Quasi-Zenith Satellite System
Service Performance Report
MADOCA-PPP
Technology Demonstration (Ionospheric Correction)
(Before Service Launch, 2ndH 2024)

July 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.

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

2. Service Performance Evaluation Conditions

2.1. Evaluation Period

From October 1, 2024 to March 31, 2025 (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	KAT100AUS	-14.3760	132.1533	R002-A01*1
1.2	TOW200AUS	-19.2693	147.0557	R002-A02*1
1.3	BULA00AUS	-22.9135	139.9031	R002-A11*1
1.4	MCHL00AUS	-26.3589	148.1449	R002-A12*1
1.5	TBOB00AUS	-29.4502	142.0574	R002-A13*1
1.6	CBLT00AUS	-27.0844	152.9515	R002-A14*1
1.7	MOBS00AUS	-37.8294	144.9753	R002-A15*1
1.8	HOB200AUS	-42.8047	147.4387	R002-A16*1
1.9	CEDU00AUS	-31.8666	133.8098	R001-A05
1.10	NNOR00AUS	-31.0487	116.1927	R001-A06
1.11	ALIC00AUS	-23.6701	133.8855	R002-A07
1.12	WLAL00AUS	-19.7786	120.6435	R001-A08
2.1	PCDN00PHL	*2	*2	R003-A01
2.2	PTGG00PHL	14.5354	121.0413	R003-A02
3.1	CIBG00IDN	*2	*2	R004-A01

*1: In December 2024, R002-A01, A02, A11, A12, A13, and A14 were newly added, and R002-A04 was split into R002-A15 and A16.

*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
4.1	0787 KAMIFURANO	43.4316	142.6430	R005-A01
4.2	0556 MURAYAMA	38.4967	140.3651	R005-A02
4.3	0223 CHICHIBU	35.9868	139.0756	R005-A03
4.4	0602 AOGASHIMA	32.4635	139.7646	R005-A03
4.5	0345 SANNAN	35.0907	134.9725	R005-A04
4.6	0696 FUKAE	32.7225	130.3522	R005-A05
4.7	0735 WADOMARI	27.4012	128.6507	R005-A06
4.8	0497 MINAMIDAITO	25.8312	131.2278	R005-A06
4.9	0749 ISHIGAKI1	24.5366	124.3012	R005-A07
4.10	2007 CHICHIJIMA-A	27.0675	142.1950	R005-A08

