Introduction of QZSS correction service

1/12/2022 at ICG Training

Nobuaki Kubo, Kaito Kobayashi, Tomohiro Ozeki, Hirotaka Kanamori (TUMSAT)

University and Laboratory

- **T**okyo **U**niversity of **M**arine **S**cience **a**nd **T**echnology
- Marine Technology and Marine Science
- Information and communication engineering laboratory (GPS/GNSS lab.)
- Staff 2 + Graduate 6 + Undergraduate 6 + Visiting Researcher 2

Research Subjects at our lab.

- Automobile navigation
- Ship navigation
- Railway navigation
- Machine control
- Pedestrian navigation
- Survey
- UAV applications
- GNSS Simulation

Applications

- Static and Kinematic Precise Positioning
- Multipath mitigation
- Software GNSS
- GNSS simulation using 3D map
- Indoor positioning
- Precise orbit determination
- GNSS/other sensors integration

Technologies behind applications

If you are interested in GNSS,
we are welcome for your join our school.

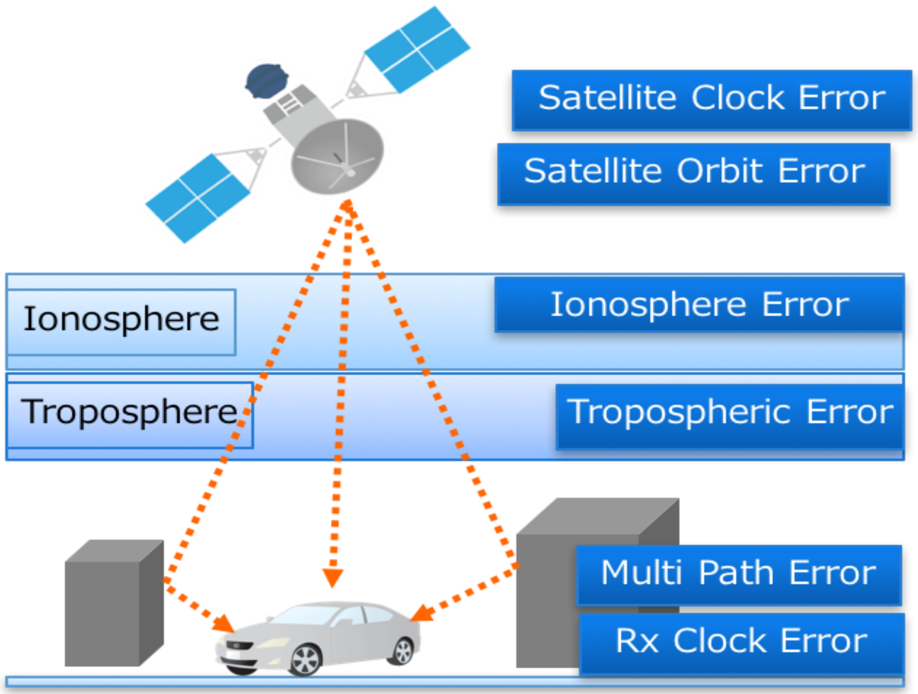
Contents

- Brief Introduction of GNSS positioning
- Test results of QZSS correction services

  -RTK vs. QZSS CLAS/SLAS/PPP

  -long term test of PPP in 7 countries

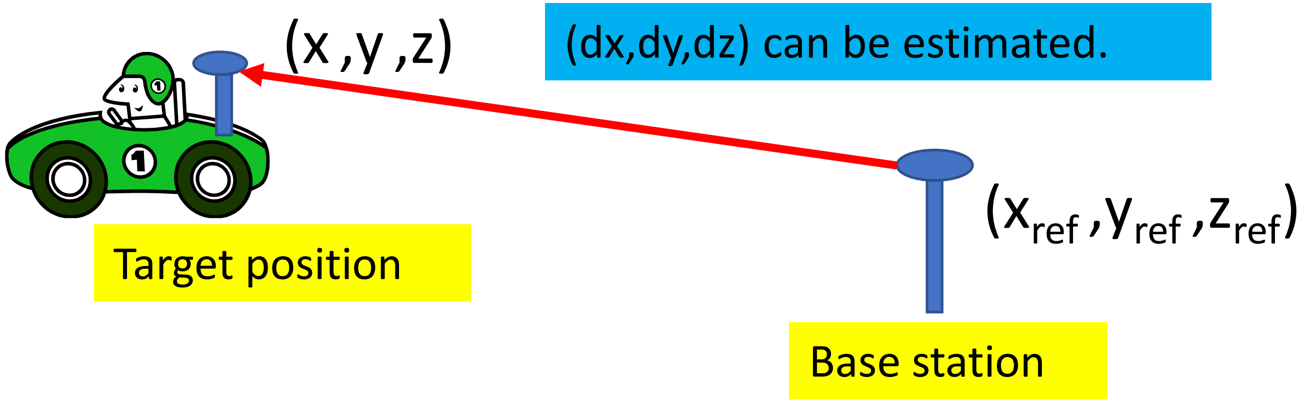
Error Sources on the GNSS measurements



Sources	Potential error size
Satellite clock errors	Broadcast : -5 ns (rms) Precise: -75 ps (rms)
Satellite orbital errors	Broadcast : -2 m (rms) Precise: -5 cm (rms)
Ionospheric errors	2-10 m (at zenith direction)
Tropospheric delay	2.3-2.5m (at zenith direction)
Multipath (open sky)	Code : 0.5-1 m Carrier : -5 cm
Receiver Noise	Code : 0.25-0.5 m (rms) Carrier : 1-2 mm (rms)

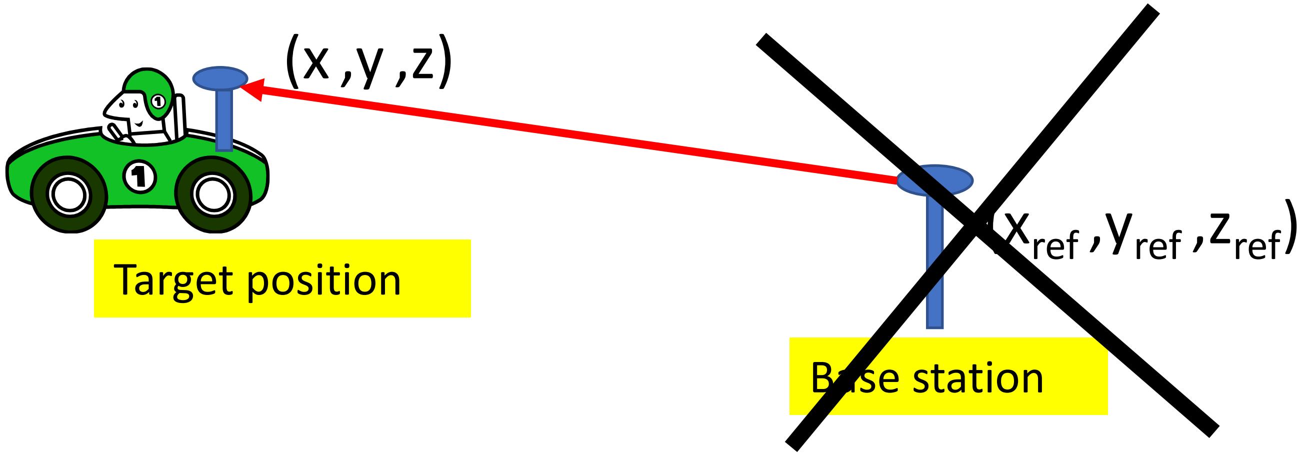
Improved GNSS (relative positioning)

- DGNSS and RTK are powerful method for error mitigation.
- They use the fact that the most of error sources change slowly in the time domain if the distance between reference and user is approx. within 10-100km.
- Please remember that differential technique provides only vector solution from base station to the target position → precise position of base station should be prepared.



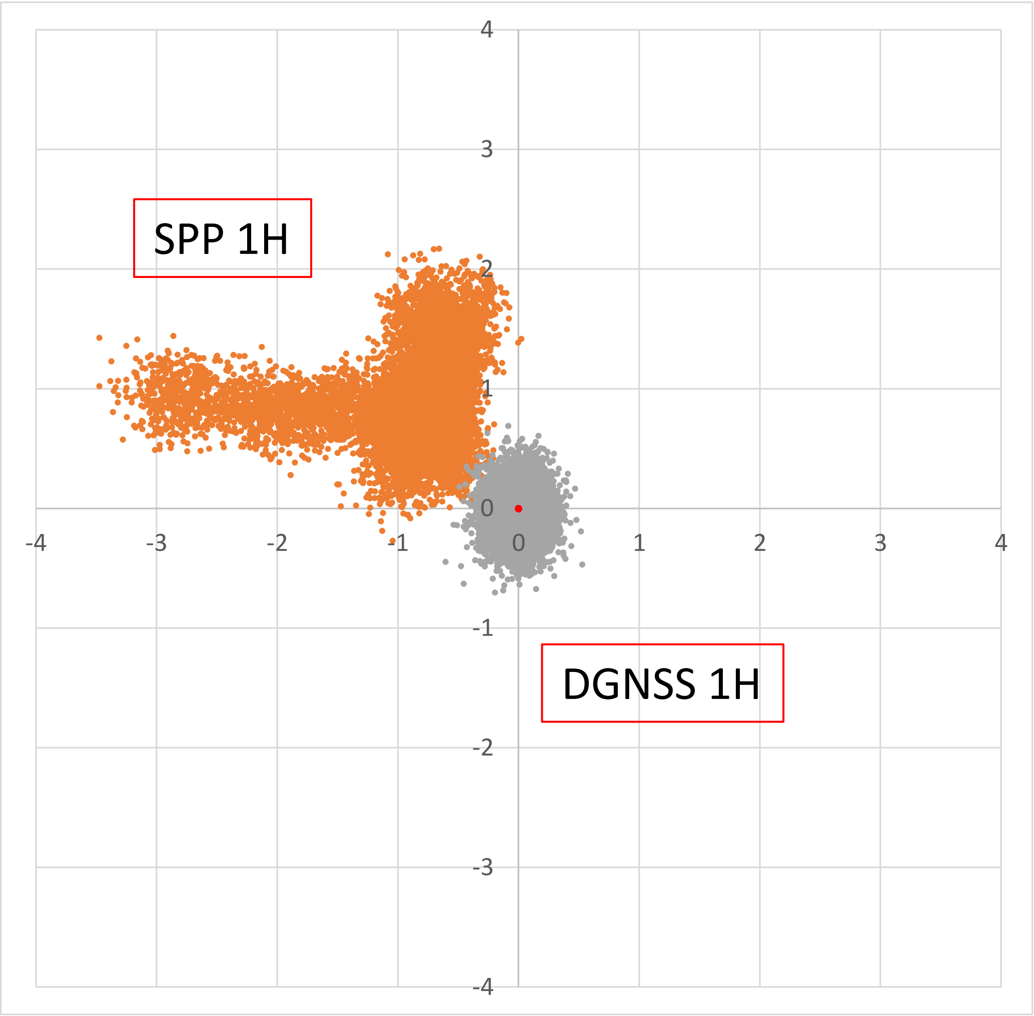
PPP (Precise Point Positioning)

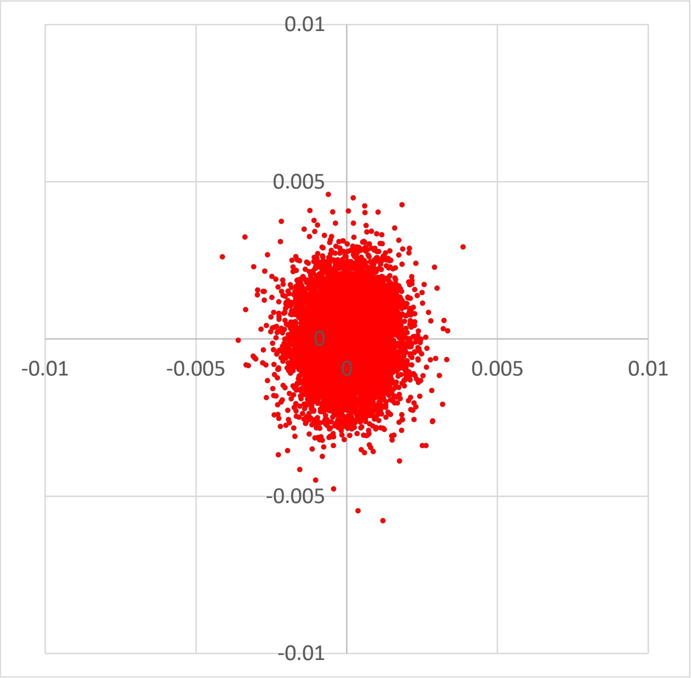
- We discussed about relative positioning to cancel the common errors.
- We switch from relative positioning to point positioning. Basically base station is not required for users.
- We need to consider the measurement errors more in details if we want to have centimeter-level accuracy in the point positioning.



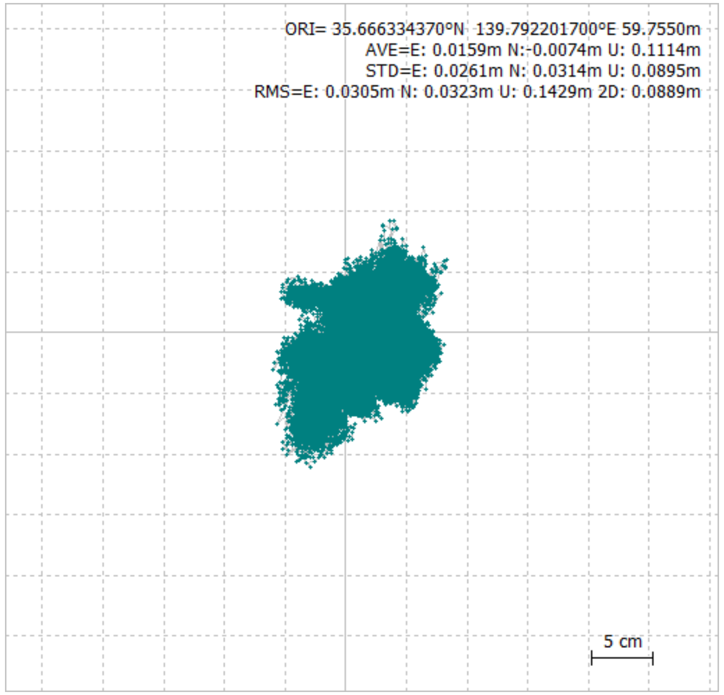
SPP, DGNSS, RTK, PPP (open sky)

Accuracy (95%)
SPP ： 1.36 m
DGNSS ： 0.44 m
RTK ： 0.003 m
PPP ： 0.081 m





RTK 1H



MADOCA-PPP 24H
(after conversion)

Different environments for GNSS

<u>Countryside</u>
1. cm-level
2. Low-cost

<u>Urban</u>
1. Decimeter-level
2. Low-cost
3. Multi-sensors

<u>Tunnel and indoor</u>
1. Impossible…

It is important to switch algorithm smoothly depending on the condition…

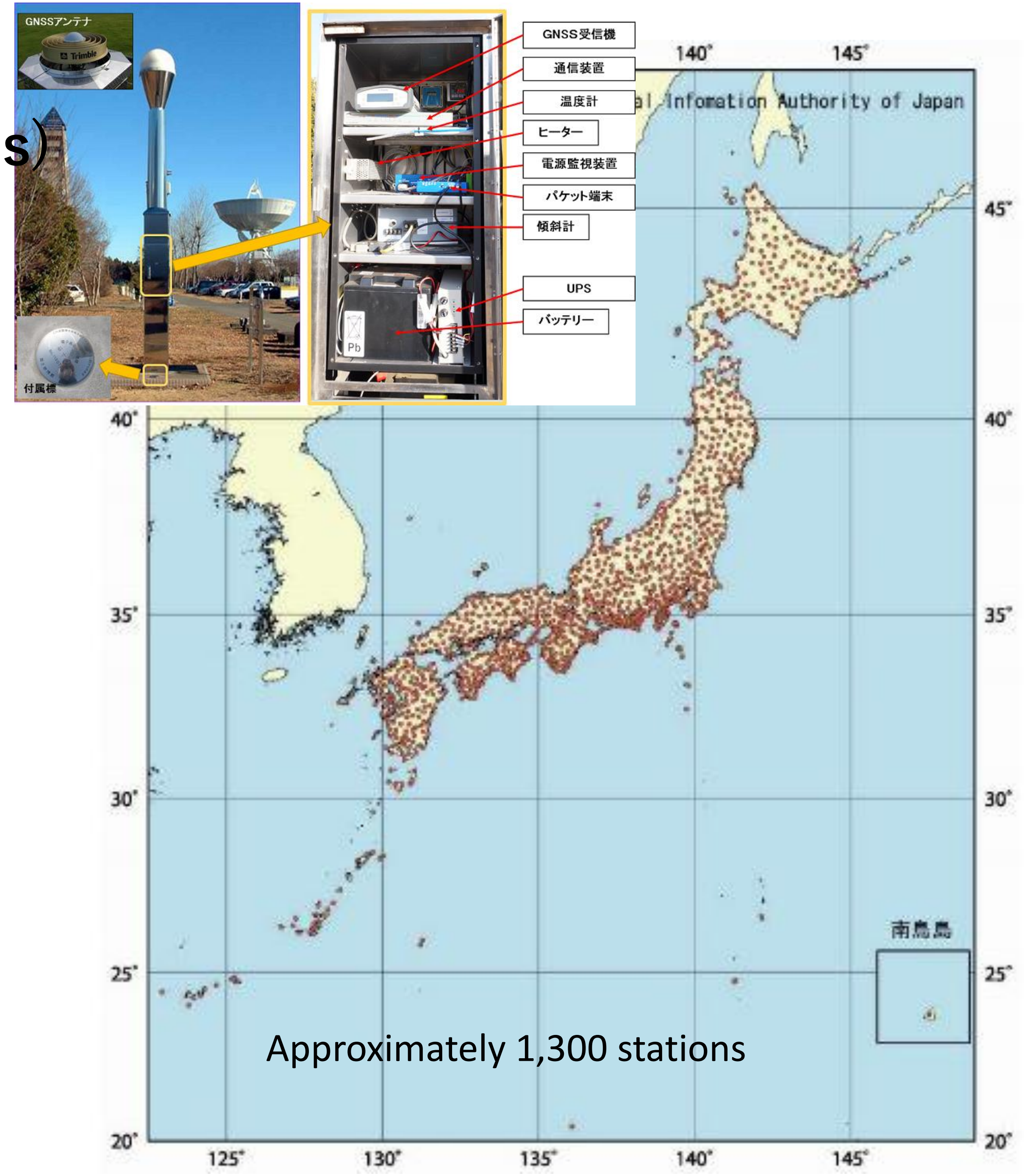
Typical characteristics

Only RTK requires near base station

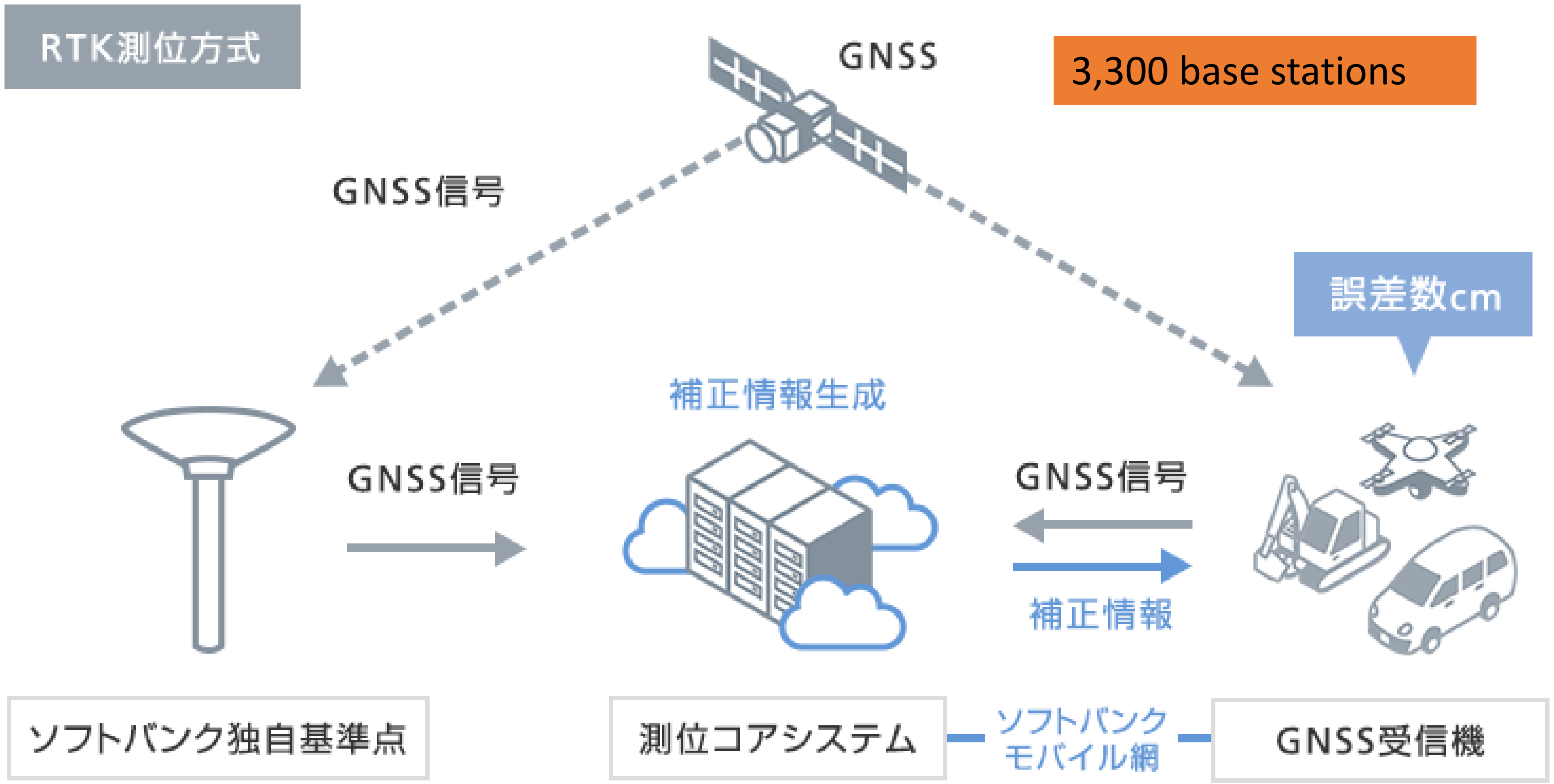
Error/service	SLAS (DGNSS)	RTK	CLAS (PPP-RTK)	PPP
Sat orbital	Not separated	Not separated	○	○
Sat clock			○	○
Iono			○	△ （next）
Tropo			○	
Convergence	Instant	Instant	-1 min.	15-30 min.
Coverage	Japan	Within about 30-50 km	Japan	No limitation
Measurements	Code	Carrier	Carrier	Carrier

