- Five types of irregularities were found
- Small irregularities (type 1, 2) are observed with a wide range of indices F10ю7 and Kp
- Larger ones (3,4, 5) were observed in a narrow range of values.

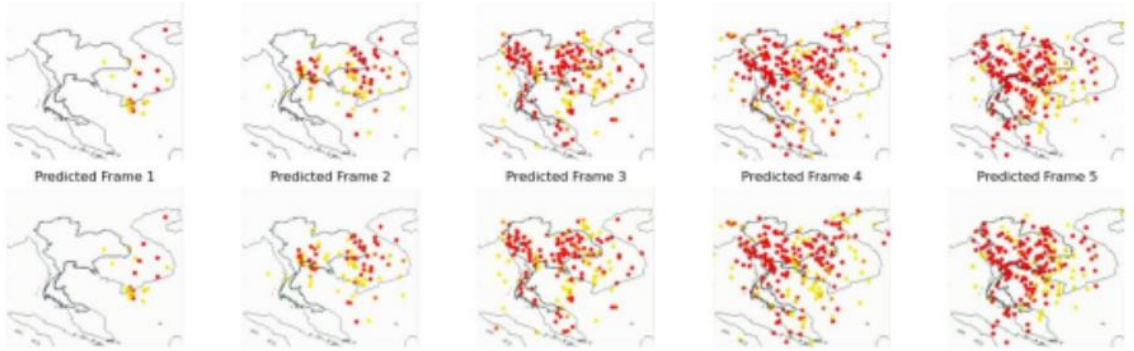
R&D results: AI for clustering of ROTI Keogram maps

(KMITL) Dr. Lin M.M.Myint, Mr. Phyo C Thu

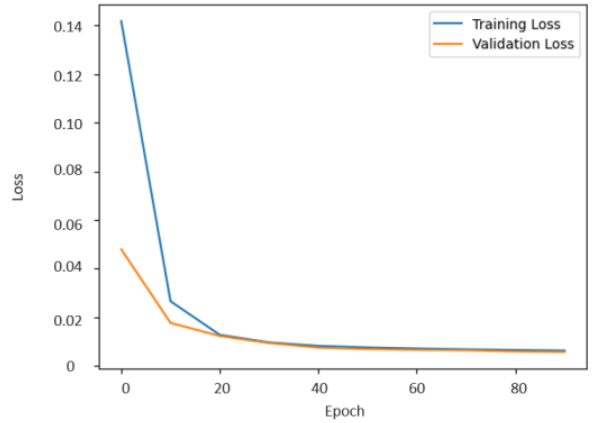
"LSTM method for ROTI map prediction"



Comparison of actual frame from ROTI map and predicted frame



Training performance of proposed convolutional LSTM model



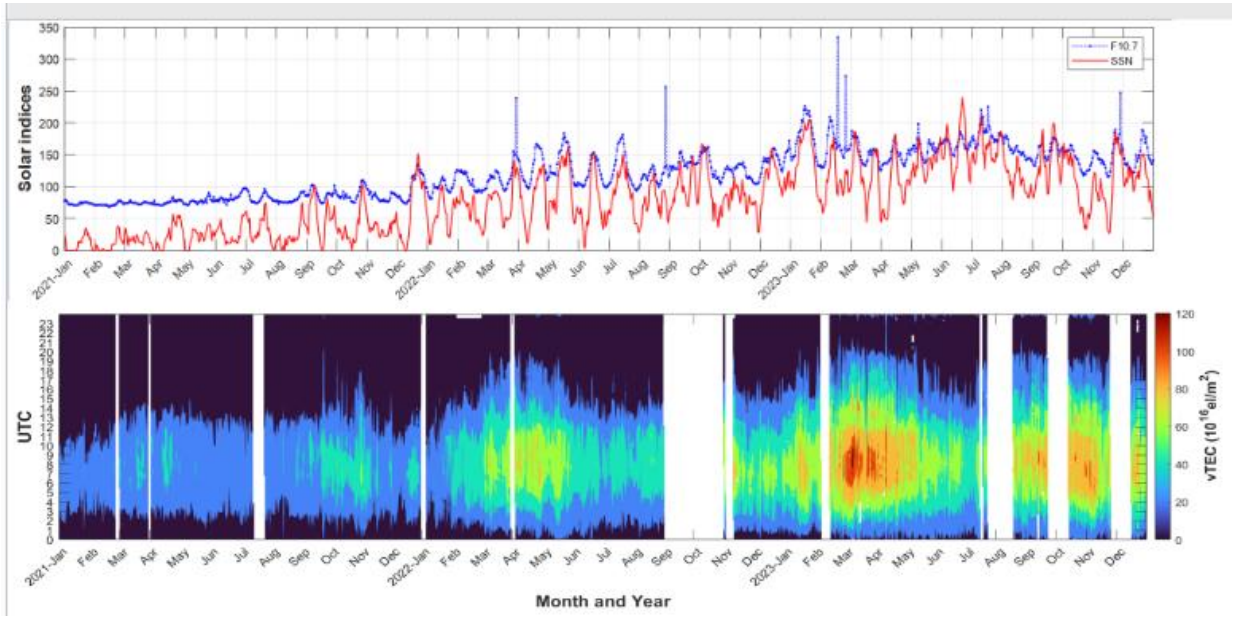
Deviation of actual frames and predicted frames

