Introduction to MADOCA

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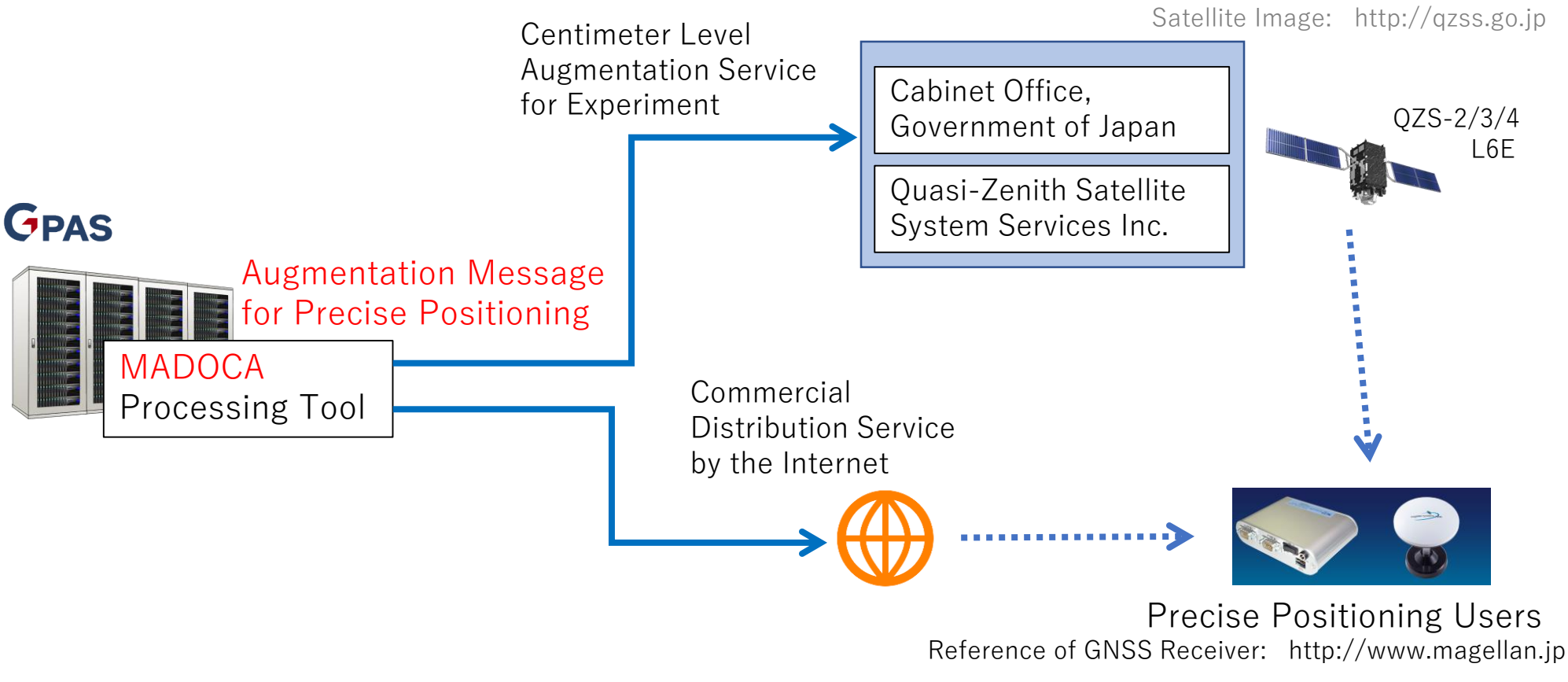
1. What is MADOCA ?

MADOCA : A processing tool developed by JAXA to estimate precise satellite orbit and clock



- GPAS is providing a service to distribute augmentation messages processed by MADOCA
- The augmentation messages are distributed by QZSS and the Internet

