GNSS Applications and QZSS High-Accuracy Services

UTOKYO_ICG GNSS TRAINING
1/28/2025
Nobuaki Kubo (TUMSAT)

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Motivation

- **PPP** has been developed by many researchers (many papers) for a long time and it's time to put it to practical use.
- Currently, **PPP-RTK** is becoming popular in the word.
- Japanese **CLAS** is one of the good example of PPP-RTK.
- We would like to share some test results of these correction services compared to the conventional RTK.

Correction service

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Error Sources	SLAS	CLAS (PPP-RTK)	MADOCA-PPP
Precise orbit	Not separated	○	○
Precise clock		○	○
Ionosphere		○	△
Troposphere		○	
Convergence	Instant	-1 min.	15-30 min.
Accuracy	Below 1 m	2-3 cm	5-10 cm
Measurement	Code phase	Carrier phase	Carrier phase
GNSS	GPS/QZSS	GPS/QZSS/ GALILEO	GPS/QZSS/ GLONASS/ GALILEO
Coverage	Japan	Japan	**Asia, Oceania**

All correction services through satellite !

Or internet.

- You don’t need to set up base station.
- You don’t need LTE/4G/5G.
- All you need is receiver and antenna.
- PPP is available within the coverage of QZSS

Elevation cutoff = 10 degree

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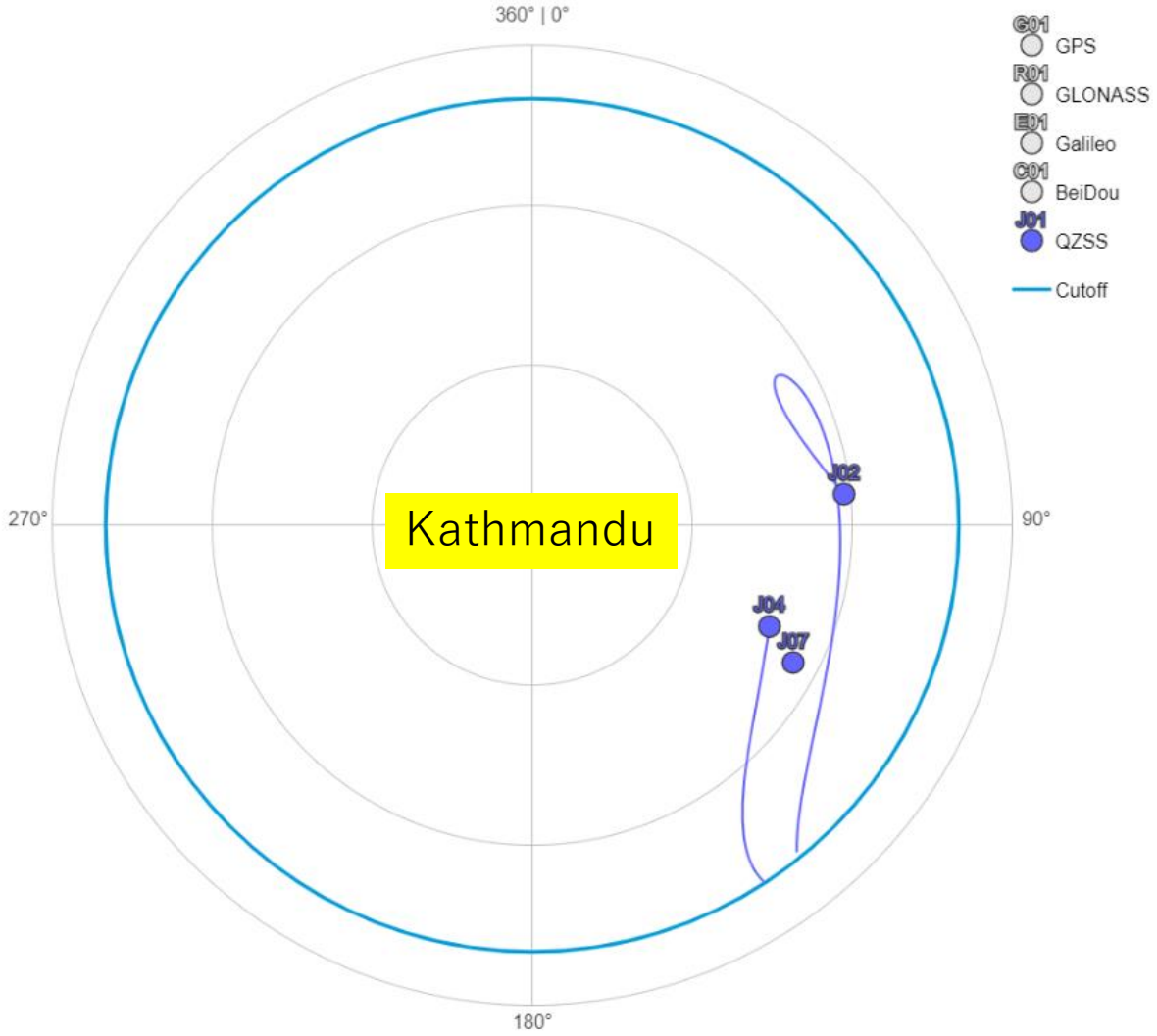

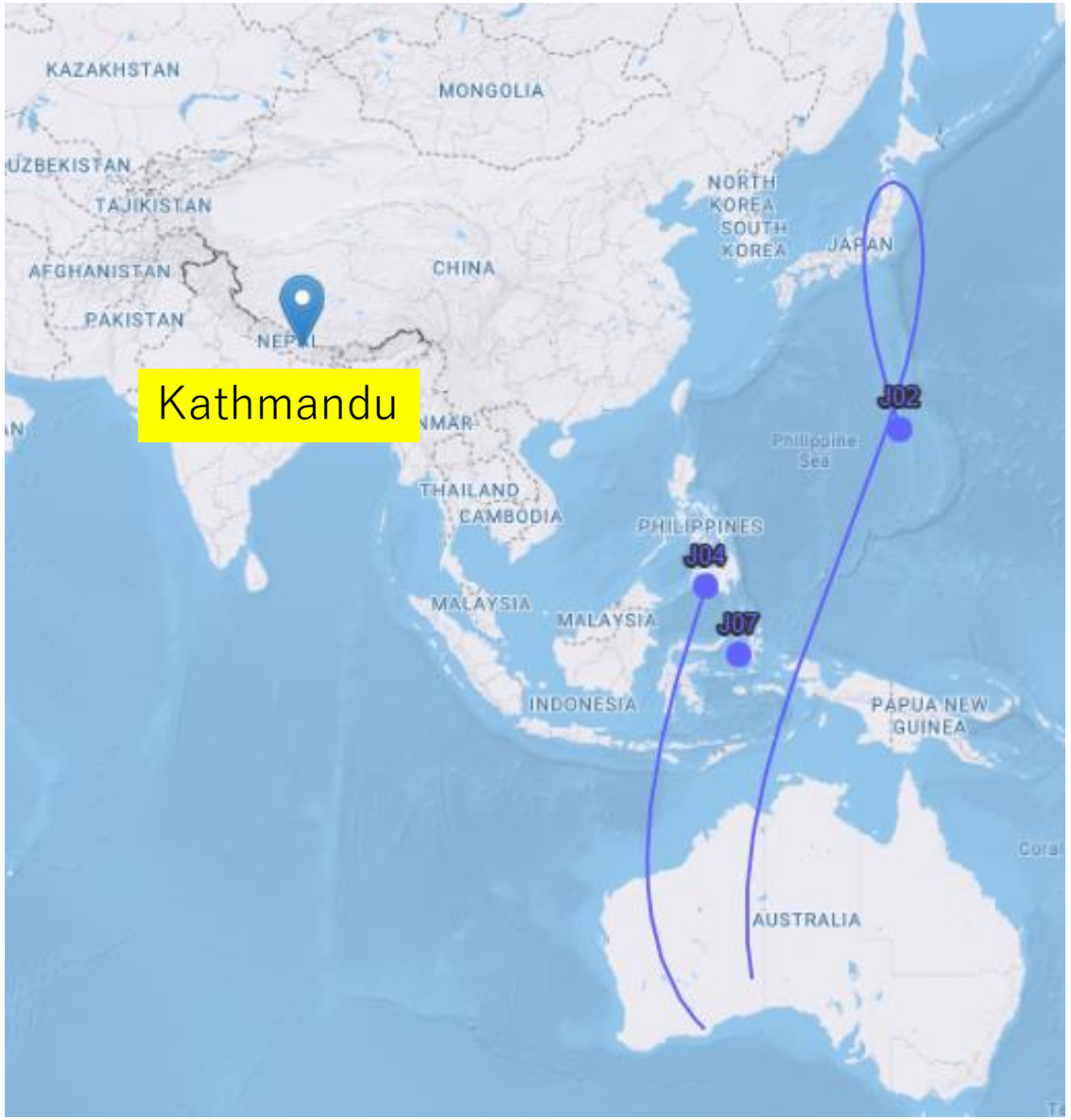

準天頂衛星の軌道（地上軌跡）

※準天頂衛星5号機、6号機、7号機は新規に追加される衛星

No.5 QZSS will be launched.
Date: February 1, 2025(Sat.)
Scheduled Launch Time:
5:30 p.m. to 7:30 p.m. (JST)
No.6 and No.7 in 2025.

Static and Kinematic Test Results using PPP/CLAS/SLAS Correction Service through QZSS

Static test results of CLAS/PPP/SLAS at TUMSAT

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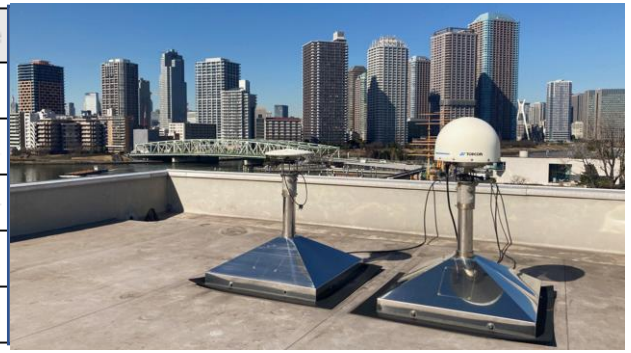
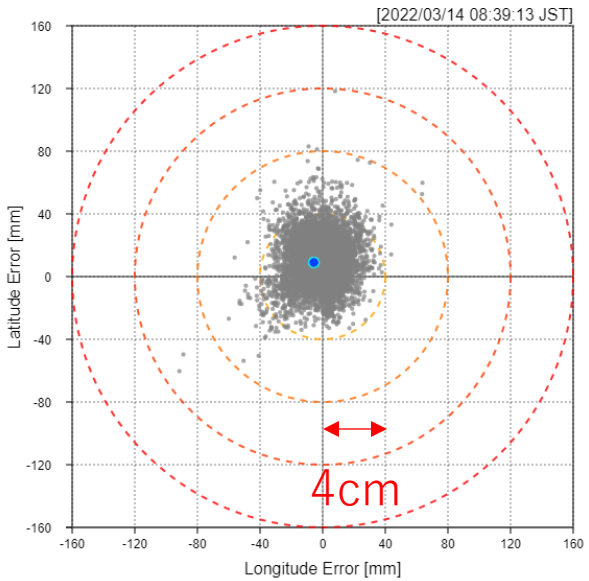
- We started the real-time evaluation of CLAS/PPP/SLAS.
- Reference position is determined by some static PPP solutions in ITRF2014.

No.	Label	Port	ID	Date (JST)	Latitude[deg]	Longitude[deg]	Height[m]	N Error[cm]	E Error[cm]	U Error[cm]	Fix type
1	CLAS	10031	POS	2022/03/14 08:38:57	35.66634190	139.79221106	59.819	0.196	-0.294	0.243	1
2	PPP	10032	POS	2022/03/14 08:38:57	35.66634163	139.79221097	59.775	-2.807	-1.140	-4.080	2
3	SLAS	10033	POS	2022/03/14 08:38:57	35.66633131	139.79220029	60.214	-32.646	-13.706	41.700	4
4	RTK	10034	POS	2022/03/14 08:38:57	35.66634026	139.79221121	59.810	-17.988	1.031	-0.620	1
5	SPP	10035	POS	2022/03/14 08:38:57	35.66635381	139.79219544	56.753	217.012	-57.624	-304.400	5

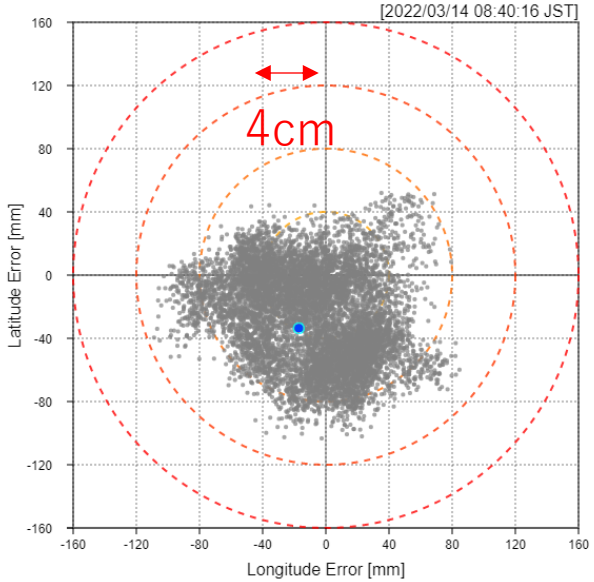


CLAS



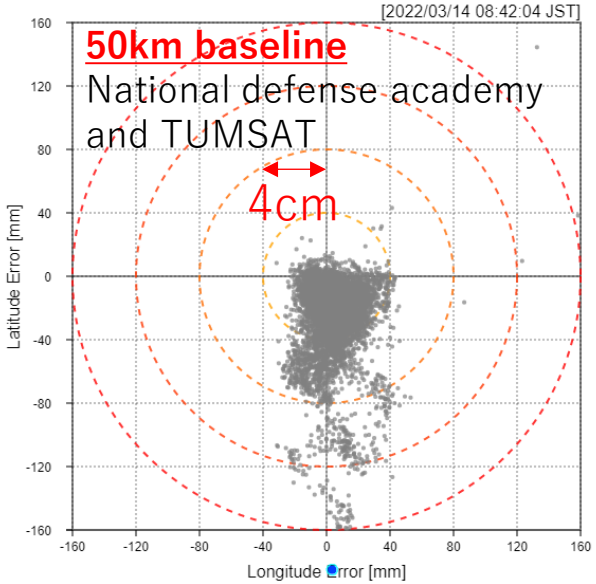
Core
AsteRx4

PPP



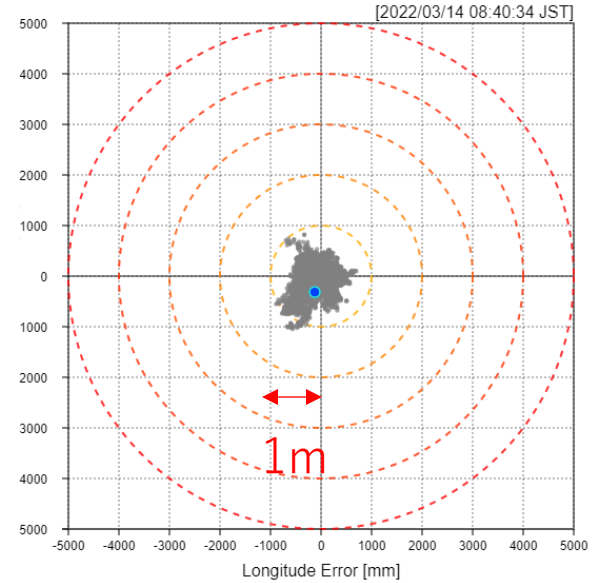
Magellan Systems Japan
MJ-3008-GM4-QZS

RTK



u-blox
F9P

SLAS



Trimble NetR9 ⇨ u-blox F9P

24h CLAS (static antenna)
June 13, 2021

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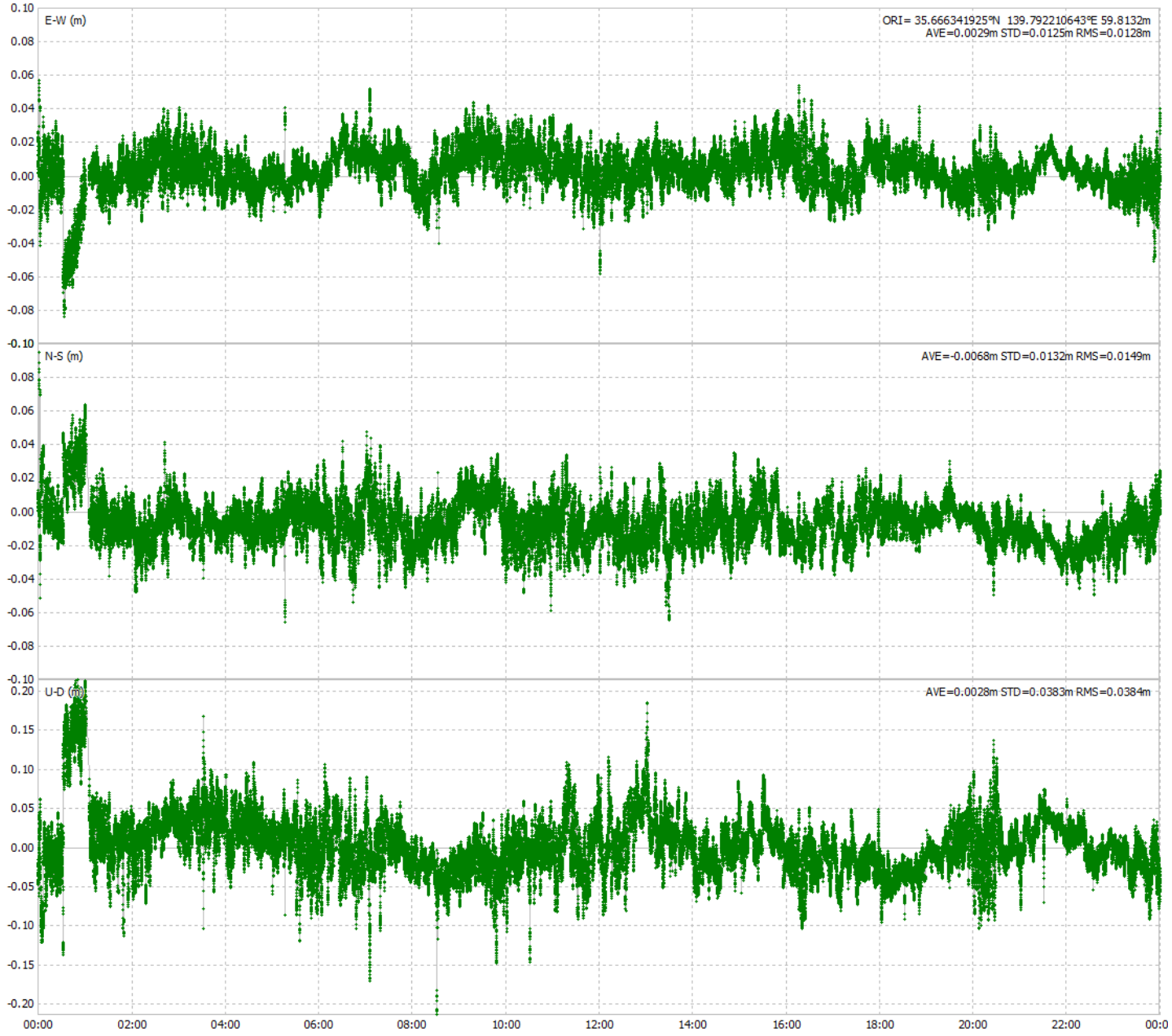
Topcon Ant.＋CORE AsteRx4

