AOSWA 2024
The Asia-Oceania Space Weather Alliance (AOSWA)

Enhanced Ionospheric Delay Gradient Estimation Using a Dynamic Time-Step Method with GNSS IGSO Satellites

Presented by

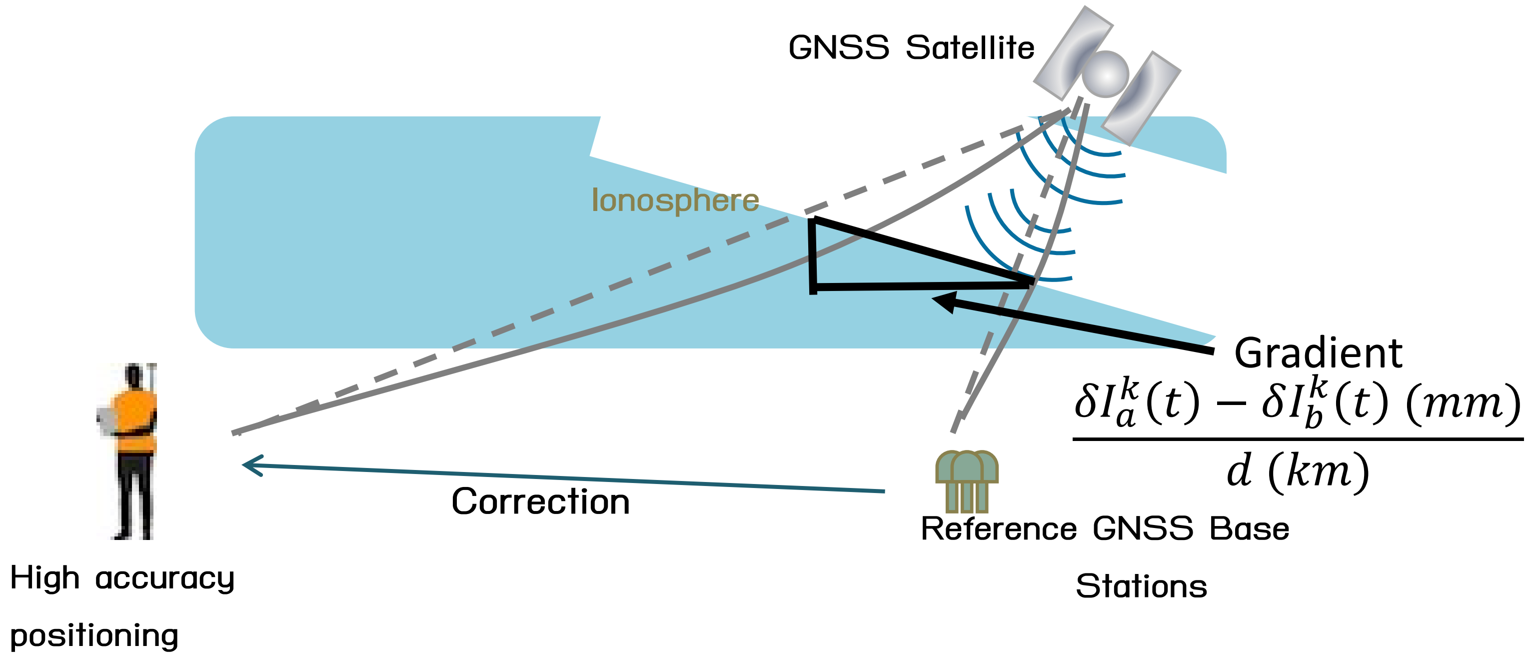
Jirapoom Budtho[1*], Pornchai Supnithi[1], Lin M. M. Myint[1]

[1] King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

Outlines

1) Background and Motivation
2) Objectives
3) Ionospheric delay gradient estimation
   - Current method (single/dual-frequency method) with GPS (MEO)
   - Implementation of BDS IGSO satellite with dynamic time-step method
4) Experimental setup, results, and discussions
5) Conclusions

