Performance Evaluation of Multi-GNSS RTK in Various Environments

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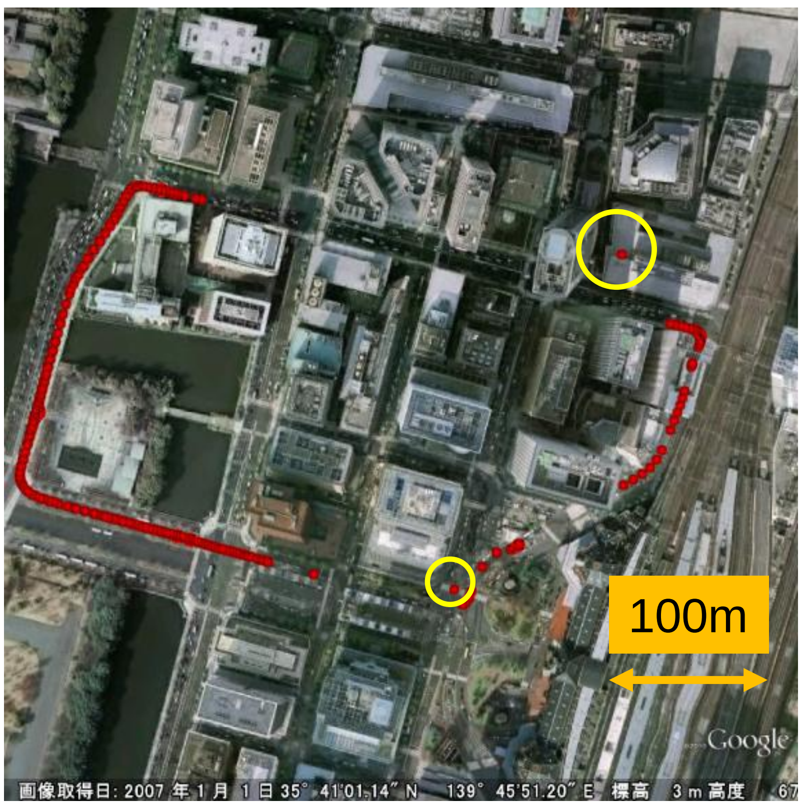
Contents

Reliability of RTK

- Reliability as well as availability of RTK are quite important for future commercial users.



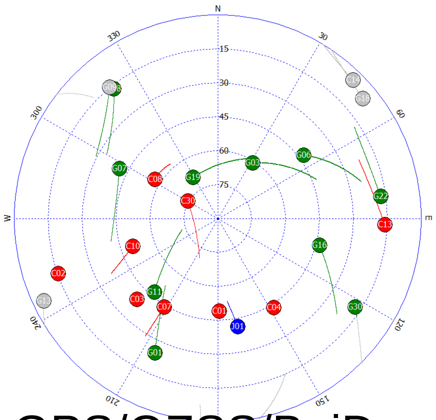
RTK-GPS example in dense urban areas (Marunouchi Tokyo)

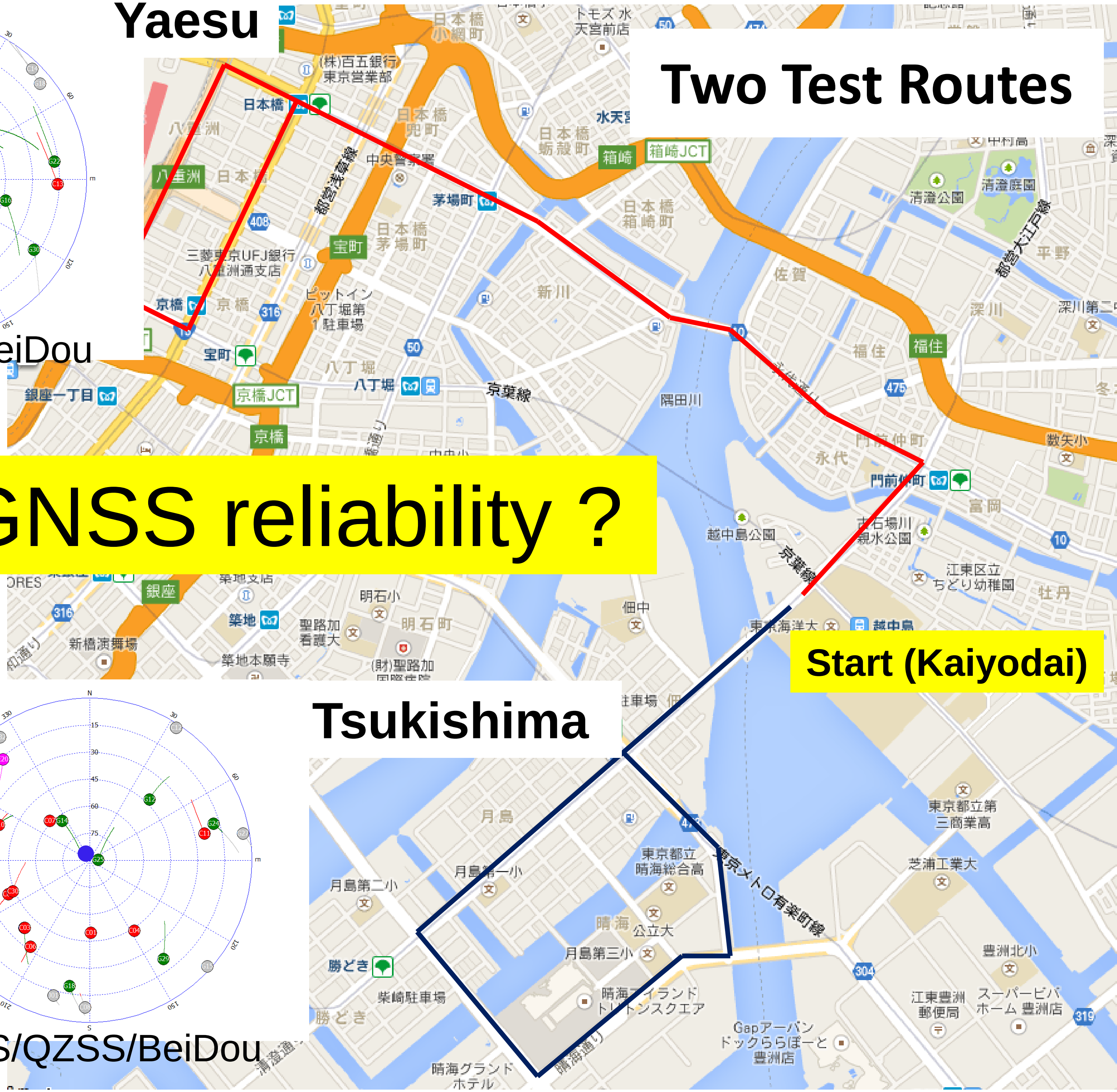
Both reliability and availability were not enough…

We need to know the current power of RTK-GNSS exactly…

Two Test Routes

RTK-GNSS reliability ?



