ASEAN IVO FORUM 2025
Bangkok, Thailand

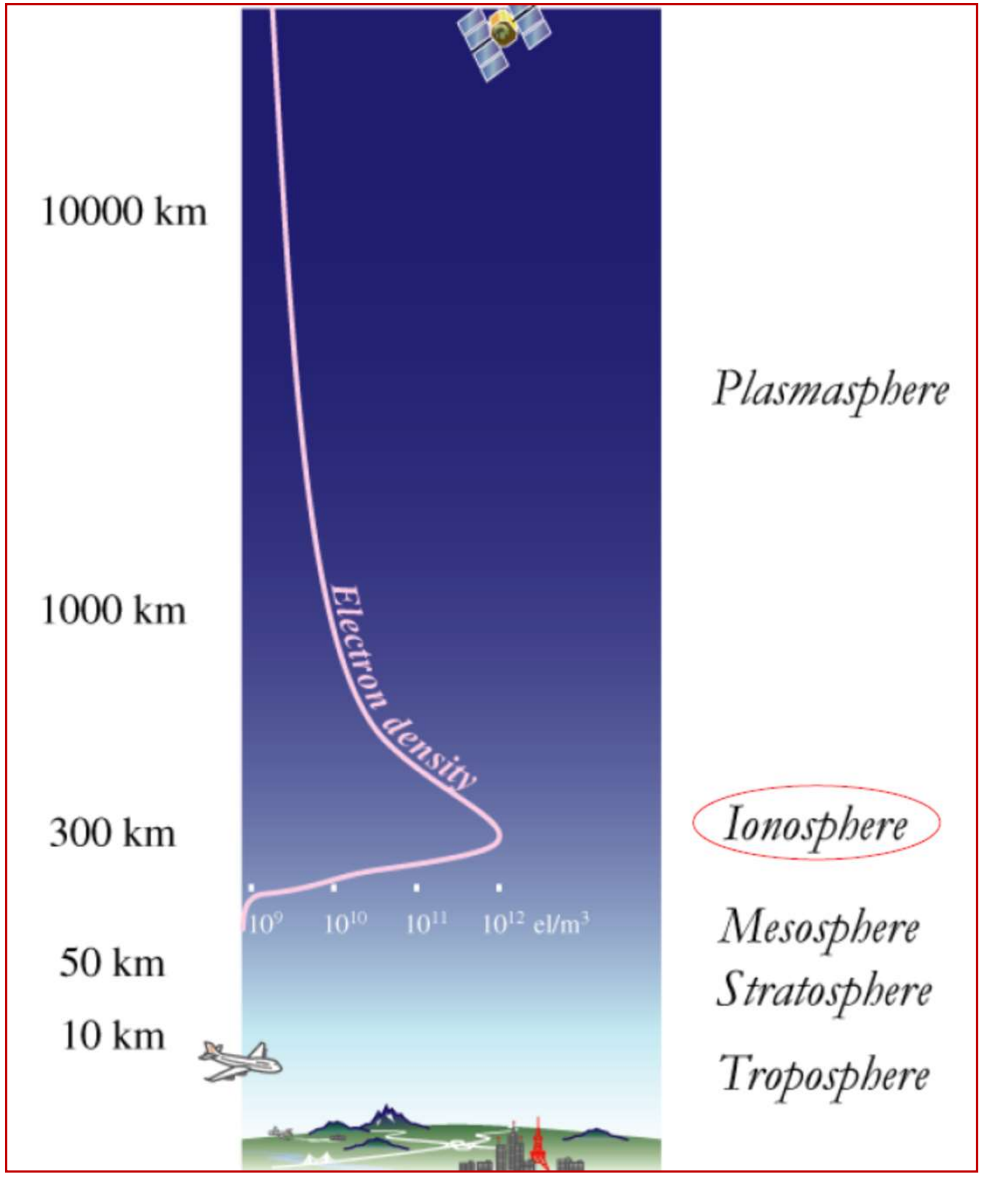
GNSS and Ionospheric Data Products for Disaster Prevention and Aviation in Magnetic Low-Latitude Regions (Phase I and II)

Presenter: Prof. Pornchai Supnithi

School of Engineering & Center of Excellence in GNSS and Space Weather

King Mongkut's Institute of Technology Ladkrabang, THAILAND

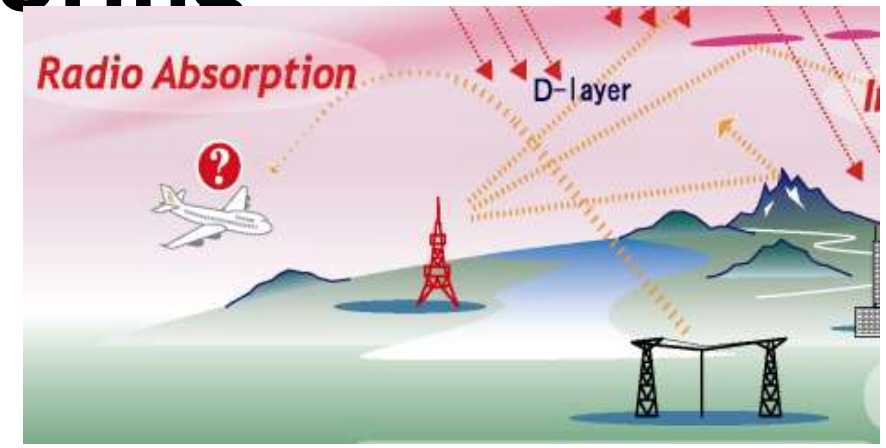
What is the ionosphere?

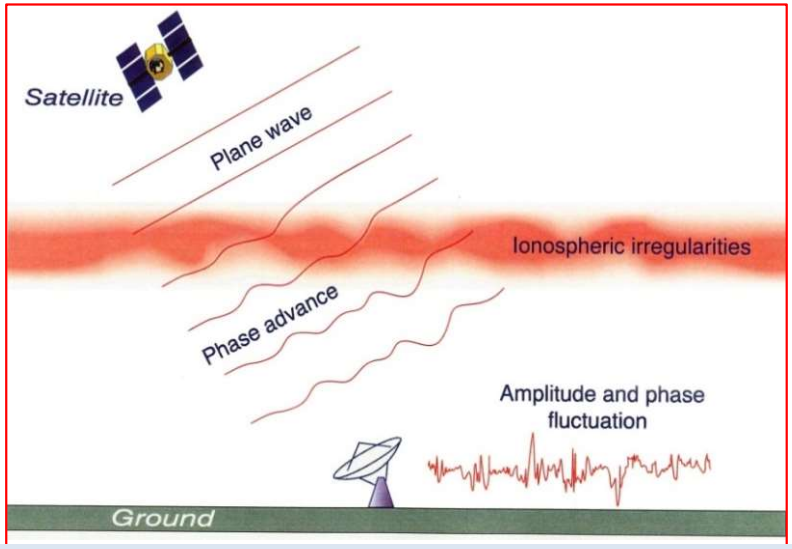


- The electron density also varies with time, location and solar activity.
- 50-1500 km height from the earth surface
- Ionized (electrons + ions) region which enhances the HF radio propagation (HF Band : 3-30 MHz)
- Free electrons and ions are due to extreme ultra violet (EUV) and X-ray