Benefits of MADOCA

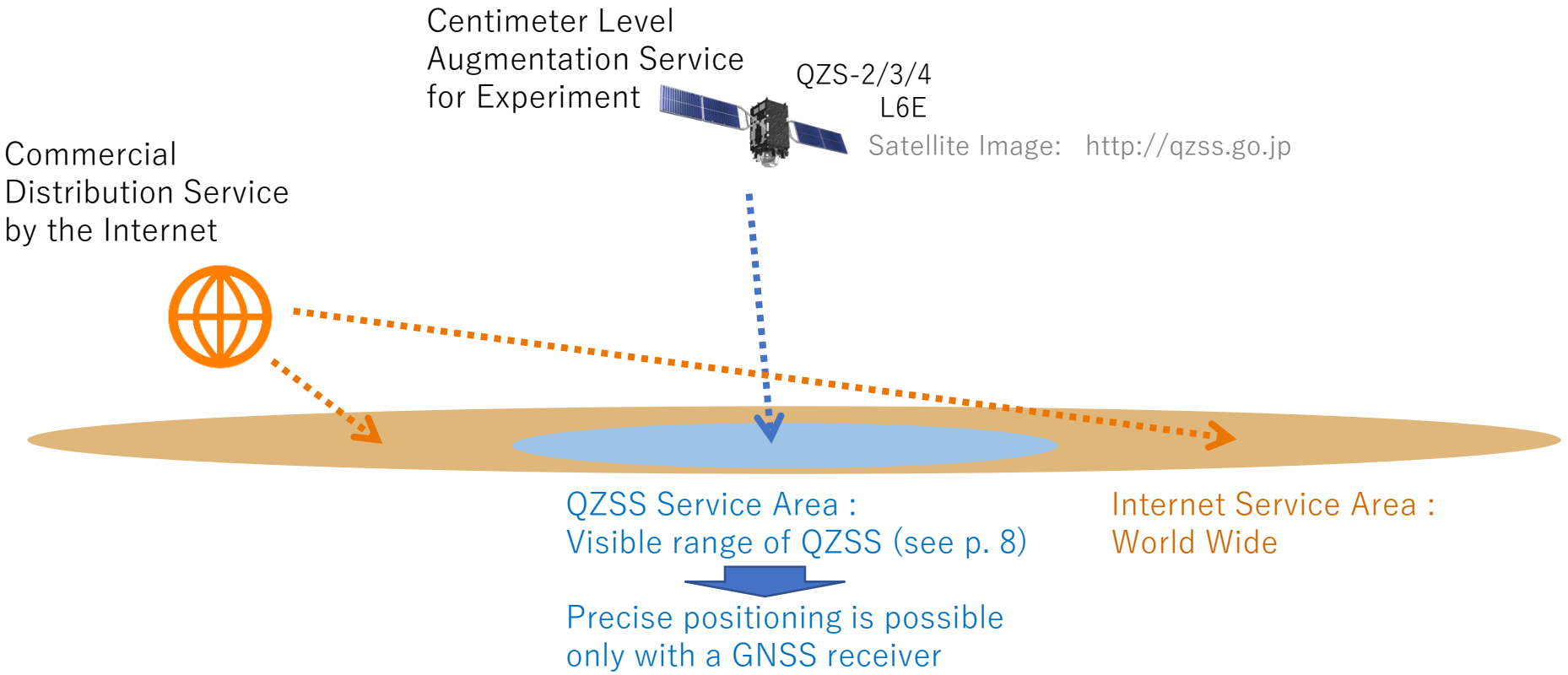
✓ No location restrictions to be used

i.e. RTK requires a continuous GNSS station (CORS) within 30 km

Note: CORS within 30 km is required to save the initial convergence time of MADOCA (see p.6).

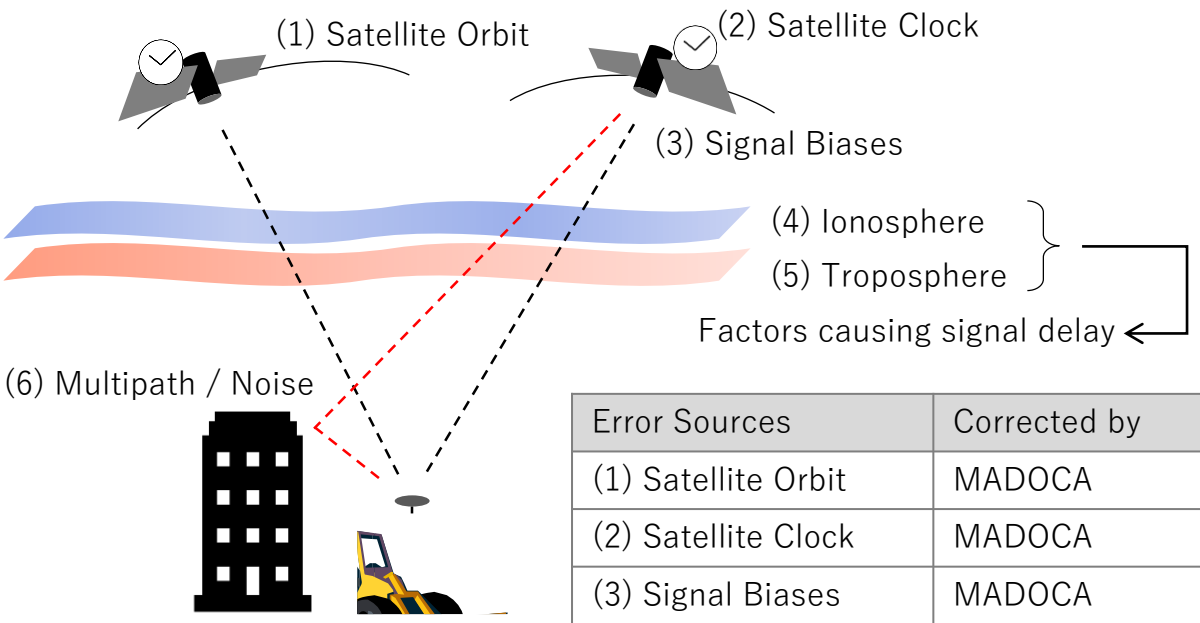
✓ No communication devices except GNSS receiver are required by receiving QZSS service

Note: To use GPAS's internet service or Local Augmentation (see p.6) , a device to access to the internet is required



Augmentation Principles

The accuracy of satellite positioning can be improved up to 10 centimeters by applying MADOCA augmentation composed of satellite-side corrections (State Space Representation) .



Error Sources	Corrected by
(1) Satellite Orbit	MADOCA
(2) Satellite Clock	MADOCA
(3) Signal Biases	MADOCA
(4) Ionosphere	Positioning Process
(5) Troposphere	Positioning Process
(6) Multipath / Noise	N/A