CORS
(continuously operating reference stations)

- In some regions, GNSS CORS networks are so well developed and dynamic that they have a more prominent role than the existing classical passive geodetic infrastructure in reference frame determination or monitoring.
- Even commercial company started to install many base stations for precise positioning services.
- It means that GNSS based survey/navigation has a potential for more reliable/safety applications



Ichimill (SoftBank starts RTK service in 2019)



3,300 base stations

GNSS + LTE + internal Ant.
All you need is switching on…

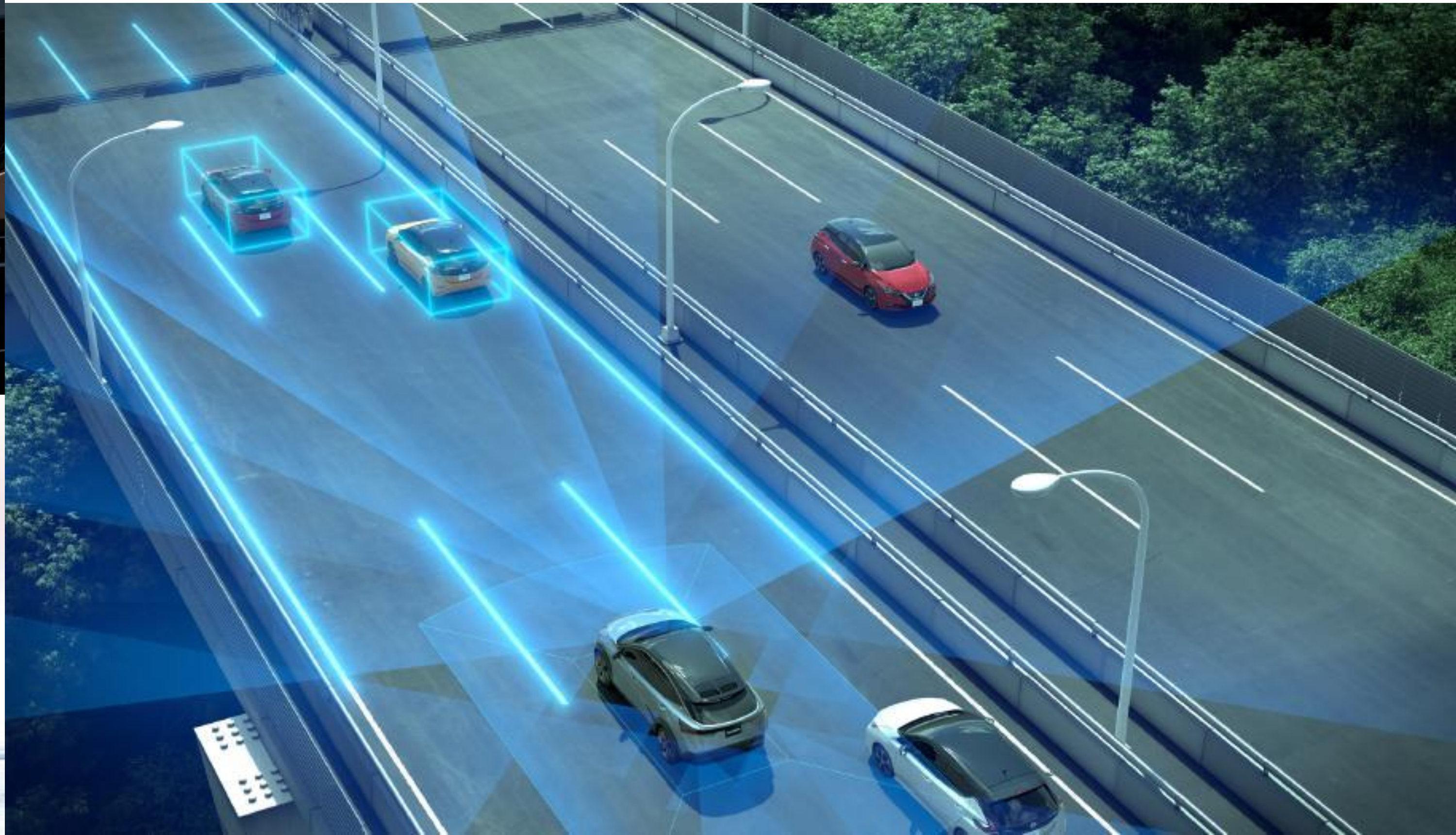
About $50/month. We can use RTK in everywhere in Japan as long as Softbank LTE is available.

The advent of very good low-cost multi-GNSS dual-frequency GNSS receiver.
Strong RTK engine !

Japanese territory (land) : 378,000 km^2
378,000/3,300 = 114 km^2
Very dense

Pro Pilot 2.0 and Eyesight X

- Nissan and Subaru for now.
- CLAS service is used.
- Precise 3D MAP is used.
- This map has been generated using RTK.



QZSS Overview -System-

Ranging Signals of QZSS

Signal	Frequency MHz	Service	Compatibility	QZS-1	QZS-2/4	QZS-3
				IGSO	IGSO	GEO
L1C/A	1575.42	Positioning	Complement GPS	✓	✓	✓
L1C		Positioning	Complement GPS	✓	✓	✓
L1S		Augmentation(SLAS)	DGPS (Code Phase Positioning)	✓	✓	✓
		Messaging	Short Messaging	✓	✓	✓
L1Sb		Augmentation(SBAS)	SBAS (L1) Service	-	-	✓
L2C	1227.60	Positioning	Complement GPS	✓	✓	✓
L5 I/Q	1176.45	Positioning	Complement GPS	✓	✓	✓
L5S		Experimental(L5 SBAS)	L5 SBAS (DFMC)	-	✓	✓
L6D	1278.75	Augmentation(CLAS)	PPP-RTK (Carrier Phase Positioning)	✓	✓	✓
L6E		Experimental(MADOCA)	PPP, PPP-AR (Carrier Phase Positioning)	-	✓	✓

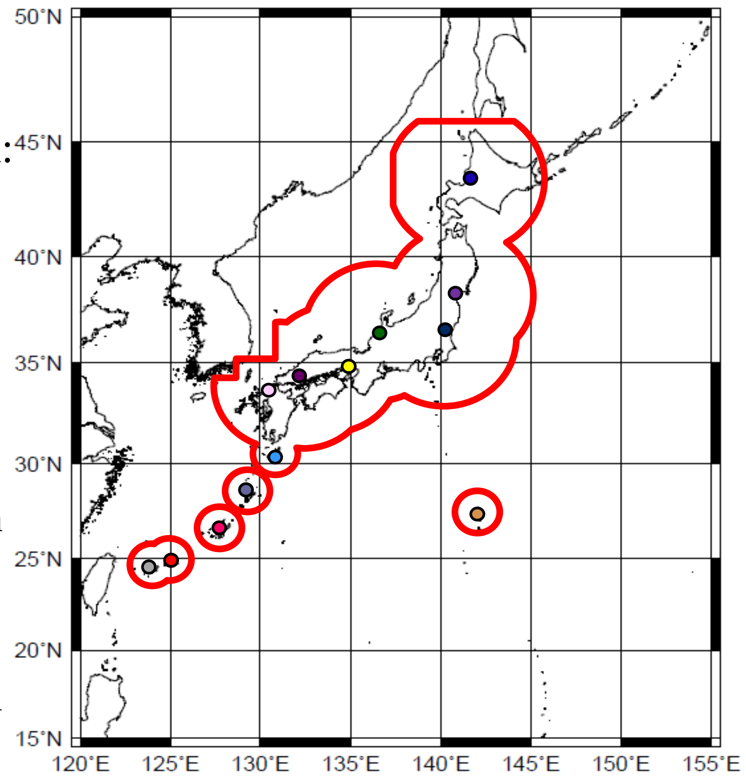
Provided by CAO

SLAS Service

Service Area of SLAS

monitoring station:

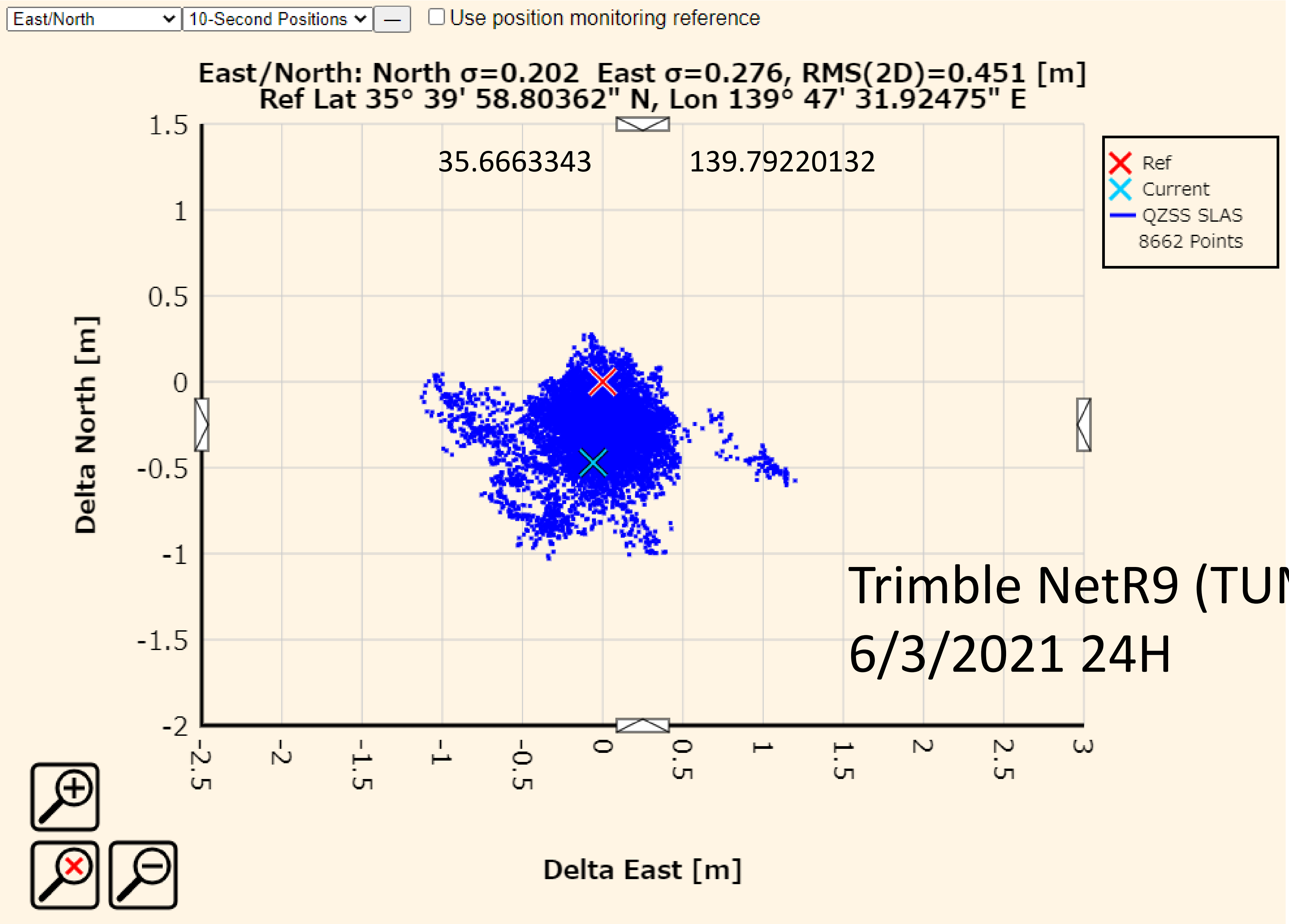
- Sapporo
- Sendai
- Hitachi-ohta
- Komatsu
- Kobe
- Hiroshima
- Fukuoka
- Tanegashima
- Amami
- Itoman
- Miyako-jima
- Ishigaki-jima
- Chichi-jima



Service Area is the area surrounded by the red line.
The left-axis is latitude, and lower-axis is longitude.

Accuracy of SLAS

positioning errorm(95%)		Remarks
horizontal	vertical	
≤ 1.0 m	≤ 2.0 m	EL mask : 10° User range error caused by user's receivers and user's situation : 0.87 m(95%)

