Quasi-Zenith Satellite System
Service Performance Report
MADOCA-PPP
Technology Demonstration (Ionospheric Correction)
(Before Service Launch, 2024)

January 2025

Cabinet Office

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1. Outline

As a demonstration, the wide-range ionospheric correction for the Asia and Oceania regions will be additionally transmitted by the L6D messages of QZS-6 and 7 to shorten the initial convergence time of MADOCA-PPP(*1). Prior to the satellite transmission, the results of the performance evaluation are described in this document as a reference.

(*1) Service Level Information for MADOCA-PPP Technology Demonstration (Ionospheric Correction) is available at the following web address.:
https://qzss.go.jp/technical/download/sli_mdc_ion_agree.html

2. Service Performance Evaluation Conditions

2.1. Evaluation Period

From July 1, 2024 to July 31, 2024 (UTC)

2.2. Evaluation Item

The following performance improvements with ionospheric correction are evaluated comparing to the case without ionospheric correction.

- Convergence Time
- Positioning Accuracy after convergence

2.3. Evaluation Points

Evaluation points in the Asia and Oceania regions are shown in Table 2.3-1. Evaluation points in Japan region are shown in Table 2.3-2. The entire service area of ionospheric correction is shown in Figure 2.3-1. Figures 2.3-2 to 2.3-5 show the service areas and evaluation points for Australia, the Philippines, Indonesia, and Japan, respectively.

Table 2.3-1 Evaluation points in the Asia and Oceania

#	Station Name	Latitude [deg]	Longitude [deg]	Area
1.1	MOBS00AUS	-37.8294	144.9753	R002-A04*1
1.2	CEDU00AUS	-31.8666	133.8098	R001-A05
1.3	NNOR00AUS	-31.0487	116.1927	R001-A06
1.4	ALIC00AUS	-23.6701	133.8855	R002-A07
1.5	WLAL00AUS	-19.7786	120.6435	R001-A08
1.6	PCDN00PHL	*2	*2	R003-A01
1.7	PTGG00PHL	14.5354	121.0413	R003-A02
1.8	CIBG00IDN	-6.490	106.849	R004-A01

*1: The area definition of R002-A04 has been updated in Dec. 2024, but results are provided as a reference.

*2: Data of these evaluation points are provided based on the intergovernmental cooperation and their locations are not disclosed in this document.

Table 2.3-2 Evaluation points in Japan

#	Station Name	Latitude [deg]	Longitude [deg]	Area
2.1	0787 KAMIFURANO	43.4316	142.6430	R005-A01
2.2	0556 MURAYAMA	38.4967	140.3651	R005-A02
2.3	0223 CHICHIBU	35.9868	139.0756	R005-A03
2.4	0602 AOGASHIMA	32.4635	139.7646	R005-A03
2.5	0345 SANNAN	35.0907	134.9725	R005-A04
2.6	0696 FUKAE	32.7225	130.3522	R005-A05
2.7	0735 WADOMARI	27.4012	128.6507	R005-A06
2.8	0497 MINAMIDAITO	25.8312	131.2278	R005-A06
2.9	0749 ISHIGAKI1	24.5366	124.3012	R005-A07
2.10	2007 CHICHIJIMA-A	27.0675	142.1950	R005-A08

