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PILOT EXPERIMENT OF MADOCA-PPP FOR BASE POINT INSTALLATION IN A REMOTE ISLANDS OF THE PHILIPPINES

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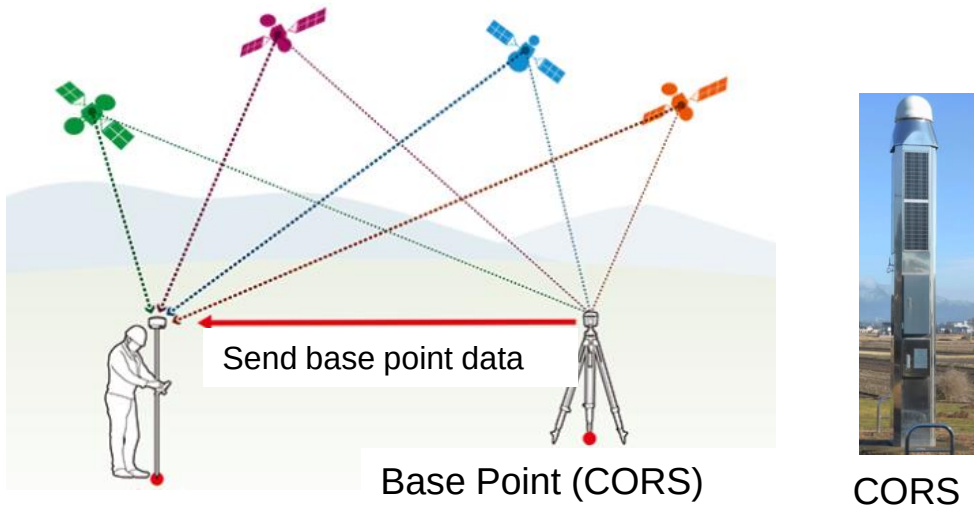
Purpose of the pilot experiment in the Philippines

The purpose

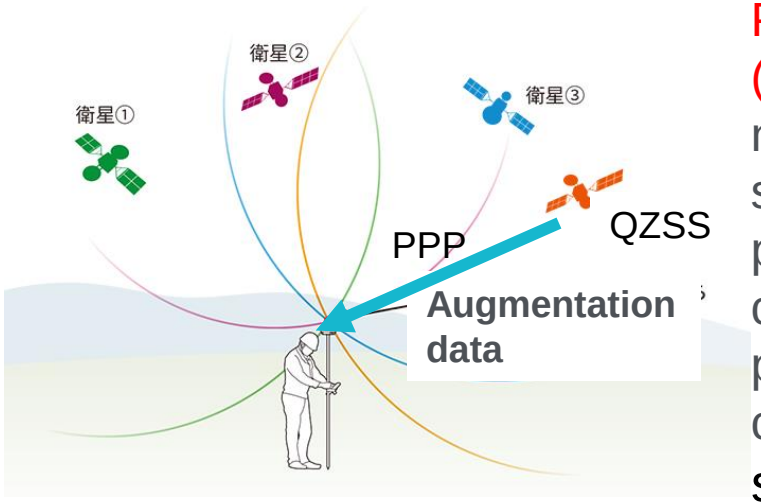
(1) Verify that MADOCA-PPP is the most effective tool for surveying remote islands where any relative positioning is not available.
(2) "Technical guideline" will be enable accurate national mapping projects to be developed for remote islands.

Single Point Positioning (SPP) is the most basic form of GNSS surveying, where a single receiver collects satellite signals to determine its position.



CORS

Relative positioning (RTK, STATIC, Network-RTK)



Stand alone positioning (SPP , PPP)

Precise Point Positioning (PPP) is a global navigation satellite system (GNSS) positioning method that calculates very precise positions with error correction data of satellite clock, orbit and signal bias (code/phase)

Technical guideline for using MADOCA-PPP

Positioning

The technical guideline will provide sufficient technical support for application to surveying methods on remote islands where we cannot use relative positioning by GNSS and will be made **open to the public with the verification results.** When any country adopts it, it will be customized depending on the country's situations.

Required Accuracy

Horizontal: SD 5 cm (CE95 10 cm)　Vertical : SD 10 cm (CE95 20 cm)

Points of technical guideline

verification

Convergence condition : Indicate the convergence condition of the positioning solution to satisfy the required accuracy.
(Acceptance criteria : Indicate the acceptance criteria for positioning solutions obtained during convergence.

Conversion to reference coordinate : Add correction amount of crustal deformation
Elevation calculation : Use the regional geoid model provided by the International Geoid Project

Draft.: Measure 2 sets for 30 minutes and check the deference between 2 sets

Domestic (Japan) verification experiment

* Verification1
- 72 hours was conducted
- Comparative verification using true cordinates by statistics .

* Verification2
- Two methods of MADOCA-PPP and RTX are observed for 40 minutes x 10 times (50 times) at 5 locations (accutually 46sets due to restart trable) with different environments *
- Statistical arrangement of convergence time and solution stability.

(1) Equipment

1) GNSS receiver

・Trimble Alloy (S/N : ①6141R40139、②6141R40178、③6205R40073)

・Core Cohac∞ TEN+ (S/N : ①D900-00530、②D900-00531、③D900-00532)