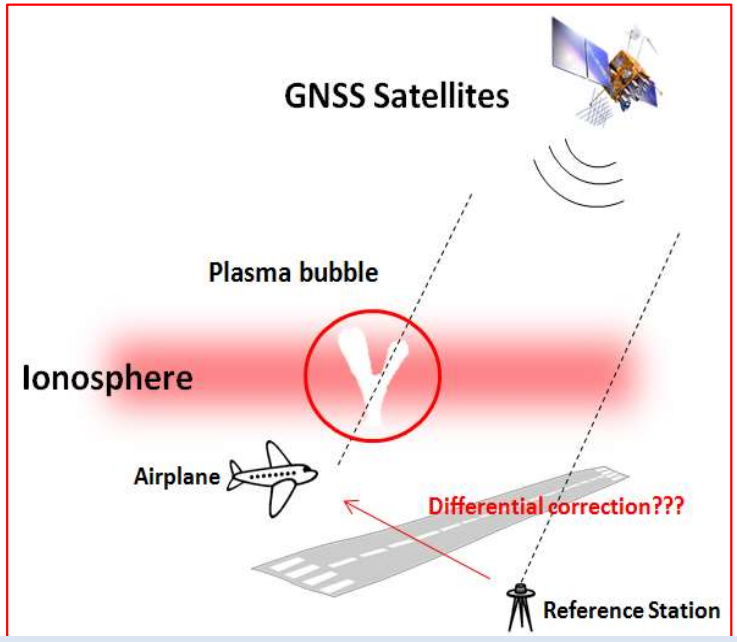
Iono Disturbance Effects & Monitoring

HF Communications in aircrafts, ships (commercial, military)
➔ Ionosonde, GNSS





Scintillations, Loss-of-lock in GNSS signals
➔ GNSS, Beacon



Navigation, Positioning
➔ GNSS, VHF Radar

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

Project Members : 5 Institutes from 4 countries

Party	Name	Party	Name
NICT, Japan	TSUGAWA Takuya	CMU, Thailand	Tharadol Komolmis
	HOZUMI Kornyanat	YTU, Myanmar	Win Zaw
KMITL, Thailand	Pornchai Supnithi	NUOL, Lao	Donekeo Lakanchan
	Watid Phakphisut		Phutsavanh Thogphanh
	Punyawi Jamjareegulgarn		Phouthong Southisombath

Project Duration : April 1st, 2019 - Mar 31th, 2021 (24 Months)

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 - September 30th, 2023 (24 Months)
Extended 6 months (April 1st, 2023- September 30th, 2023):

Project Information

Background :

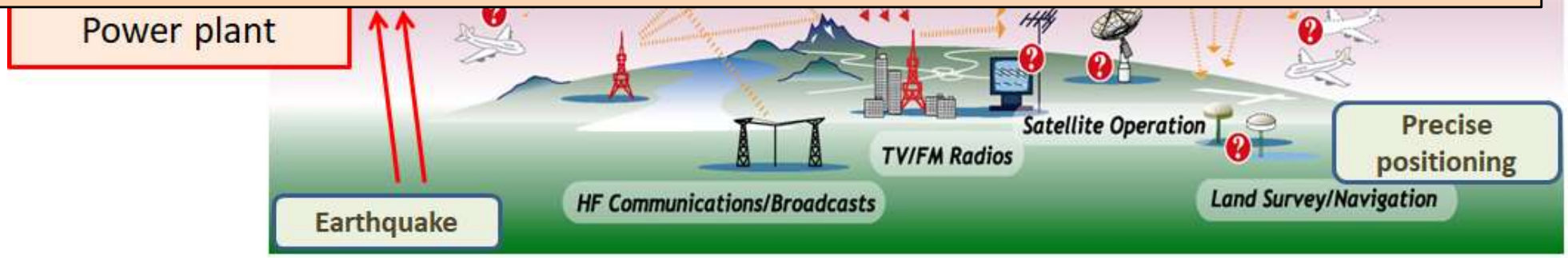
Ionospheric irregularity such as plasma bubble

➔ typically occurs after sunset due to the bottomside instability

➔ degrades HF communication, precise positioning and aeronautical navigation.

Targets:

1. Expand GNSS and ionospheric monitoring system in neighboring countries (Laos, Myanmar, Cambodia)
2. Daily GNSS data products for disaster prevention and aviation
3. Ionospheric data products and disturbance prediction models for disaster prevention and aviation
4. Support the Installation of a new VHF radar station at Chumphon campus, Thailand

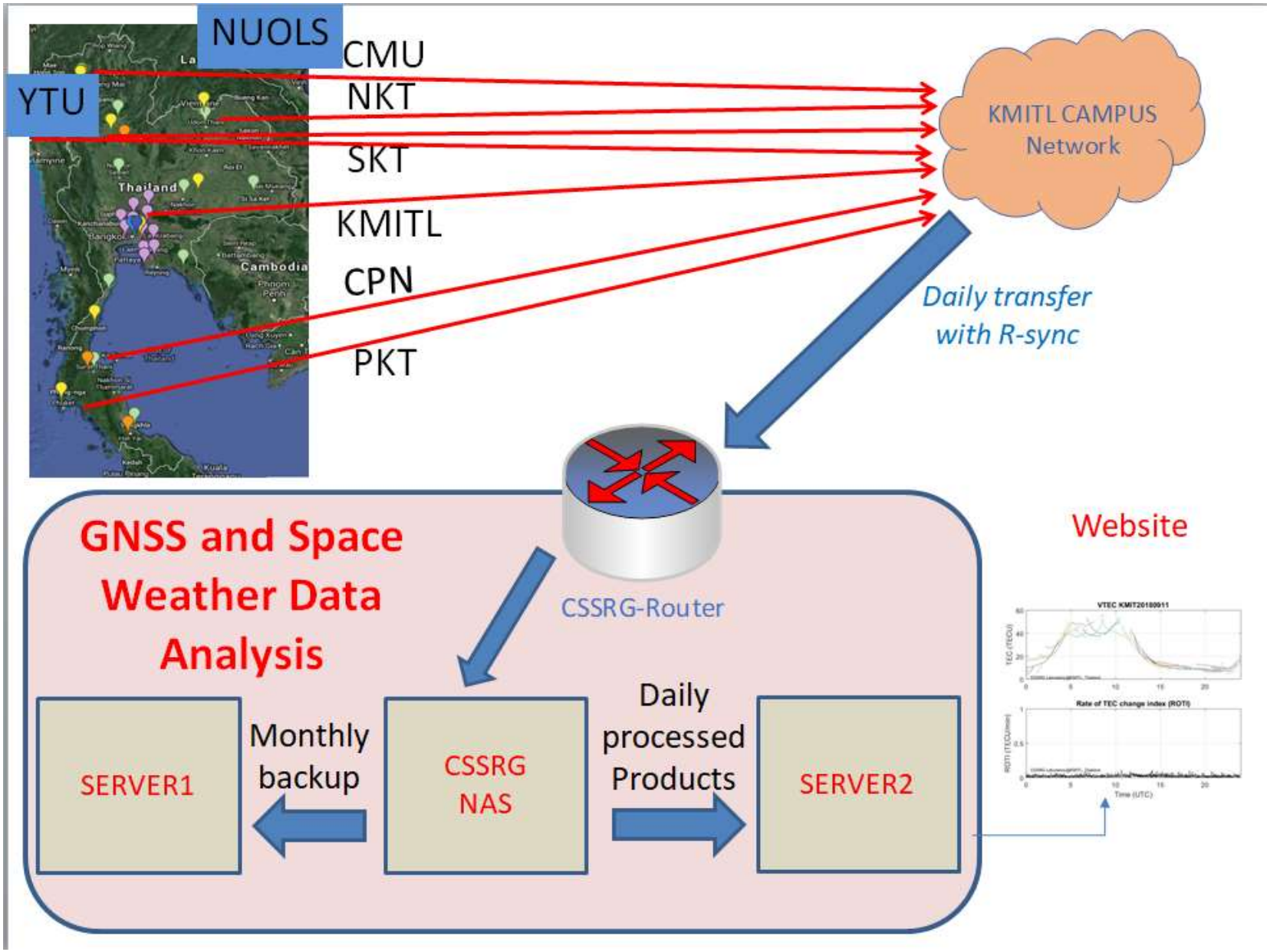


PHASE I

GNSS & space Weather Website: http://iono-gnss.kmitl.ac.th/?page_id=807

GNSS receiver

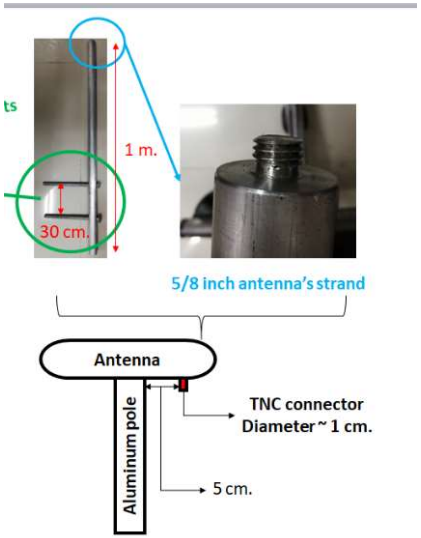
Ionosonde system



PHASE I

Expanded GNSS and ionospheric monitoring system (NUOL, YTU)

