Performance Evaluation and A New Disaster Prevention System of Precise Point Positioning at Sea

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Motivation

- **Sea Buoys**

Previous Research :

Teruyuki Kato, "GNSS buoy array in the ocean for natural hazard mitigation", 2015 AGU Fall Meeting, 2015.12.

Limitation of Sea Buoys :

Construction Costs and Period / Power Ensure / Maintenance

Improvements in This Research :

Tsunami Detection using Ships

→① Increase of Analysis Data

② Observation of Higher Accuracy Sea Level Fluctuations

Motivation

- **Tsunami Detection using Ships**

Previous Research :

Ryuta Nakasone and Nobuaki Kubo, "New Approach for Tsunami Detection Based on RTK-GNSS Using Network of Ships", ION GNSS 2012, 2012.9.

Limitation of Previous Research :

- **Analysis of Anchoring Ships in the Bay**
- **Consideration of the Application in Ships using PPP(Precise Point Positioning)**

Objective

Our Objective is to verify the performance on board

and

consider new utilization of PPP.

1. We verified the performance of PPP on the ship.

2. We proposed a disaster preventing system using ships in the anchorage instead of sea buoys and applying PPP.

High Accuracy of Single Positioning

- It requires accurate estimation of various errors.

Various Errors	Features
①Precise Orbit and Clock	Precise orbit provides the satellite position accuracy of less than 10cm. Precise clock provides the clock correction accuracy of less than 0.1ns (about 3cm).
②Ionosphere Free Combination	We apply an appropriate coefficient to dual-frequency carrier phase. It is possible to clear the large part of the impact of the ionosphere.
③Global Ionosphere Distribution Map (IONEX)	It is possible to correct by describing the VTEC (Vertical Total Electron Content) of the ionosphere in the form of two-dimensional grid.
④Troposphere Delay Estimation	We perform the calculation by the model. Troposphere delay in zenith direction is to use the expression of Saastamoinen.
⑤Satellite Code Bias	Different types of code and frequency cause the different hardware bias. We have to consider these bias.
⑥Position Calculation	We used the method of least squares.

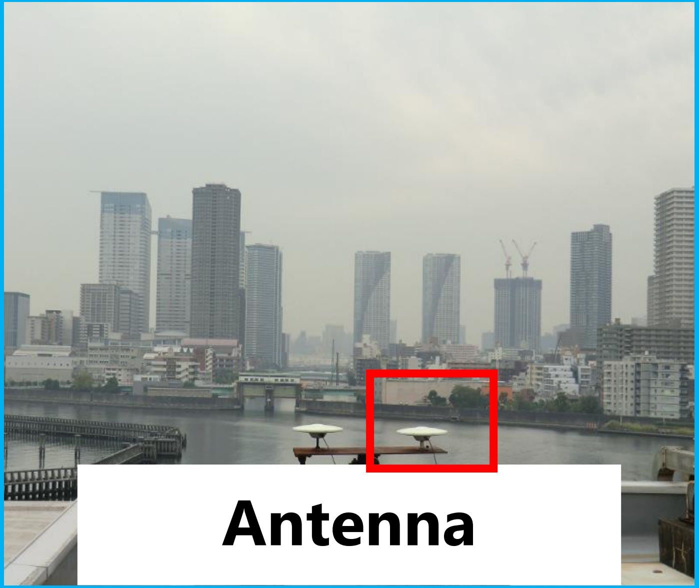
High Accuracy of Single Positioning

Receiver	Trimble NetR9
Antenna	Trimble Zephyr Geodetic 2
Satellites	Case 1. and Case 2. GPS,QZSS Case 3. GPS,QZSS,GLONASS
Frequencies	Dual-Frequency (L1 and L2)
Experimental Hour	24 hours
Positioning Interval	1 Hz
Elevation Mask	15 deg
CN(Carrier to Noise) Threshold	30 dB
Precise Orbit and Clock	Case 1. and Case 2. QZSS Final Case 3. MADOCA real-time product
Ionosphere Estimation	Case 1. Klobuchar Model Case 2. Ionosphere Free Case 3. PPP

Case 1. and Case 2. used only pseudo-range (code).

Experimental Place :