Fix rate：99.6%



24h PPP (static antenna)
June 13, 2021

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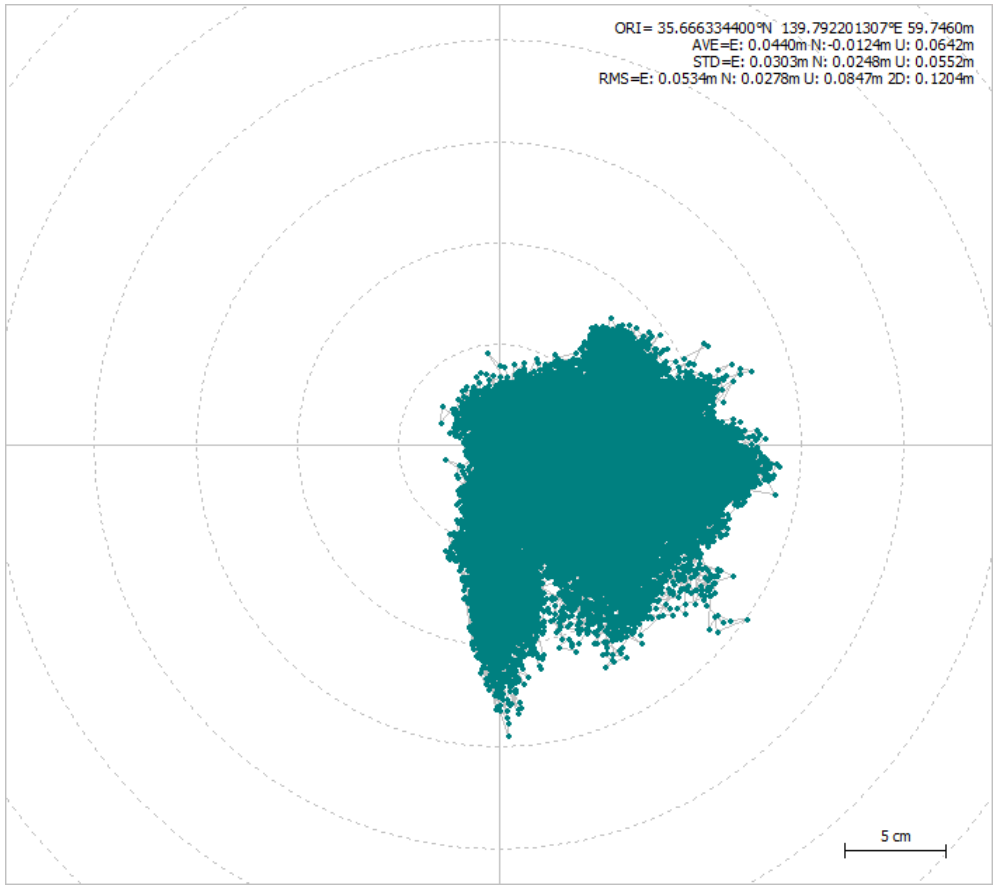
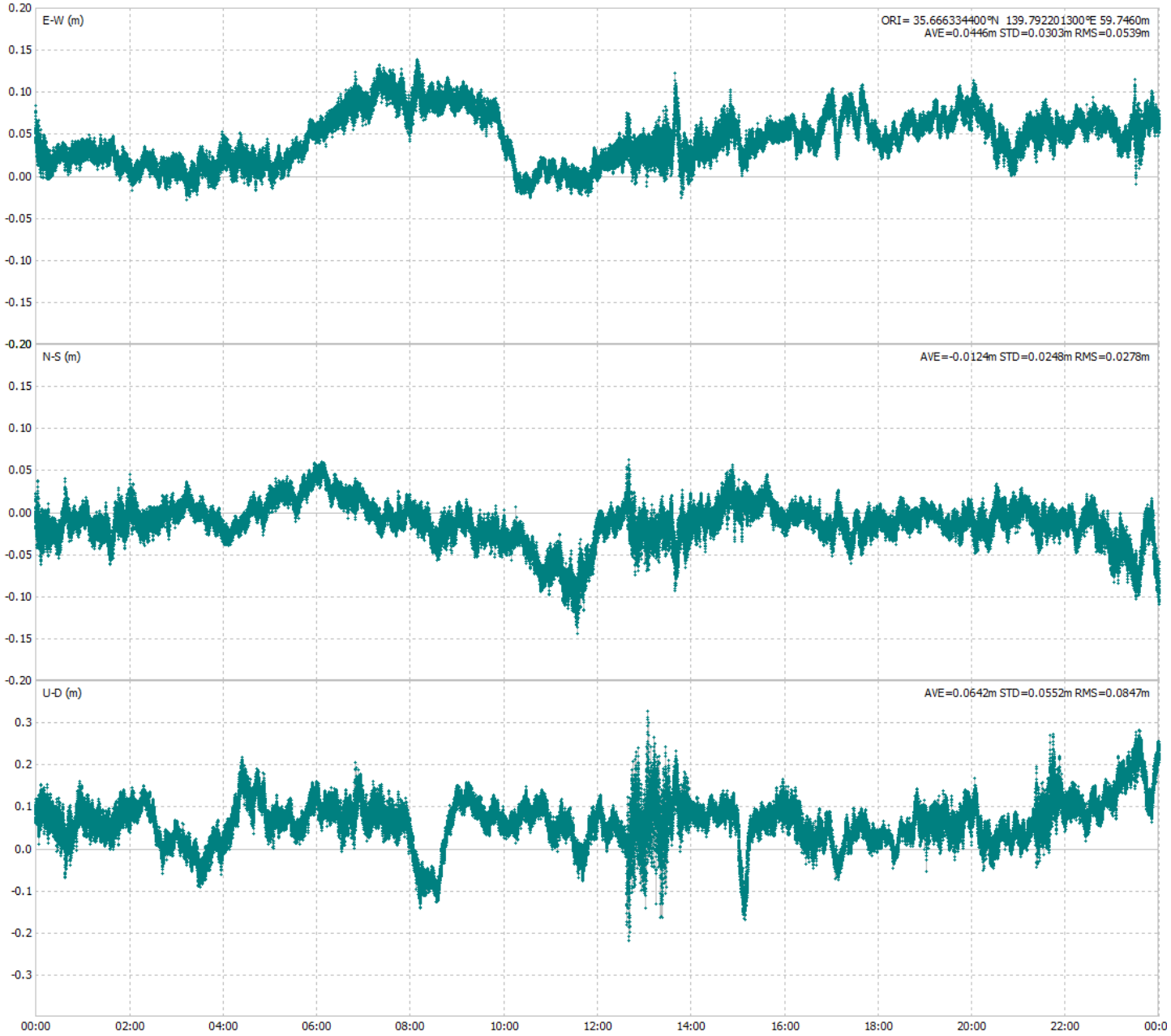
Trimble Ant. + MSJ receiver





24h SLAS (static antenna)
June 13, 2021

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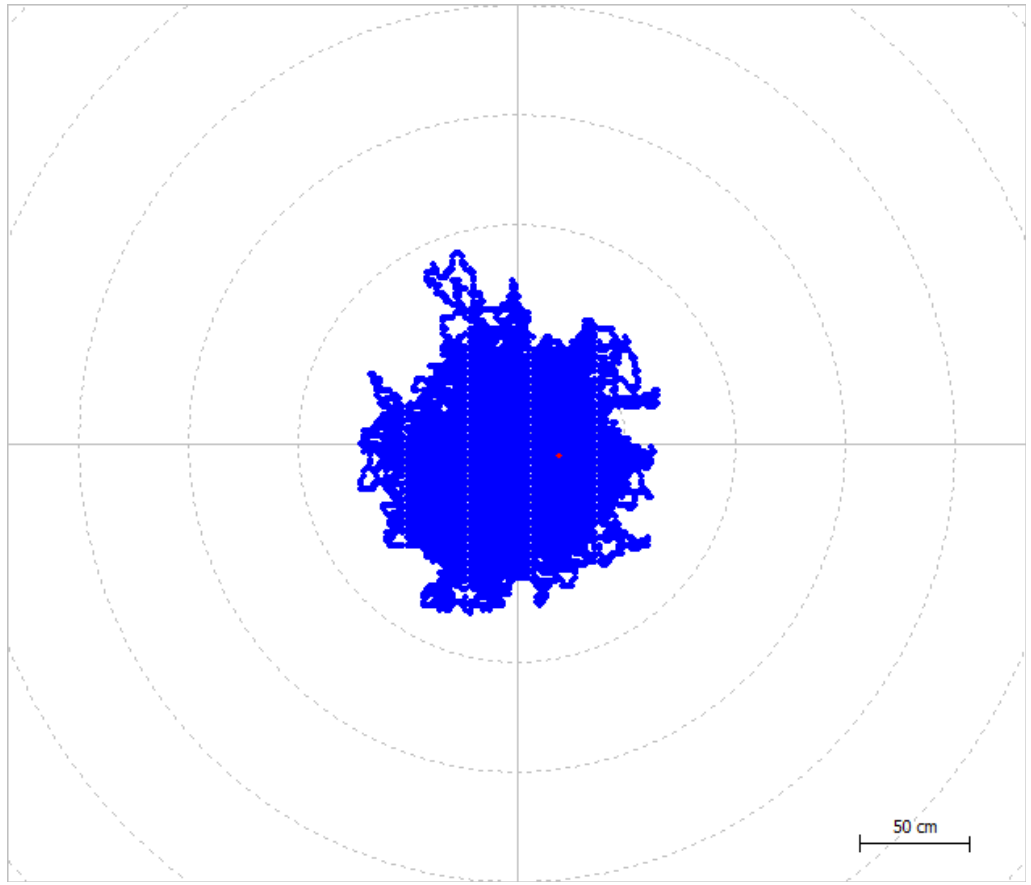
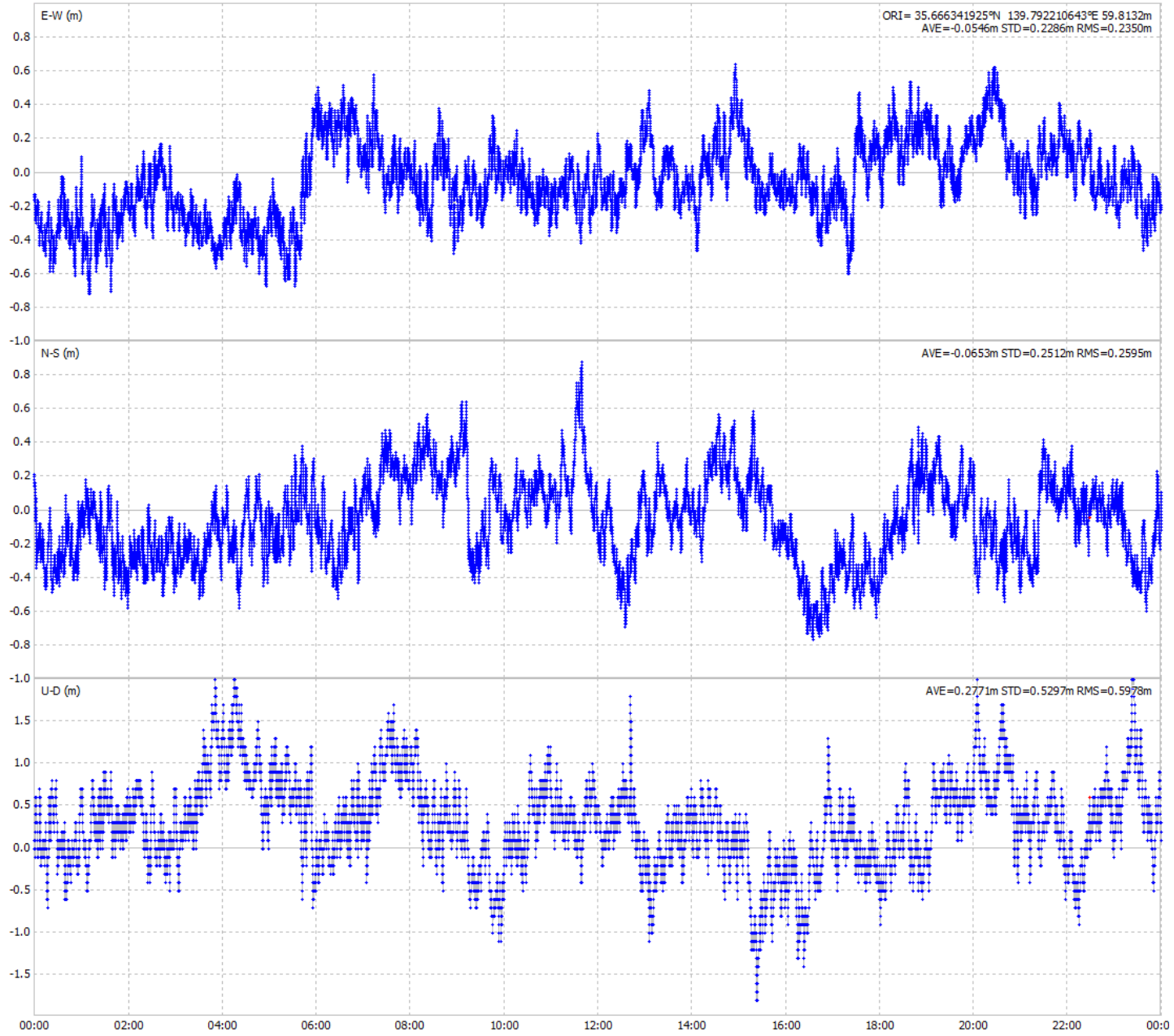
Trimble Ant.＋u-blox F9P receiver





1. Kinematic test at farmer (Iwaki-san)
CLAS/PPP/SLAS based on RTK

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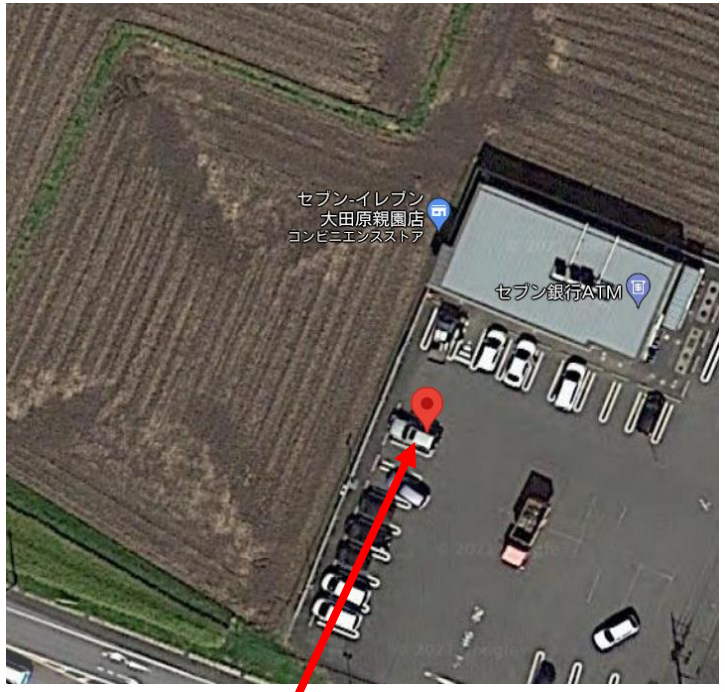
Test field (Google)



Base station for RTK was set up here.

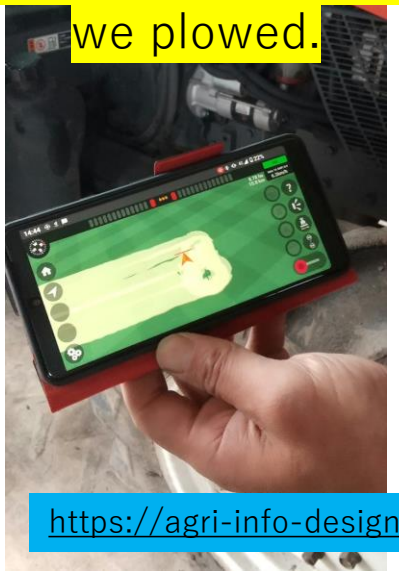
GPS-703-GGG-HV

4 splitter

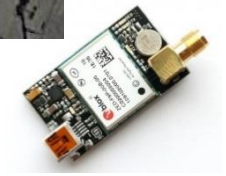
Pre-planting soybeans

Lighthouse (PPP)

Useful software !
We can see where we plowed.



https://agri-info-design.com/



u-blox F9P(SLAS)

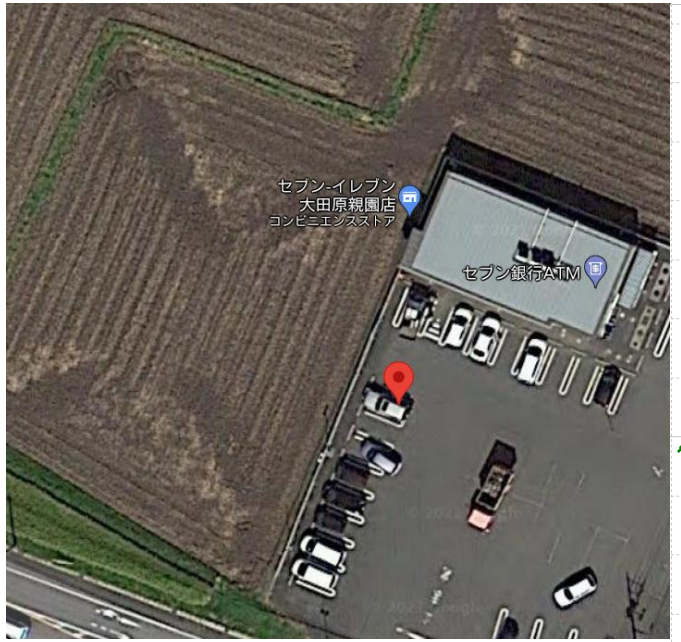
u-blox F9P(RTK)

Core AsteRx4(CLAS)

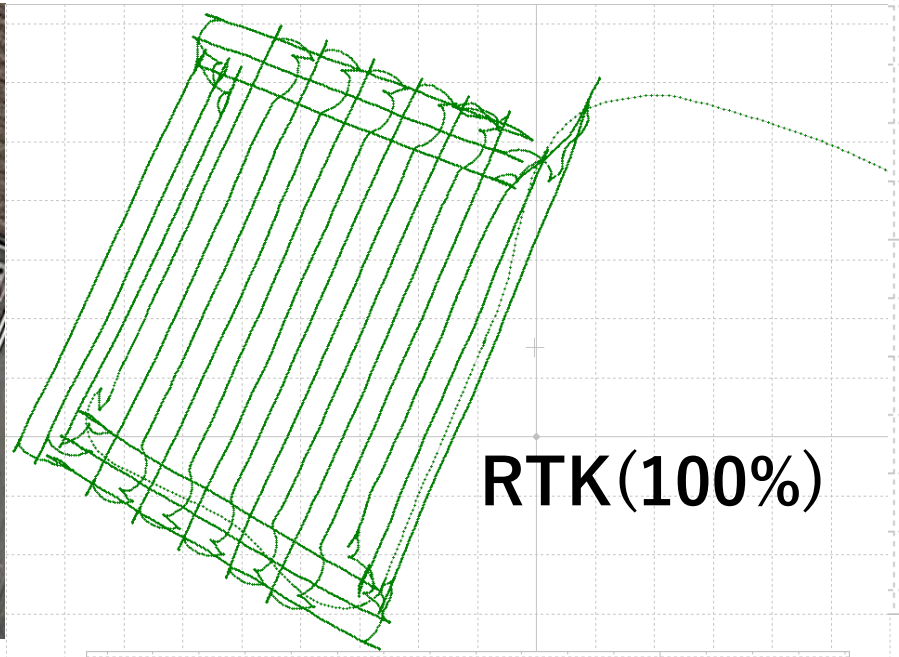
GNSS antenna

Lidar/Camera

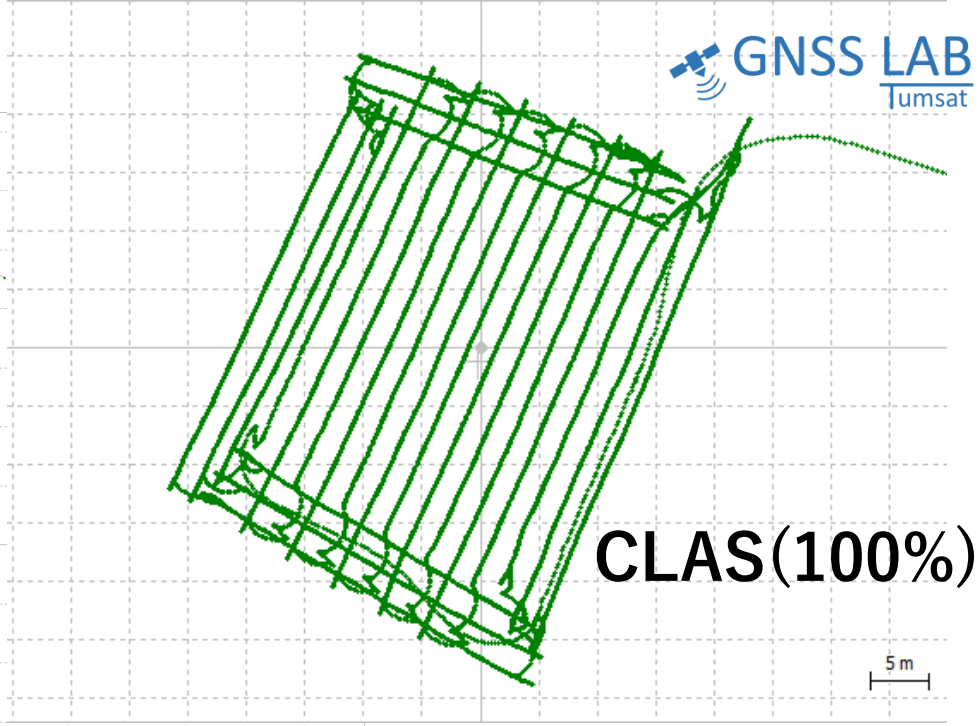
Ground Truck Comparisons



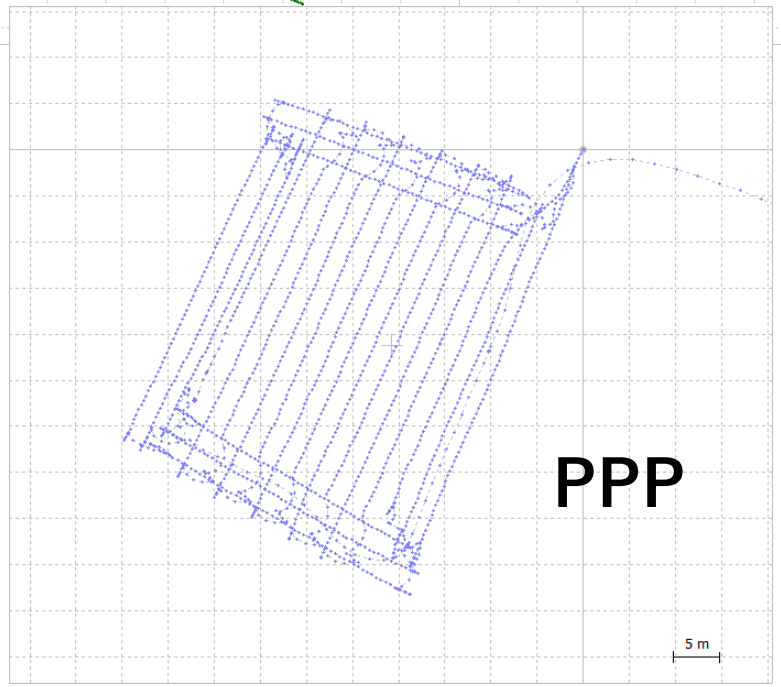
Test field
difficult to compare...



