Project Title: GNSS and Ionospheric Data Products for Disaster Prevention and Aviation in Magnetic Low-Latitude Regions (Phase II)

Background :

The ionosphere in the magnetic low-latitude and the magnetic equator region is observed to be highly unstable due to unique disturbance events, resulting in degradation in performances of communication and navigation. Therefore, It needs to be analyzed or forecasted based on the collected data including GNSS and other related data from the station networks in the region. Based on the measurements, data products and prediction models are implemented for positioning, navigation, communications, and aviation, especially in this region.

Targets:

1. To expand GNSS and ionospheric monitoring system into Cambodia.
2. To upgrade data products and disturbance prediction models for disaster prevention and aviation developed in Phase I
3. To develop a low-cost real-time kinematics (RTK) receiver system and test its performance during Plasma Bubble using the data collected from newly installed stations in Phase I.
4. To continue the recently established GNSS and SW Excellence Center at KMITL and conduct capacity building for domestic network and partnered institutions on GNSS technology, ionosphere, and Space Weather parameters understanding.

Speaker: Asst. Prof. Dr. Lin Min Min Myint, KMITL, Thailand

Project Title: GNSS and Ionospheric Data Products for Disaster Prevention and Aviation in Magnetic Low- Latitude Regions (Phase II)

Project Members : 6 Institutes from 4 countries

Party	Name	Party	Name
NICT, Japan	TSUGAWA Takuya	CMU, Thailand	Tharadol Komolmis
	HOZUMI Kornyanat		Prayoonsak Praychan
	NISHIOKA Michi	GISTDA, Thailand	Sittiporn Channums
KMITL, Thailand	Pornchai Supnithi	NUOL, Lao	Donekeo Lakanchan
	Watid Phakphisut		Phutsavanh Thogphanh
	Punyawi Jamjareegulgarn		Phouthong Southisombath
	Prasert Kenpankho	CADT, Cambodia	Khema Van
	Somkit Sophan		Phutphalla Kong

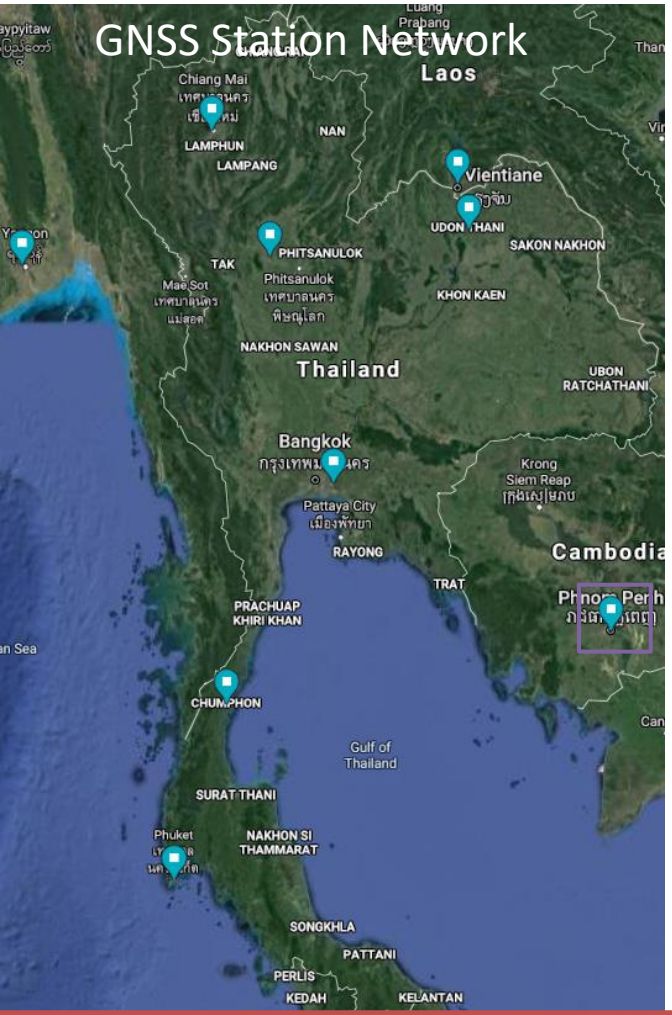
Project Duration : April 1st, 2021 - March 31st, 2023 (24 Months)
*Extended 6 months until September 30th, 2023

Project Budget: First year (April 1st, 2021 – March 31st, 2022) : 39,880 USD
Second year (April 1st, 2022 – March 31st, 2023) : 39,980 USD

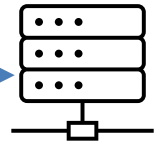
Project Activities: 1st April 2021 – 31st March 2022