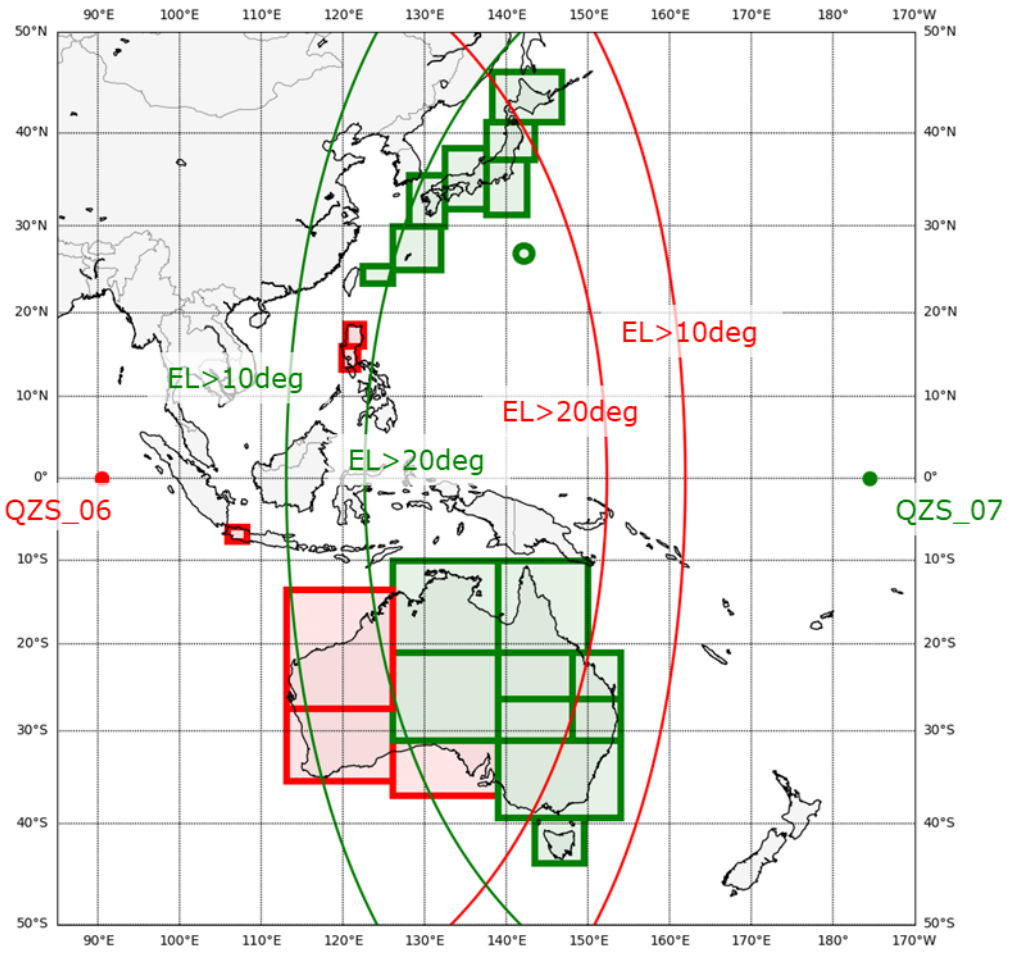

Figure 2.3-1 Service area of technology demonstration (Ionospheric Correction)