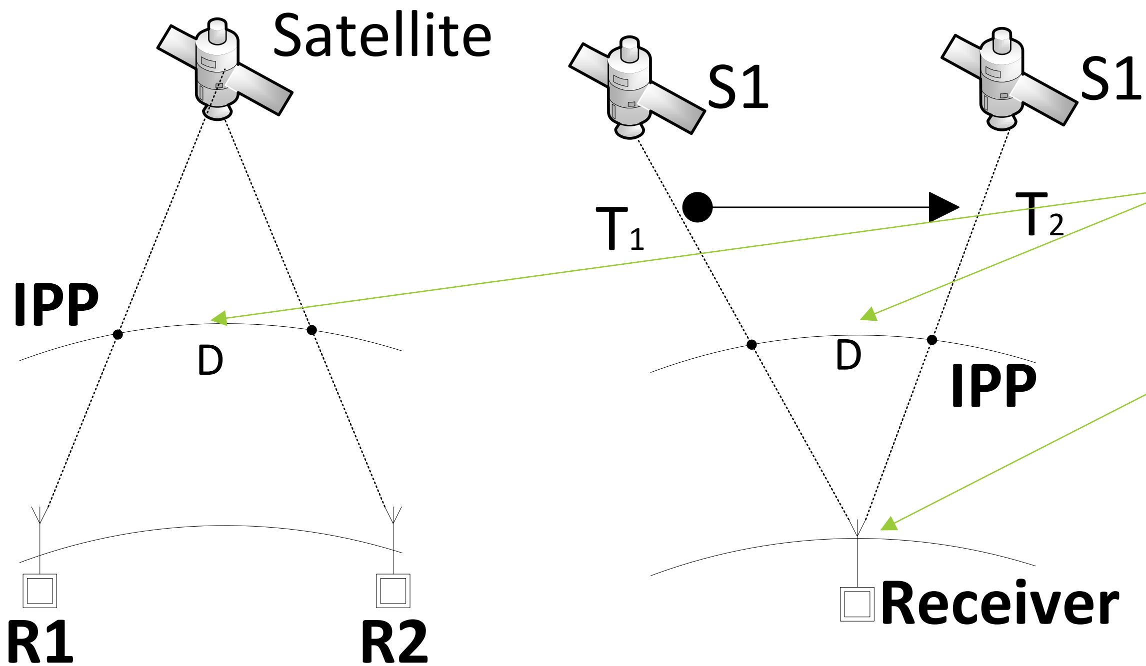
Ionospheric effects on relative positioning



*To achieve high-accuracy positioning, it is essential to monitor ionospheric delay gradients.

Ionospheric delay gradient estimation

Station-Pair Method	Time-Step Method



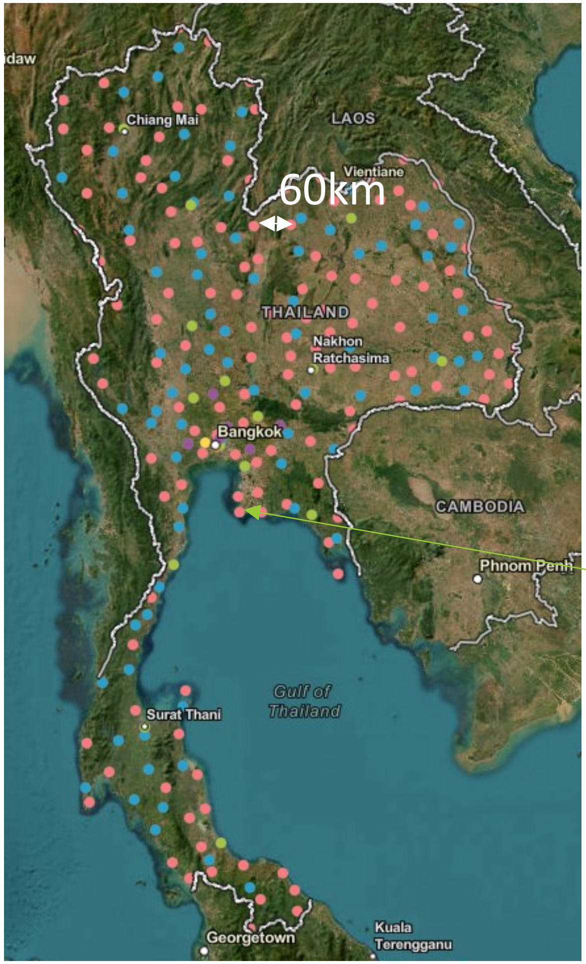
For ionospheric monitoring: D < 1Km is necessary

*Needs 1 GNSS station

[Jiyun Lee et al., 2012]

[Jiyun Lee et al., 2017]

National CORS Data Center, Thailand



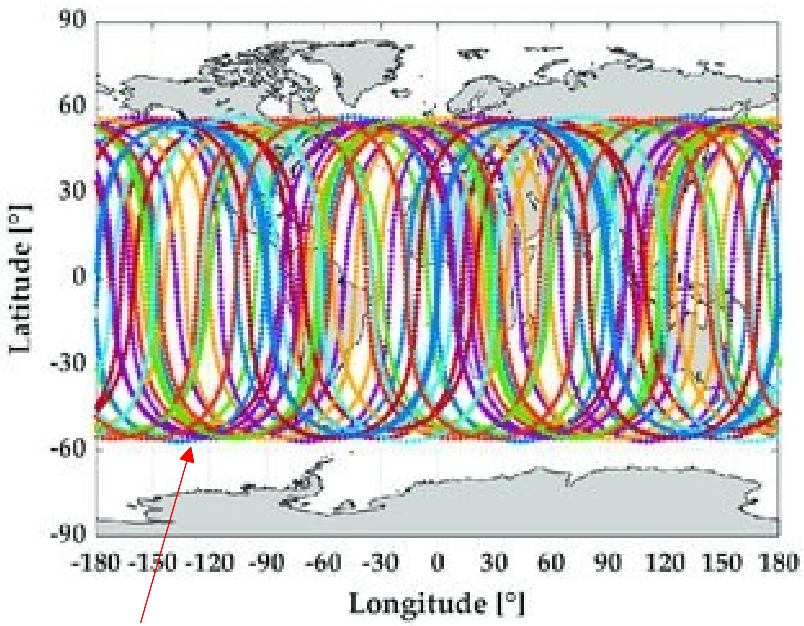
-Minimum 2 station distance: 60 km
-Not possible for station-pair method
-The time-step method is suitable for short baseline estimation.
-Post-process data are available 30-sec sampling rate data.

