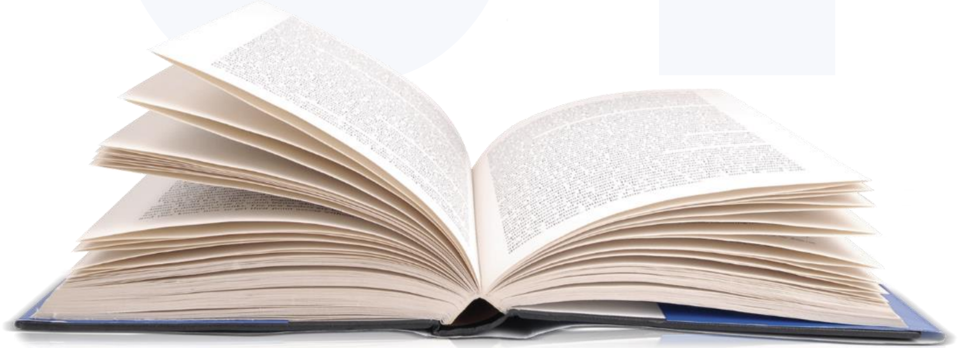
MADOCA PPP Introduction

Yize Zhang
zhyize@163.com
Tokyo University of Marine Science and Technology

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

01

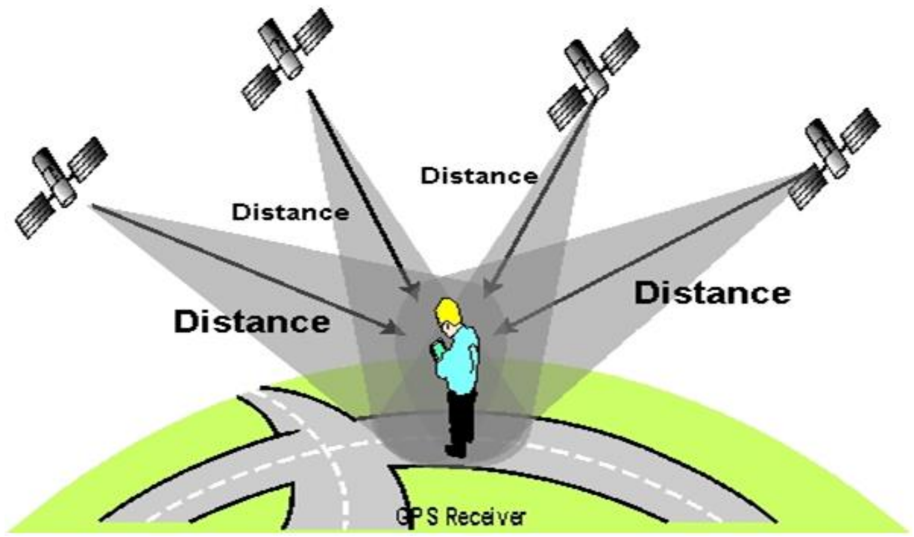
GNSS and QZSS



What is GNSS?

- GNSS is a constellation of satellites providing signals from space that transmit positioning and timing data to GNSS receivers.

- GNSS can provide positioning, navigation, and timing (PNT) service for users on the ground and space..



https://www.spirent.com/blogs/positioning/2017/january/what-does-2017-hold-for-gnss

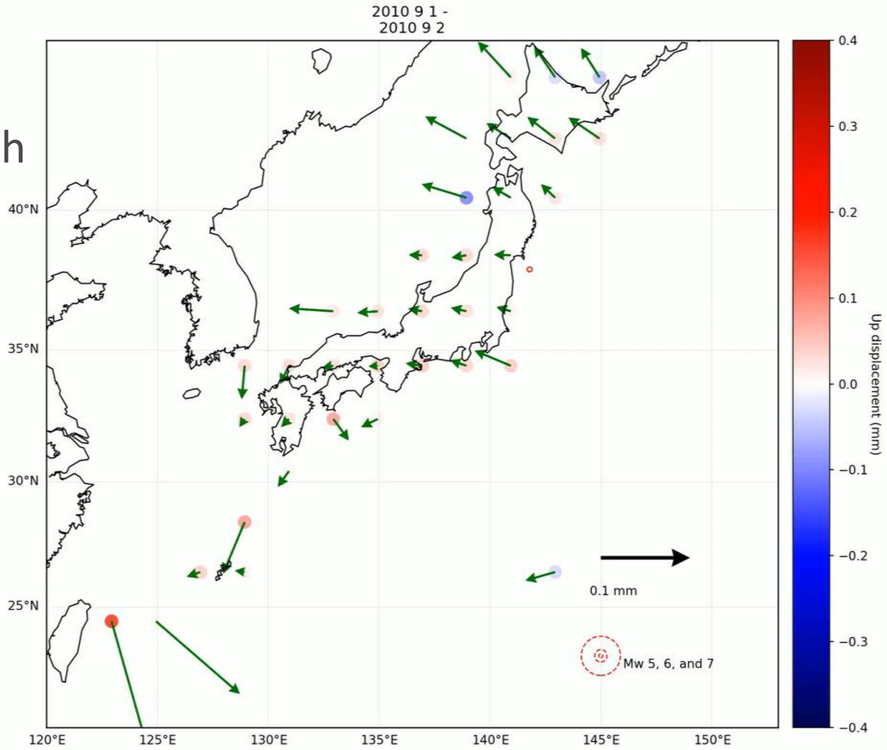
GNSS in earthquake monitoring

GNSS can also aplied in many other areas such as earthquake monitoring, atmosphere monitoring, message communication.

Months-long thousand-kilometre-scale wobbling before great subduction earthquakes