※Positioning Signal : GPS、QZSS、GLONASS、Galileo

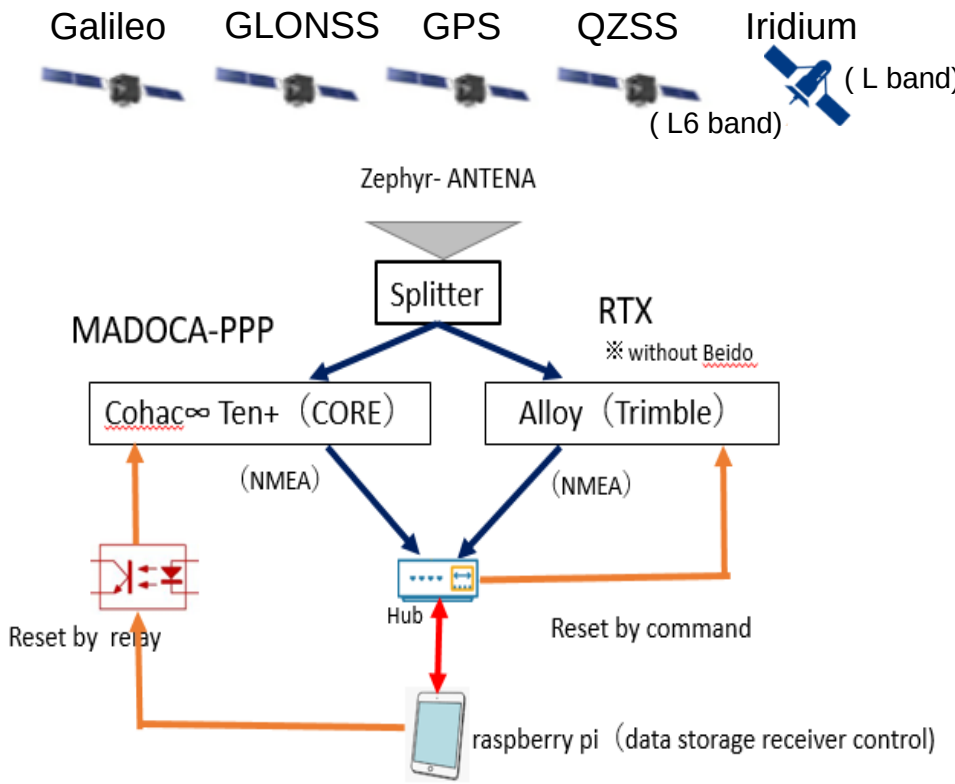
2) GNSS Antena

・Trimble Zepher Geodetic2 (S/N : ①5000114042)

・Trimble Zepher Geodetic3 (S/N : ①1430767526、②6122223912、③612223902)

3) Splitter

・INSTOCK Wireless Components GPS420 3unit



Measurement system for Baseline test points of GSI

72 hours observation (calculation of antenna position)

- Observations were conducted for 72 hours from August 4, 2023 , 9:00 JST (UTS 0:00) to August 7, 2023 , 9:00 JST .
- In order to obtain true coordinates, the current coordinates of the reference antenna position were calculated from baseline analysis using with 3 CORS from GSI (including practical network average calculation).

Table Using CORS and R5 solution coordinates

point name	R5 release date	Latitude (dms)	Longitude (dms)	Ellipsoid height (m)
Tsukuba (92110)	2023-07-28	360622.0052	1400513.9299	70.357
Ishishita (960583)	2023-07-28	360653.3240	1395553.4388	67.656
Ami (960584)	2023-07-28	360152.8146	1401208.8408	70.902

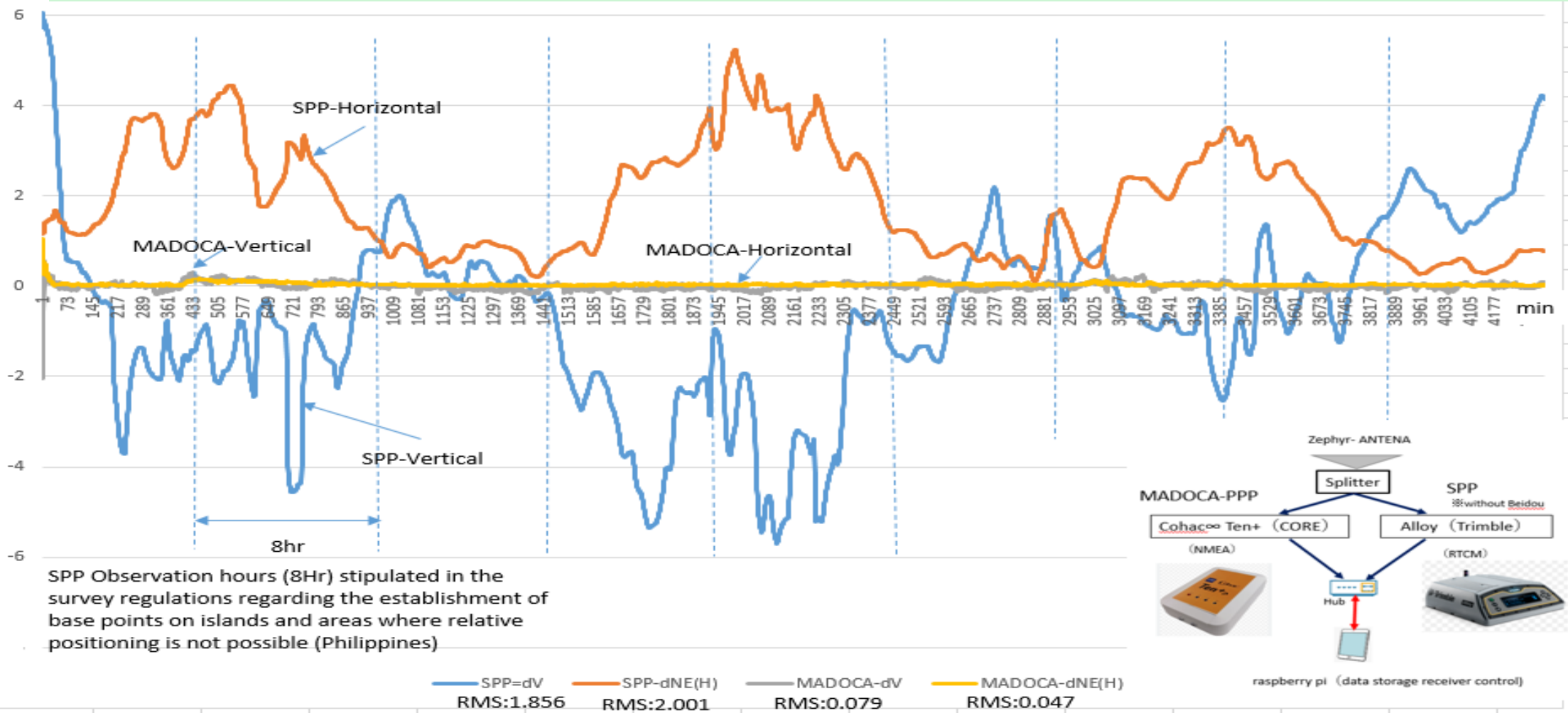
Table. Practical network average results

Observation date	Latitude (dms)	Longitude (dms)	Ellipsoid height (m)
2023-08-04	360545.1100	1400638.3995	74.6669
2023-08-05	360545.1099	1400638.3994	74.6700
2023-08-06	360545.1099	1400638.3996	74.6705
average	360545.1100	1400638.3995	74.6702