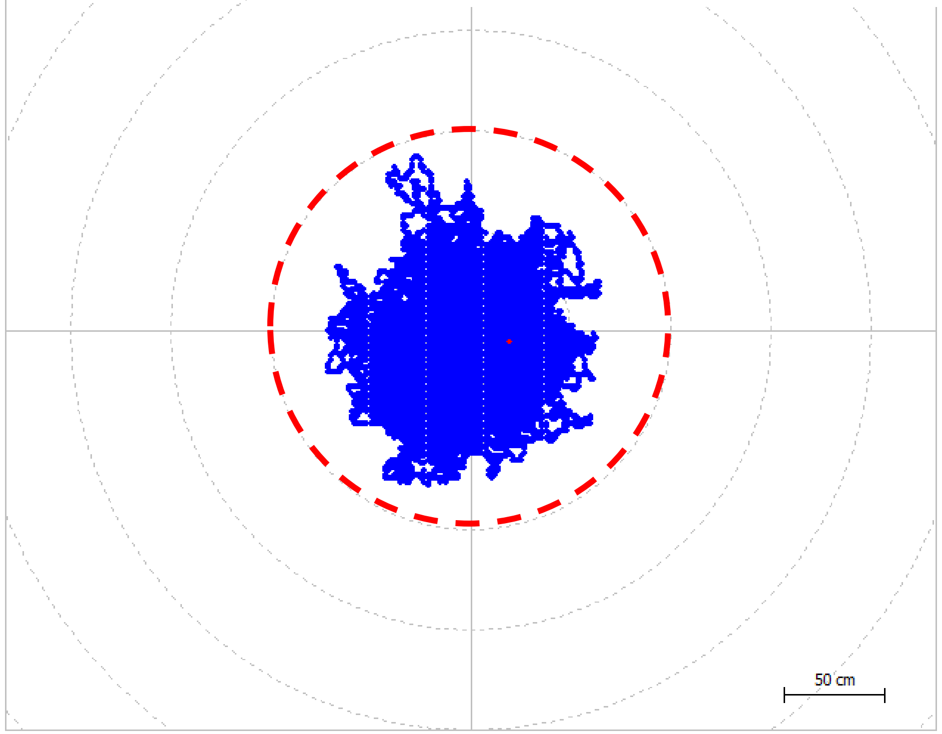


Trimble NetR9 (TUMSAT)
6/3/2021 24H

u-blox F9P (TUMSAT)
6/13/2021 24H

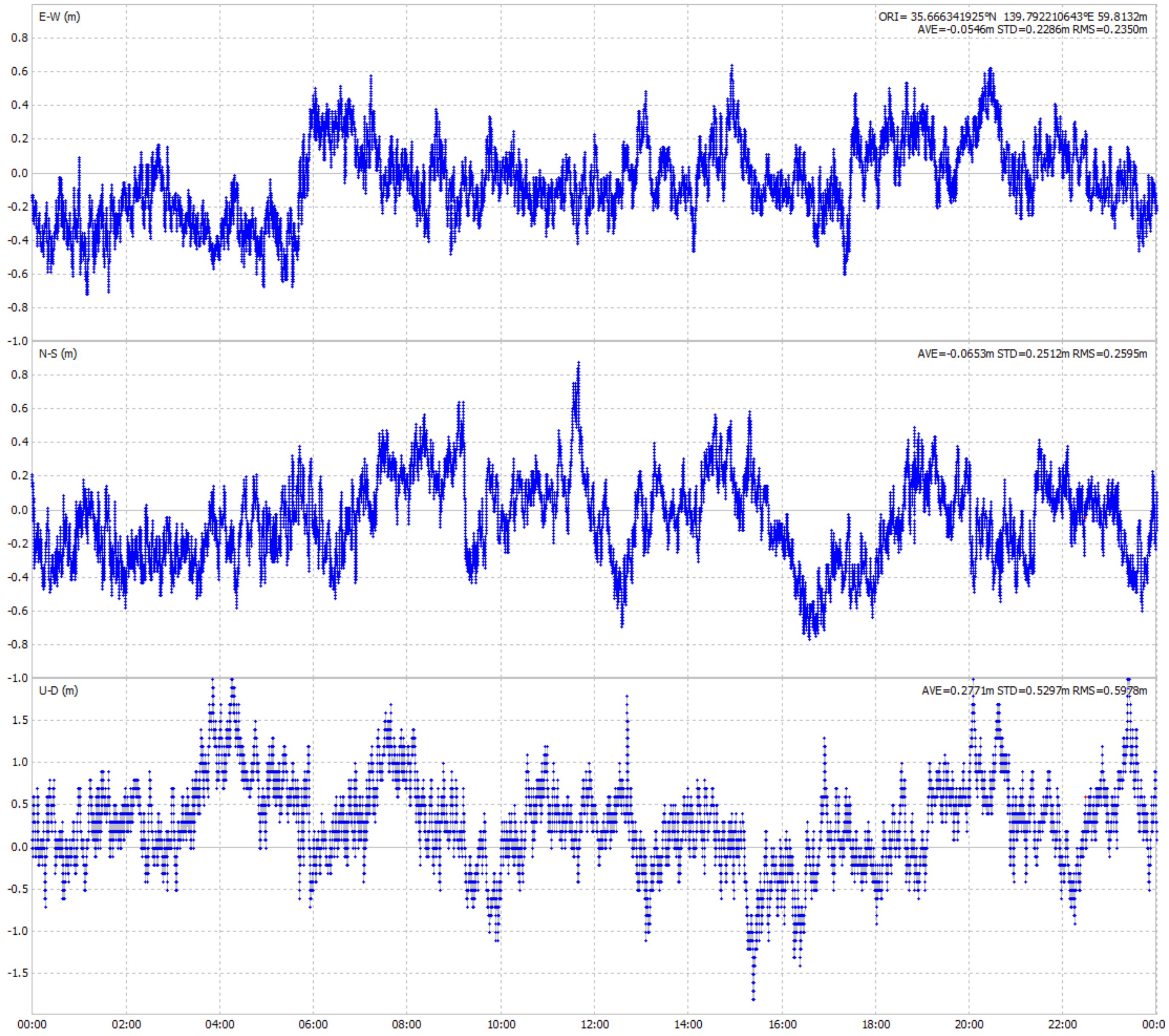
トリンブルアンテナ＋u-blox F9P受信機

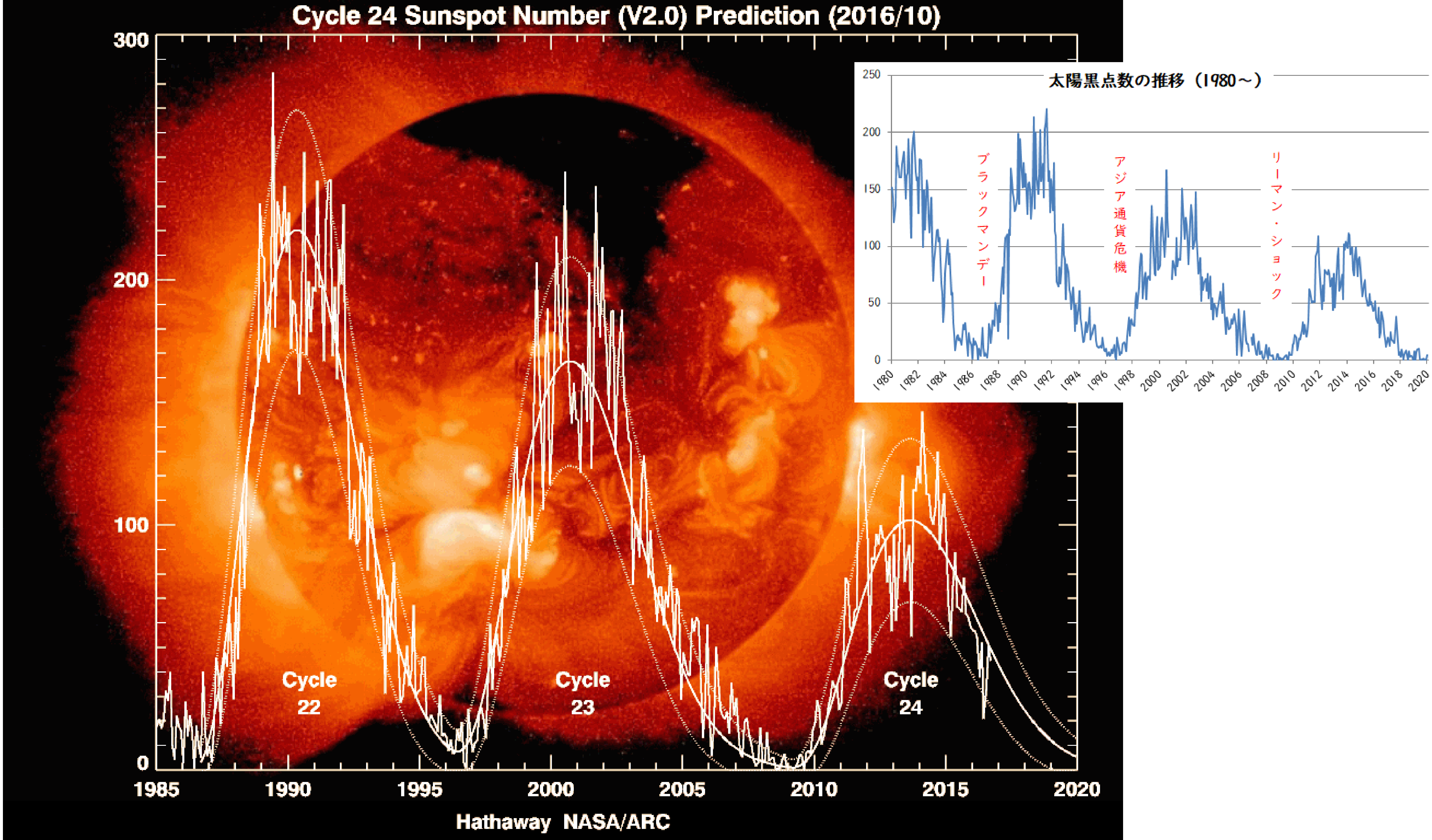
SLAS測位率：100%



※赤点線が真値から1m
(公称水平精度 95%値)

※真値はF3解より算出
Lat=35.66634193、Lon=139.79220106、 Hight=59.81



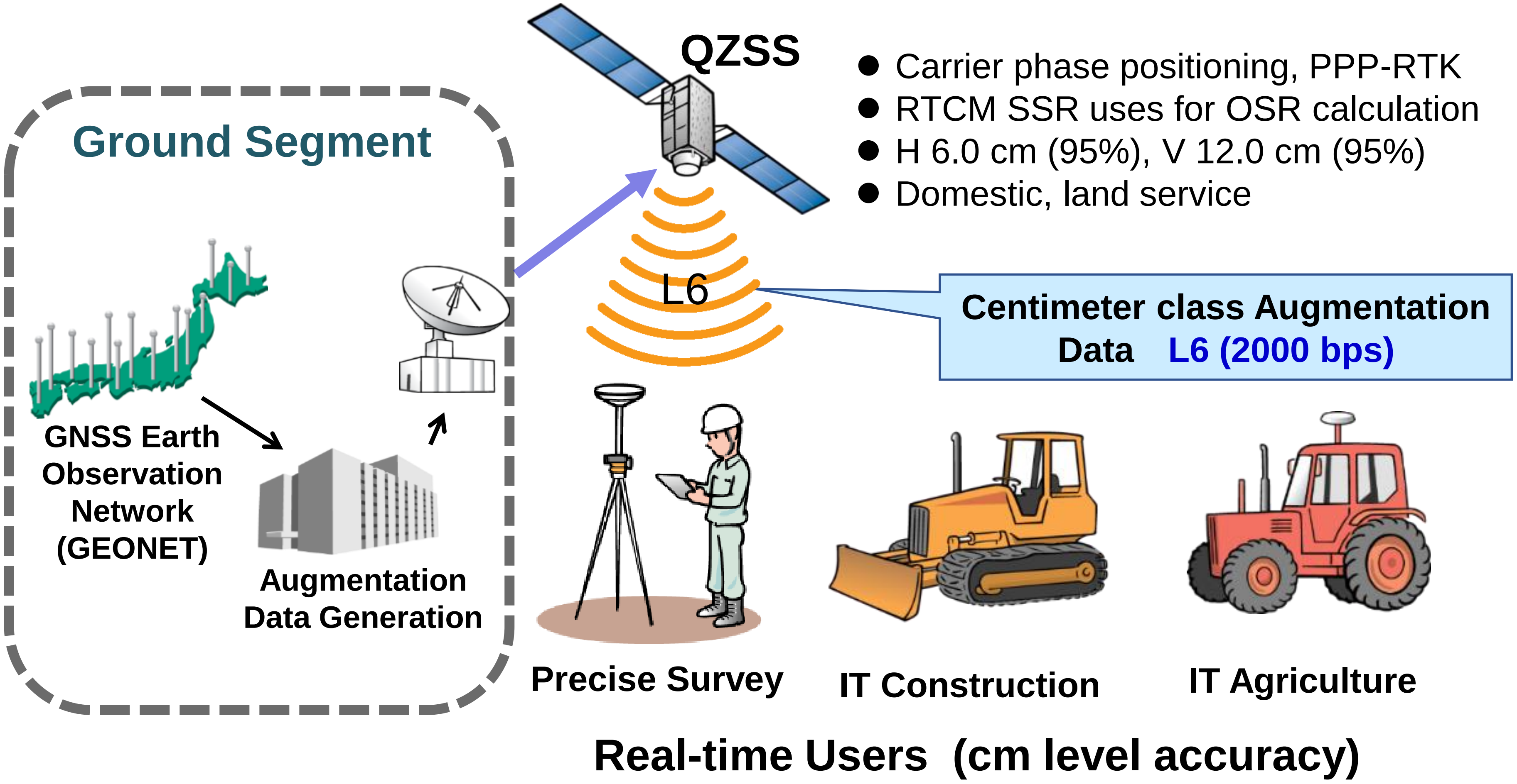


Cycle 24 Sunspot Number (V2.0) Prediction (2016/10)
300
200
100
0
1985
1990
1995
2000
2005
2010
2015
2020
Cycle 22
Cycle 23
Cycle 24
Hathaway NASA/ARC
太陽黒点数の推移（1980～）
250
200
150
100
50
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
ブラックマンデー
アジア通貨危機
リーマン・ショック

CLAS Service

Centimeter Level Augmentation Service: CLAS

- Carrier phase positioning, PPP-RTK
- RTCM SSR uses for OSR calculation
- H 6.0 cm (95%), V 12.0 cm (95%)
- Domestic, land service

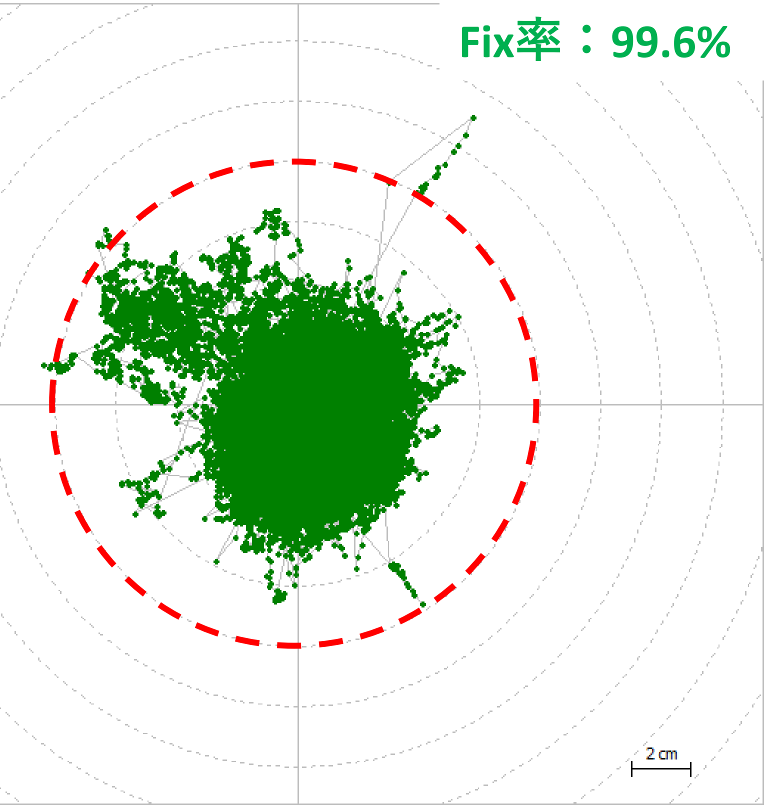


CLAS : Core AsteRx4 (TUMSAT)
6/13/2021 24H

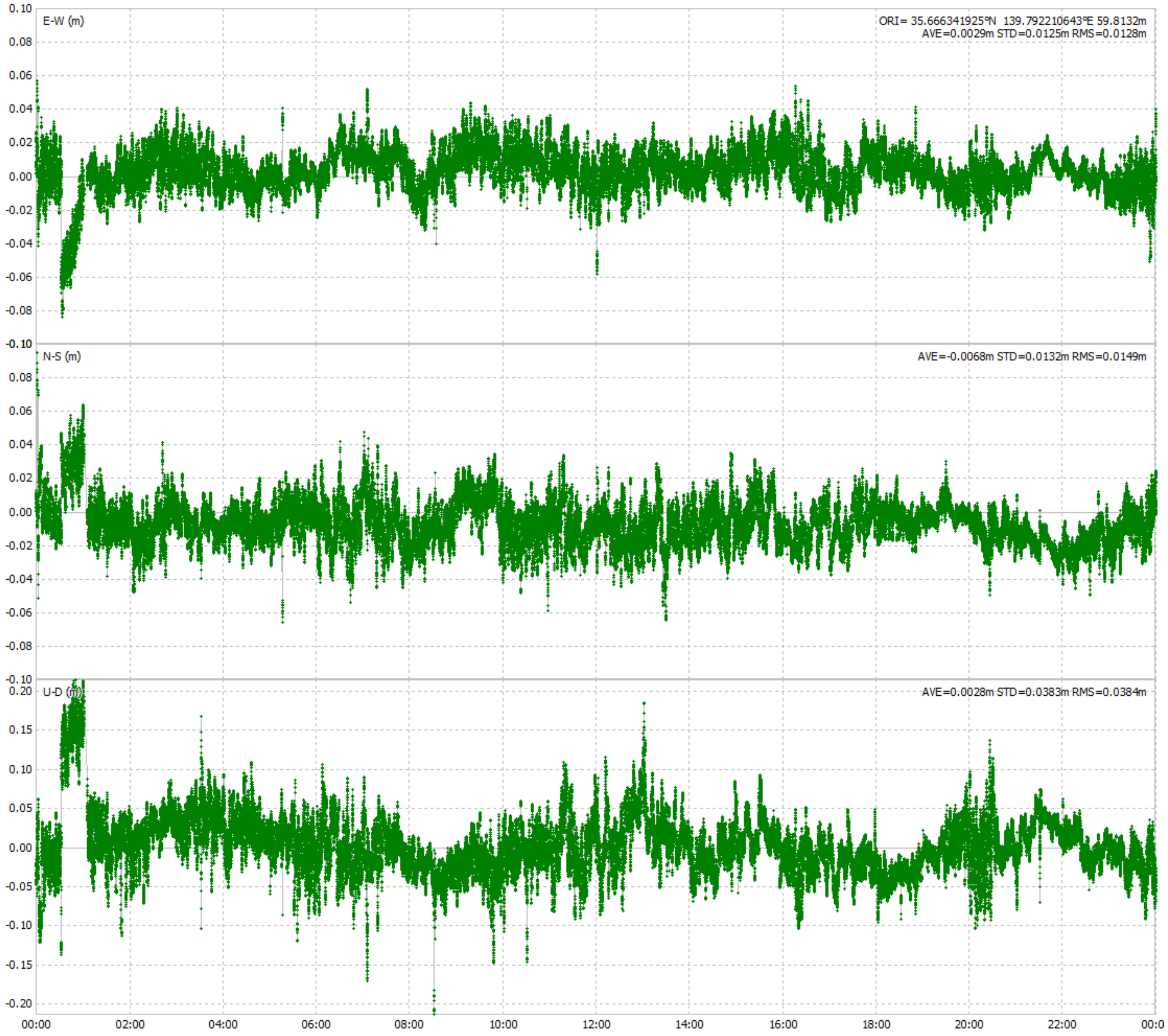
※真値はF3解より算出
Lat=35.66634193、Lon=139.79220106、 Hight=59.81

トプコンアンテナ＋CORE AsteRx4受信機

Fix率：99.6%

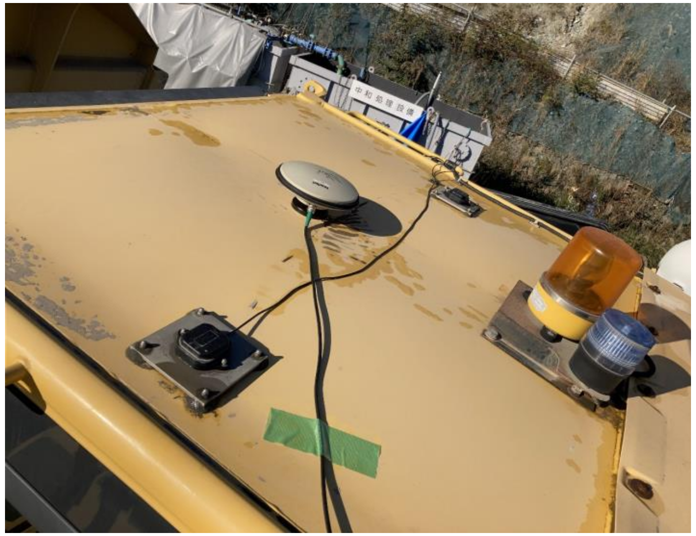


※赤点線が真値から6cm
(公称水平精度 95%値)