1. GNSS station at NUOL: Site survey ➔ NUOL

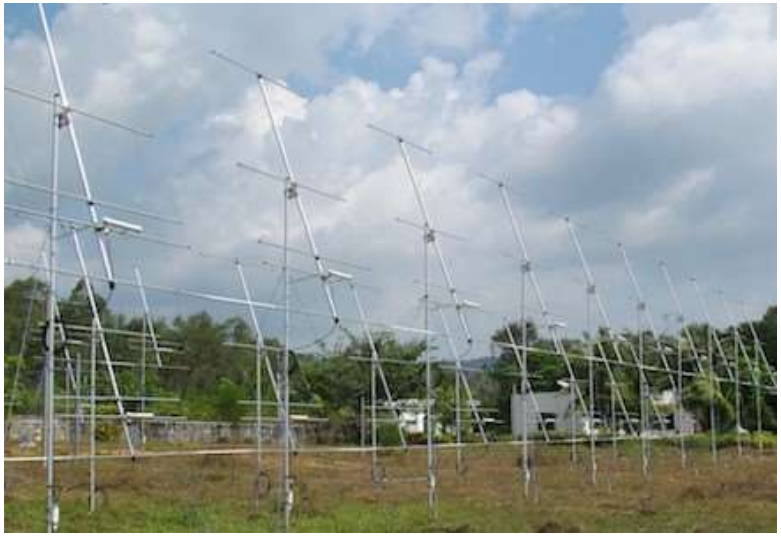


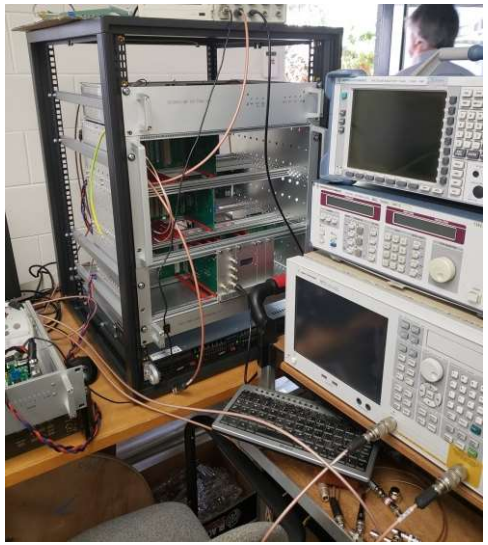
2. GNSS station at YTU (Mynamar): Site survey ➔ YTU

Unfortunately, after the political situation in Myanmar, this station was removed.

PHASE I

Chumphon International Radar Station:



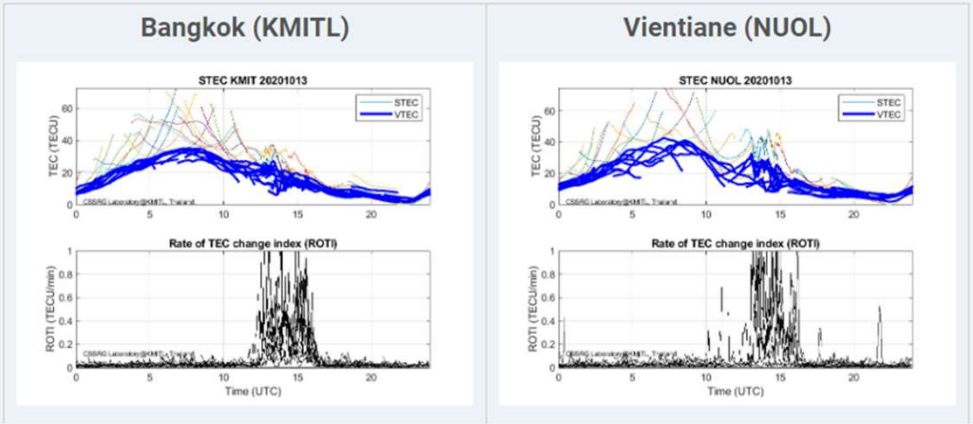


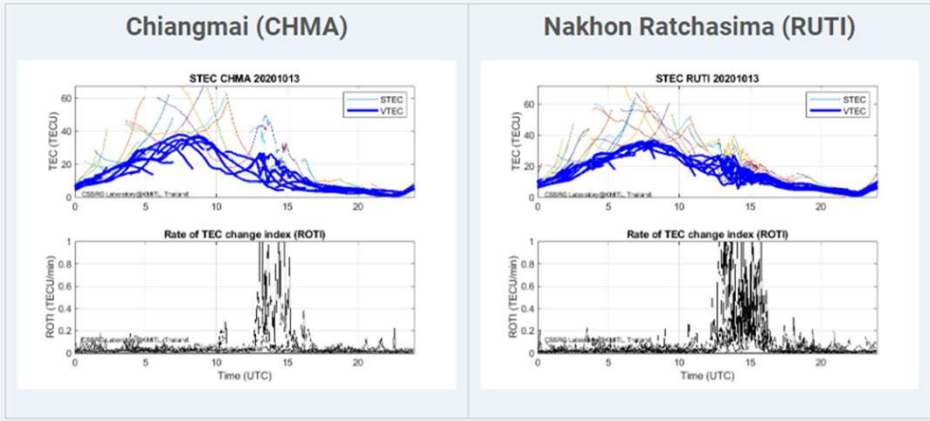
Additional budget:

~$600,000 (NICT)
~ $15,000 (KMITL)