R&D description		Subcategories		Responsible members
A :	To Install dual-frequency GNSS receiver in Cambodia			KMITL, CADT, NICT
B:	To upgrade daily GNSS and SW data products for disaster and aviation	a:	Modify daily GNSS data such as 2-D TEC maps, ROTI data products including the data from Laos, Cambodia	KMITL, CADT, NUOL
		b:	Upgrade daily ionospheric data products for Communications and Aviation.	KMITL, NICT, CADT, GISTDA, CMU
		c:	Develop AI and Machine learning model the applications of GNSS and Aviation	KMITL, NICT
C	To develop and test a real-time kinematics (RTK) positioning system using the post- processed data from newly installed GNSS network.			KMITL, NUOL, CADT
D	To support capacity- building for domestic network and partnered institutions on GNSS technology, ionosphere, basic space weather			ALL

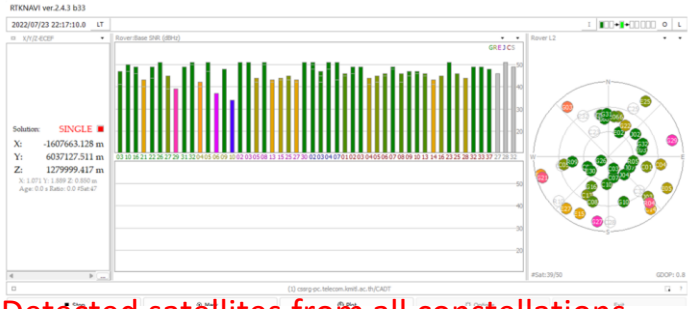
Project Activities:
A: Expanding GNSS and Ionospheric Monitoring System into Cambodia



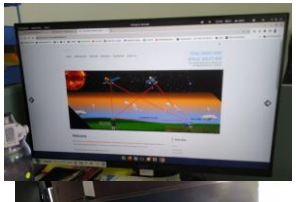
GNSS Antenna → GNSS receiver → Computer → KMITL Server



Checking satellites availability and received signal SNR



Detected satellites from all constellations



Computer for data processing

CADT Innovation Center Building

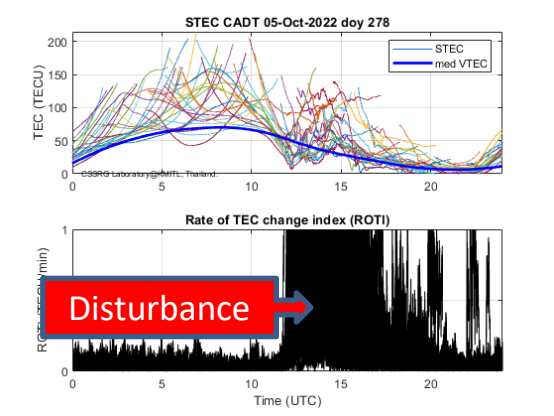
NovAtel PwrPak7 GNSS receiver, GNSS-850 GNSS antenna, computer and other required equipment have been installed at Cambodia Academy of Digital Technology (CADT), Phnom Penh, Cambodia by the project members from KMITL, Thailand and CAD, Cambodia together.

Budget: GNSS Receiver Set: ~20221.70$ (in 2021) + Installation Trip Expense: 800$ (in 2022) + CADT Desktop Computer: 2530$ (in 2023)

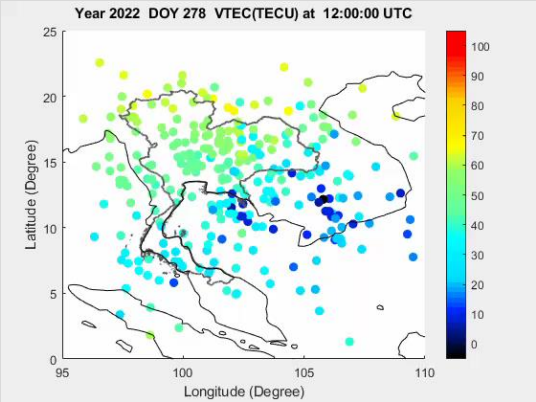
Project Activities:
A: Expanding GNSS and Ionospheric Monitoring System into Cambodia

We have studied Ionospheric Variation and Disturbance Information based on GNSS data from the new CADT station, Cambodia together with other stations.