Only this area has baseline lower than 15 km distance from 2 stations.

[Dumrongchai, Puttipol, et al. "Performance assessment of continuously operating reference stations using the deemed rover analysis approach with NRTK GNSS technique in Thailand." Survey Review 56.398 (2024): 438-447.]

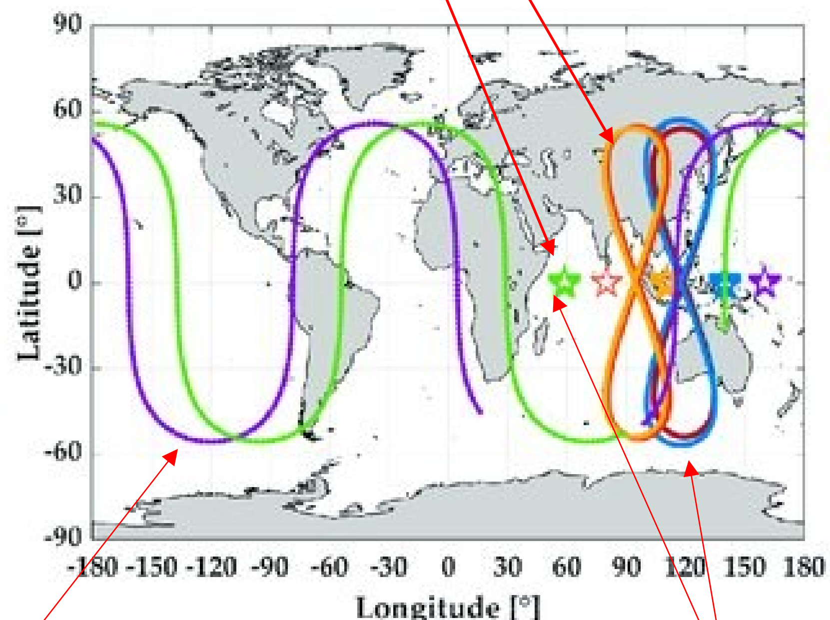
MEO vs IGSO satellite trajectories

GPS MEO satellites



20,000km alt.

BDS MEO GEO IGSO satellites



20,000km alt.

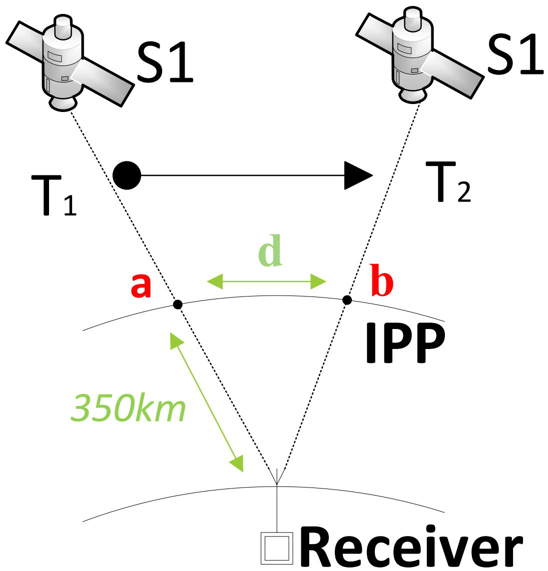
35,786km alt.

[Gao, Zhouzheng, et al. "Robust Kalman filter aided GEO/IGSO/GPS raw-PPP/INS tight integration." Sensors 19.2 (2019): 417.]

2) Objectives

- To propose ionospheric delay gradient estimation by using the IGSO BDS.
  - To compare the number of ionospheric delay gradients estimation.
  - To compare the lowest baseline between MEO and IGSO satellites.

The reference time-step method



Time-Step Method

[Seeber et al., 2008.]

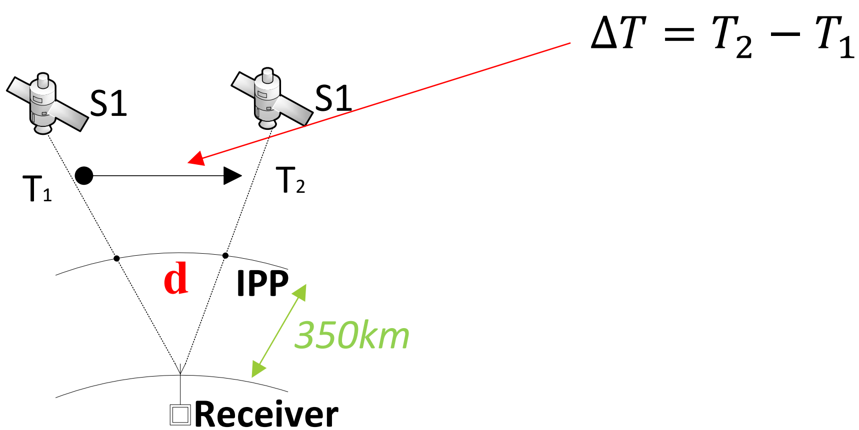
Ionospheric delay $\delta I = \frac{40.3}{f_1^2} 9.5196(P_2 - P_1)$