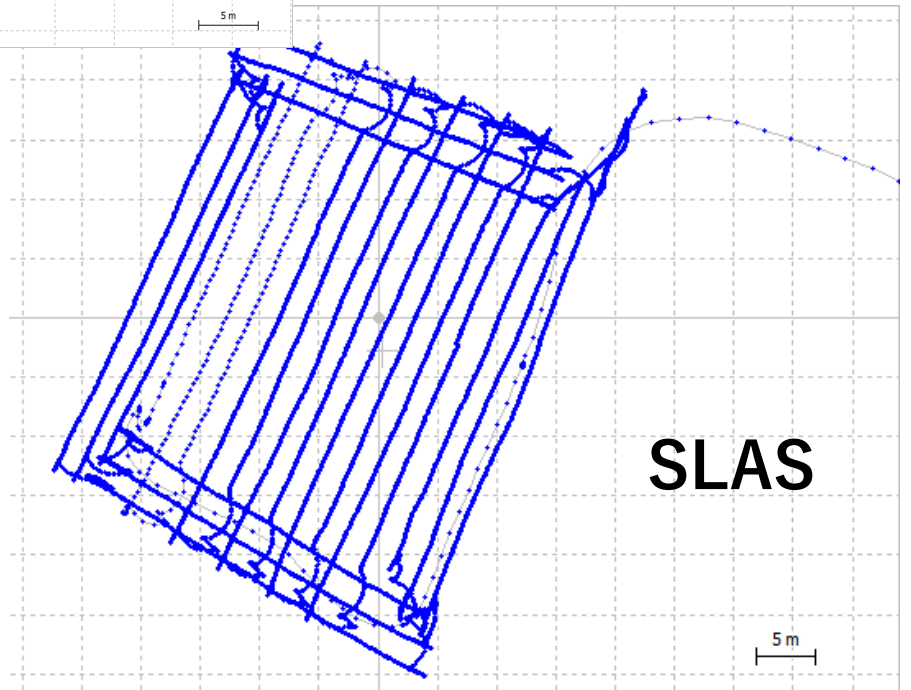
RTK(100%)



CLAS(100%)



PPP



SLAS

Position Errors for CLAS/PPP/SALS

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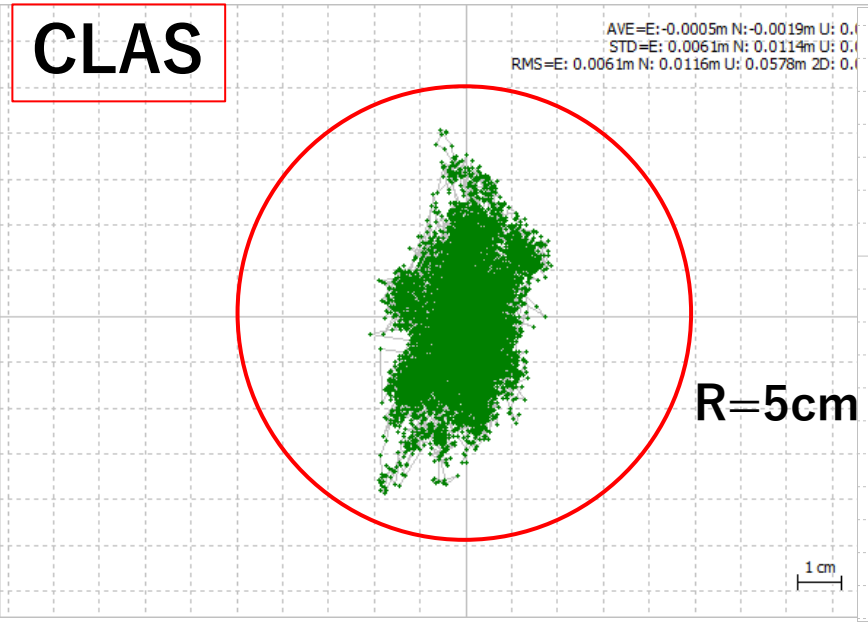
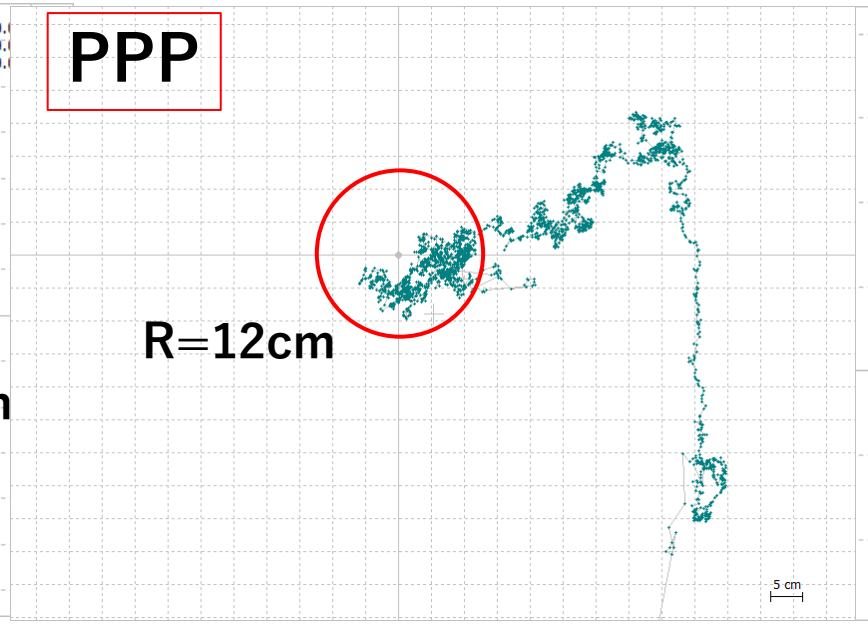
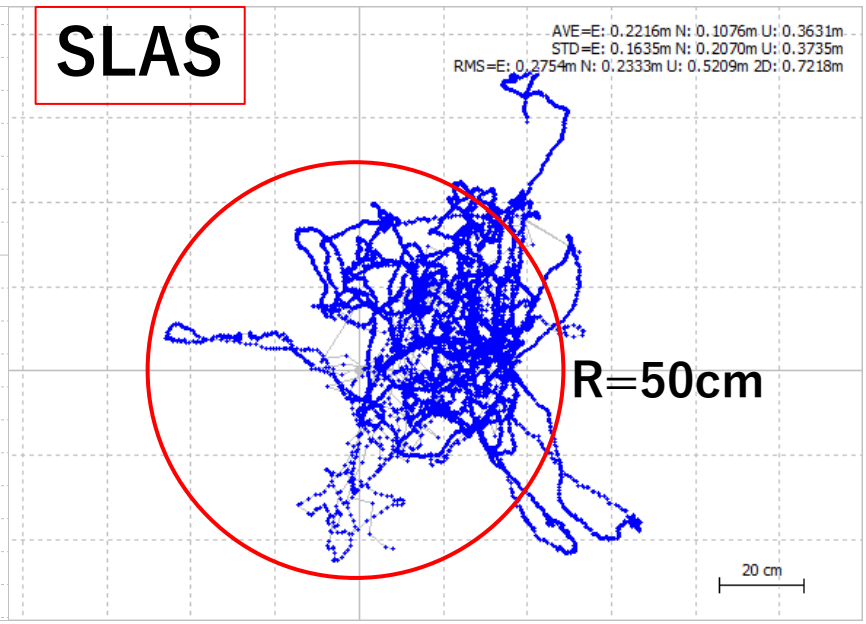
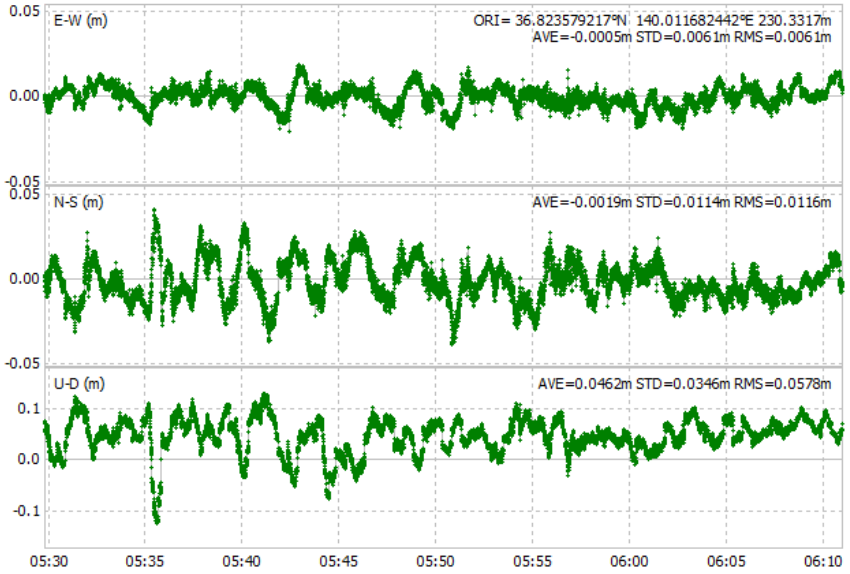
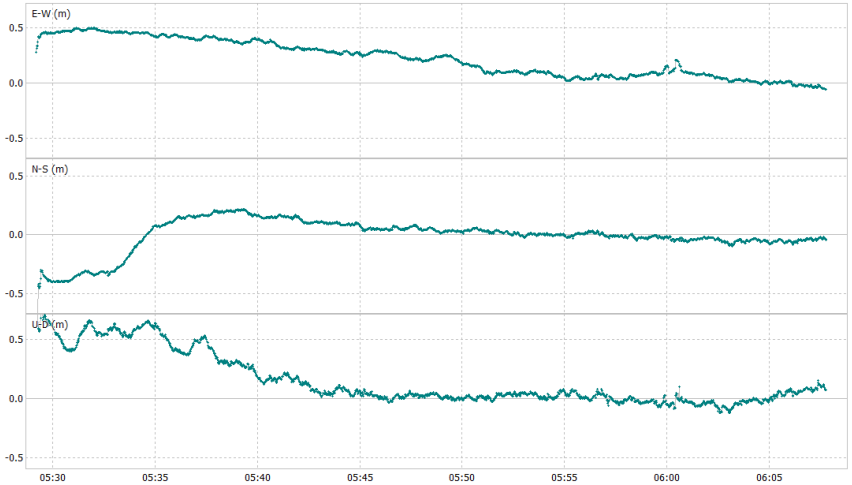
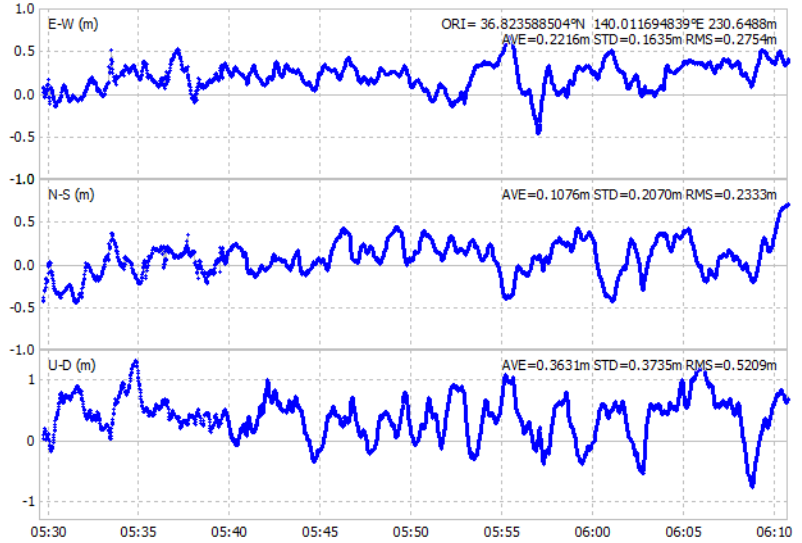




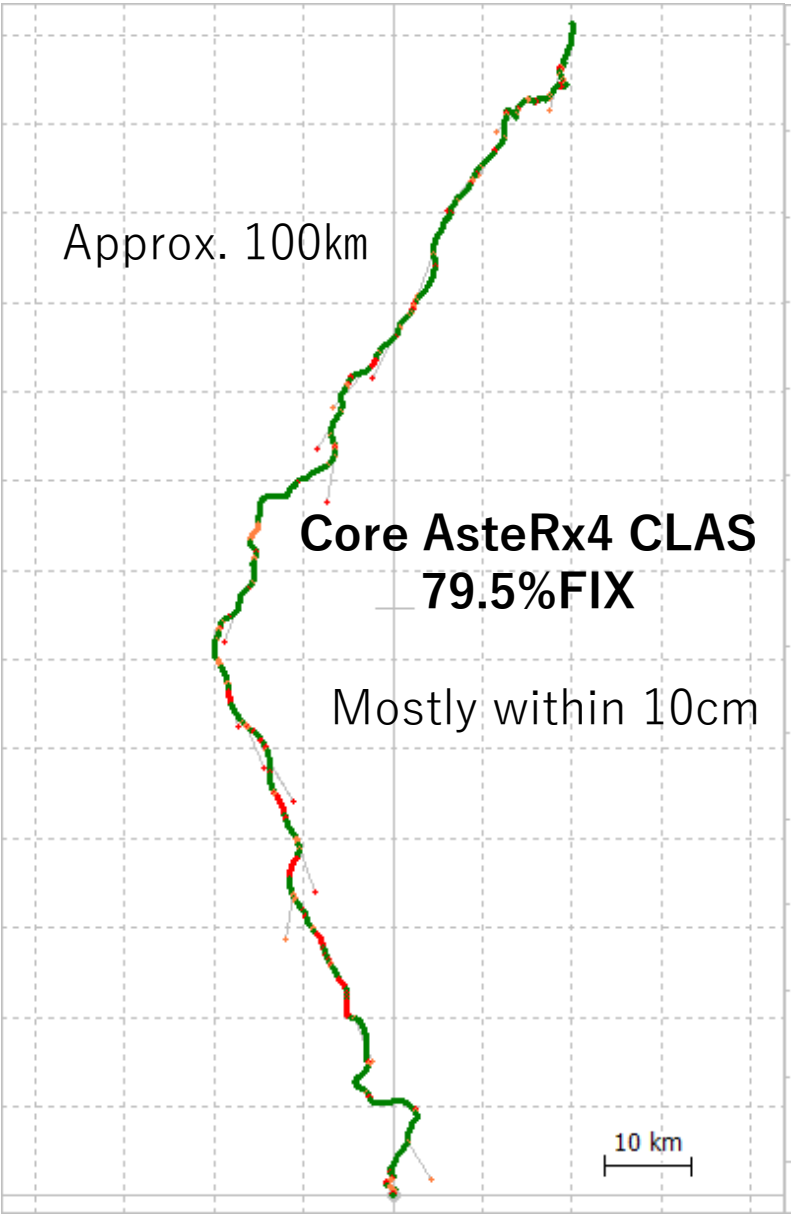


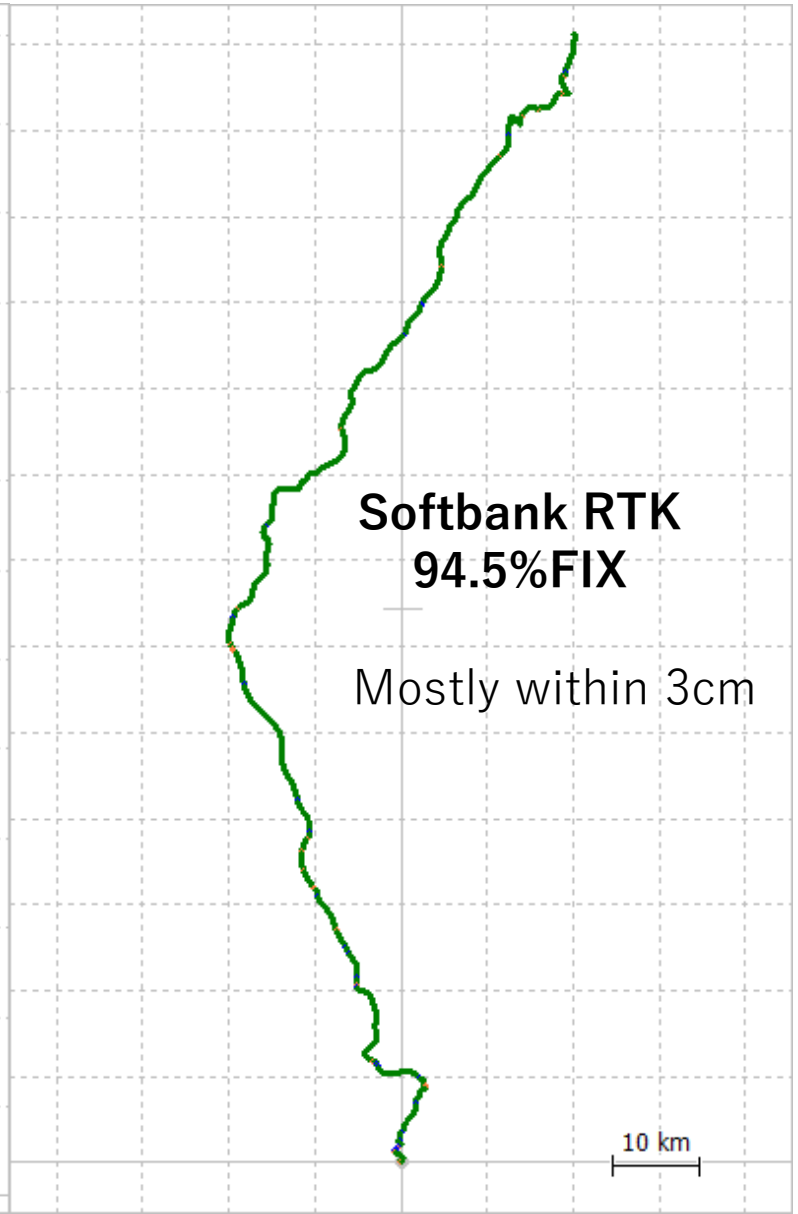


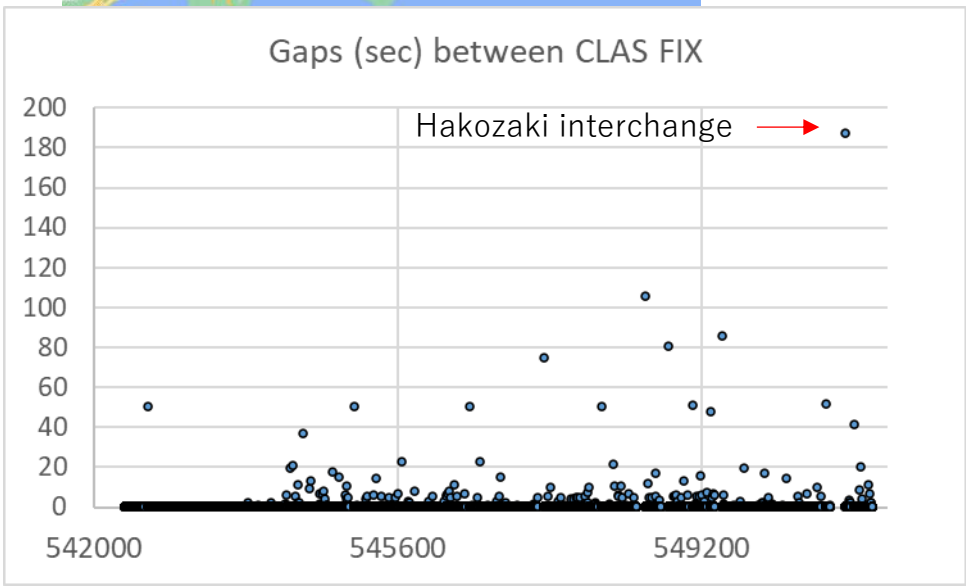




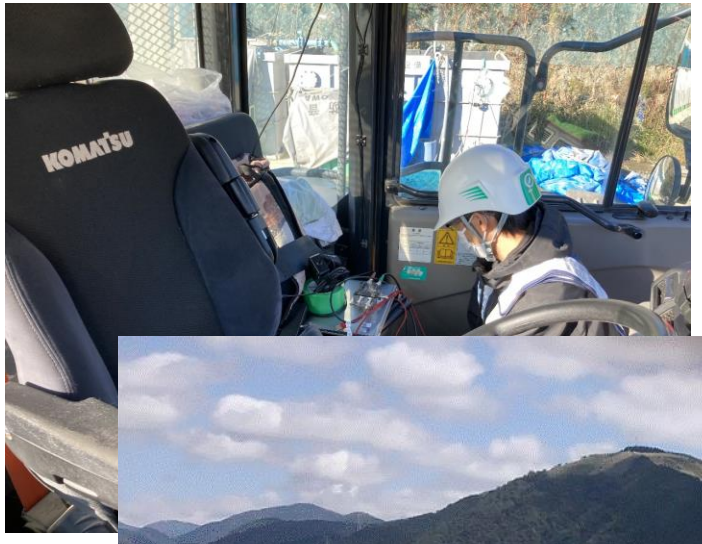
2. CLAS during 100km expressway







3. CLAS/PPP demonstration at real construction site



- Sand/Soil delivery and fill using dump truck
- CLAS/PPP/RTK through same antenna
- Position comparisons for about 6 hours