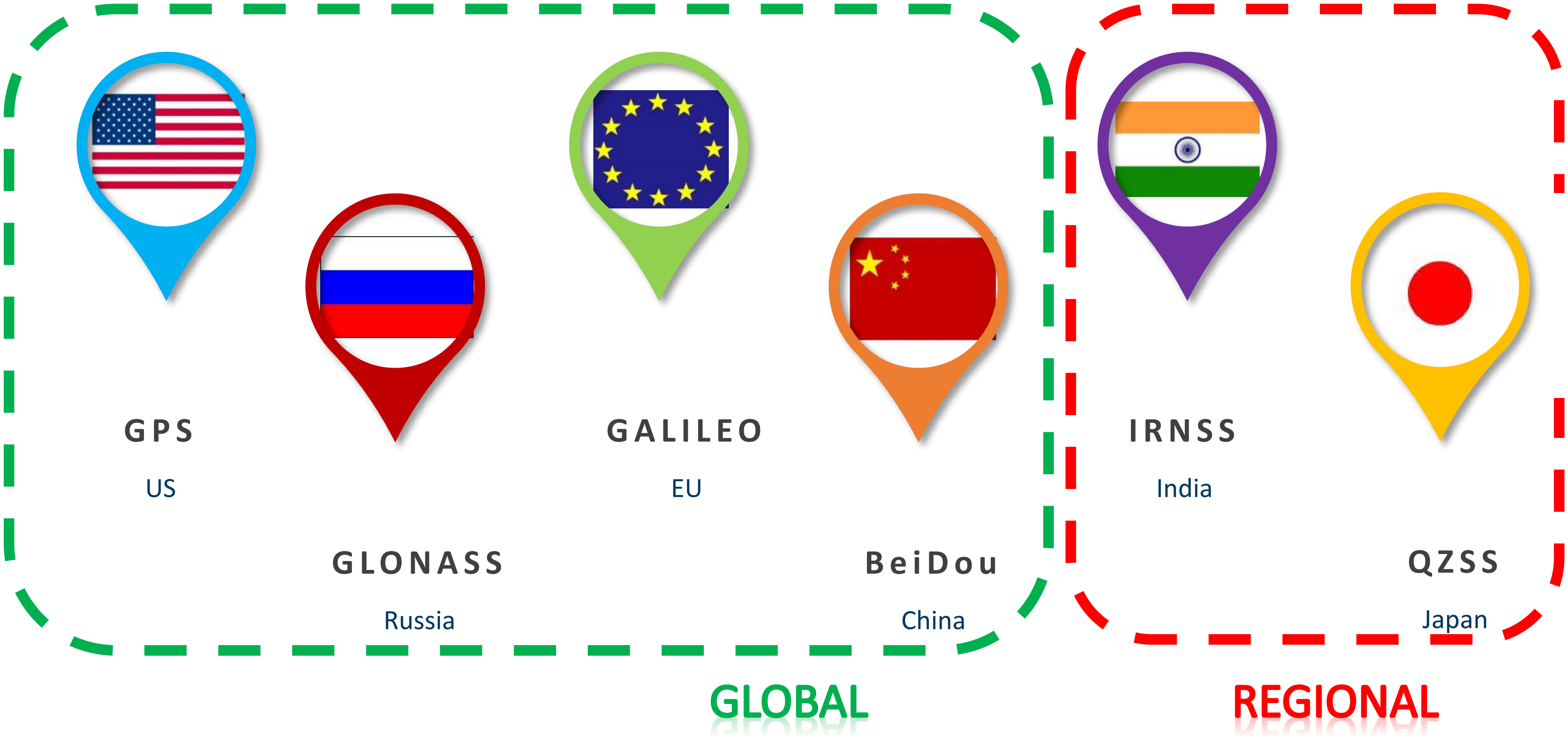
Jonathan R. Bedford, Marcos Moreno, Zhiguo Deng, Onno Oncken, Bernd Schurr, Timm John, Juan Carlos Báez & Michael Bevis

Nature **580**, 628–635(2020) | Cite this article

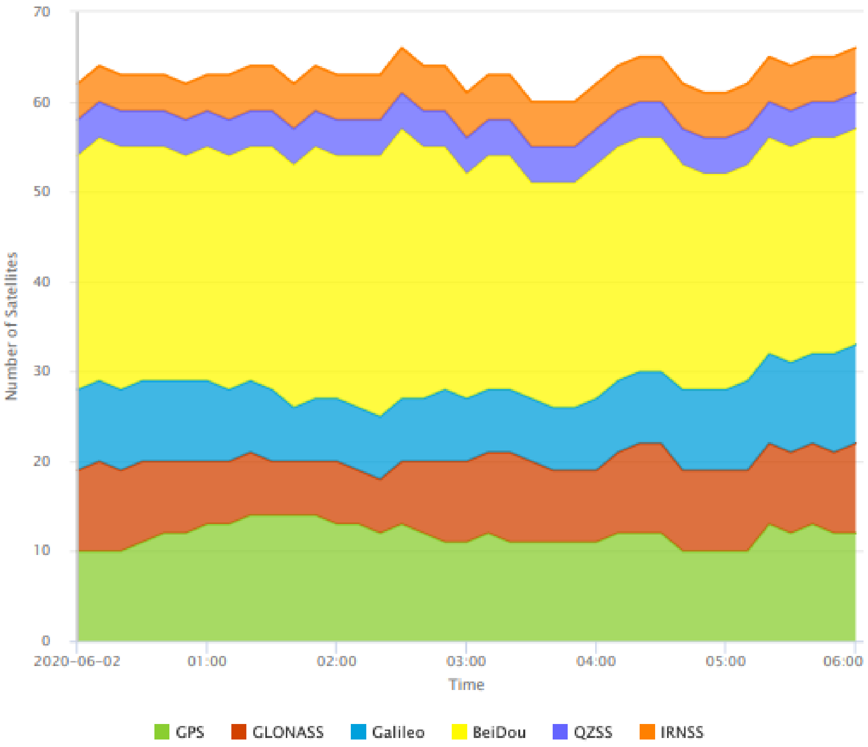


https://www.nature.com/articles/s41586-020-2212-1

GNSS systems

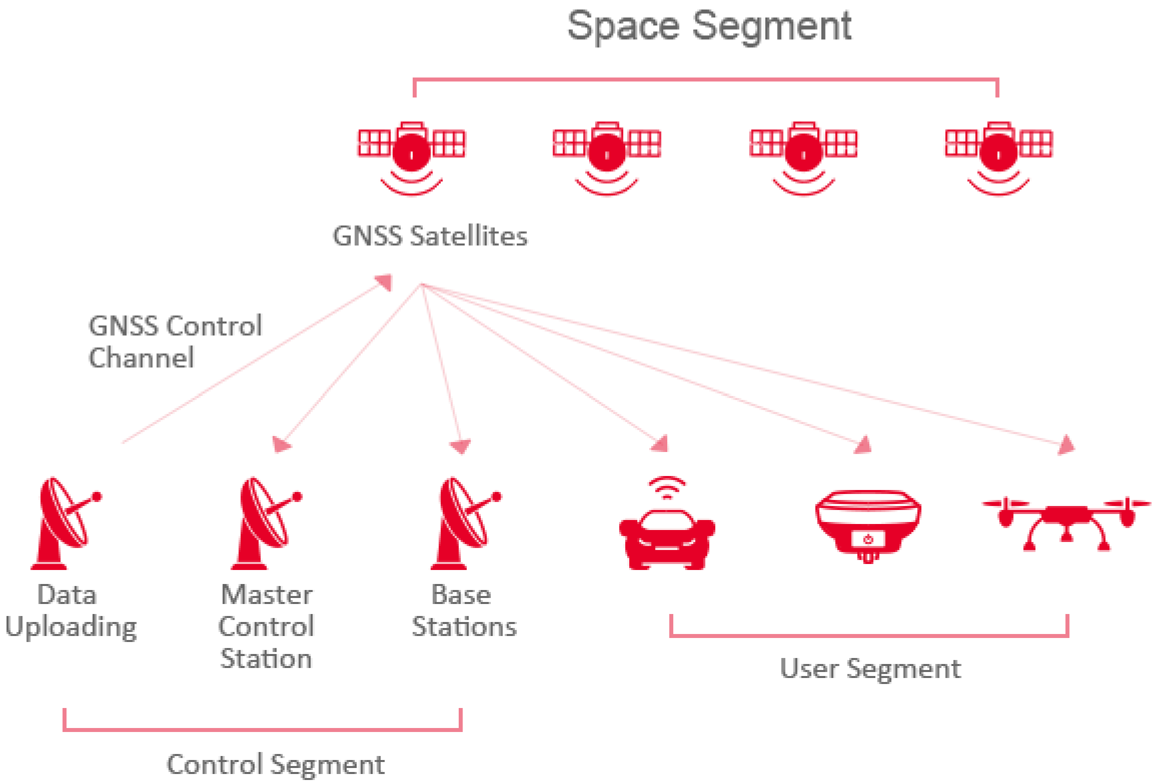


GNSS visibility at Tokyo



https://www.gnssplanning.com

GNSS segments



https://www.tersus-gnss.com/technology

QZSS

QZSS is a Japanese satellite positioning system composed mainly of satellites in quasi-zenith orbits (QZO).