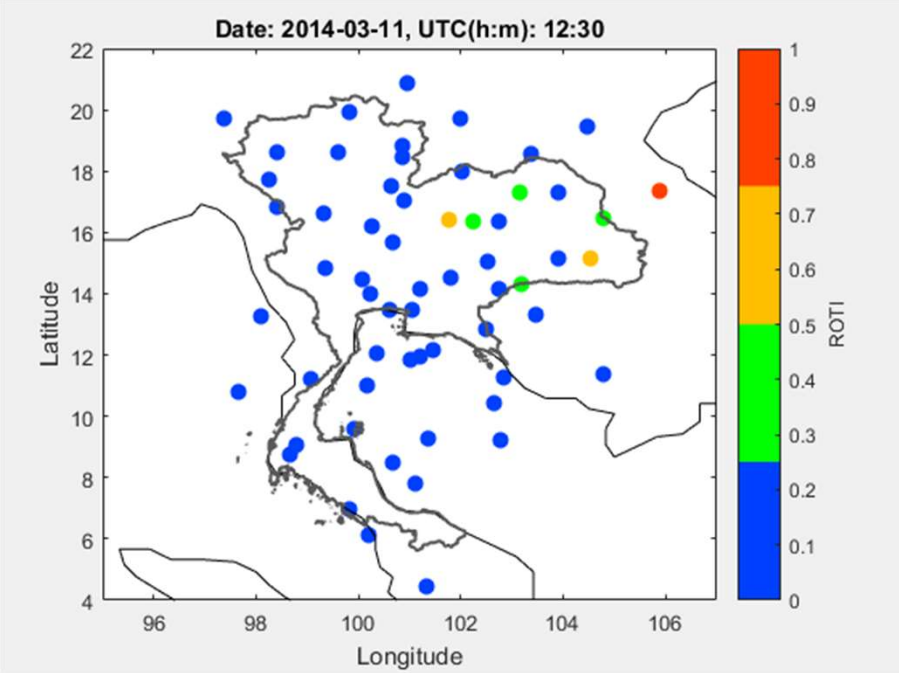
PHASE I

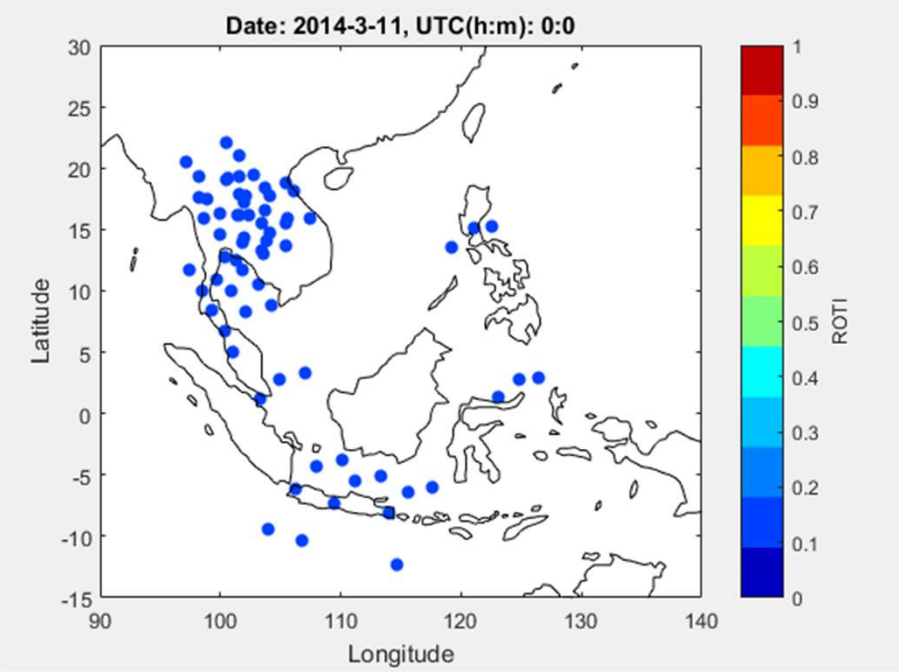
Daily TEC/ROTI Plots





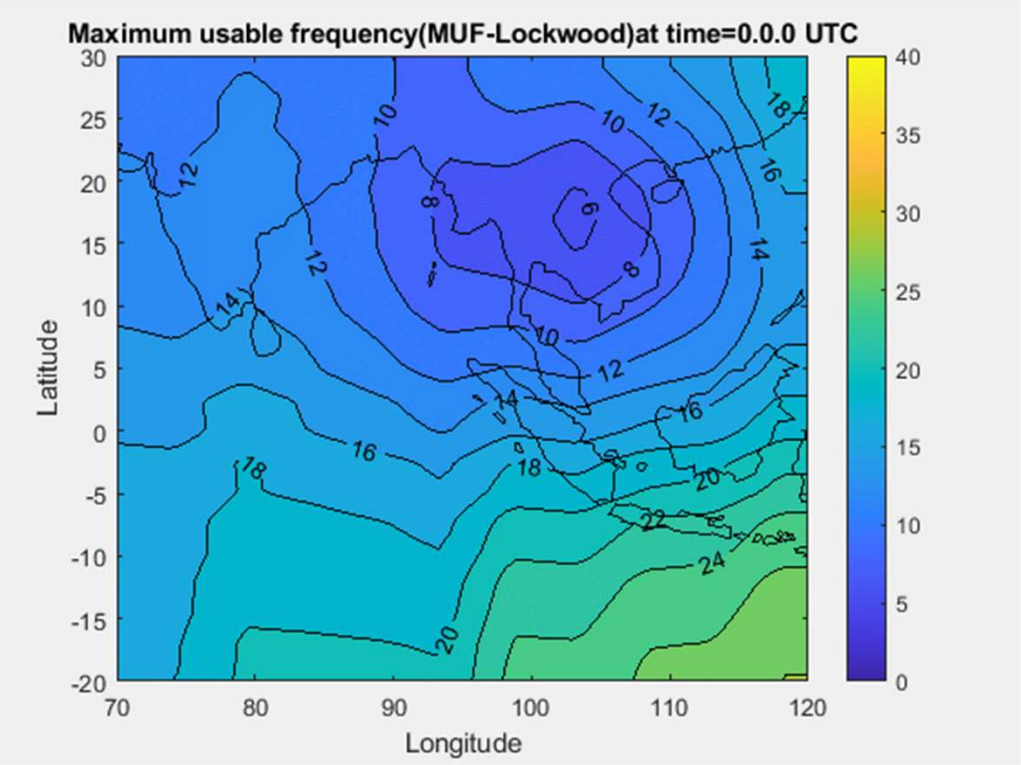
2-D ROTI Map



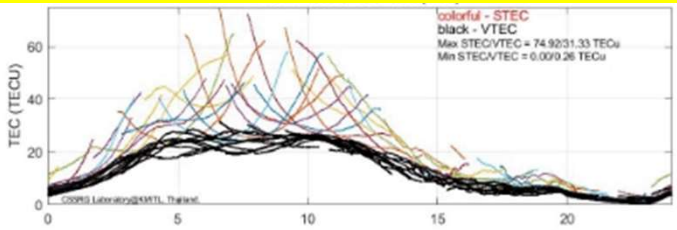


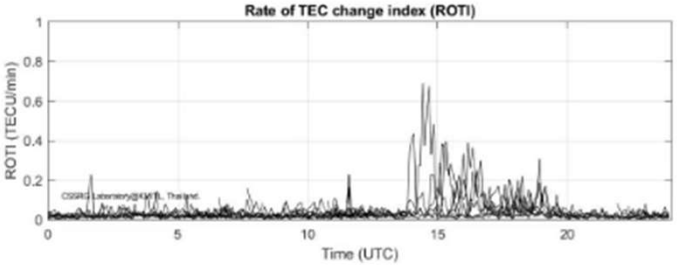
PHASE I

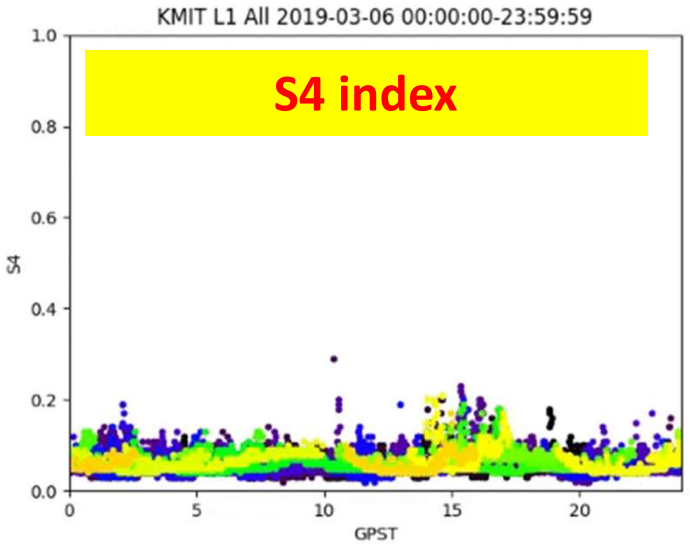
Maximum usable frequency (MUF) Map



TEC / ROTI Plots







 # days with scintillation (2019) = 47 days

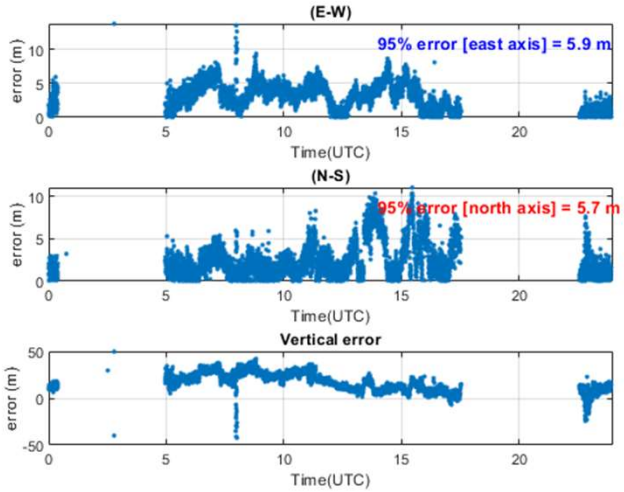
PHASE I

(Single positioning)