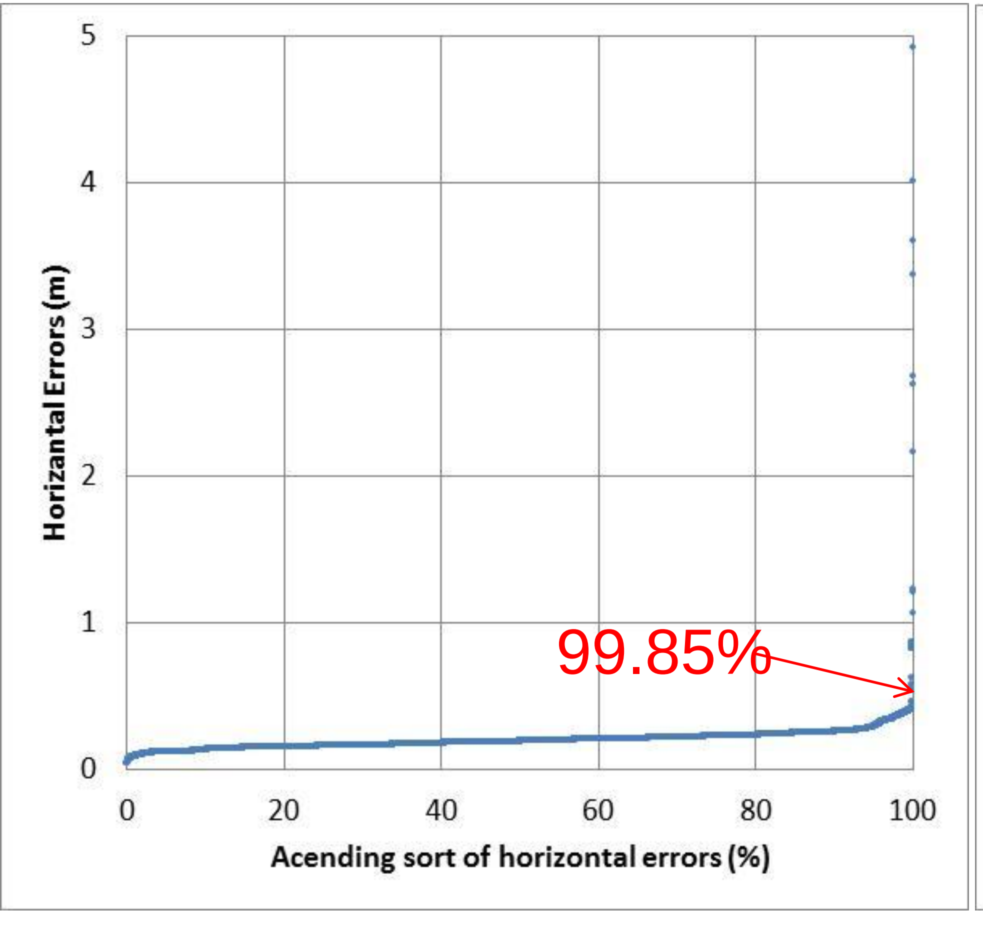


Tsukishima Route	FIX rate	Percentage below 0.5m (Horizontal)
GPS	21.7 %	99.96 %
GPS/QZS	39.8 %	99.73 %
GPS/QZS/BeiDou	71.6 %	99.85 %

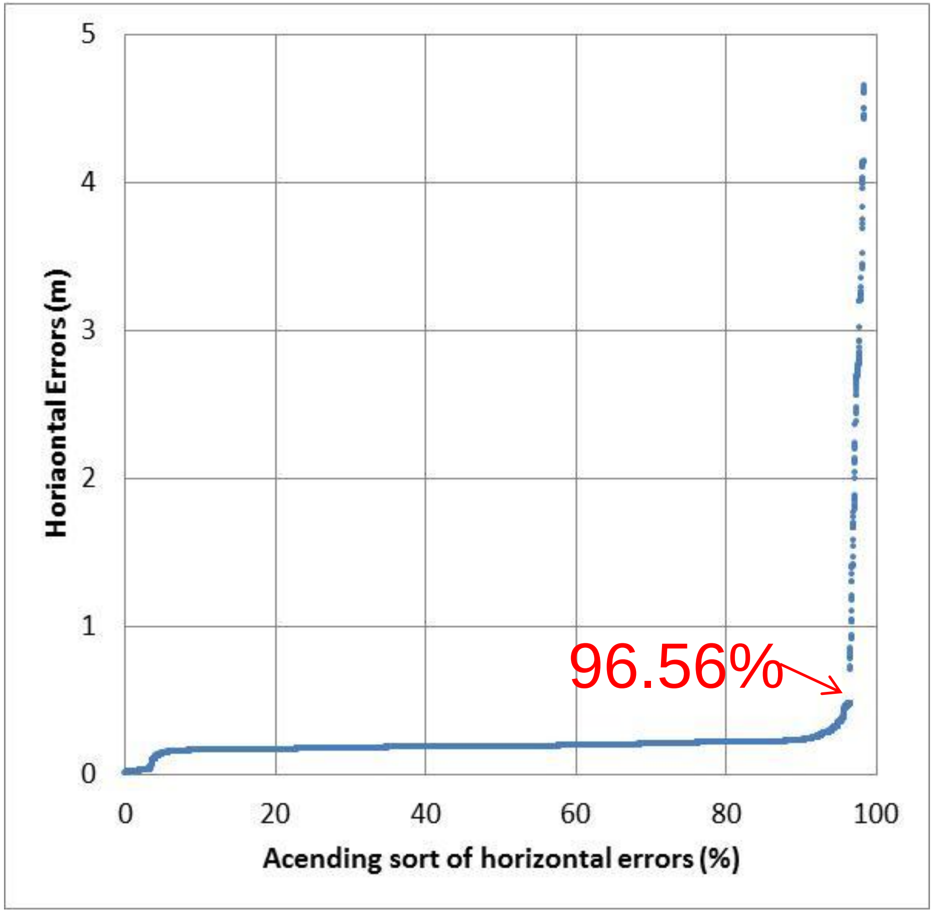
Yaesu Route	FIX rate	Percentage below 0.5m (Horizontal)
GPS	22.0 %	99.74 %
GPS/QZS	27.1 %	99.80 %
GPS/QZS/BeiDou	33.1 %	96.56 %

* “POS/LV” assures 20-30 cm errors under this route condition
* RTK : Laboratory engine was used.