QZSS has been operated as a four-satellite constellation from November 2018, and at least three satellites are visible at all times from locations in the Asia-Oceania region. QZSS can be used in an integrated way with other GNSS systems.

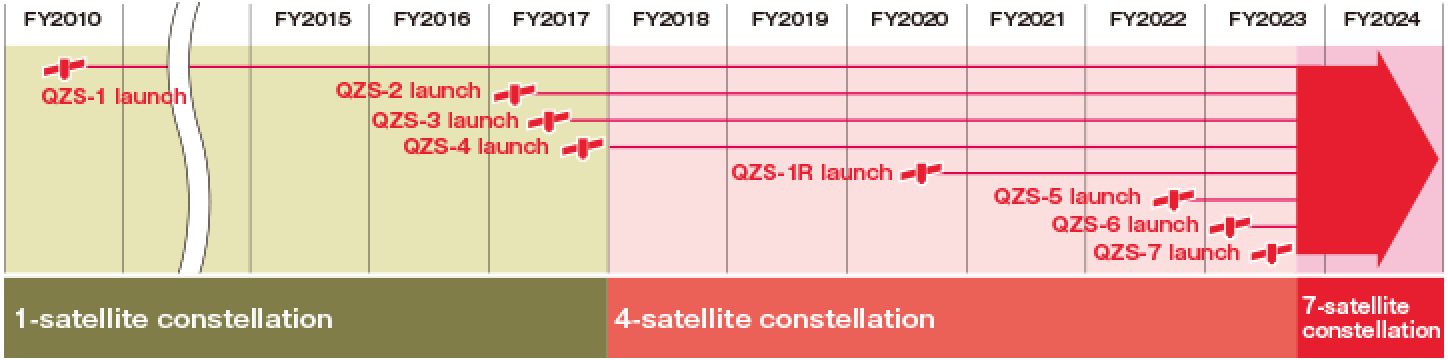
http://qzss.go.jp/en/

QZSS visibility at Tokyo

https://app.qzss.go.jp/GNSSView/gnssview.html

QZSS development

Satellite	PRN	BLOCK	Type	Longitude	Launch
QZS-1	J01	IQ	IGSO	130~140°E	2010.09.11
QZS-2	J02	IIQ	IGSO	130~140°E	2017.06.01
QZS-3	J07	IIG	GEO	126.9~127.1°E	2017.08.19
QZS-4	J03	IIQ	IGSO	130~140°E	2017.10.09



http://qzss.go.jp/en/

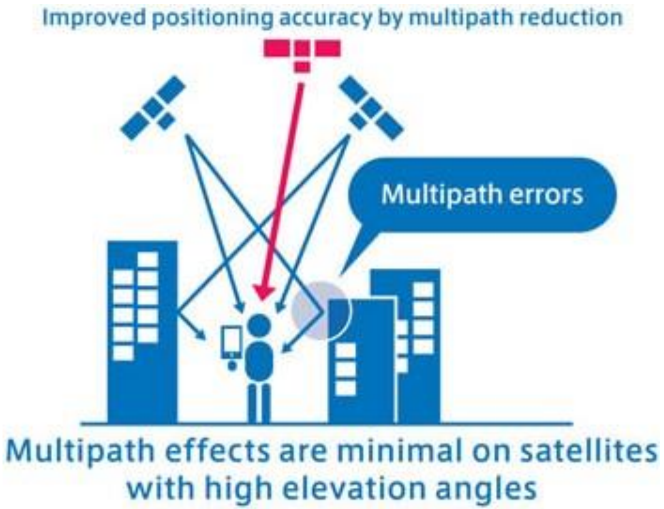
QZSS signals and services

Frequency	Signal	Service
1575.42MHz	L1C/A	PNT
	L1C	PNT
	L1S	Sub-meter Level Augmentation Service(SLAS) Satellite Report for Disaster and Crisis Management (DC Report)
	L1Sb	SBAS
1227.60MHz	L2C	PNT
1176.45MHz	L5	PNT
	L5S	Positioning Technology Verification Service
1278.75MHz	L6D	Centimeter Level Augmentation Service (CLAS)
	L6E	Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis (MADOCA)

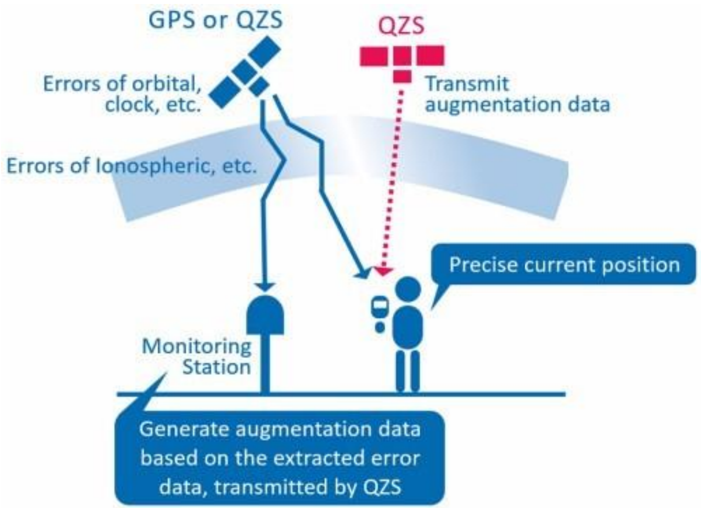
http://qzss.go.jp/en/

Benefit of QZSS

(1) Increase visible satellite number; high elevation at most East-Asia countries, with small multipath errors in urban environment.

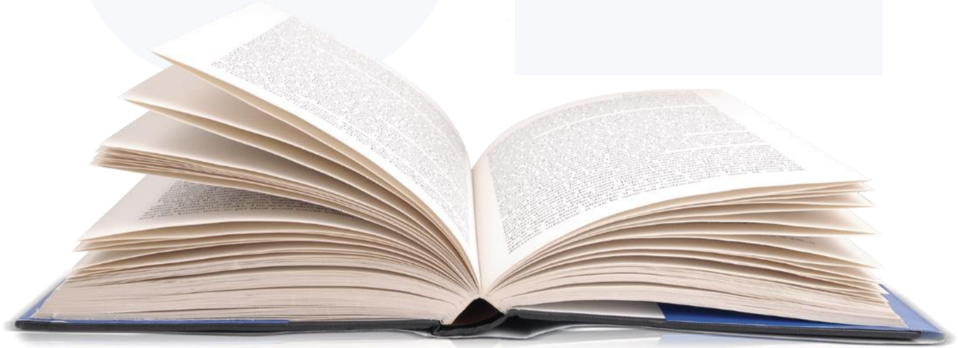


(2) QZSS transmit different types of augmentation data (SLAS, CLAS, MADOCA), enable different level of positioning service.



