United Nations Workshop on the International Space Weather Initiative

Vienna, Austria (26 – 30 June 2023)

Session 6: Space Weather Effects on Technology

Effects of Equatorial Plasma Bubbles on Performances of Real-Time Kinematics (RTK)

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

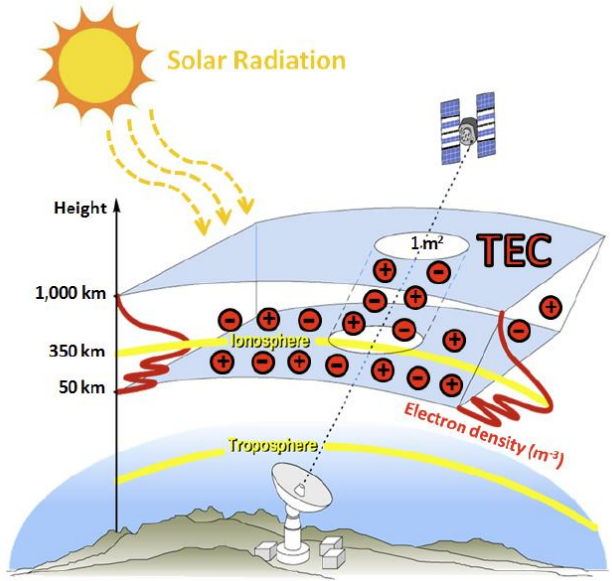
King Mongkut's Institute of Technology Ladrkabang (KMITL), THAILAND

Outline

- Introduction
- Equatorial Plasma Bubbles (EPB)
- Effects of EPBs on RTK Performances

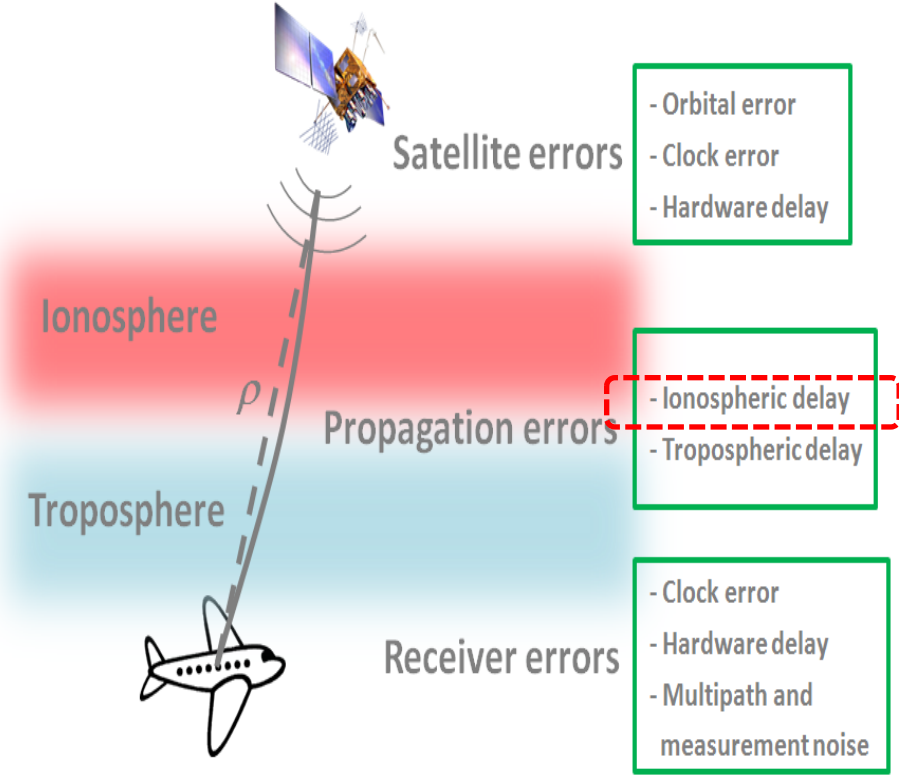
Equatorial Plasma Bubble (EPB) Phenomenon

Ionospheric Delay

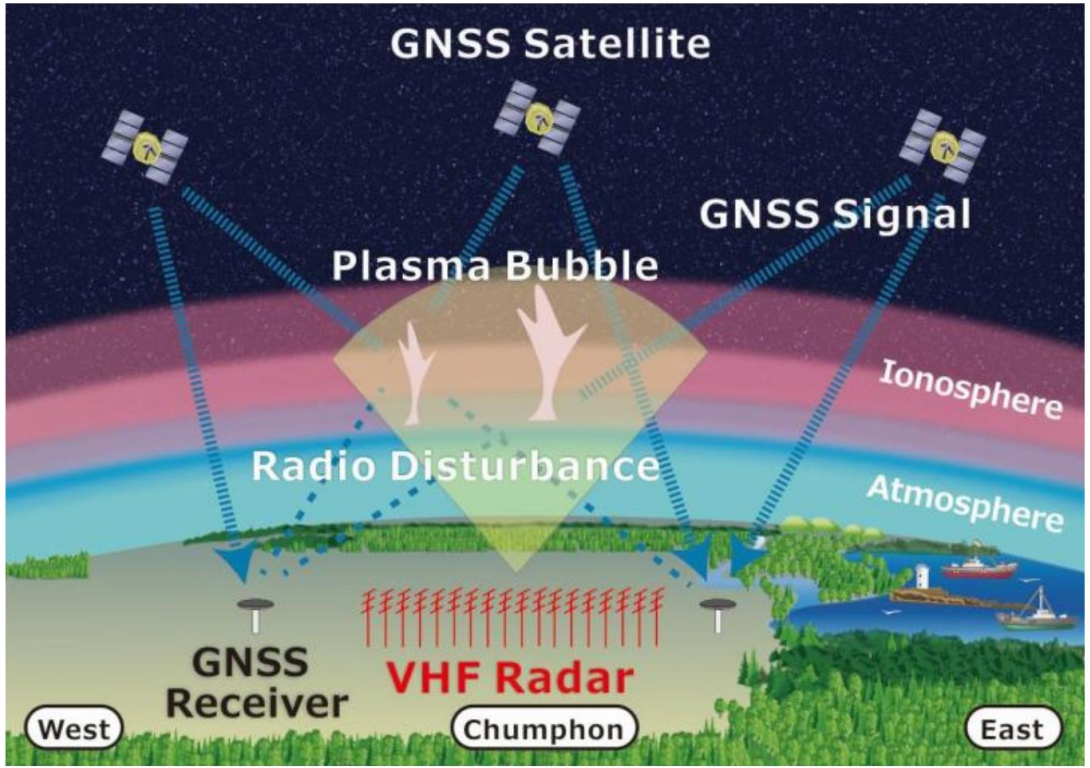


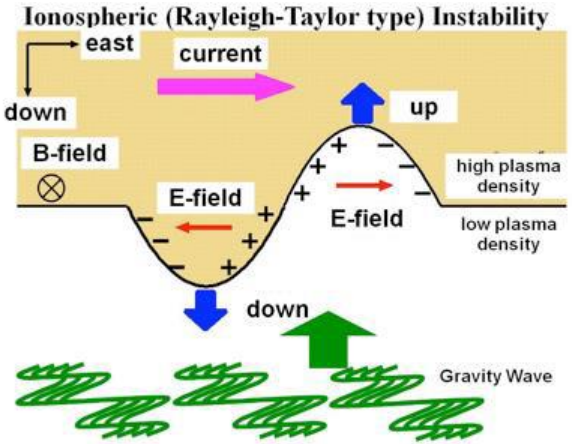
$$dTEC = \frac{40.3\ STEC}{f^2}$$

STEC = slant total electron content (el/m²)



Equatorial Plasma Bubbles (EPB)