All RTK Horizontal Errors

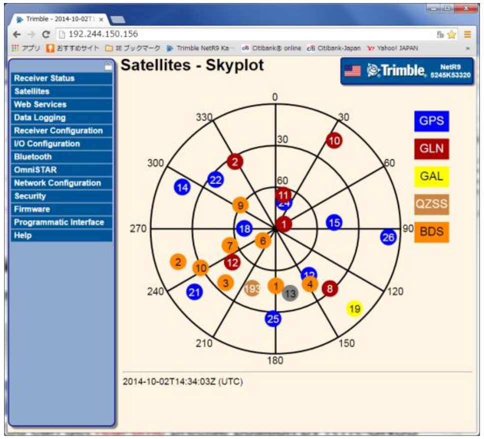


Tsukishima Route



Yaesu Route

We will provide local-area CORS network
(collaboration between universities)



CORS(Continuously Operating Reference Stations)

observation data via the Internet

Tokyo(Komaba, Hongo, Hiyoshi, Kaiyodai…)
Bangkok(Thailand), Jakarta(Indonesia)

What you can do ?

You can get real-time precise position by RTK-GNSS

Rover

Communication Link

Reference

Multi-GNSS RTK Test using Car

Test	Schedule
1st	2014/8/13 13:07–13:32
2nd	2014/8/13 17:26–17:52
3rd	2014/8/13 22:26–22:50
4th	2014/8/14 8:36–9:02
5th	2014/8/14 12:07–12:35

* GPS/QZS/GLONASS/GALILEO/BeiDou are entirely used in this test
* Trimble SPS855 receiver was used
* RTK : Trimble and Laboratory engine

Summary of Test Results
(Trimble RTK engine)

Multi-GNSS RTK

	Average NUS	Fix rate	Maximum latency
Test 1	12.3	58.7%	23 seconds
Test 2	12.3	75.4%	29 seconds
Test 3	13.6	65.5%	27 seconds
Test 4	12.4	60.0%	22 seconds
Test 5	14.2	70.5%	6 seconds

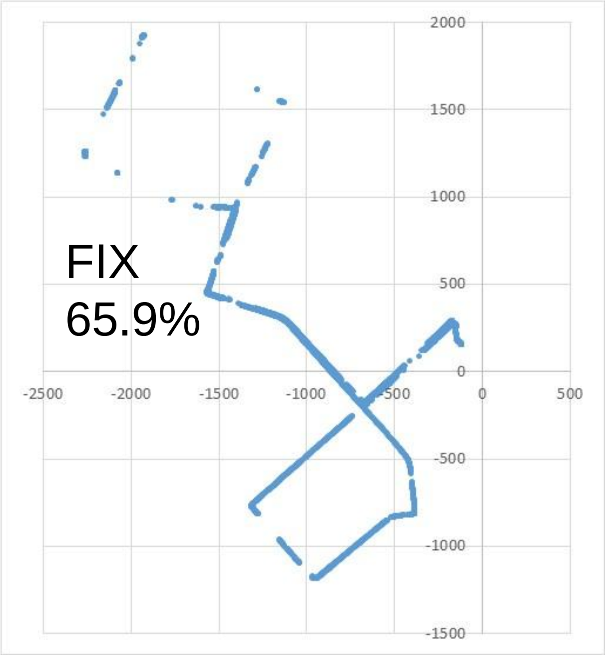
GPS VS. Multi-GNSS RTK (using two same receivers : SPS855)

Test 5	Average NUS	Fix rate	Maximum latency
GPS	5.8	26.8%	10 seconds
Multi-GNSS	14.2	70.5%	6 seconds

Details of Test 3 Results

(Laboratory RTK engine)

Test 3	Average NUS	Fix rate
Trimble	13.6	65.5%
Lab.	13.6	65.9%



FIX rate comparison between GNSS combinations

	G	GJ	GC	GR	GJC	GJCR
FIX rate (%)	48.2	58.2	55.5	55.4	64.7	65.9
Velocity (%)	67.0	80.3	86.5	82.4	91.5	94.7