The Fixed Point of Land at our university

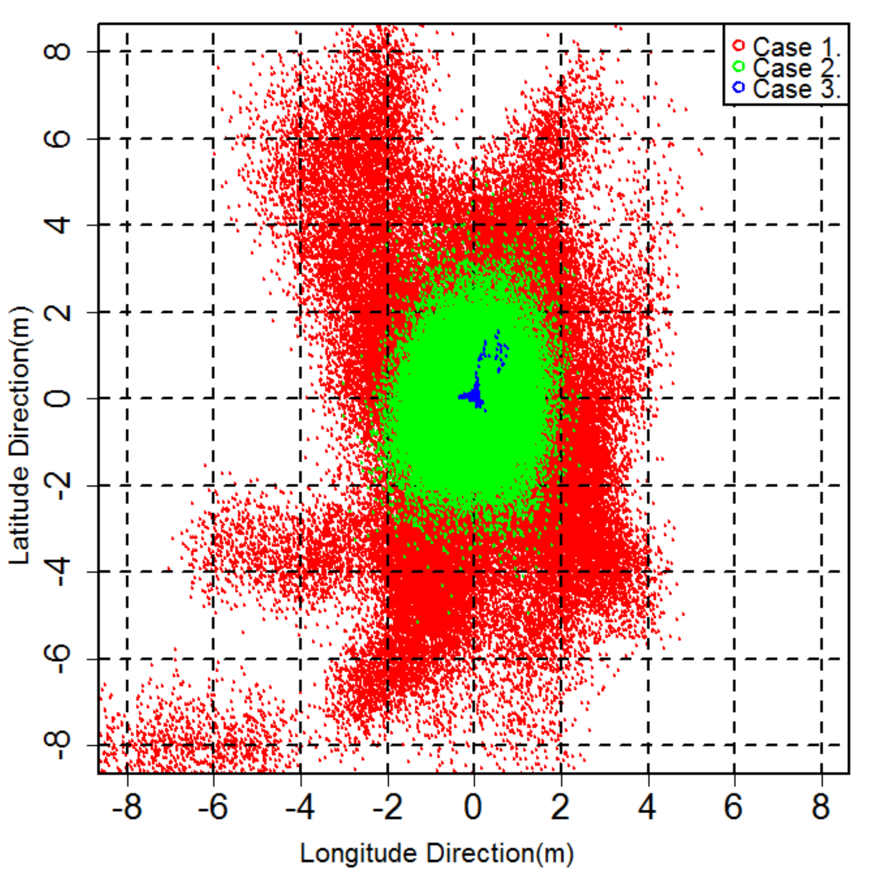


High Accuracy of Single Positioning

Relative Positioning Solution：Post-Processed RTK(Real Time Kinematic)

Base Station：The Rooftop of Our University (Tokyo, Japan)

Horizontal Positioning Error Distribution



Positioning Accuracy

		Latitude [m]	Longitude [m]	Height [m]
Case 1. Klobuchar Model	Standard Deviation	3.148	1.867	8.480
	Average	-0.326	-0.163	2.962
	RMS	3.165	1.874	8.982
Case 2. Ionosphere free	Standard Deviation	0.639	0.871	1.799
	Average	-0.059	-0.045	0.255
	RMS	0.642	0.873	1.817
Case 3. PPP	Standard Deviation	0.057	0.071	0.121
	Average	0.016	-0.003	0.111
	RMS	0.060	0.071	0.164

Comparison of Sea Buoys and Ships

	Sea Buoys	Ships
GPS/GNSS Applications	・Sea Level Fluctuations	・Position Information of their Own Ships
	・Weather and Sea Conditions	・Connected to Navigational Instruments
Method of Data Transmission to the Land	Satellite Communication Tools	・Large Ships : Satellite Communication Tools
		・Small Ships : None
Installation Rate of GPS/GNSS	100%	・Large Ships : 100%
		・Small Ships : 98%

Large Ships are engaged in international voyages more than 300 gross tons.

Experiments

We performed experiments using the ship in order to determine whether a new application proposed.

⬇

We performed PPP experiments using CenterPoint RTX and MADOCA on the ship.

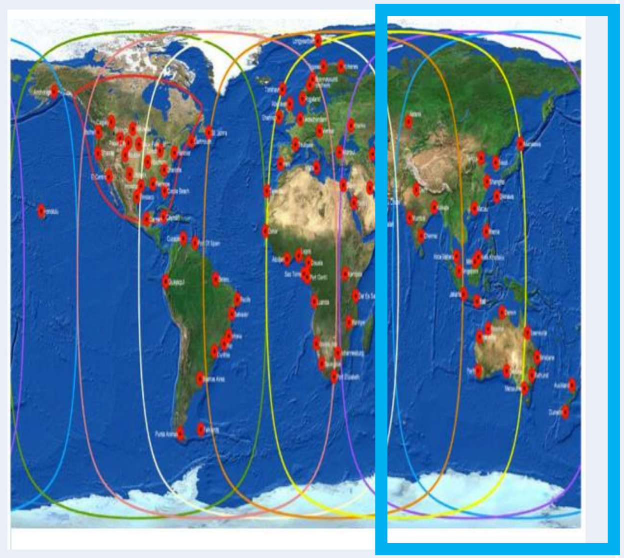
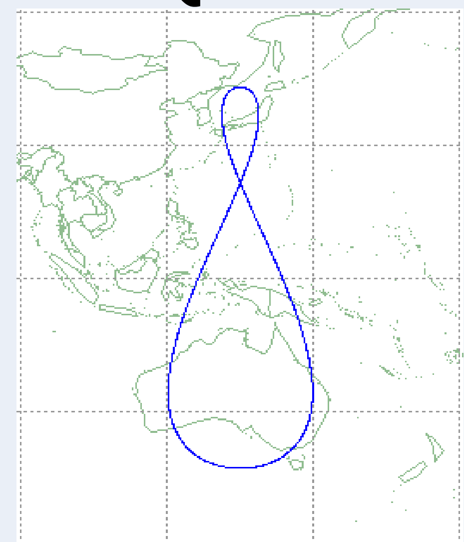
CenterPoint RTX (Real Time eXtended) :

It is possible to obtain correction information of PPP on all land more than 90% using OmniSTAR.