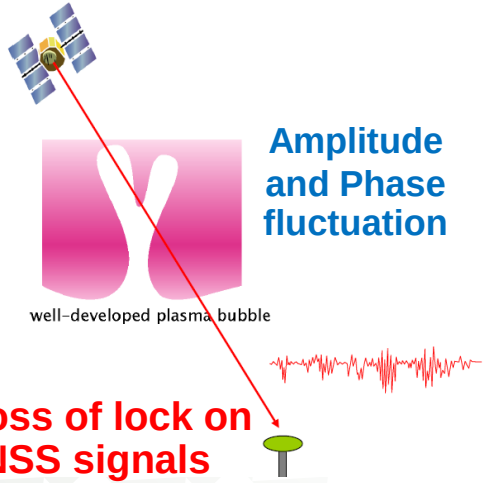


Local ionospheric disturbance

- driven by global disturbance (e.g. magnetic storms)
- local irregularity
- occurs after sunset, near magnetic equator

Effects of EPB

Scintillation

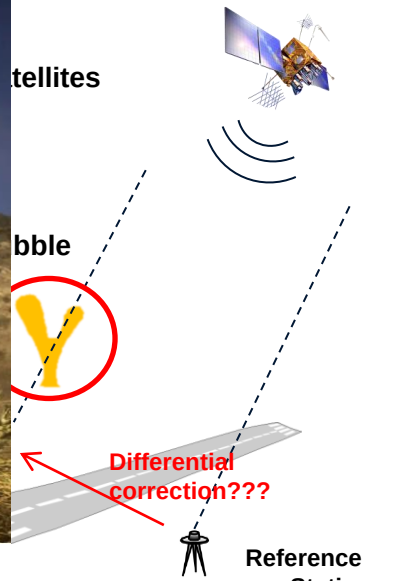


Amplitude and Phase fluctuation

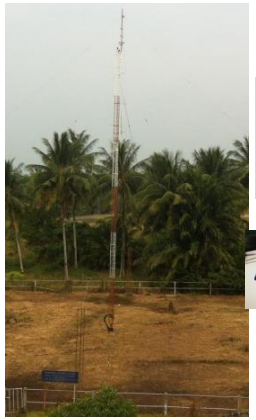
➔ Loss of lock on GNSS signals

VHF Comm.

tical navigation

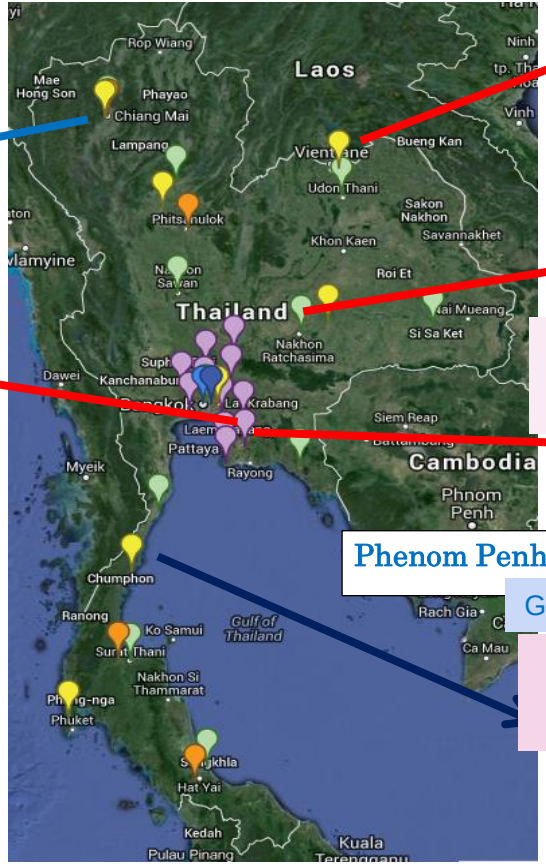


Research Facilities



Ionosonde
GNSS receiver
Beacon receiver

Chiangmai (CHM)



Vientiene (Laos)

GNSS receiver

Nakhon Ratchasima (NKR)

GNSS receiver

Bangkok (STFD)

GNSS receiver

Bangkok (KMITL)

GNSS receiver
Beacon receiver

Phenom Penh

GNSS receiver

Chumphon (CPN)

Ionosonde
GNSS receiver
Beacon receiver
VHF radar

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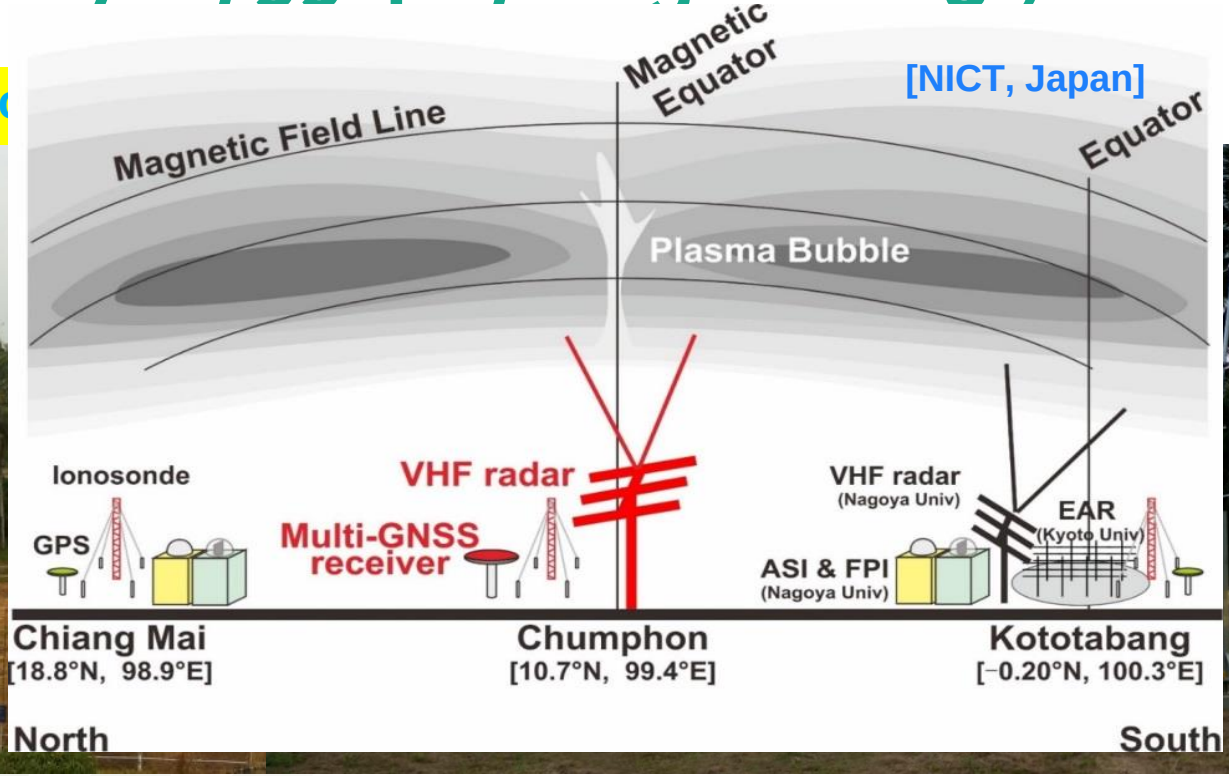
Chumphon observatory (10.7°N, 99.4°E, Magn. Lat. 3°)

[NICT, Japan]