02

GNSS Positioning Techniques

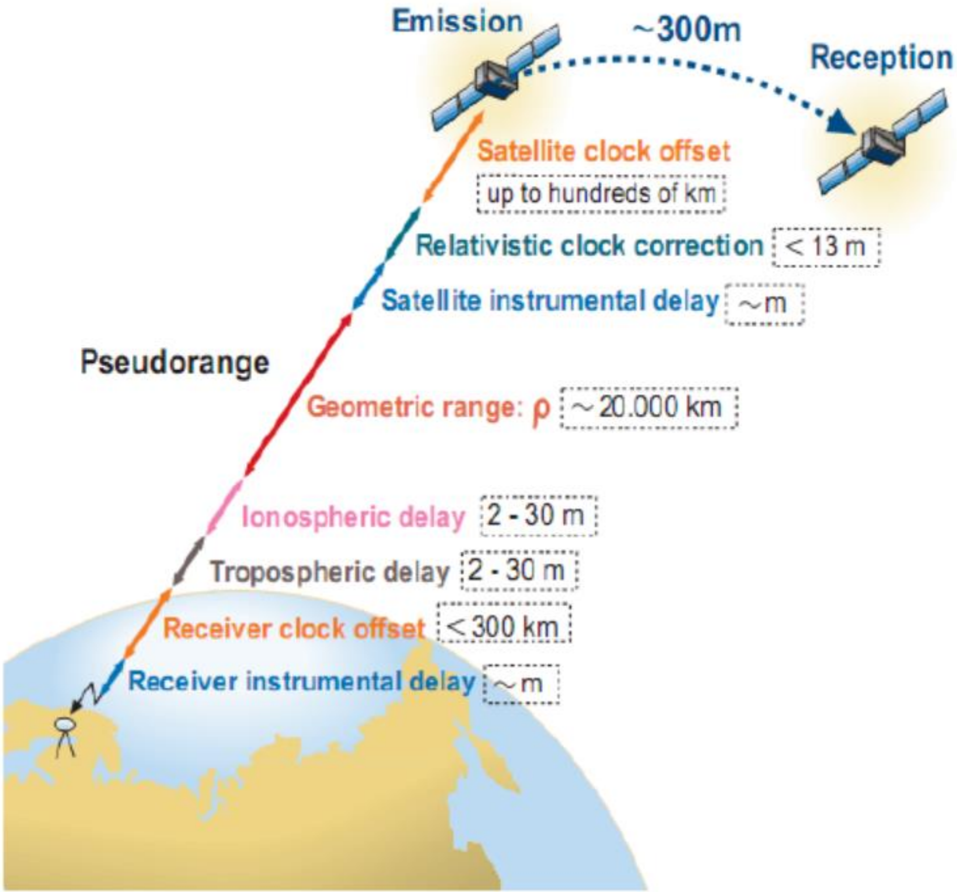


GNSS Positioning Techniques

Point Positioning
- SPP (Single Point Positioning)
- PPP (Precise Point Positioning)

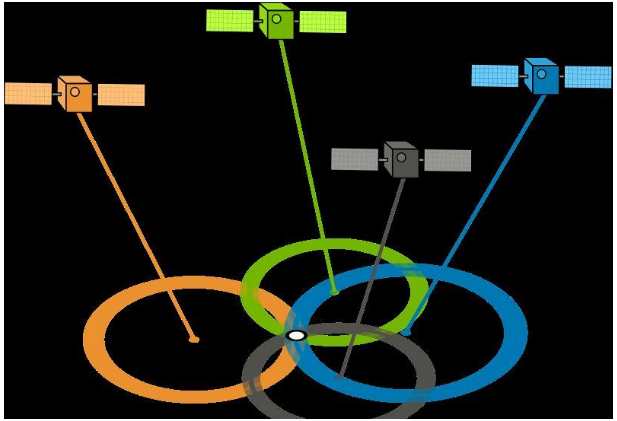
Relative Positioning
- DGNSS (Differential GNSS)
- RTK (Real Time Kinematic)

GNSS Observation and Errors



SPP

- **SPP**: With code observation(pseudo-range) from at least 4 satellites, we can know the receiver positioning from by Least Square or Kalman Filter.



$$P_f^j = \rho^j + c\cdot\delta t_f - c\cdot\delta t_f^j - \Delta_{rela}^j + T^j - \frac{I^j}{f^2} + \varepsilon_{P_f}$$

- P_f^j: Pseudo-range observation
- ρ^j: Geometric distance from satellite to receiver(X, Y, Z)
- $c\cdot\delta t_f$: Receiver clock
- $c\cdot\delta t_f^j$: Satellite clock
- Δ_{rela}^j: Relativity correction
- T^j: Troposphere delay
- $\frac{I^j}{f^2}$: Ionosphere delay
- ε_{P_f}: Noise and other modeled corrections

From SPP to PPP

	SPP	PPP
Observables	Code(30cm)	Code (30cm)+Carrier phase (3mm)
Satellite ephemeris	Broadcast ephemeris (0.5~2m)	Precise ephemeris (1cm~10cm)
Error correction	Ionosphere, troposphere, relativity	Ionosphere, troposphere, relativity, instrument delay (DCB), phase windup, tidal correction
Positioning accuracy	1~10m(Kinematic)	1~2cm(Static), 5~20cm(Kinematic)

Why we can get high accuracy from PPP?