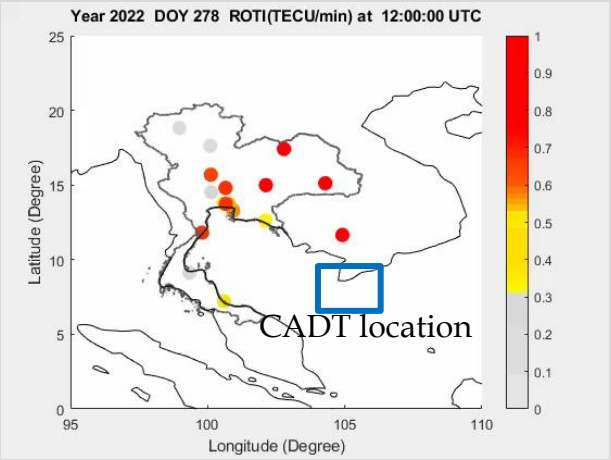
Date: 5/10/2022



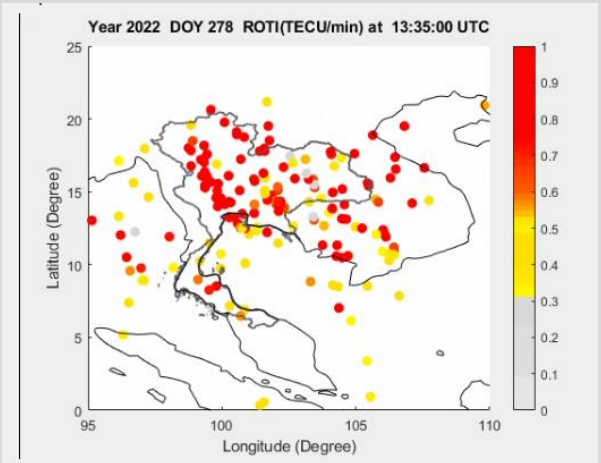
TEC at Ionospheric Pierce Point (IPP)



The Rate of TEC index (ROTI) at each stations

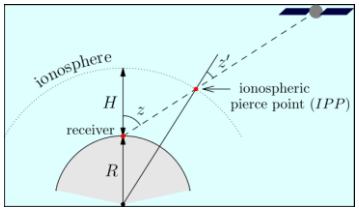


ROTI at Ionospheric Pierce Point (IPP)



Using the data from CADT, we can observe more coverage area of the ionospheric variations.

Note: *ionospheric pierce point* (IPP) isthe signal transmitted from the satellite to the receiver crosses the ionospheric shell in IPP .



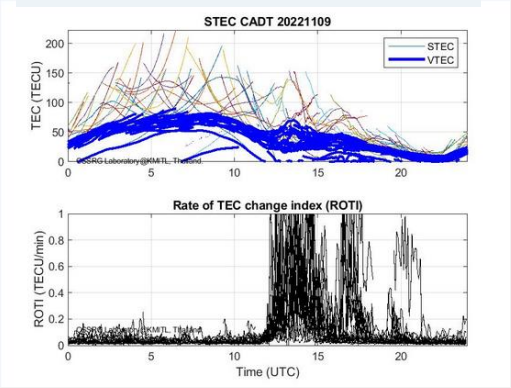
Budget: KMITL Server Upgrade: ~2,340.00$ (in 2022) + NUOL SW Learning Center: ~3,740.00$ (in 2023)

Project Activities: B: To upgrade daily GNSS and SW data products for disaster and aviation

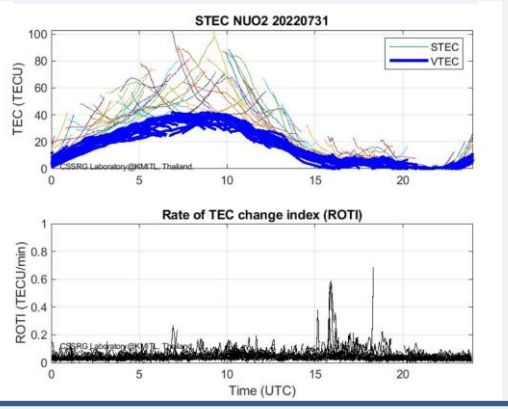
a) Modify daily GNSS data such as 2-D TEC maps, ROTI data products including the data from Laos, Cambodia

Daily Slant TEC (STEC) and ROTI Plots

Cambodia (CADT)