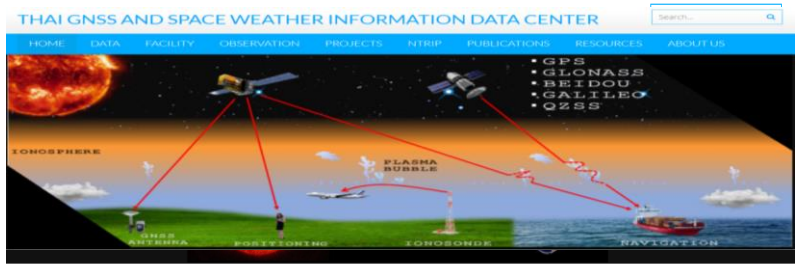
Magnetometer

Optical Sky Imager

GNSS receiver

Thai GNSS and Space Weather Information Center

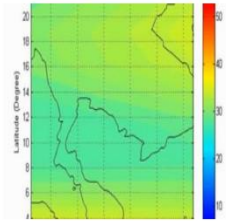
http://iono-gnss.kmitl.ac.th



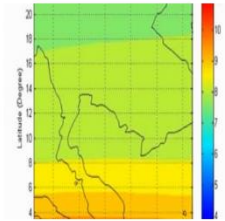
WELCOME

Welcome to the Thailand GNSS and Space Weather Information Data Center hosted at King Mongkut's Institue of Technology Ladkrabang (KMITL)

KNOWLEDGE



VTEC IRI MODEL



FOF2 IRI MODEL

ent status of GNSS and Ionospheric monitoring networks and the efforts to create a GNSS and Ionospheric database in Thailand. These data are the Ionosphere, Troposphere, GPS/GNSS technology, Geodesy and applications on the aeronautical navigation, satellite communication, ners. At present KMITL, Chulalongkorn University, Chaingmai University, NICT as well as Kyoto University, Japan have cooperated to install a itoring equipment such as Ionosondes, all-sky Imager, magnetometer as well as GNSS receivers in various locations of Thailand such as kok, and Phuket. Other GPS networks and Ionosonde stations exist, whereby each network is owned and operated independently. For example, s 11 stations, the Royal Thai Navy owns three Ionosonde stations, the Thai Meteorological Department houses 5-7 GPS receivers and the d owns 3-4 GPS receivers. We aim to create the database of GPS data and Ionospheric parameters in the Thailand location. In our plan, the data ong various universities and agencies is being foreseen. At present, Thai GNSS and Space Weather Information Data Center is collecting the data ell as the Ionosonde stations by using the script at each station to send the raw data through the Internet to the server at KMITL. The database is of TEC and enhances the study of the Ionosphere.

Center of Excellence in GNSS and Space Weather

Ionospheric Disturbances

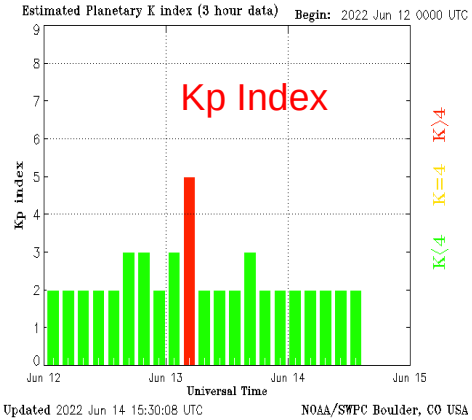
- The electron density in the ionosphere varies with time, location, and solar and geomagnetic activities

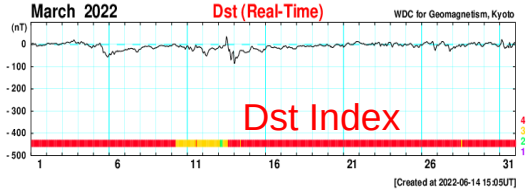
- **Global Condition (earth's geomatic activity)**
  - Kp - Planetary K-index
  - Dst – Disturbance Strom Time indices

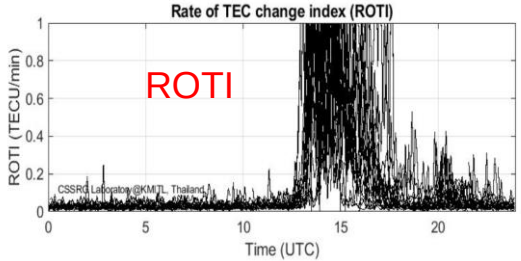
- **Local Ionospheric Conditions**
  - Rate of TEC Change Index (ROTI)

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

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

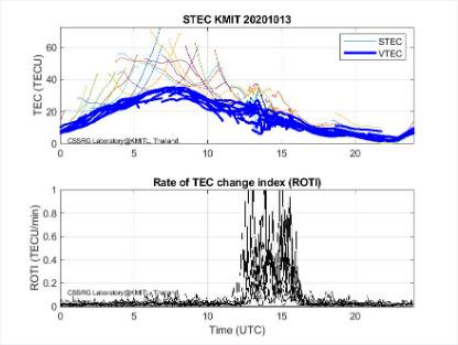




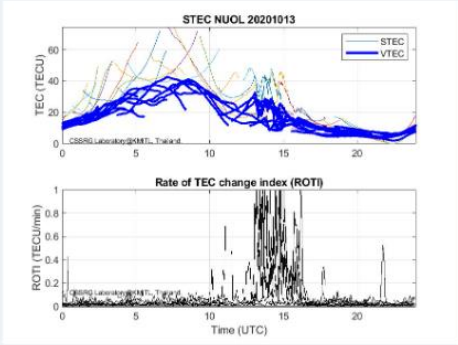


Daily TEC/ROTI Plots

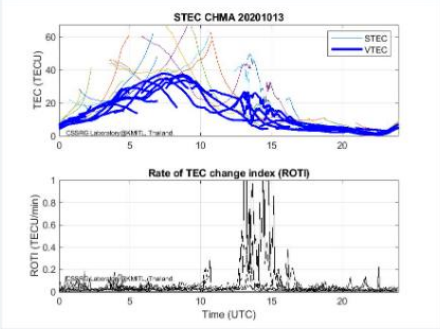
Bangkok (KMITL)



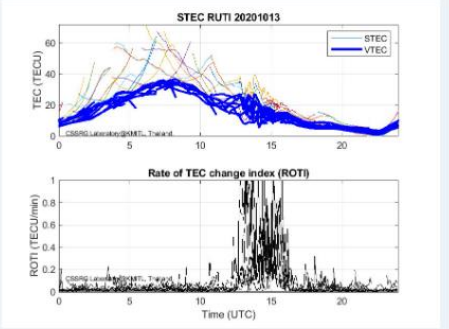
Vientiane (NUOL)



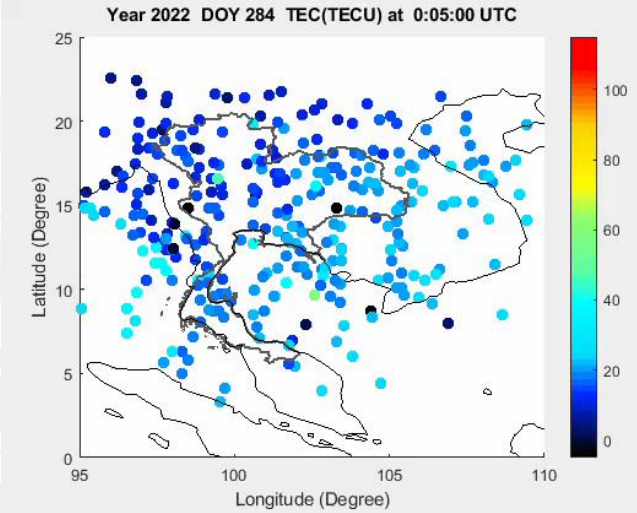
Chiangmai (CHMA)