Velocity : Doppler based velocity output
G:GPS J:QZSS C:BeiDou R:GLONASS

Number of satellites over ** degree

Elevation	GPS	QZSS	BeiDou	GLONASS
15 >	10	1	7	8
45 >	3	1	1	1

QZSS was actually over 85 degree during test 3

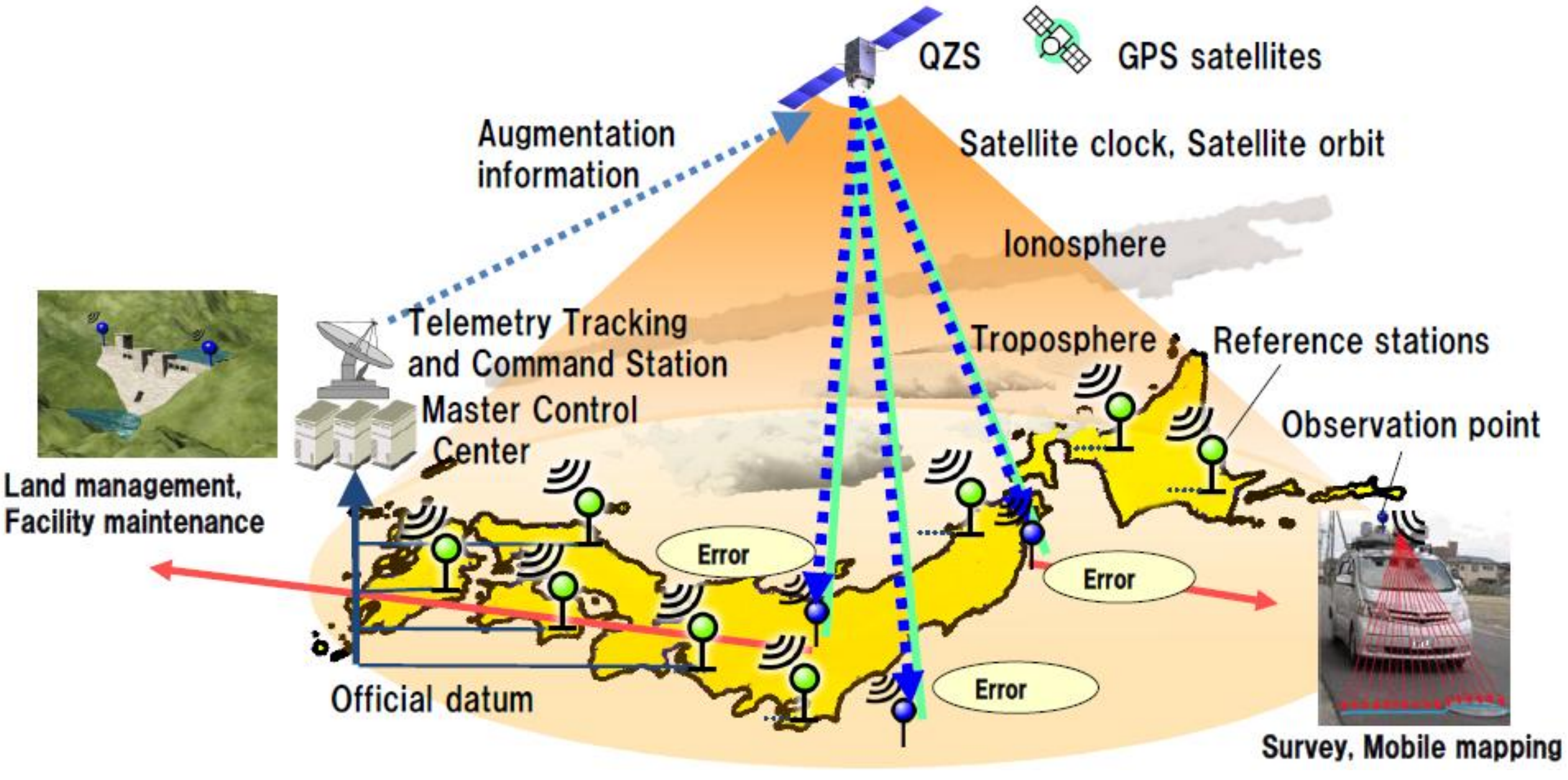
Centimeter Level Augmentation Service in QZSS

- Local RTK test has been demonstrated. However, it can't be widely used
- Network VRS services are available in Japan (JENOBA, Nippon GPS Data Service etc.)
- Convenient but expensive. Wireless internet stability and too many lines (Latency happens)
- What if we receive correction data from QZSS
- <u>QZSS LEX signal </u>is assigned for this purpose

System Overview

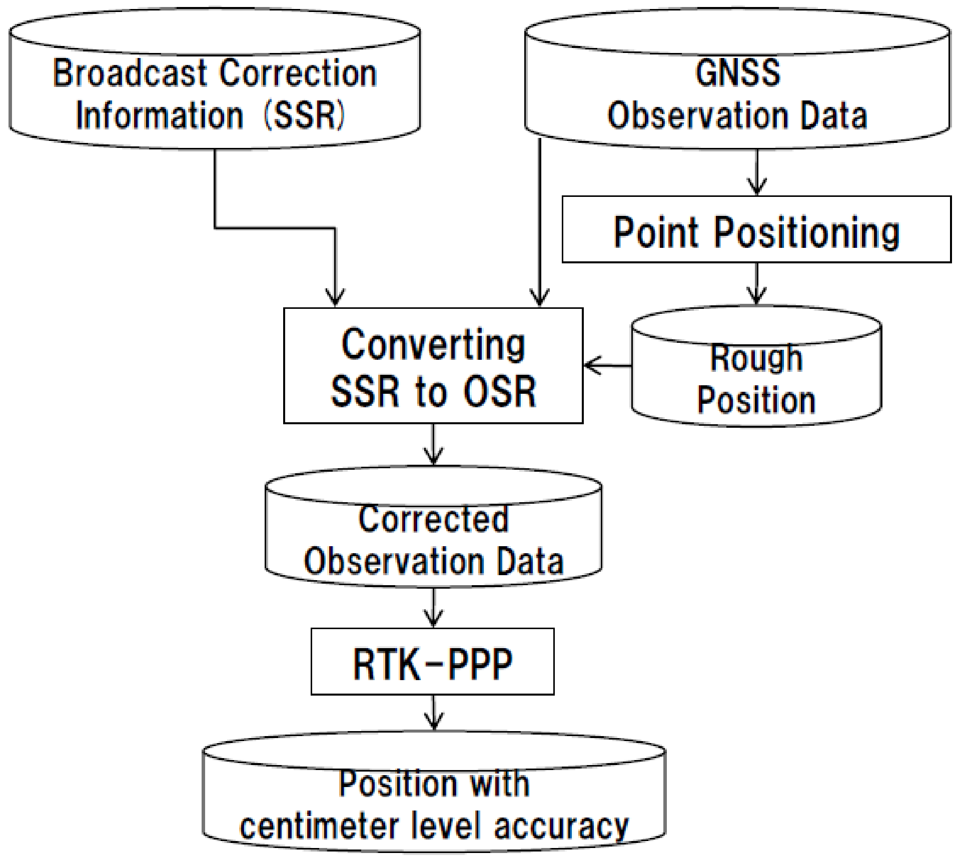
QZS broadcasts all the necessary GNSS error correction information for user to perform RTK-PPP in all over Japan.

- Corrections for each area and satellite are estimated in real time from Japanese Reference point (GEONET) to be adapted into "Japanese Geodetic Datum (JGD) 2011".
- Data rate of the signal is 2kbps. Compression of correction is necessary.
- Integrity information is broadcast with the correction information.



User’s Positioning Method

- GNSS error correction information is represented in state space.
  (SSR: State Space Representation)
- It can be converted to pseudorange/carrier phase corrections at user’s position.
  (OSR: Observation Space Representation)



User only requires a GNSS antenna and receiver.

Correction Information

- Location dependent correction and satellite dependent correction represented in state space are provided.
- The correction in CLAS corresponds to that in step 3 of RTCM-SSR, which enables user to perform "RTK-PPP".

Table. Contents of the correction

Satellite Clock Correction	Delta Clock C0
	Delta Clock C1
	Delta Clock C2
Satellite Orbit Correction	Delta-Radial
	Delta-Along-Track
	Delta-Cross-Track
Satellite Code Biases	
Satellite Phase Biases	
Slant Ionosphere (Slant TEC)	
Vertical Troposphere	Dry component
	Wet component

Requirements

●Positioning Accuracy and TTFF(Time To First Fix):

6 cm (95%) in horizontal, 12 cm (95%) in vertical within 1 minute.

●Coverage:

Homeland of Japan and its territorial sea except for several isolate islands.