MADOCA(Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis) :

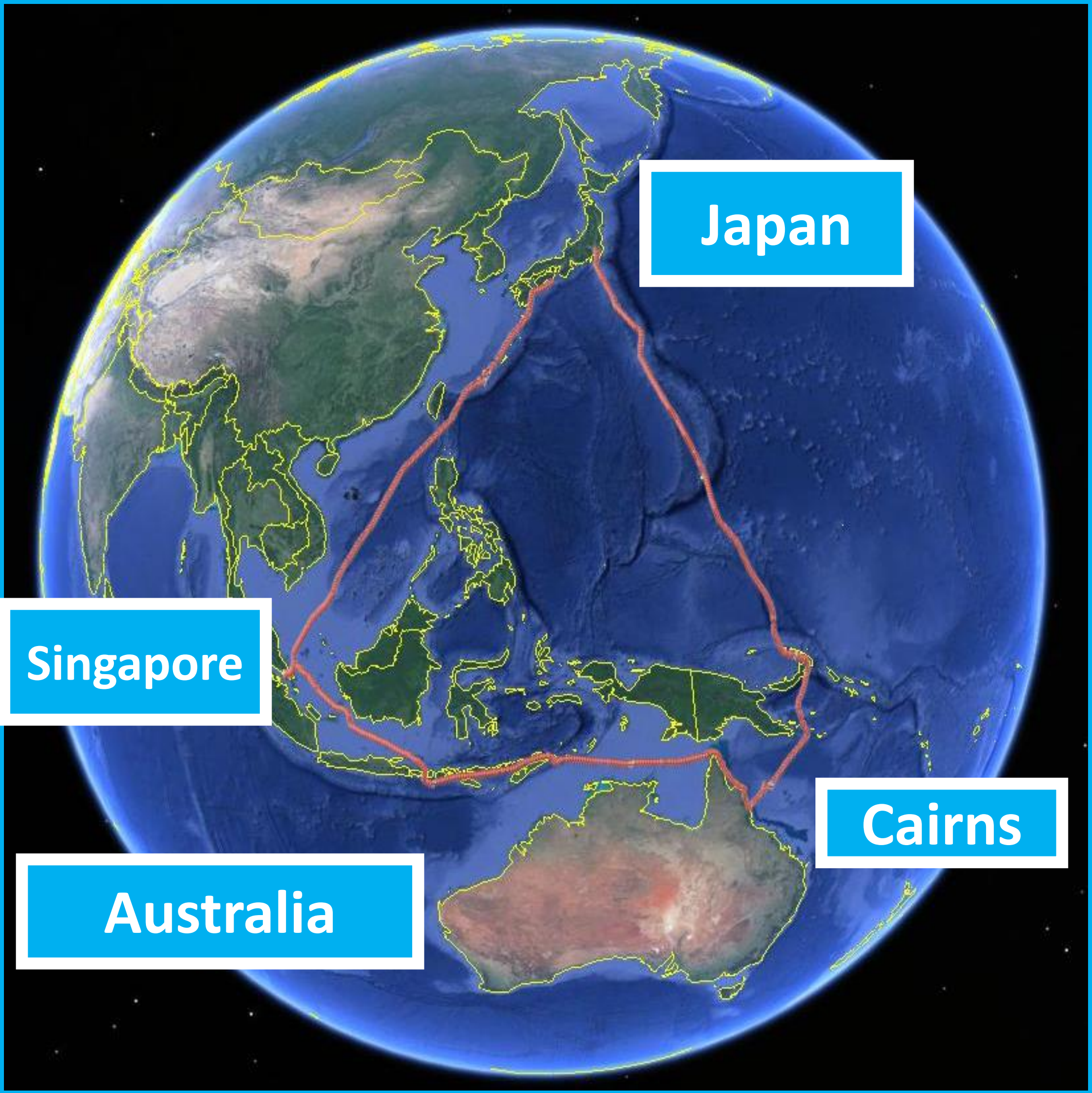
- **Satellite orbit and clock determination for multiple GNSS constellations provided by QZSS (Quasi-Zenith Satellite System)**
- **Internet broadcasting of real-time products (2014.09.11~)**

CenterPoint RTX and MADOCA

	CenterPoint RTX	MADOCA
Satellite to Send the Correction Information	**OmniSTAR :**  (http://gpsworld.com/look-no-base-station-precise-point--ppp/positioning)	**QZSS :**  (IS-QZSS)
Satellites	GPS,GLONASS,QZSS, BeiDou	GPS,GLONASS,QZSS
Data Transmission Speed	600 bps	2,000 bps
Processing	Only Real-time	Both Off-line and Real-time