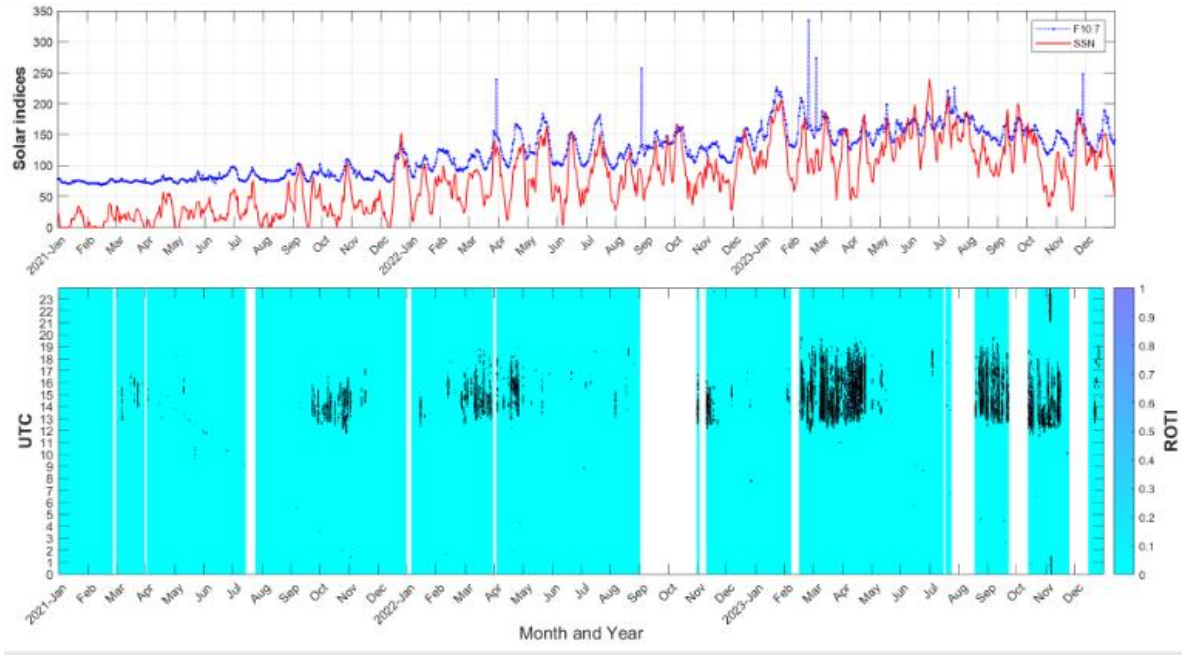
Evaluation method	Frame1	Frame2	Frame3	Frame4	Frame5
MSE	0.00155	0.00184	0.00134	0.00107	0.00105
SSIM	0.98977	0.98587	0.98934	0.99269	0.99370

R&D results: **VTEC analysis (NUOL)**

P. Thammavongsy, P. Panthongsy, D. Lakanchanh

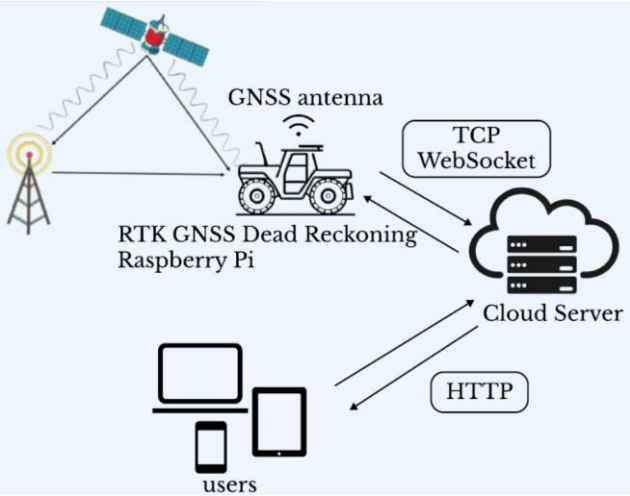
Results: Observed VTEC at NUO station from 2021 to 2023