Step1. We specified acceptable amount of each factor of the residual error caused from compression and decompression based on:

・Two-year data gathered from the application demonstration
・Analysis of necessary condition that the ground user can fix carrier phase ambiguities of minimum number of satellites within 1minutes

Step2. We designed the temporal and spatial interval of each correction and their numerical resolution, which satisfy the allocated residual error and also adapt to the total data amount of correction information (2kbps).

Update Interval (Time)

- Given the allocated errors, we designed temporal and spatial interval for each error correction component.
- The temporal interval is shown below. Integrity and other necessary information like an epoch of correction, IOD, PRN are provided every 30 seconds.

Compressed augmentation information format

Broadcasted Item	Components	Update period [s]
High-speed correction items	Satellite dependent elements (Satellite clock errors in navigation message, etc.)	5
Low-speed correction items	Satellite dependent elements (Satellite orbit errors in navigation message, etc.)	30
	Frequency, Satellite, Location dependent elements (Ionospheric delay, etc.)	30
	Location dependent elements (Tropospheric delay, etc.)	30
	Frequency / Satellite dependent elements (IFB, etc.)	30
Integrity (Signal-In-Space, Atmosphere Quality)		30
Other(GNSS time, IOD, PRN, etc.)		30

Update Interval (Space)

- Spatial grid points are defined for troposphere and ionosphere.
- The interval is 50 to 60 km depending on the location covering the homeland and its surrounding ocean except for several isolate islands.
- Ground users interpolate correction at surrounding grid points to obtain the correction at their location.

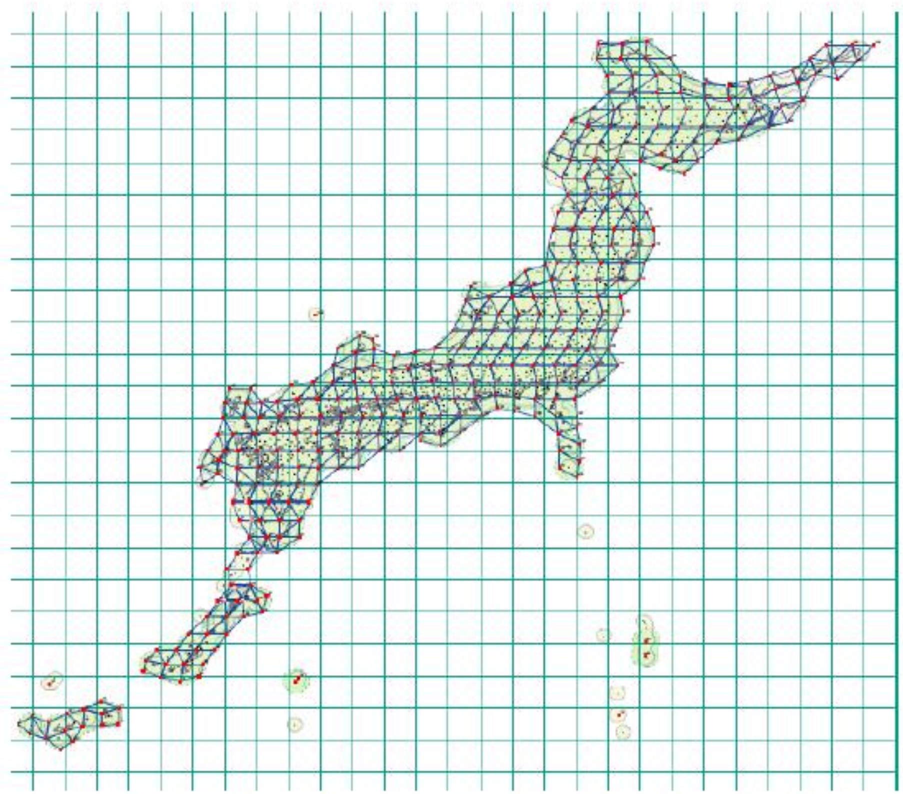


Figure. Preliminary design of grid allocation

Integrity Information

●Alert flag

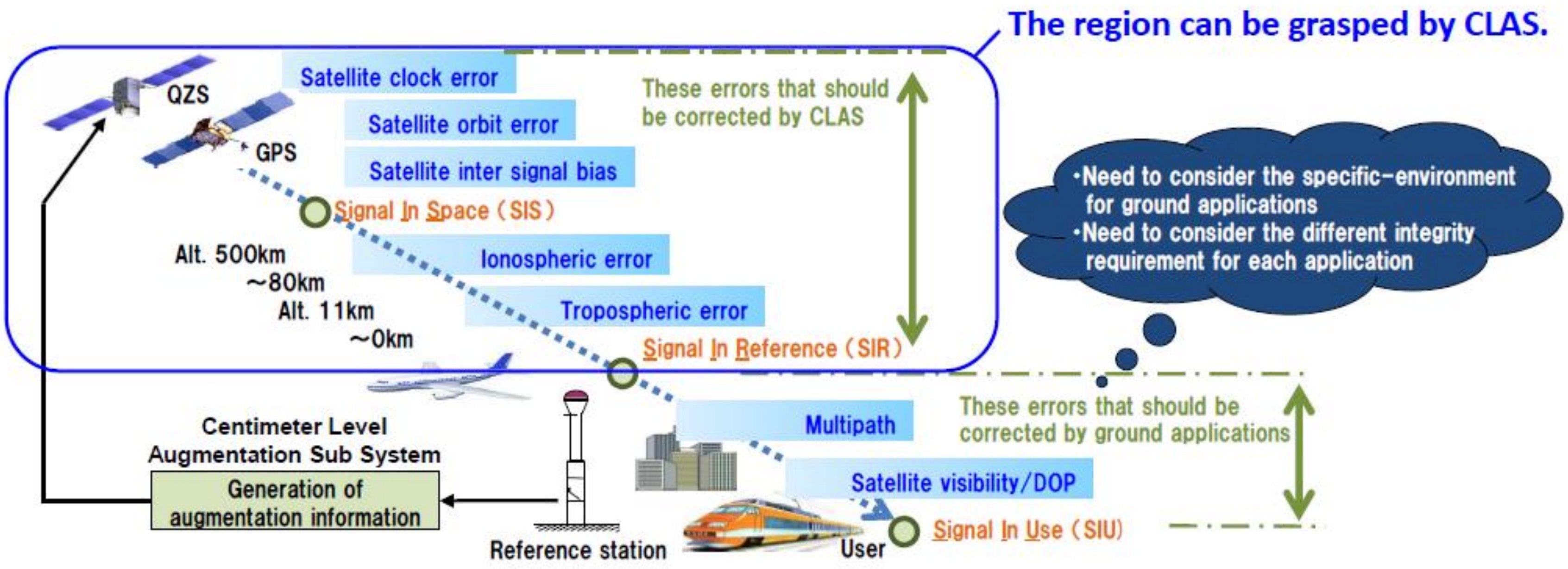
・Alert flag: Alert flag indicates presence or absence of malfunction of total system

● Other information

In order that the user can perform RTK or RTK-PPP positioning with reliability, following information is also provided.