Ionospheric delay gradient

$$\nabla I_{SD}(t) = \frac{\delta I_a^k(t) - \delta I_b^k(t)\ (mm)}{d\ (km)}$$

P_x = Pseudo-range measurement
D = baseline length
f = GNSS frequency

Proposed dynamic Time-step method with IGSO satellite



Time-Step Method

haversine formula

$a = \sin^2(\Delta\varphi/2) + \cos\varphi_1 \cdot \cos\varphi_2 \cdot \sin^2(\Delta\lambda/2)$

$c = 2 \cdot \text{atan2}(\sqrt{a}, \sqrt{(1-a)})$

$\mathbf{d} = R \cdot c$ (km.)

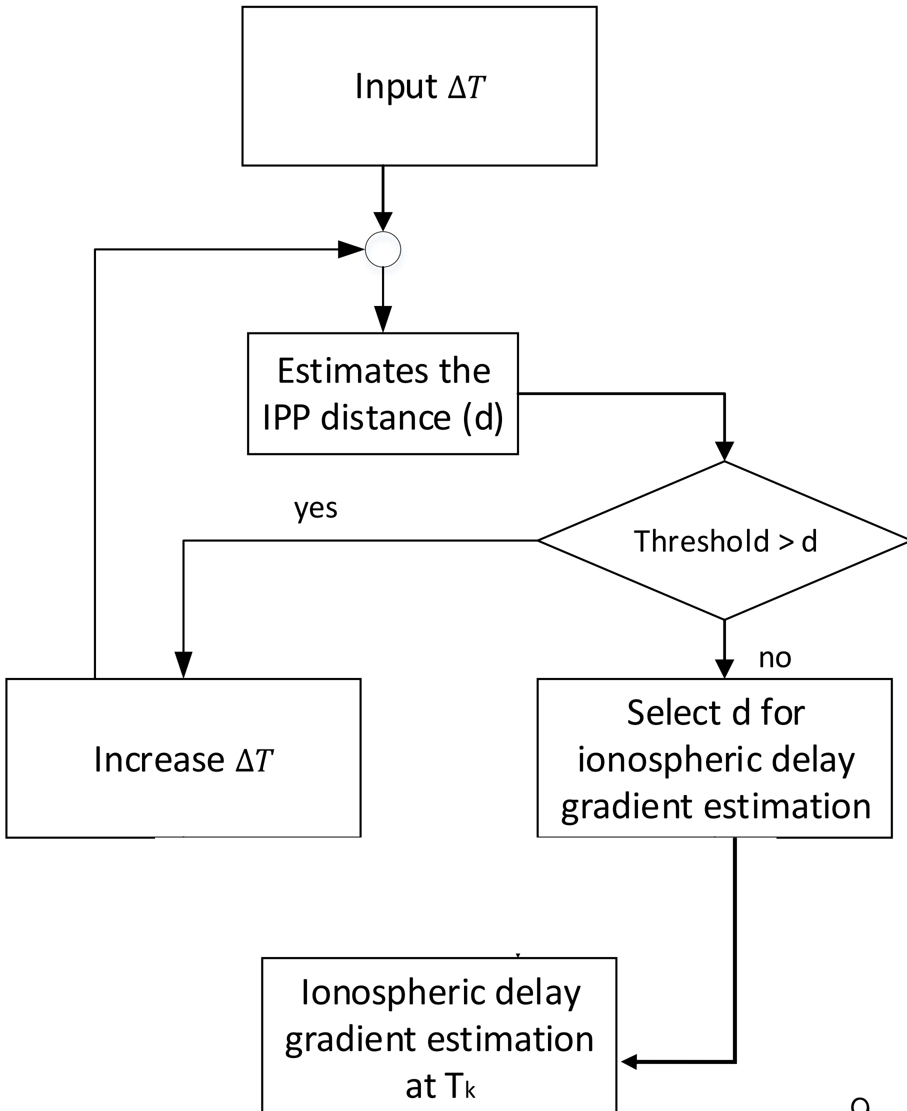