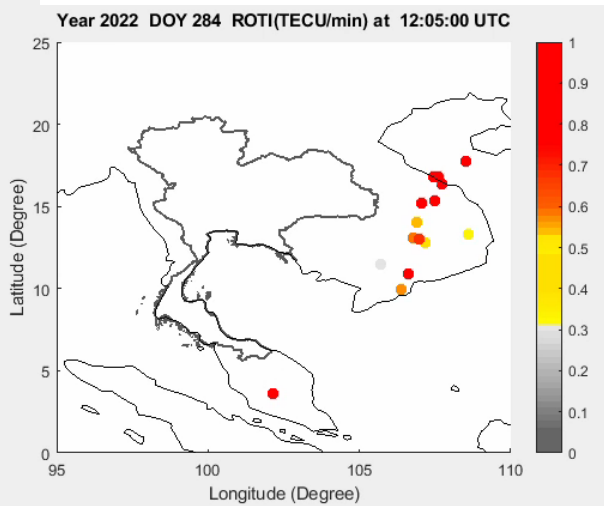


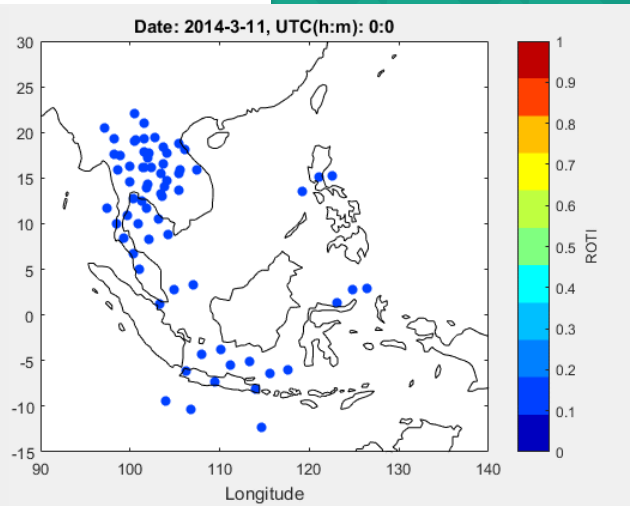
Nakhon Ratchasima (RUTI)



2-D TEC/ROTI Map



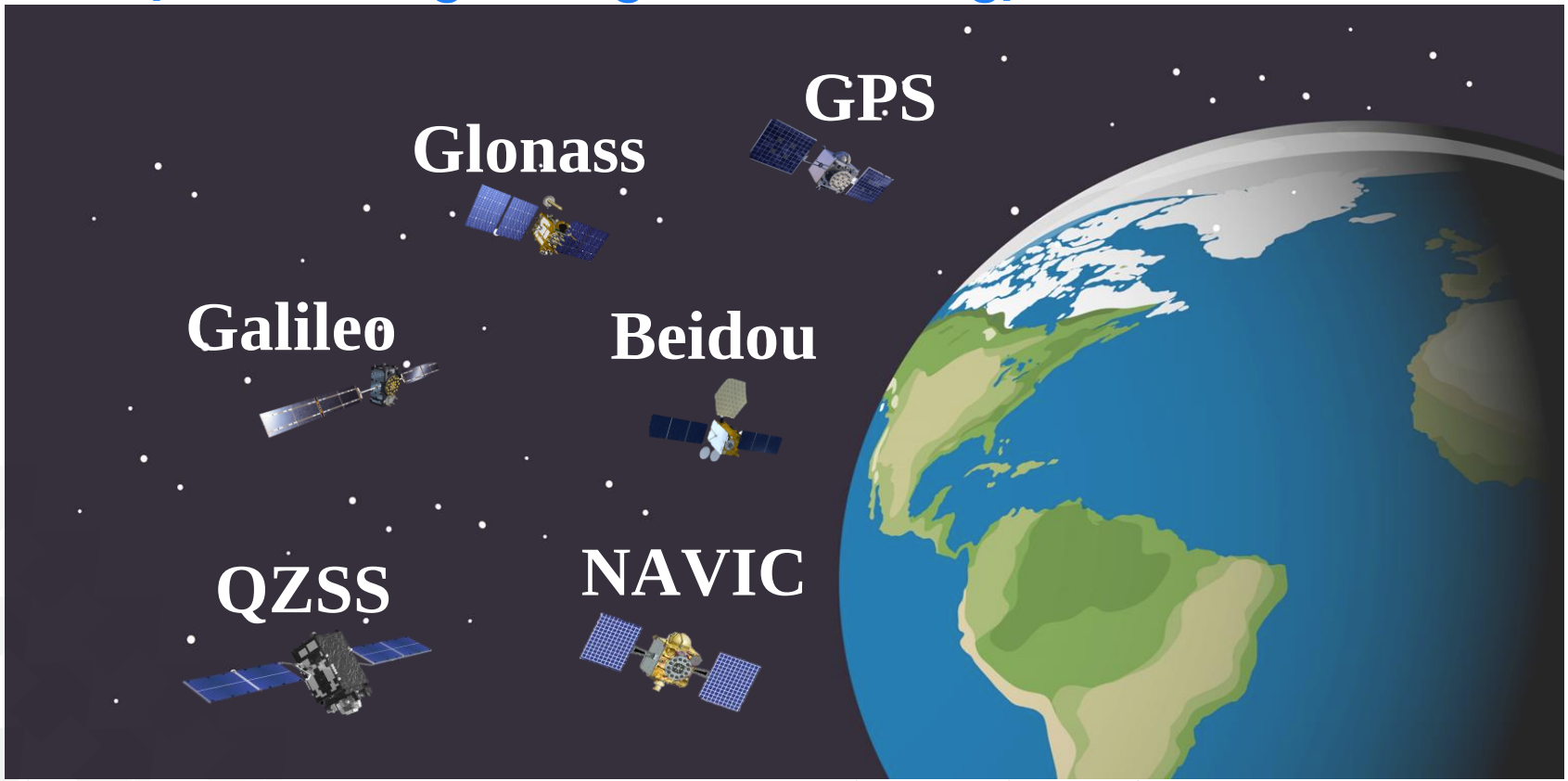




Real-time kinematics (RTK) Technology

GNSS System – National PNT Infrastructure

(Positioning, Navigation, Timing)



Ref. Uragan-K (GLONASS-K, 14F143) - Gunter's Space Page (skyrocket.de), Artwork: The European Commission is about to place an order for more Galileo spacecraft, QZSS.go.jp, ilrs.gsfc.nasa.gov

GNSS Frequency Bands

	E5/L5 Band	L2 Band	E6 Band	E1/L1 Band
GPS	1176.45 MHz *L5-BPSK*	1227.6 MHz *L2-BPSK*		1575.42 MHz *L1-BPSK*
Glonass	1176.45 MHz *L5OC* 1202.025 MHz *L3OC*	1246.0 MHz *BPSK* 1248.06 MHz *L2OC*		1602.0 MHz *BPSK* 1575.42 MHz *L1OCI* 1600.995 MHz *L1OC*
Galileo	1176.45 MHz *E5* 1207.14 MHz *E5*		1278.75 MHz *E6-BPSK*	1575.42 MHz *E1-CBOC*
Beidou	1207.14 MHz *E5* 1207.14 MHz *E5* 1207.14 MHz *E5*		1268.52 MHz *B3* 1278.75 MHz *B3-A*	1561.098 MHz *B1* 1575.42 MHz *BOC*
QZSS	1176.45 MHz *L5*	1227.6 MHz *L2C*	1278.75 MHz *LEX-BPSK*	1575.42 MHz *L1*
NAVIC	1176.45 MHz *IRNSS-BPSK*			

Pseudorange (R)