✓1 Carrier phase observation is used

✓2 Precise ephemeris (orbit and clock) is used

✓3 All errors are considered

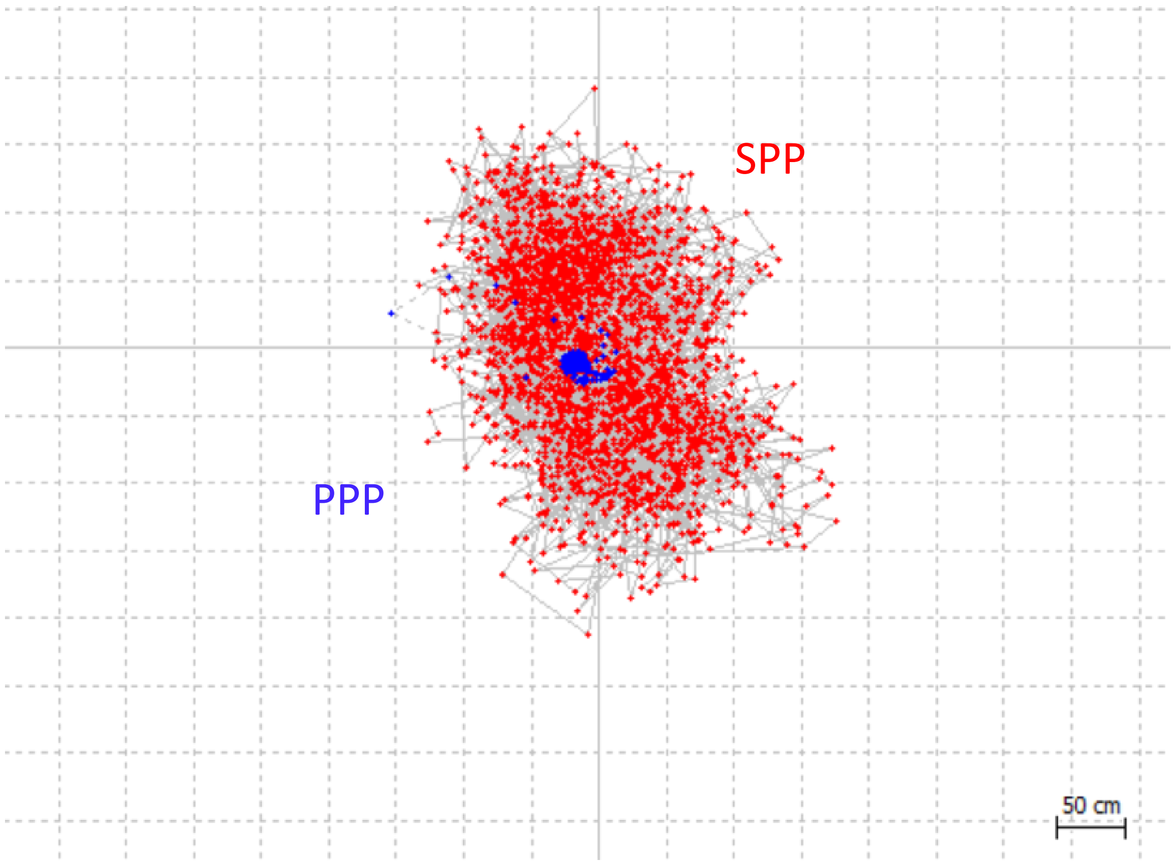
✓4 All inaccurate errors are estimated

Accuracy of different ephemeris

Type		Accuracy	Latency	Updates	Sample Interval
Broadcast	orbits	~100 cm	real time	--	daily
	Sat. clocks	~5 ns RMS ~2.5 ns SDev			
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~3 ns RMS ~1.5 ns SDev			
Ultra-Rapid (observed half)	orbits	~3 cm	3 - 9 hours	at 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~150 ps RMS ~50 ps SDev			
Rapid	orbits	~2.5 cm	17 - 41 hours	at 17 UTC daily	15 min
	Sat. & Stn. clocks	~75 ps RMS ~25 ps SDev			5 min
Final	orbits	~2.5 cm	12 - 18 days	every Thursday	15 min
	Sat. & Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.: 5 min

http://www.igs.org/products

SPP vs. PPP

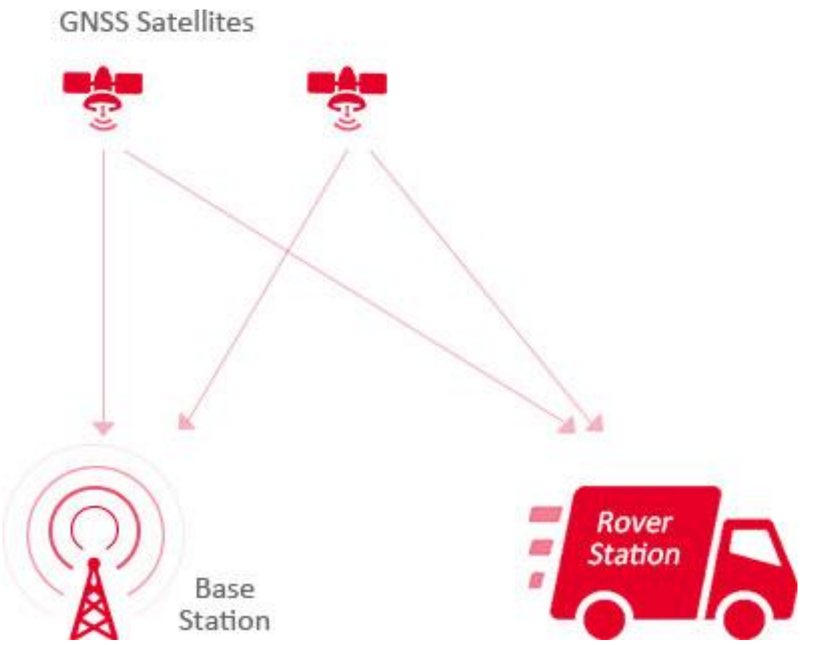


DGNSS

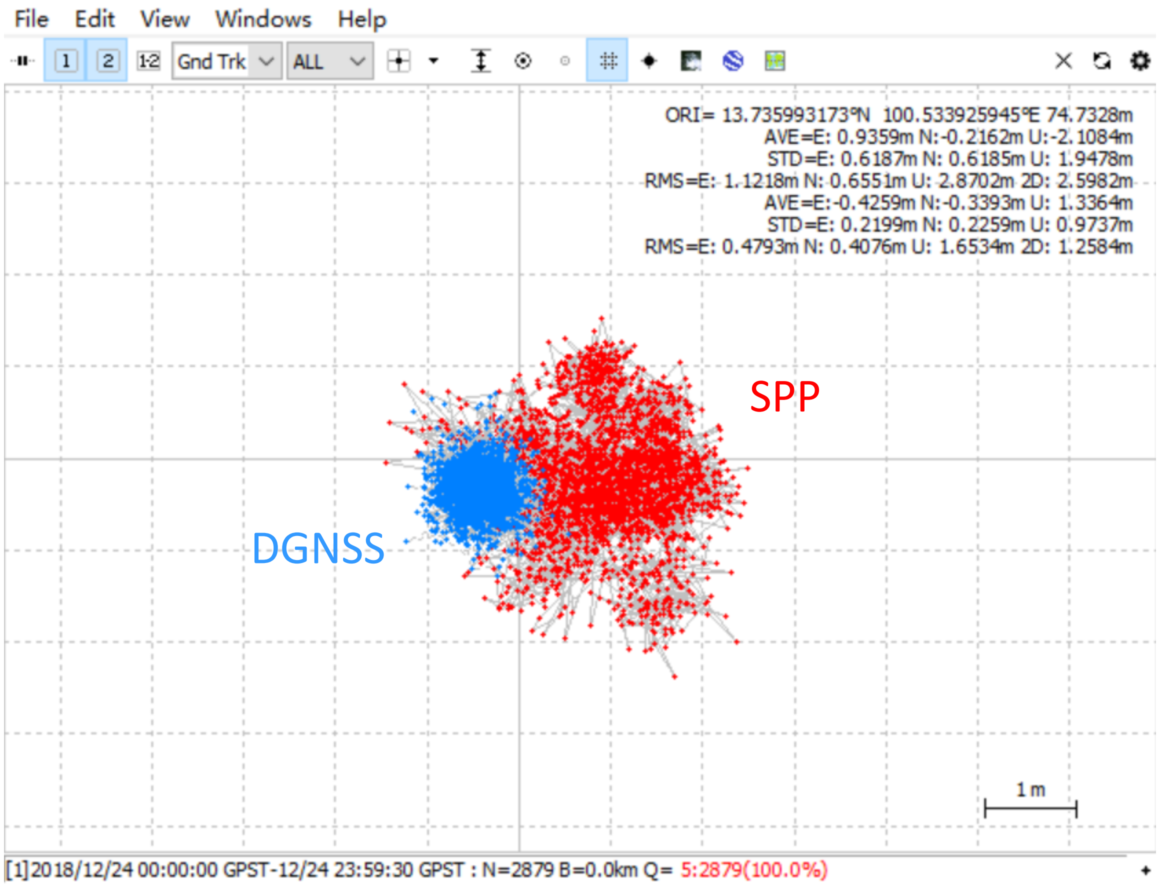
For two stations within a few kilometers, the errors from satellite and atmosphere, is at the similar level.

By setting up a base station, we can use the “station differencing” strategy to remove the common errors.