R&D results: RTK utilization in agriculture (NUOL)

Dr. Phosy Phanthongsy
Dr. Donkeo Lakachanh



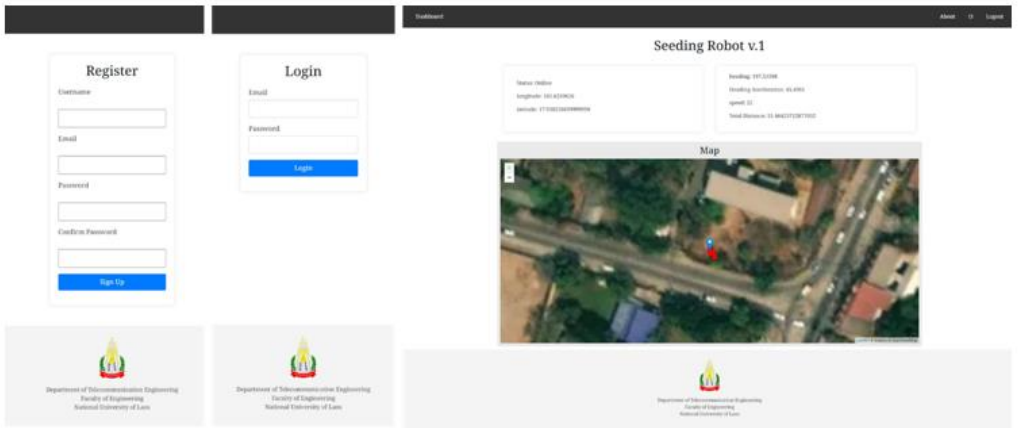


Figure 7 User interface for RTK positioning and monitoring

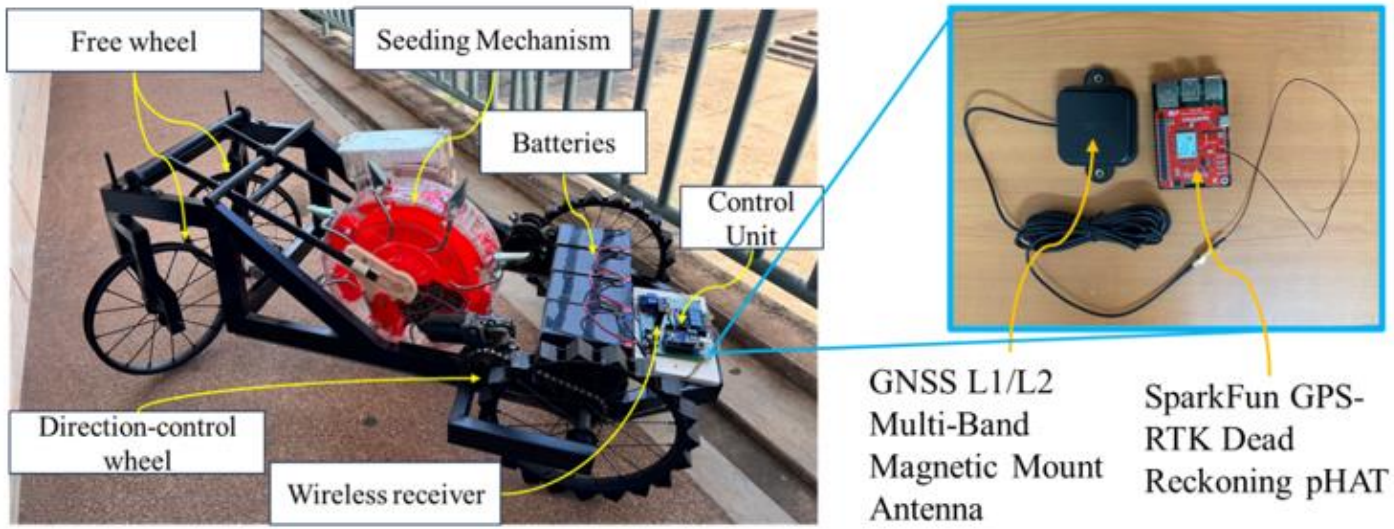
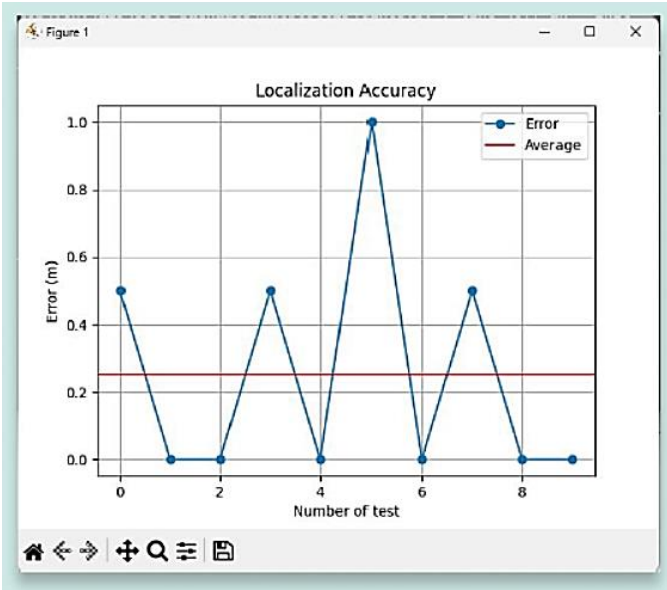