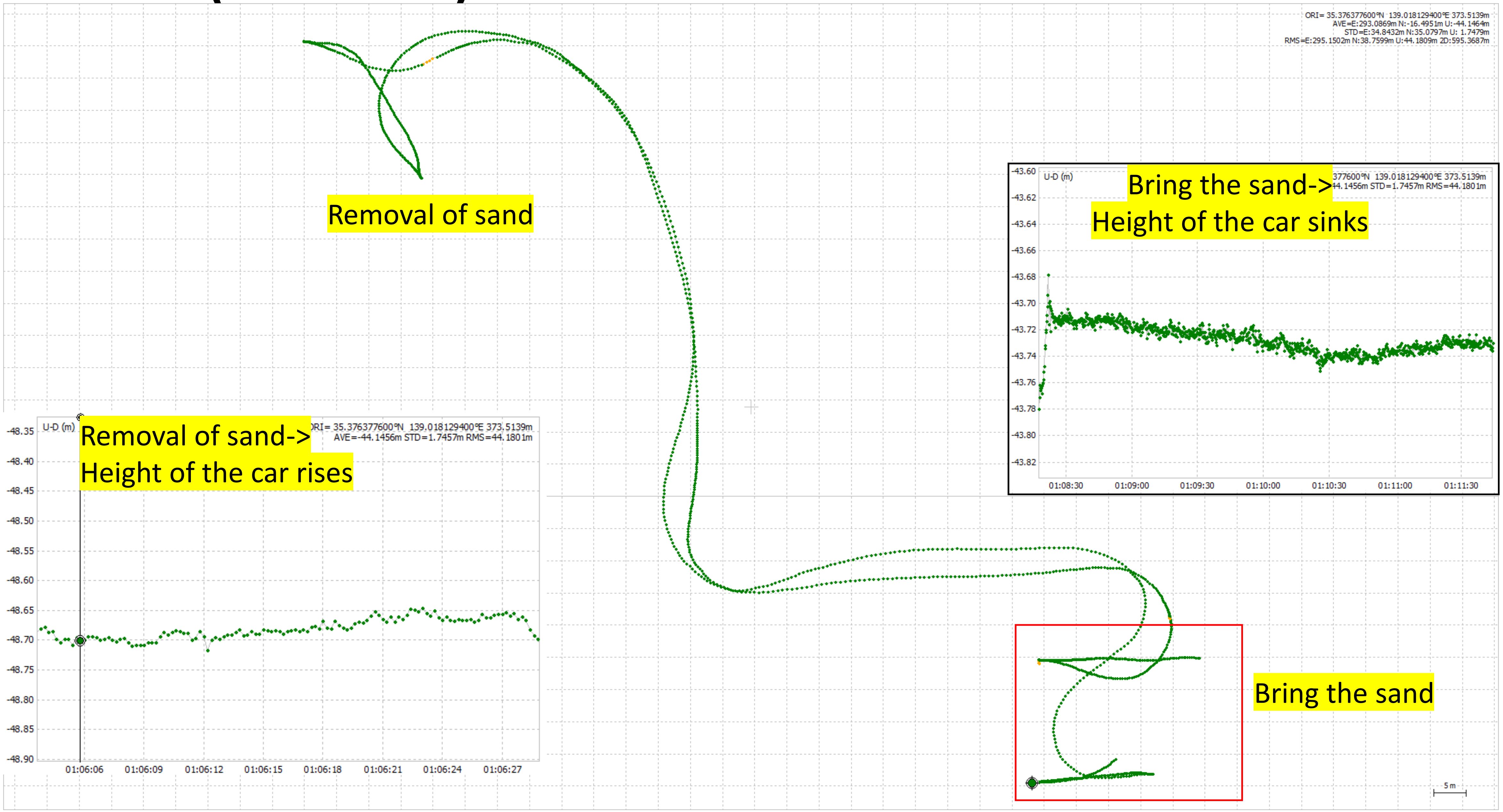


Test results at real construction site

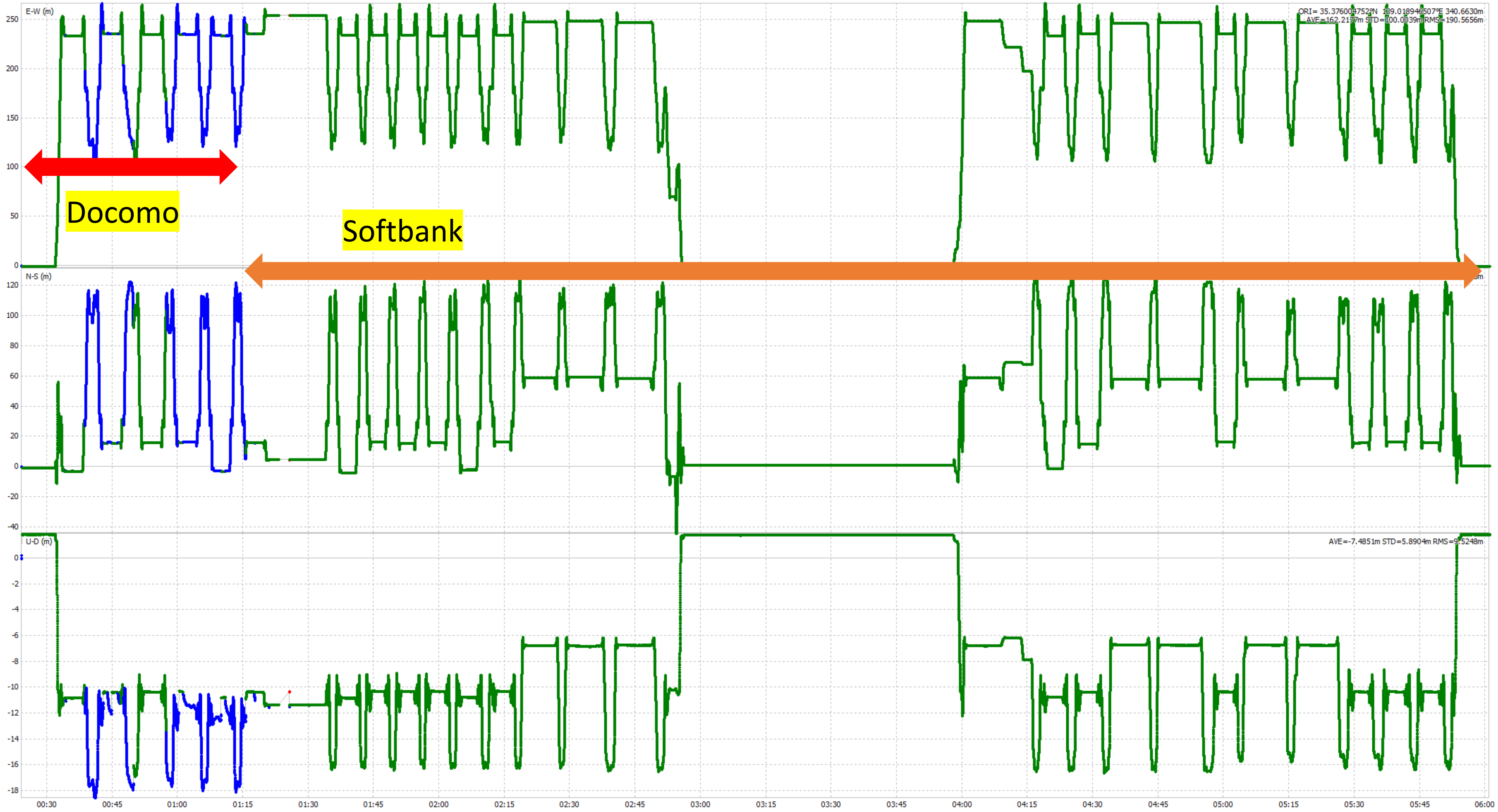
・KOMATUS製の重ダンプの運転席天井にNovAtelアンテナを設置。新東名の盛り土作業の連続運用中
・運転席横の補助座席に4分配、受信機、PC等々を設置
・データ取得は9時～15時(JST)　10時過ぎにsimを交換
・測位間隔は5Hz



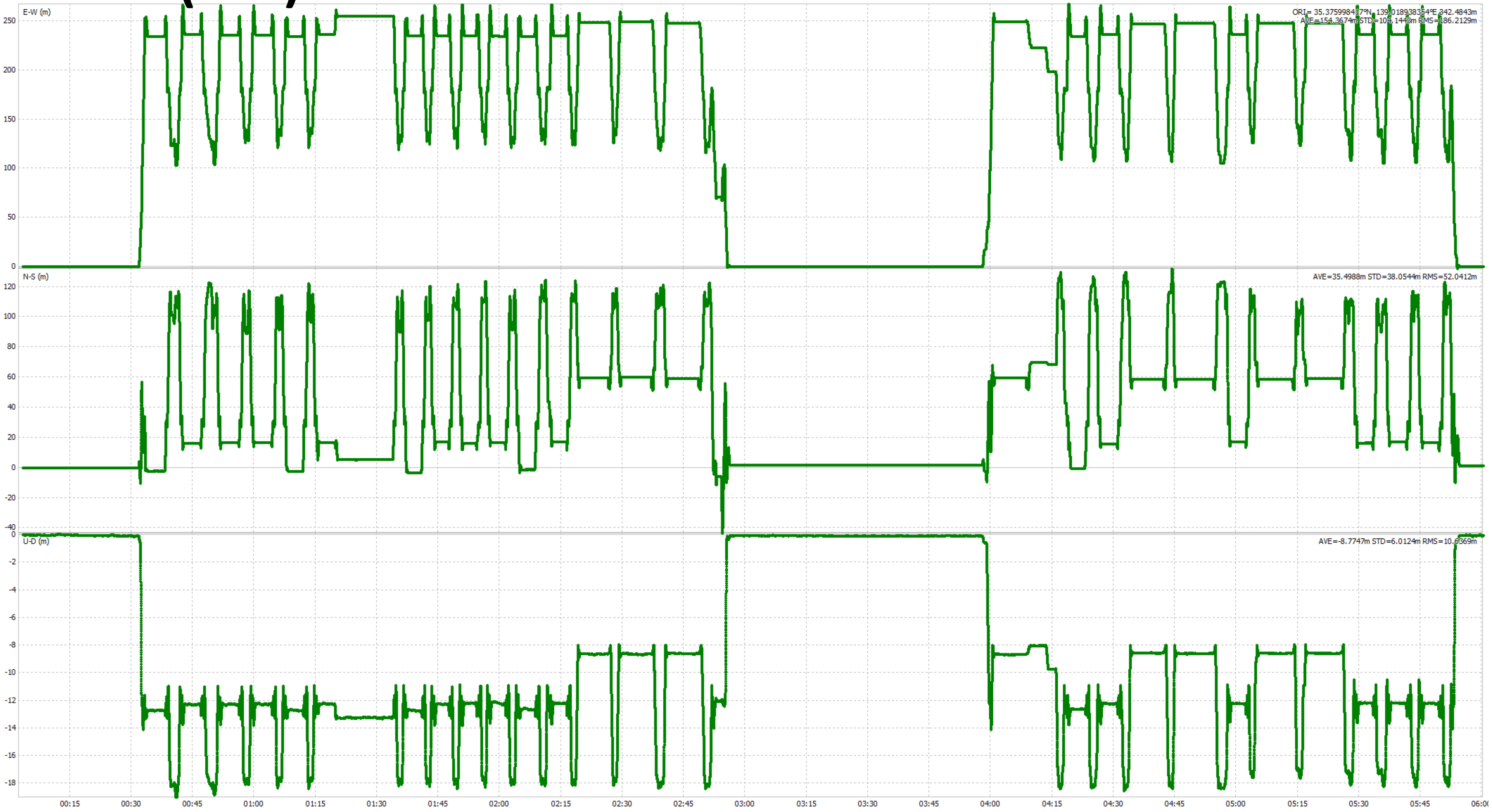
RTK results (horizontal)



RTK results (LLH)

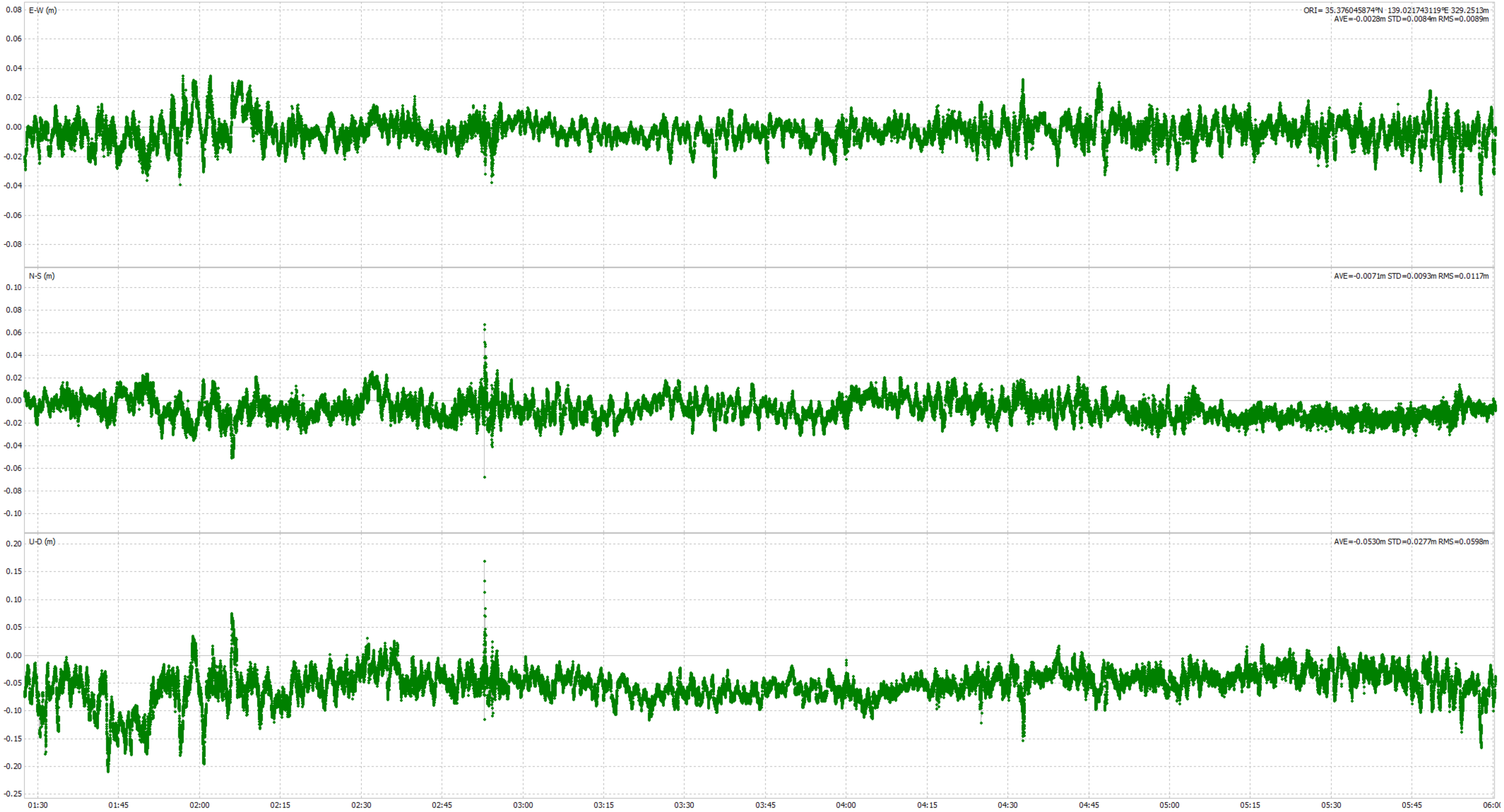


CLAS results (LLH)



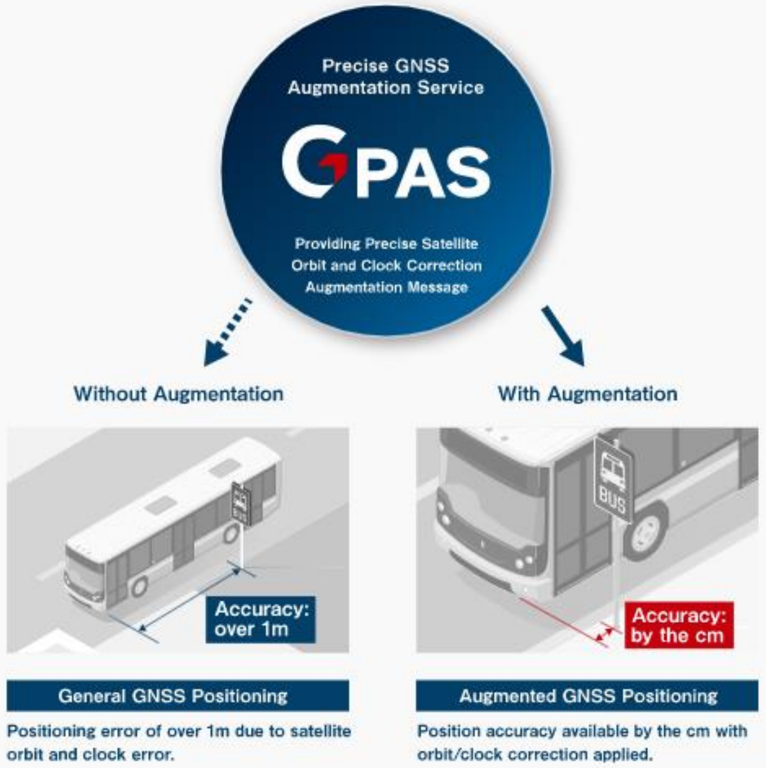
Fix率：100%

Comparison between RTK and CLAS



MADOCA-PPP（GPAS）

GPAS aspires to be a company that contributes to the realization and prosperity of a safer, more secure and more comfortable society by providing highly accurate positioning services at anytime and from anywhere in the world.



By applying an augmentation message of precise satellite orbit and clock correction, a centimeter-class GNSS positioning accuracy can be achieved.

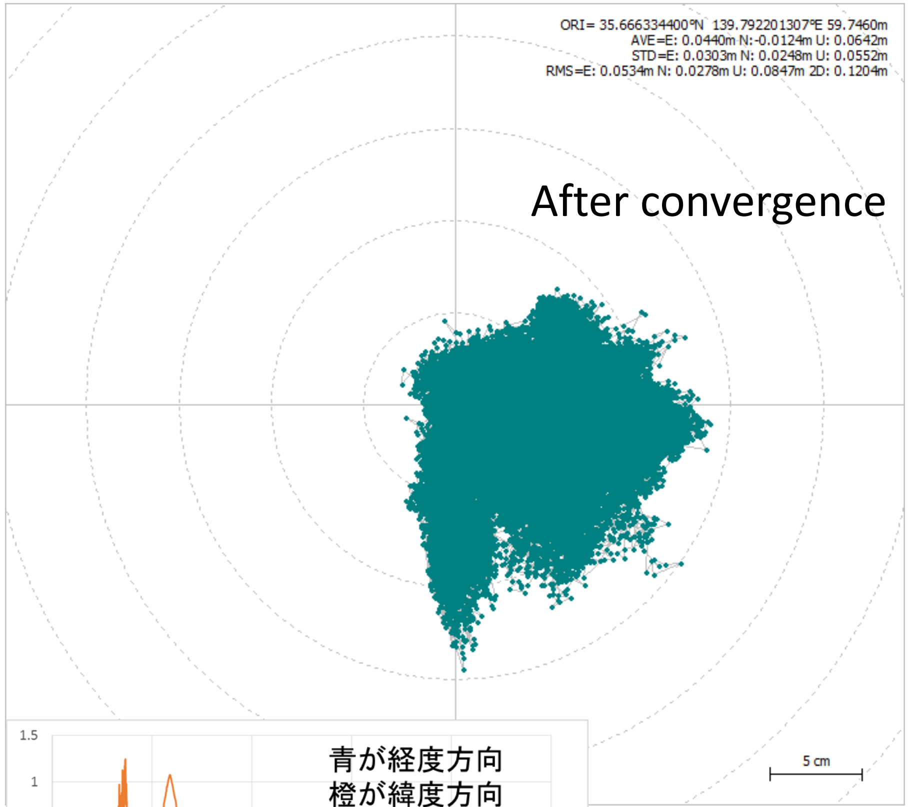
Message providing via the internet

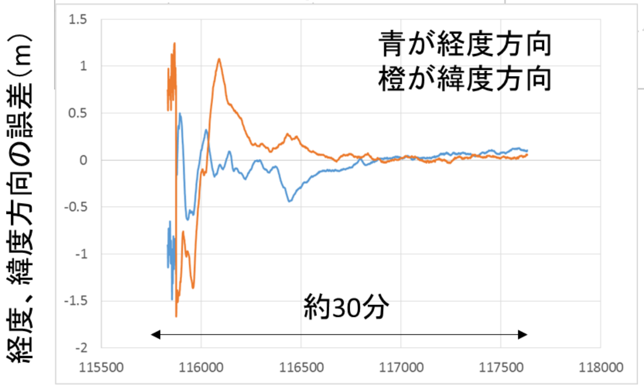
GPAS augmentation service is available at anytime and from anywhere in the world via the internet.