Figure 2. Observation situation o

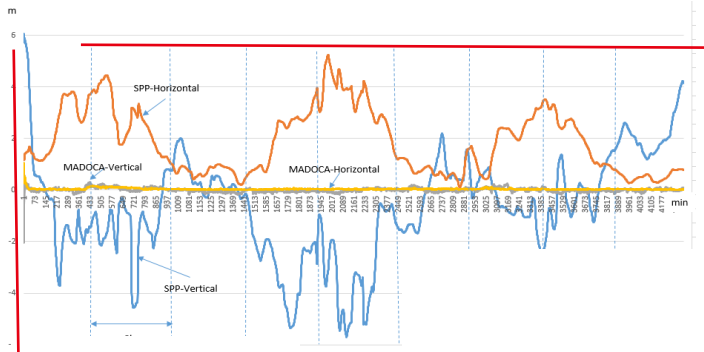
Results of 72 hours observation

- SPP has a periodicity of approximately 24 hours and is less stable than PPP
- PPP (the graph below is MADOCA-PPP) is stable after initial convergence

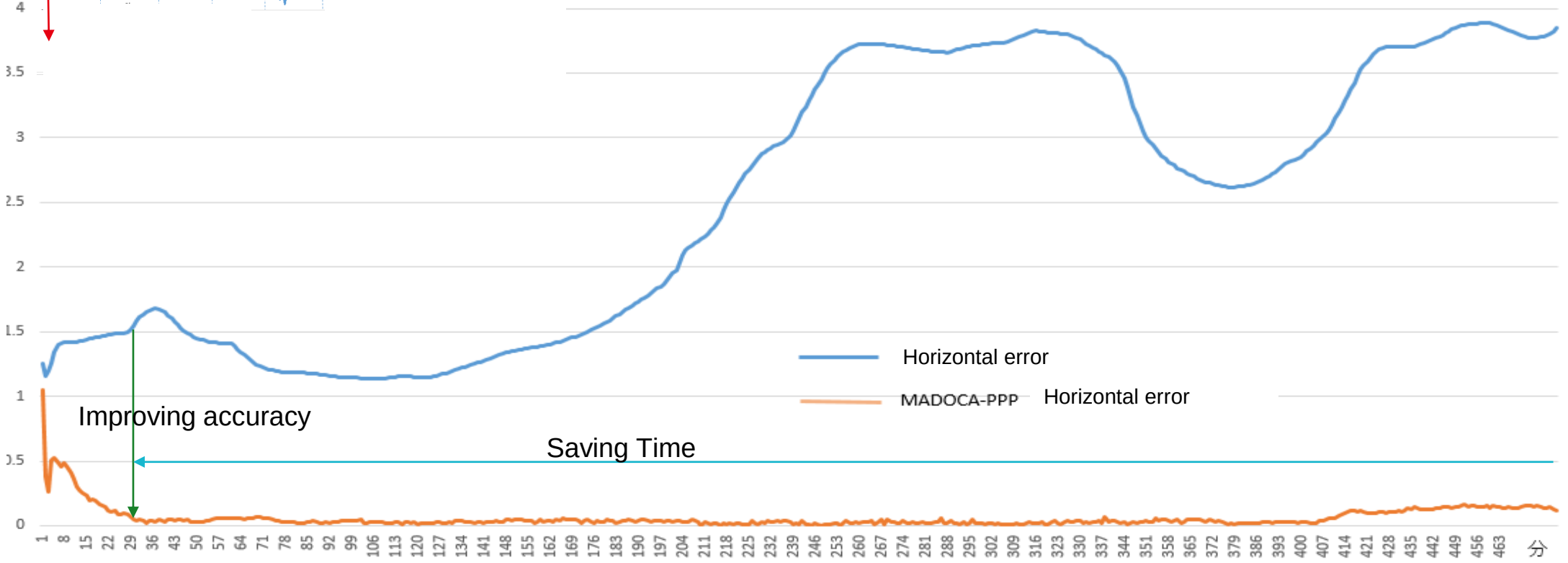


SPP Observation hours (8Hr) stipulated in the survey regulations regarding the establishment of base points on islands and areas where relative positioning is not possible (Philippines)

Results of the first 8 hours /72 observation



This graph is an expanded version of the first 8 hours.
Compared to the 8-hour observation period, the time reduction of 7 hours and 30 minutes and the significant improvement in accuracy are clearly shown.



Baseline field (5 locations) observation

- Observations were conducted using the Geospatial Information Authority of Japan's baseline field.
- MADOCA-PPP and RTX simultaneous observation for 40 minutes
- Baseline field coordinates are current period coordinates

Fig. Observation status of baseline field

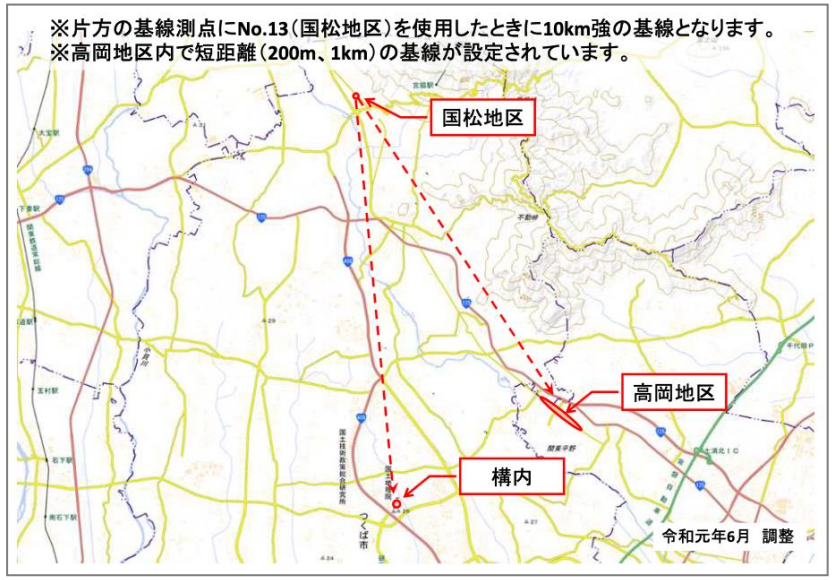


Figure . Baseline field location

Table . Baseline field measurement points and result values used

	Takaoka No.1	Takaoka No.5	Takaoka No.10	Premises No.11	Kunimatsu No.13
Latitude (dms)	360738.44422	360745.1723	360759.2594	360620.43868	361253.06302
Longitude (dms)	1400834.80801	1400824.39256	1400802.58220	1400515.56917	1400415.79012
Ellipsoid height	47.791	48.312	49.339	66.928	67.473
X	-3959304.313	-3959043.864	-3958498.440	-3957208.496	-3950773.565
Y	3305446.372	3305568.201	3305823.233	3310188.480	3306752.347
Z	3739642.260	3739810.066	3740161.366	3737711.257	3747482.290

Baseline field observation results

- Time series plots were created from the results obtained for each set (46) . Right side figure shows the results of Takaoka No. 1 's first set .
- As trend, it can be seen that all positioning results fluctuate immediately after the start of observation, but converge over time.
- Snapshots of the horizontal distribution of each data are shown in Figures.
- MADOCA solution, we obtained results that both 2σ and RMS were below 10cm in about 25 to 30 minutes .