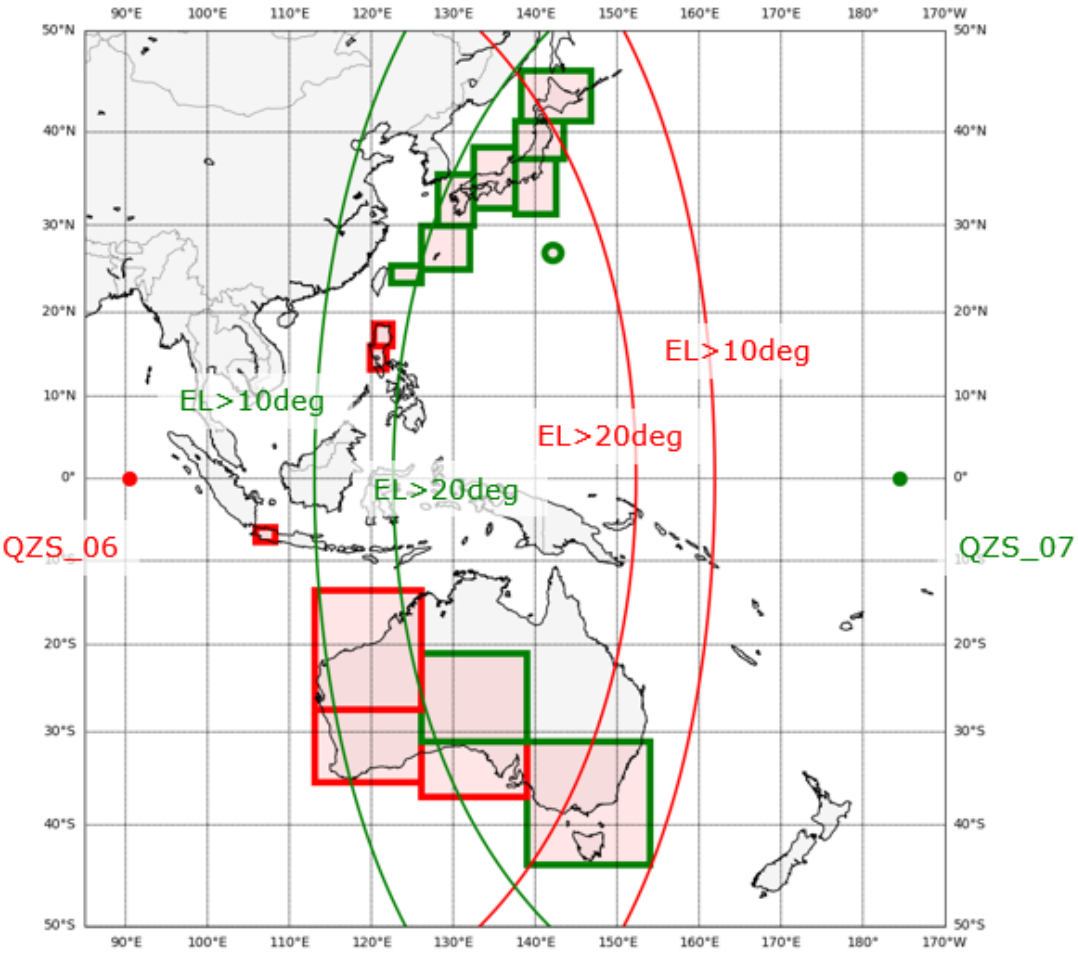

Figure 2.3-1 Service area of technology demonstration (Ionospheric Correction)

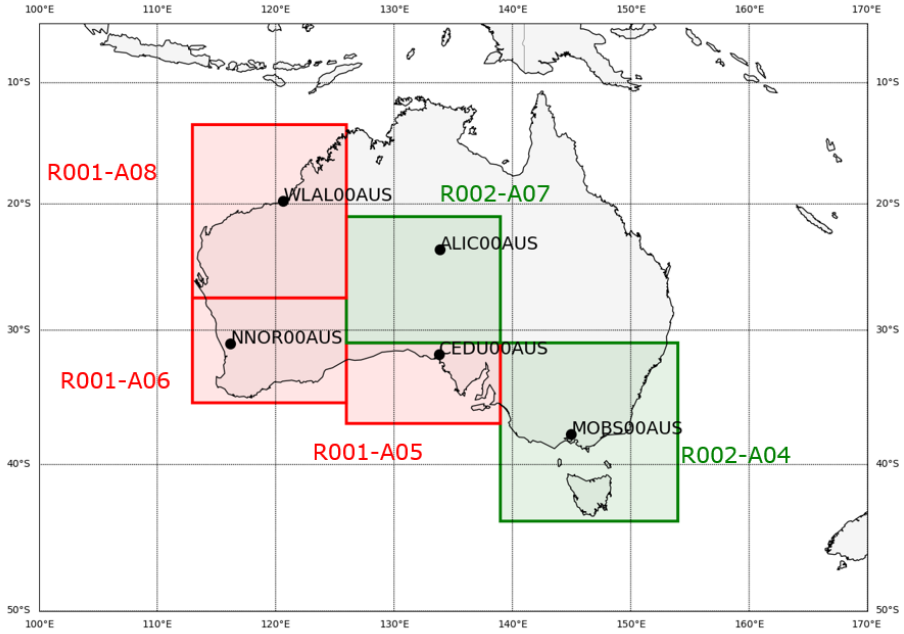

Figure 2.3-2 Service areas and evaluation points in Australia*

*: The area definition of R002-A04 has been updated in Dec. 2024, but results are provided as a reference.