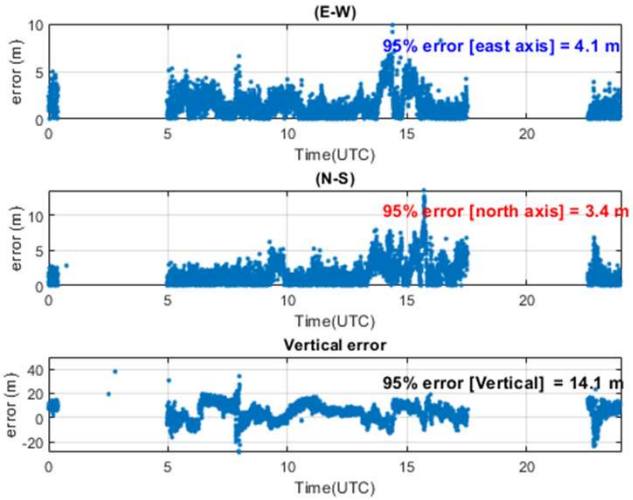
11 March 2018

Chiangmai

No correction



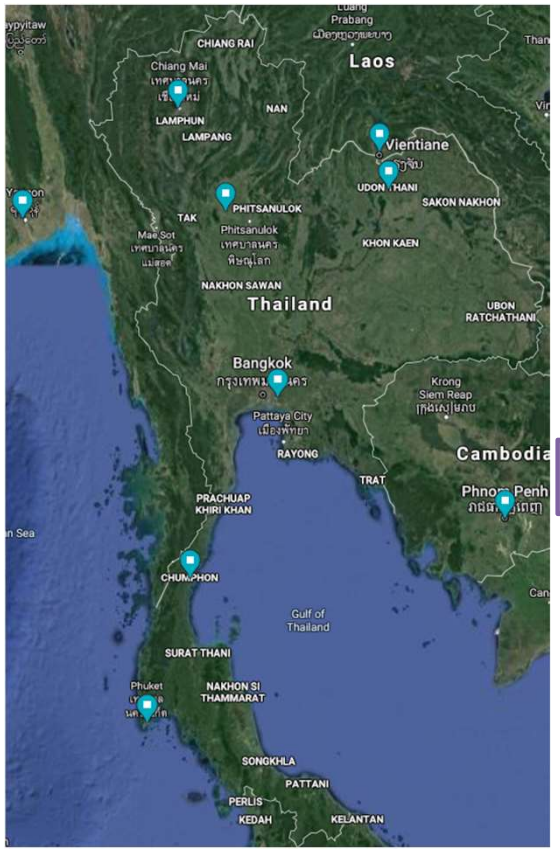
STEC correction



	No Corr.	STEC Correction	Correction (%)
Horizontal	5.7 m	3.8 m	**33.33 %**
North	5.7 m	3.4 m	**40.35 %**
East	5.9 m	4.1 m	**30.51 %**
Vertical	31.9 m	14.1 m	**55.80 %**
Mean			**40.00 %**

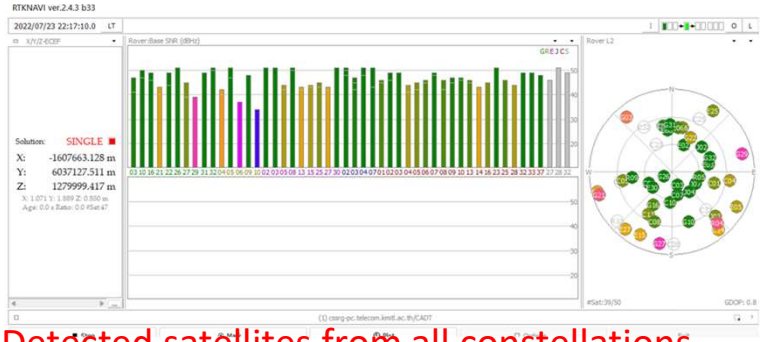
PHASE II

A: Expanding GNSS and Ionospheric Monitoring System into Cambodia

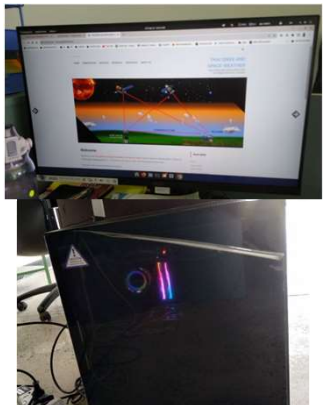


GNSS Antenna → GNSS receiver → Computer → KMITL Server

Checking satellites availability and received signal SNR

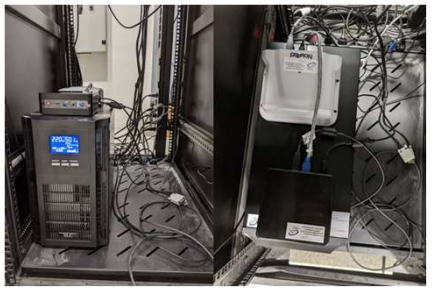


Detected satellites from all constellations



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.

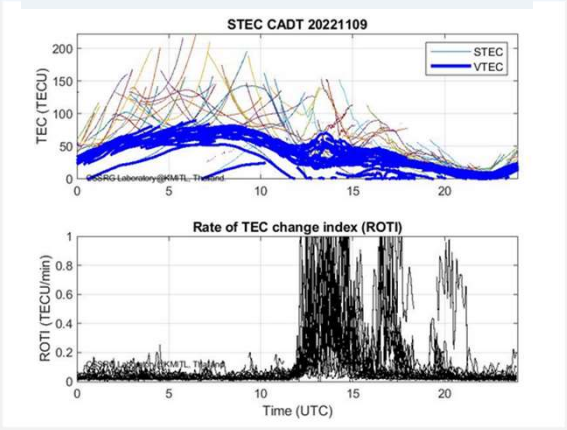
GNSS Receiver Set Installation in 2022 + CADT Desktop Computer for analysis in 2023

PHASE II

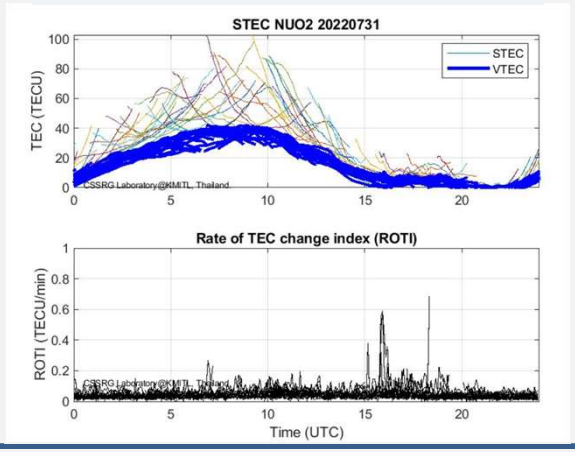
a) Modify daily GNSS data such as 2-D TEC maps, ROTI data products including the data from Laos, Cambodia