⇨ The pseudorange $R(t)$ at time t (at the receiver)

$$R(t) = c\tau + c\left(b_s^j - b_r\right) + \varepsilon_{mult}(t) + n$$

$$R(t) = \underbrace{\rho(t, t-\tau)}_{1} + \underbrace{\delta_{ion}(t)}_{2} + \underbrace{\delta_{tro}(t)}_{3} + c\left(\underbrace{b_s^j}_{4} - \underbrace{b_r}_{5}\right) + \varepsilon_{mult}(t) + n$$

t = arrival time at the receiver

t-τ = emission time from the satellite

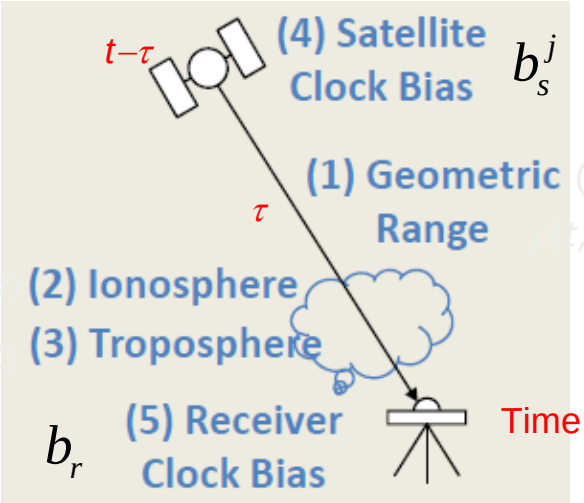
τ = transit time

δt_U = receiver clock bias

δt^S = satellite clock bias

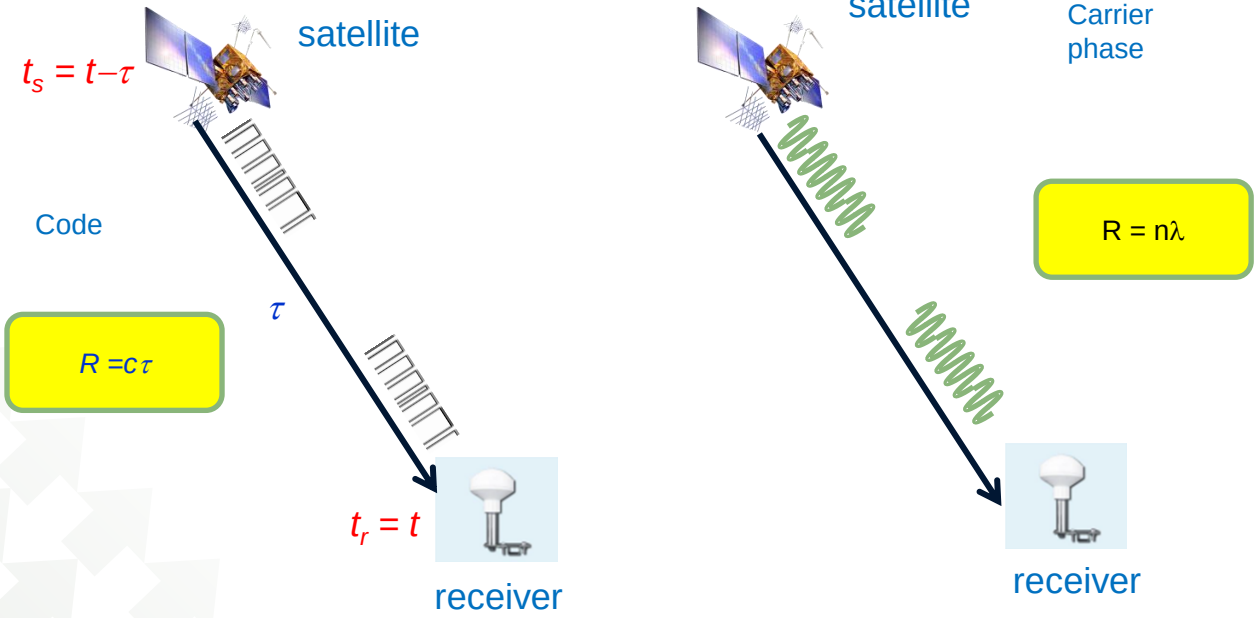
$\varepsilon_{mult}(t)$ = multipath

n = errors

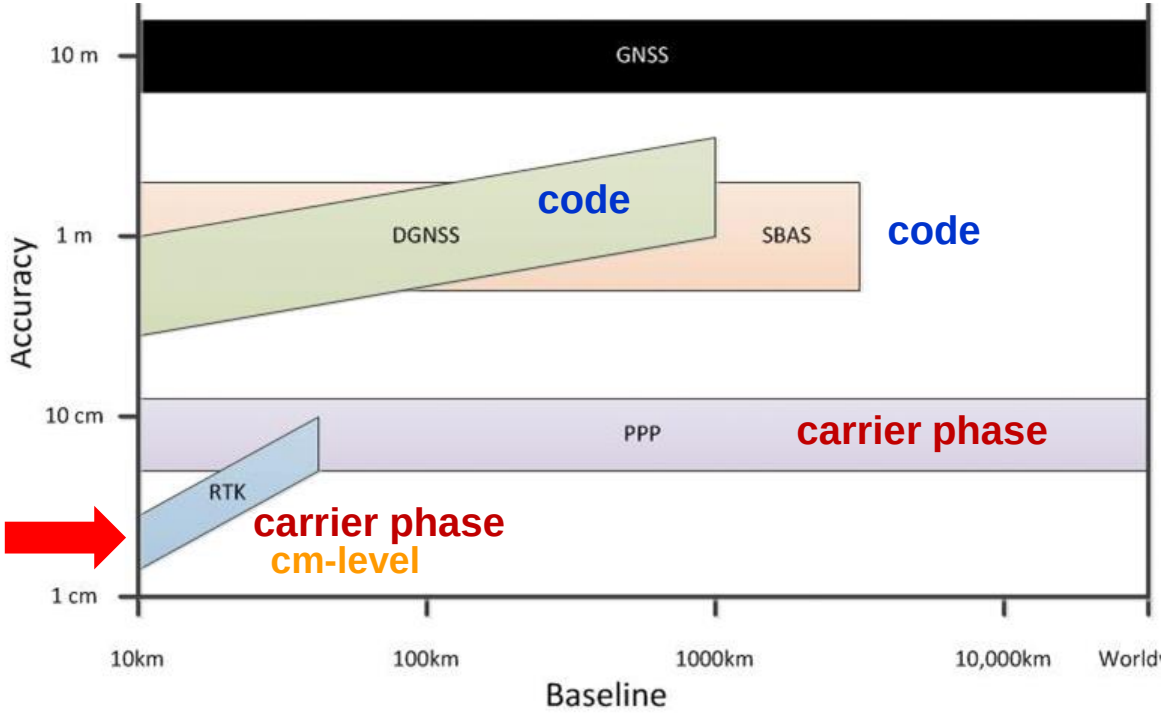


Code vs. Carrier phase pseudorange

- Pseudorange (R) can be computed from 'code' or 'carrier phase'