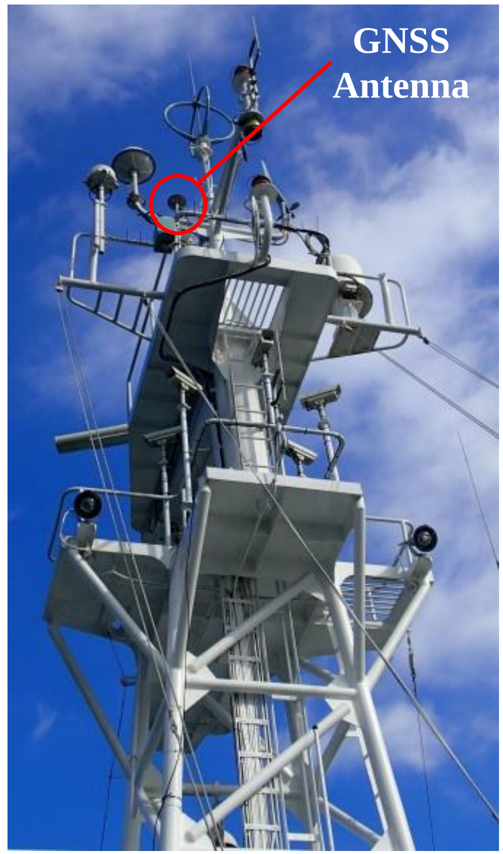
・SSR URA: Signal in Space user ranging error

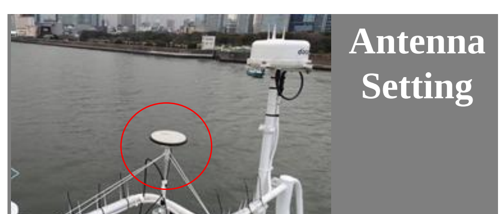
・Atmospheric correction quality indicator: user ranging error due to residual ionosphere and troposphere



Centimeter level Experiment -Maritime-

Evaluation test of CMAS-PPP using inter-signal phase bias correction, geo-referencing by Japan's CORS (GEONET) in Tokyo Bay as shown below.