46 sets at 5 locations

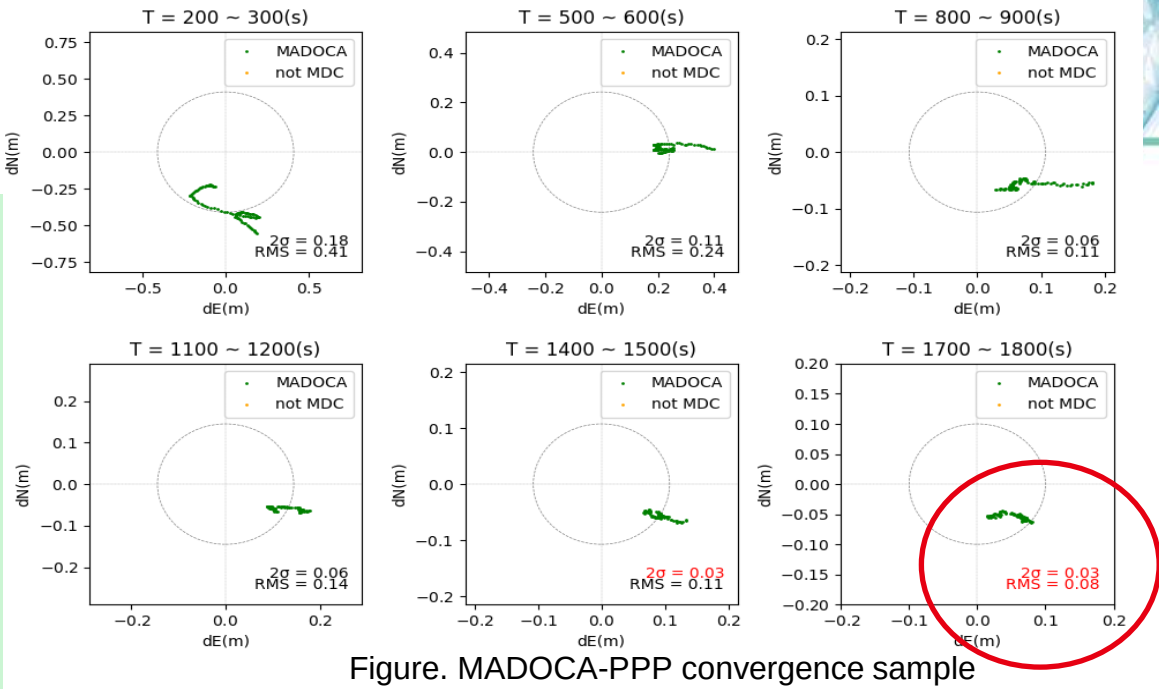


Figure. MADOCA-PPP convergence sample

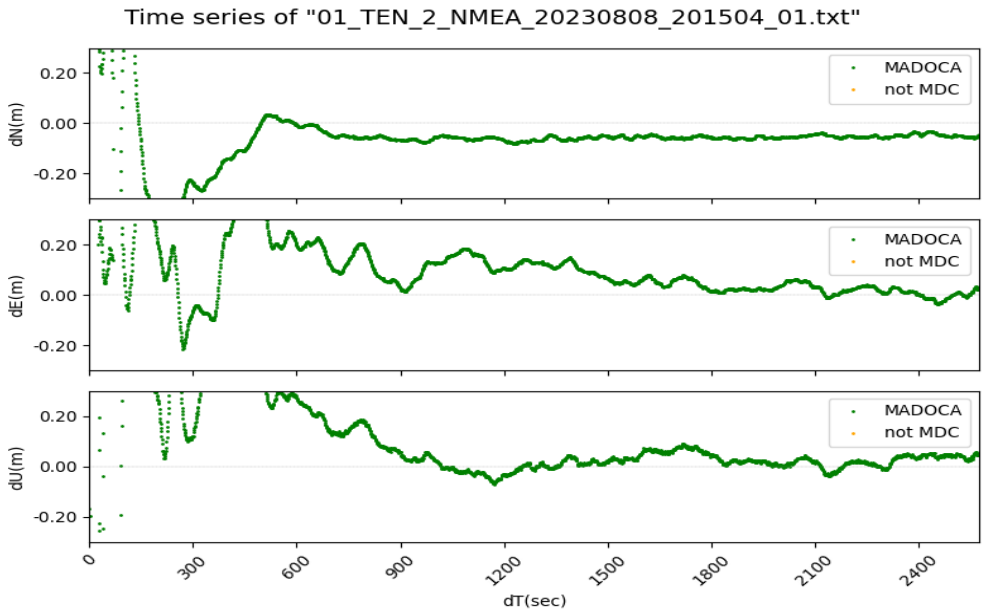
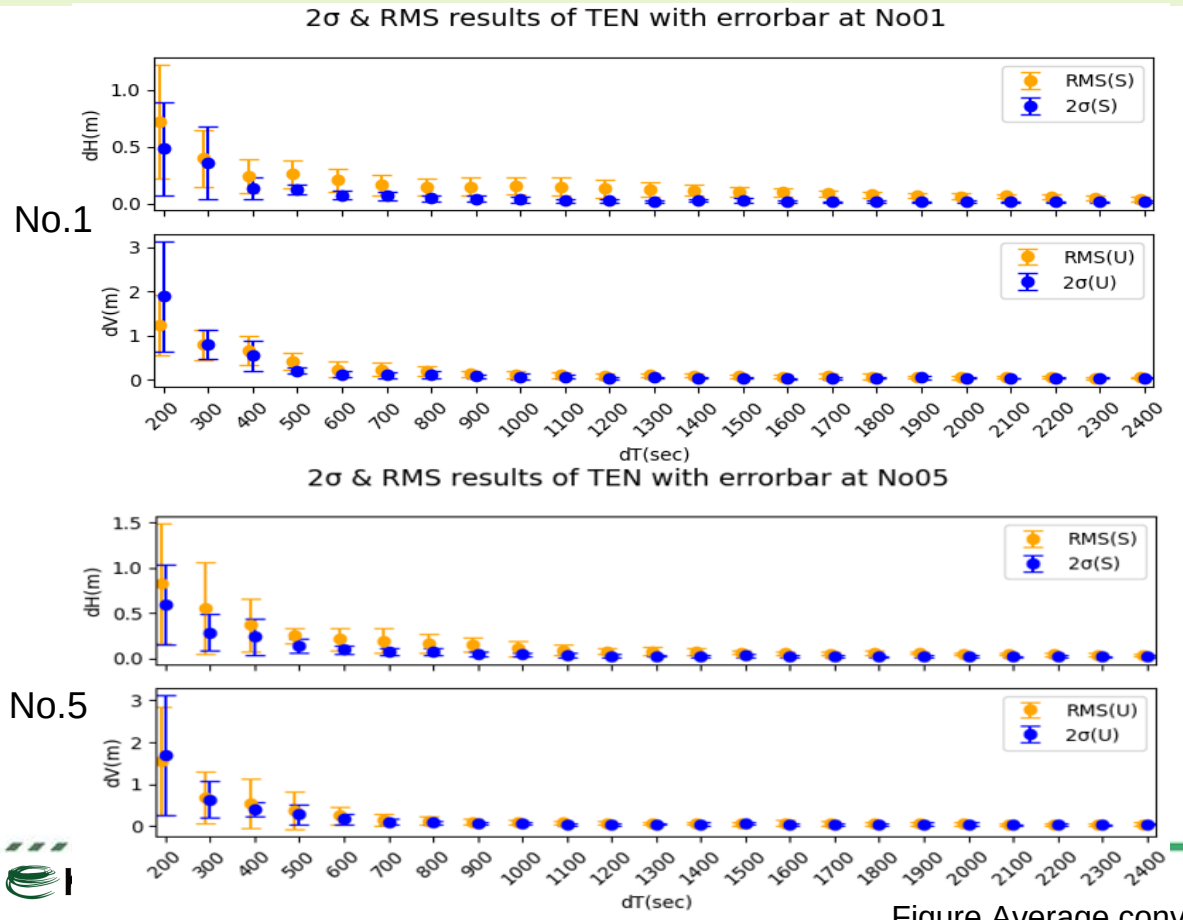