Ground trucks of RTK as a reference

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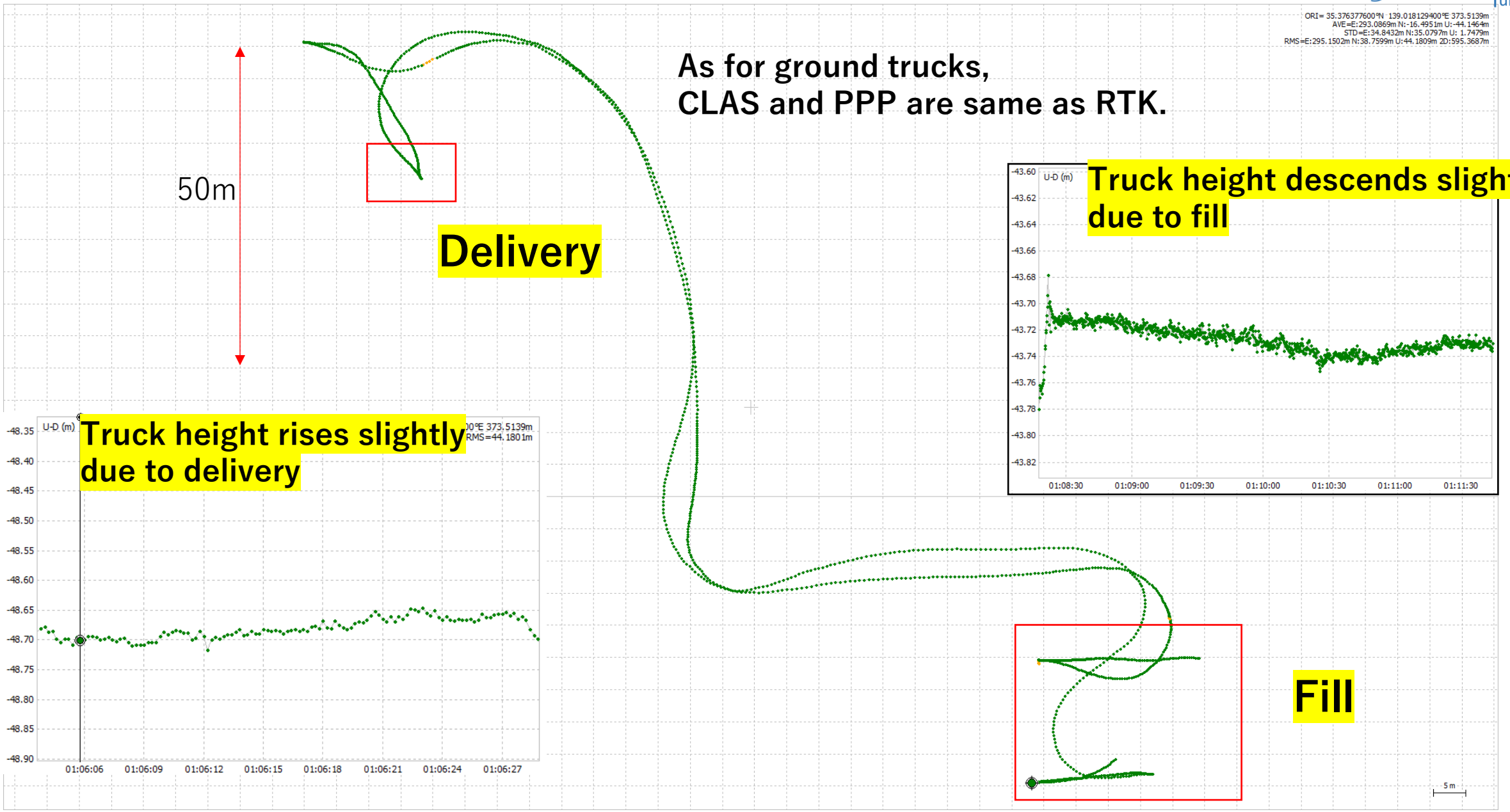
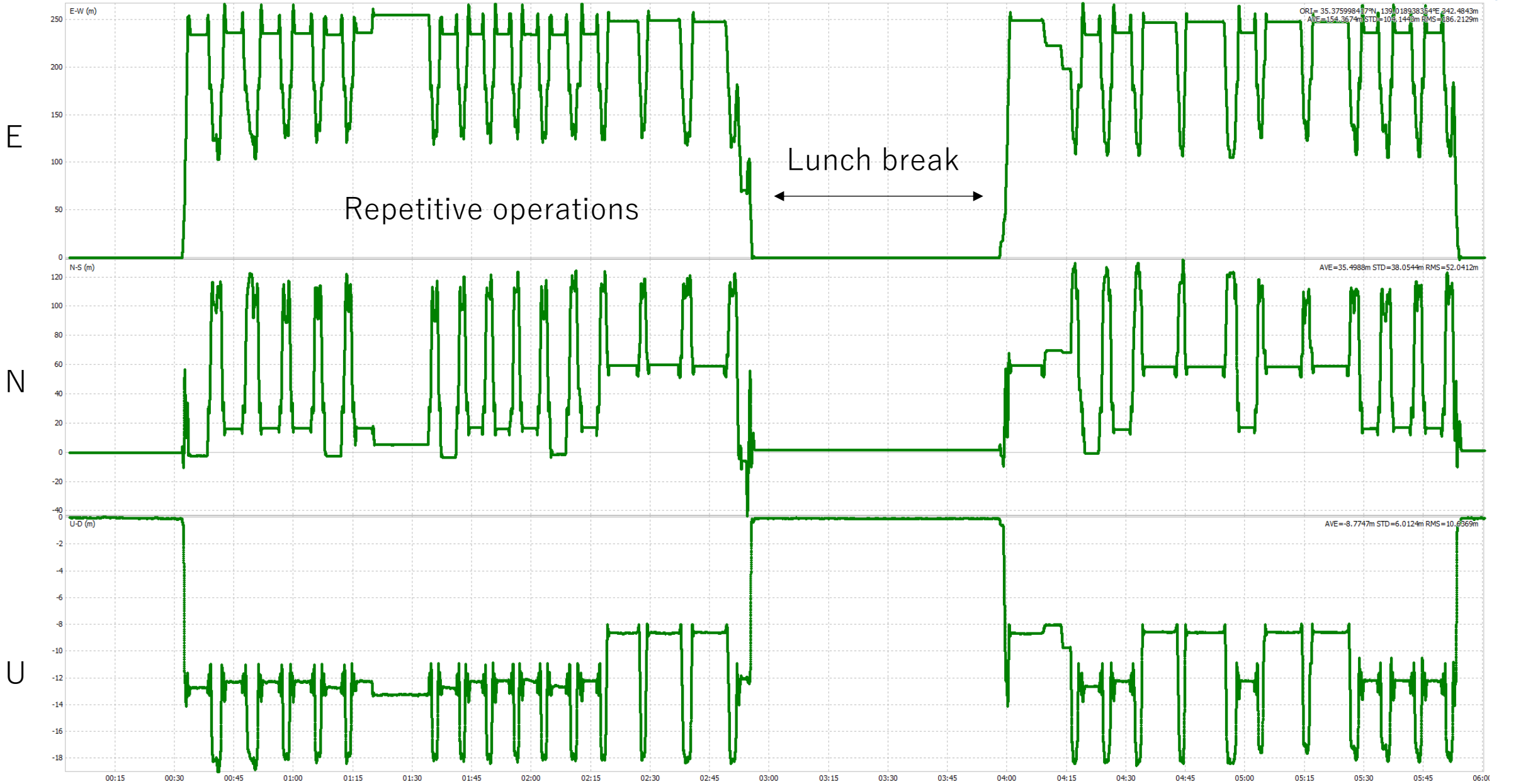


Relatively open sky condition but some steep slope of soils

Temporal ENU positions of CLAS



Comparisons between CLAS and RTK

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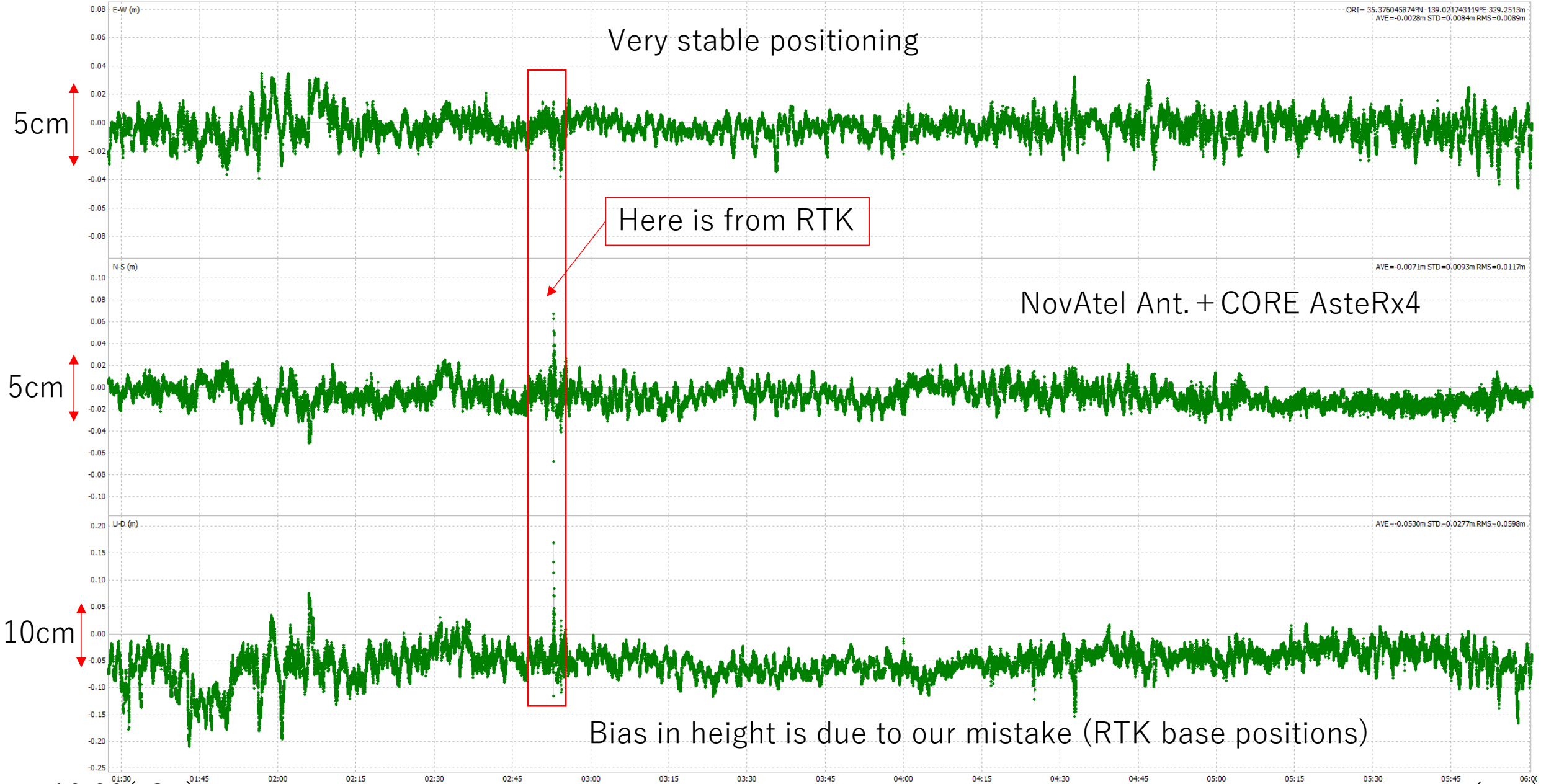

Comparisons between PPP and RTK

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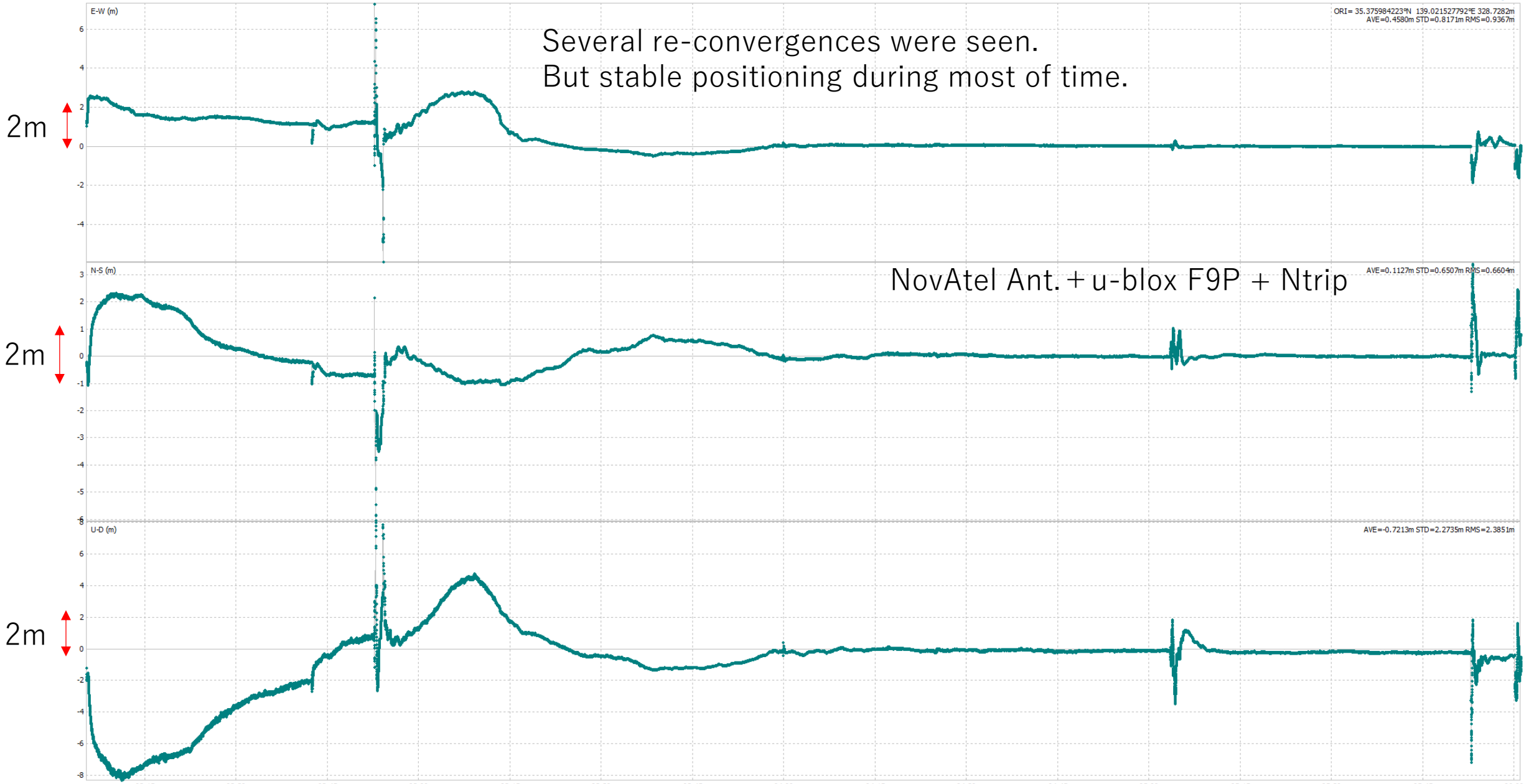

11:10(JST)

15:00(JST)

4. Sendai Airport Test by ENRI

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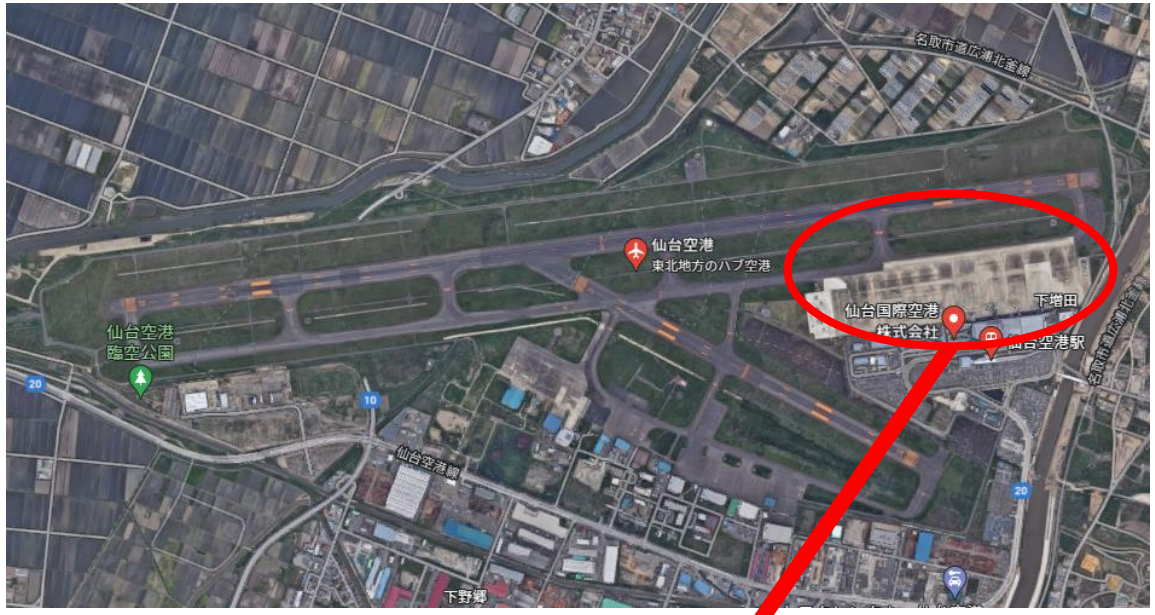
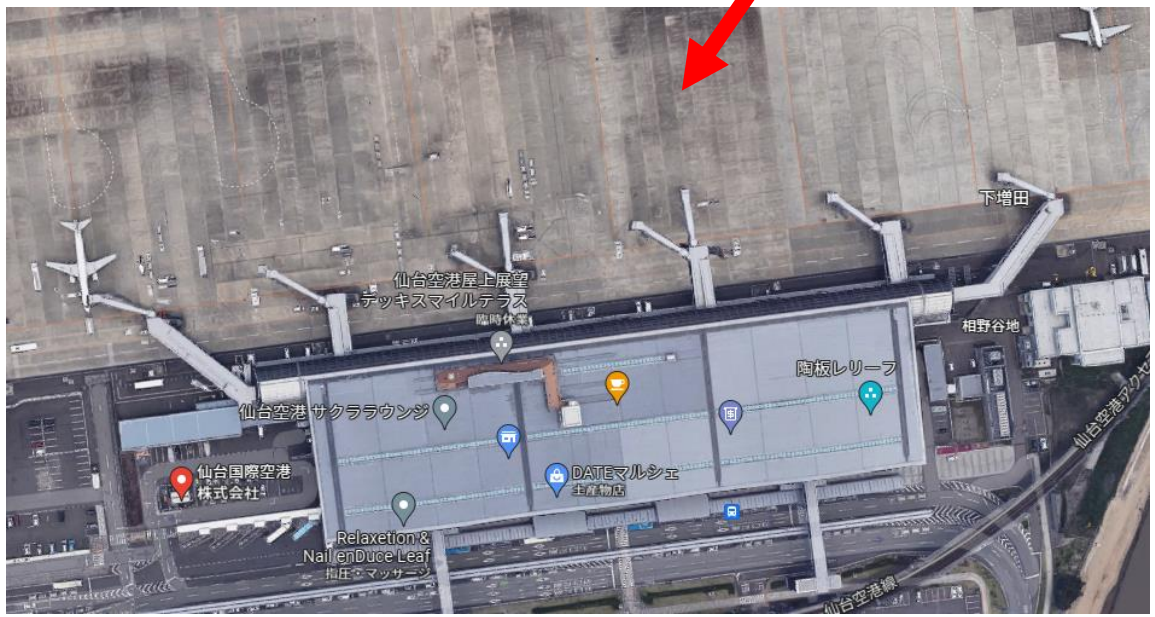
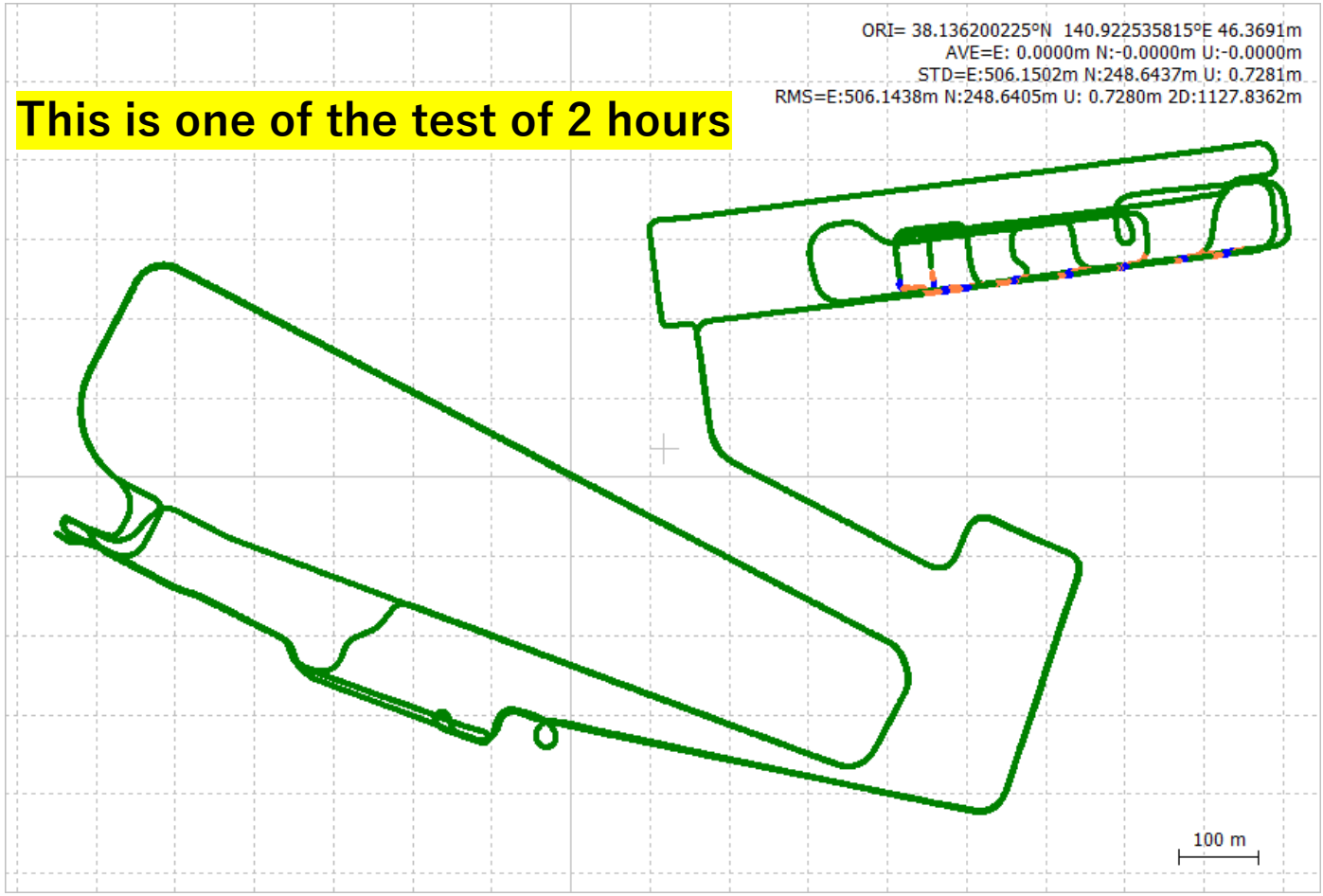