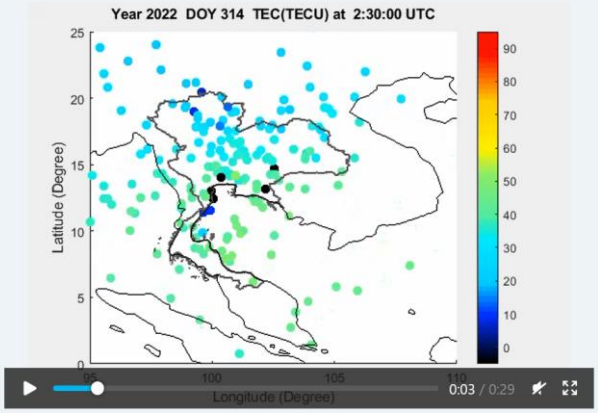


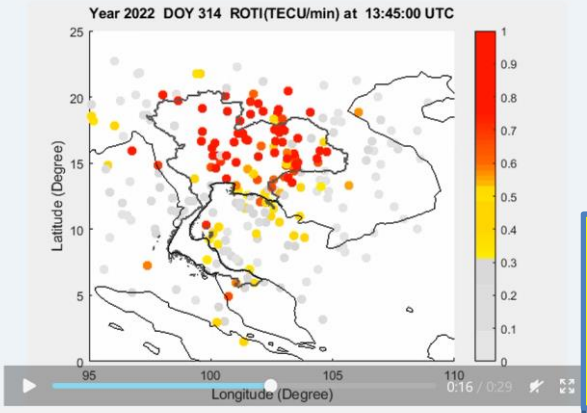
Laos (NUOL)



Using the data from newly installed stations, we can extend the coverage area of the ionospheric observation and increase the resolution of the TEC and ROTI maps.

TEC and ROTI Maps with Data from new CADT and NUOL stations





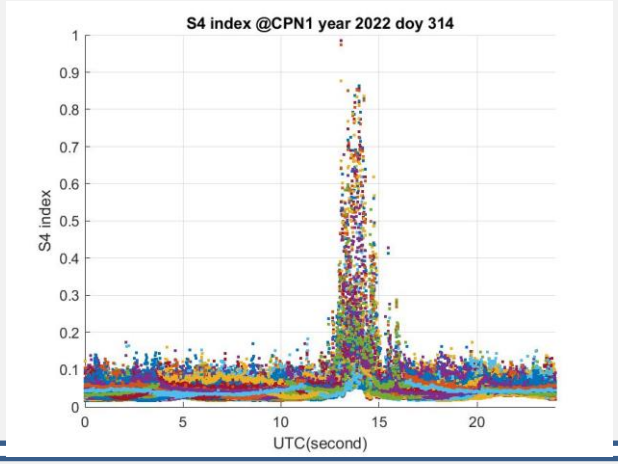
Daily Maps and Plots can be observed at KMITL's GNSS and SW Excellence Center
http://iono-gnss.kmitl.ac.th/?page_id=807

b) Upgrade daily ionospheric data products for Communications and Aviation.

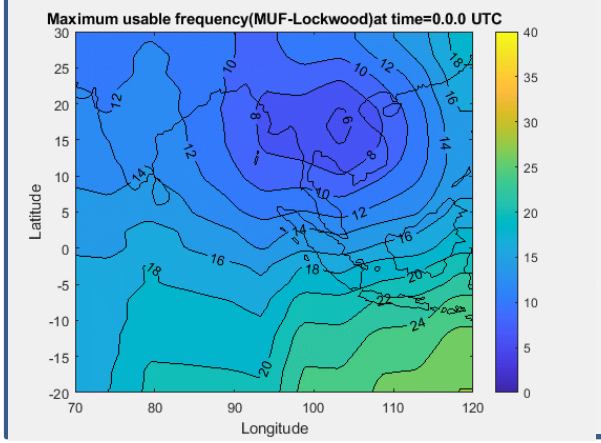
S4 index is used to measure the severity of scintillation (fluctuation) on GNSS or GPS signals.

Daily S4 at Chumphon Station near magnetic equator can be observed at KMITL's GNSS and SW Excellence Center
http://iono-gnss.kmitl.ac.th/?page_id=807