Similar as SPP, DGNSS is based on code observation.



SPP vs. DGNSS

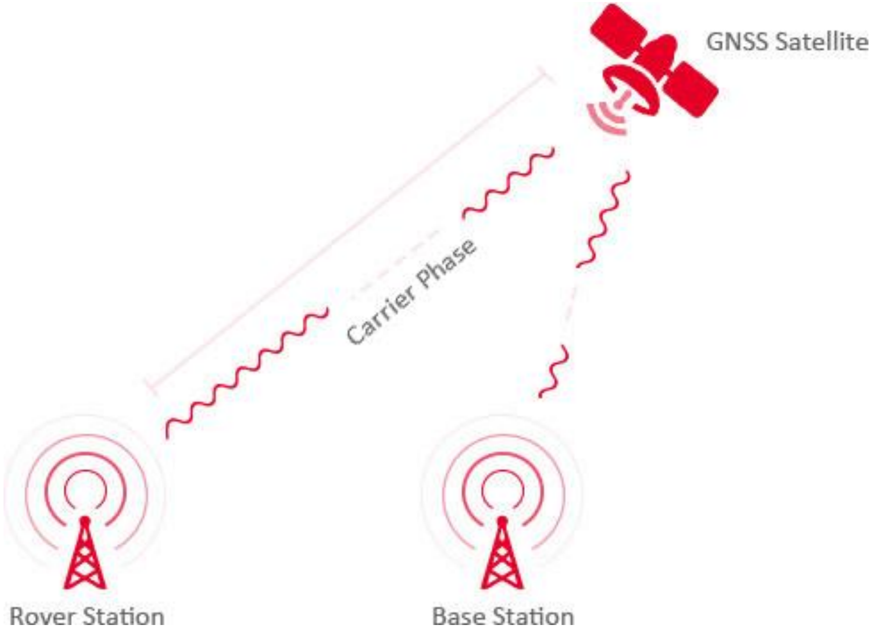


STD improve from [0.62, 0.62,1.95]m to [0.22, 0.23, 0.97]m

RTK

Similar as DGNSS, RTK also needs a base station to eliminate most errors.
What is more, carrier phase observation is also used.

Compared with PPP, RTK can fix the ambiguity within short time(e.g. several seconds), thus provides 1~3cm positioning solution accuracy instantaneously.



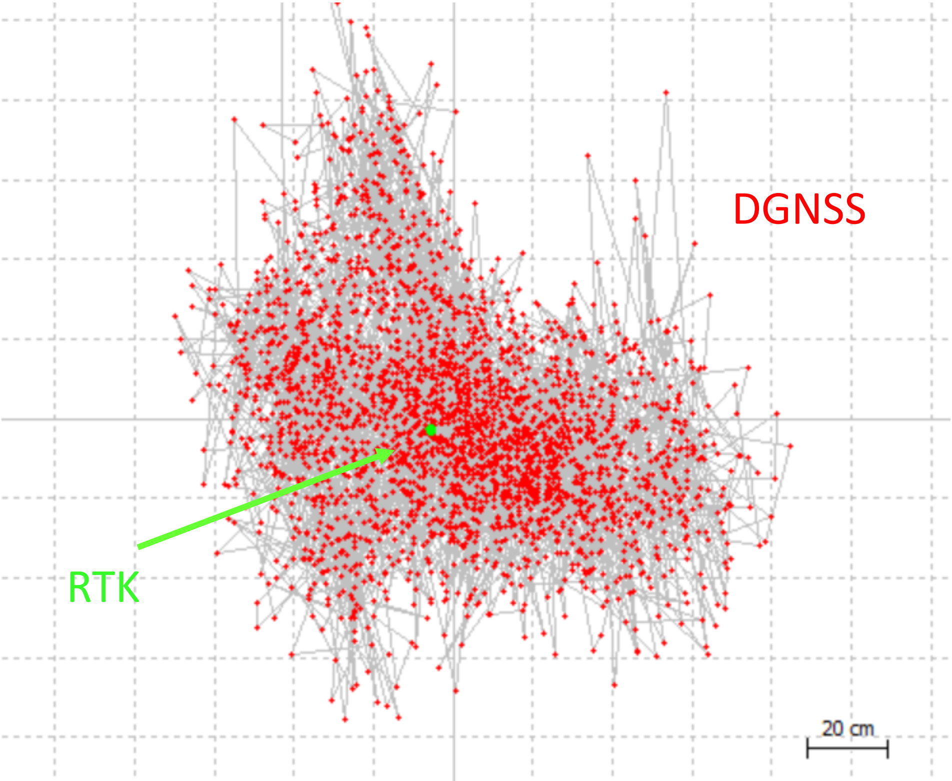
Why we can get high accuracy from RTK?

✓1 Carrier phase observation is used

✓2 Errors from satellite and atmosphere are eliminated

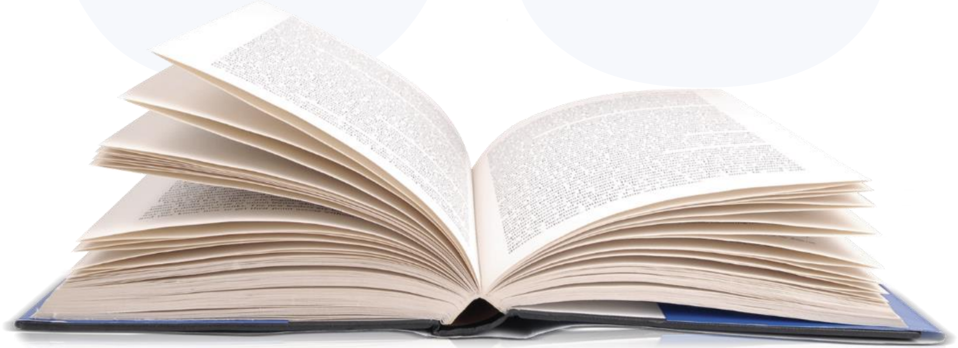
✓3 Ambiguity can be fixed

DGNSS vs. RTK



03

MADOCA PPP



Real-time PPP

- For post-processing PPP, we can use IGS or JAXA precise orbit and clock file;
- For real-time PPP, we can use State Space Representation (SSR) correction with broadcast ephemeris.

- In real-time PPP, the residual part satellite orbit and clock error in broadcast ephemeris is corrected by SSR message (BRDC+SSR), making the accuracy of orbit and clock within 10 cm.
- For other error correction and parameter estimation, it is same as the post-processed PPP.

SSR and OSR (Observation Space Representation)

- OSR describes lump sum of GNSS errors. Example: network RTK(VRS, MAC, FKP);
- SSR describes each individual GNS error. Example: PPP.