Daily Slant TEC (STEC) and ROTI Plots

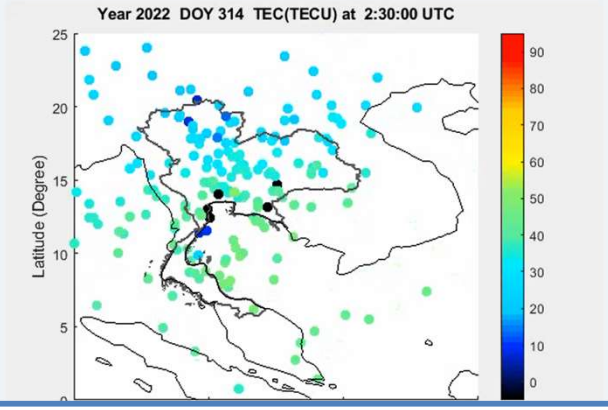
Cambodia (CADT)

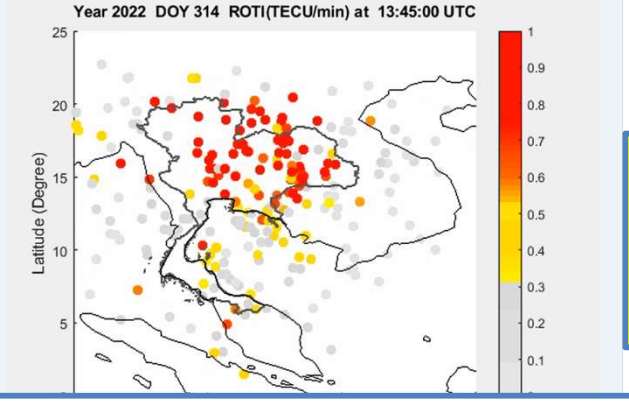


Laos (NUOL)



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





- ✓ Studied Ionospheric Variation using GNSS data from the new CADT station, Cambodia together with other stations.
- ✓ Extended the area of the ionospheric study with higher resolution of the TEC and ROTI maps using the data from newly installed 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

KMITL Server Upgrade to keep more data in 2022 (~5 GB/day) + NUOL SW Learning Center in 2023

PHASE II

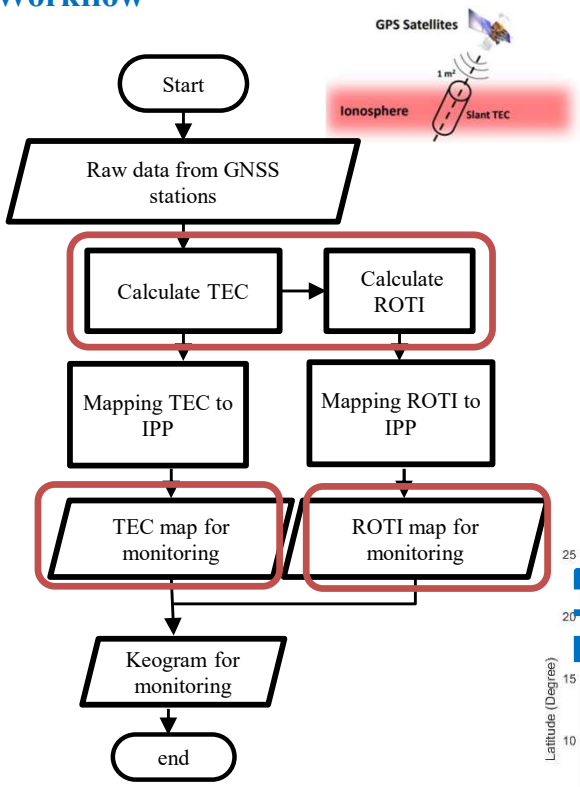
a) Modify daily GNSS data such as 2-D TEC maps, ROTI data products including the data from Laos, Cambodia

Observations using Keograms

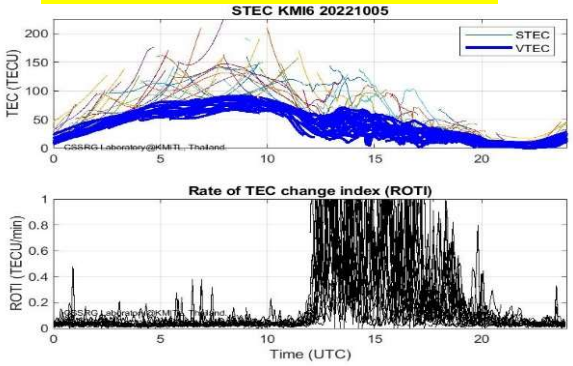
ROTI KEOGRAM

- ❑ the projections of vertical TEC values at each latitude/longitude against the time variable.
- ❑ are very helpful in monitoring the development of EPBs in their lifetime.

Workflow

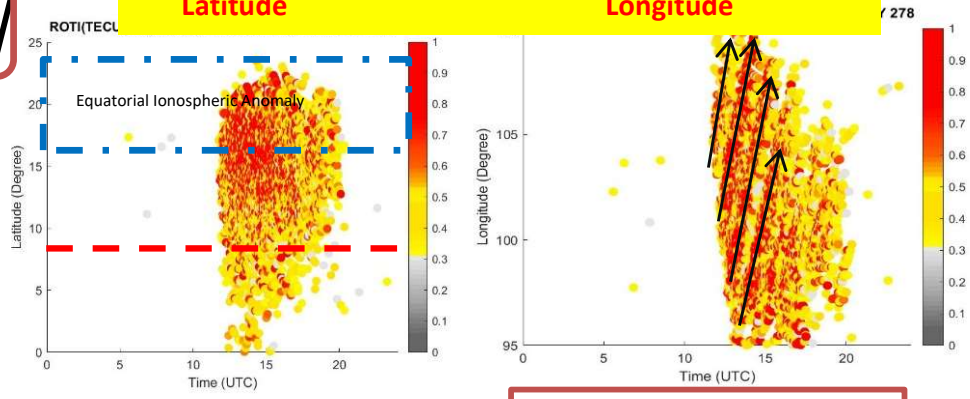


TEC and ROTI at Each Station



ROTI Keogram

Latitude **Longitude**



higher disturbances at higher latitudes

Forecast the EPB movement (Δlong/Δlat) = speed

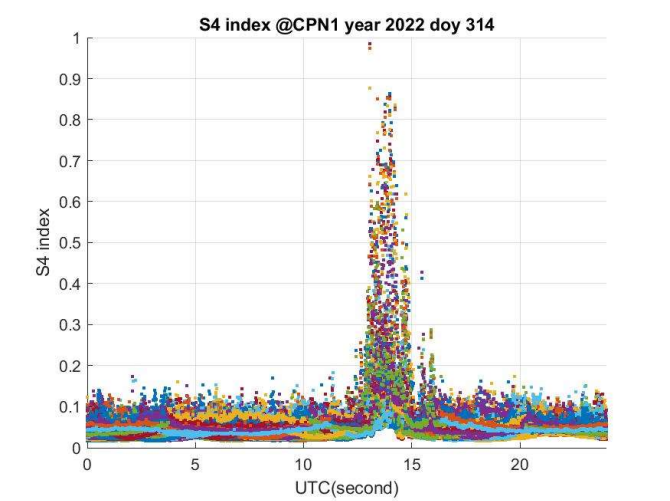
PHASE II

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

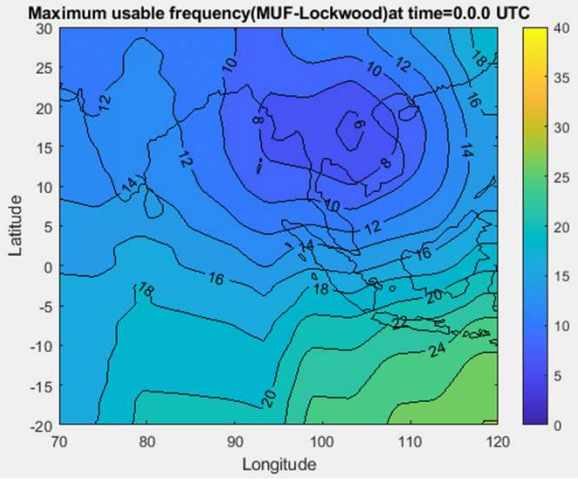
S4 index is used to measure the severity of scintillation (fluctuation) on GNSS or GPS signals.