We have gathered GNSS data for 3 days with ENRI.



RTK : 97.4% FIX except for airfield apron
These positions are used as reference.

Horizontal Errors of CLAS and SLAS

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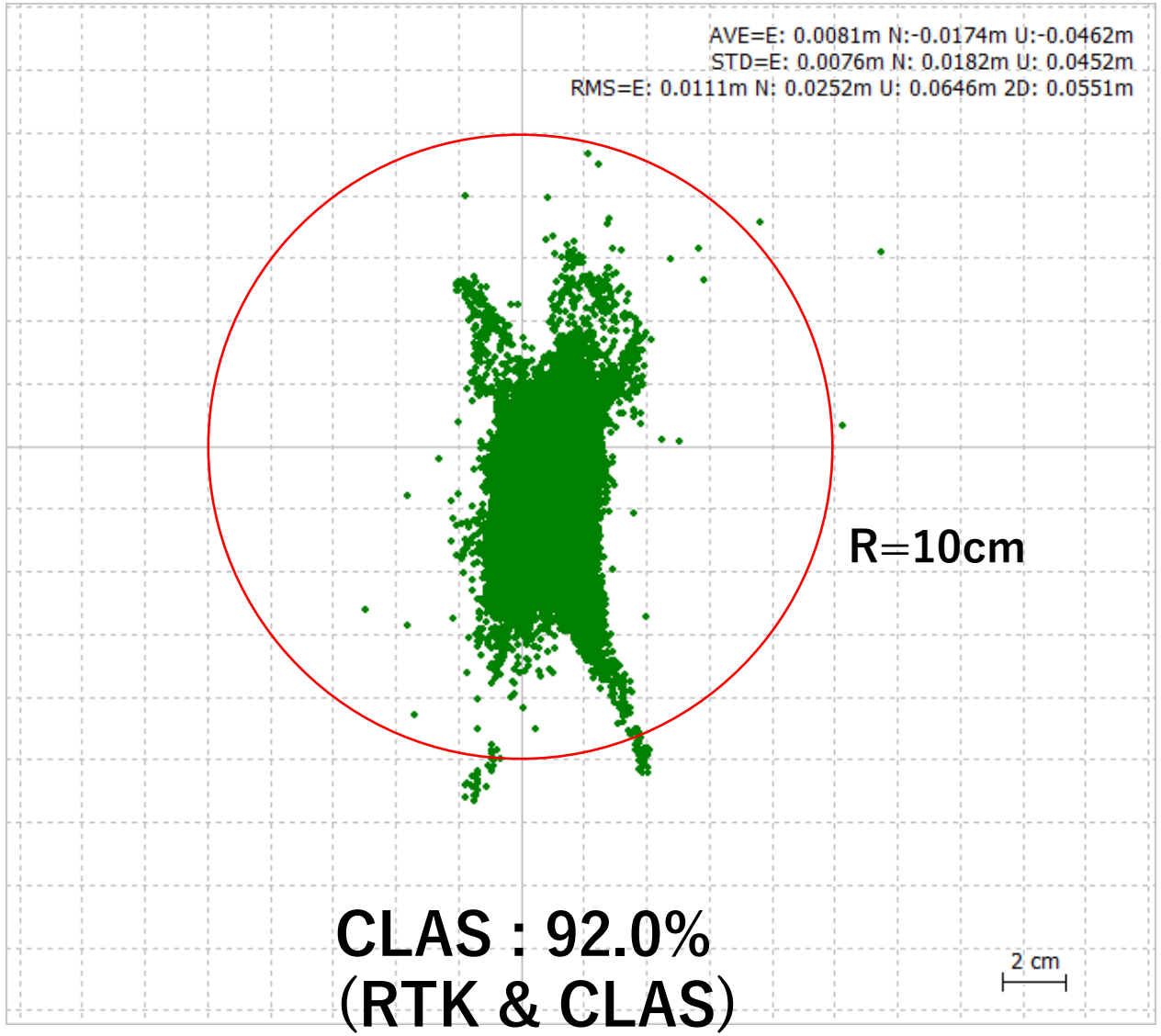
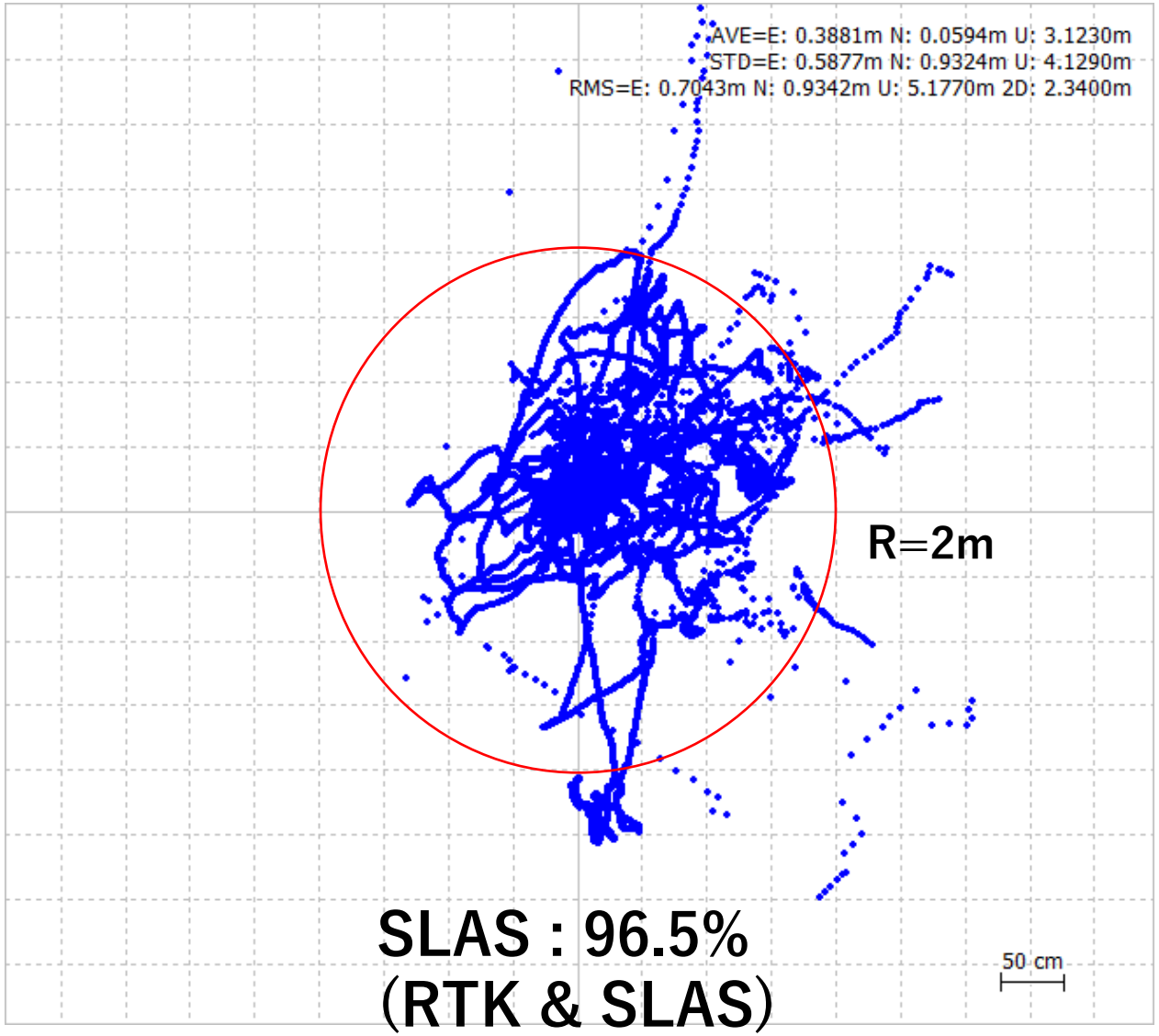


CLAS : 92.0%
(RTK & CLAS)



SLAS : 96.5%
(RTK & SLAS)

Short summary

- Performance evaluation of PPP/CLAS/SLAS for both static and kinematic were introduced.
- Static (95%): PPP 10cm (aft conv.), CLAS 3cm, SLAS 1m
- Kinematic (95%): PPP 15cm (aft conv.), CLAS 3-4cm, SLAS 1m
- CLAS can be used instead of RTK to some degree.
- PPP will be useful for monitoring stations because the base station of RTK moves due to the crustal movement.
- **PPP is updated for PPP-AR and short convergence**.

Open source programs for PPP/PPP-RTK

- https://github.com/QZSS-Strategy-Office/madocalib
- https://github.com/QZSS-Strategy-Office/claslib

Continuous development

- JAXA and some related companies are still improving PPP as well as PPP-RTK especially in terms of **short convergence time of PPP**.
- The advantages of both methods can be exploited for development. We will do our best to achieve **the same performance as the current PPP-RTK overseas**.
- If you are interested in this R&D, please let me know.
- **MGA conference** will be good opportunity for you to know the latest status of QZSS.
- https://www.mga-conference.com/

MADOCA PPP Performance evaluation in Asia and Oceania

MADOCA PPP Performance evaluation in Asia and Oceania

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- The first objective is to evaluate real MADOCA PPP performance in several countries in Asia and Oceania.
- **The second objective is to find the potential users of PPP in these countries.**

MADOCA

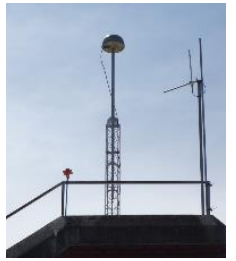
After 15 min., we can get 10 cm accuracy. With new method, we can shorten the time and PPP-AR is possible

Product(LEX signal)

GPS・GLONASS・QZSS
Precise orbit and clock
+Galileo







Evaluation

- Receiver is multi-GNSS receiver manufactured by Magellan Systems Japan.
- Locations are 1 in Japan and 7 in foreign countries.
- Errors in each station are evaluated based on true position (ITRF2014)→**suitable for moving platform in global.**
- **GNSS receiver for MADOCA-PPP is prepared as a chip (ASIC).**

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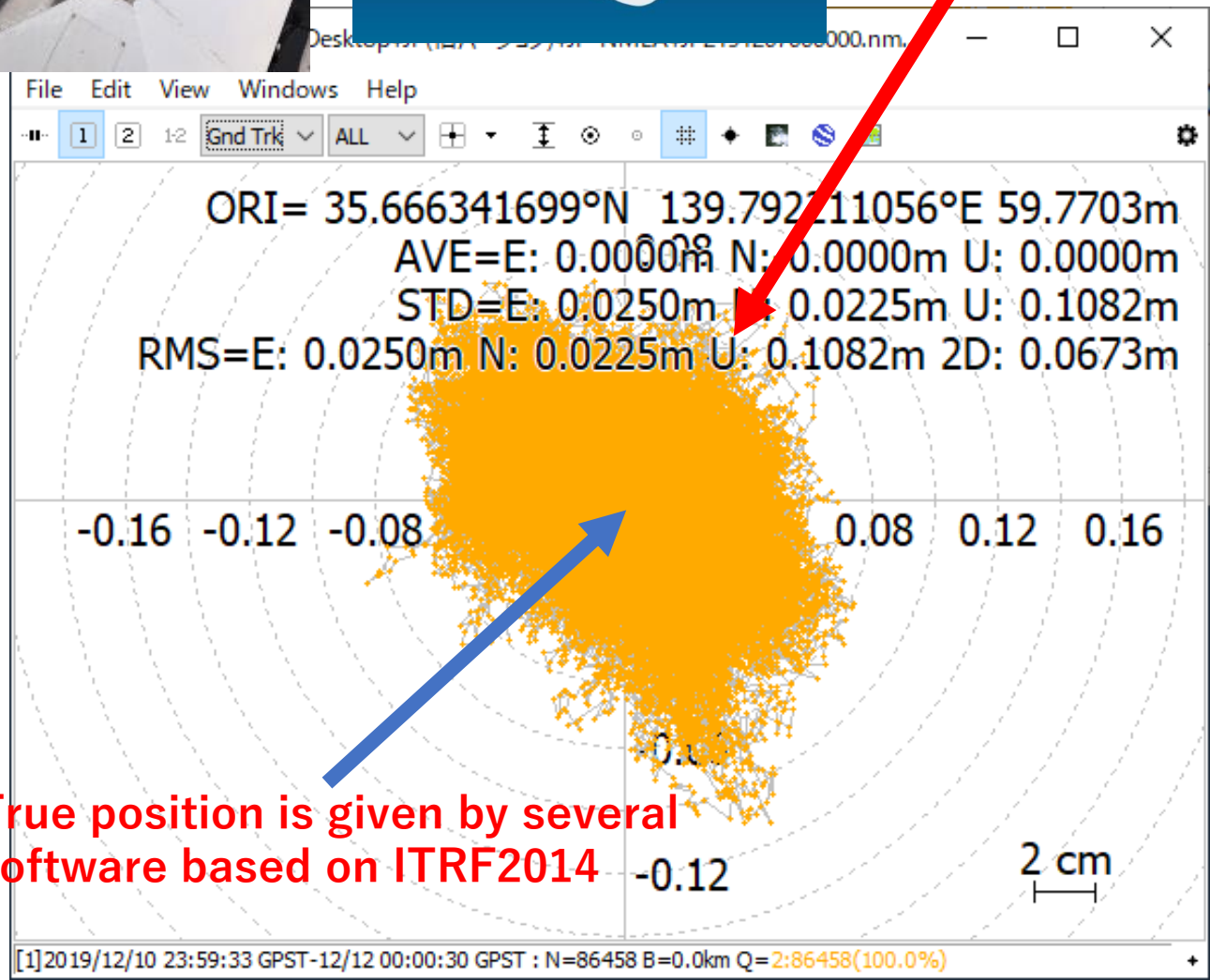
NMEA (PPP)