Fig. 1 Error Sources on Satellite Positioning

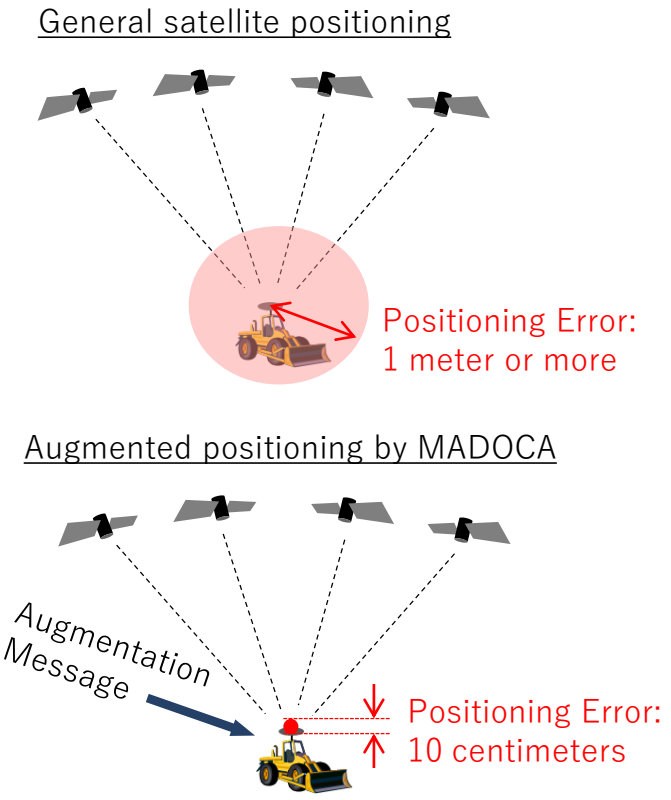
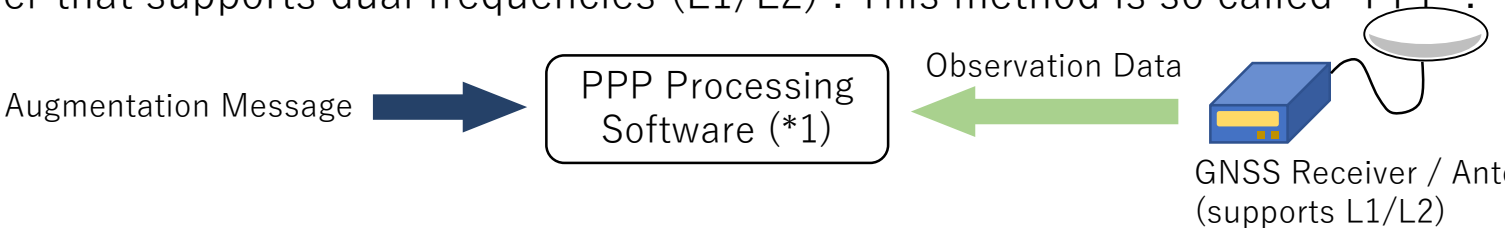


Fig. 2 Image of GNSS Augmentation by MADOCA

Notice: Positioning accuracy is affected not only by MADOCA performance, but also by receiver performance or by the performance of user's positioning algorithm.

[PPP: Precise Point Positioning]

Positioning with 10cm accuracy is available using MADOCA augmentation message and GNSS receiver that supports dual frequencies (L1/L2) . This method is so called "PPP".



(*1) GNSS Receivers with built-in PPP processing software are commercially available. (Reference) https://www.magellan.jp/english

Fig. 3 Configuration of PPP

[PPP-AR: PPP with Ambiguity Resolution]

Positioning accuracy can be further improved by ambiguity resolution using phase bias (FCB) correction in augmentation message.

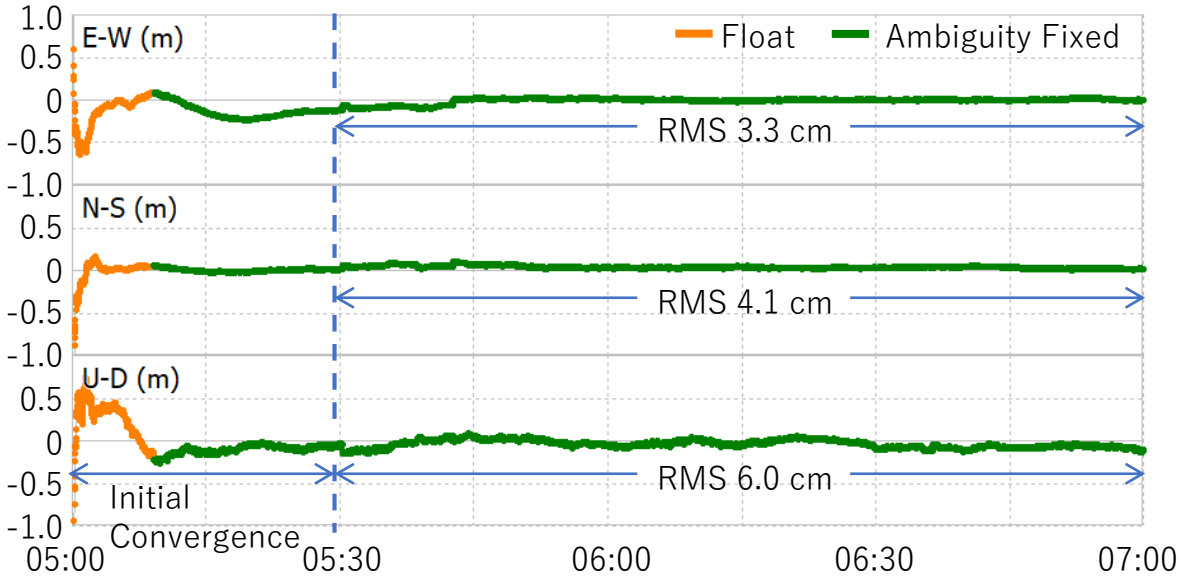


Fig. 4 Example of PPP-AR result

Initial Convergence Time	approx. 30 minutes

Since ionosphere and troposphere errors are estimated by the Kalman filter after the start of positioning, the positioning requires "initial convergence time" to reach 10 cm accuracy.