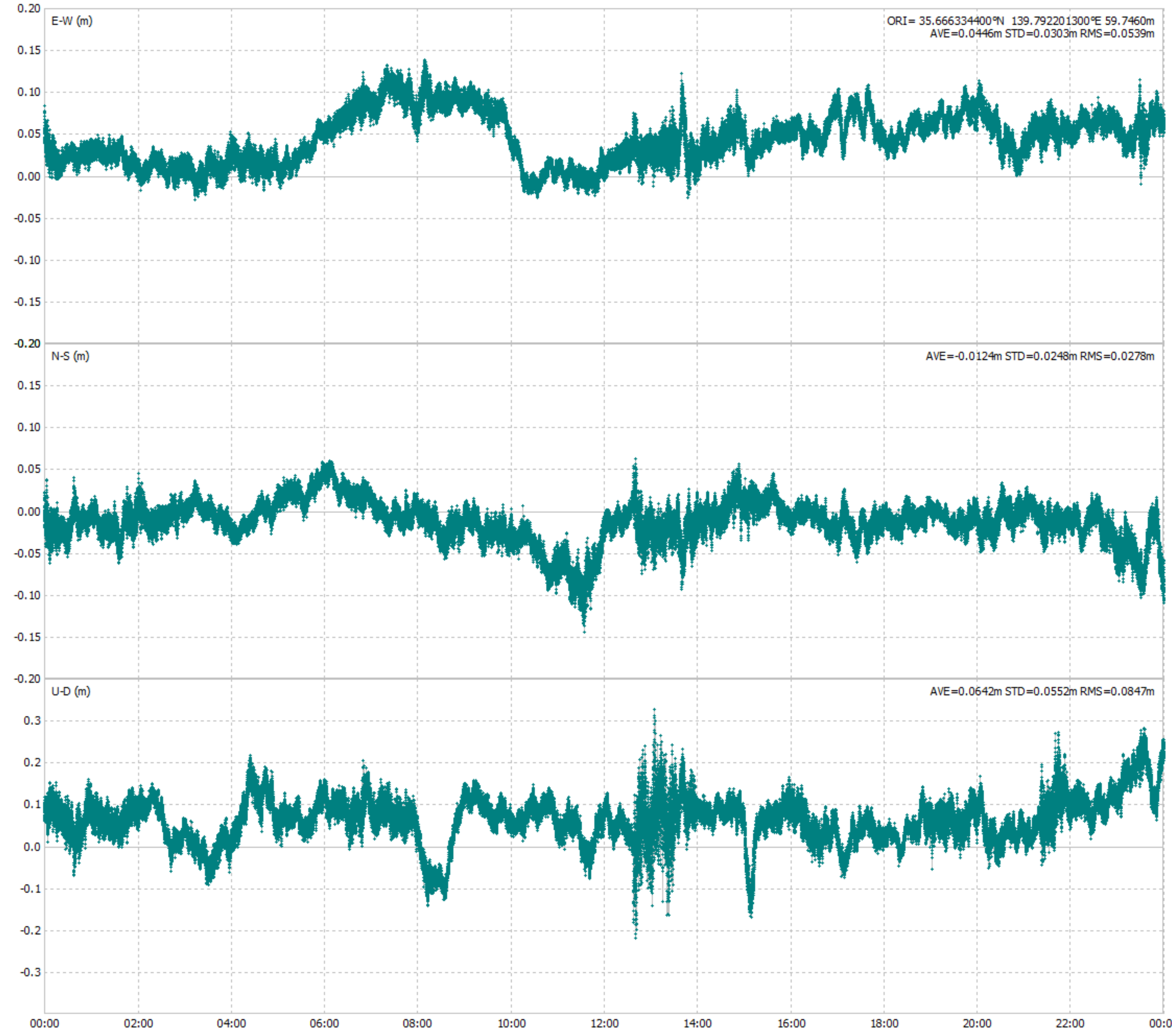
PPP : u-blox F9P (TUMSAT)
6/13/2021 24H

※真値はF5解より算出
Lat=35.6663344、 Lon=139.7922013、 Hight=59.746

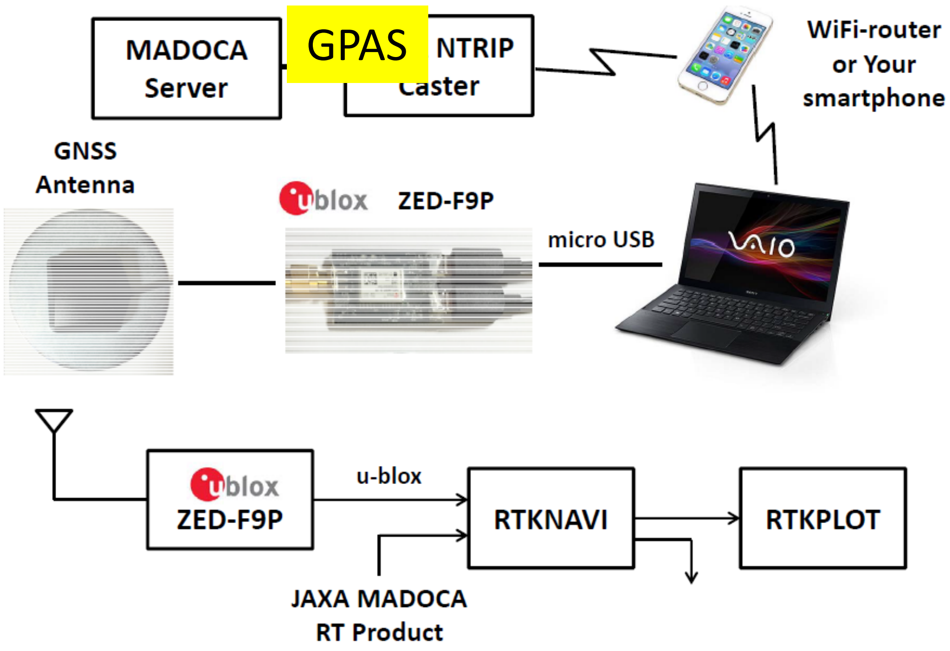
u-blox F9P+GPAS PPP correction

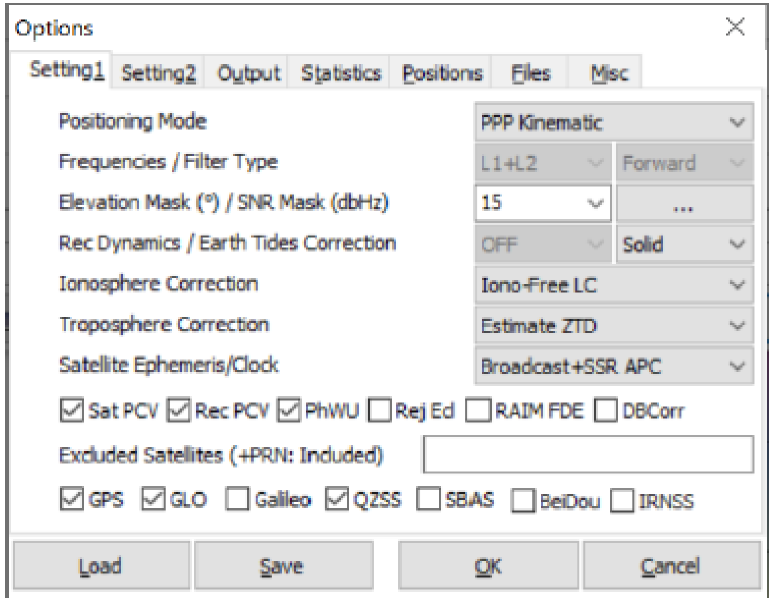


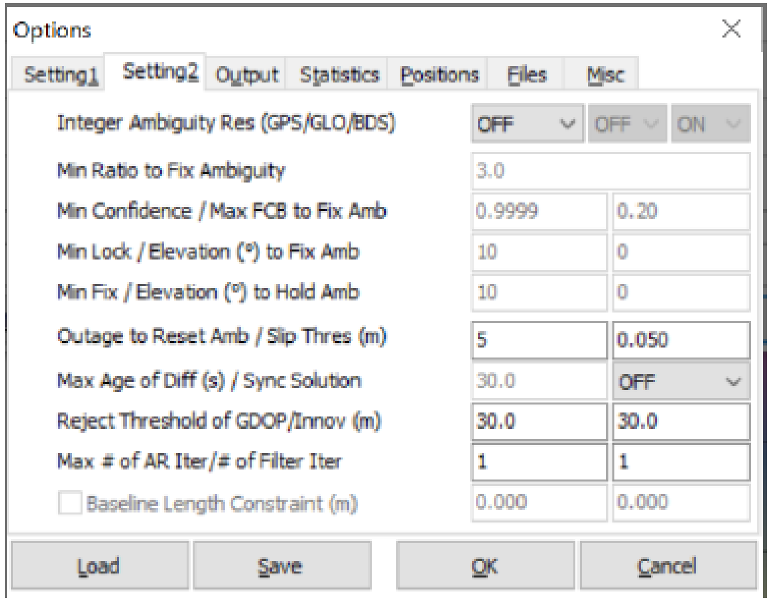


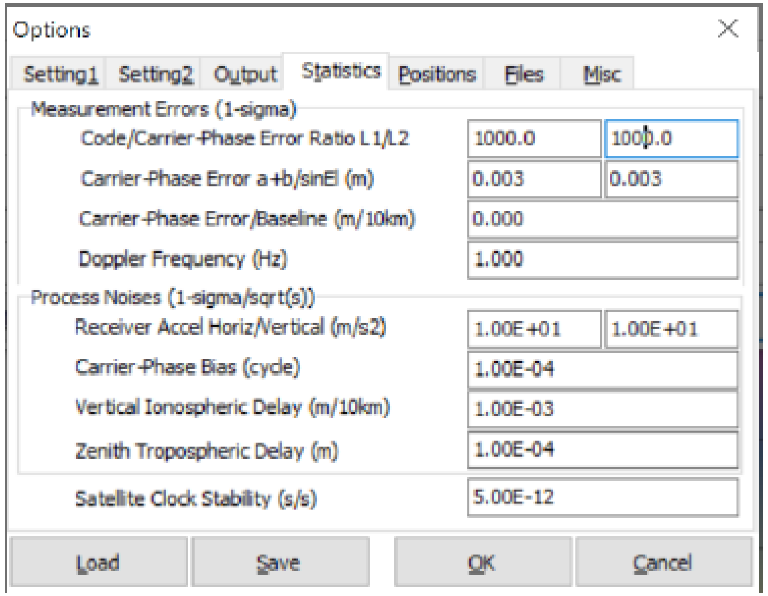


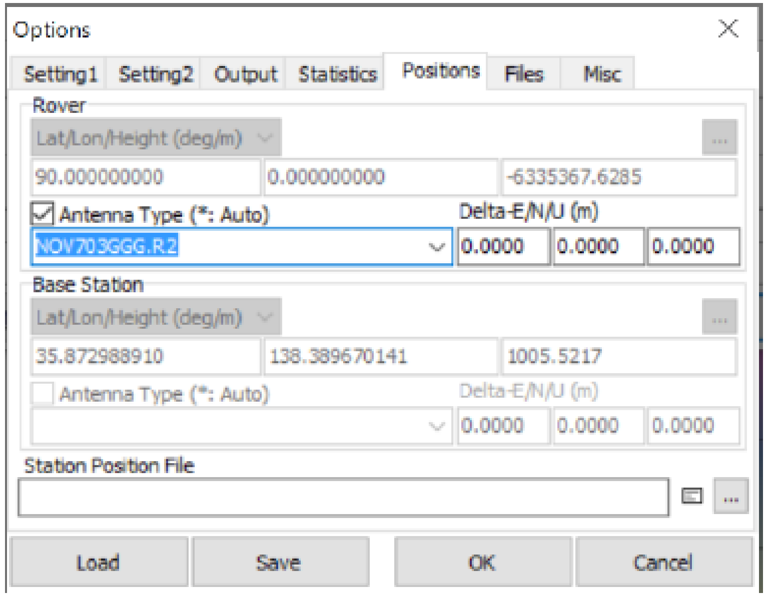
RTKNAVI PPP
-how to set-











MADOCA PPP Performance evaluation in Asia and Oceania

- The first objective is to evaluate real MADOCA PPP performance in several countries in Asia and Oceania.
- Receiver is multi-GNSS receiver manufactured by Magellan Systems Japan.
- **The second objective is to find the potential users of PPP in these countries.**

MADOCA

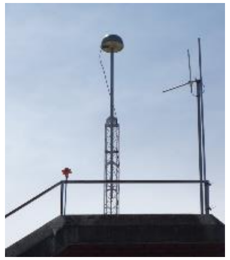
After 15 min., we can get 10 cm accuracy. With new method, we can shorten the time and PPP-AR is possible

Product(LEX signal)

GPS・GLONASS・QZSS
Precise orbit and clock



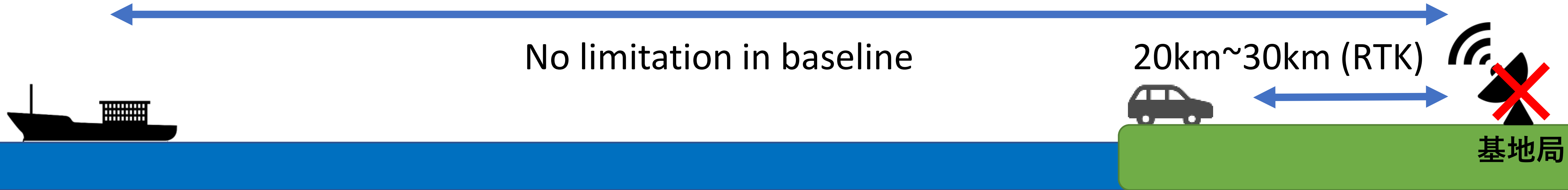




Issues in sea and undeveloped area

It is difficult to use cm-level accuracy on the sea and undeveloped areas without controlled base stations.

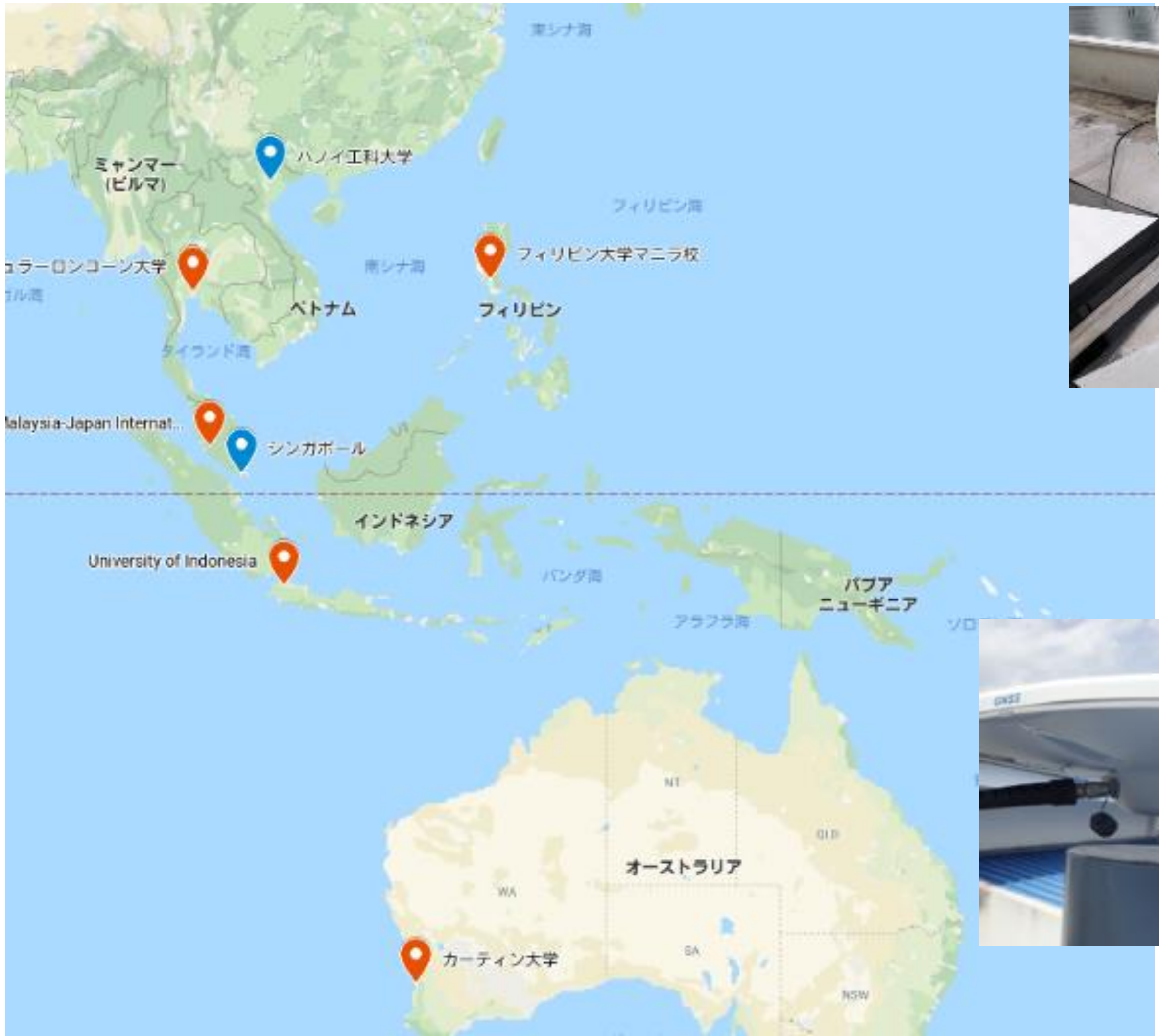
PPP is possible through the satellite



Outline of locations

Locations (Time)

TUMSAT JAPAN （August 2019）
Chula Thailand （August 2019）
UOP Philippine （August 2019）
MJIIT Malaysia （Nov. 2019）
Curtin Australia （Nov. 2019）
UOI Indonesia （Dec. 2019）
Singapore： （Feb. 2021）
Vietnam： （）