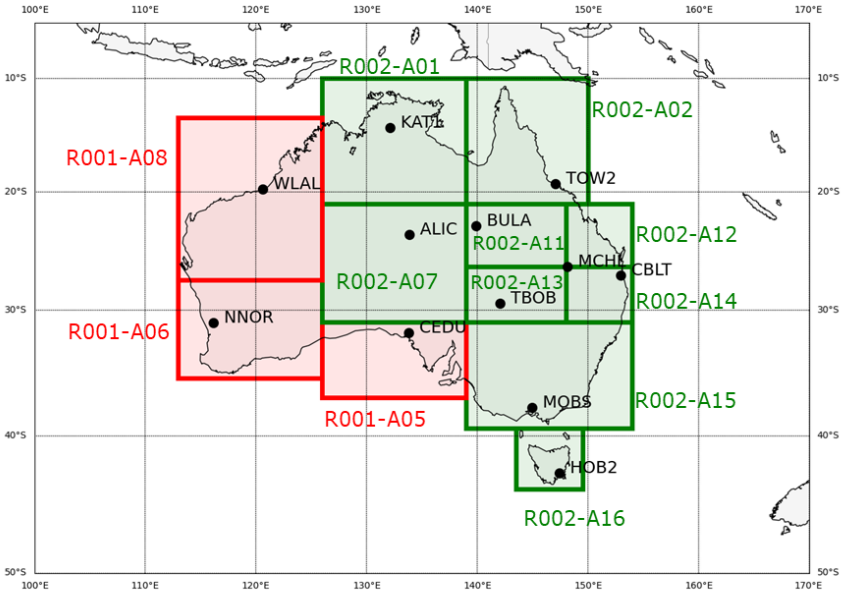

Figure 2.3-2 Service areas and evaluation points in Australia

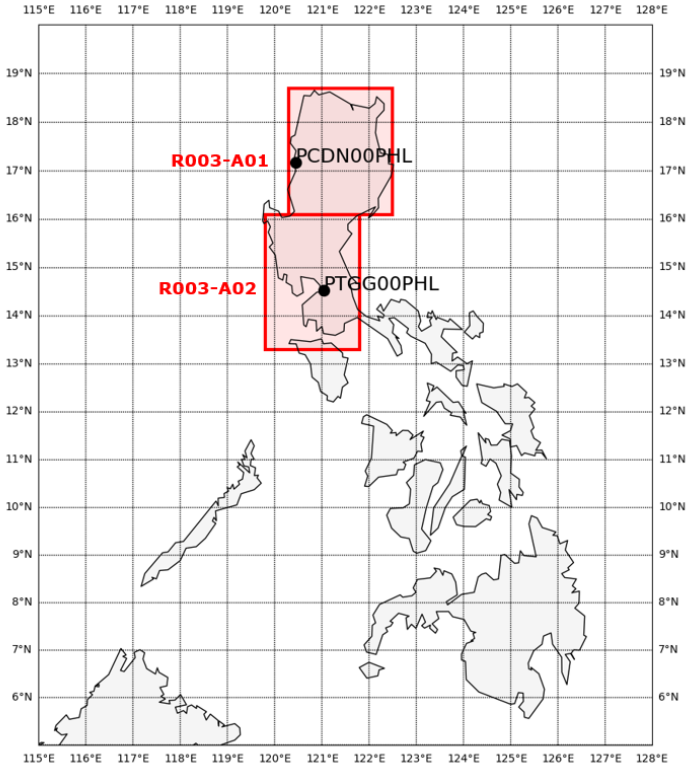

Figure 2.3-3 Service areas and evaluation points in the Philippines

Figure 2.3-4 Service areas and evaluation points in Indonesia

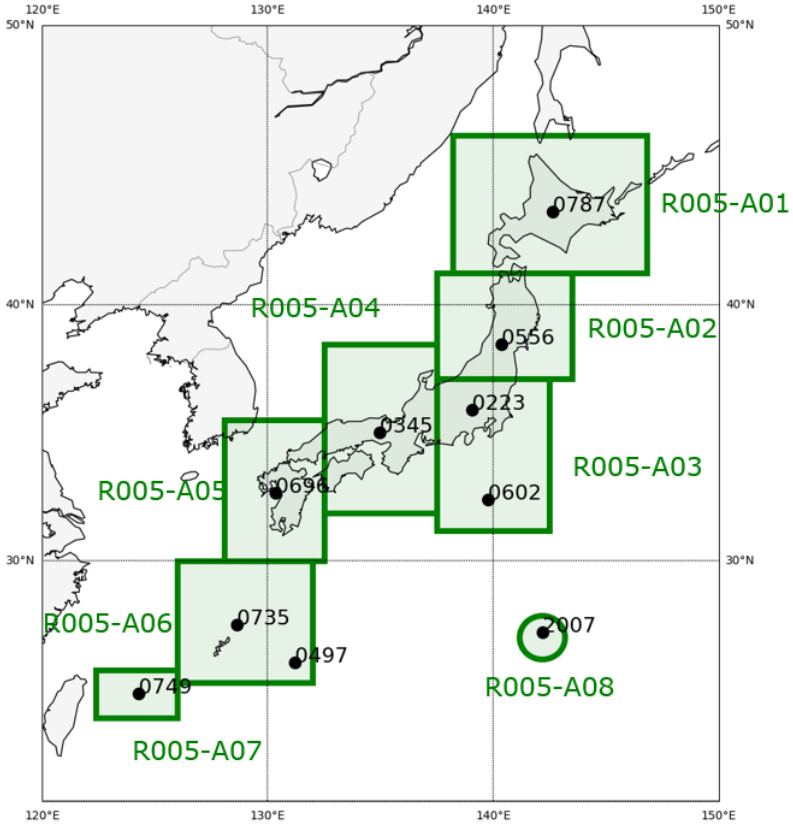

Figure 2.3-5 Service areas and evaluation points in Japan

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, L5) Galileo (E1, E5a) GLONASS(L1, L2)	GPS(L1, L2) QZSS(L1, L5) 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 1.4
  - 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.

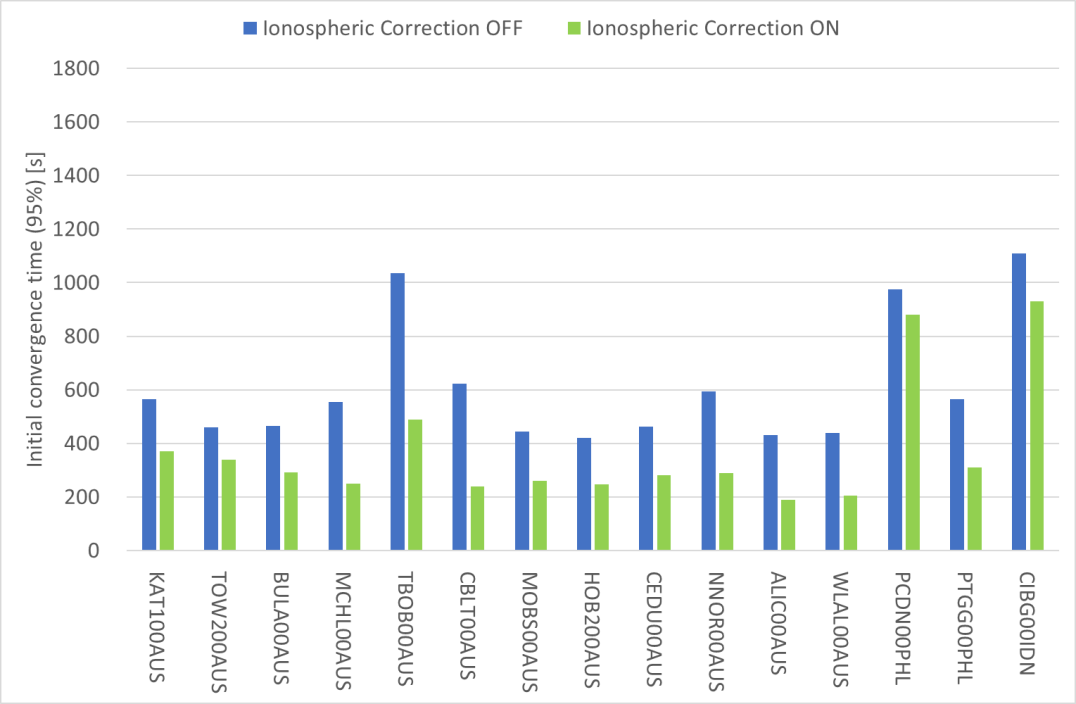

Figure 3.1-1 Initial Convergence Time (Asia and Oceania)