Positioning Accuracy	Less than 10 cm

After the initial convergence, the positioning accuracy is less than 10 cm.

Time to First Fix (TTFF)	approx. 10 minutes

In this case, it takes approx. 10 minutes from the start of positioning to the ambiguity resolution.

5. Local Augmentation

Initial convergence time and TTFF can be saved by estimating ionosphere/ troposphere errors using continuous GNSS observation station (Local Station).

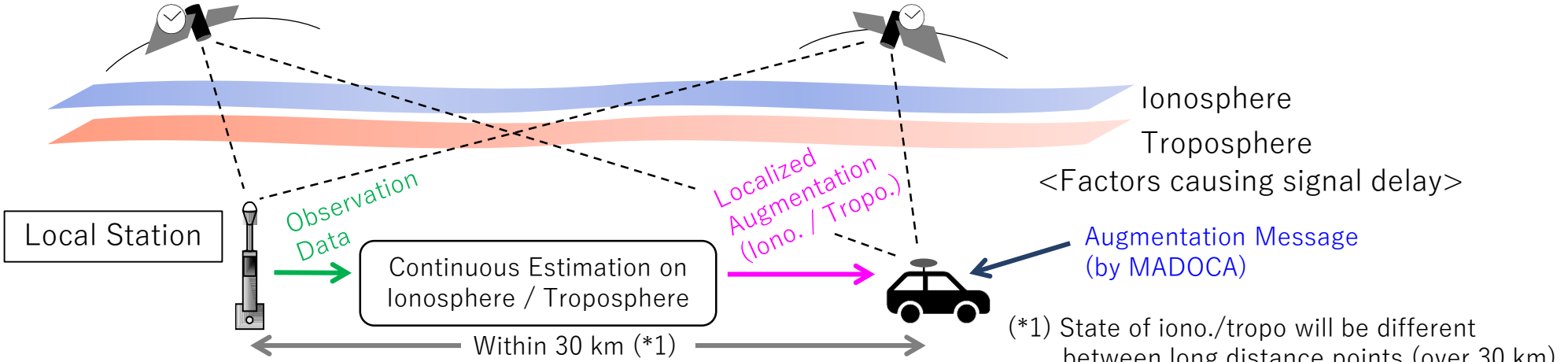


Fig. 5 Image of Localized Augmentation

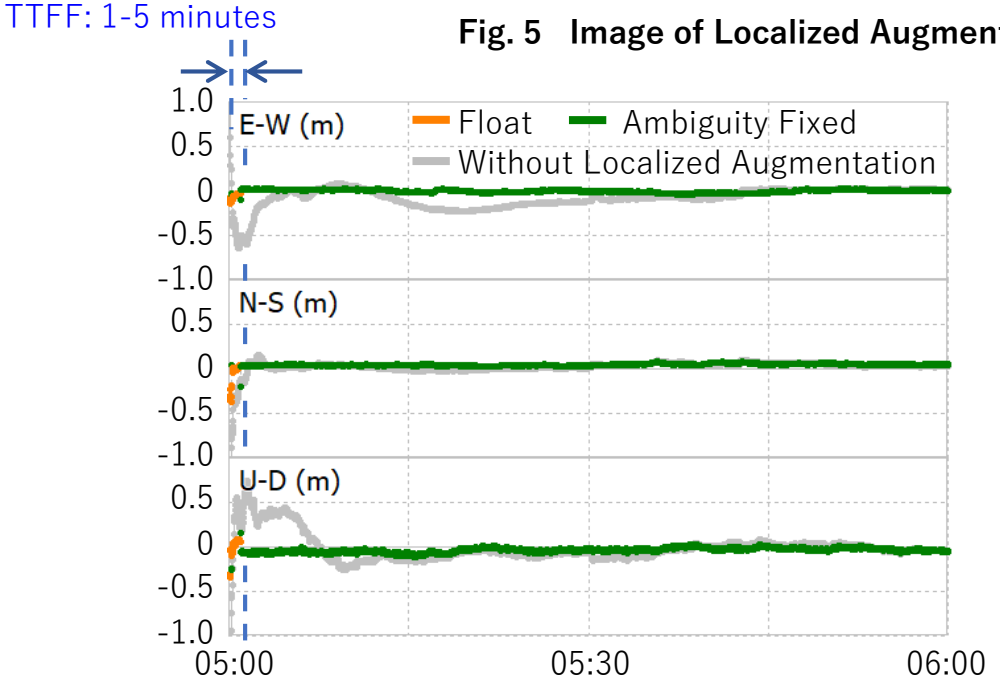


Fig. 6 Example of PPP-AR result with Localized Augmentation

Initial Convergence Time	approx. 1 minute

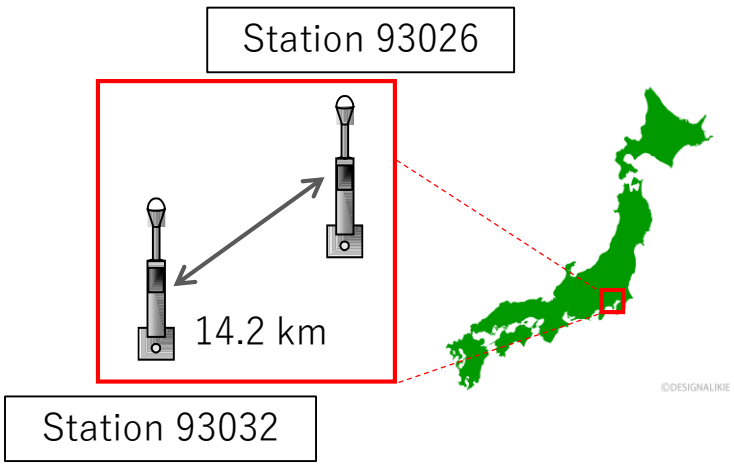
Initial convergence time is shortened to 1 minute by applying "Local Augmentation".