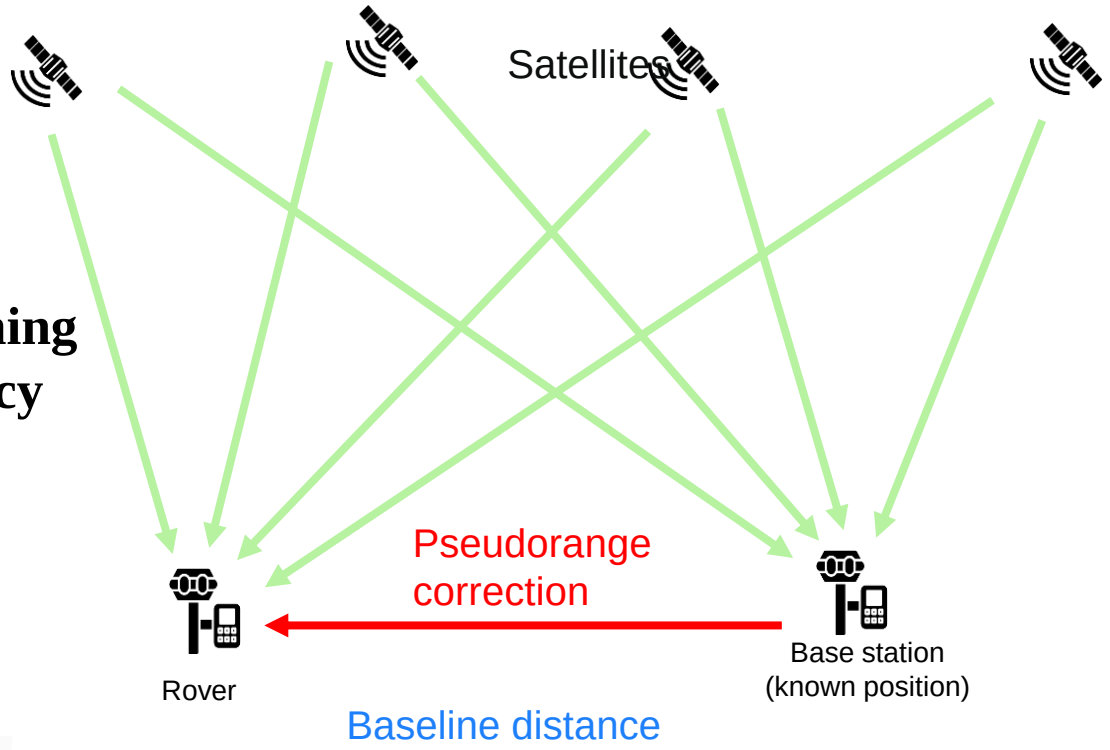
Positioning accuracy levels



Single-Point Posiitoning (SPP)
meter-level

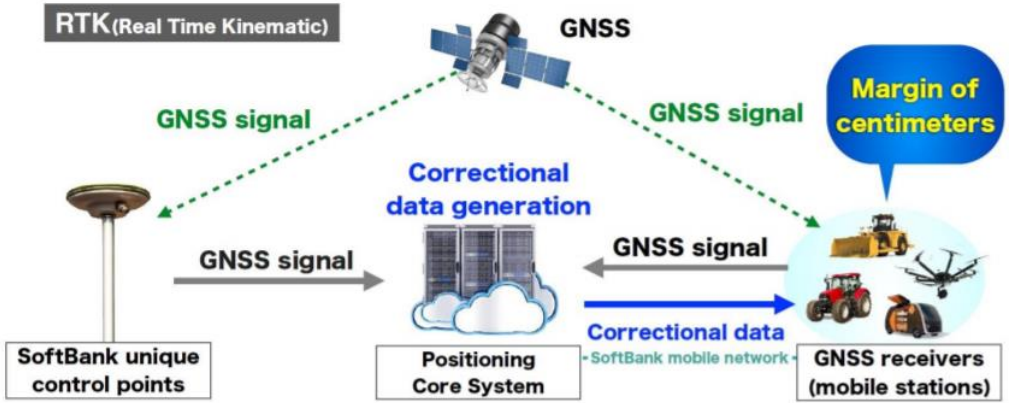
Real-Time Kinematic Positioning (RTK)

Relative Positioning
cm- level accuracy
- **Base**
- **Rover (User)**



RTK service by Softbank company

- Since November 2019
- 3,300 control points

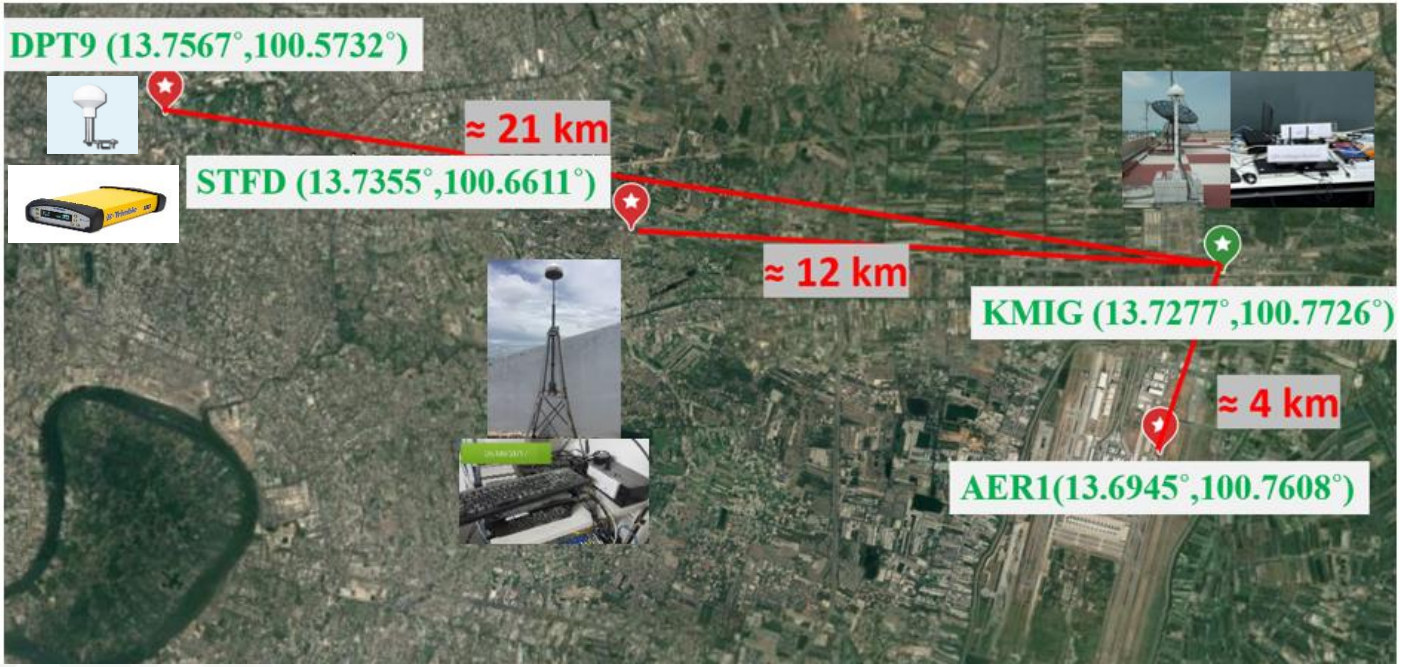


From www.softbank.com

Urban traffic management (UTM)