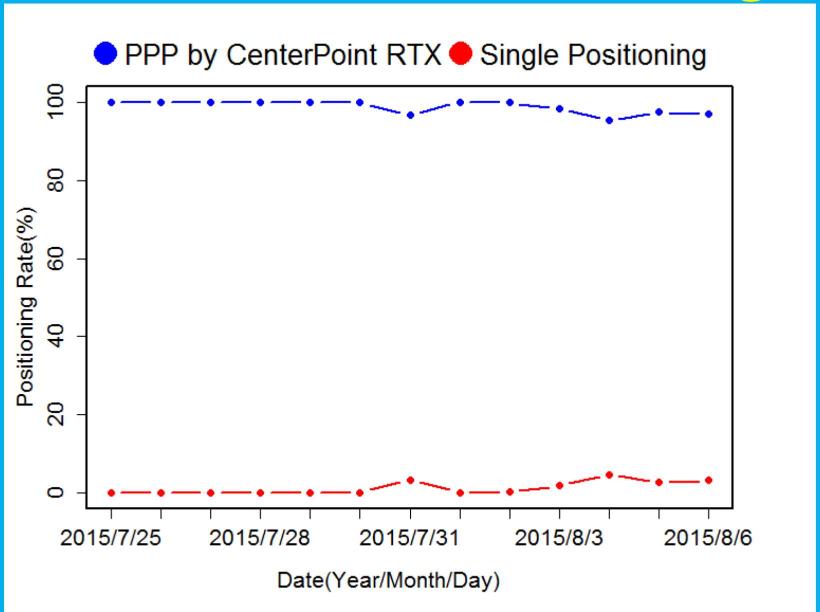
Experiments

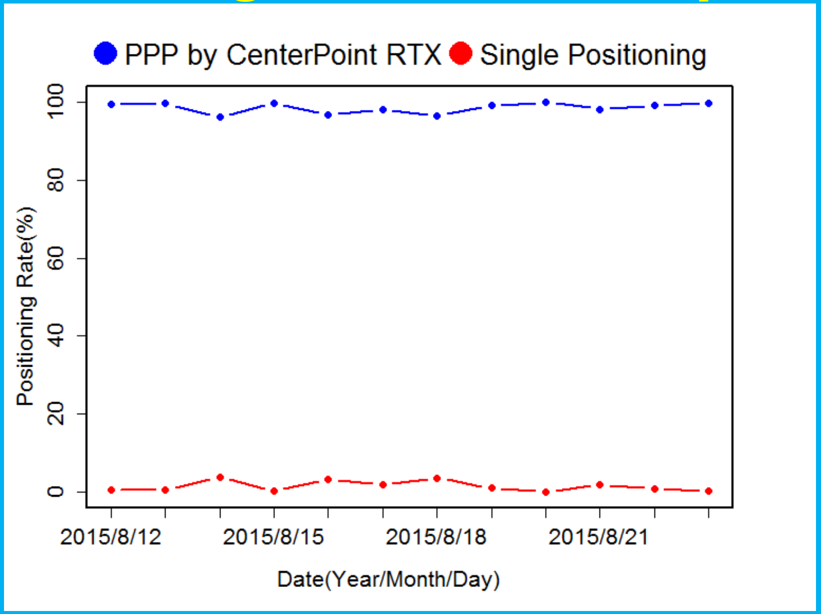
- **Experimental Setup : 40 days (Japan ~ Cairns ~ Singapore ~ Japan)**