Figure 8 Seeding Robot with RTK positioning module



Scientific Contribution:

Presentations at International Conferences:

No	Paper title	Author names	Affiliation	Conference name	The date of the conference	The venue
1	Statistics of the Equatorial Plasma Bubbles in February, March and May 2023 at CPN station, Thailand, and NUOL station, Laos	P. Thammvongsy, P. Supnithi, L. M.M. Myint, D. Larkanchanh, P. Phanthongsy, P. Southisombath and M. Nishioka	NUOLS (Laos), KMITL (Thailand), NICT(Japan)	AOSWA 2023 Workshop	9-11/10/2023	Kuala Lumpur, Malaysia
2	The network of continuous GPS observation in Vietnam and adjacent region and evaluation of the ionospheric quasi-biennial oscillation (QBO) of TEC amplitude of equatorial ionization anomaly (EIA)	D. Thanh	IGP (Vietnam)	AOSWA 2023 Workshop	9-11/10/2023	Kuala Lumpur, Malaysia
3	Ground Subsystem Error Contribution of a Multi-Constellation GBAS Based on a CORS Network in the Vicinity of Airport Areas	M. Cuetas, J.Budtho, P.Supnithi, S. Saito	KMITL (Thailand) ENRI (Japan)	ION-GNSS+ 2024	15-20/92024	Baltimore, USA
4	Artificial Intelligence Applications in Ionospheric Irregularities: A Bibliometric Analysis	A. Kongthon, P. Supnithi	KMUTT (Thailand) KMITL (Thailand)	PICMET	4-8/82024	Portland, Oregon
5	Identification of Equatorial Ionospheric Irregularities using Clustering Techniques on ROTI Keogram Images	G.Mutasov, P. Supnithi, L. M.M. Myint, J.Budtho, N. Tongkasem, M.Nishioka	KMITL (Thailand) NICT (Japan)	AOSWA 2024 Workshop	5-810/2024	Bangkok, Thailand
6	The classification of Spread – F using Machine learning with Data from VHF radar and Ionosonde at Chumphon station, Thailand	T. Thanakulketsarat, P. Supnithi, L. M.M. Myint, J.Budtho, N. Tongkasem, M.Nishioka, S. Perwitasari	KMITL (Thailand) NICT (Japan)	AOSWA 2024 Workshop	5-810/2024	Bangkok, Thailand
7	Seasonal Characteristics of Ionospheric Plasma Densities in 2021 to 2023 at Vientiane Station, Laos	P. Thammavongsy, P. Panthongsy, D. Lakanchanh, P. Supnithi, L.M.M. Myint, P. Septi, M. Nishioka	NUOL (Laos) KMITL(Thailand) NICT(Japan)	AOSWA 2024 Workshop	5-810/2024	Bangkok, Thailand
8	Monitoring Ionospheric Irregularities and TEC Variations During High solar activity in 2024	N. Tongkasem, P. Supnithi, L. M.M. Myint, M.Nishioka	KMITL(Thailand) NICT(Japan)	AOSWA 2024 Workshop	5-810/2024	Bangkok, Thailand
9	Continuous GNSS network and some study results on time variation of the Equatorial Ionization Anomaly in the Vietnam and adjacent region	M. Le Huy	IGP (Vietnam)	AOSWA 2024 Workshop	5-810/2024	Bangkok, Thailand