Positioning Accuracy	Less than 10 cm

Positioning accuracy is the same as no localized augmentation.

Time to First Fix (TTFF)	approx. 1 minute

TTFF is also shortened to 1 minute.



Acknowledgement : Station 93026/95032 are operated by GSI as a part of GEONET.

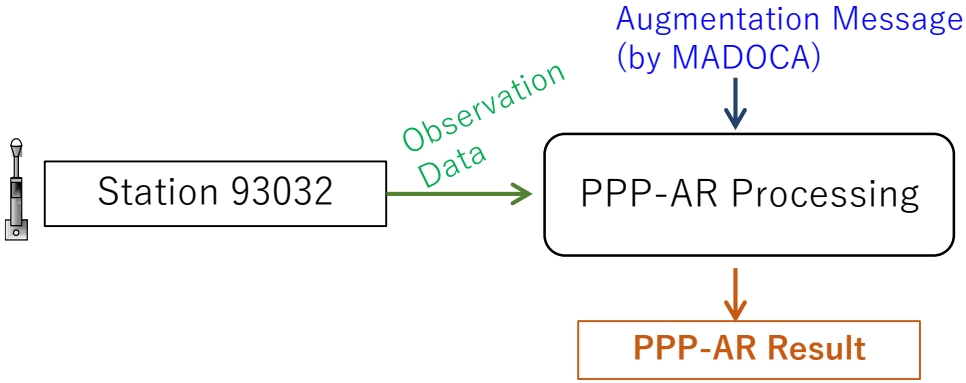
Station 93026

Receiver	TOPCON NETG5
Antenna	TRM59800.80 GSI
Position	Lat 35.563402508 N Lon 139.67335861 E Hgt 47.537 m

Station 93032

Receiver	Trimble NetR9
Antenna	TPSCR.G5 GSI
Position	Lat 35.436484221 N Lon 139.65375210 E Hgt 70.615 m