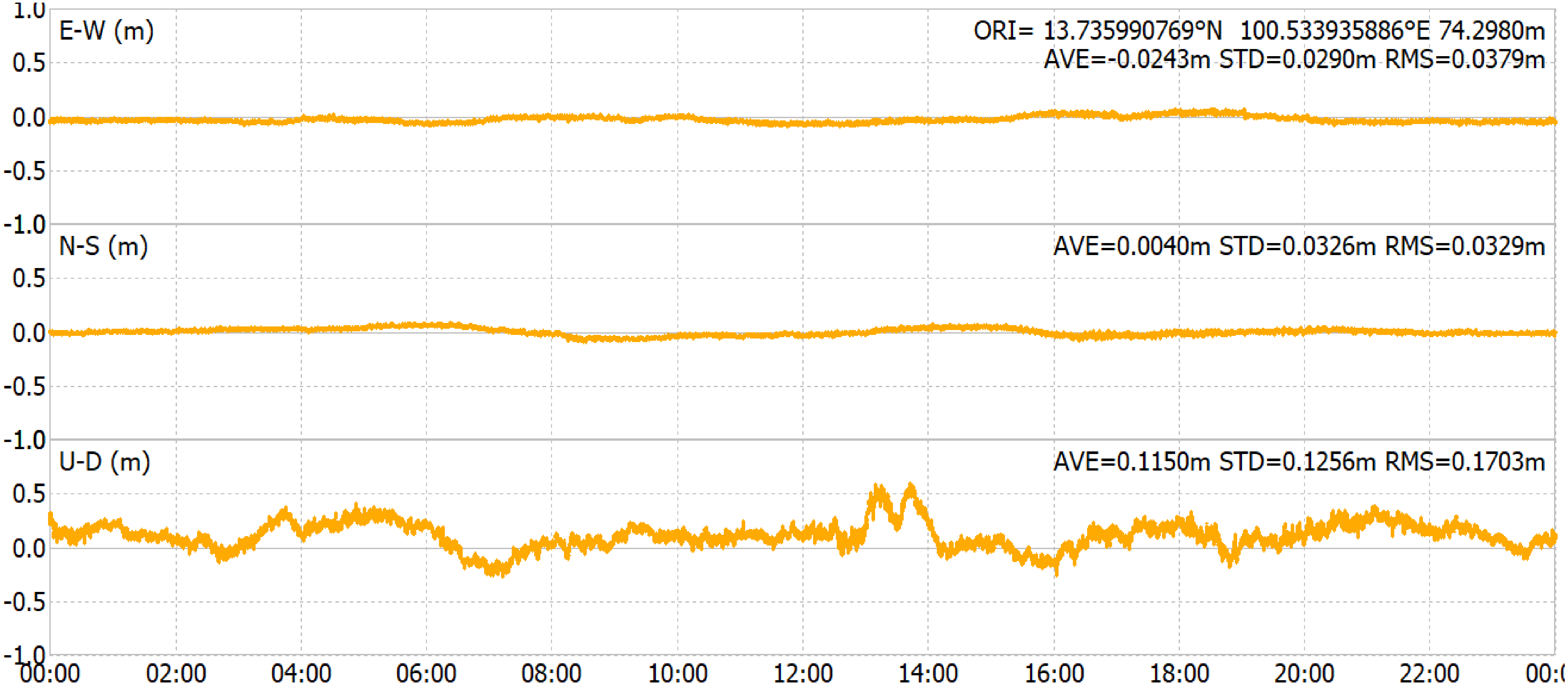
Thailand

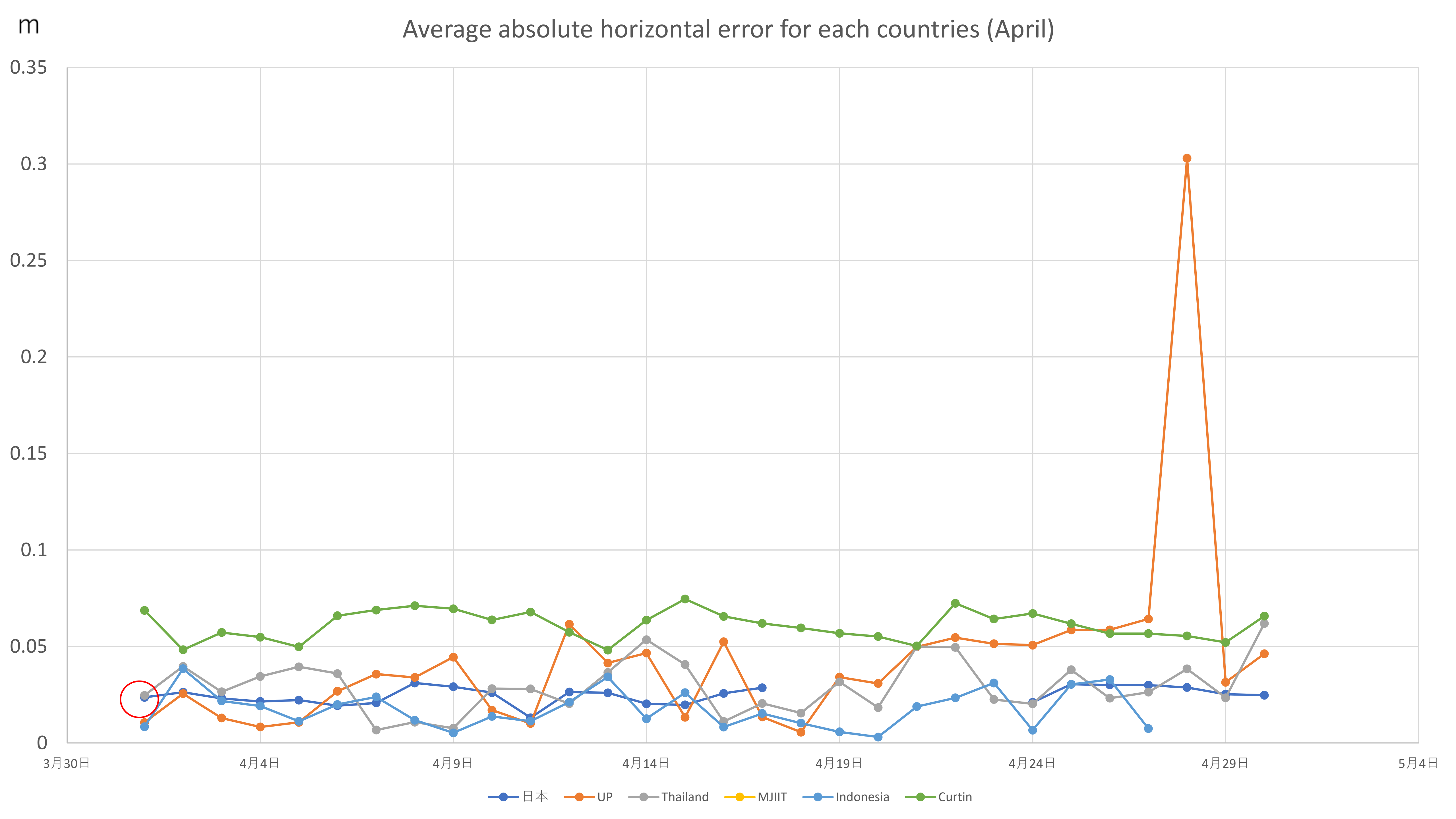
Tokyo

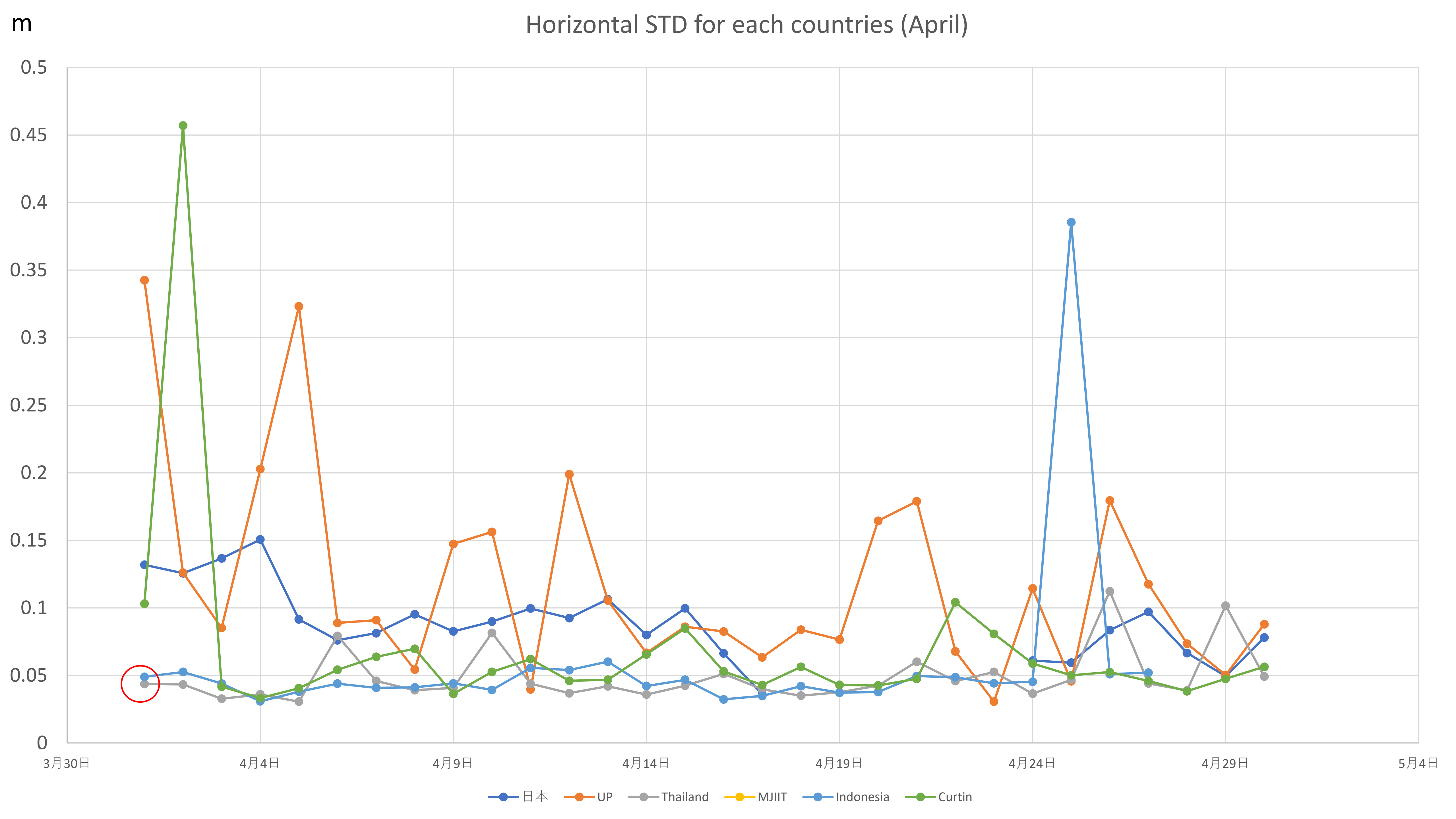
Australia→

←Malaysia

1,Apr,2020,real time (Thailand)




m
Average absolute horizontal error for each countries (April)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3月30日
4月4日
4月9日
4月14日
4月19日
4月24日
4月29日
5月4日
日本
UP
Thailand
MJIIT
Indonesia
Curtin

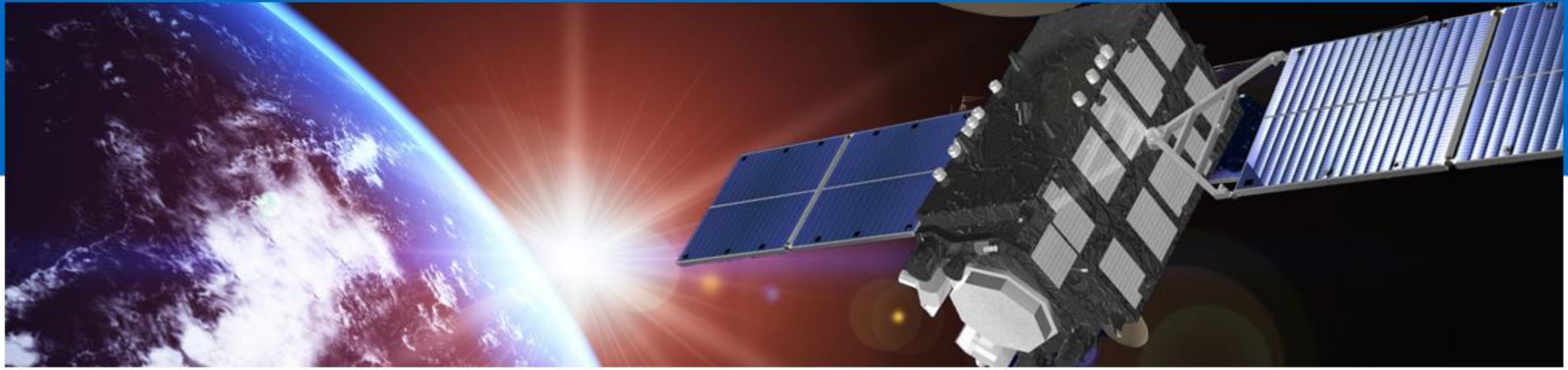


m
Horizontal STD for each countries (April)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
3月30日
4月4日
4月9日
4月14日
4月19日
4月24日
4月29日
5月4日
日本
UP
Thailand
MJIIT
Indonesia
Curtin

スタート | 未読12346件 - Yahoo!メー | GNSS TUTOR | JP-NMEA201912.pdf | Curtin-NMEA201912.pdf

http://www.denshi.e.kaiyodai.ac.jp/gnss_tutor/madoca.html

GNSS TUTOR



About this site

This site is mainly for students/beginners who learn basic of GNSS including precise positioning. We will update the experiments at least once a month in "Report". If it is difficult to modify RTKLIB by yourselves, please check "RTKcore". In addition, performance of MADOCA PPP in several countries are updated in "MADOCA PPP".

- TopPage
- RTKcore
- Report
- MADOCA PPP

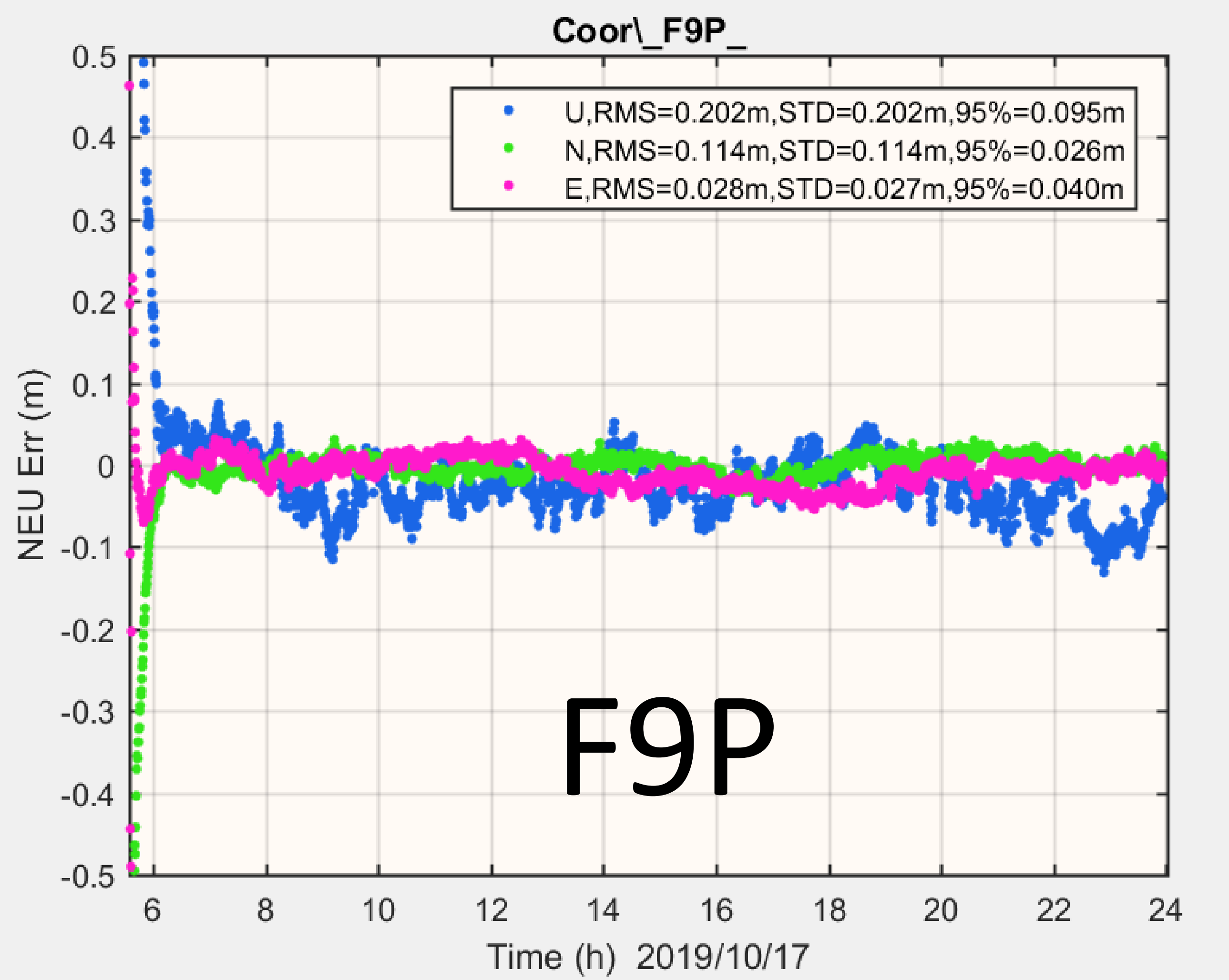
国立大学法人 東京海洋大学
Tokyo University of Marine Science and Technology

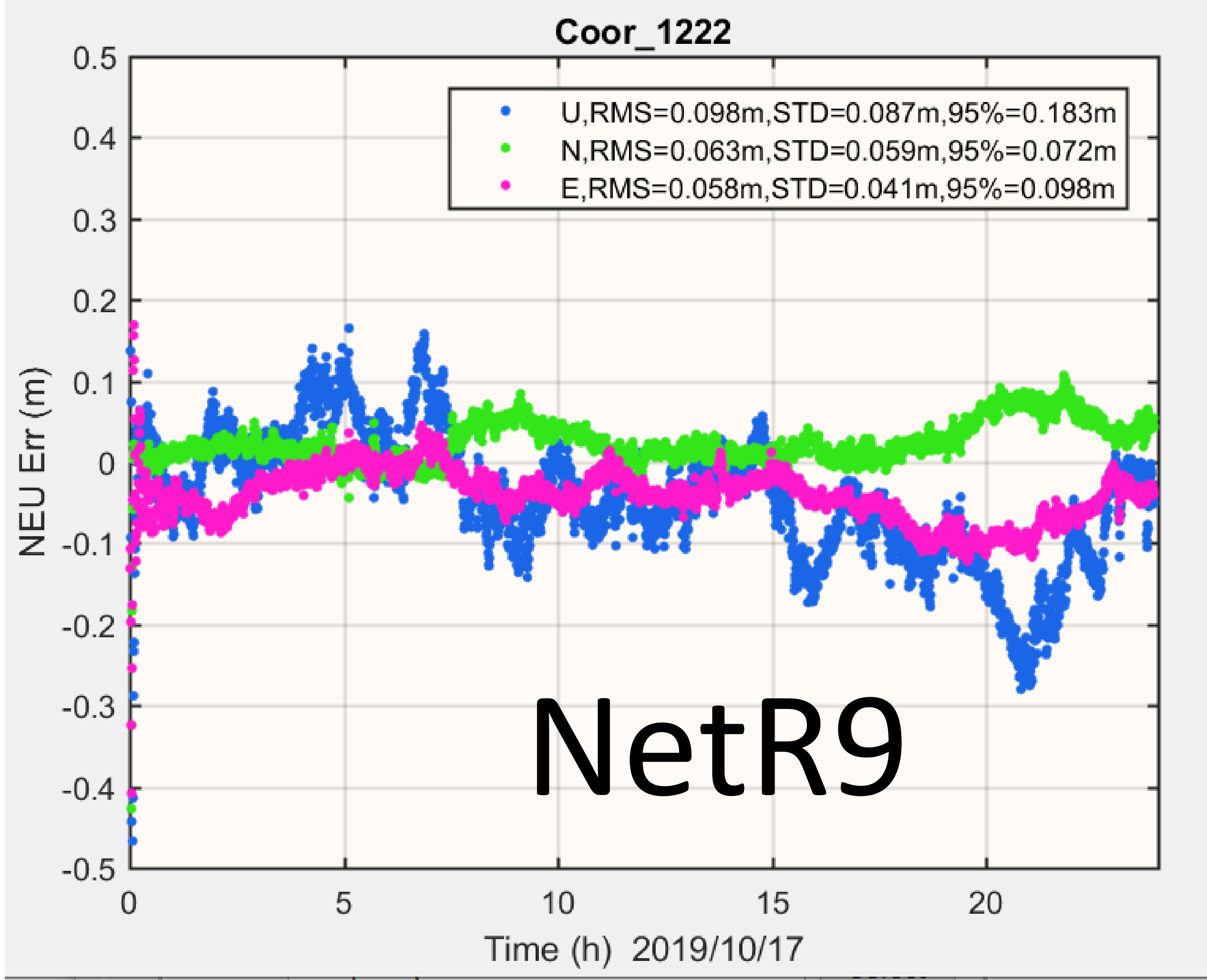
東京海洋大学 海洋工学部
海事システム工学科 GPS/GNSS研究室

News

GNSS TUTOR is updated (1/14/2020).