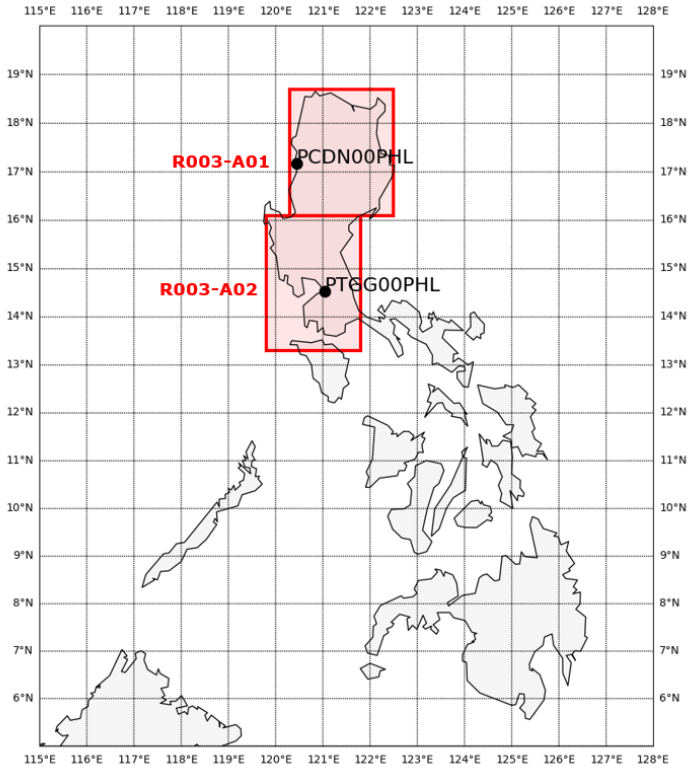

Figure 2.3-3 Service areas and evaluation points in the Philippines

Figure 2.3-4 Service areas and evaluation points in Indonesia

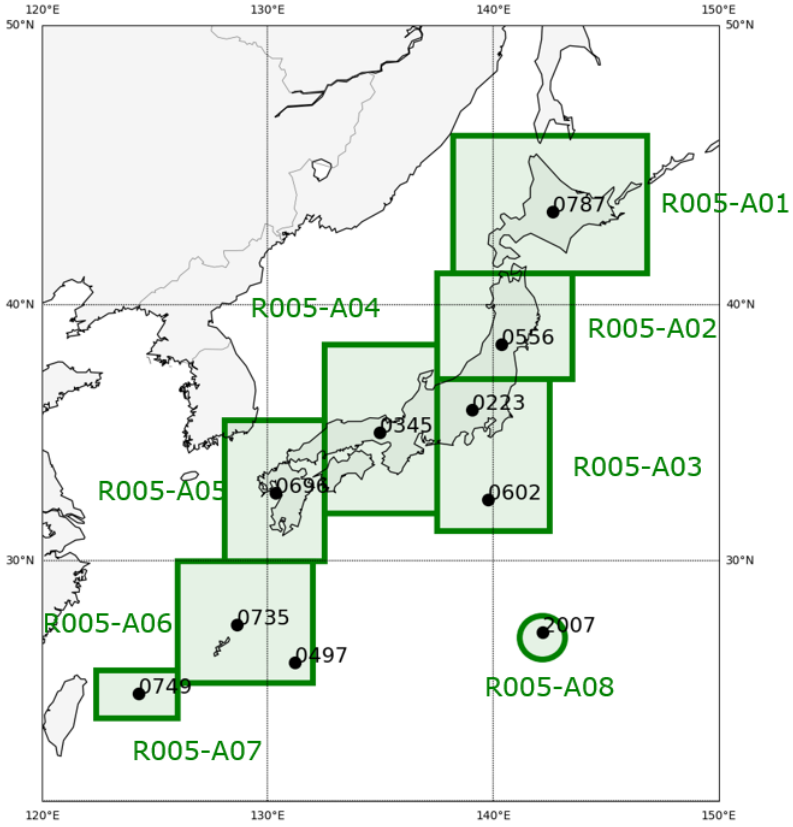

Figure 2.3-5 Service areas and evaluation points in Japan

2.4. Augmented GNSS

- GPS+QZSS+Galileo+GLONASS

2.5. Calculation Conditions

2.5.1. Evaluation Conditions

- PPP Conditions

  See Table 2.5-1.