Results and Discussion

CenterPoint RTX : Change in the Positioning Rate on the ship

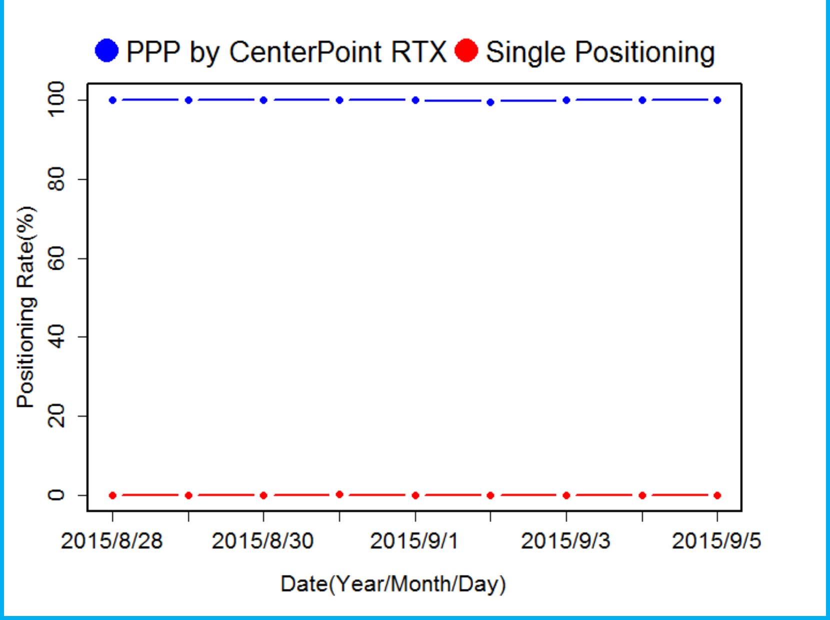




Tokyo~ Cairns

Cairns~ Singapore

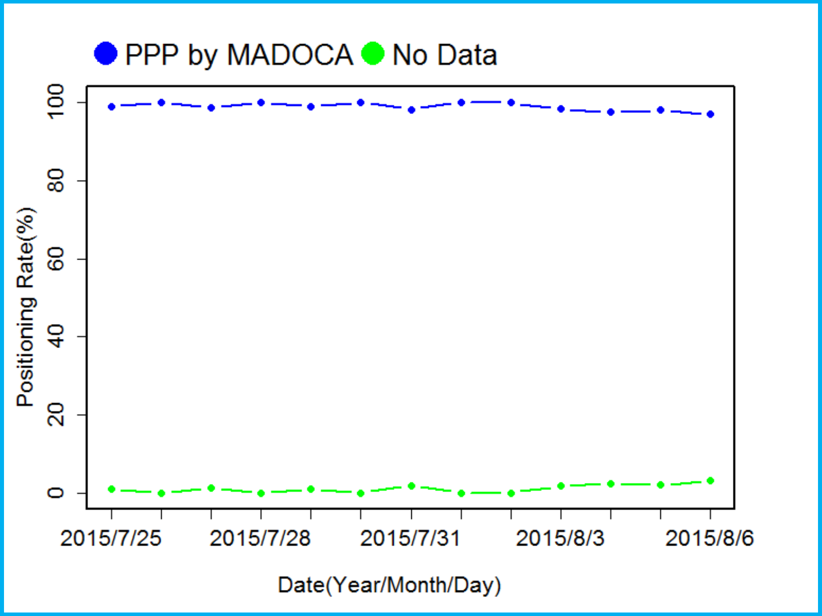
Singapore~ Kobe

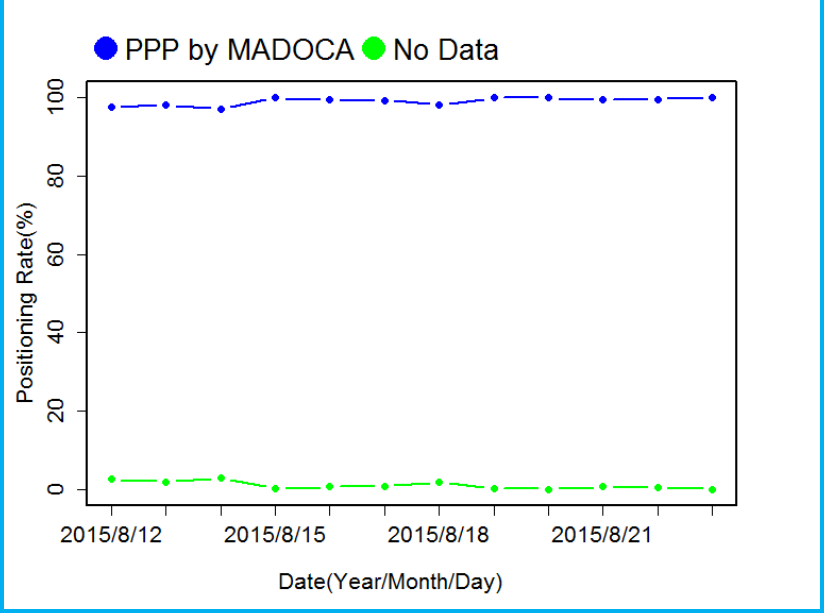


Positioning Rate of PPP was more than 95%.

Results and Discussion

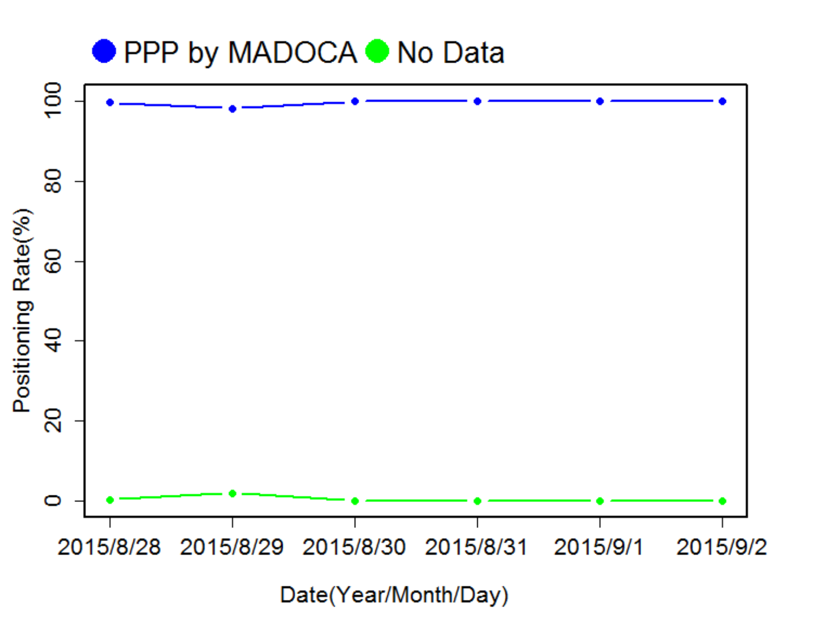
MADOCA : Change in the Positioning Rate on the ship