Case 1 : PPP-AR



Case 2 : PPP-AR with Local Augmentation

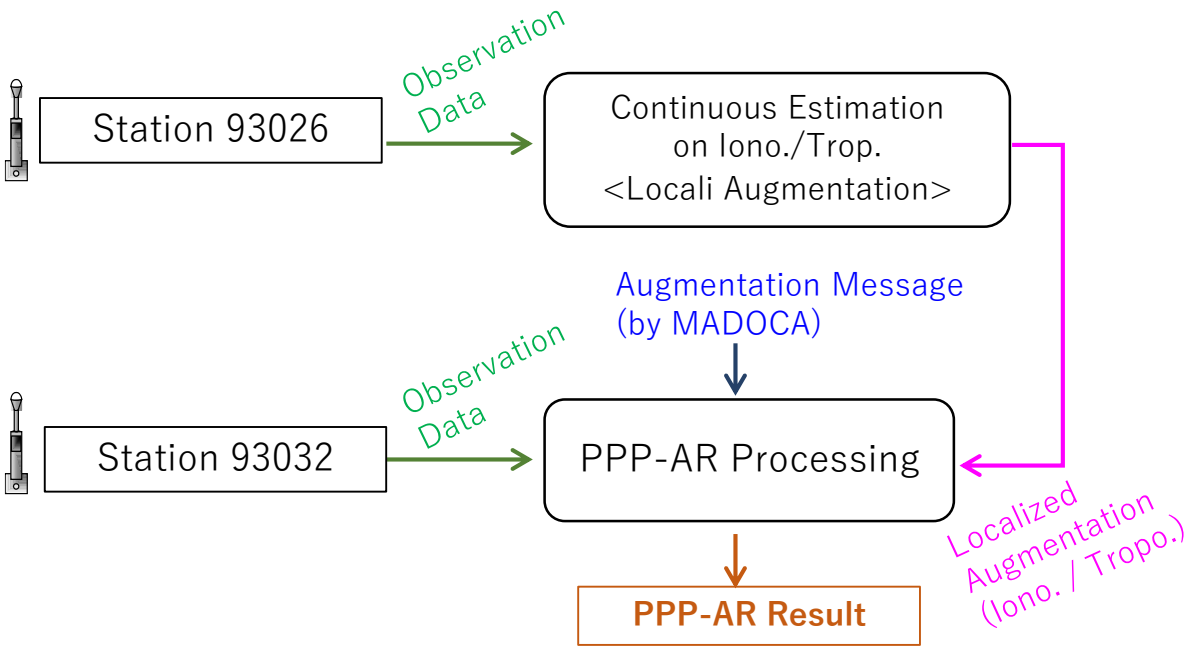


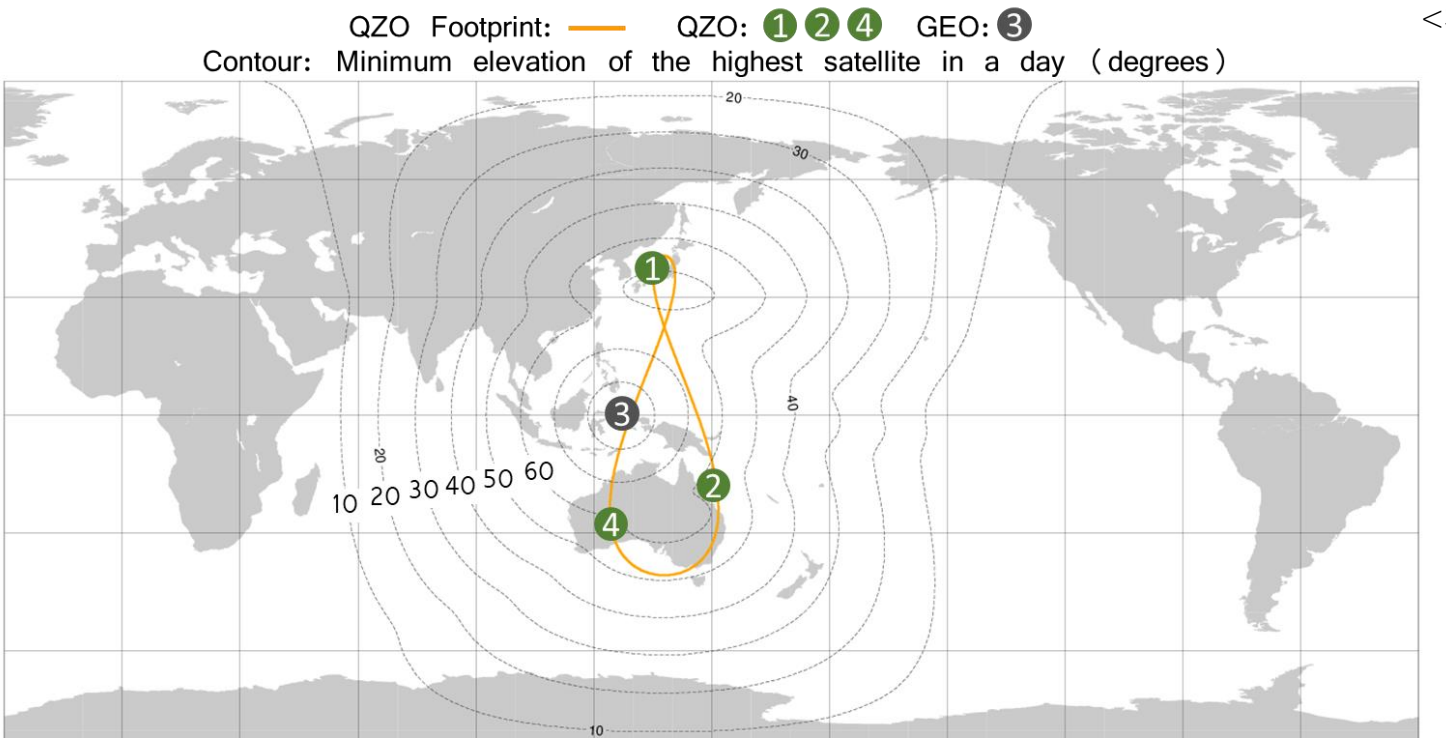
Fig. 7 Configuration of the Demonstration

7. GNSS Augmentation Service for Experiment with QZSS

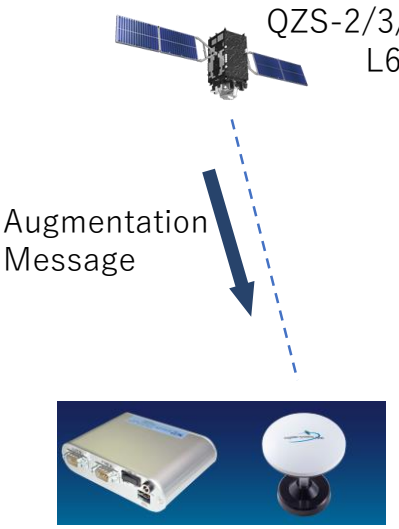
GNSS augmentation messages generated by MADOCA are being distributed from QZSS*1 as an experiment service on L6E channel.

*1) Distributed from QZS-2, 3, 4 (excluding QZS-1)

QZSS visibility



<Sample Configuration for Utilization>



GNSS Receiver / Antenna compatible with MADOCA

Reference of GNSS Receiver: http://www.magellan.jp

Satellite Image: http://qzss.go.jp

8. GNSS Augmentation Service by GPAS

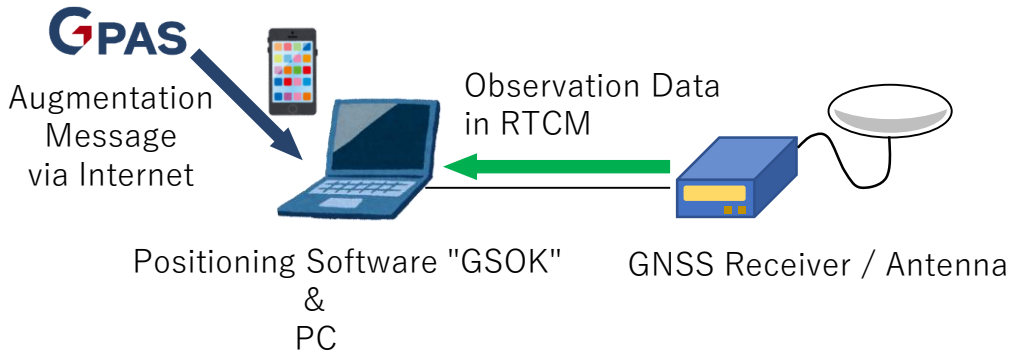
Global Positioning Augmentation Service (GPAS) is commercially distributing GNSS augmentation messages through the Internet.