Table 2.5-1 PPP Conditions

No.	Item	Without wide-area ionospheric correction	With wide-area ionospheric correction	Notes
1	Positioning method	PPP Kinematic	PPP Kinematic	
2	Observation Data Frequency	GPS(L1, L2) QZSS(L1, L2) Galileo (E1, E5a) GLONASS(L1, L2)	GPS(L1, L2) QZSS(L1, L2) Galileo (E1, E5a) GLONASS(L1, L2)	
3	Ionospheric correction method	Estimate ionospheric delay for each satellite	Estimate ionospheric delay for each satellite and constrain with wide-area ionospheric information	
4	Tropospheric correction method	Estimate zenith tropospheric delay	Estimate zenith tropospheric delay	
5	Ambiguity resolution	Apply	Apply	
6	Elevation mask	10 deg	10 deg	

- Tool and Data

  The MADOCA-PPP test library (MADOCALIB; Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning Test Library), and the archived L6 messages are utilized (*1).

  - MADOCALIB: version 1.3
  - Key parameter setting: See Table 2.5-2 (These and other parameters are same as the sample configuration files in the library.)

Table 2.5-2 Parameter setting

Item	PPP-AR (sample_pppar.conf)	PPP-AR (sample_pppar_iono.conf)	Notes
pos1-posmode	ppp-kine	ppp-kine	
pos1-frequency	l1+2	l1+2	
pos1-soltype	forward	forward	
pos1-elmask	10	10	
pos1-tidecorr	on	on	
pos1-ionoopt	est-stec	est-stec	
pos1-tropopt	est-ztd	est-ztd	
pos1-sateph	brdc+ssrapc	brdc+ssrapc	
pos1-navsys	29	29	
pos2-ionocorr	off	on	
pos2-armode	continuous	continuous	
pos2-arsys	25	25	
pos2-arthres	2.5	2.5	
pos2-arelmask	15	15	
pos2-slipthres	0.15	0.15	
pos2-rejionno	100	100	
pos2-rejgdop	30	30	
pos2-siggpsIIR-M	0	0	
pos2-siggpsIIF	0	0	
pos2-siggpsIIIA	0	0	
pos2-sigqzs1_2	1	1	
stats-eratio1	300	300	
stats-eratio2	300	300	
stats-uraratio	0.1	0.1	
stats-errphase	0.003	0.003	
stats-errphaseel	0.003	0.003	
file-satantfile	igs20.atx(*2)	igs20.atx(*2)	
file-rcvantfile	igs20.atx(*2)	igs20.atx(*2)	

(*1) MADOCALIB is available at the following web address:
https://qzss.go.jp/en/technical/dod/madoca/madoca_test-library.html (English)
https://qzss.go.jp/technical/dod/madoca/madoca_test-library.html (Japanese)

Archives are available at the following web address:
https://sys.qzss.go.jp/dod/en/archives/agree_madoca.html

(*2) The antenna phase information file was obtained on the IGS Web site.
https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/GNSS_product_holdings.html

2.5.2. Initial Convergence Time

- The PPP calculation was performed every 15 minutes during the evaluation period.
- By using each calculation result, the positioning accuracy (95%) was statistically calculated every 30 seconds.
- Initial convergence time was calculated as the time for the positioning accuracy (95%) to reach below 30 cm horizontally and 50 cm vertically from the start of PPP calculation.

2.5.3. Positioning Accuracy after Convergence

- The PPP calculation started at 00:00:00 every day.
- By using each calculation result, the positioning accuracy (95%) was statistically calculated every 30 seconds.
- Positioning Accuracy after convergence was the horizontal and vertical positioning accuracy (95%) from 00:30:00 to 23:59:30 every day.

3. Evaluation Results

3.1. Initial Convergence Time

See Figure 3.1-1, 3.1-2, Table 3.1-1, and Table 3.1-2.