Comparison between low-cost and high-end
kinematic mode : GPS/GLO/QZSS (IGS final), TUMSAT





SLAS/CLAS/MADOCA comparison at the same time

Brief test at Iwaki farm
RTK vs. SLAS/CLAS/MADOCA-PPP

GPS-703-GGG-HV

5m

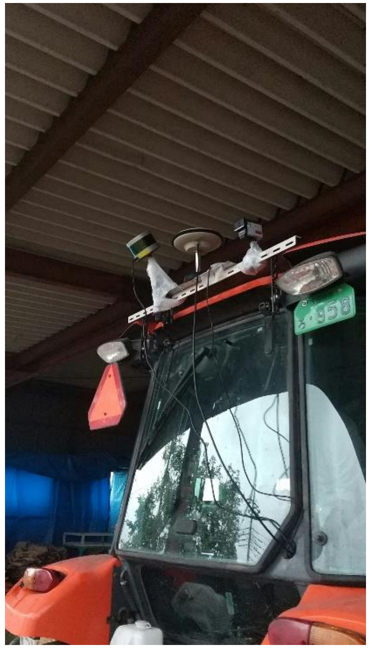
4 splliter

Lighthouse受信機

MADOCA-PPP

DC Truth

5m



F9P(SLAS)
5Hz

F9P(rawx)
5Hz

AsteRx4 5Hz

CLAS

Test environment

Plow a field for soybeans

10-20cm required

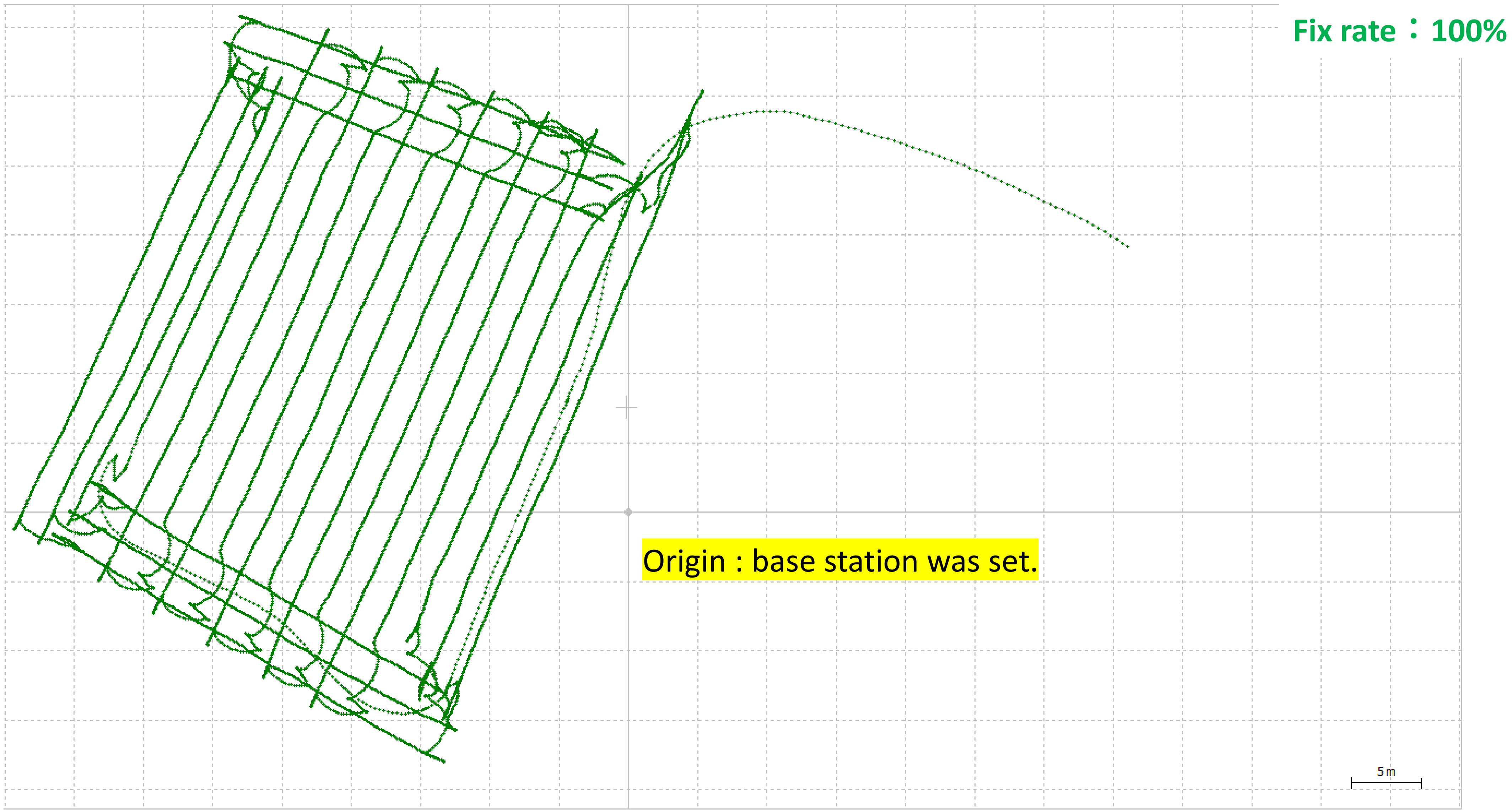
SPP ×

SLAS △

CLAS/MADOCA ○

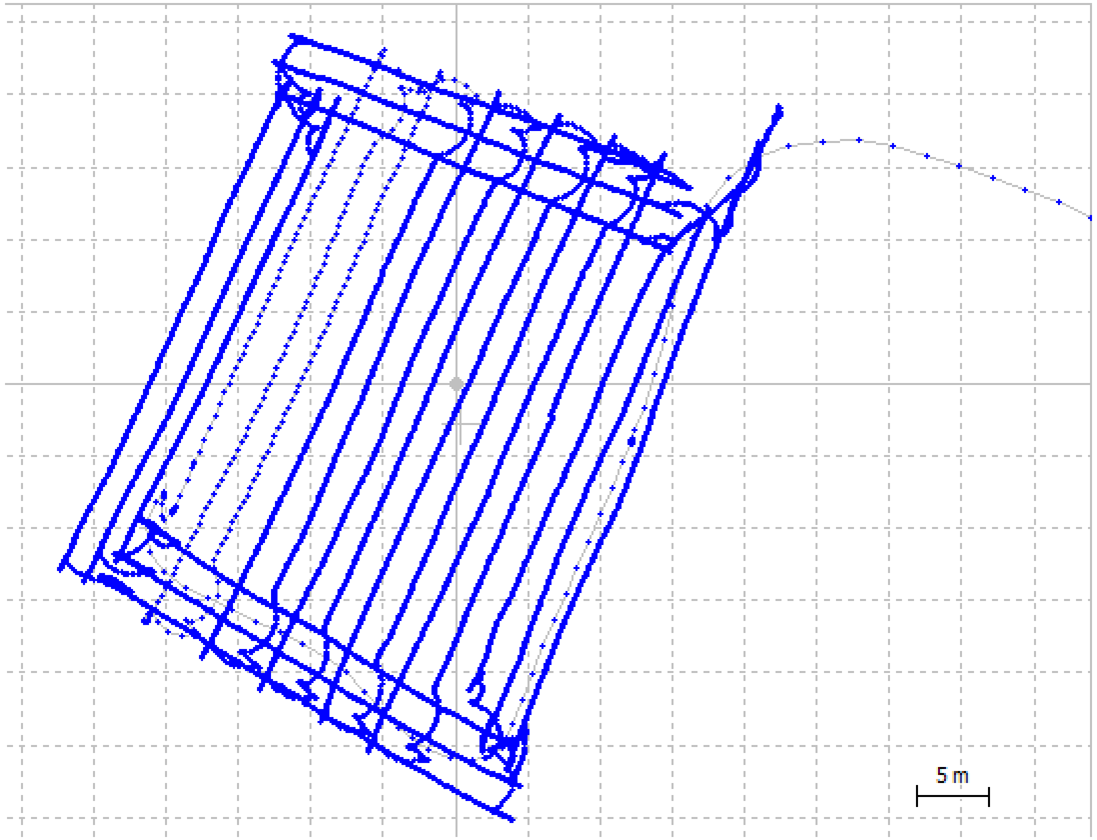
https://agri-info-design.com/agribus-navi-2/

Post-processed RTK

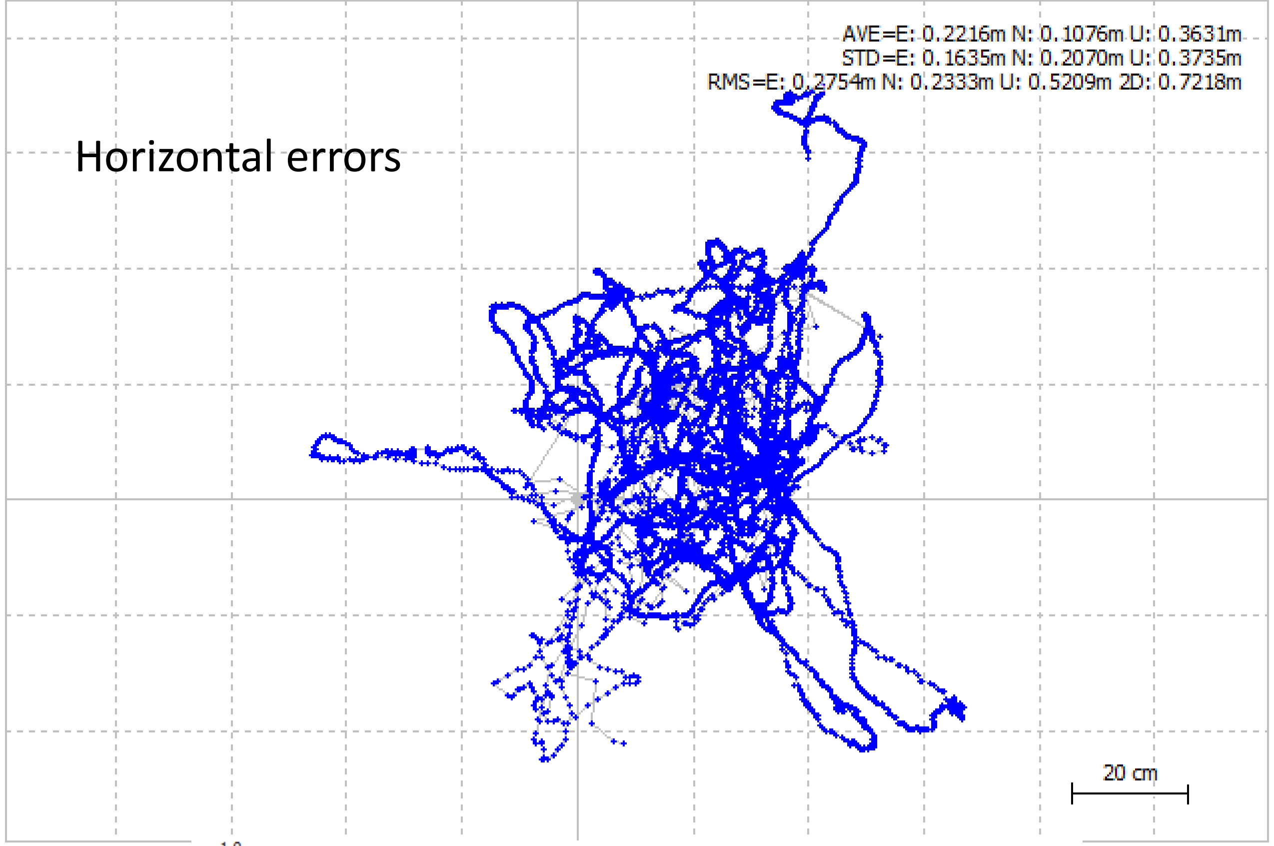


RTKLIB_b33でリファレンス位置を生成(解析条件：GQEB、15度、35dB、Fix and Hold)
解析時間：5時29分45秒～6時11分0秒(GPSTIME)