Tokyo~ Cairns

Cairns~ Singapore

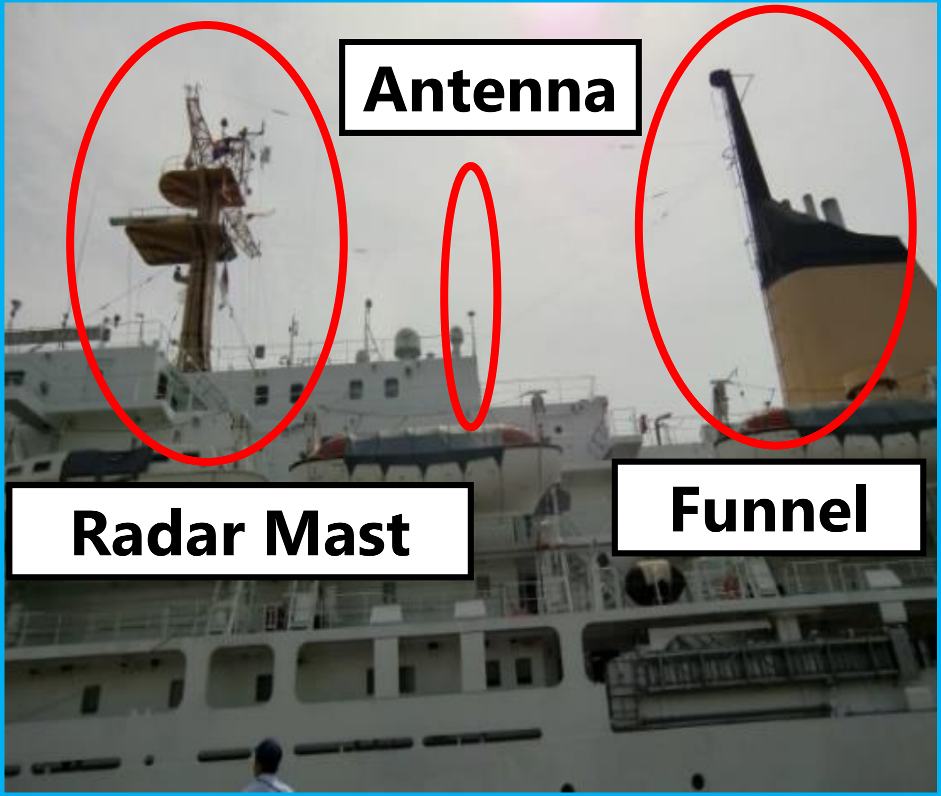


Singapore~ Kobe

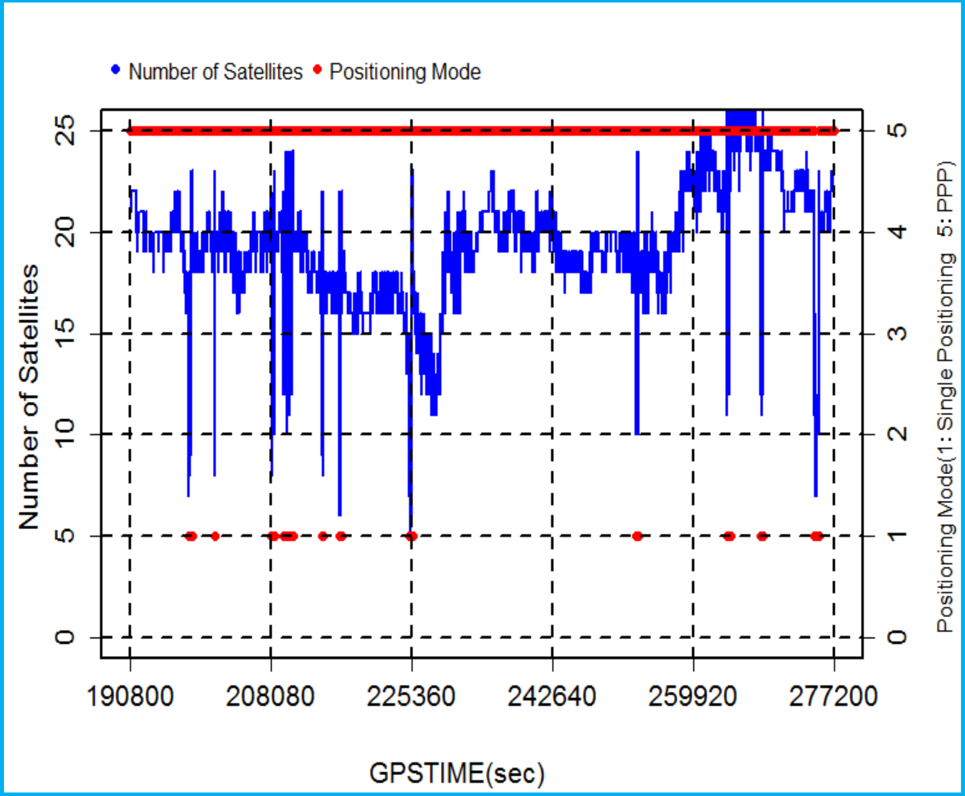
Positioning Rate of PPP was more than 97%.