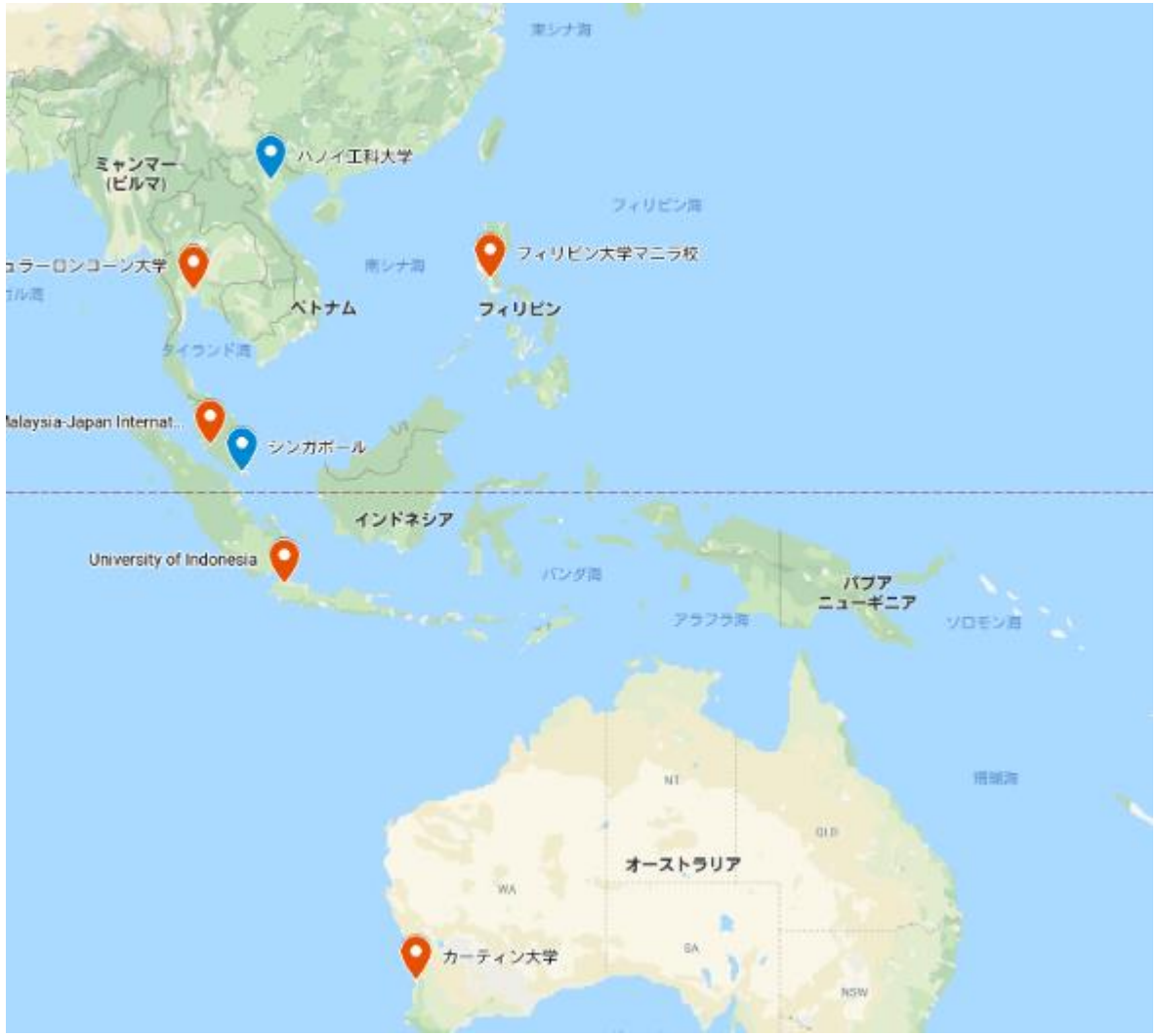


True position is given by several software based on ITRF2014

Outline of locations

Locations（Time）

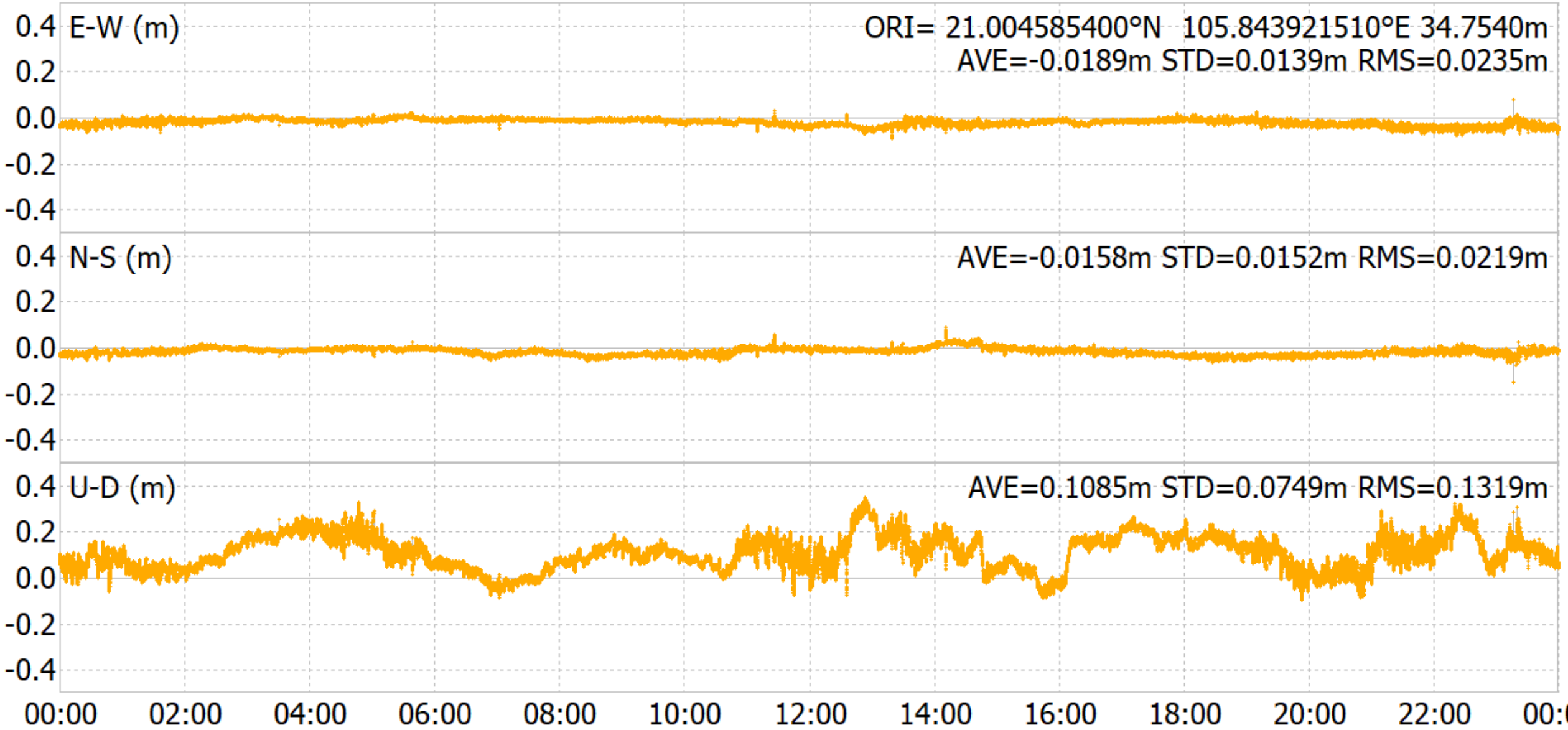
TUMSAT JAPAN（August 2019）
Chula Thailand（August 2019）
UOP Philippine（August 2019）
MJIIT Malaysia（Nov. 2019）
Curtin Australia（Nov. 2019）
UOI Indonesia（Dec. 2019）
Singapore（Feb. 2021）
Vietnam（March 2023）



5,Nov,2023,real time

HUST, Vietnam

GNSS LAB Tumsat



5 years (2020-2024)
95% Percentile of Horizontal Errors

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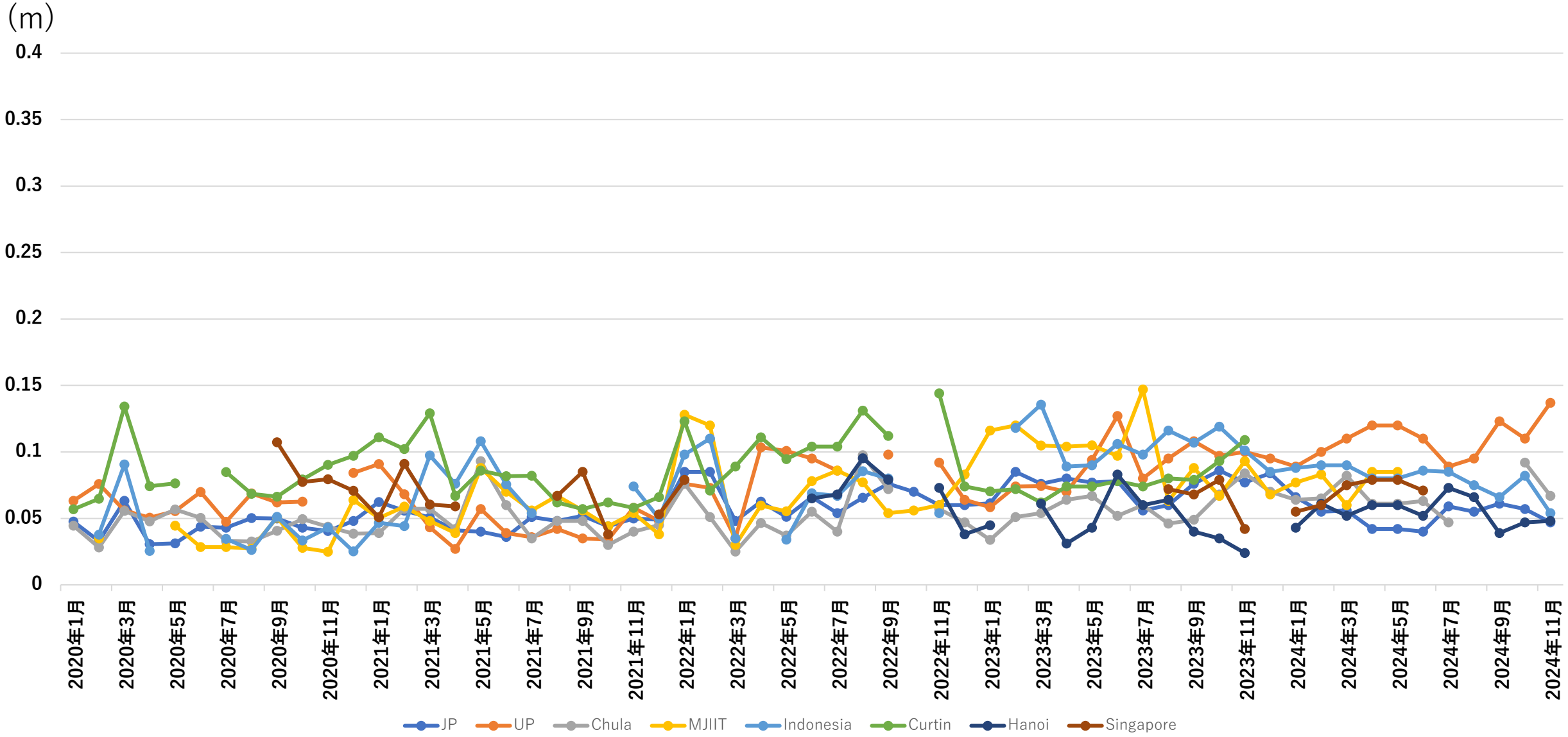
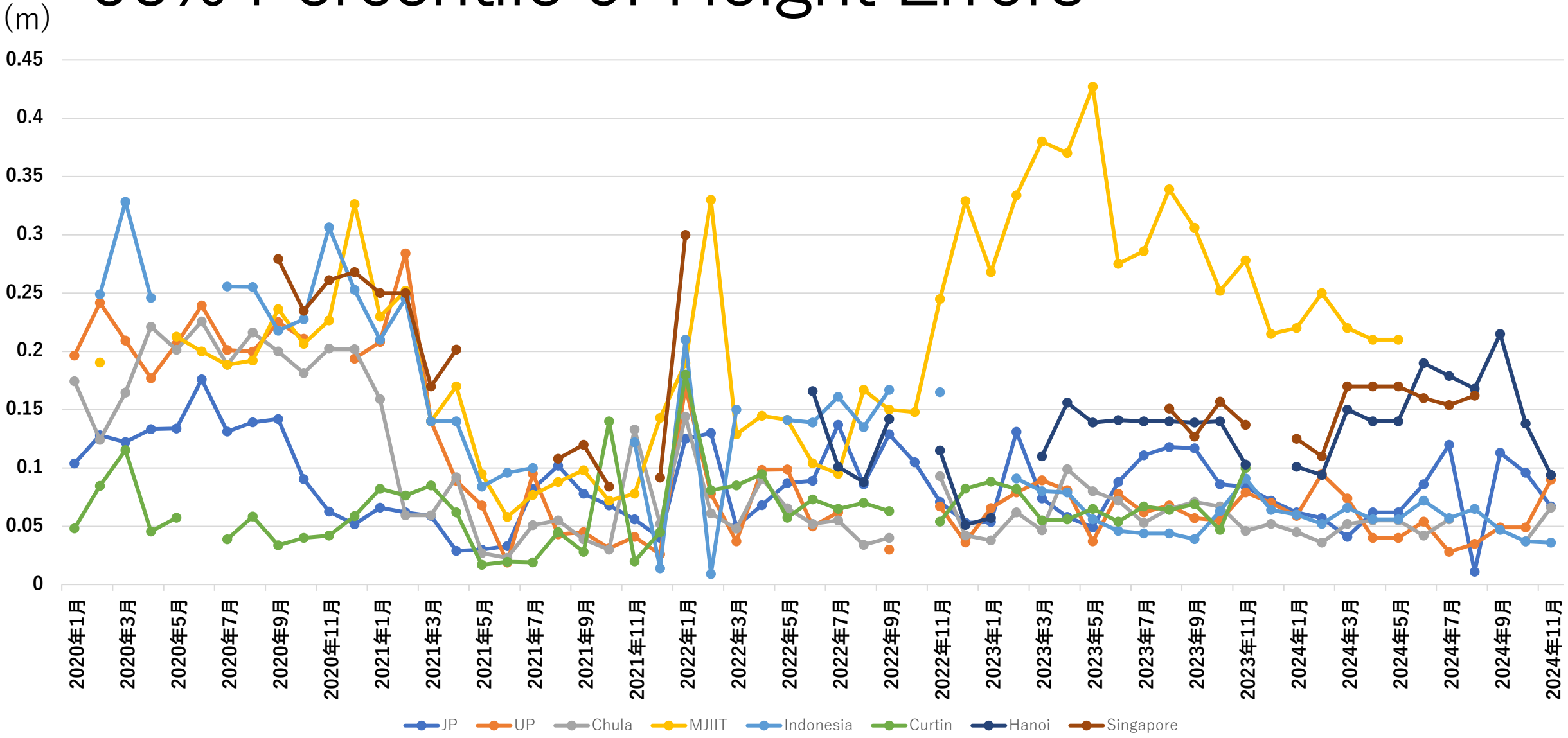
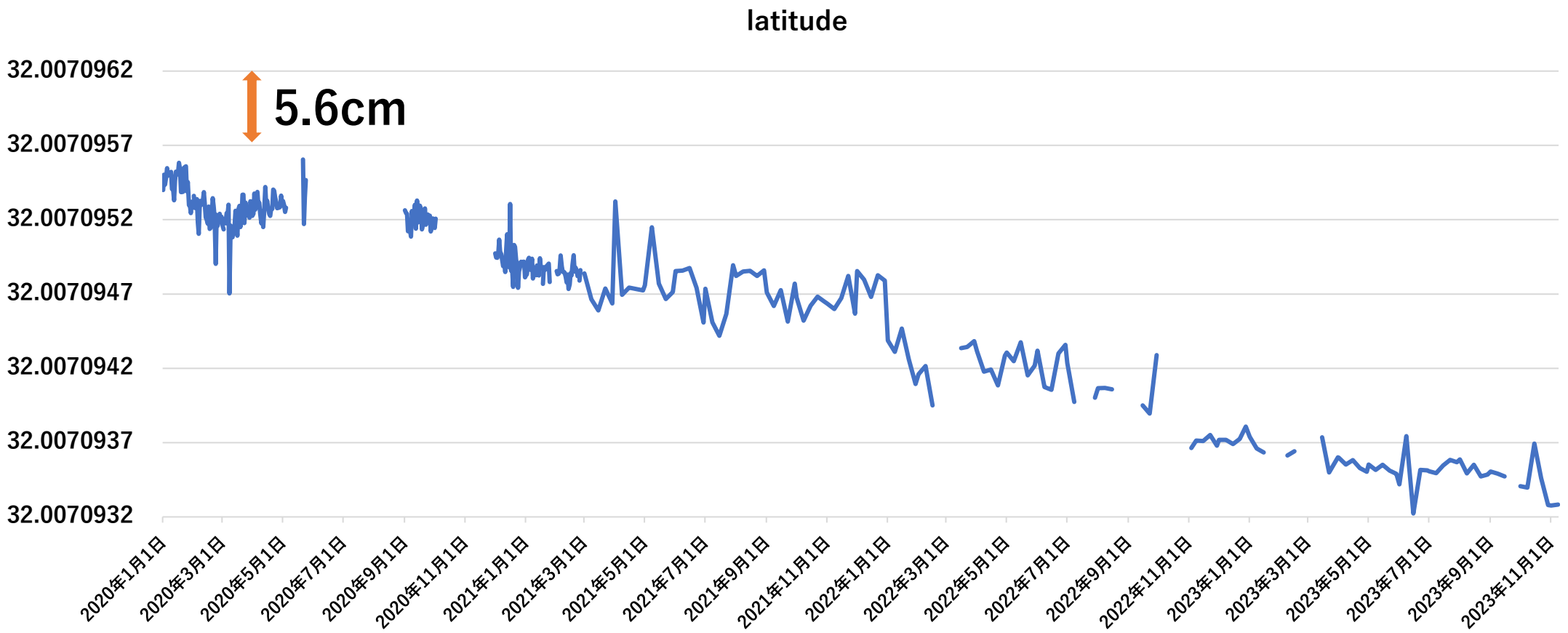


5 years(2020-2024)
95% Percentile of Height Errors

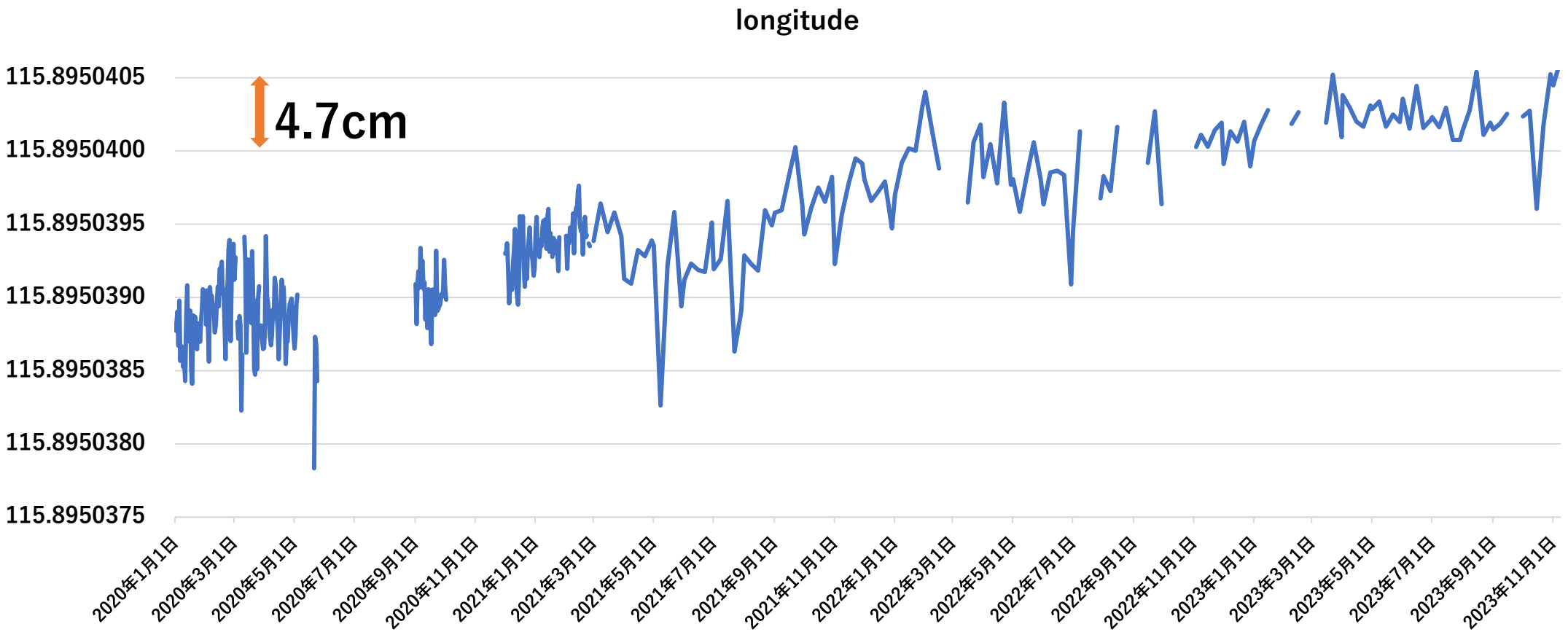
GNSS LAB Tumsat



Variations of Latitude in PPP results at Curtin University



Variations of Longitude in PPP results at Curtin University



Motion by VLBI observation

According to GSI's VLBI observations, the plate is moving about **7 cm** per year in a north-east direction.

Our PPP result shows that the plate is moving about **7.5 cm** per year to the north-east direction.

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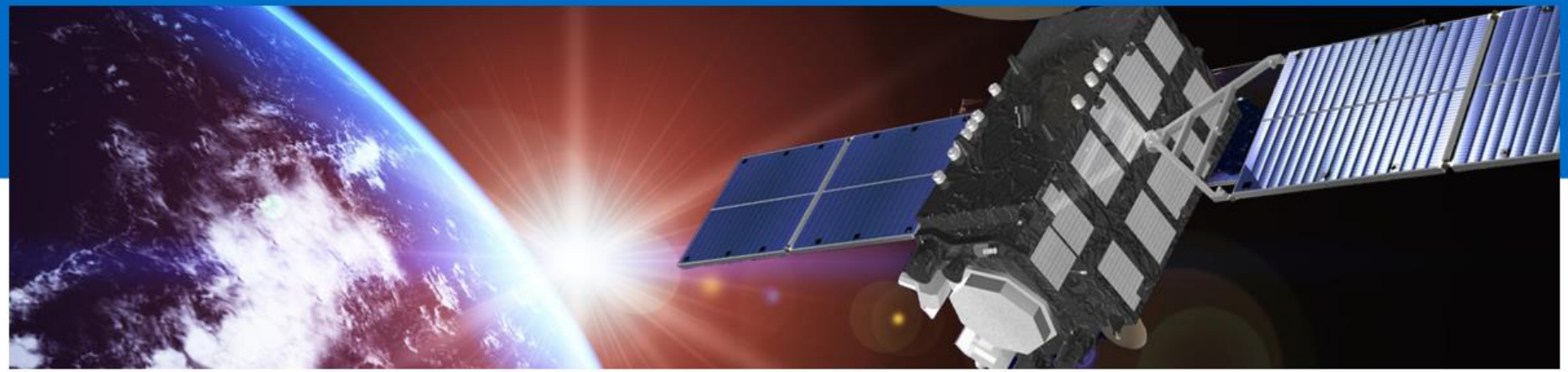

About this site

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

News

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

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


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2024/02/08
More
Level of GPS interference
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Medium 2-10%
High > 10%
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Tanzania
Malawi

Do you have any question/comments?