Figure . RTX convergence sample

Figure 6. MADOCA-PPP and RTX time series convergence sample

Baseline field observation results

- MADOCA solutions obtained at each station were divided into 100-second intervals, and 2σ and RMS were calculated and evaluated . Error bars indicate the standard deviation (8～10 sets) from the mean value. From this result, statistically speaking, we also obtained evidence that convergence stable time for 8 ～ 10 sets of observation



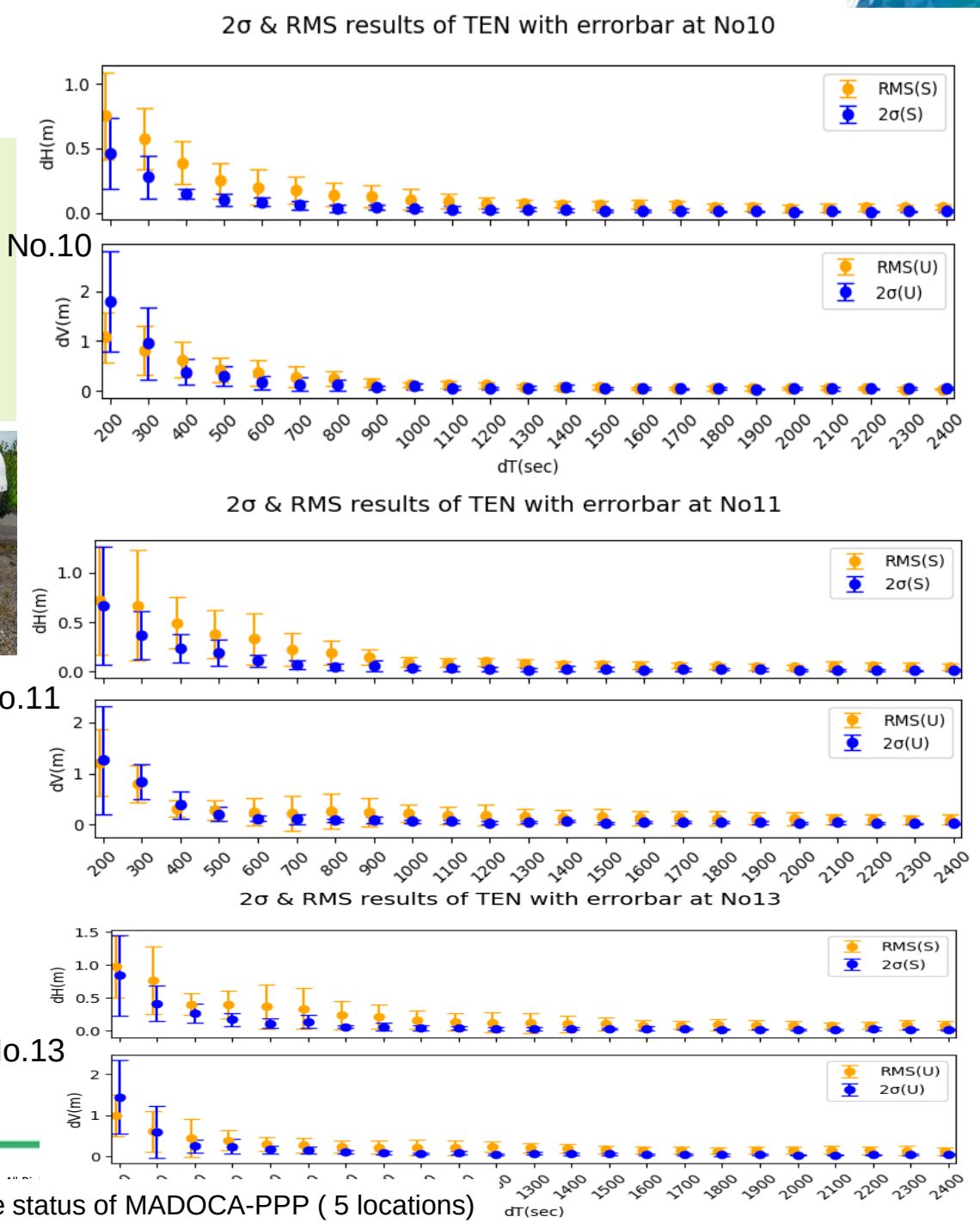


Figure Average convergence status of MADOCA-PPP (5 locations)

Conclusion based on statistical data

- The reference measurement time was determined from the convergence time distribution for each
- With TEN +, the CE95 value for which the RMS is 10 cm or less horizontally is 30 minutes: 1800SEC , and even if the RMS is 20 cm or less in the vertical direction.