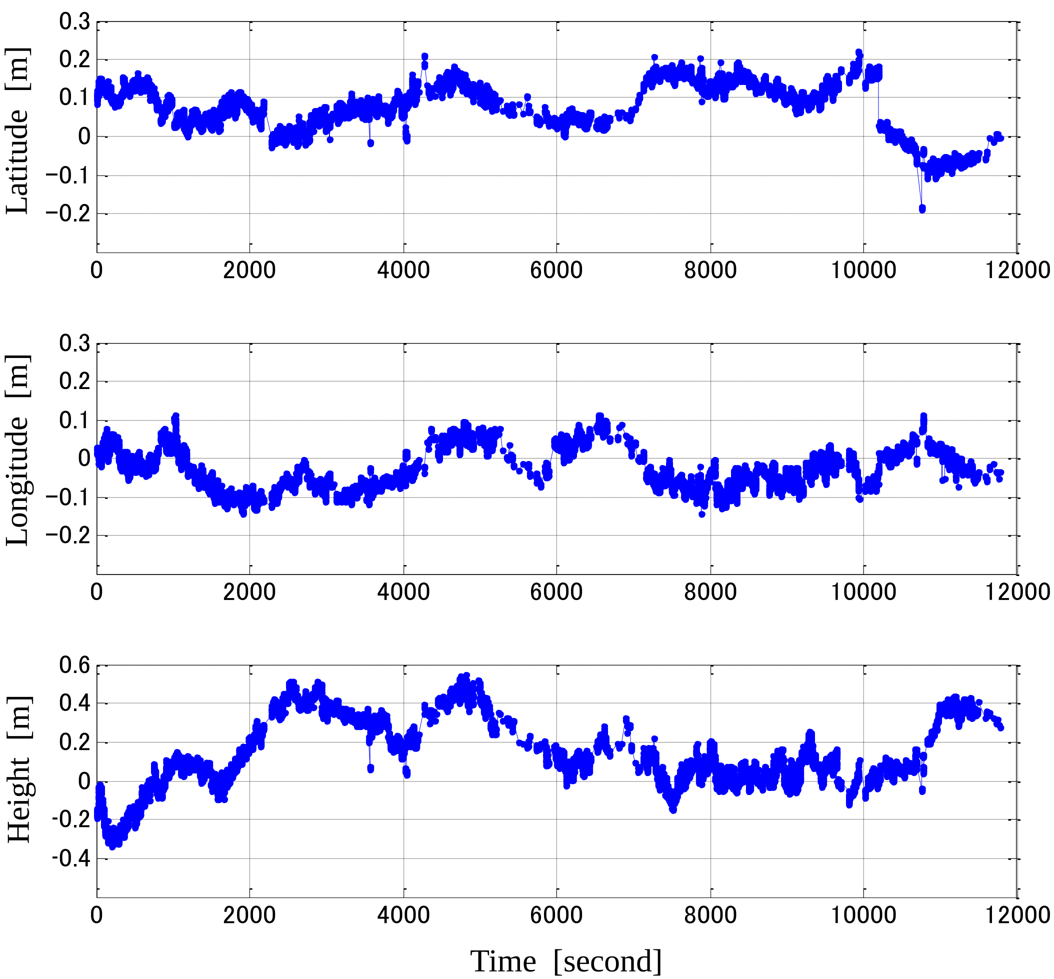


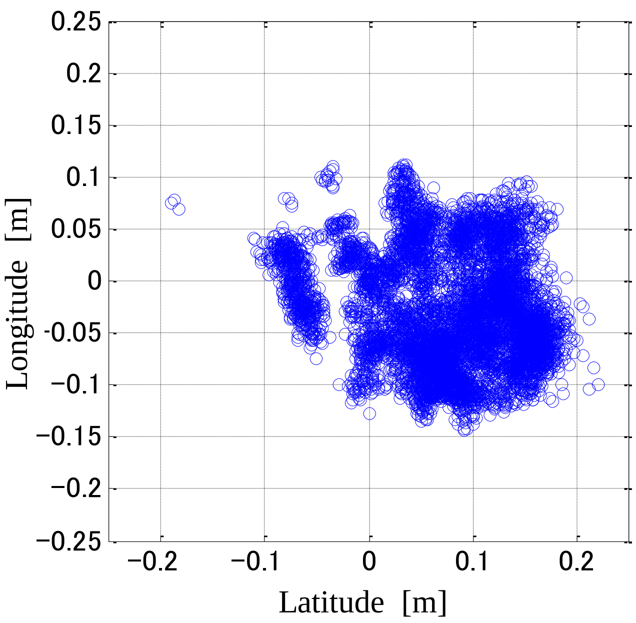


Condition : Post-processing	
Date	7th March
SSR Server	CMAS 2010
Augmented Signals	GPS L1, L2
Decode of LEX signal	TUMSAT SDR
Receiver PPP computation	RTKNAVI in RTKLIB
Reference	VRS using GEONET as reference stations
Testing	TUMSAT Mitsubishi Electric
Augmentation Delivery	SPAC

Centimeter level Experiment -Maritime-

It has wider coverage and tens of minute convergence time, and targets accuracy of 10 cm RMSE horizontal. Algorithm has been further improving.





	Lat. [cm]	Long. [cm]	Height [cm]	Horiz. [cm]	3D [cm]
Std.Div.	6.5	5.3	18.1	4.4	11.9
Bias	7.7	2.8	13.5	10.8	22.5
RMSE	10.1	6.0	22.6	11.7	25.5

※ Evaluation based on ISO Quality Principle

Summary

- Multi-GNSS RTK tests were introduced.
- Multi-GNSS contributes greatly to RTK performance.
- Higher elevation satellites are necessary for RTK in urban areas.
- Centimeter level augmentation service using QZSS was introduced.
- Ship experiment showed the service provided good performance within 10cm at present.
- It will be important for user to choose the positioning method (PPP, RTK, DGNSS, Single) according to the requirement.

Any comments and questions ?

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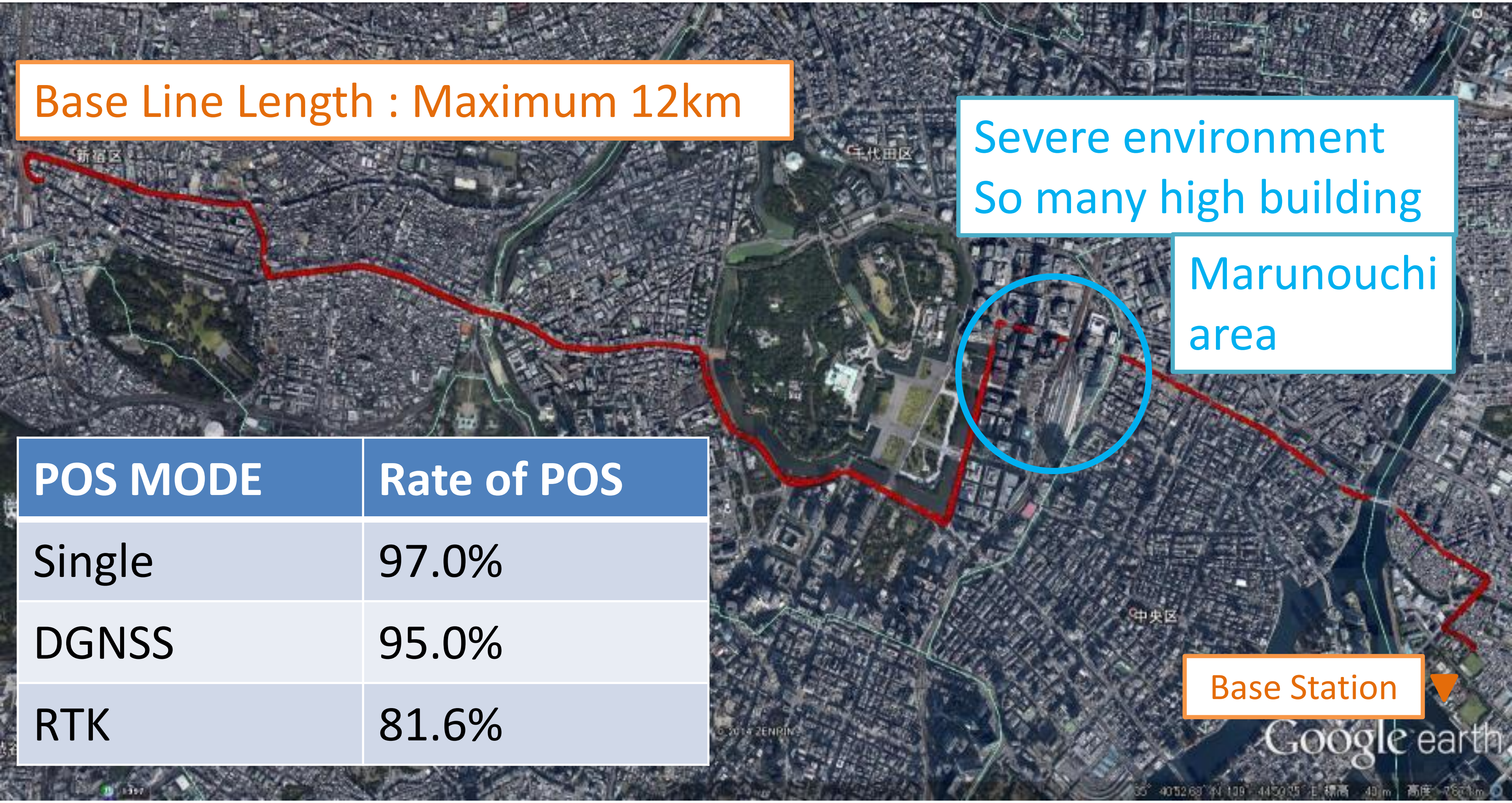
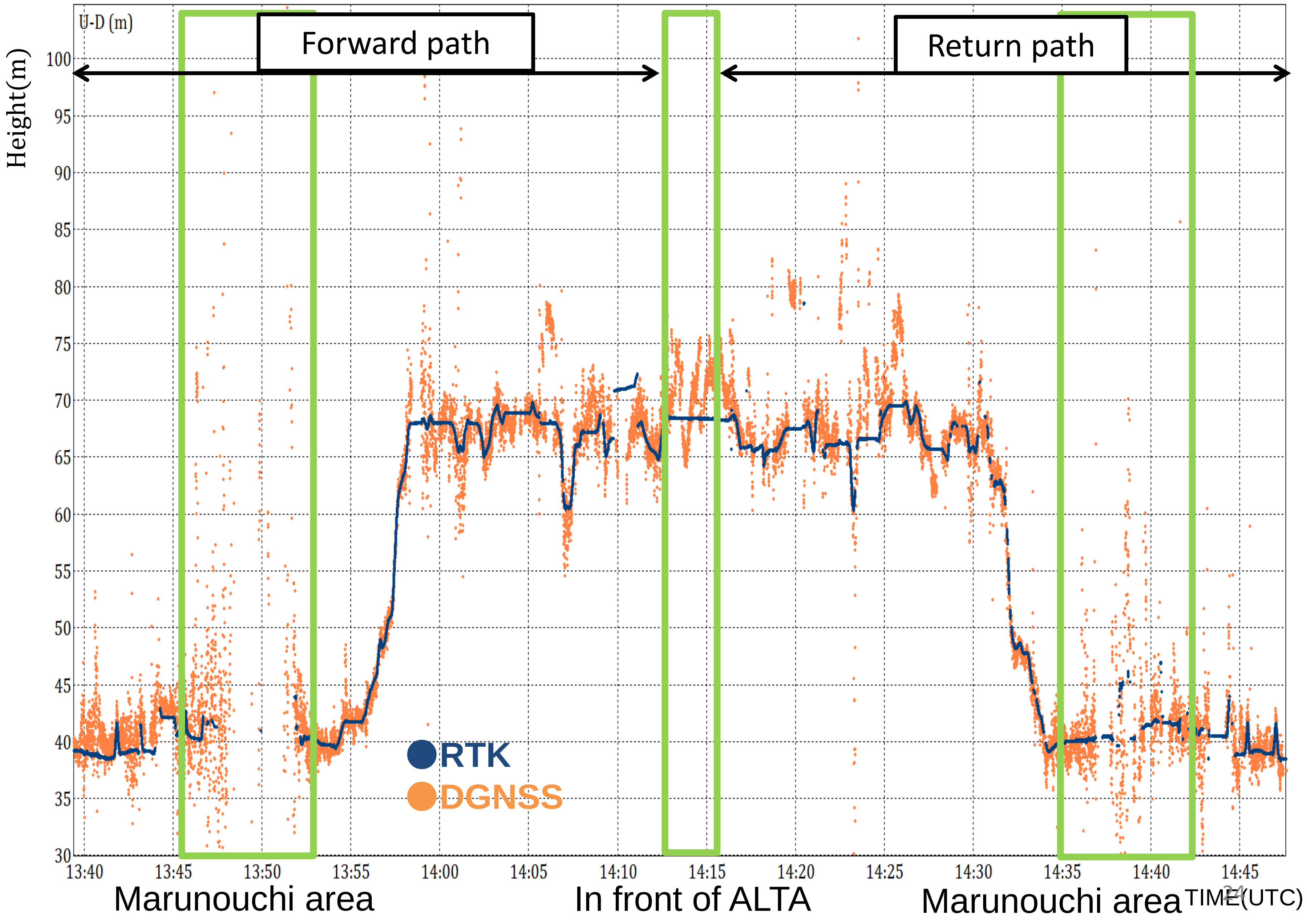