Experimental Environment and Change in the Number of Satellites

Experimental Environment



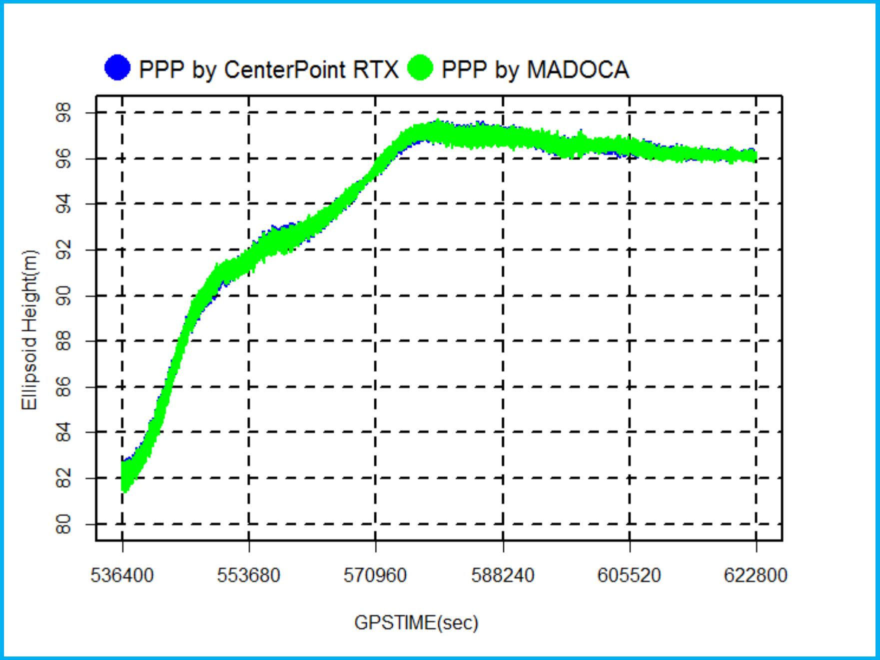
Change in the Number of Satellites (PPP by CenterPoint RTX : 2015.8.4.)



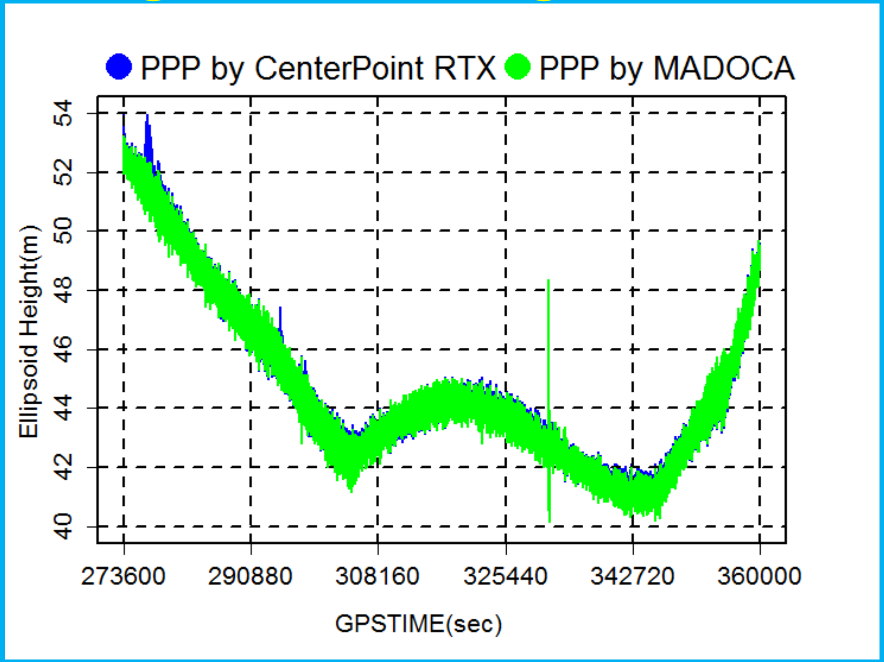
Positioning Rate of PPP was the smallest.

Results and Discussion

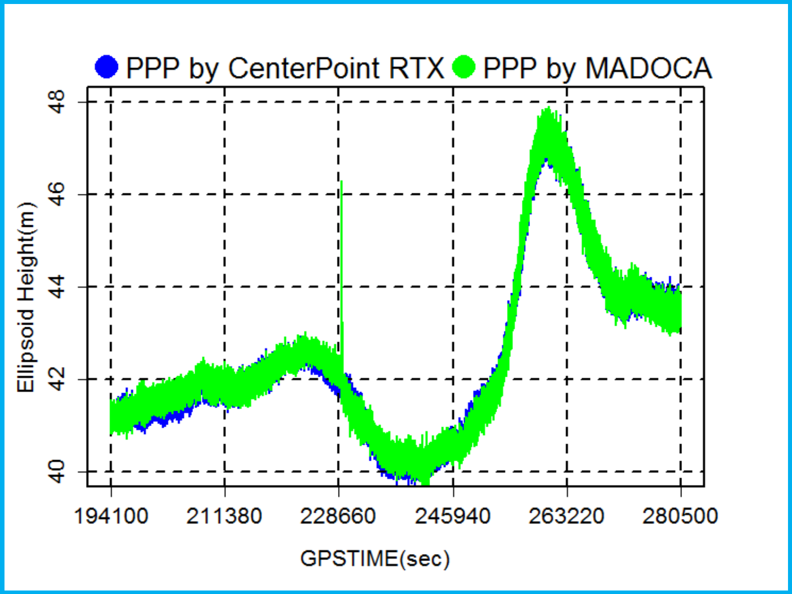
CenterPoint RTX and MADOCA : Positioning Results of Height Direction