GNSS Applications

Monitoring base station (station) using PPP

Furuno : GNSS Automatic Displacement Measurement System

Hitachi Zosen : GNSS Ocean Buoy

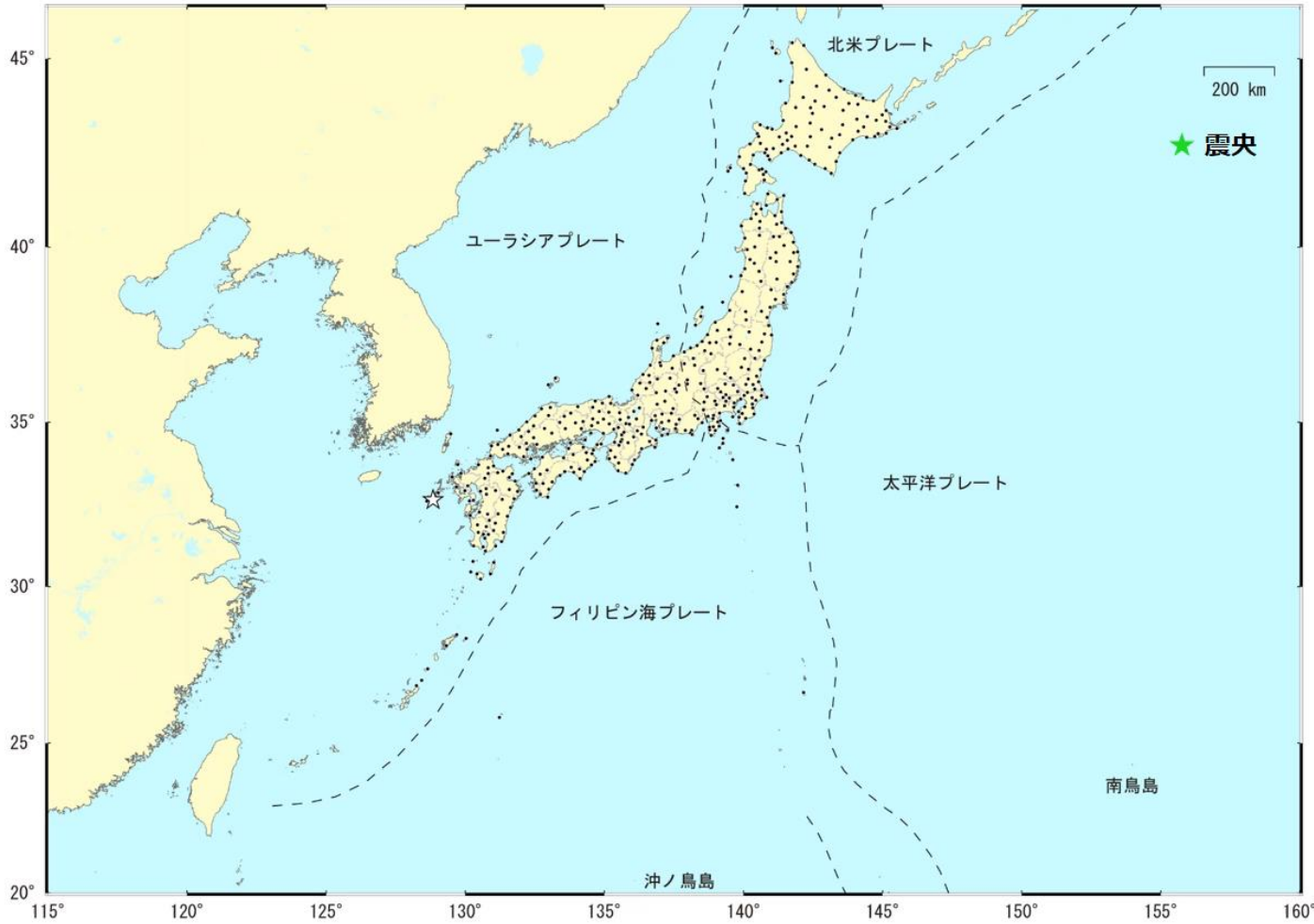
RTK has been used for these applications. As for buoy, PPP will be better selection.
For monitoring the base station of RTK, PPP can be used to monitor the base station itself.

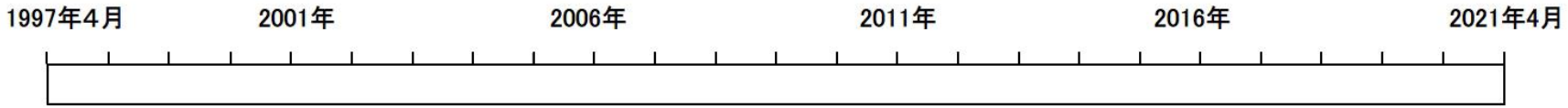
Monitoring base stations

（GEONET:GNSS Earth Observation Network System)

電子基準点がとらえた日本の地殻変動（水平）

国土交通省 国土地理院 Geospatial Information Authority of Japan





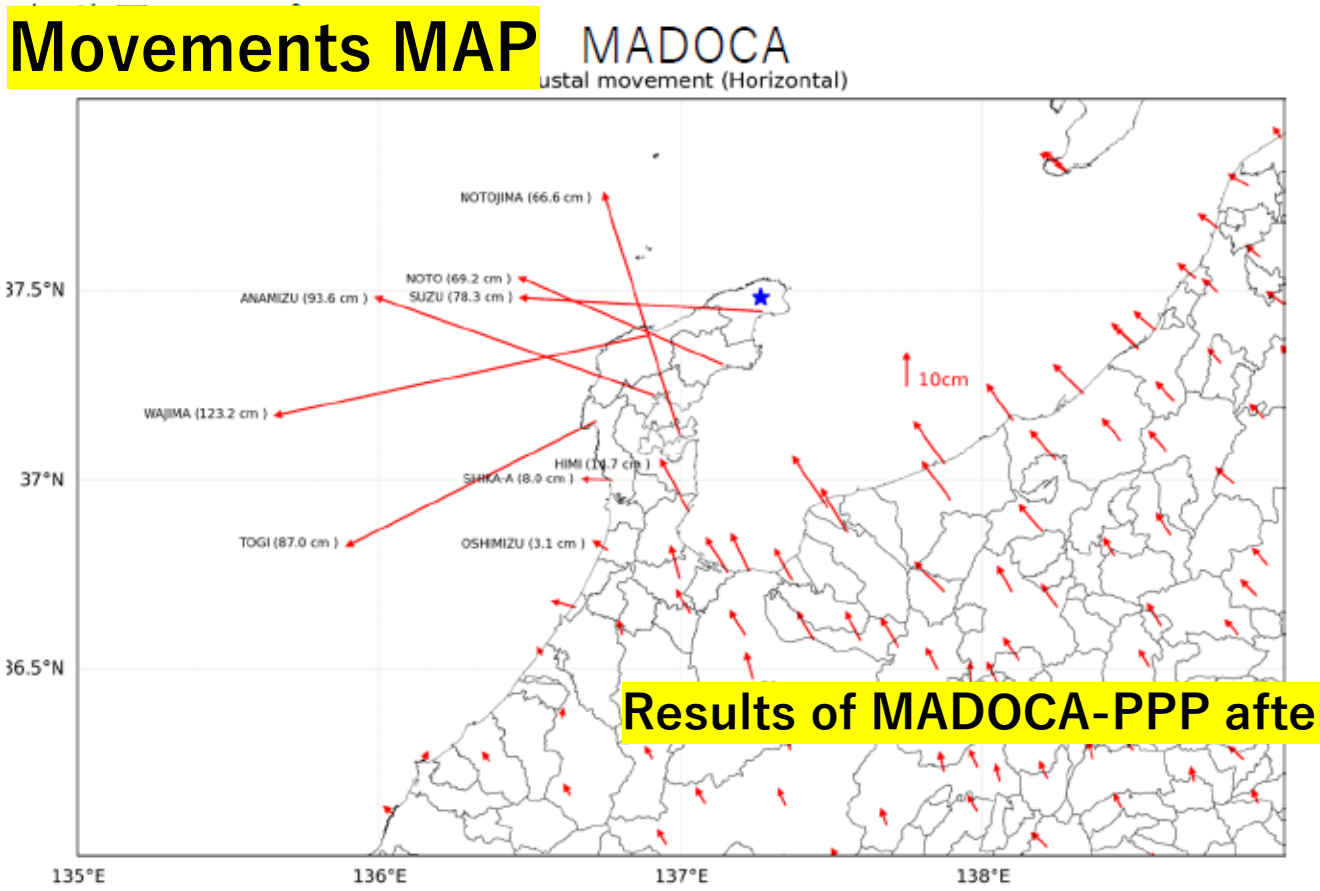
About 1,300 stations

CLAS uses part of these stations.

This is a very sophisticated system.

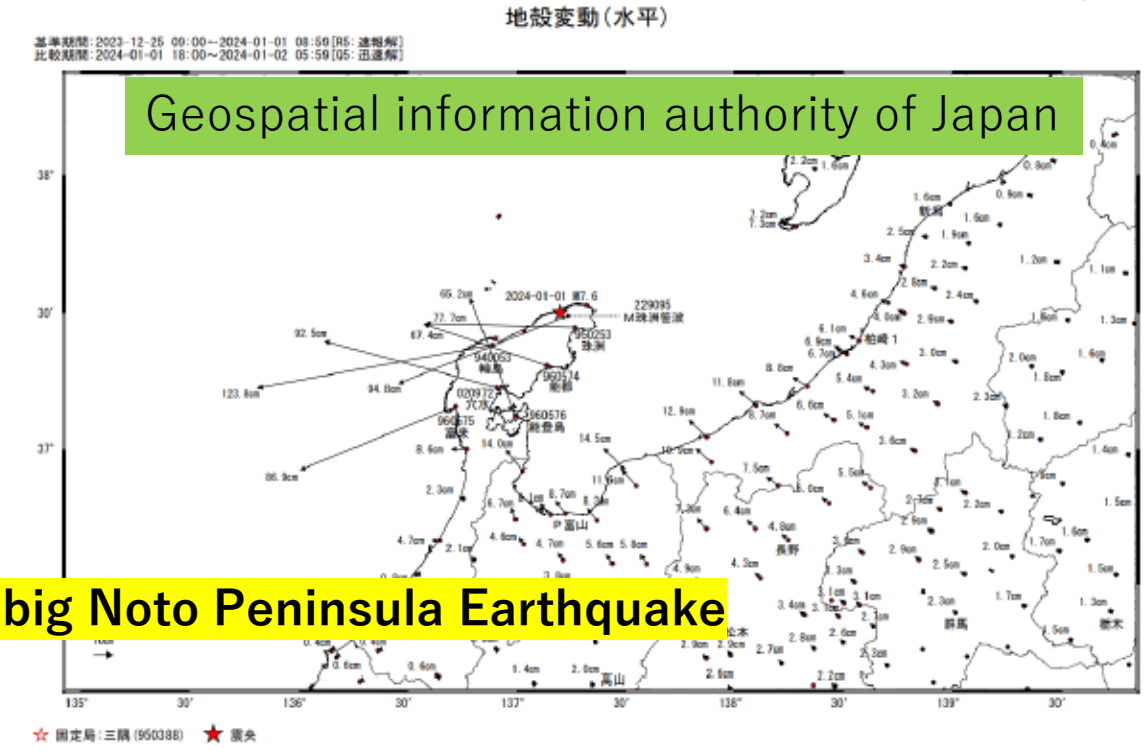
PPP might be used for this purpose.

Movements MAP



国土地理院(R5解)

GNSS LAB Tumsat



Results of MADOCA-PPP after big Noto Peninsula Earthquake

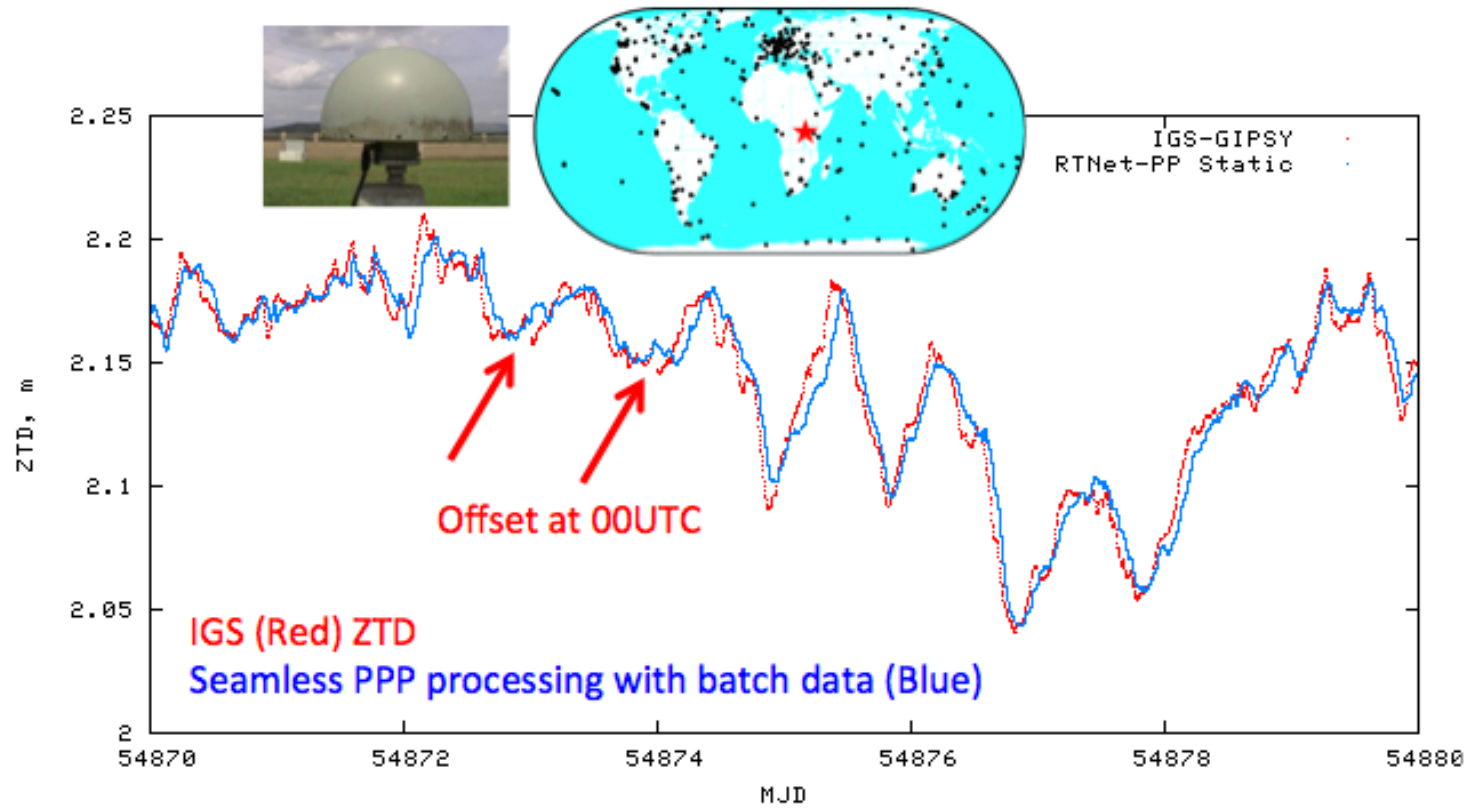
電子基準点	MADOCA	国土地理院	差分
輪島	123.2cm	123.8cm	-0.6cm
穴水	93.6cm	92.5cm	1.1cm
富来	87.0cm	86.9cm	0.1cm
珠洲	78.3cm	77.7cm	0.6cm
能登	69.2cm	67.4cm	1.8cm
能登島	66.6cm	65.2cm	1.4cm

Differences between GSI and student's analysis using MADOCA-PPP

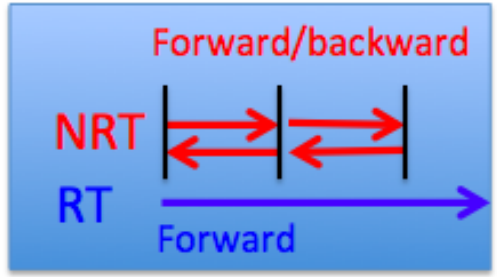
GNSS Meteorology

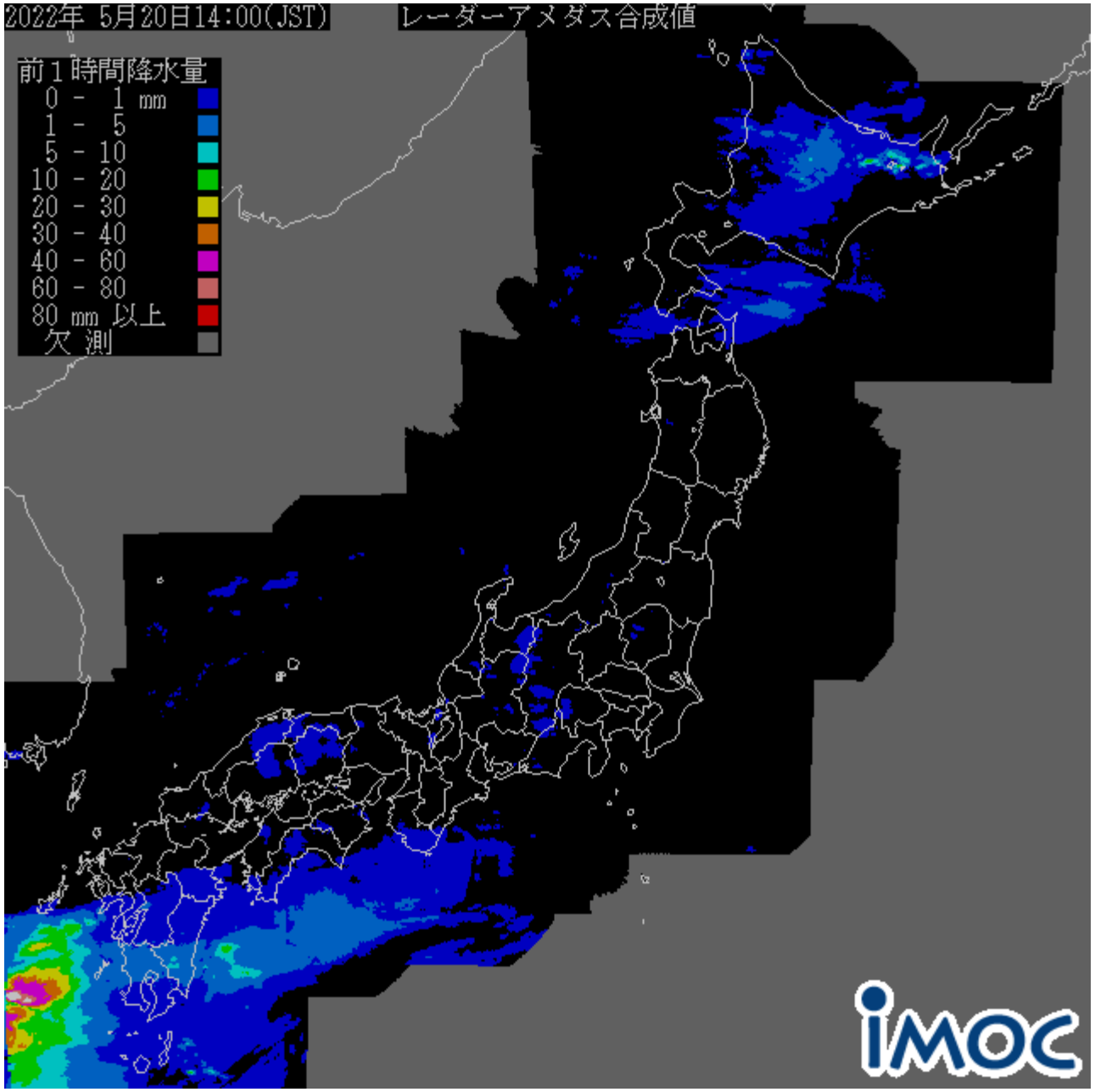
GNSS LAB Tumsat

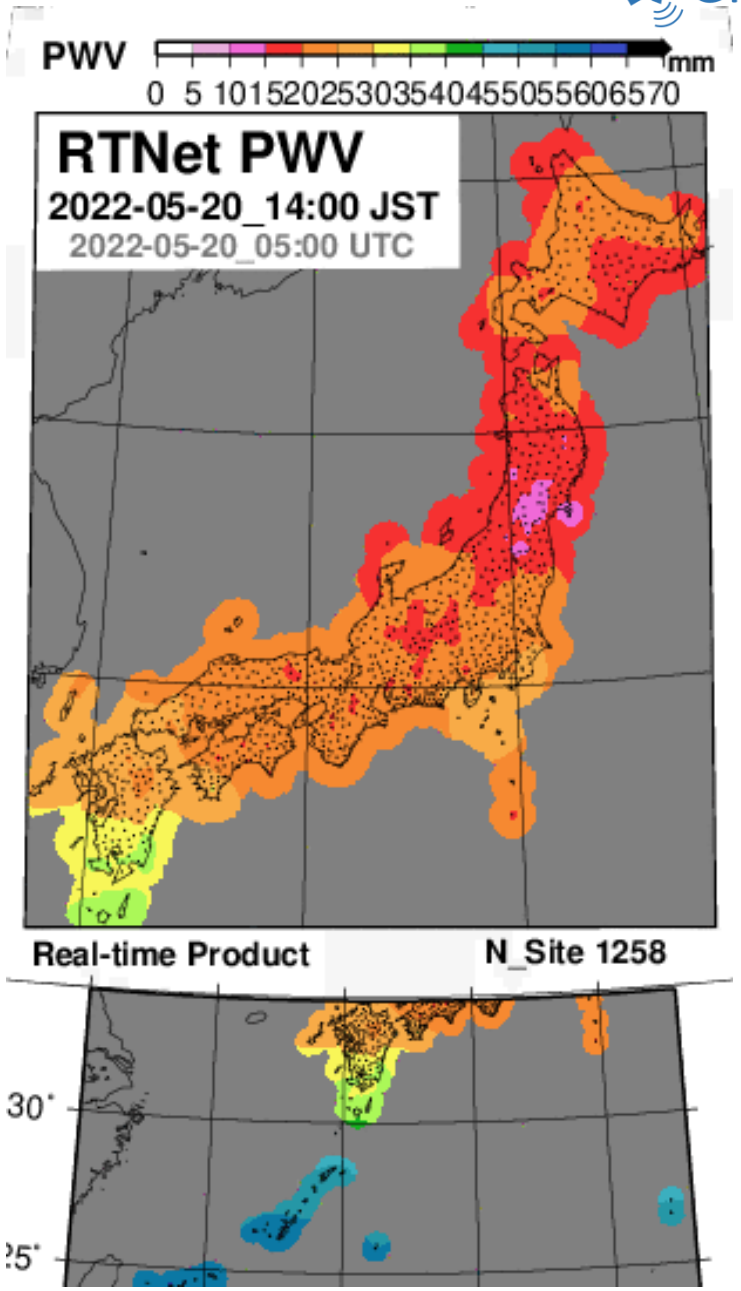
Near Real Time Processing with Forwarding Kalman Filter