POS MODE	Rate of POS
Single	97.0%
DGNSS	95.0%
RTK	81.6%

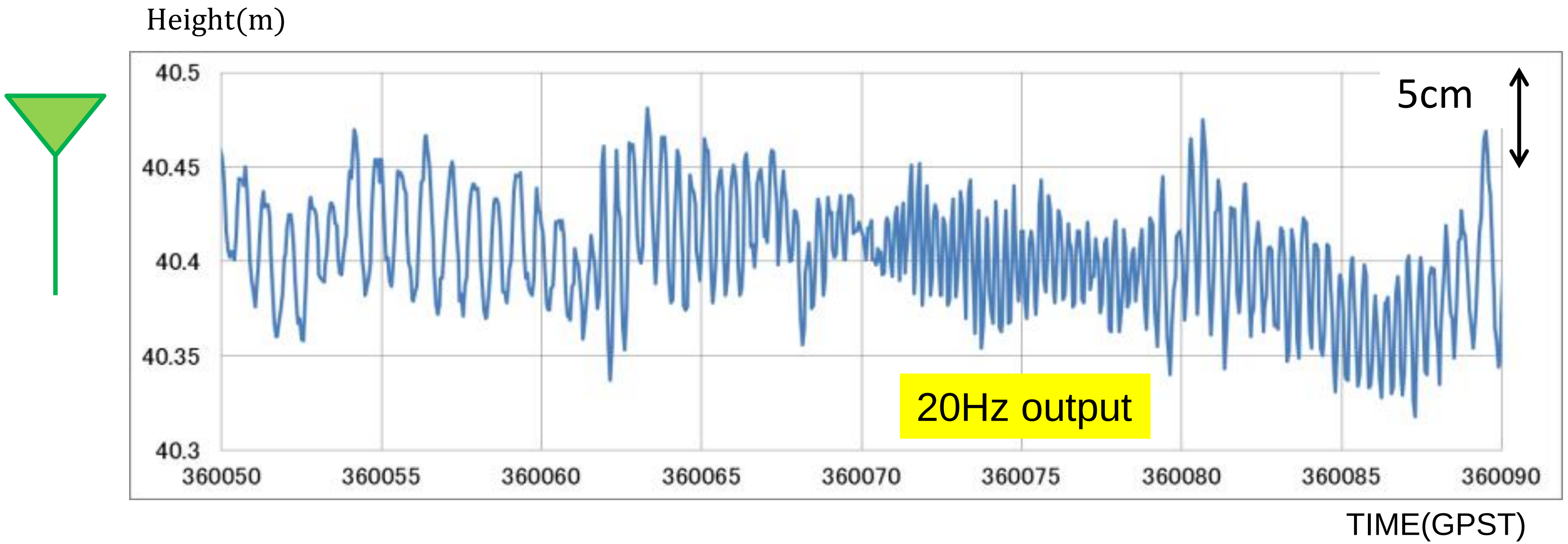
Shinjuku Route 20 TUMSAT

U-D Results



Height(m)
U-D (m)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
Forward path
Return path
RTK
DGNSS
13:40
13:45
13:50
13:55
14:00
14:05
14:10
14:15
14:20
14:25
14:30
14:35
14:40
14:45
Marunouchi area
In front of ALTA
Marunouchi area
TIME(UTC)

Another Experiment



- Applications
  - Checking the status of the road pavement
  - Verification of land subsidence