Where φ *is latitude*

λ *is longitude*

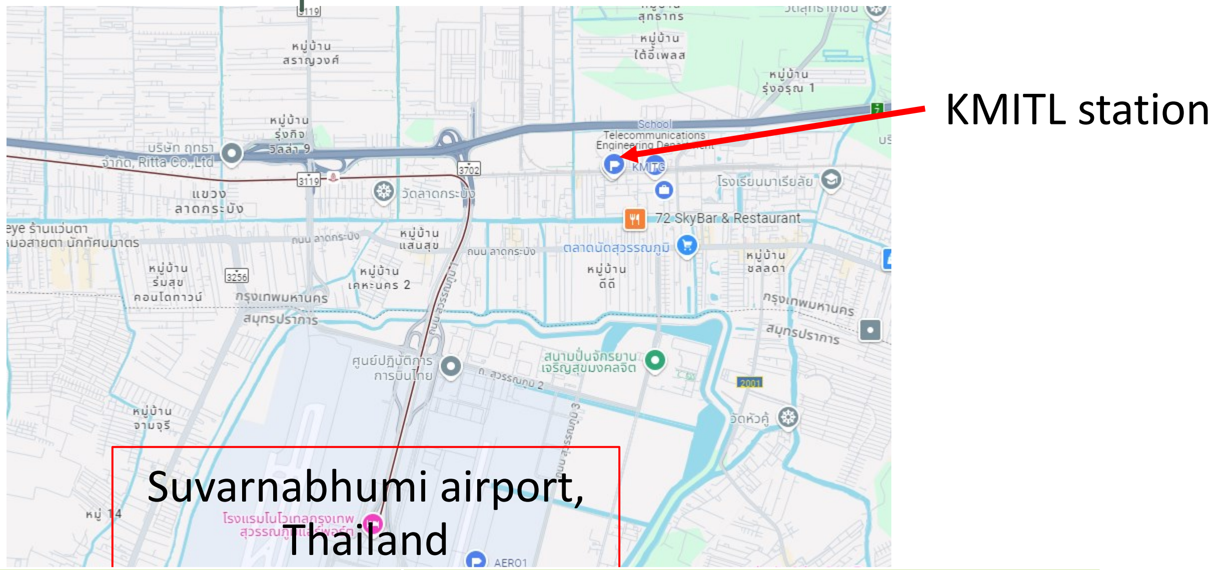
R *is earth's radius 6,371 + 350km*

IPP height

IPP distance



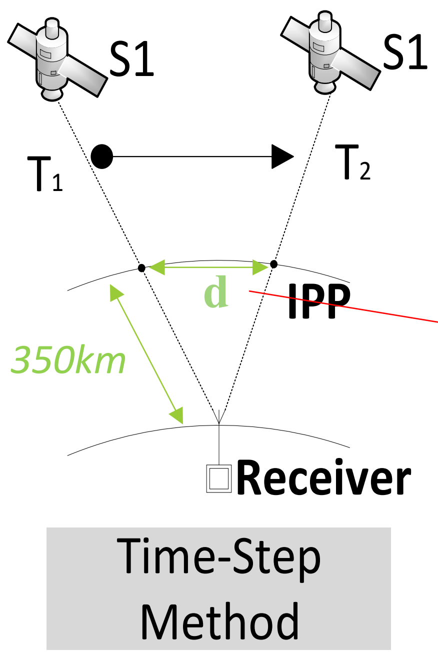
4.1) The experimental setup

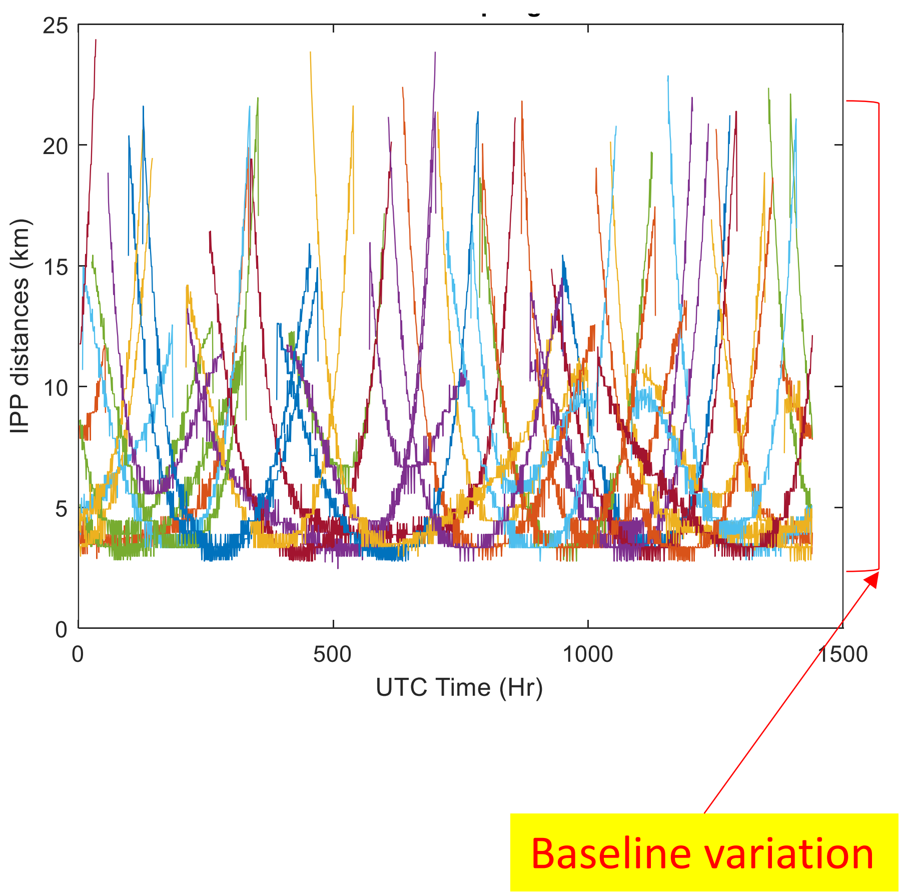


Station for station-pair method	KMITL (13.72N 100.7736E)
GNSS receiver	NovAtel Propak 6
	30-sec sampling rate
GNSS antenna	NovAtel GNSS-850
	5-degree elevation mask
Satellites	GPS (MEO), BDS (MEO&IGSO)