- IGS ZTD (post-processing) tends to show offset at 00UTC because of window processing
- **Seamless** processing of batch data helps to avoid jumps of solutions at data boundary







GNSS LAB
Tumsat

Precise positioning anywhere in the world

Simple survey in campus

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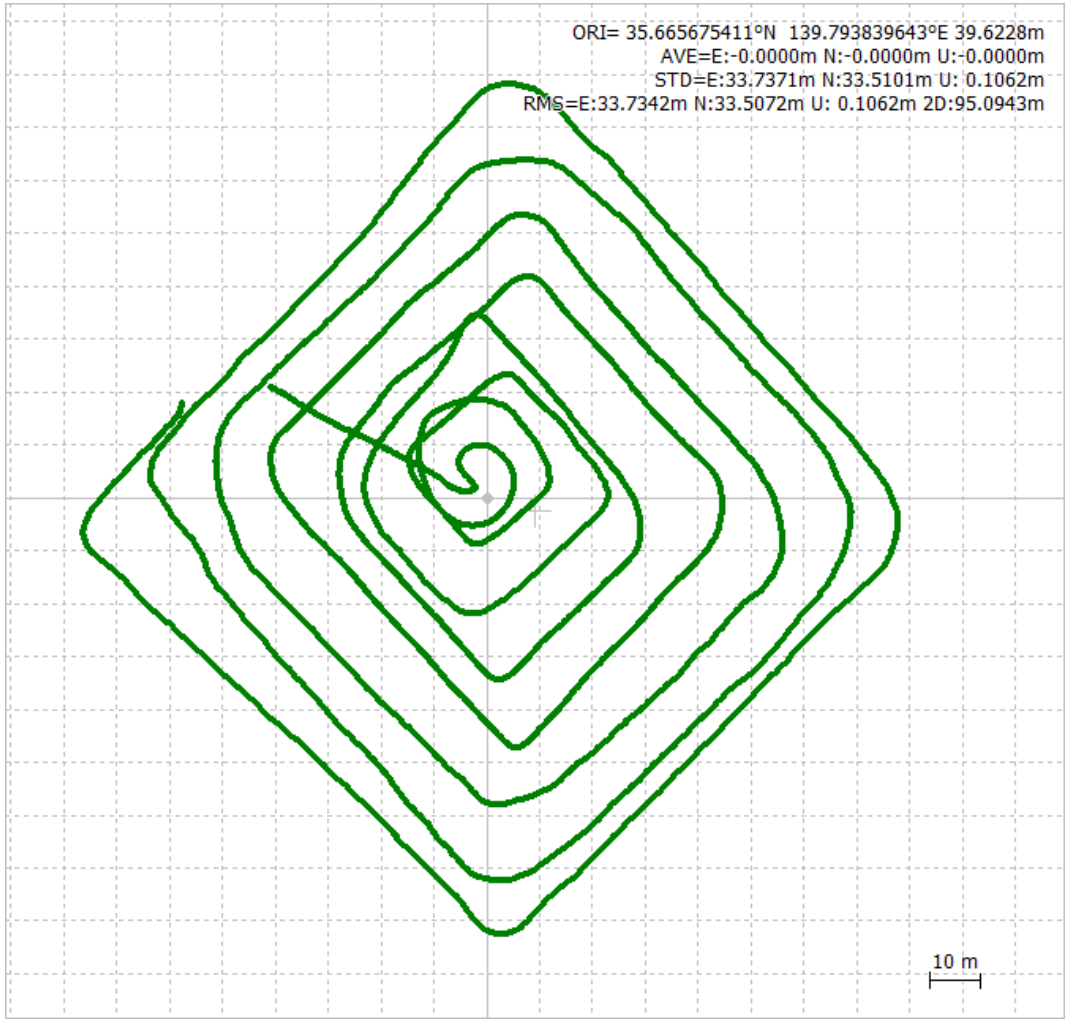
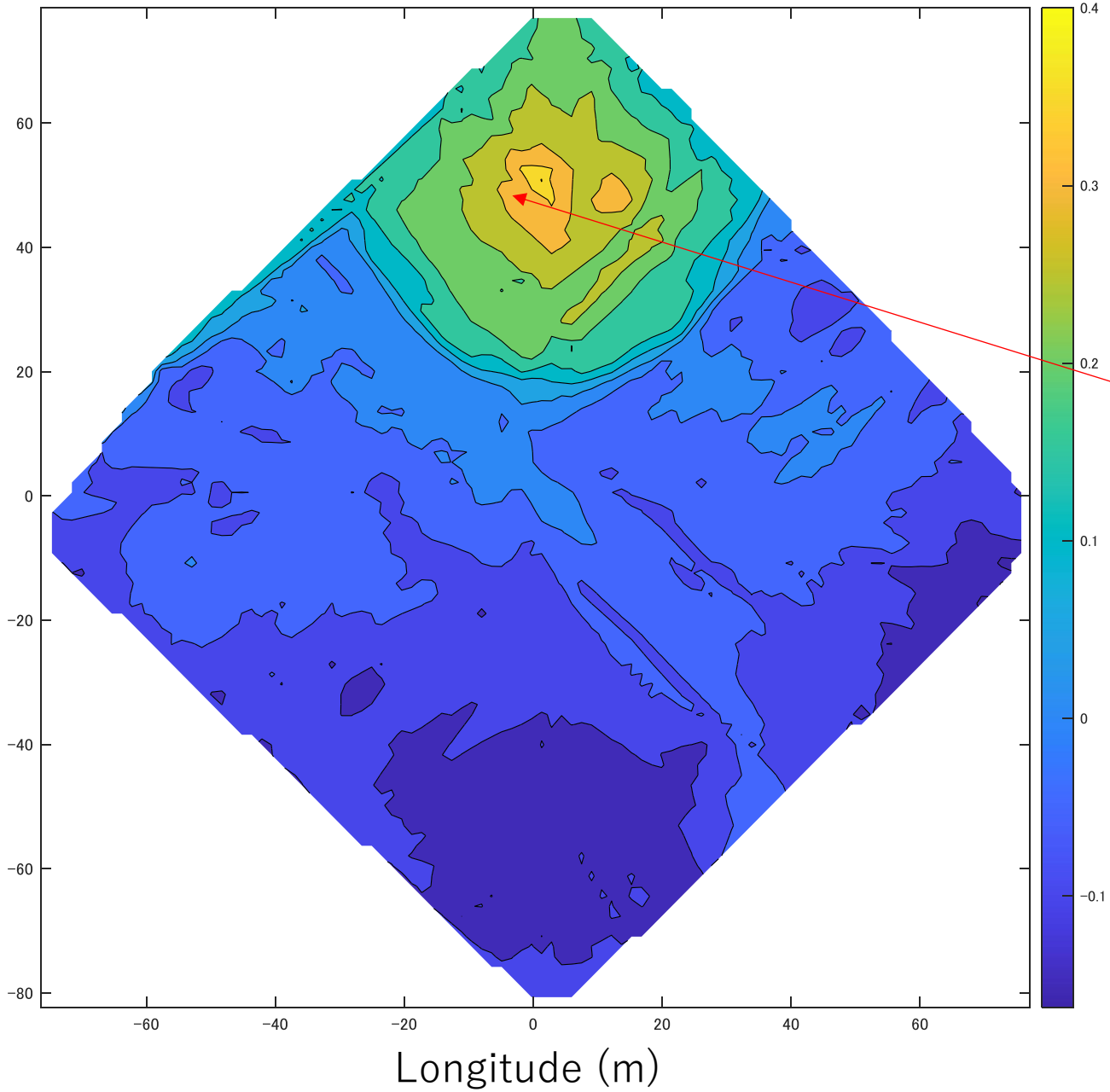


Install a cm-level receiver and antenna on the bicycle. Go around in a proper circle and generate a map of altitude

Unit is m



You can clearly see that the area around the baseball mound is high.

You can also see the exact slope of the road.

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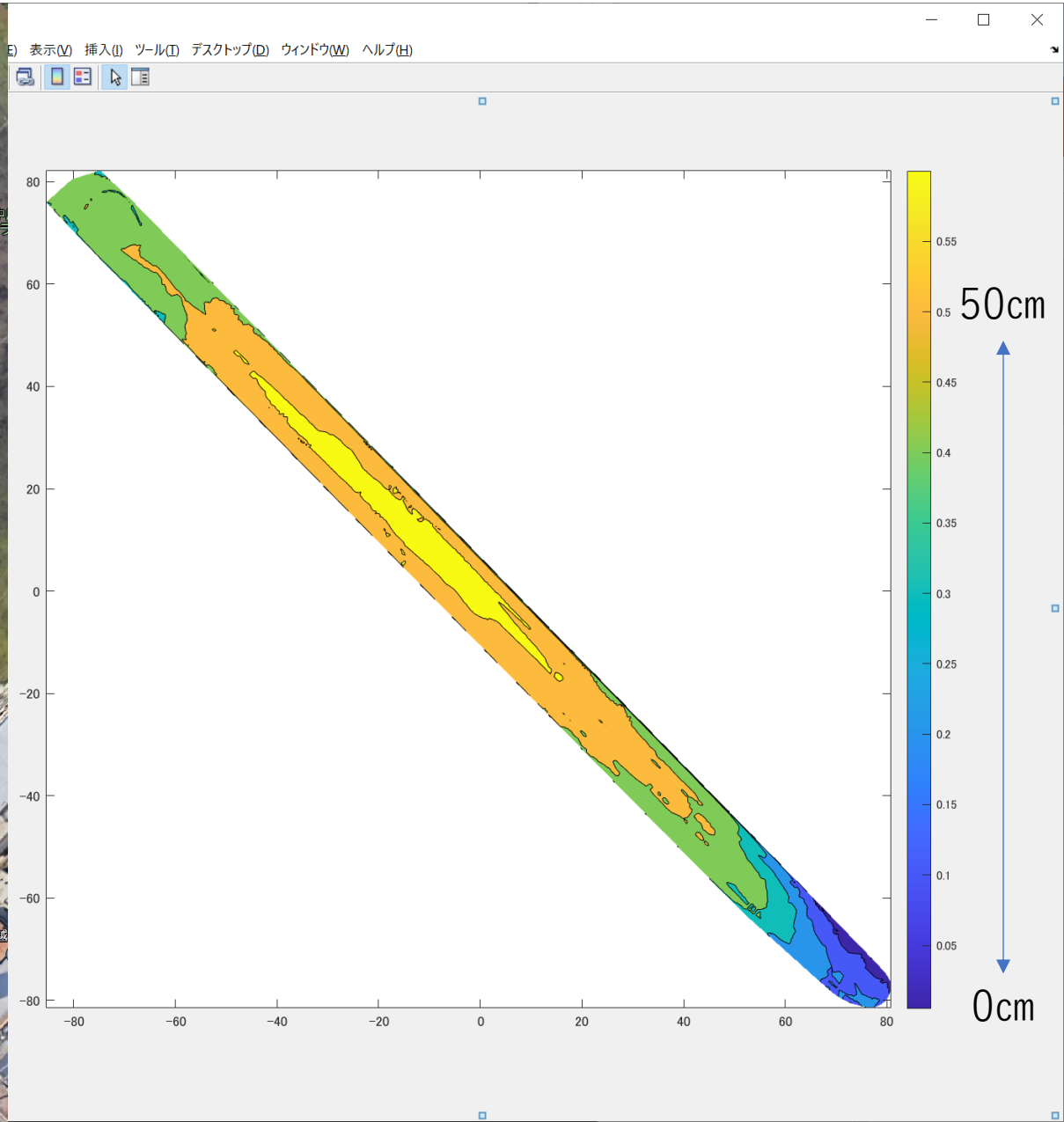

Precise 3D map generation by GNSS/IMU/Speed/Lidar

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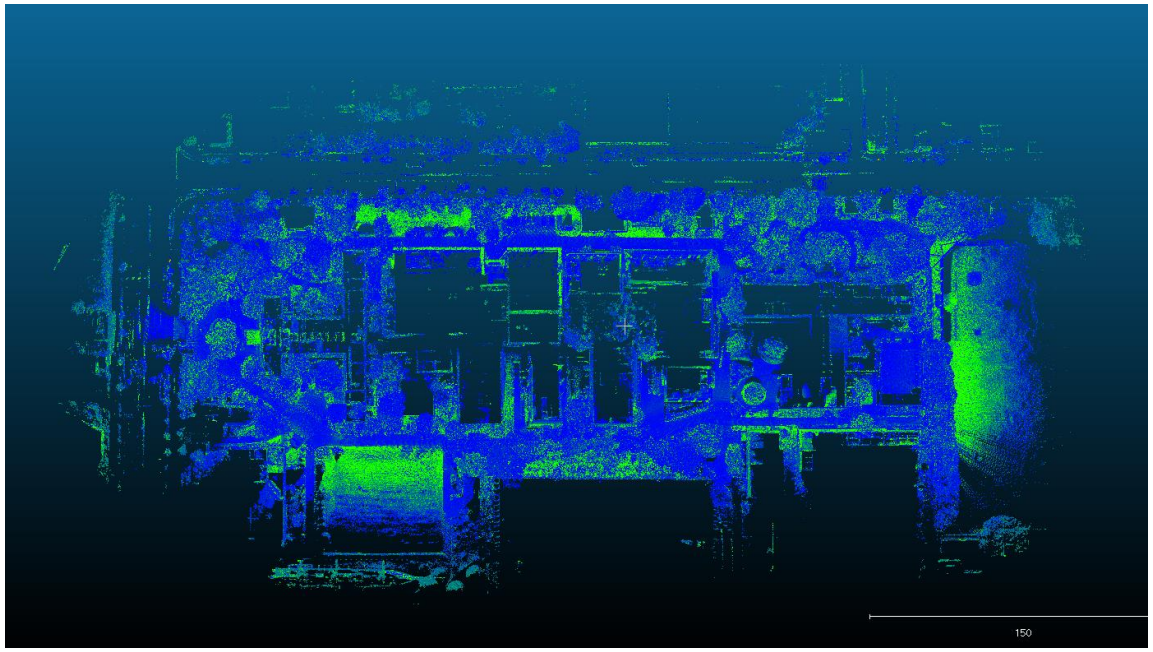
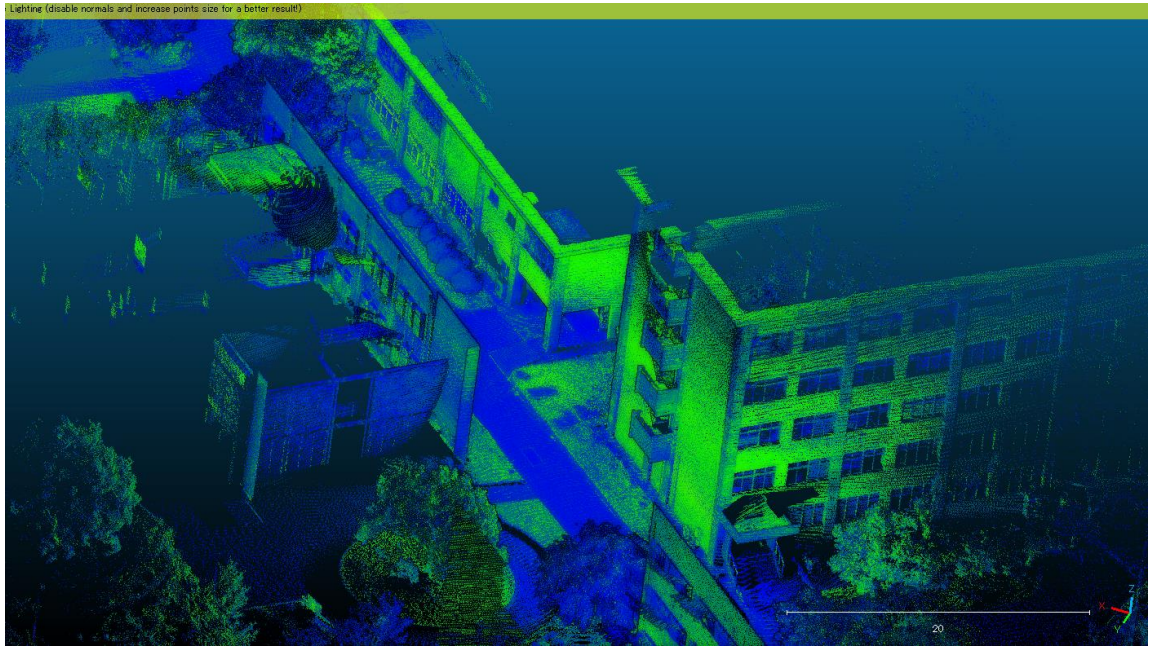
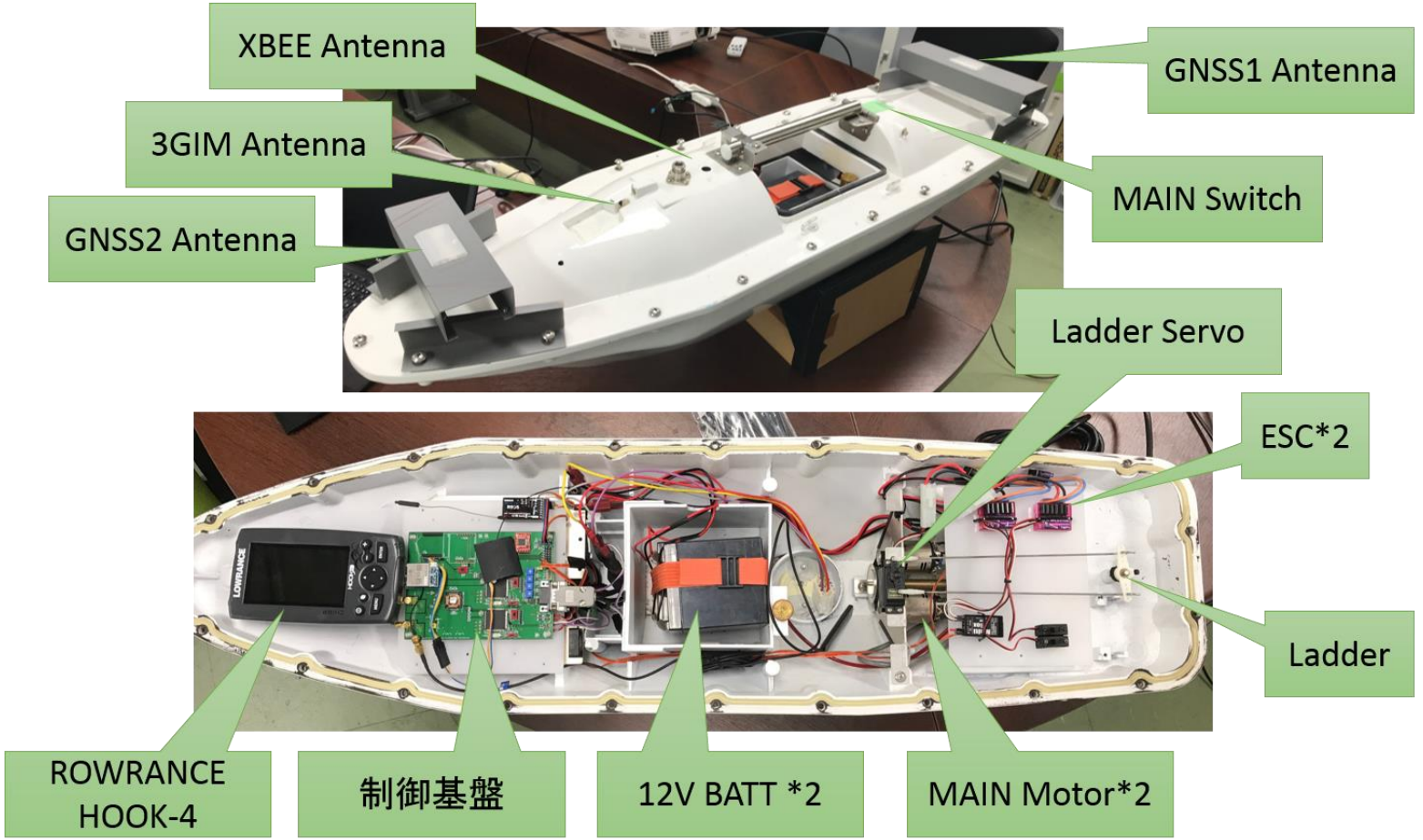




Depth Surveying by Small Boat



Depth Survey Results at Campus Pond

GNSS LAB Tumsat