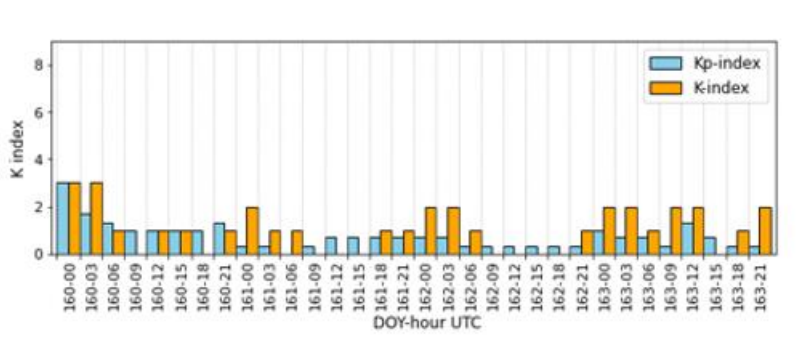
Daily S4 Index from Chumphon Station



Maximum usable frequency (MUF) Map



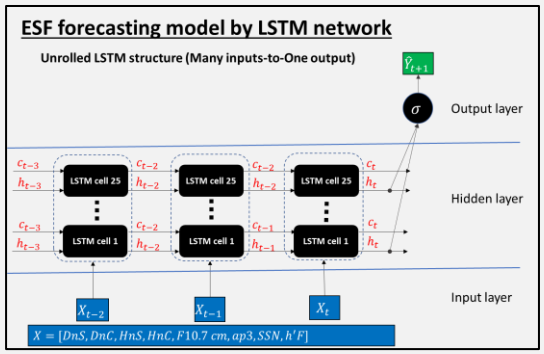
Local Geomagnetic K index from Magnetic Equator Phuket Station

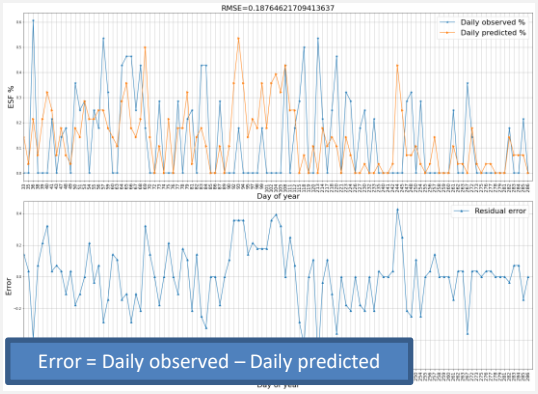


Project Activities:
B: To upgrade daily GNSS and SW data products for disaster and aviation

c) Develop AI and Machine learning model for the applications of GNSS and Aviation.

Develop the Equatorial Spread-F (ESF) forecasting model using Long-Short Term Memory (LSTM)

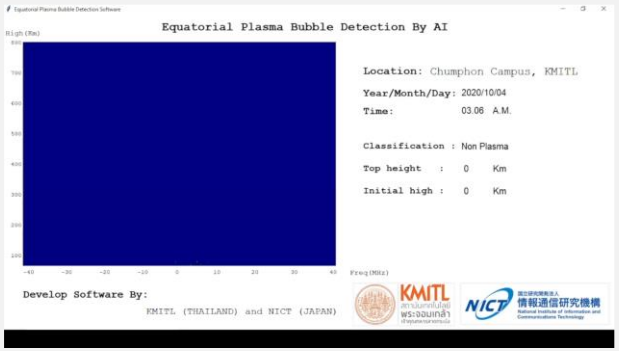




Prediction of the ESF daily percentage in 2019

- ESF daily percentage prediction can achieve 0.18 of RMSE
- High errors are seen around DOY 92 – DOY 213

Develop a machine learning model using support vector machines (SVM) and Singular Value Decomposition (SVD) to detect the occurrences of equatorial plasma bubbles