- Benefit of SSR:

✓SSR requires low bandwidth for large areas;

✓Unlimited number of users and costs;

✓Different service with different accuracy;

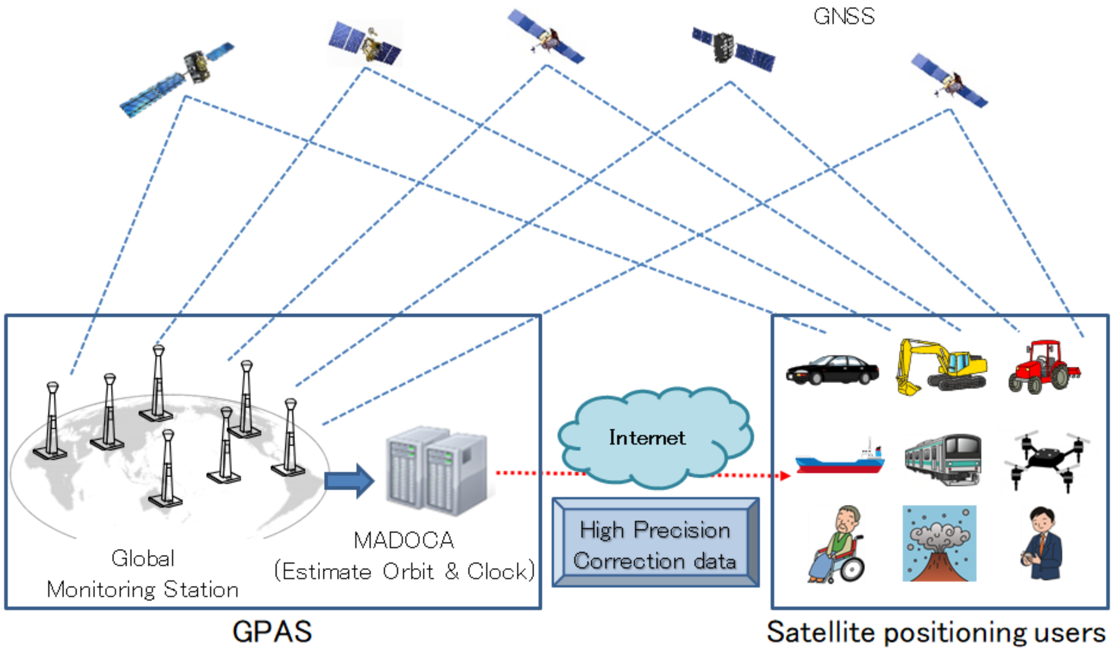
✓Single/dual/triple frequency application;

✓Independent of GNSS(troposphere and ionosphere).

SSR message

Message Type	Message Name
1057	SSR **GPS Orbit** Correction
1058	SSR **GPS Clock** Correction
1059	SSR **GPS Code Bias**
1060	SSR GPS Combined Orbit and Clock Corrections
1061	SSR GPS URA
1062	SSR GPS High Rate Clock Correction
1063	SSR **GLONASS Orbit** Correction
1064	SSR **GLONASS Clock** Correction
1065	SSR **GLONASS Code Bias**
1066	SSR GLONASS Combined Orbit and Clock Correction
1067	SSR GLONASS URA
1068	SSR GLONASS High Rate Clock Correction

What is MADOCA?



- ✓MADOCA(Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis) is developed by JAXA/GPAS.
- ✓MADOCA provides GPS/GLONASS/QZSS orbit and clock SSR corrections through QZSS or internet in real-time.

https://www.gpas.co.jp/en/service_madoca.php

MADOCA products

RTCM SSR format

Product	Interval		RTCM Message		
	Estimation	Provide	GPS	GLONASS	QZSS
Orbit correction	30	1	1057	1063	1246
Clock correction	1	1	1058	1064	1247
HR-Clock correction	1	1	1062	1068	1251
URA	1	1	1061	1067	1250

MADOCA products accuracy

✓Goal of orbit/clock accuracy:

Product	Offline			Real-Time		
	GPS	GLO	QZS	GPS	GLO	QZS
OBT	3cm	7cm		6cm	9cm	
CLK	0.1ns	0.25ns		0.1ns	0.25ns	

✓Actual accuracy:

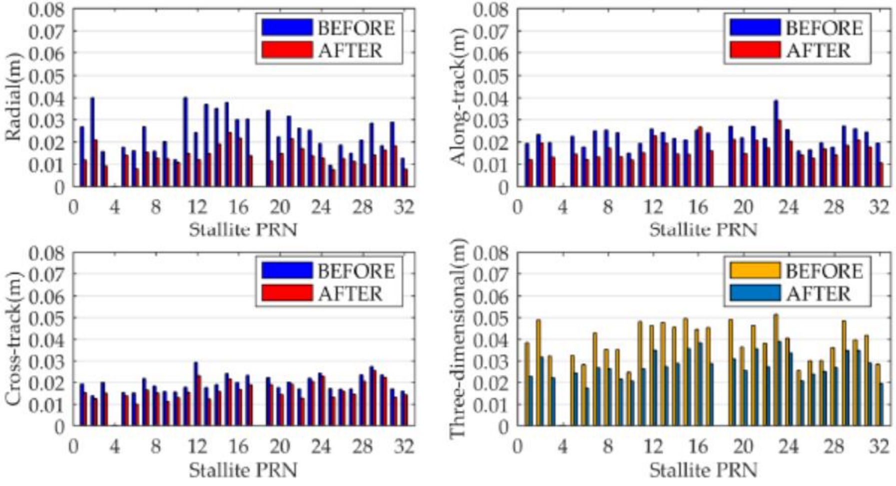


Figure 4. Seven-day average-RMS errors of all available GPS satellites in radial, along/cross-track, and three-dimensional (3D) directions.

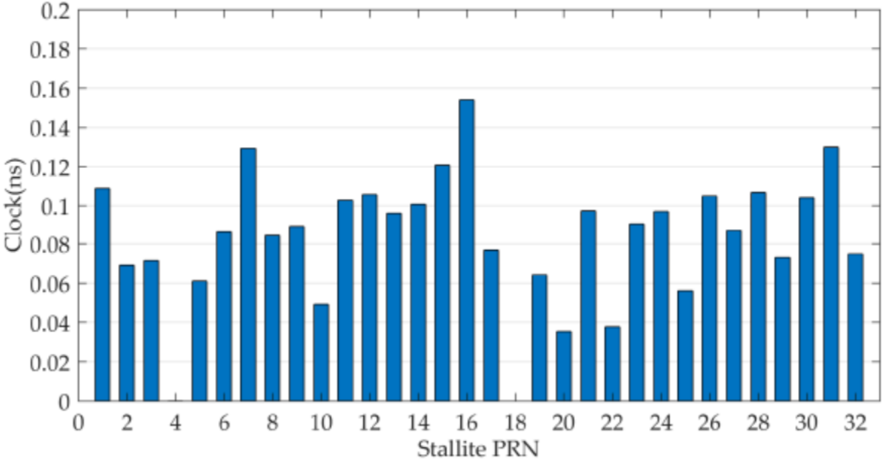


Figure 6. Seven-day average-STD clock errors of all available GPS satellites.