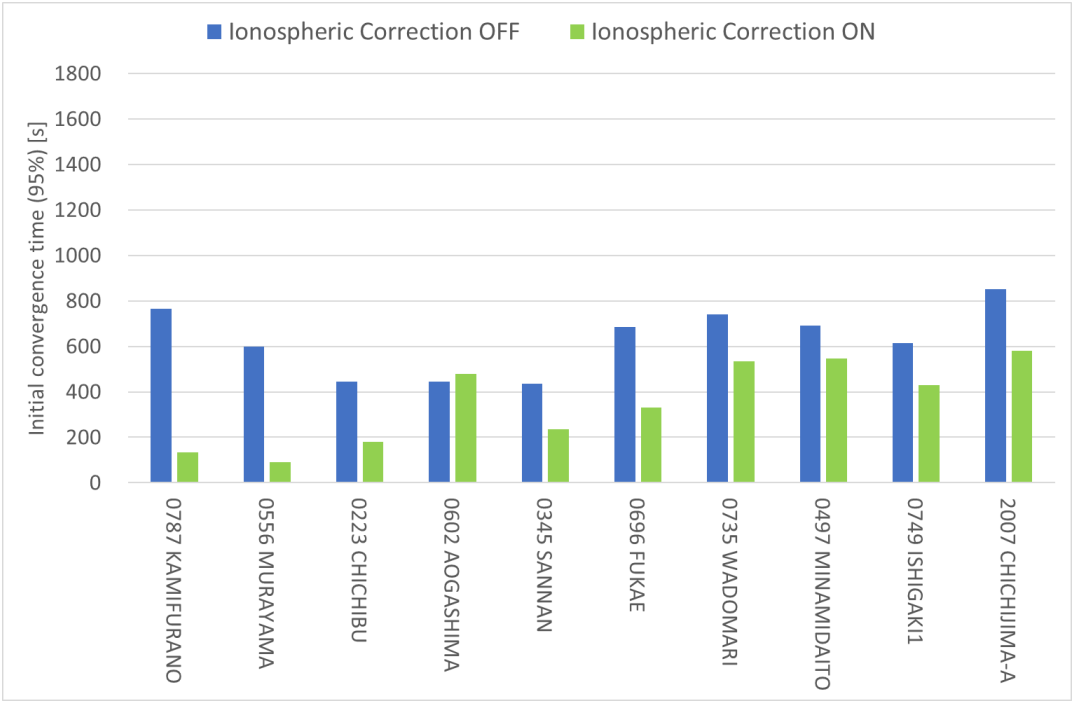

Figure 3.1-2 Initial Convergence Time (Japan)

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

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1.1	KAT100AUS	OFF	540	540	660	570	570	510
		ON	330	330	360	390	420	390
1.2	TOW200AUS	OFF	360	420	480	480	480	540
		ON	120	240	420	420	420	420
1.3	BULA00AUS	OFF	-	-	450	450	420	540
		ON	-	-	300	300	270	300
1.4	MCHL00AUS	OFF	540	570	540	570	570	540
		ON	210	360	300	180	210	240
1.5	TBOB00AUS	OFF	-	-	870	900	1290	1080
		ON	-	-	480	510	510	450
1.6	CBLT00AUS	OFF	-	-	600	600	660	630
		ON	-	-	270	210	210	270
1.7	MOBS00AUS	OFF	420	450	450	450	450	450
		ON	270	270	270	270	240	240
1.8	HOB200AUS	OFF	-	-	450	390	420	420
		ON	-	-	420	210	180	180
1.9	CEDU00AUS	OFF	450	-	480	450	480	450
		ON	150	-	330	330	330	270
1.10	NNOR00AUS	OFF	570	570	600	630	600	600
		ON	120	240	300	330	360	390
1.11	ALIC00AUS	OFF	420	420	450	420	450	420
		ON	90	90	300	270	180	210
1.12	WLAL00AUS	OFF	390	390	480	420	570	390
		ON	210	90	300	270	210	150
2.1	PCDN00PHL	OFF	1350	1080	840	780	720	1080
		ON	1200	690	840	720	750	1080
2.2	PTGG00PHL	OFF	870	570	510	420	480	540
		ON	390	240	300	210	300	420
3.1	CIBG00IDN	OFF	1800	1680	930	660	810	780
		ON	1800	1350	840	420	540	630

unit [s]

Table 3.1-2 Initial Convergence Time (Japan)

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
4.1	0787 KAMIFURANO	OFF	660	690	750	750	870	870
		ON	270	150	60	90	90	150
4.2	0556 MURAYAMA	OFF	540	540	600	600	660	660
		ON	270	120	30	0	30	90
4.3	0223 CHICHIBU	OFF	480	450	450	420	420	450
		ON	270	150	180	150	180	150
4.4	0602 AOGASHIMA	OFF	510	480	450	420	390	420
		ON	450	480	390	510	570	480
4.5	0345 SANNAN	OFF	480	450	420	420	420	420
		ON	300	270	210	180	210	240
4.6	0696 FUKAE	OFF	570	570	720	750	750	750
		ON	390	270	300	330	360	330
4.7	0735 WADOMARI	OFF	900	750	660	690	720	720
		ON	690	540	420	390	570	600
4.8	0497 MINAMIDAITO	OFF	600	720	660	720	690	750
		ON	600	570	420	450	570	660
4.9	0749 ISHIGAKI1	OFF	900	570	540	540	540	600
		ON	630	480	300	330	390	450
4.10	2007 CHICHIJIMA-A	OFF	930	870	780	780	810	930
		ON	630	630	450	540	630	600

unit [s]