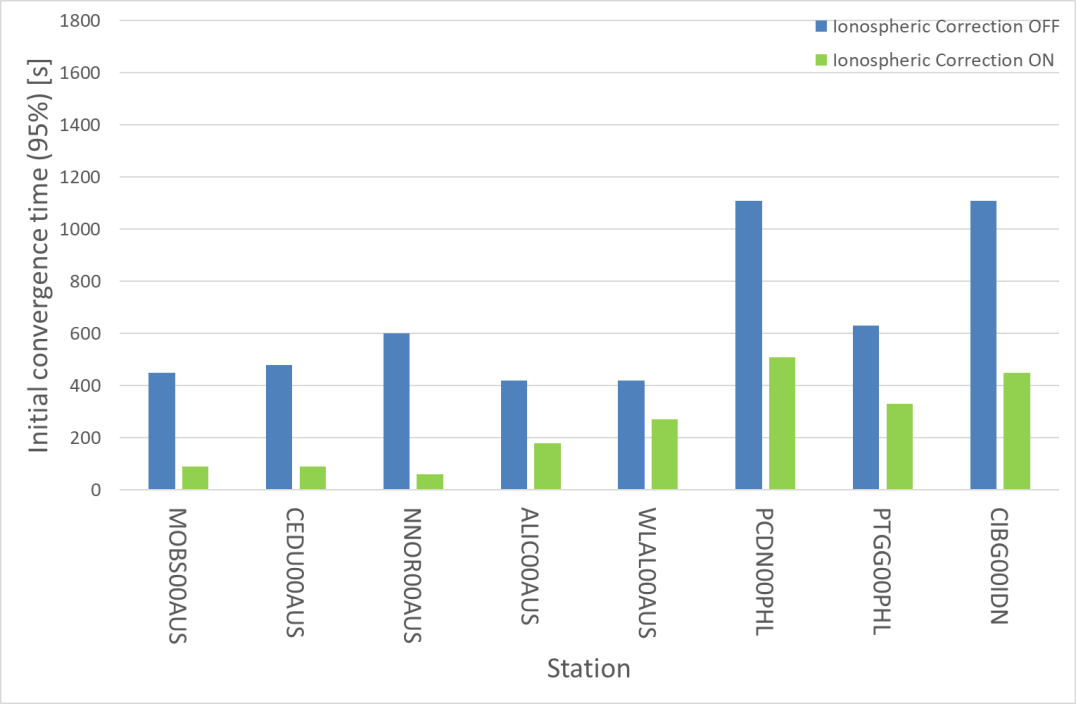

Figure 3.1-1 Initial Convergence Time (Asia and Oceania)

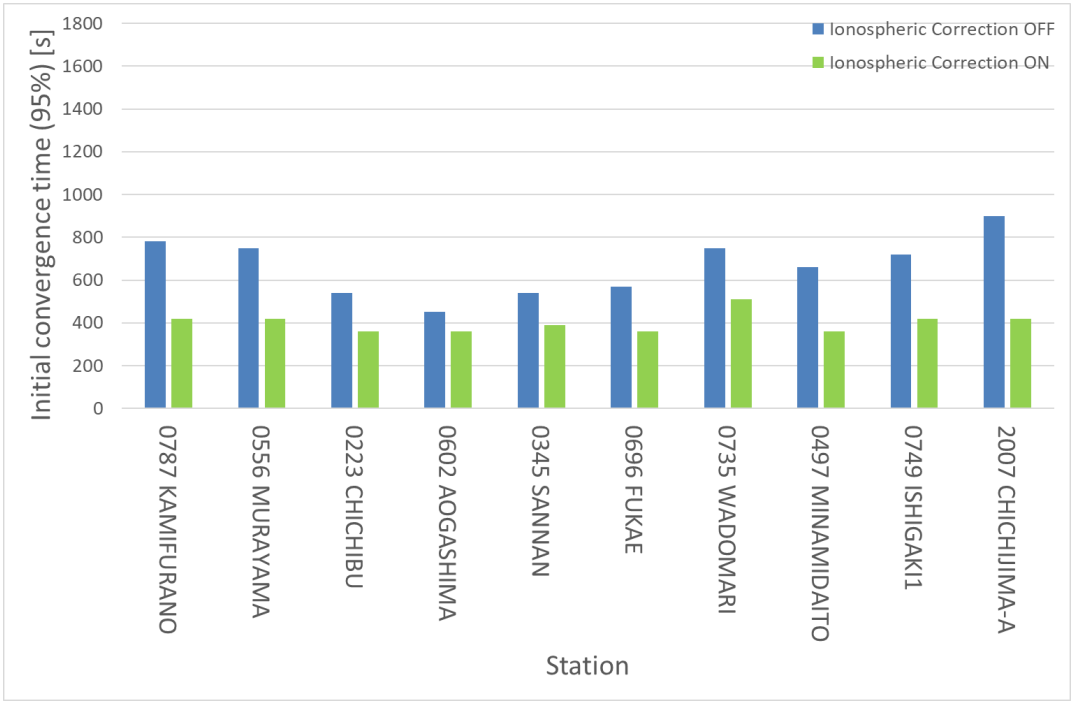

Figure 3.1-2 Initial Convergence Time (Japan)

Table 3.1-1 Initial Convergence Time (Asia and Oceania)

#	Station	Initial Convergence Time [s]	
		Iono. Correction OFF	Iono. Correction ON
1.1	MOBS00AUS	450	90
1.2	CEDU00AUS	480	90
1.3	NNOR00AUS	600	60
1.4	ALIC00AUS	420	180
1.5	WLAL00AUS	420	270
1.6	PCDN00PHL	1110	510
1.7	PTGG00PHL	630	330
1.8	CIBG00IDN	1110	450