4.2) Results

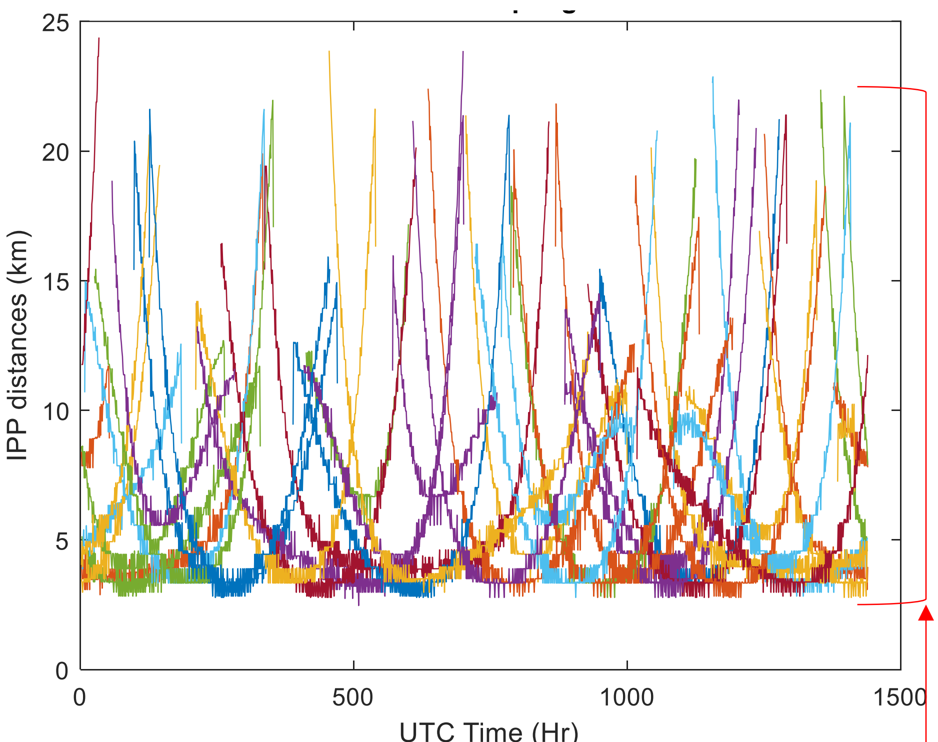
The IPP baseline distance from time-step method (GPS)