dx.doi.org/10.3390/s19112580

MADOCA products

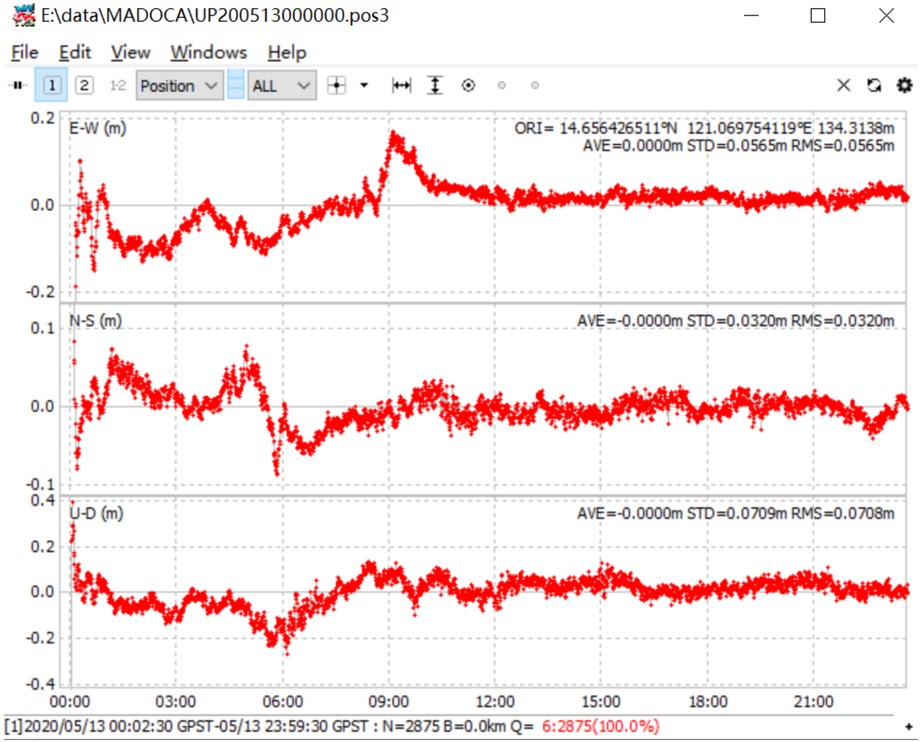
- ✓1 Real-time message from QZSS L6E signal (signal decoding, only areas where QZSS is visible)

- ✓2 Real-time message from Ntrip (User account required, global, internet required)

- ✓3 Offline RTCM3 SSR file from FTP (For post-processing)

Real-time MADOCA PPP from QZSS L6E signal

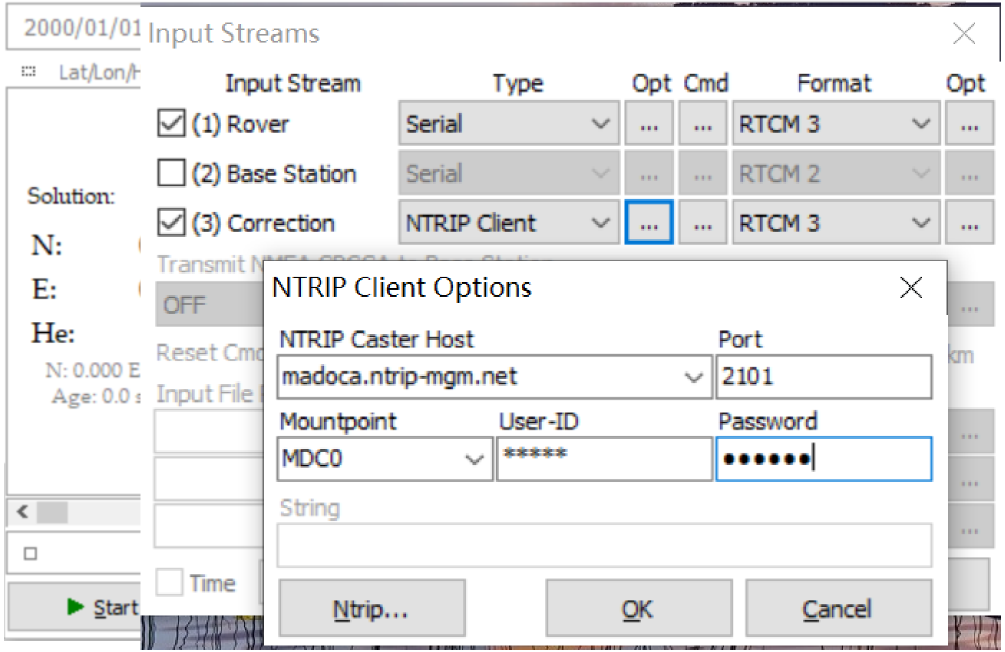
- The MSJ(Magellan System Japan) receiver can provide high precision positioning by using L6 signal from QZSS.



Real-time MADOCA PPP from Ntrip

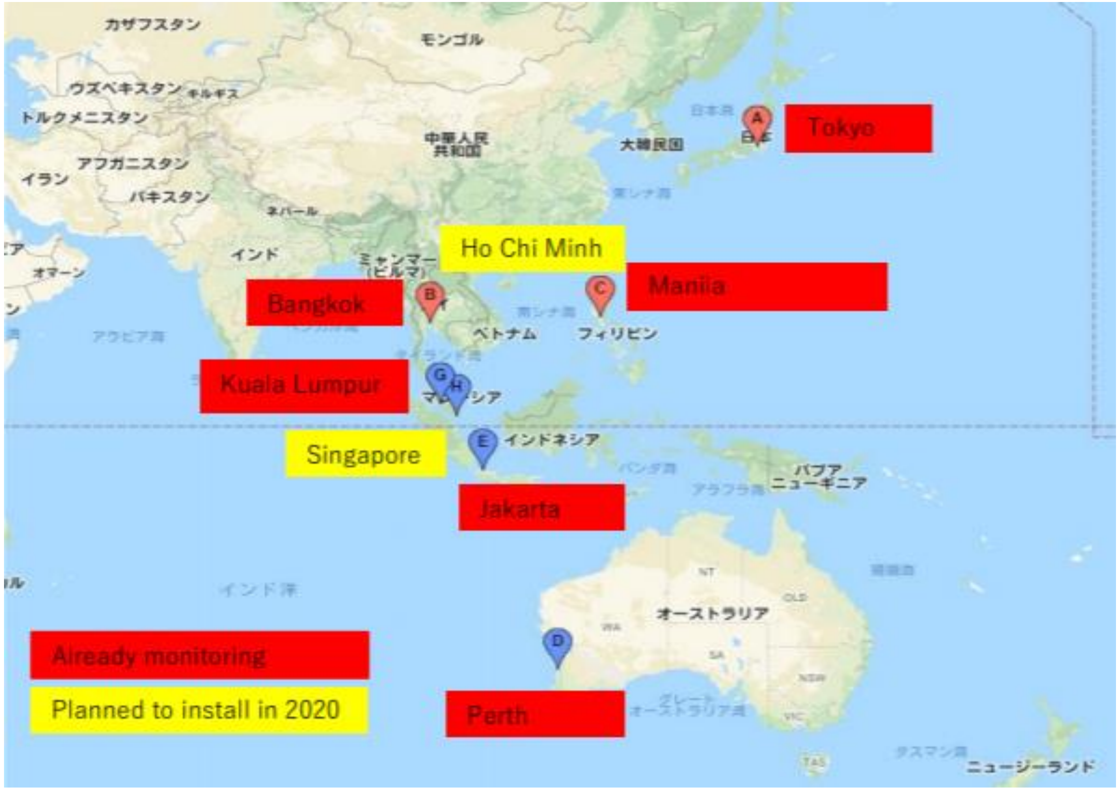
- RTKLIB
- GPASLIB
- MAD-PI; MAD-WIN; MADDRIOD （Webinar 3）

RTKNAVI ver.2.4.3 b31



Monitoring of MADOCA performance

- We are monitoring the performance of MADOCA PPP in some Asian and Oceanian countries.



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Thank you!