Conclusion: Observation time of 10 cm horizontally and 20 cm vertically (CE95) is 1800sec

Statistically, if you measure it for 1800 seconds, there is a 95% provability that horizontal accuracy will be less than 10 cm.

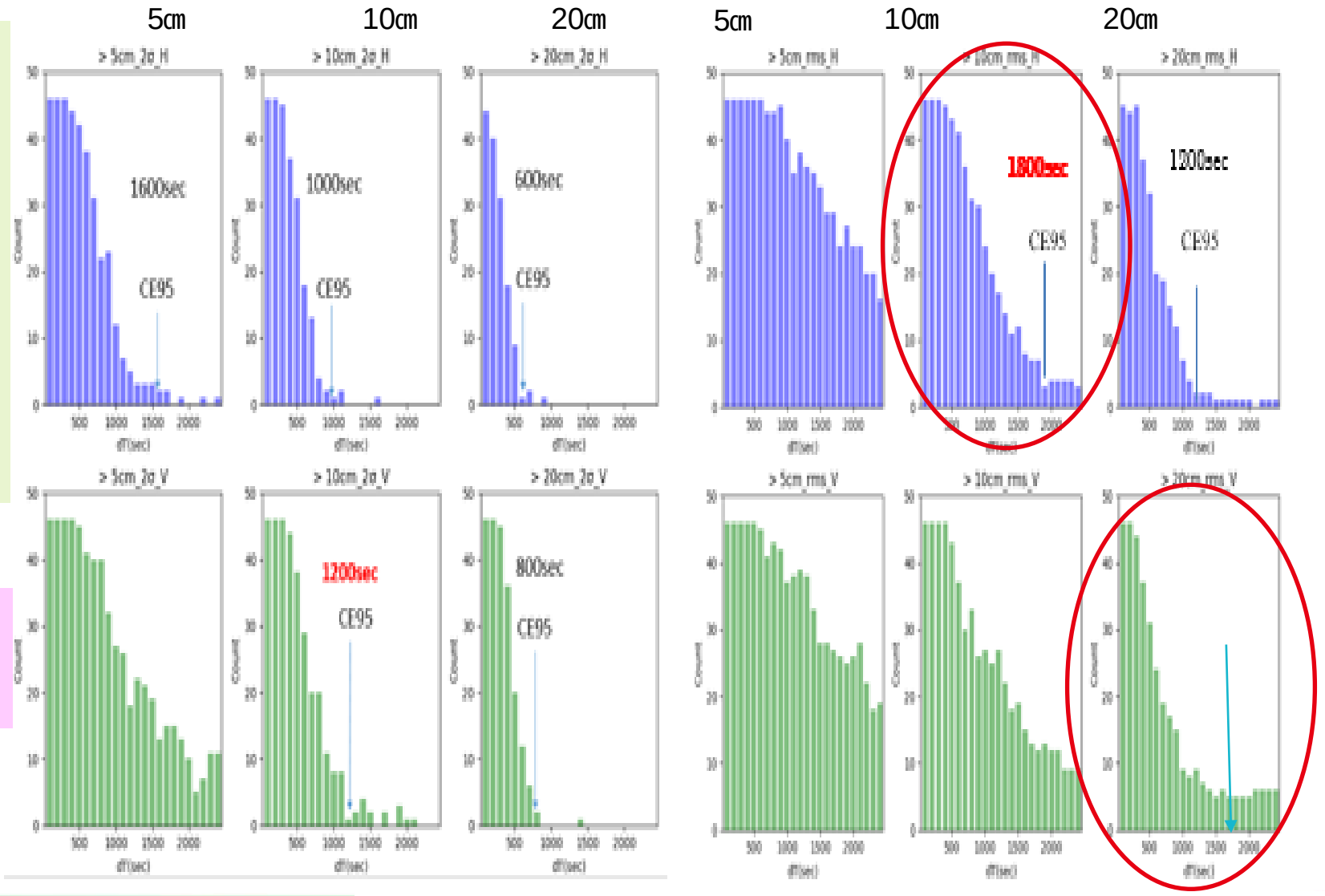


Figure . Number of sets by accuracy and convergence time

MADOCA-PPP Technical guideline (outline)

How to install base points using MADOCA-PPP in areas where relative positioning is not possible

Technical guideline (DRAFT)

Ver.1.0

On the way

1) Number of observations , data acquisition interval

Observation time	Data acquisition interval
One set of 100 epochs with 1700 or more epochs after the start of observation. Two sets of observations will be conducted.	1 second

remarks 1. After completing the first set of observations, reinitialize and perform the second set of servations .

2) Observation conditions

messenger for Mamoru Star	QZSS , GPS , GALILEO and GLONASS satellite
minimum altitude angle	15 ° is standard
number of satellites	10 more than a satellite

remarks 1. Use a tripod or antenna pole to position the antenna .
2.Obtain satellite flight forecast information and check the number of satellites

3) Evaluation

Number of evaluation unit	2 Sets
Evaluation method	Difference between sets
Standerd Accuracy	100 mm or less (200mm or less for height)

remarks 1. The addapted coordinates values are the average values obtained from two sets of observations

ΔN is the difference in the north-south direction of the horizontal plane, and ΔE is the difference in the east-west direction of the horizontal plane.

Verification of technical guidelines

Comparison between sets was performed as one set (100 epochs: 1701-1800).