Source: https://www.kiast.or.kr/

RTK Experiments



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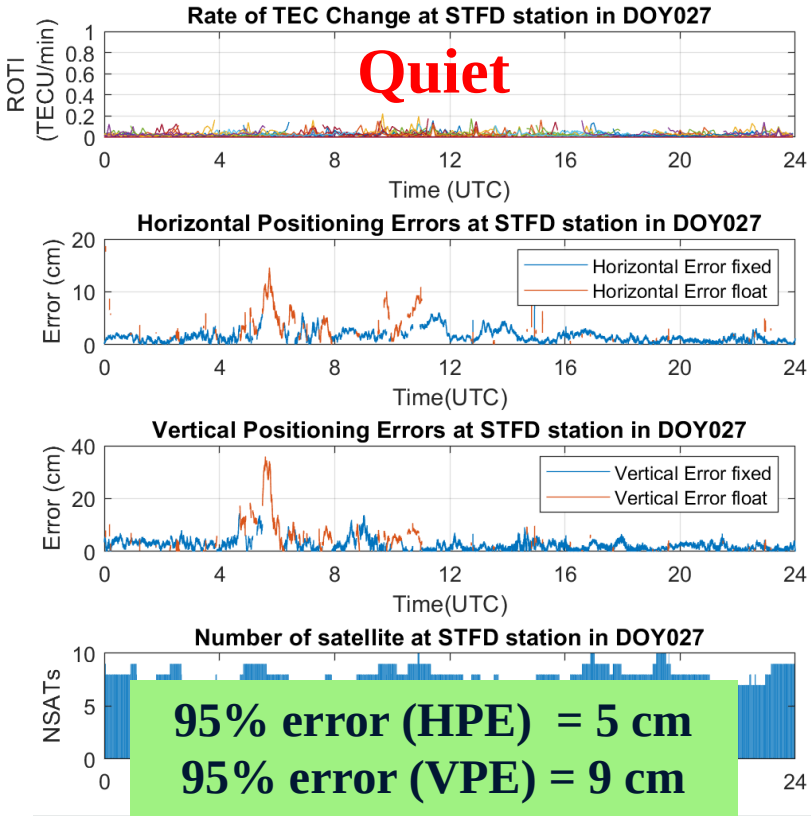
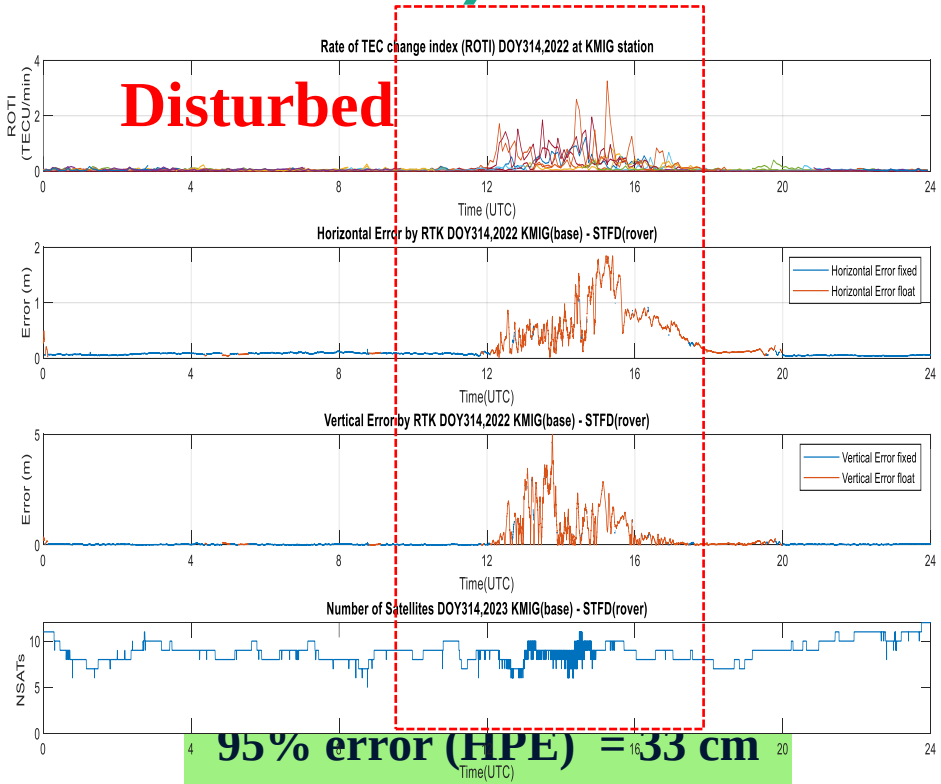
RTK Performances (12-km baseline)



95% error (HPE) = 5 cm
95% error (VPE) = 9 cm

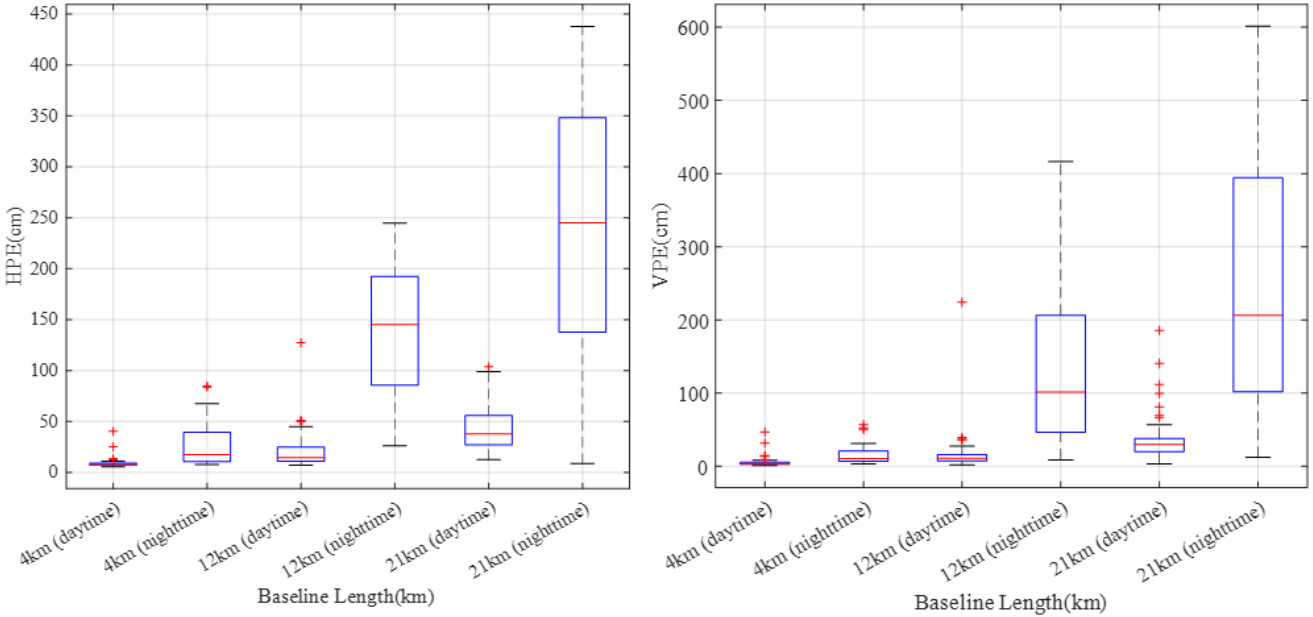


95% error (HPE) = 33 cm
95% error (VPE) = 48 cm

P.C.Thu et al.,"A study on the Relationship between the Real-Time Kinematic Positioning Performance and Ionospheric Daly Gradient," ISEA 2022, Kyoto, Sept. 2022. (Hybrid)

3)

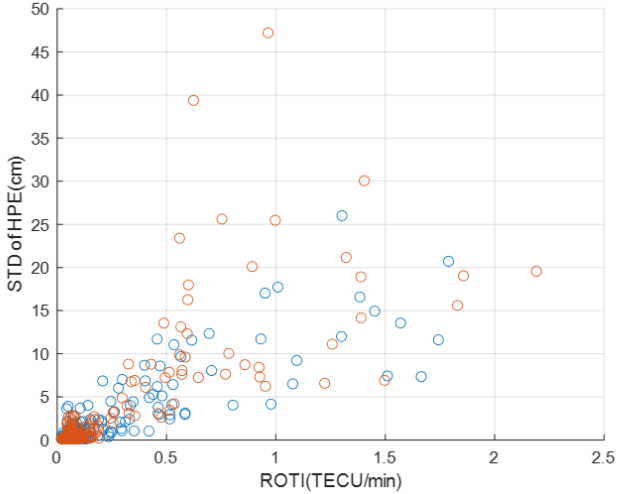
RTK Performances at each baseline length

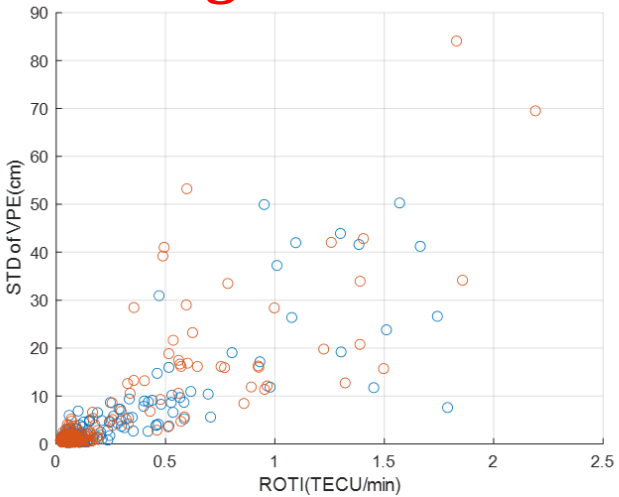


[ION GNSS+ 2023]