Table 3.1-2 Initial Convergence Time (Japan)

#	Station	Initial Convergence Time [s]	
		Iono. Correction OFF	Iono. Correction ON
2.1	0787 KAMIFURANO	780	420
2.2	0556 MURAYAMA	750	420
2.3	0223 CHICHIBU	540	360
2.4	0602 AOGASHIMA	450	360
2.5	0345 SANNAN	540	390
2.6	0696 FUKAE	570	360
2.7	0735 WADOMARI	750	510
2.8	0497 MINAMIDAITO	660	360
2.9	0749 ISHIGAKI1	720	420
2.10	2007 CHICHIJIMA-A	900	420

3.2. Positioning Accuracy after Convergence

See Figure 3.2-1, 3-2-2, 3-2-3, 3-2-4, Table 3.2-1, and 3.2-2.

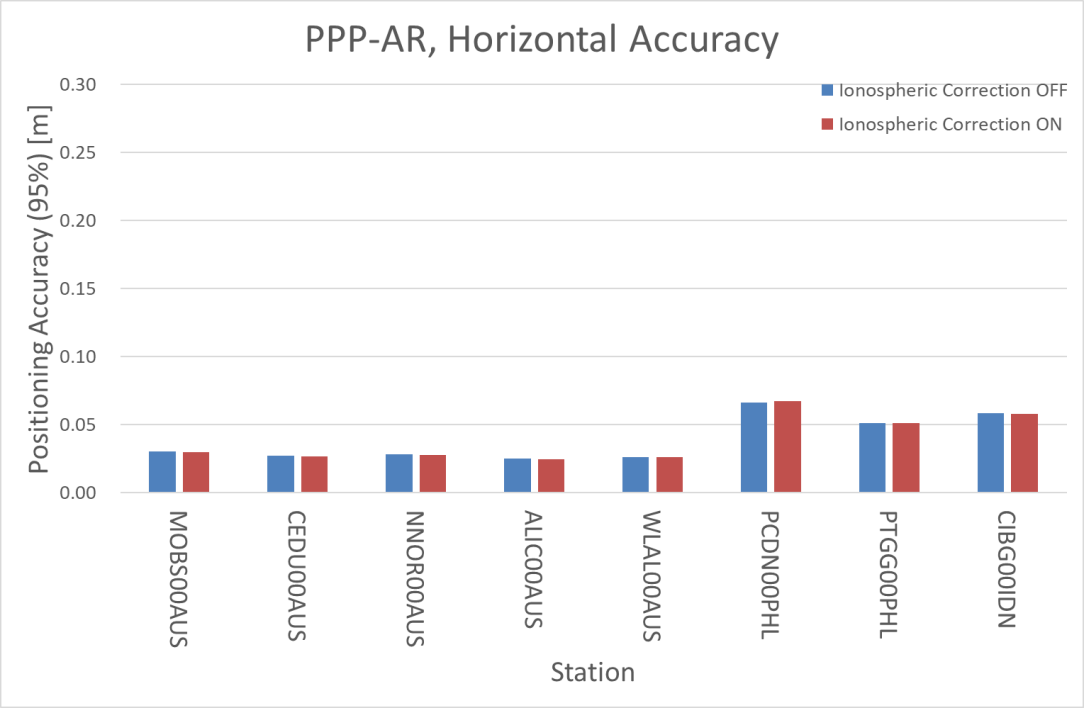

Figure 3.2-1 Horizontal Positioning Accuracy after Convergence (Asia and Oceania)