Service Menu

	Augmentation Product	Interface
Basic Service	Real-time SSR stream (no FCB)	NTRIP
	SSR file download (no FCB)	SFTP
Basic + FCB Service FCB : Fractional Cycle Bias	Real-time SSR stream (incl. FCB)	NTRIP
	SSR file download (incl. FCB)	SFTP
Ephemeris Service	Ultra-Rapid / Rapid / Final	please inquire

Please visit GPAS's website to apply for user registration :
http://www.gpas.co.jp

<Sample Configuration for Utilization>



GNSS Receiver / Antenna
compatible with MADOCA

Reference: http://www.magellan.jp

9. Specifications of Augmentation Message

The augmentation messages conform to RTCM SSR standard format stage-1 and stage-2 proposed in 2013-2014. Supported satellites are GPS, GLONASS, and QZS-1*1.

*1) QZS-2,3,4 and Galileo will be supported by October 2022.

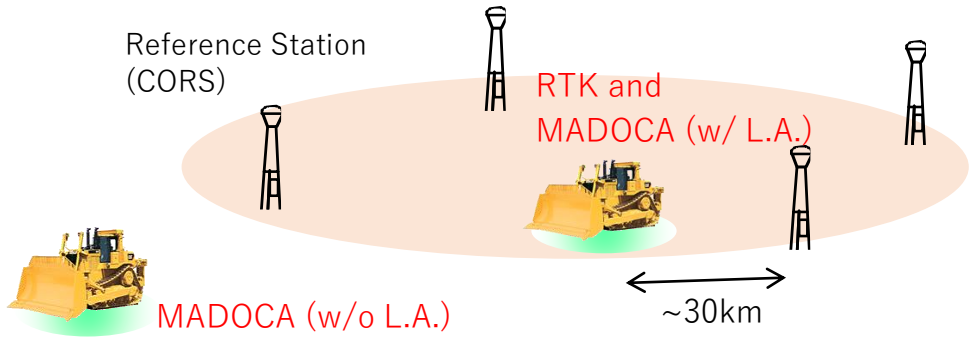
Product	Estimation Interval (sec)	Message Interval (sec)	RTCM Message Type #		
			GPS	GLONASS	QZSS
<QZSS Service: Centimeter Level Augmentation Service for Experiment>					
Orbit Correction	30	30	1057	1063	1246
High-Rate Clock Correction	1	2	1062	1068	1251
User Range Accuracy (URA)	1	30	1061	1067	1250
Code Bias	10800	30	1059	1065	1248
<Internet Service: Commercial Service by GPAS>					
Orbit Correction	30	1	1057	1063	1246
Clock Correction	1	1	1058	1064	1247
High-Rate Clock Correction	1	1	1062	1068	1251
User Range Accuracy (URA)	1	1	1061	1067	1250
Code Bias	10800	1	1059	1065	1248
Phase Bias (FCB)	900	1	11	--	13

For details, please see our website:
https://www.gpas.co.jp/service_madoca.php

10. Technical Features on PPP/PPP-AR compared to RTK

	MADOCA-PPP/PPP-AR	RTK
Horizontal Positioning Accuracy	10 centimeters	Centimeter-level
Convergence Time	<Without Local Augmentation> About 10-30 minutes <With Localized Augmentation> Few minutes	Less than 1 minute
Service Coverage*1	<Without Local Augmentation> Worldwide <With Local Augmentation> Limited	Limited
Coordinate System*2	Absolute (ITRF)	Relative (Depends on Reference Station)

*1) Local augmentation and RTK require reference GNSS station(s) within 30 km, which limits coverage. MADOCA (w/o L.A.) is available worldwide regardless of location of reference station.



*2) PPP/PPP-AR calculates absolute coordinates of user, and RTK calculates relative coordinates from a reference station. This difference will be advantage or disadvantage depending on application.

For example, relative coordinates are useful for local surveys. On the other hand, absolute coordinates can clarify the crustal movement or amplitude caused by an earthquake.

11. MADOCA Utilization Activities with QZSS Experimental Signal Service

Purpose

Widely use of high-precision positioning service from QZSS (MADOCA) in Asia-Oceania region

Scheme of the Activity

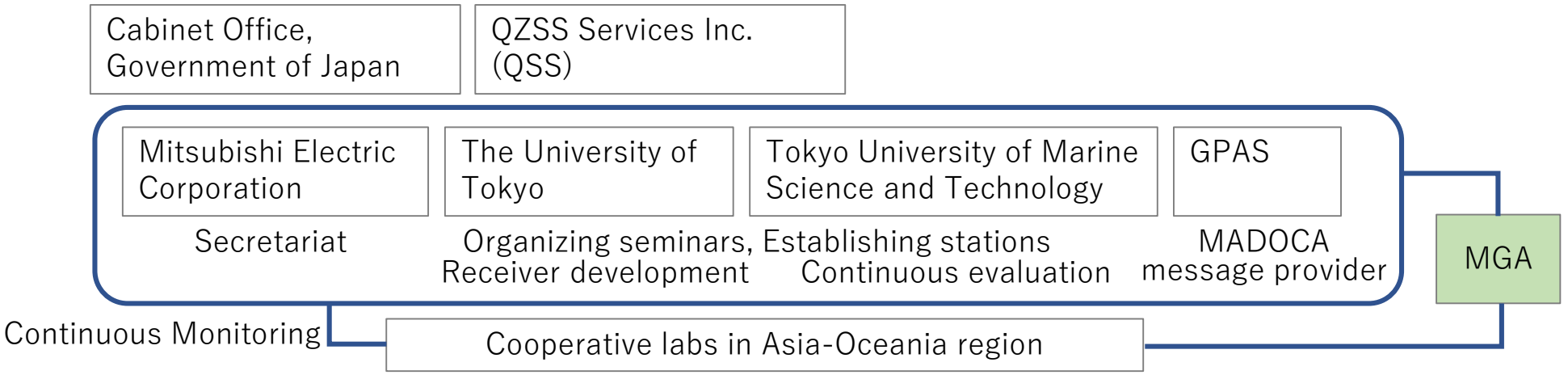
Act. 1 : Establishing monitoring stations and continuous evaluation

- ✓ Establish monitoring stations in Asia-Oceania region, and continuously evaluate the positioning accuracy as a reference MADOCA performance.