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

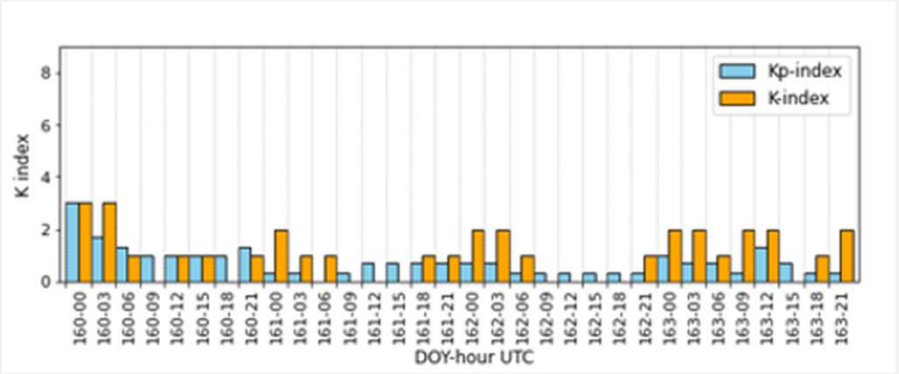
Daily S4 Index from Chumphon Station



Maximum usable frequency (MUF) Map



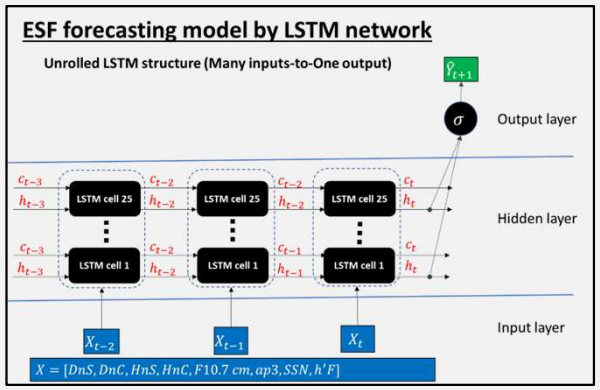
Local Geomagnetic K index from Magnetic Equator Phuket Station

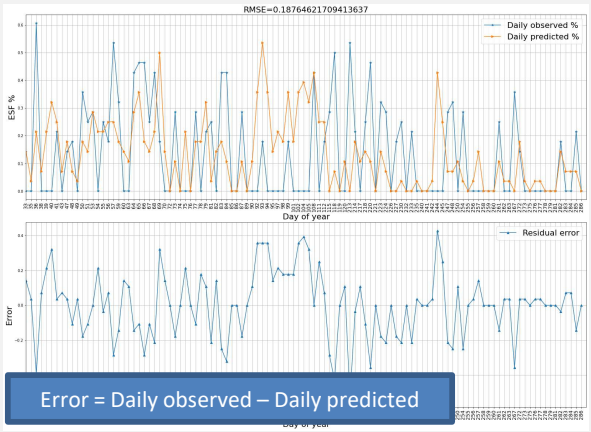


PHASE II

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)

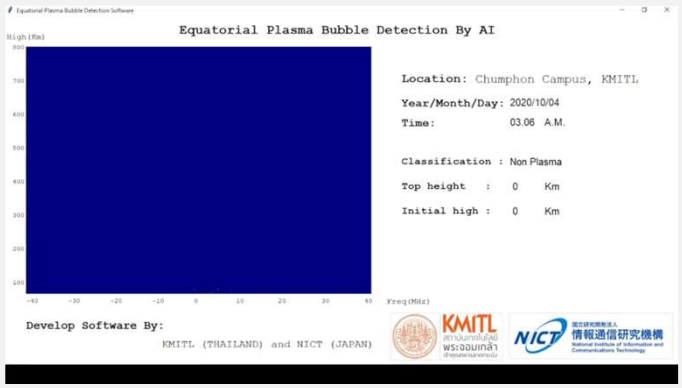




Prediction of the ESF daily percentage in 2019

- 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

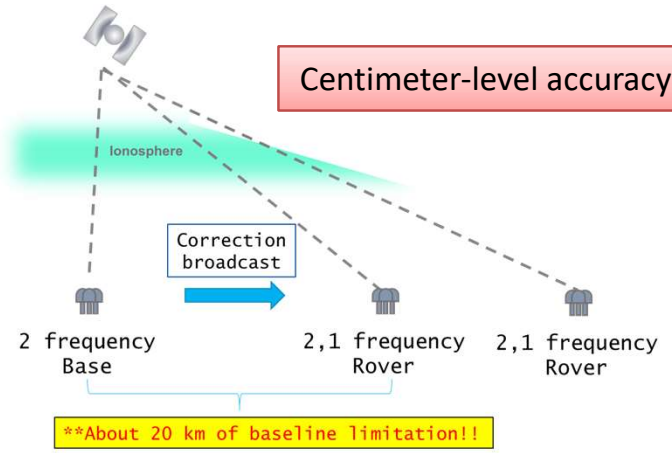


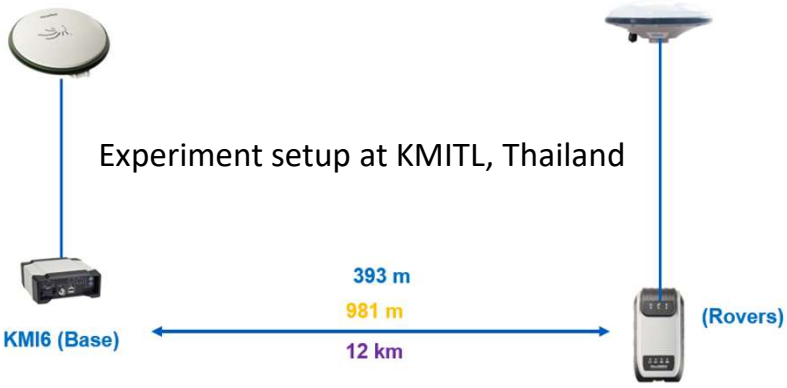
Compare 4 Kernels / Accuracy	Accuracy of SVM model (%)	Accuracy of SVD+SVM model (%)
Linear	82.58%	83.05%
Sigmoid	62.77%	63.42%
Radial Basis Function	**86.67%**	**87.58%**
Polynomial Kernel	83.76%	84.47%

An SVM model using RBF Kernels provides the highest accuracy.

PHASE II

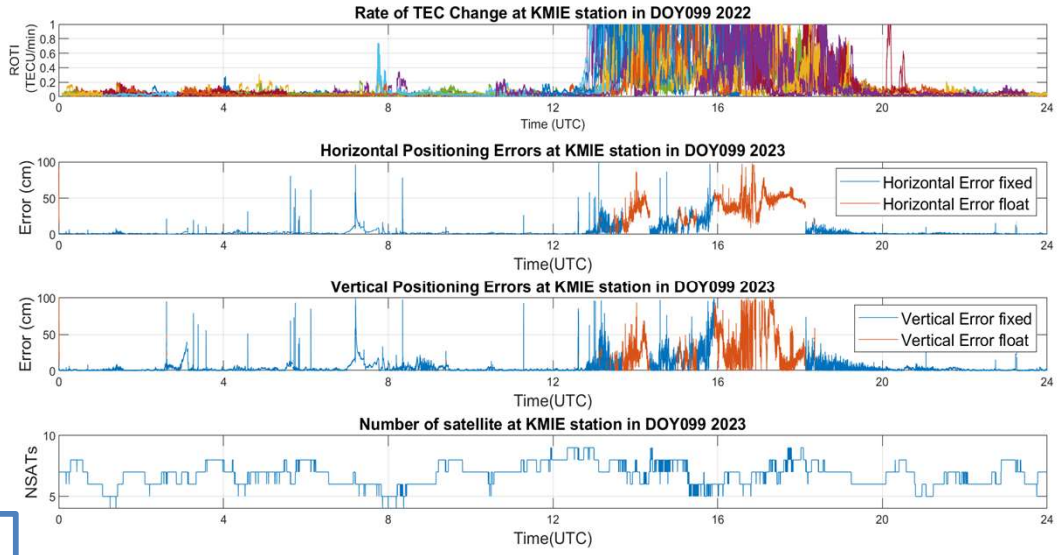
C: To develop and test a real-time kinematics (RTK) positioning system using the post-processed data from the newly installed GNSS network.