RTK Performances vs. ROTI

12-km baseline length



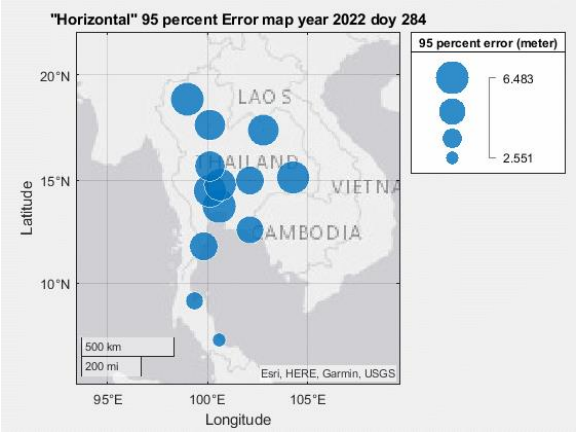


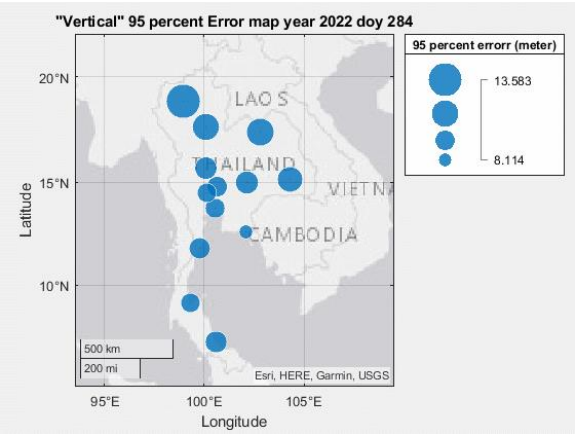
[ION GNSS+ 2023]

Positioning Error Map

Single-point positioning

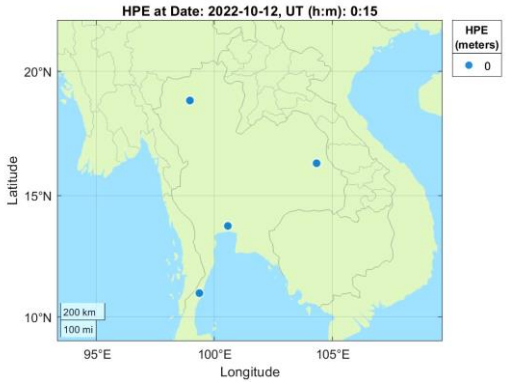
meter-scale





RTK positioning

cm-scale



Open Problems

- EPB detection
  - Multi-constellation, multi-frequency
  - Hybrid data sources
  - Near real-time detection/prediction
- EPB Mitigation in positioning and navigation

Available Software Download

- TEC computation software (MATLAB)
- Single-frequency Positioning (MATLAB):
- TEC gradient computation (MATLAB)
- Kalman filters for positioning with data (sensor) fusion (MATLAB)
- L1-SBAS positioning (MATLAB)

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

https://www.ukm.my/aoswa/

The 6th Asia-Oceania Space Weather Alliance Workshop (AOSWA 2023)

9-11 October 2023 | Bangi Resort Hotel, Selangor, Malaysia

Abstract deadline: June 30th, 2023

Sessions:

1. Connect the Local Observation to Global Network
2. CGMS Efforts to Improve User Access to Operational Space Weather Data
3. Education/Space weather awareness to the community through education
4. Application of Artificial Intelligence (AI) in Space Weather
5. Ionosphere-Thermosphere Dynamics and Coupling
6. Technique and Validation of Space Weather Forecast
7. Space Weather Impacts
8. General Topics of Space Weather

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Universiti Kebangsaan Malaysia
The National University of Malaysia

Naratif Baharu UKM
Universiti Watan Kita

Institut Perubahan Iklim
Institute of Climate Change

Technically supported by

NICT

Thanks!

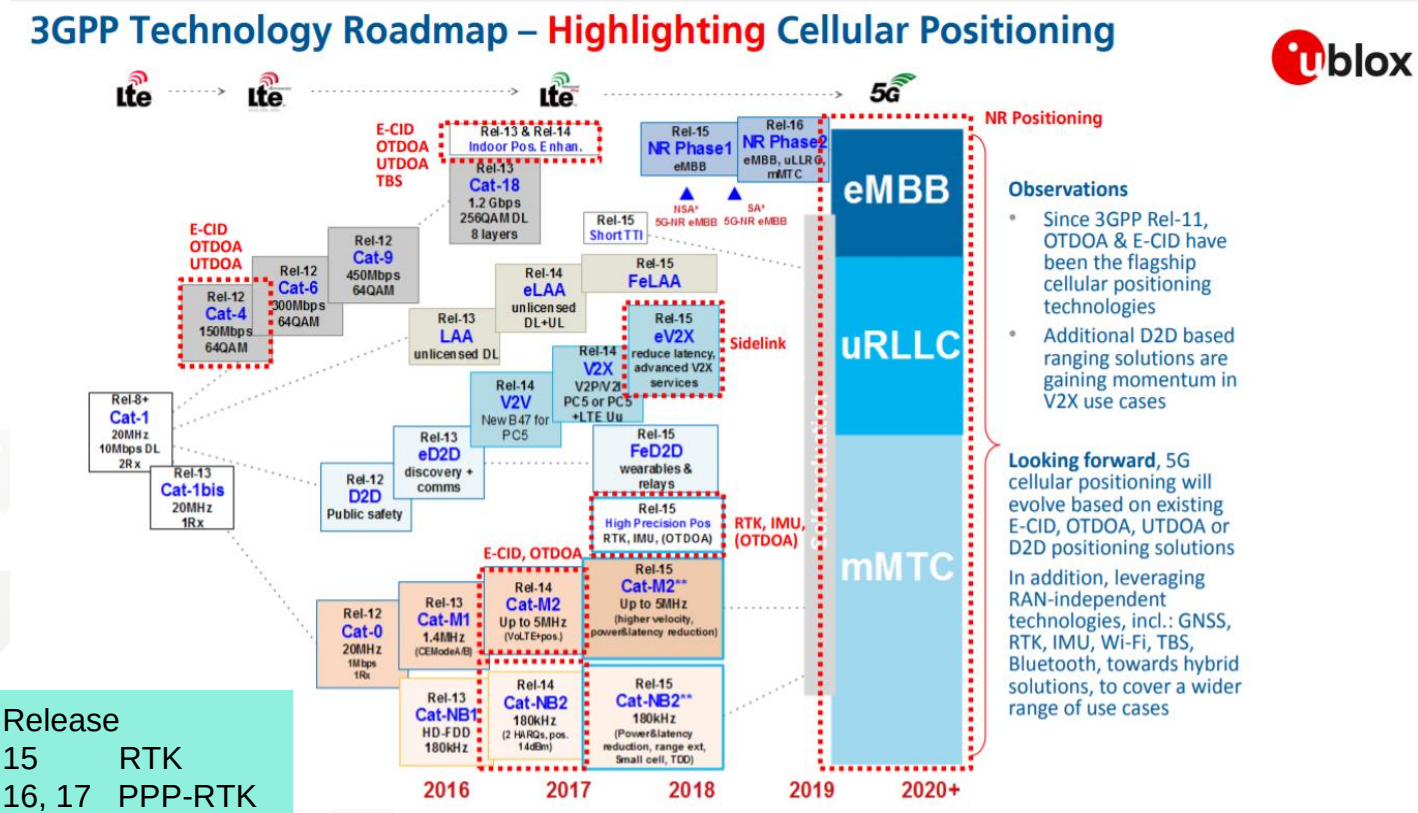
Homepage : https://sites.google.com/site/pornchaisupnithi/

GNSS and Space Weather Information Center:

Center of Excellence in GNSS and Space Weather:

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

Positioning in LTE/5G



Release	
15	RTK
16, 17	PPP-RTK

S. Lu, "5G standards overview&3GPP Tech Evolution Trends. CW SIG Event Sep 2018