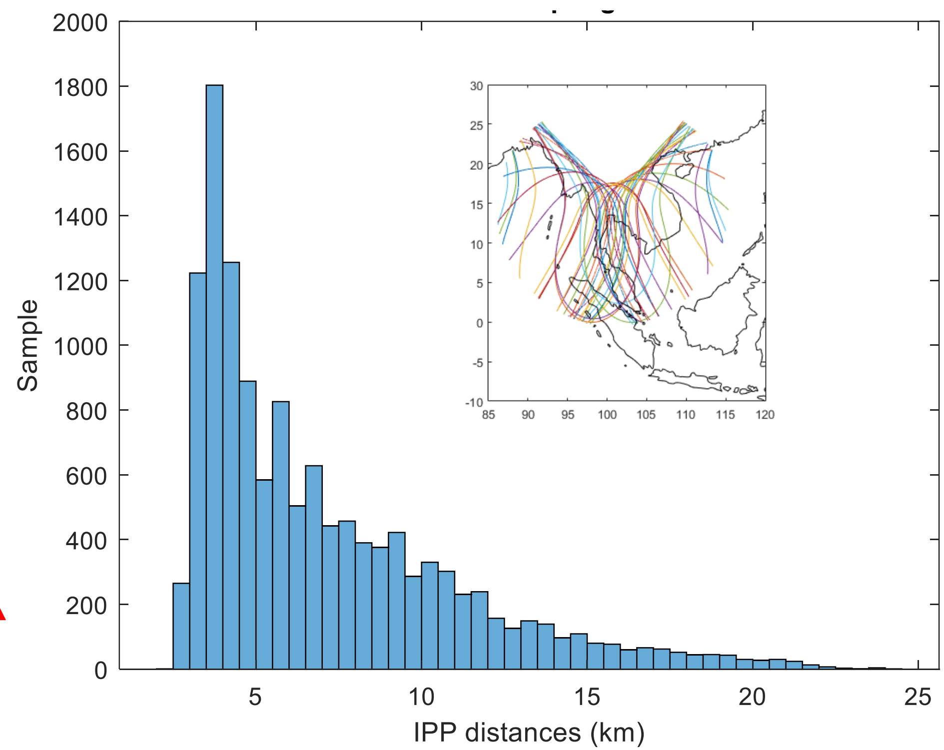




4.2) Results

IPP baseline distance at 30-sec sampling rate from GPS

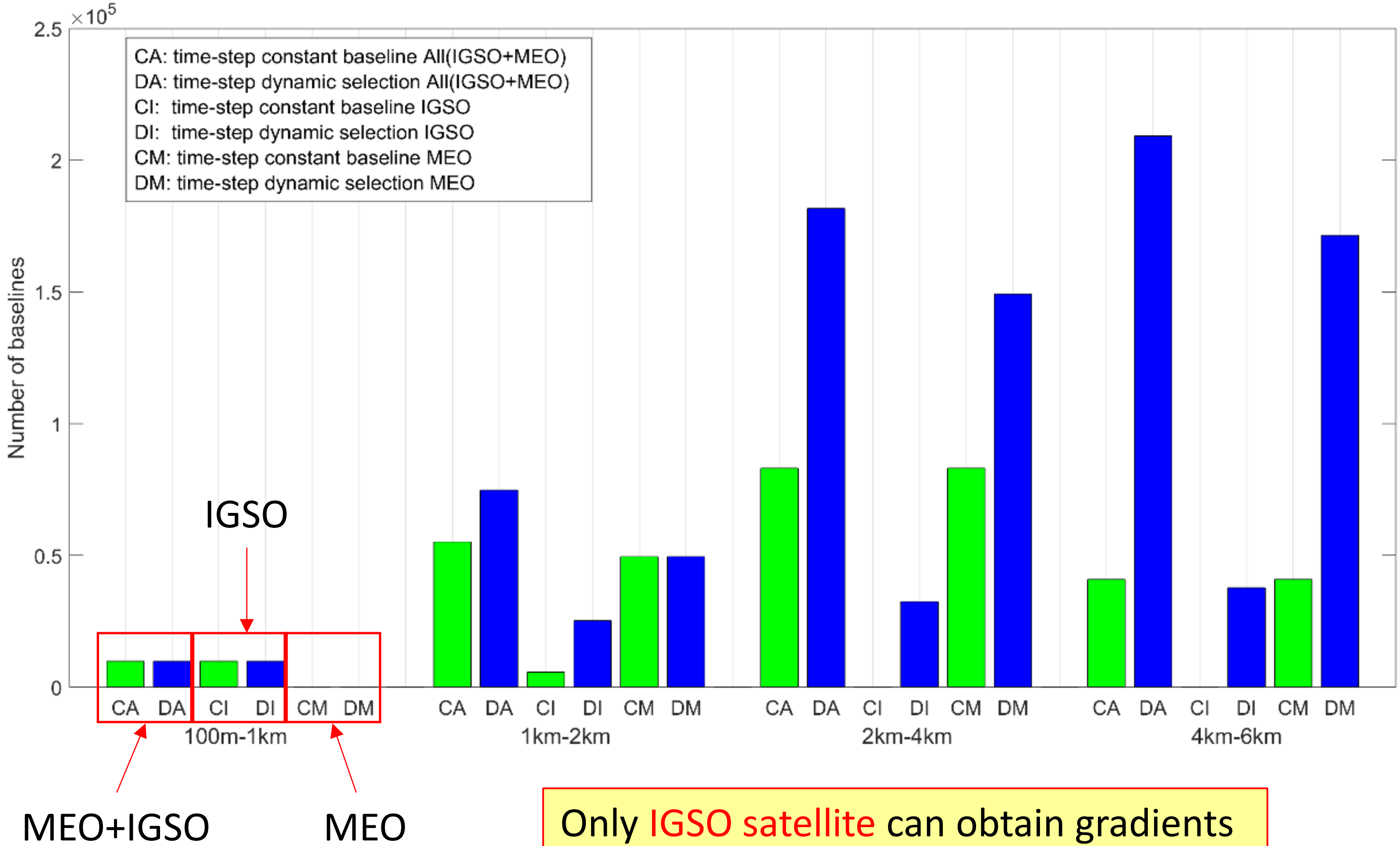




Baseline variation

4.2) Results

Samples of dynamic time-step method using BDS



Only IGSO satellite can obtain gradients from baseline lower than 1 km.