Scientific Contribution:

Presentations at International Conferences:

No	Paper title	Author names	Affiliation	Conference name	The date of the conference	The venue
10	Effects of Geomagnetic Storms on Equatorial Ionization Anomaly and Equatorial Ionospheric Plasma over Thailand	L.M.M. Myint, P. Supnithi, J. Budtho, P. Septi, M. Nishioka	KMITL(Thailand) NICT(Japan)	AOSWA 2024 Workshop	5-8/2024	Bangkok, Thailand
11	Enhanced Ionospheric Delay Gradient Estimation Using a Dynamic Time-StepMethod with GNSS IGSO Satellites	J. Budtho, P. Supnithi, L. M. M. Myint	KMITL(Thailand)	AOSWA 2024 Workshop	5-8/2024	Bangkok, Thailand

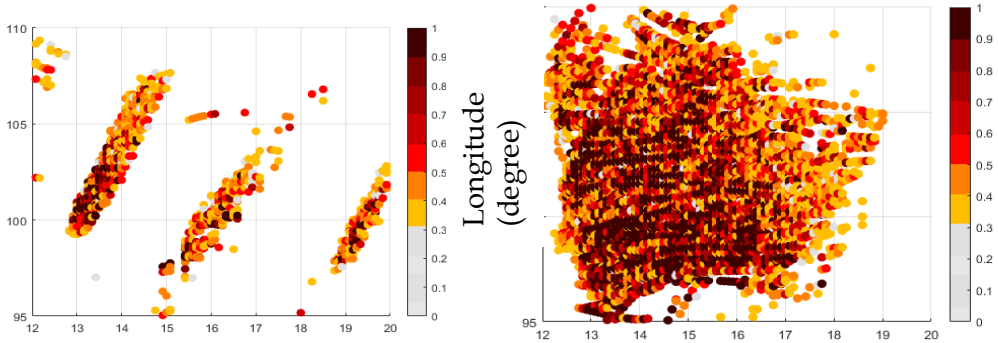
Journal Publications

No	Paper title	Author names	Affiliation	Journals name	The publisher of the Journal	The volume number and Pages
1	Equatorial spread-F forecasting model with local factors using the long short-term memory network	P. Thammavongsy, P. Supnithi ,L. Myint, K. Hozumi and D. Lakanchanh	NUOL (Laos) KMITL (Thailand) NICT (Japan)	**Earth, Planets and Space** **(Q1 level, SJR)**	Springer Open	Vol 75, No. 118, 04 August 2023 https://doi.org/10.1186/s40623-023-01868-7
2	Classification of the equatorial plasma bubbles using convolutional neural network and support vector machine techniques	T. Thanakulketsarat, P. Supnithi ,L. Myint, K. Hozumi and M.Nishioka,	KMITL (Thailand) NICT (Japan)	**Earth, Planets and Space** **(Q1 level, SJR)**	Springer Open	Vol 75, No. 161, 16 October 2023 https://doi.org/10.1186/s40623-023-01903-7

Societal Impact:

- Research on AI for TEC and ROTI maps
  - ➔ TEC map and ROTI map aid EPB detection and prediction
  - ➔ Used by positioning, navigation agencies
    - ➔ Aerothai, ICAO, Meteorology Dept.)

(Example) ROTI Keogram



- Low-cost RTK receivers and applications in space weather, agriculture, etc.
  - ➔ Educational, Agriculture, Space Weather area

- Control Room/Learning Center benefits the educational aspect and visibility
  - ➔ Capacity-building, education, research at NUOLS, ITC, and CADT

Conclusion:

- **Trainings:**
  - ITC (Cambodia) on RTK setup and performance evaluation
  - KMITL(Thailand) on RTK setup and performance evaluation

- **GNSS receiver installation:**
  - ITC - Cambodia, IGP – Vietnam (planned in Dec 2024)

- **Research results:**
  - (NUOL) set up Space Weather Learning Center, analyze TEC at NUOL, assemble RTK system for agriculture
  - (ITC, CADT) analyze TEC and ROTI parameters
  - (KMITL) AI clustering on ROTI keograms and VHF radar images, ROTI map construction, VHF radar analyses

- **Publications:**
  - 11 conference papers/abstracts, 2 Journal articles