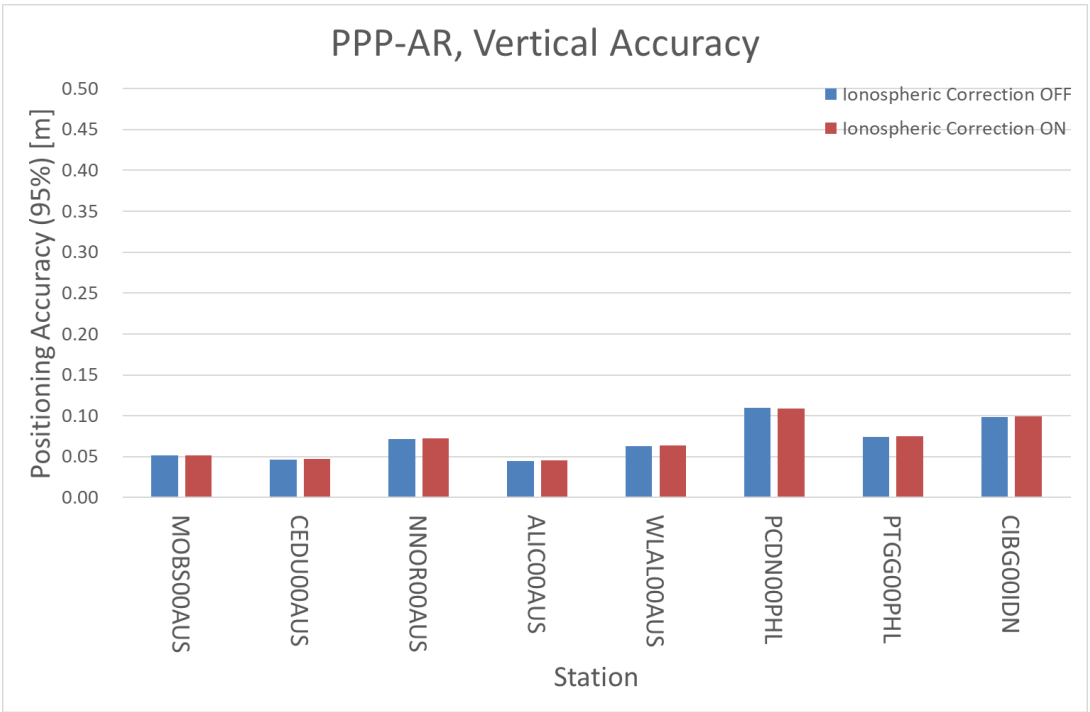

Figure 3.2-2 Vertical Positioning Accuracy after Convergence (Asia and Oceania)

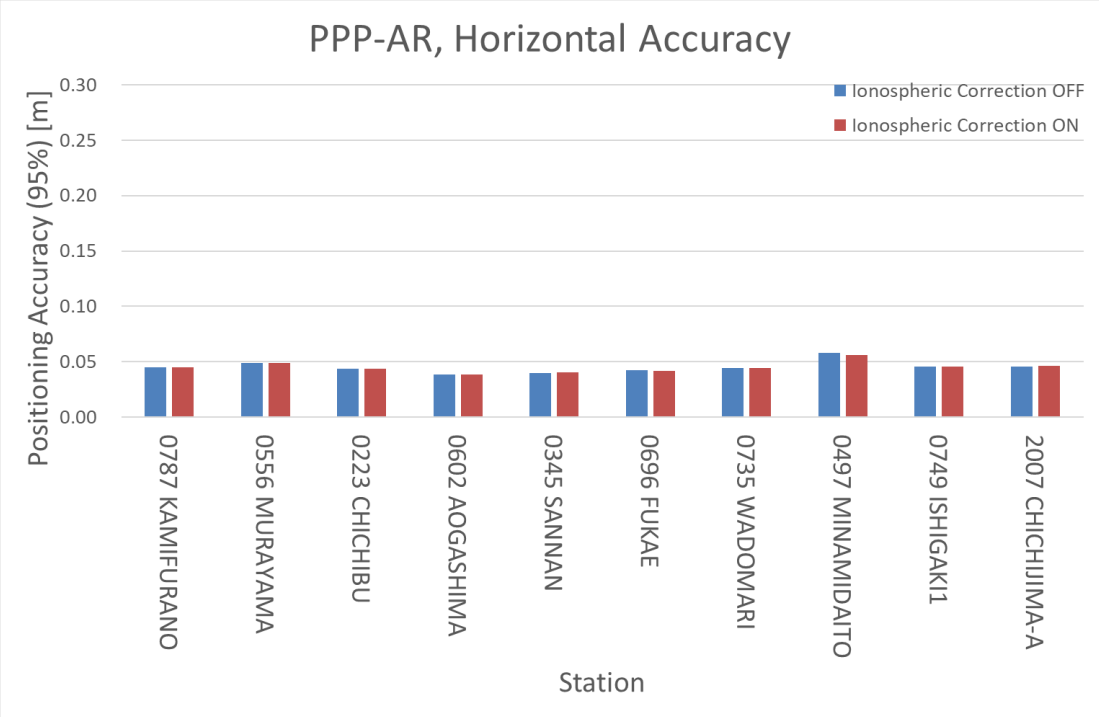

Figure 3.2-3 Horizontal Positioning Accuracy after Convergence (Japan)