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).



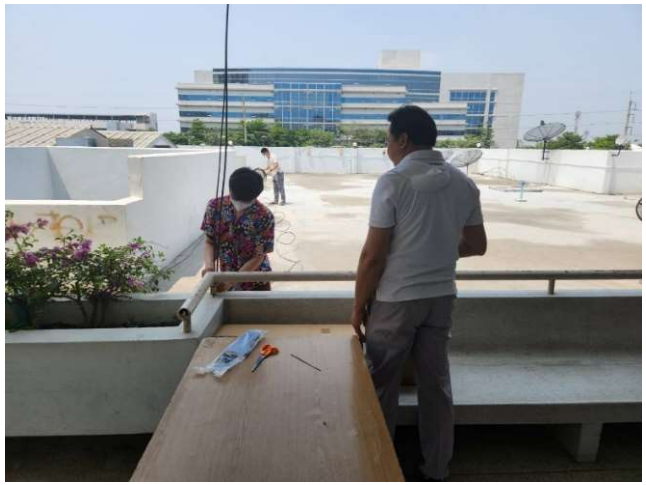
New BKG Ntrip Caster Software can provide TRK services using our receiver network as base stations through the internet.

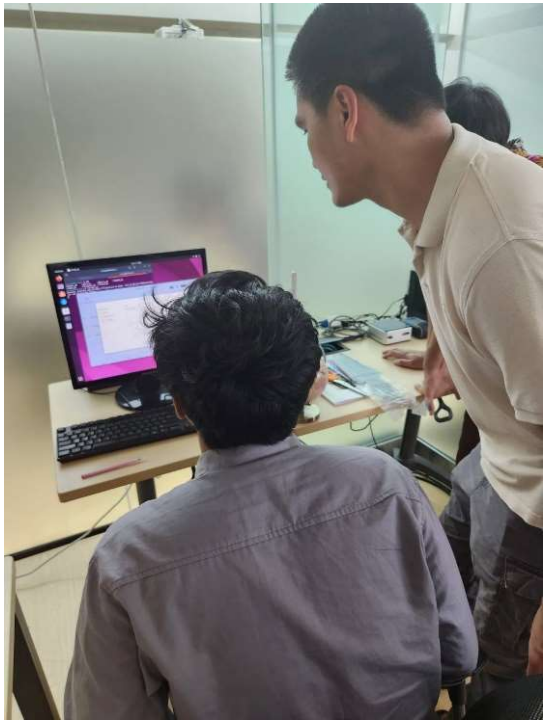
Found that significant impact of EPB events on RTK's accuracy performance

BKG Ntrip Caster Software upgrade in 2023 + 4 portable RTK sets in 2023 (To be continued in new project)

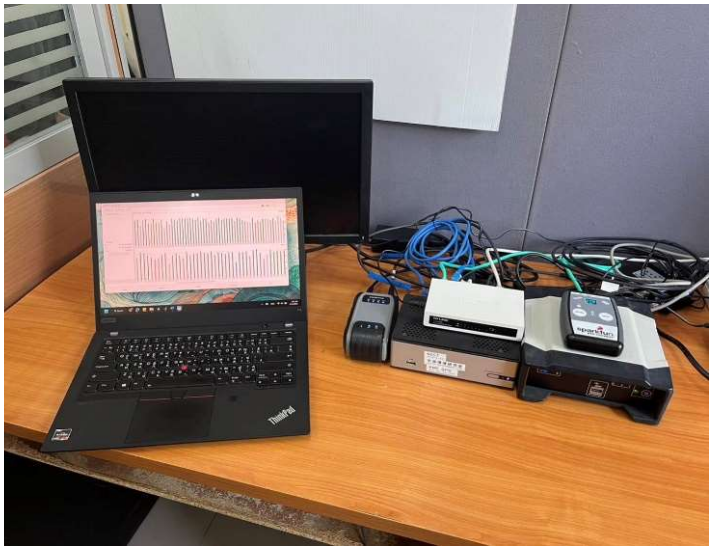
PHASE II

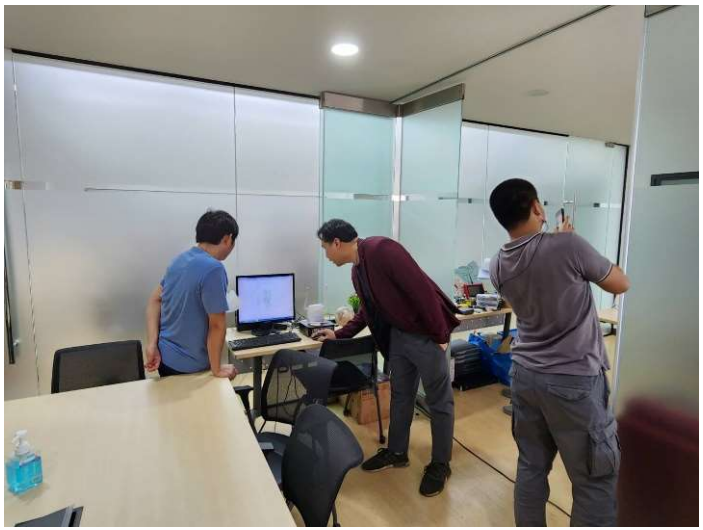
C: To develop and test a real-time kinematics (RTK) positioning system using the post-processed data from the newly installed GNSS network.





RTK Experiments at KMITL





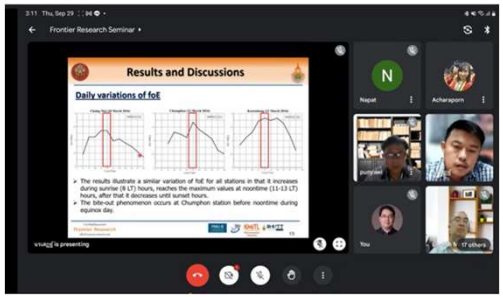
D: Meetings/Workshop

Kick-off Meeting @KMITL

Lab visit @KMITL

GNSS & S/W Training Workshop at CADT

PMU-B Frontier Research & ASEAN-IVO Seminar



Scientific Contribution:

Types	Amount
Conferences	15 papers/abstracts
International Journals (Q1)	3 papers

Societal Impact:

- Enhance **better understanding of ionospheric disturbance** **in magnetic equator and low-latitude region**, particularly, ASEAN region.
- Useful ionospheric disturbance detection for **aviation and HF communications**, prevalent, in aviation and communications in disaster situation, especially, along the coastal areas.
- Better disturbance characterization is required to determine performance of **high-accuracy GNSS system** used in other industries such as precisioned agriculture and autonomous driving.
- **Regional data collection** is important for long-term study and useful to **global model improvement** (such as IRI model and IGS model).

Thank You and Q/A

GNSS and Space Weather Information Center:

Center of Excellence in GNSS and Space Weather:

http://iono-gnss.kmitl.ac.th