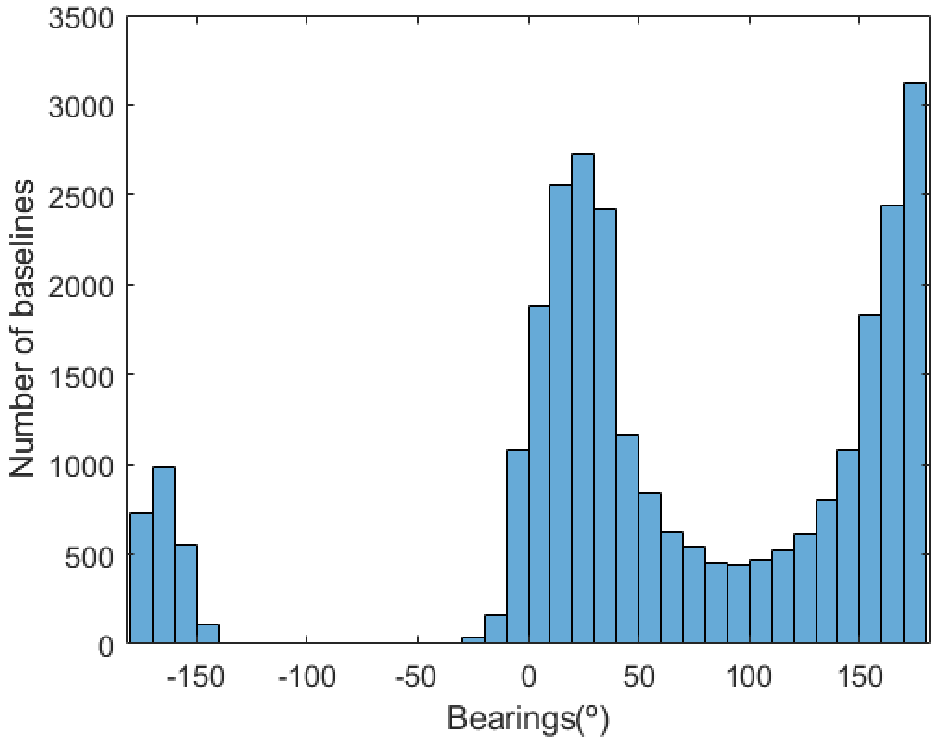
4.2) Results

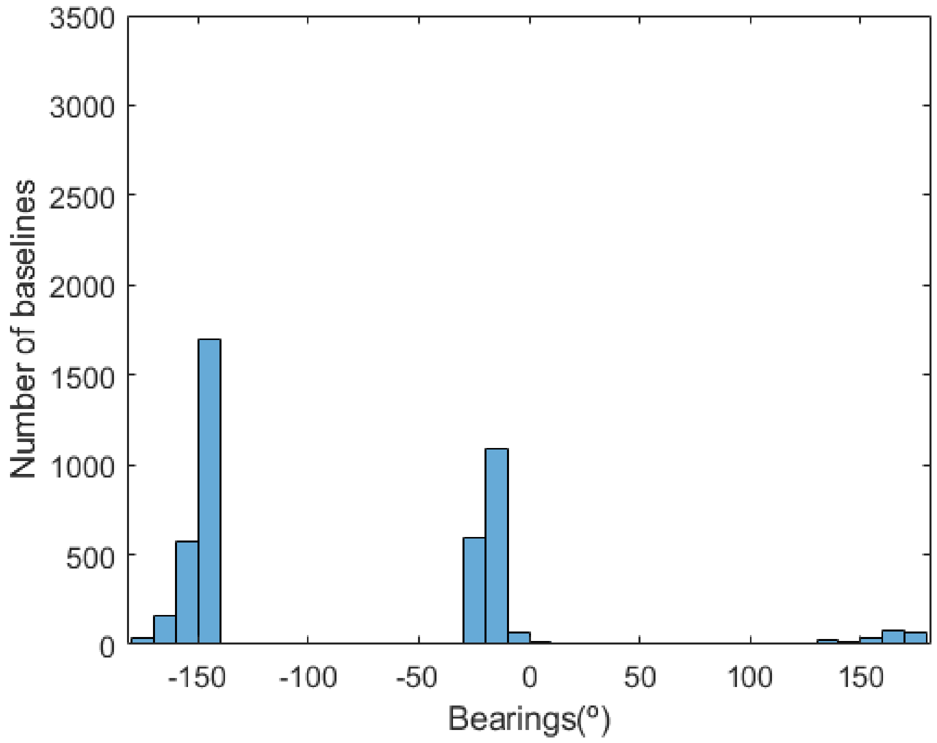
Number of baselines using 30-sec sampling rate

Test	Test 1		Test 2		Test3		Test 4	
Baseline Range	100m-1km		1km-2km		2km-4km		4km-6km	
Time-step method σ_{VIG}	σ_{VIG} constant baseline	σ_{VIG} IPP's dynamic selection	σ_{VIG} constant baseline	σ_{VIG} IPP's dynamic selection	σ_{VIG} constant baseline	σ_{VIG} IPP's dynamic selection	σ_{VIG} constant baseline	σ_{VIG} IPP's dynamic selection
GPS MEO	--	--	39540	39540	119781	161151	46779	172190
BDS MEO	--	--	49517	49517	83086	149219	40881	171460
BDS IGSO	9841	9841	5631	25235	--	32457	--	37723
BDS MEO + IGSO	9841	9841	55148	74752	83086	181676	40881	209183

4.2) Results

Distribution of baseline directions by BDS orbit





The IGSO satellite mostly travel on N-S directions

5) Conclusions

- The minimum baseline for estimating ionospheric delay gradients using a GPS (MEO) receiver with a 30-second sample rate is 4 km.

- The IGSO constellation from the BDS satellite offers a minimum baseline of 500 meters, which is advantageous for ionospheric delay gradient estimation.

- Ionospheric monitoring can be conducted using NCDC stations.

Acknowledgement

- King Mongkut’s institute of Technology Ladkrabang.
- ICT Virtual Organization of ASEAN Institutes and NICT

Thank you for your attention.

MEO vs IGSO satellite observation speed