3.2. Positioning Accuracy after Convergence

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

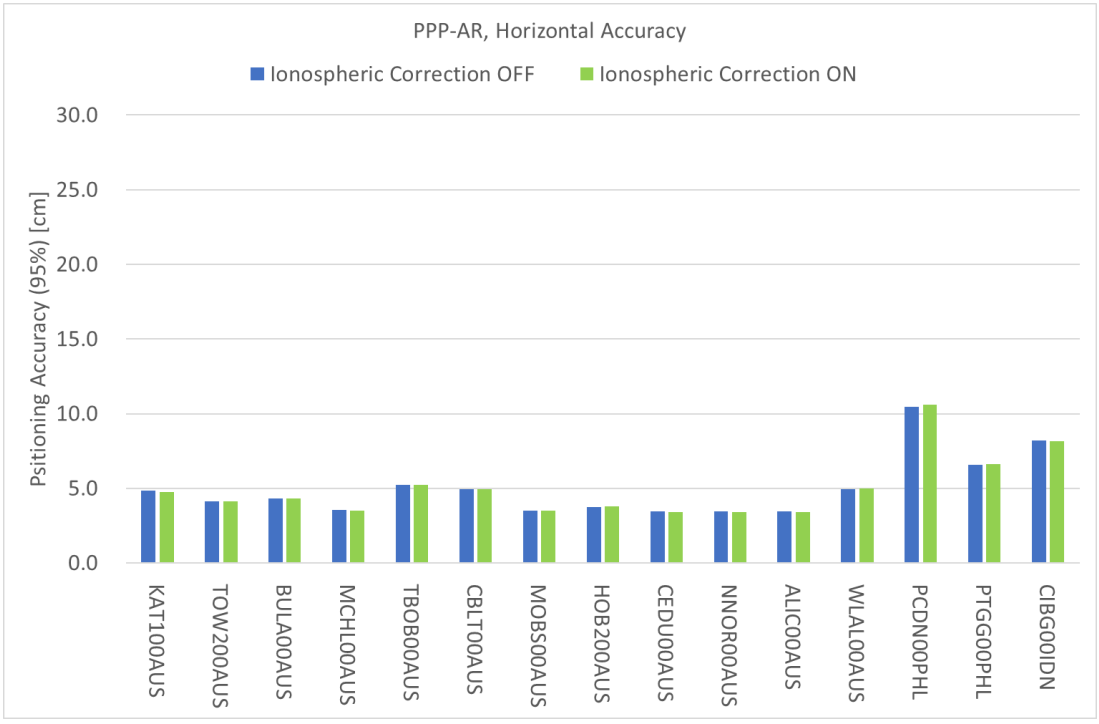

Figure 3.2-1 Horizontal Positioning Accuracy after Convergence (Asia and Oceania)

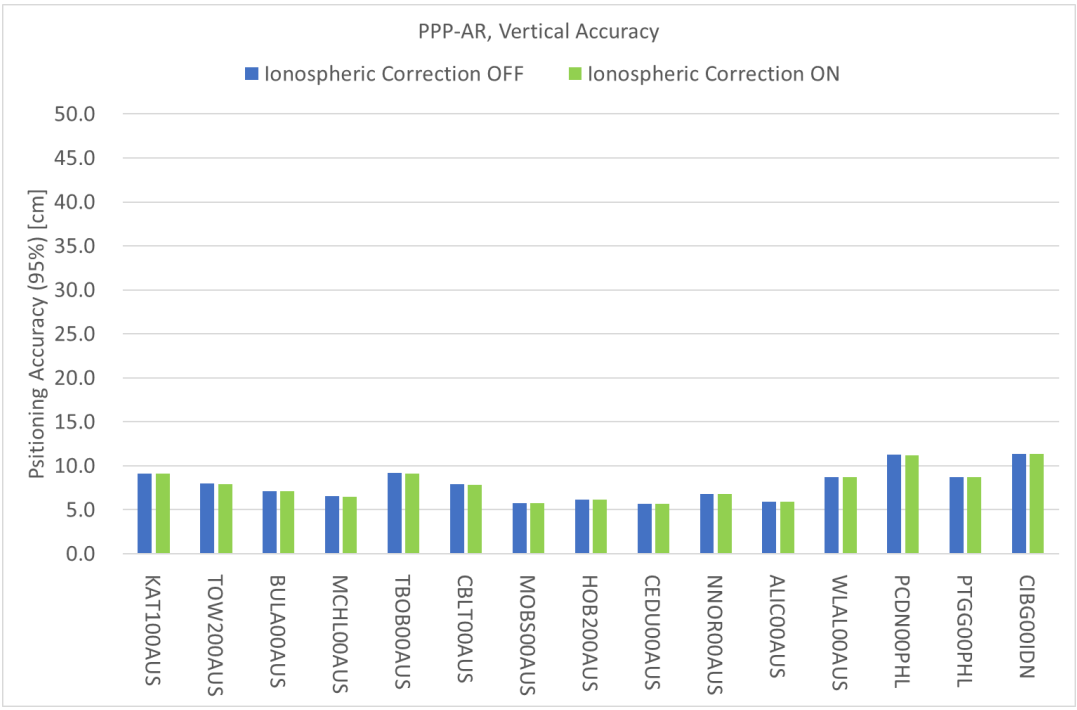

Figure 3.2-2 Vertical Positioning Accuracy after Convergence (Asia and Oceania)