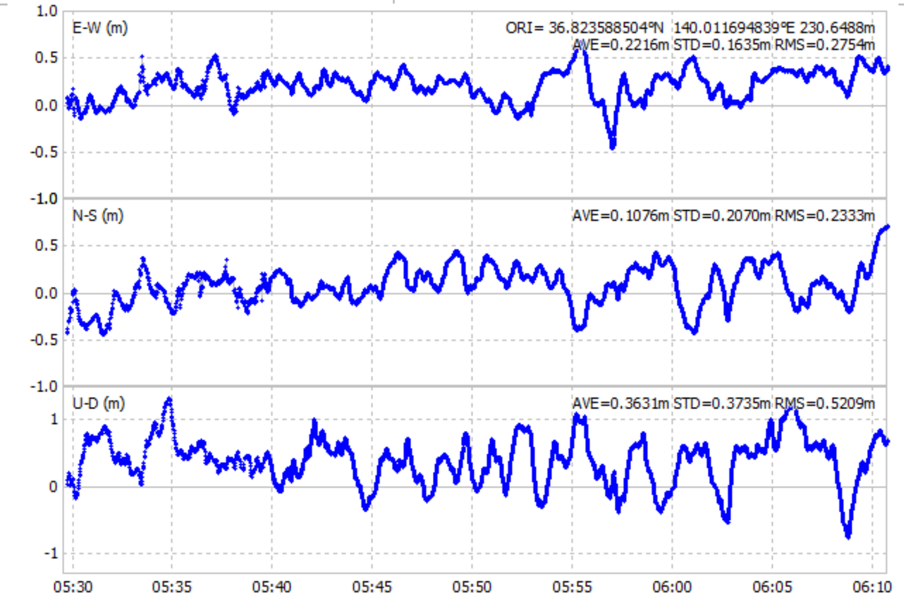
SLAS



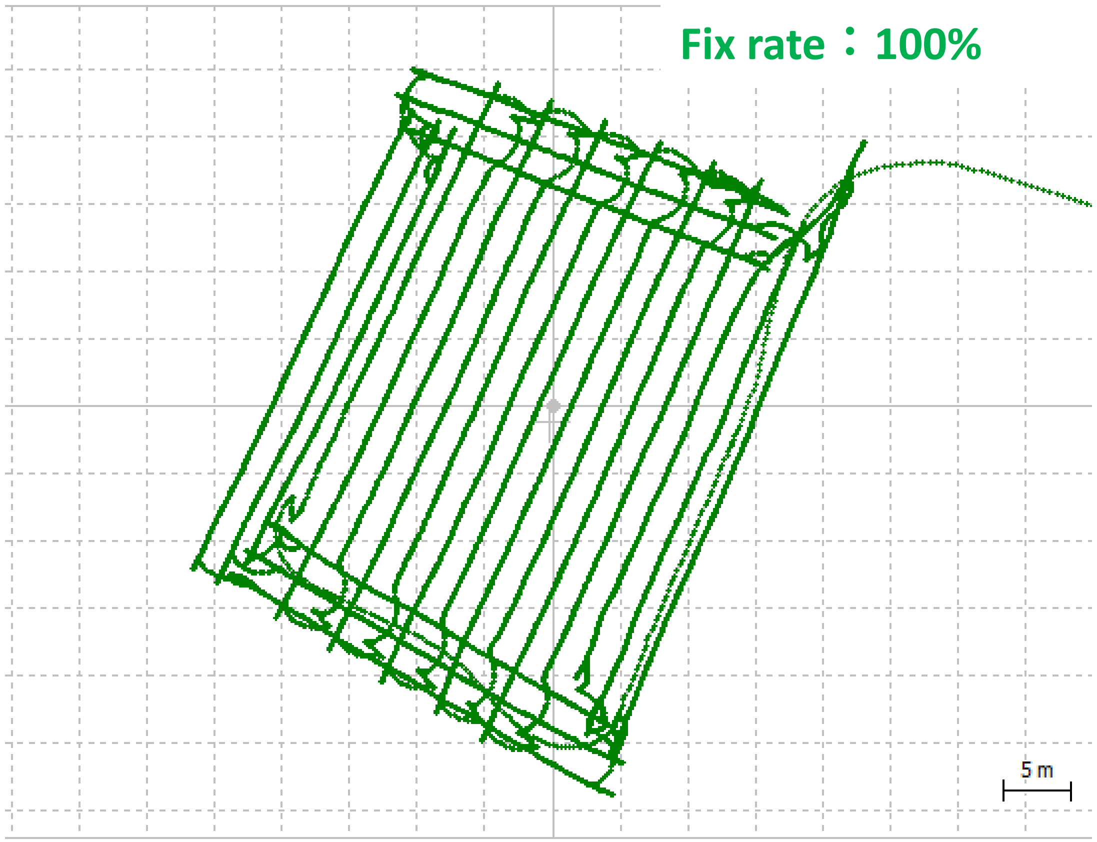
SLAS 100%

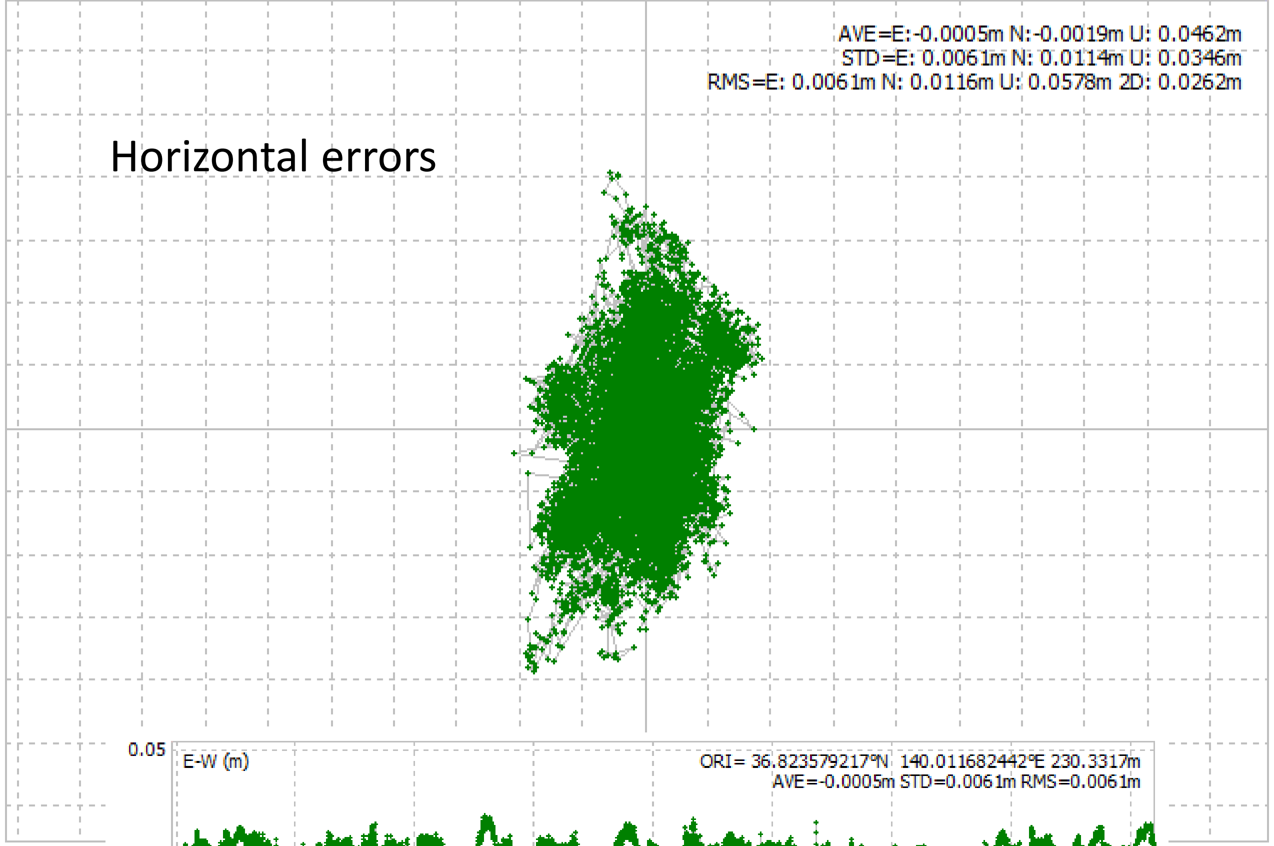


LLH errors

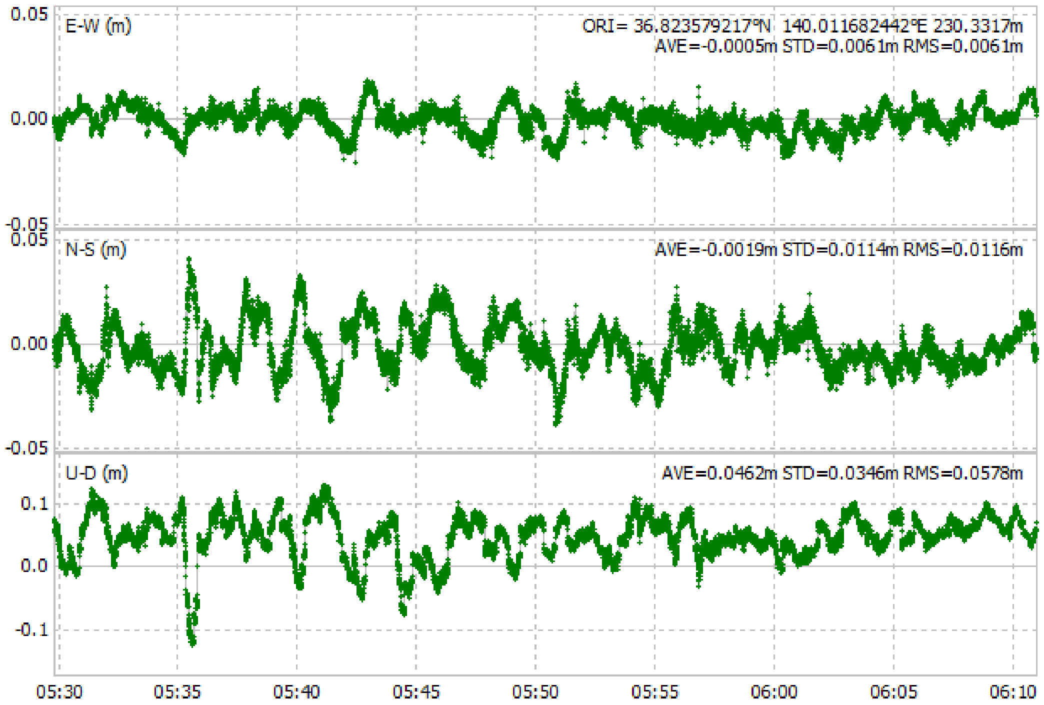


CLAS

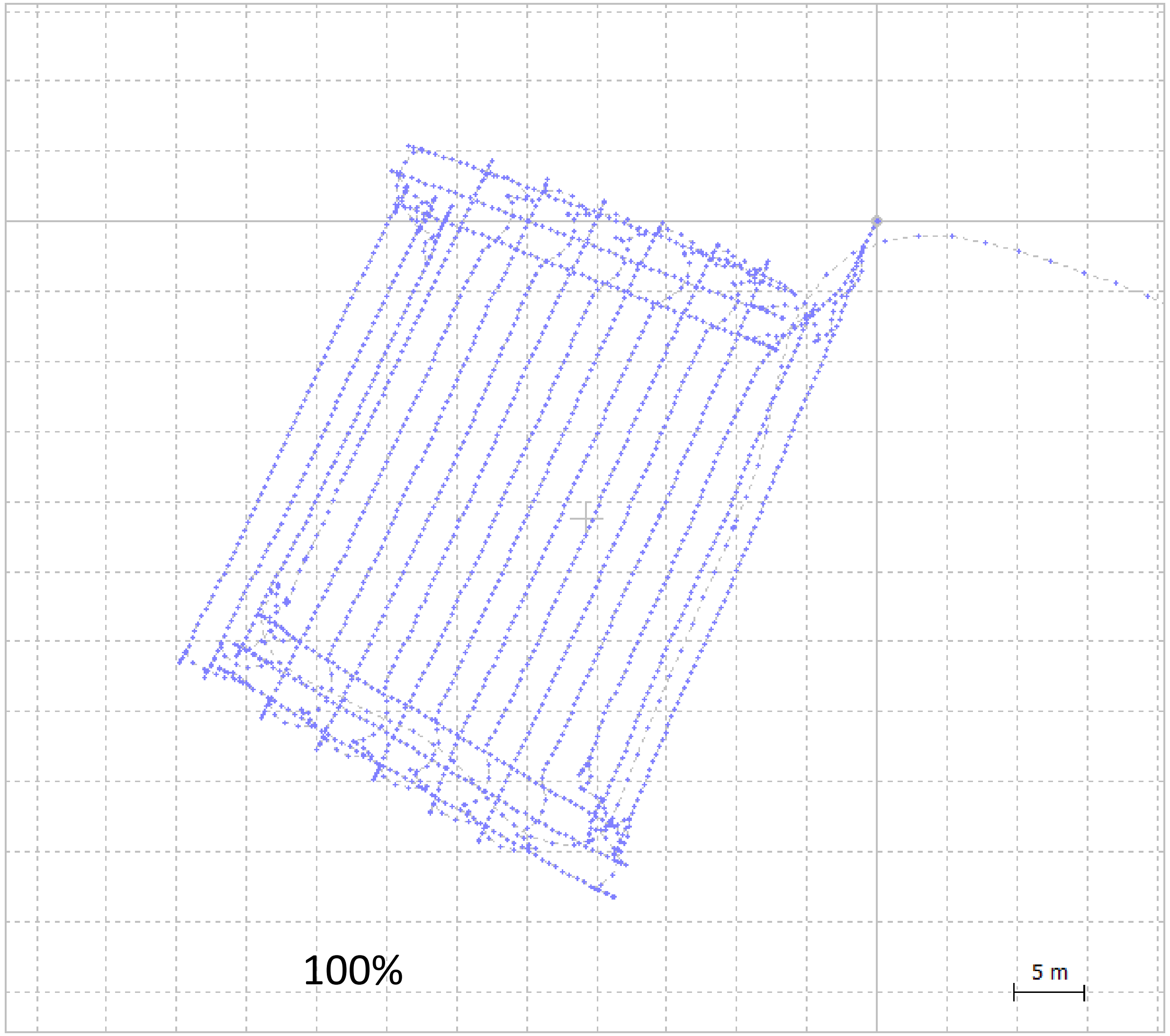




LLH errors

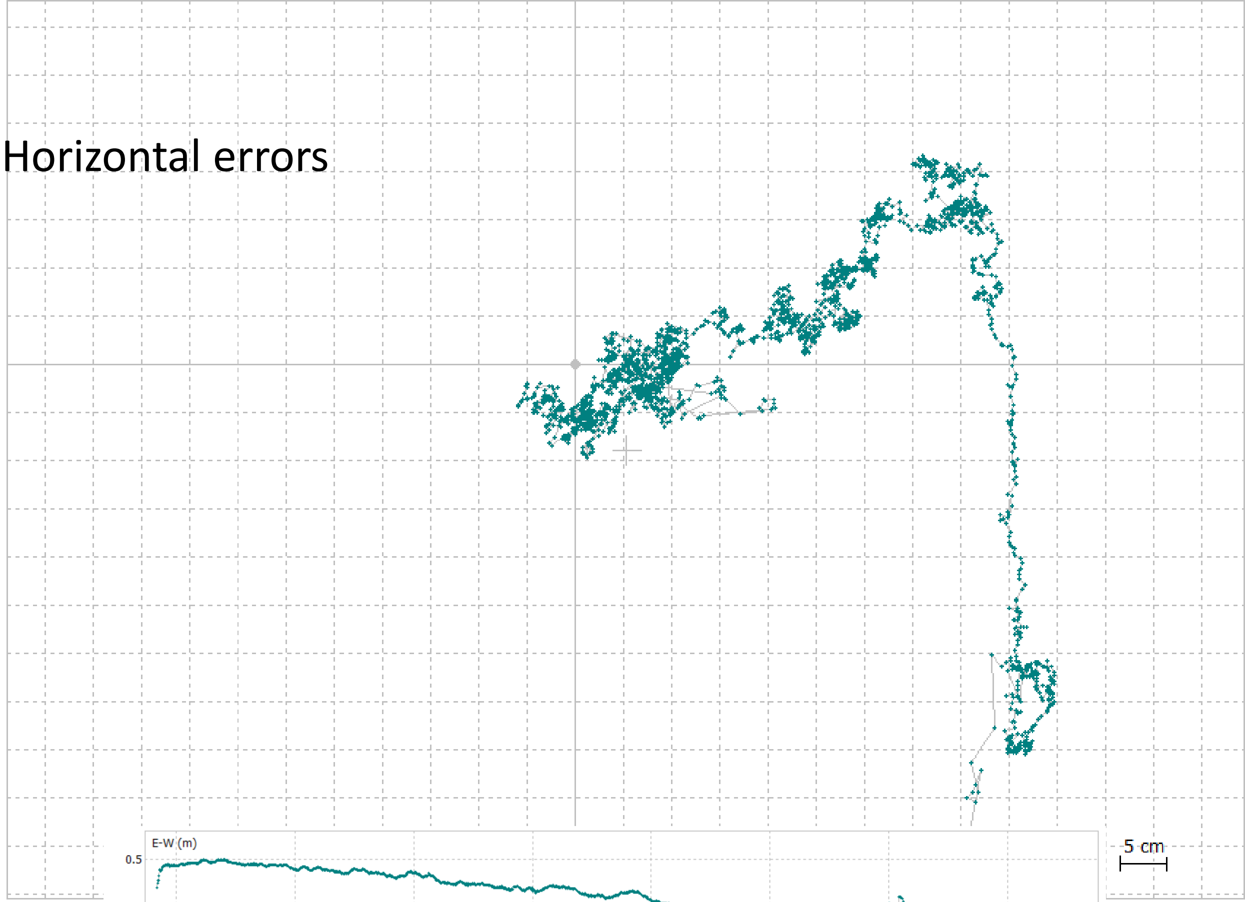


MADOCA-PPP

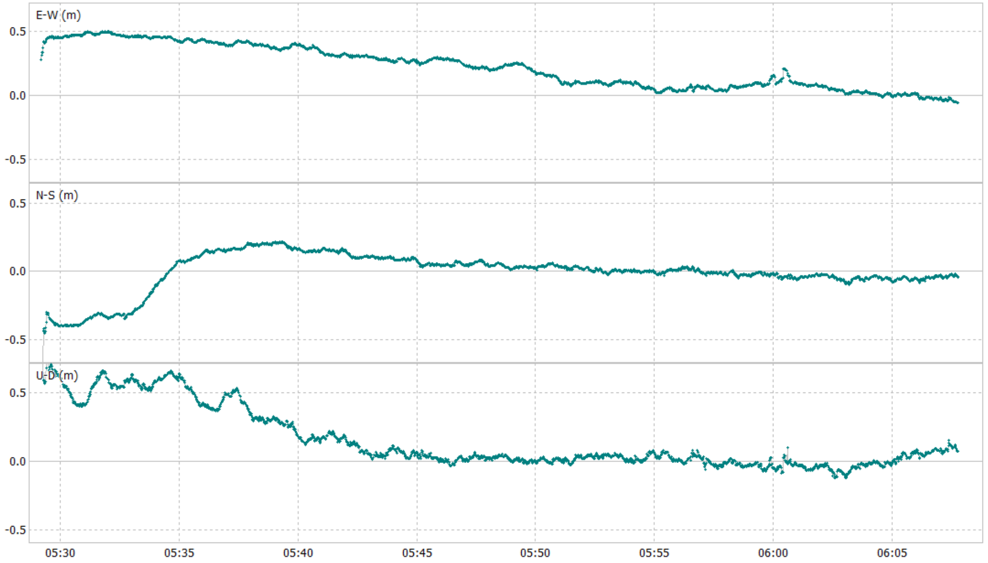


100%

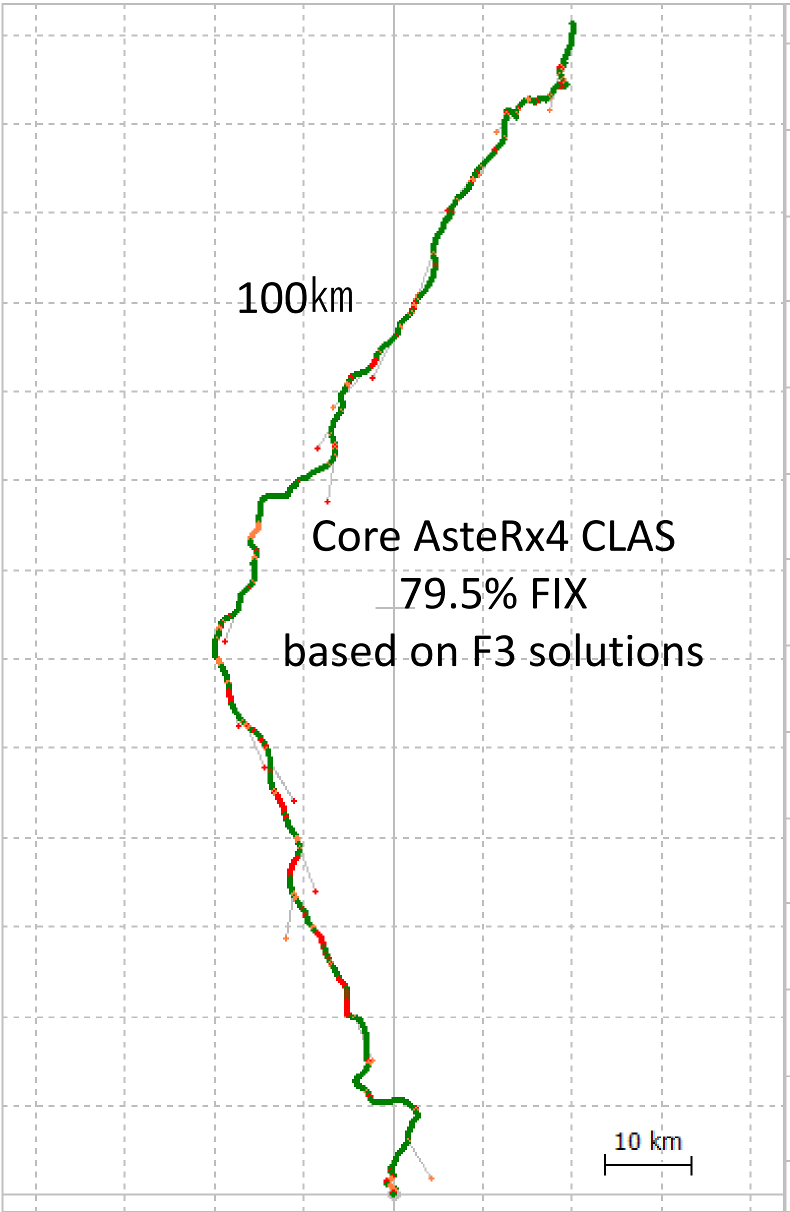
Horizontal errors

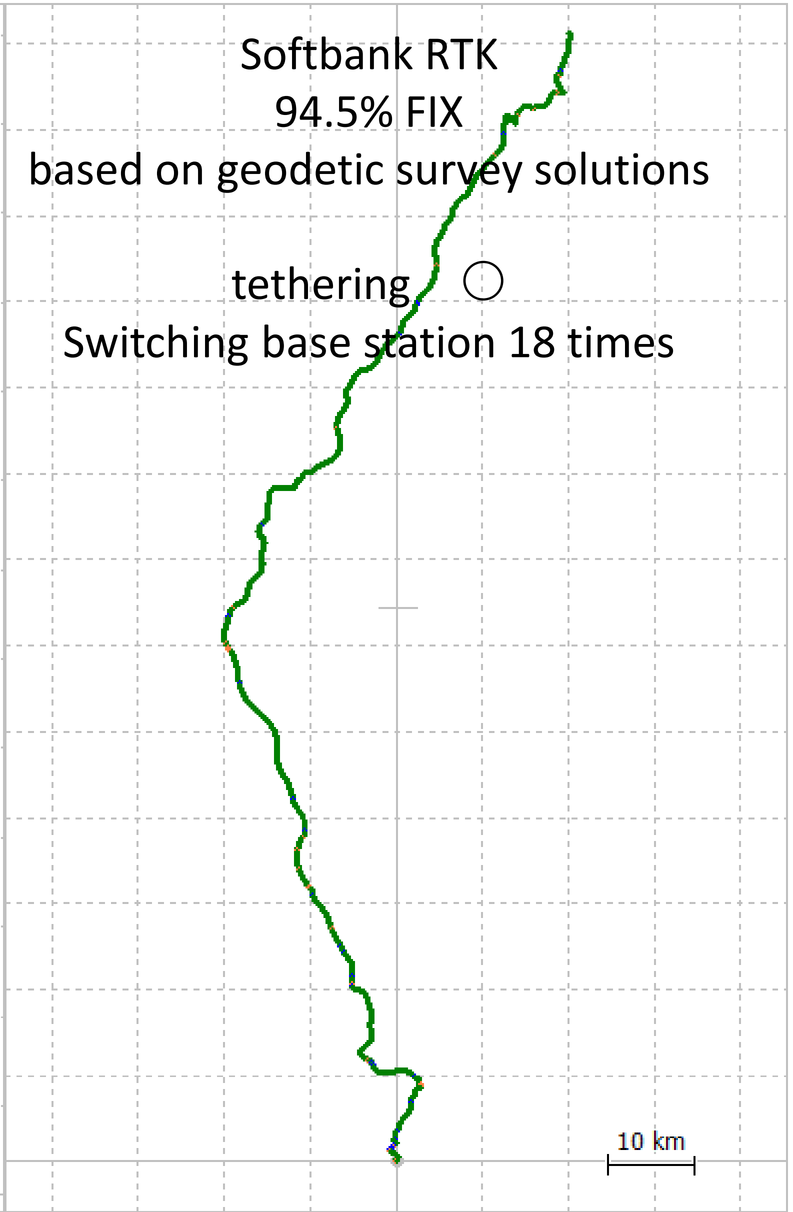


LLH errors

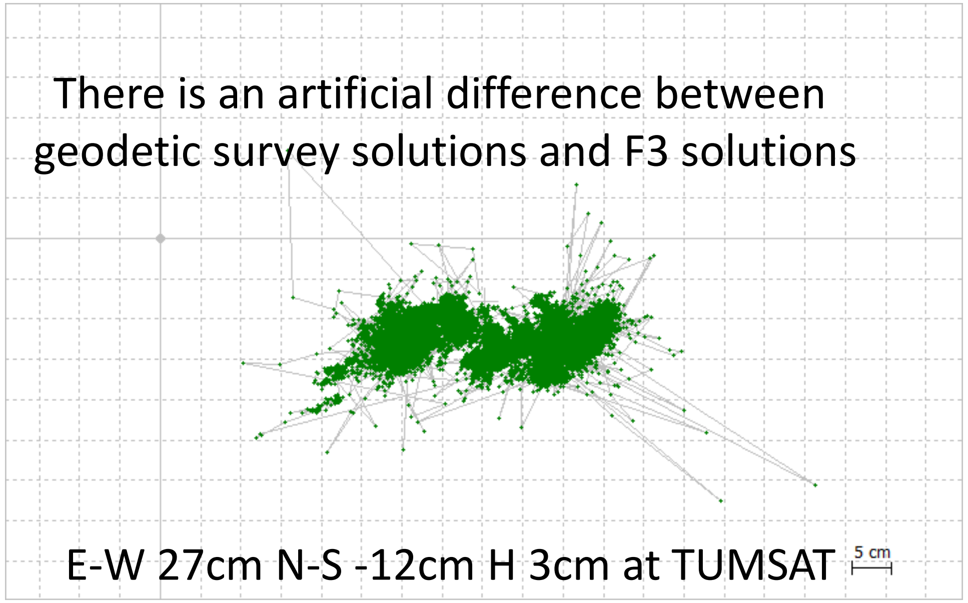


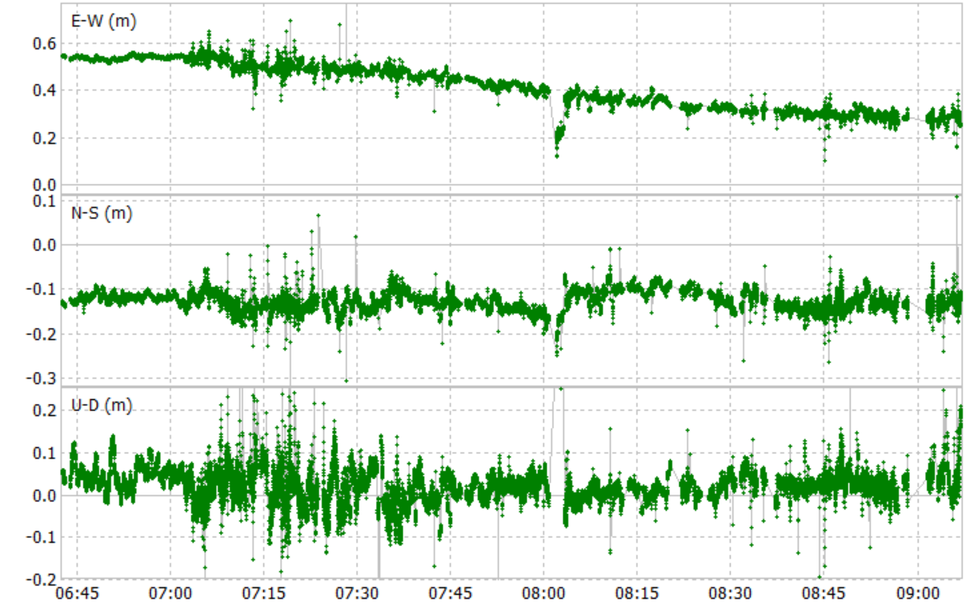
CLAS at highway(continuously about 100 km)





Horizontal difference





Do you have any questions ?

nkubo@kaiyodai.ac.jp

PPP-RTK and PPP-AR

- First of all, CLAS is assumed one of the PPP-RTK method.
- As you can see slide 10, both CLAS(PPP-RTK) and PPP are same in that error sources are separated such as precise sat clock, precise orbit, and atmospheric errors. It is called SSR (state space representation). As for normal DGNSS/RTK, it is called OSR (observation space representation).
- Then, PPP-RTK normally uses double-difference technique to resolve carrier phase ambiguities. And last, PPP-RTK resolves ambiguities. Therefore, we see FIX or not FIX in PPP-RTK.
- On the other hand, PPP does not use double-difference technique. We will wait for convergence of errors especially for ionospheric error. Therefore, wee don't see FIX or not FIX in PPP.
- However, PPP also can resolve carrier phase ambiguities with FCB (fractional cycle bias) and it is called PPP-AR. If we have better estimated ionospheric errors, convergence time is greatly reduced.
- **PPP-RTK and PPP-AR have different approaches into ambiguity resolution but it seems to be the performance of both will be close.**