Field	Set No.	ΔN average residual (m)	ΔE average residual (m)	ΔU average residual (m)	ΔNE(m)	ΔN - difference between sets (mm)	ΔE - difference between sets (mm)	ΔU - difference between sets (mm)	Difference accuracy judgment
1	1	-0.0540	0.0516	0.0694	0.0759				
	2	0.0230	-0.0582	-0.0613	0.0633	77.0	-109.9	-130.7	△
	4	-0.0270	-0.0036	0.0099	0.0354	-50.0	54.7	71.2	○
	6	-0.0685	0.0661	0.0524	0.0954	-41.5	69.7	42.4	○
	7	-0.0607	-0.0681	0.1948	0.0915	7.8	-134.2	142.4	△
	8	0.0055	0.0578	-0.0305	0.0585	66.2	125.9	-225.3	△
	9	-0.0448	-0.1017	0.0446	0.1113	-50.3	-159.5	75.1	△
5	1	-0.0093	-0.0827	-0.0206	0.0834				
	2	-0.0155	0.0361	0.0455	0.0406	-6.2	118.8	66.1	△
	3	0.0232	0.0295	0.0254	0.0399	38.7	-6.6	-20.1	○
	4	-0.0282	0.0951	0.0882	0.0993	-51.4	65.6	62.8	○
	5	-0.0154	0.0486	0.0067	0.0520	12.8	-46.5	-81.5	○
	7	0.0096	-0.0506	-0.0289	0.0519	25.0	-99.2	-35.6	○
	8	-0.0198	0.0559	-0.0395	0.0597	-29.4	106.6	-10.6	△
	9	0.0101	0.0233	0.1289	0.0255	29.8	-32.7	168.4	○
	10	-0.0069	-0.0128	-0.0367	0.0205	-17.0	-36.1	-165.7	○
10	1	-0.0341	0.0322	0.0275	0.0487				
	2	0.0107	0.0612	0.0582	0.0628	44.8	29.0	30.7	○
	3	-0.0132	-0.0218	-0.0085	0.0312	-24.0	-83.0	-66.6	○
	4	-0.0175	-0.0506	0.0559	0.0539	-4.2	-28.9	64.4	○
	5	-0.0471	0.0139	-0.0128	0.0495	-29.6	64.5	-68.7	○
	6	0.0365	-0.1059	-0.0427	0.1126	83.5	-119.7	-30.0	△
	7	-0.0297	-0.0202	-0.0604	0.0368	-66.2	85.7	-17.7	○
	8	0.0106	0.0138	-0.0256	0.0176	40.3	34.0	34.8	○
	9	0.0060	-0.0218	0.0028	0.0255	-4.5	-35.6	28.4	○
	10	-0.0384	-0.0412	0.1643	0.0595	-44.4	-19.4	161.5	○
11	1	-0.0167	0.0847	0.0239	0.0864				
	2	0.0568	0.0577	-0.2737	0.0815	73.6	-27.0	-297.6	△
	3	-0.0077	-0.0395	-0.0377	0.0435	-64.5	-97.2	236.0	△
	4	0.0128	0.0345	-0.0547	0.0380	20.4	74.1	-17.0	○
	5	-0.0601	0.0363	0.0409	0.0704	-72.9	1.7	95.6	○
	6	0.0084	0.0106	-0.4170	0.0157	68.5	-25.6	-457.9	×
	7	-0.0825	-0.1235	0.8394	0.1485	-90.8	-134.2	1256.4	×
	9	0.0181	0.0056	0.0573	0.0224	100.5	129.1	-782.1	×
	10	-0.0599	-0.0807	-0.1450	0.1011	-78.0	-86.3	-202.3	△
13	1	0.0025	0.0625	-0.0607	0.0642				
	2	0.0093	0.2897	-0.0300	0.2900	6.8	227.2	30.7	○
	3	-0.0024	0.1215	-0.2070	0.1217	-11.7	-168.2	-177.0	△
	4	0.0309	-0.0335	-0.1035	0.0468	33.3	-155.0	103.5	△
	5	0.0340	0.0340	0.0340	0.0340	3.1	67.5	137.5	○
	6	0.0199	-0.0230	-0.1698	0.0305	-14.1	-57.0	-203.8	△
	7	-0.0089	-0.0286	0.0361	0.0319	-28.8	-5.6	205.9	△
	8	0.0067	-0.0371	-0.2265	0.0384	15.6	-8.5	-262.6	△
	9	0.1026	0.0864	-0.1822	0.1343	95.9	123.5	44.3	△
	10	0.0511	0.0537	0.2105	0.0742	-51.5	-32.7	392.7	○
10cm less									○
		97.8%	91.1%	88.9%		97.8%	73.3%	77.8%	53%
20cm less									○△
		100.0%	97.8%	97.8%		100.0%	100.0%	93.3%	93%

Work in island

Basic policy for overseas demonstrations

1. Understanding and promoting the use of MADOCA-PPP
2. Practice of

ocean remote island

* Target islands **:** Maricaban (base point) - Balahibong Manok Island (mapping)
* Base point set up in Pisa, Maricaban Island (MADOCA-PPP & 8 hour measurement)
* Surveying Balahibong Manok Island from the base point using RTK (satellite image control point)
* Single point survey conducted using MADOCA-PPP for verification (backup of RTK)

* DTM has purchased data from aircraft SAR and obtained a quotation for satellite images.

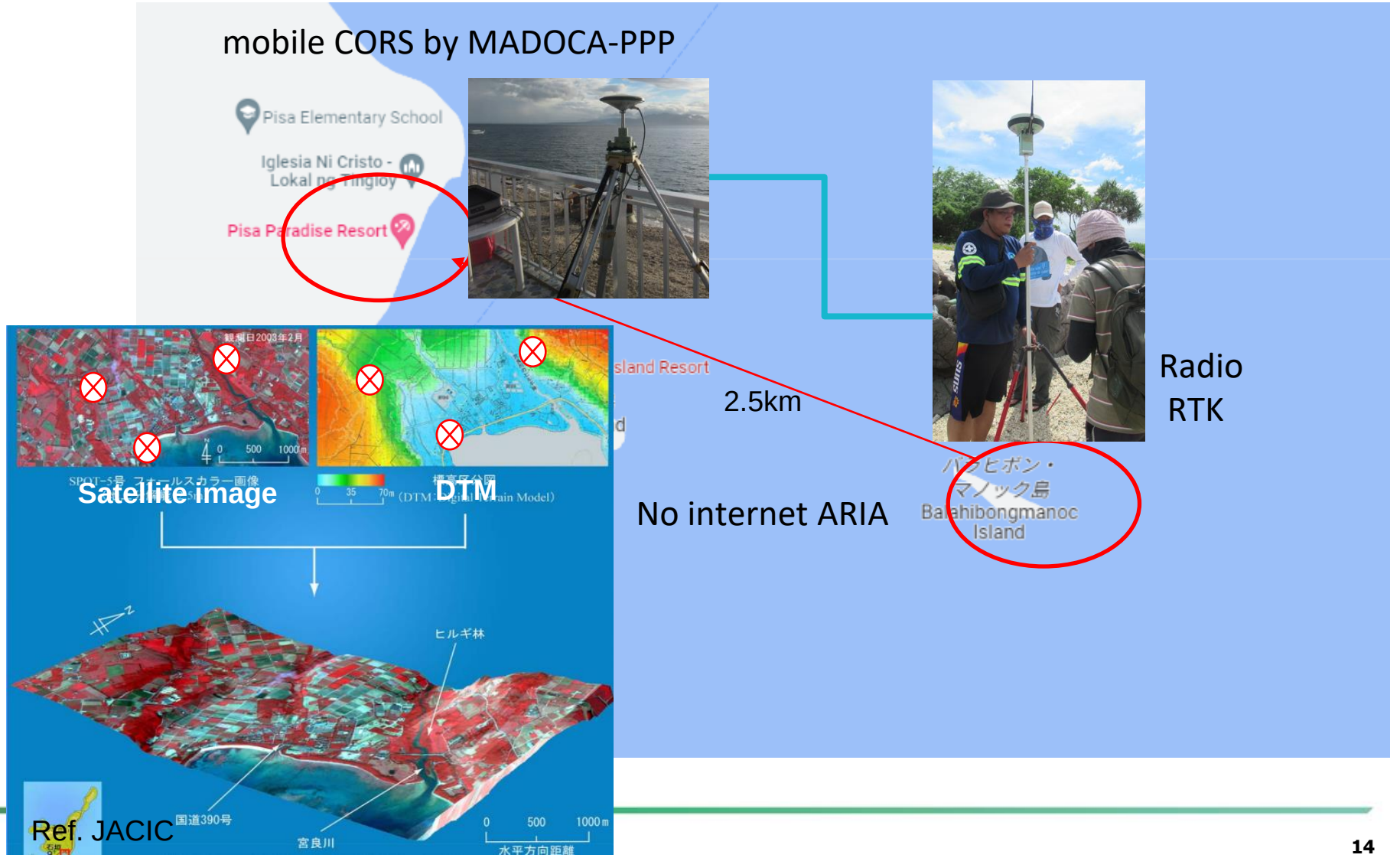
Figure 11. Location of overseas remote island demonstration