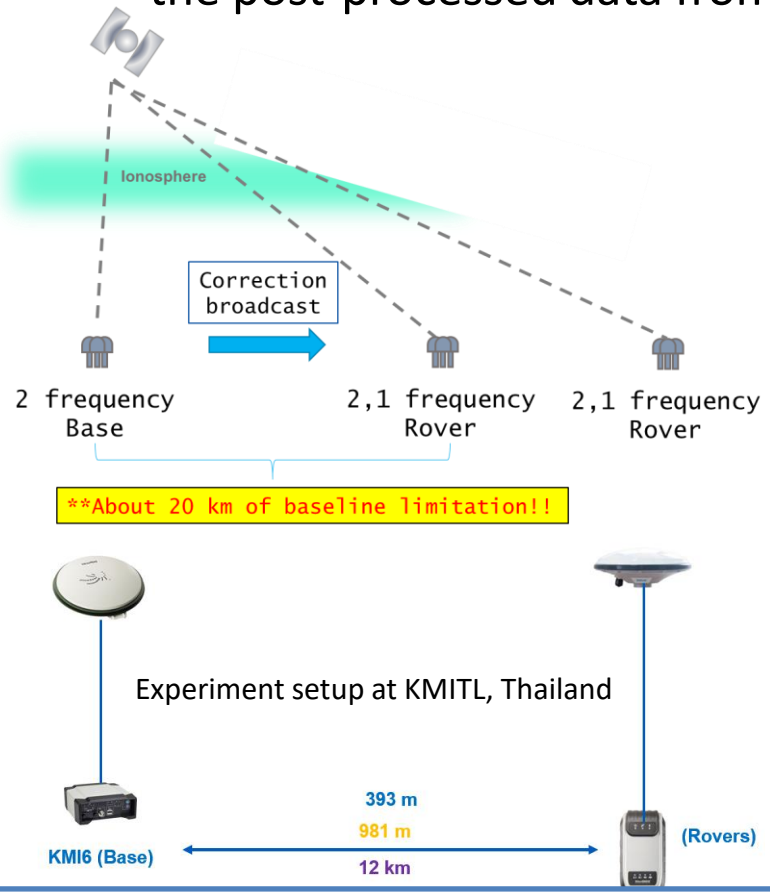


Accuracy Compare 4 Kernels	Accuracy of SVM model (%)	Accuracy of SVD+SVM model (%)
Linear	82.58%	83.05%
Sigmoid	62.77%	63.42%
Radial Basis Function	**86.67%**	**87.58%**
Polynomial Kernel	83.76%	84.47%

An SVM model using RBF Kernels provides the highest accuracy.

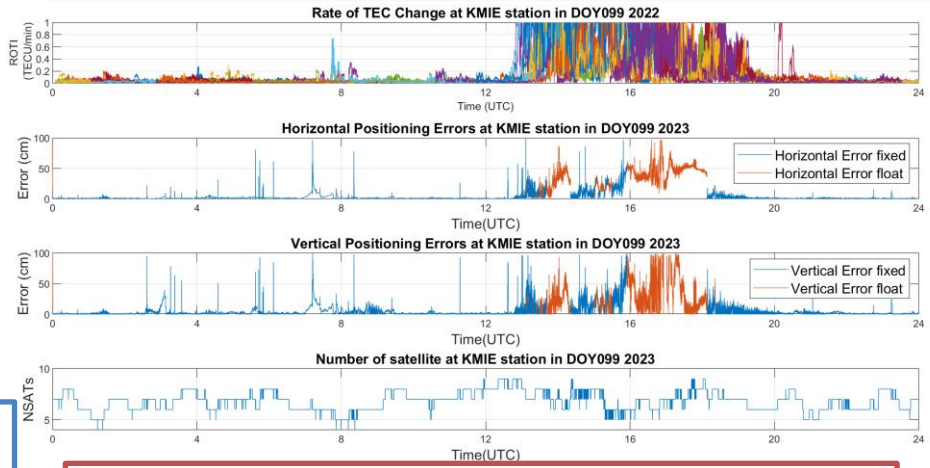
Project Activities:

C: To develop and test a real-time kinematics (RTK) positioning system using the post-processed data from the newly installed GNSS network.



Methods

- ✓ purchase low-cost RTK receiver systems.
- ✓ Upgrade Ntrip Caster software to conduct real-time RTK testing
- ✓ Test purchase RTK systems at different baselines at KMITL (due to time constraints).



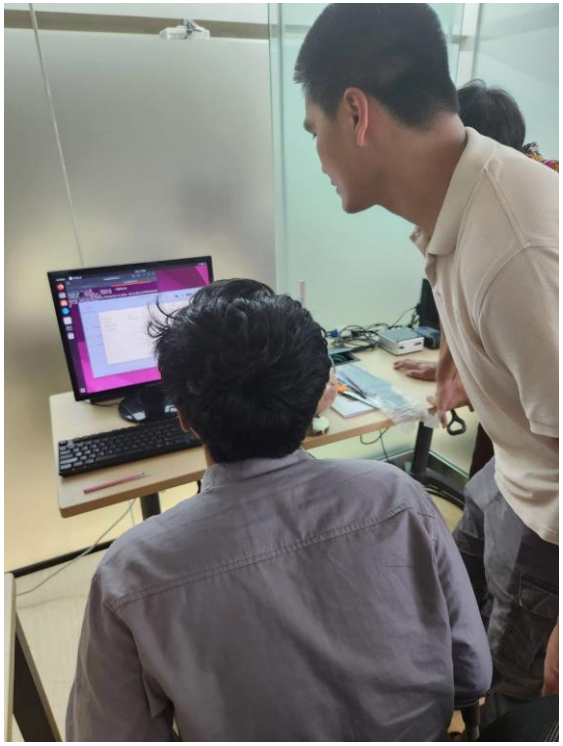
New BKG Ntrip Caster Software can provide TRK services using our receiver network as base stations through internet.