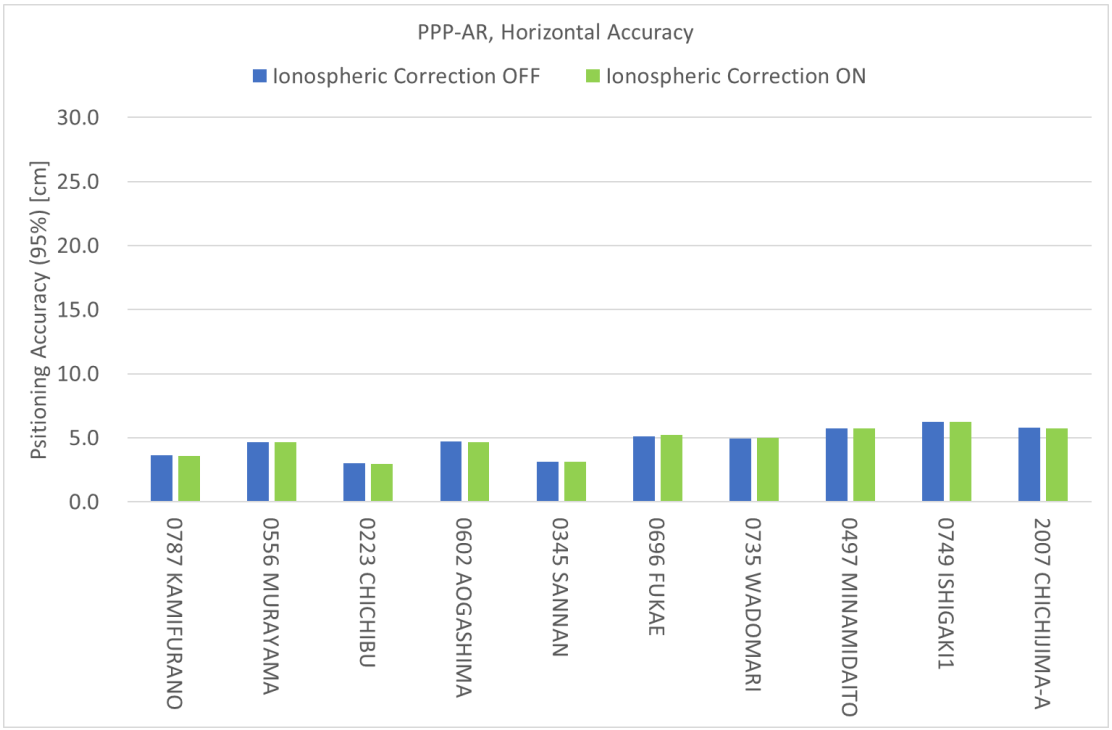

Figure 3.2-3 Horizontal Positioning Accuracy after Convergence (Japan)