Act. 2 : Promotion and Enhancement

- ✓ Enhancement of low-cost MADOCA receiver system
- ✓ Promote GNSS and QZSS/MADOCA technology through webinars, trainings, lectures, and pilot projects

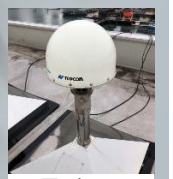
Framework



Monitoring Stations

Monitoring Station (7) Planning (1)


Bangkok


Tokyo


Perth

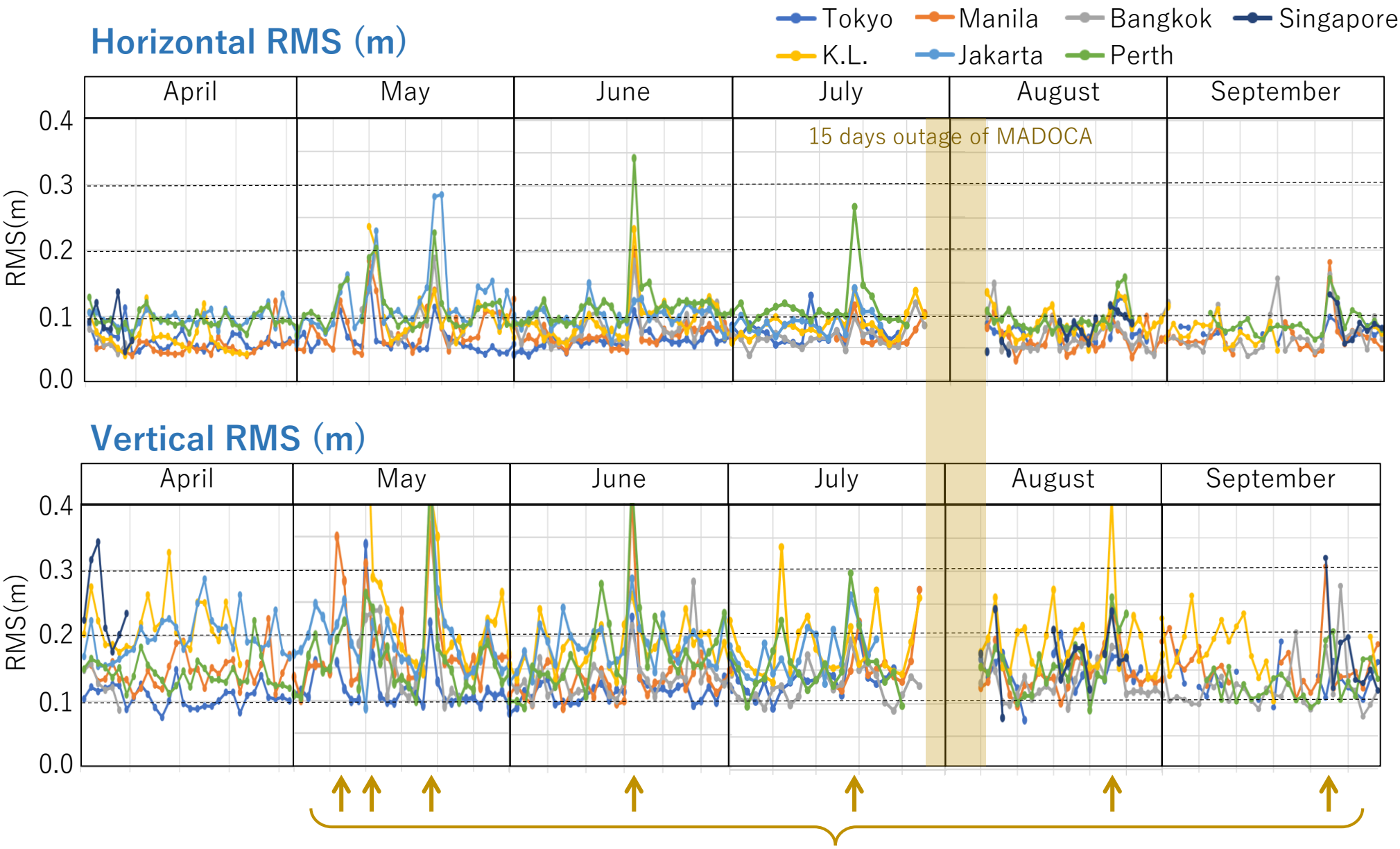
	Country/Region	City	Institution
	Japan	Tokyo	Tokyo University of Marine Science and Technology
	Philippines	Manila	University of the Philippines
	Thailand	Bangkok	Chulalongkorn University
	Malaysia	Kuala Lumpur	Malaysia-Japanese International Institute of Technology
	Indonesia	Jakarta	University of Indonesia
	Australia	Perth	Curtin University
	Singapore	Singapore	Nanyang Technological University
	Vietnam	Ho Chi Minh	Ho Chi Minh City International University

Monitoring Availability in FY2021/H1

Available Unavailable Outage of MADOCA

City	Availability	April	May	June	July	August	September
Tokyo	80.3%						
Manila	83.1%						
Bangkok	71.0%						
Kuala Lumpur	77.0%						
Jakarta	59.0%						
Perth	85.2%						
Singapore	15.3%						

13. Positioning Accuracies on Each Monitoring Station



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