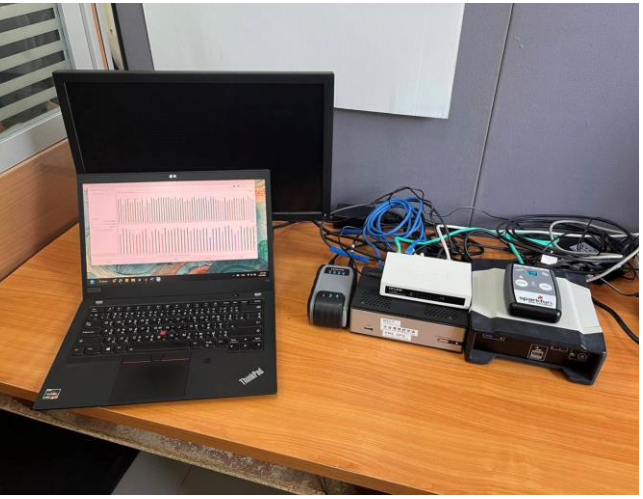
Found that significant impact of EPB events on RTK's accuracy performance

Budget: BKG Ntrip Caster Software: ~1084$ (in 2023) + 4 portable RTK receiver sets: ~8000$ (in 2023)

Project Activities:

C: To develop and test a real-time kinematics (RTK) positioning system using the post-processed data from the newly installed GNSS network.



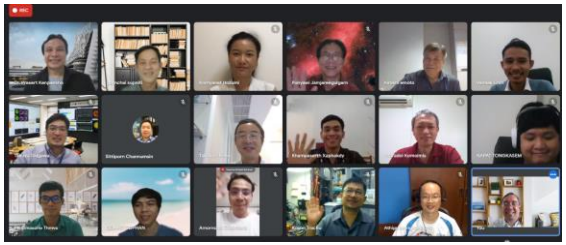


RTK Experiments at KMITL

Project Activities:
D: Capacity Building and Knowledge Sharing

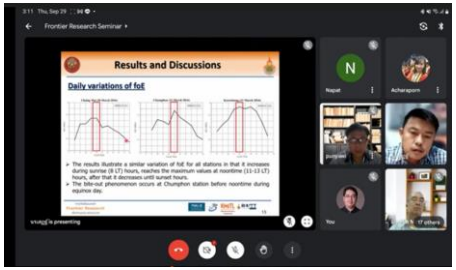
No.	Activity	Mode/Location	Date	# Participant
1	Project Kick-Off Meeting and Technical Workshop	Online	July 29th, 2021	35
2	GNSS & S/W Training Workshop	Onsite, at CADT in Cambodia	July 21st, 2022	20
3	PMU-B Frontier Research & ASEAN-IVO Seminar	Hybrid, at KMITL in Thailand	Sept. 29th, 2022	40

Project Kick-Off Meeting and Technical Workshop



GNSS & S/W Training Workshop at CADT

PMU-B Frontier Research & ASEAN-IVO Seminar



Scientific Contribution:

Published Journal Papers:

No:	Paper title:	Author names	Affiliation	Journal name:	The publisher of the Journal	The volume number and Pages
1	Analysis of local geomagnetic index under the influence of equatorial electrojet (EEJ) at the equatorial Phuket geomagnetic station in Thailand	L.M. M. Myint, K. Hozumi S. Saito P. Supnithi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan ENRI, NIMPAT, Tokyo, Japan	Advances in Space Research	Committee on Space Research (COSPAR)	Vol. 70, No. 5, 1 September 2022, pp 1429-1440
2	Simultaneous equatorial plasma bubble observation using amplitude scintillations from GNSS and LEO satellites in low-latitude region	K. Seechai L.M. M. Myint, K. Hozumi M. Nishioka S. Saito M. Yamaoto P. Supnithi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan ENRI, NIMPAT, Tokyo, Japan Kyoto University, Uji, Kyoto, Japan	Earth, Planets and Space	Springer Open	Vol 75, No. 127, 23 August 2023, pp https://doi.org/10.1186/s40623-023-01877-6

Budget: Article Publishing Charge: 2600$ (in 2022)

Scientific Contribution:

Presentations at International Conferences:

No:	Paper title:	Author names	Affiliation	Conference name:	The date of the conference	The venue of the conference
1	Equatorial Plasma Bubble detection by Support Vector Machine at Chumphon Station, Thailand	T.Thanakulketsarat, P. Supnithi, L. Myint, K. Hozumi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	2022 37th ITC CSCC	05-08/07/2022	Duangjitt Hotel, PHUKET, THAILAND
2	Comparison study of amplitude scintillation between GNSS and satellite beacon receivers in Thailand	K. Seechai L. Myint, K. Hozumi P. Supnithi,	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	2022 37th (TC CSCC	05-08/07/2022	Duangjitt Hotel, PHUKET, THAILAND
3	Support Vector Machine (SVM) for equatorial plasma bubble detection from VHF Radar Images at Chumphon VHF Radar Station, Thailand	T.Thanakulketsarat, P. Supnithi, L. Myint, K. Hozumi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	ISEA-16	12-16/09/2022	Uji Campus, Kyoto University, Kyoto, Japan
4	Time Series Prediction of the Equatorial Spread-F Occurrence using the LSTM network	P. Thammavongsy, P. Supnithi, L. Myint, K. Hozumi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	ISEA-16	12-16/09/2022	Uji Campus, Kyoto University, Kyoto, Japan
5	Study of Equatorial Geomagnetic Field Activities and its Relationship with Ionospheric disturbances at Low-Latitude	L. Myint, K. Seechai, K. Hozumi, P. Supnithi,	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	ISEA-16	12-16/09/2022	Uji Campus, Kyoto University, Kyoto, Japan

Scientific Contribution:

Presentations at International Conferences:

No:	Paper title:	Author names	Affiliation	Conference name:	The date of the conference	The venue of the conference
6	Near Real-time Equatorial Plasma Bubble Monitoring System using GNSS at the Low Latitude Region in ASEAN	N. Tongkasem, L. Myint, P. Supnithi, K. Hozumi D. Lakanchanh T. Nhem	KMITL, Bangkok, Thailand NICT, Tokyo, Japan NUOL, Vientiane, Laos CADT, Phnom Penh, Cambodia	URSI GASS 2023	19-26/8/2023	Sapporo Convention Center, Sapporo, Japan
7	Effects of Equatorial Plasma Bubbles over Real-Time Kinematic Positioning in Low-Latitude Region	P. Thu, P. Supnithi, L. Myint, J. Budtho	KMITL, Bangkok, Thailand	ION GNSS+ 2023	11-15/9/2023	Hyatt Regency Denver, Colorado
8	Comparative Study of the Equatorial Plasma Bubbles using VHF Radar Images and Spatial ROTI Maps at Low-Latitude Region	N. Tongkasem, L. Myint, P. Supnithi, K. Hozumi	KMITL, Bangkok, Thailand NICT, Tokyo, Japan	ION GNSS+ 2023	11-15/9/2023	Hyatt Regency Denver, Colorado
9	Investigations of User Positioning Errors by Using Local DFMC SBAS Correction with Higher-Order Ionospheric Delay Mitigation in Thailand	S. Sophan, P. Supnithi, L. Myint,	KMITL, Bangkok, Thailand	IconSpace 2023	3-4/10/2023	DoubleTree Resort by Hilton Penang, Malaysia

Budget: Two Conferences: (registration Fees + transportation and accommodations fee) ~5930$ (in 2023)

Societal Impact:

Data product using ionospheric parameters and other relative data collected from GNSS receiver, Ionosonde, VHF radar, and magnetometer can

- Enhance **understanding of ionospheric disturbance** in **magnetic equator and low-latitude region**, particularly, ASEAN region.
- Be useful in detecting ionospheric disturbances and geomagnetic storms for **aviation and HF communications**, prevalent, in aviation and communications in a disaster situation.

Better disturbance characterization is required to determine performance of **high-accuracy GNSS systems** used in other industries such as smart agriculture and autonomous driving.

Regional data collection is important for long-term study and is useful to **global model improvement** (such as IRI model and IGS model).

The researchers from the partnered institutes in Cambodia and Laos are encouraged to work on **joint research** with the data collected for local communities.

Conclusion:

- The project has accomplished installing the GNSS receiver system in CADT, Phnom Penh, Cambodia.
- The GNSS data from the new station is available and they are being analyzed to observe the ionospheric disturbances.
- The data products for ionosphere observation such as TEC and ROTI 2-D plots and maps have been modified to include the new stations from Laos and Cambodia.
- We maintained and upgraded daily ionospheric data products such as S4 index plots, MUF maps, and K-index for Communications and Aviation. We also developed AI and machine learning models to analyze and predict ESF and EPB using the measured data from Ionosonde and the newly installed VHF radar in Chumphon, Thailand.
- We conducted RTK experiments using a new Ntrip Castering software at KMITL.
- We have organized three workshops and seminars for capacity building and knowledge sharing.
- We will continue to implement EPB prediction using AI and applications of precise positioning RTK, collaborating with our project partner institutes with the facilities and equipment sponsored by this ASEN-IVO project.