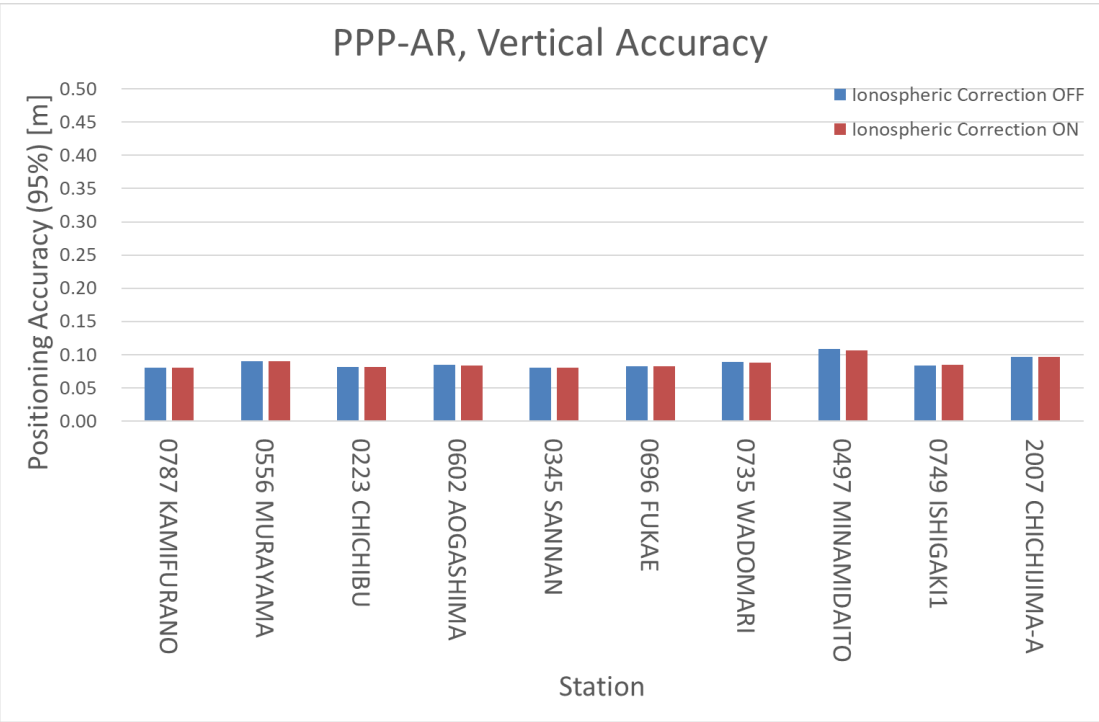

Figure 3.2-4 Vertical Positioning Accuracy after Convergence (Japan)

Table 3.2-1 Positioning Accuracy after Convergence (Asia and Oceania)

#	Station	Positioning Accuracy after Convergence [cm]			
		Iono. Correction OFF		Iono. Correction ON	
		Horizontal	Vertical	Horizontal	Vertical
1.1	MOBS00AUS	3.03	5.19	3.01	5.16
1.2	CEDU00AUS	2.72	4.61	2.66	4.69
1.3	NNOR00AUS	2.85	7.14	2.80	7.25
1.4	ALIC00AUS	2.50	4.47	2.45	4.54
1.5	WLAL00AUS	2.64	6.31	2.60	6.36
1.6	PCDN00PHL	6.65	10.94	6.76	10.91
1.7	PTGG00PHL	5.11	7.44	5.14	7.50
1.8	CIBG00IDN	5.84	9.81	5.78	9.96

Table 3.2-2 Positioning Accuracy after Convergence (Japan)

#	Station	Positioning Accuracy after Convergence [cm]			
		Iono. Correction OFF		Iono. Correction ON	
		Horizontal	Vertical	Horizontal	Vertical
2.1	0787 KAMIFURANO	4.52	8.07	4.49	8.00
2.2	0556 MURAYAMA	4.89	9.06	4.88	9.02
2.3	0223 CHICHIBU	4.35	8.14	4.40	8.20
2.4	0602 AOGASHIMA	3.84	8.51	3.84	8.41
2.5	0345 SANNAN	4.01	8.03	4.06	8.00
2.6	0696 FUKAE	4.22	8.28	4.16	8.23
2.7	0735 WADOMARI	4.44	8.91	4.46	8.84
2.8	0497 MINAMIDAITO	5.83	10.83	5.62	10.66
2.9	0749 ISHIGAKI1	4.59	8.40	4.59	8.50
2.10	2007 CHICHIJIMA-A	4.57	9.69	4.62	9.71