Pilot experiment as more practical survey methods

In areas where relative positioning from CORS is not possible, it is more efficient to determine just one point using PPP and perform RTK from this point than to measure all survey points using PPP.

・Establish a temporary base point in PISA. (SPP 8 hours measurement and PPP)
・RTK will be performed through simultaneous observation of the signal at this base point and the rover.
・We will also carry out MADOCA-PPP observation to confirm the difference with RTK.

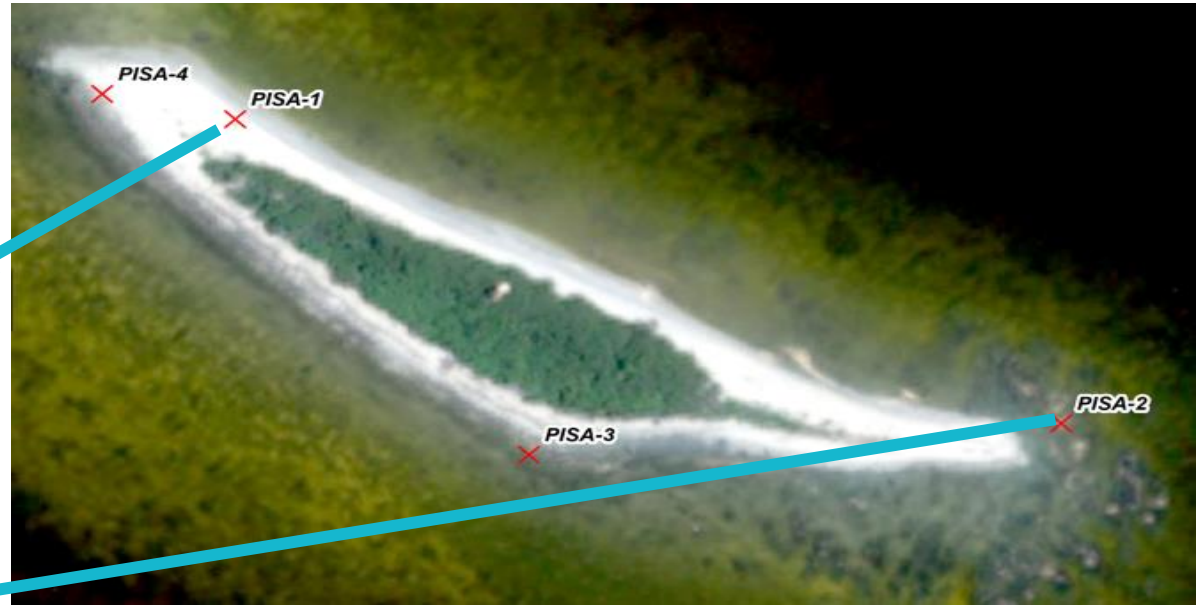
“PPP+RTK” is the best geocoding method for making control points, such as overlay satellite images and aircraft SAR DTM.



Ref. JACIC

Result of RTK and MADOCA-PPP

WGS 84		
Point ID	Longitude	Latitude
PISA (BASE)	120 56 39.5581	13 38 07.9388
PISA-1	120 57 52.1355	13 37 39.9708
RTK-1(10)	120.9644821	13.62776969
MADOCA-PPP	120.9644818	13.6277698
誤差	2.83333E-07	-1.05556E-07
誤差(cm)	3.073732799	-1.167766489
PISA-2	120 58 00.0190	13 37 36.7516
RTK-2(10)	120.9666719	13.62687544
MADOCA-PPP	120.9666709	13.6268757
誤差	1.04444E-06	-2.55556E-07
誤差(cm)	11.33062279	-2.827224161
PISA-3	120 57 55.3328	13 37 35.9233
PISA-4	120 57 50.1463	13 37 40.6224



Ref. JACIC

Establishment of new digital society using GNSS and Geospatial information

Communications Satellites/ IoT & VDES satellites

GNSS Satellites, QZSS

microsatellites Optics,Highper & SAR Constellation

MADOCA-Augmentation data

Local augmentation data Upload from JAPAN

・SNS Data
・IoT, AI, Big Data
・Administrative data
・Mobile data

CORS

High-Precision Positioning Data Center

・World Geodetic system
・MADOCA augmentation
・Network-RTK
・PRS92

Geospatial information Platform

Provision of services by the private sector

Shipping	transportation		logistics	Infrastructure Management	Surveying & Maps	agriculture	Construction & Urban Planning
Safe navigation	Suspicious vessel, illegal fishing vessels	Traffic congestion alleviation, autonomous driving	Smart Transportation	Improving Logistics Efficiency & automation	Ensuring safety Cost Savings	Maps & nautical charts Remote Island Survey	GNSS Guidance Agri-robot	i-Construction (Machine Control)

Designing the future of people, communities and planet by connecting the dots

KOKUSAI KOGYO