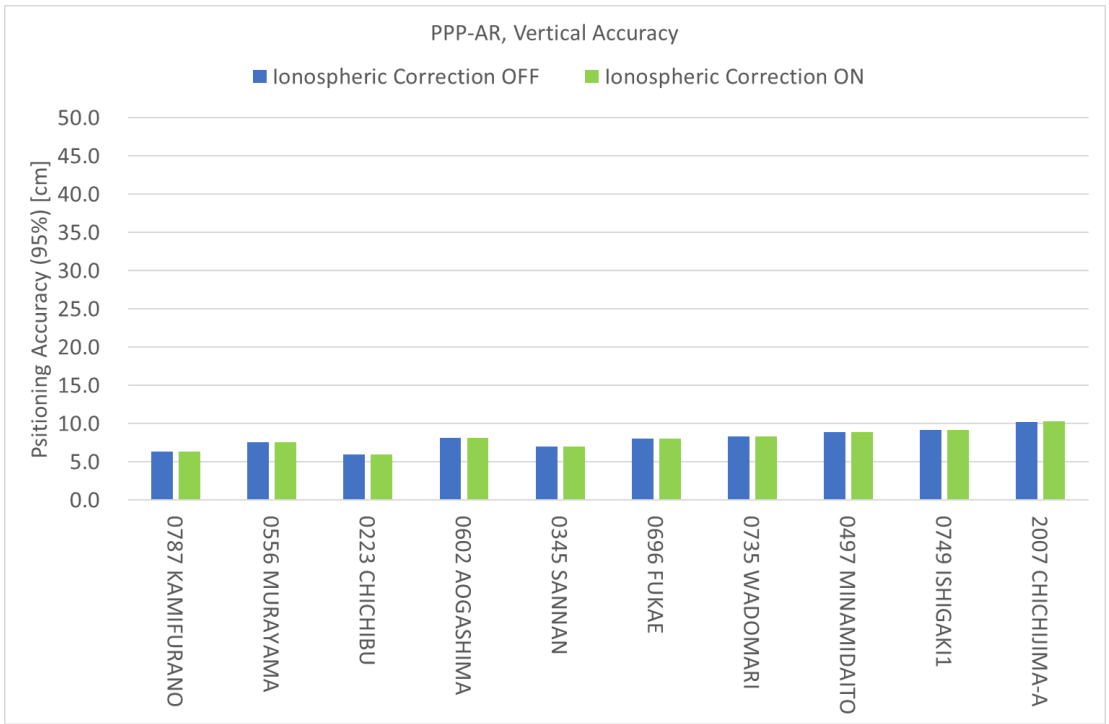

Figure 3.2-4 Vertical Positioning Accuracy after Convergence (Japan)

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

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1.1	KAT100AUS	OFF	3.8	5.1	5.1	5.8	5.4	4.0
		ON	3.7	5.1	5.1	5.5	5.1	4.0
1.2	TOW200AUS	OFF	3.3	4.2	4.3	4.0	4.4	4.7
		ON	3.3	4.2	4.3	4.0	4.2	4.7
1.3	BULA00AUS	OFF	-	-	4.3	4.3	4.4	4.3
		ON	-	-	4.3	4.3	4.4	4.3
1.4	MCHL00AUS	OFF	2.8	3.5	3.7	3.8	3.9	3.5
		ON	2.8	3.5	3.6	3.8	3.8	3.6
1.5	TBOB00AUS	OFF	-	-	4.6	4.9	5.9	5.4
		ON	-	-	4.6	4.9	5.7	5.8
1.6	CBLT00AUS	OFF	-	-	4.8	5.2	4.9	4.9
		ON	-	-	4.7	5.1	5.0	5.0
1.7	MOBS00AUS	OFF	2.8	3.6	3.8	3.6	3.8	3.5
		ON	2.8	3.6	3.7	3.6	3.8	3.5
1.8	HOB200AUS	OFF	-	-	3.9	3.7	3.8	3.7
		ON	-	-	3.9	3.7	3.8	3.7
1.9	CEDU00AUS	OFF	2.7	-	3.7	3.6	3.7	3.6
		ON	2.7	-	3.7	3.6	3.6	3.6
1.10	NNOR00AUS	OFF	3.2	3.5	3.5	3.5	3.6	3.2
		ON	3.2	3.5	3.5	3.5	3.5	3.2
1.11	ALIC00AUS	OFF	3.0	3.7	3.7	3.5	3.7	3.2
		ON	3.0	3.6	3.7	3.4	3.5	3.2
1.12	WLAL00AUS	OFF	4.0	4.4	5.4	5.2	5.9	4.9
		ON	4.0	4.4	5.4	5.2	5.9	4.9
2.1	PCDN00PHL	OFF	15.5	11.5	8.0	6.7	10.2	11.1
		ON	15.8	11.8	8.0	6.7	10.3	11.1
2.2	PTGG00PHL	OFF	9.0	6.1	5.9	5.3	6.1	7.1
		ON	9.0	6.2	5.9	5.3	6.2	7.1
3.1	CIBG00IDN	OFF	10.5	8.5	5.6	7.0	8.8	8.7
		ON	10.4	8.3	5.6	7.0	8.9	8.7

unit [cm]

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

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
1.1	KAT100AUS	OFF	8.4	9.4	9.3	9.5	9.4	8.8
		ON	8.4	9.4	9.3	9.4	9.4	8.8
1.2	TOW200AUS	OFF	6.2	7.9	8.3	9.3	8.2	8.1
		ON	6.2	7.8	8.2	9.2	8.2	8.1
1.3	BULA00AUS	OFF	-	-	7.9	6.9	7.3	6.5
		ON	-	-	7.8	6.8	7.3	6.5
1.4	MCHL00AUS	OFF	6.4	6.1	7.0	7.1	6.8	5.8
		ON	6.4	6.2	6.9	7.1	6.8	5.8
1.5	TBOB00AUS	OFF	-	-	8.4	8.9	10.8	8.6
		ON	-	-	8.4	8.7	10.5	8.8
1.6	CBLT00AUS	OFF	-	-	7.6	7.9	8.3	7.9
		ON	-	-	7.6	7.9	8.2	7.8
1.7	MOBS00AUS	OFF	5.6	5.8	5.7	5.9	6.3	5.4
		ON	5.6	5.9	5.7	5.8	6.3	5.4
1.8	HOB200AUS	OFF	-	-	6.5	5.8	6.3	6.1
		ON	-	-	6.5	5.8	6.2	6.0
1.9	CEDU00AUS	OFF	5.1	-	6.1	5.7	5.7	6.0
		ON	5.1	-	6.1	5.8	5.6	6.0
1.10	NNOR00AUS	OFF	5.8	6.2	6.7	7.8	7.3	6.8
		ON	5.8	6.2	6.7	7.8	7.2	6.8
1.11	ALIC00AUS	OFF	5.1	6.4	6.9	5.6	6.0	5.6
		ON	5.1	6.3	6.9	5.5	6.0	5.6
1.12	WLAL00AUS	OFF	6.9	7.1	9.3	9.1	11.1	8.9
		ON	6.9	7.1	9.3	9.1	11.0	8.9
2.1	PCDN00PHL	OFF	16.0	13.2	9.6	8.4	9.5	10.6
		ON	16.1	13.1	9.6	8.4	9.4	10.6
2.2	PTGG00PHL	OFF	11.3	9.0	7.8	7.0	8.7	8.7
		ON	11.3	9.1	7.8	7.0	8.7	8.7
3.1	CIBG00IDN	OFF	16.8	13.7	8.9	8.2	10.0	10.6
		ON	16.8	13.7	8.9	8.2	10.0	10.7

unit [cm]

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

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
4.1	0787 KAMIFURANO	OFF	3.3	3.5	3.7	3.5	4.0	4.0
		ON	3.2	3.5	3.7	3.4	3.8	3.9
4.2	0556 MURAYAMA	OFF	4.2	4.8	4.5	4.6	4.7	5.1
		ON	4.2	4.8	4.6	4.6	4.7	5.1
4.3	0223 CHICHIBU	OFF	3.2	3.0	3.0	3.1	2.8	3.0
		ON	3.2	3.0	3.0	3.1	2.8	3.0
4.4	0602 AOGASHIMA	OFF	5.0	4.6	4.2	4.6	4.9	5.2
		ON	5.0	4.6	4.1	4.4	4.8	5.1
4.5	0345 SANNAN	OFF	3.5	3.3	3.0	3.0	3.0	3.1
		ON	3.5	3.3	3.0	3.0	3.0	3.0
4.6	0696 FUKAE	OFF	5.2	5.1	4.6	4.9	5.4	5.6
		ON	5.2	5.0	4.9	5.0	5.6	5.7
4.7	0735 WADOMARI	OFF	5.5	5.1	4.4	4.7	4.8	5.1
		ON	5.5	5.1	4.5	4.8	4.9	5.1
4.8	0497 MINAMIDAITO	OFF	5.0	5.0	5.0	5.9	6.3	7.4
		ON	5.2	4.9	5.0	5.8	6.1	7.4
4.9	0749 ISHIGAKI1	OFF	6.7	5.8	5.6	5.9	6.4	7.1
		ON	6.7	5.7	5.6	5.9	6.4	7.1
4.10	2007 CHICHIJIMA-A	OFF	5.1	5.2	5.2	5.8	6.4	7.2
		ON	5.1	5.2	5.2	5.7	6.3	7.1

unit [cm]

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

#	Station	Ionospheric correction	2024			2025		
			Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
4.1	0787 KAMIFURANO	OFF	7.3	5.9	5.9	6.1	6.3	6.6
		ON	7.4	5.9	6.0	6.3	6.3	6.5
4.2	0556 MURAYAMA	OFF	7.1	6.4	6.3	7.9	8.9	8.9
		ON	7.1	6.4	6.3	8.0	8.9	8.9
4.3	0223 CHICHIBU	OFF	6.5	6.1	5.6	5.9	5.4	6.2
		ON	6.6	6.2	5.5	5.9	5.5	6.2
4.4	0602 AOGASHIMA	OFF	9.2	9.2	7.2	7.7	7.4	8.1
		ON	9.3	9.2	7.2	7.7	7.4	8.1
4.5	0345 SANNAN	OFF	6.7	7.0	6.6	7.2	6.8	7.6
		ON	6.7	7.0	6.6	7.3	6.9	7.6
4.6	0696 FUKAE	OFF	9.0	8.7	7.6	7.6	7.4	8.1
		ON	9.1	8.7	7.7	7.6	7.5	8.2
4.7	0735 WADOMARI	OFF	9.9	9.0	7.3	7.7	7.5	8.5
		ON	10.0	8.9	7.4	7.7	7.6	8.5
4.8	0497 MINAMIDAITO	OFF	10.6	9.8	8.0	8.5	8.2	8.4
		ON	10.7	9.7	8.1	8.4	8.2	8.5
4.9	0749 ISHIGAKI1	OFF	12.0	8.7	8.1	8.9	8.2	9.5
		ON	12.0	8.7	8.1	8.8	8.2	9.5
4.10	2007 CHICHIJIMA-A	OFF	10.2	10.6	10.4	10.2	9.6	10.7
		ON	10.3	10.6	10.5	10.2	9.6	10.7

unit [cm]