Tokyo~ Cairns



Cairns~ Singapore



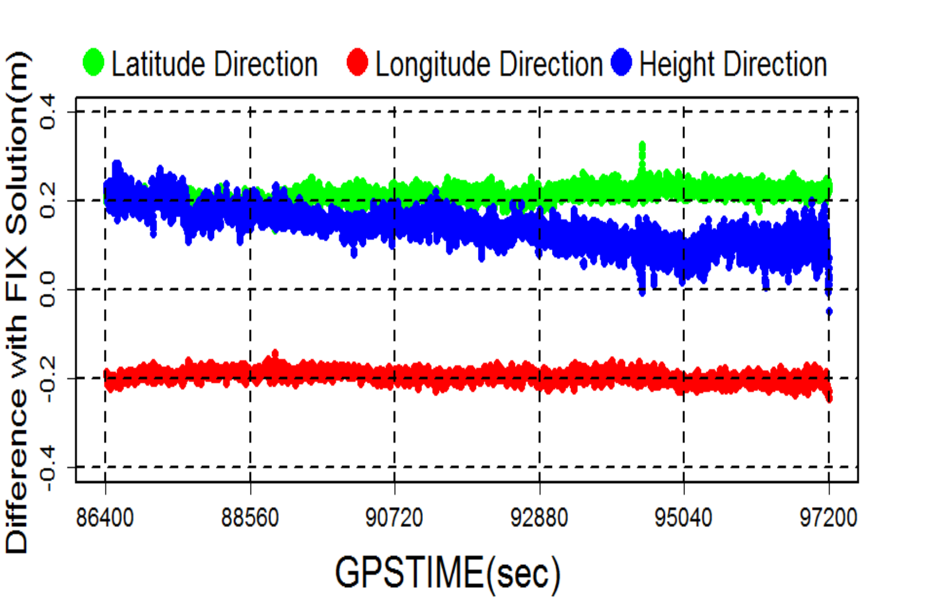
Singapore~ Kobe

Positioning Results of Height Direction calculated by CenterPoint RTX and MADOCA were almost same.

Comparison to Relative Positioning Solution (Post-Processed RTK)

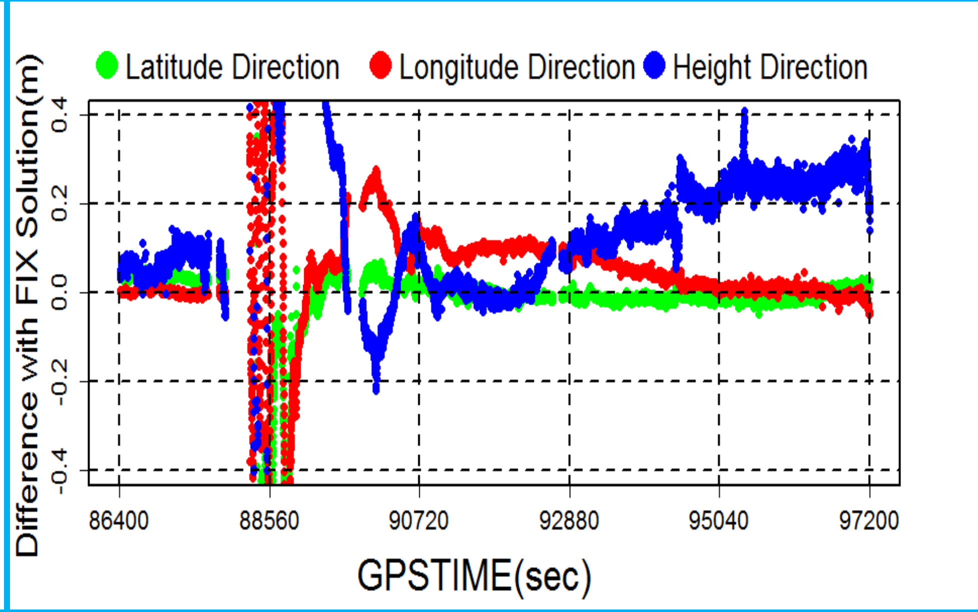
CenterPoint RTX and MADOCA : Traveling State at Japan (3 hours)

PPP by CenterPoint RTX



	Latitude (m)	Longitude (m)	Height (m)
Standard Deviation	0.016	0.012	0.043
Average	0.214	-0.194	0.141
RMS	0.215	0.194	0.147

PPP by MADOCA

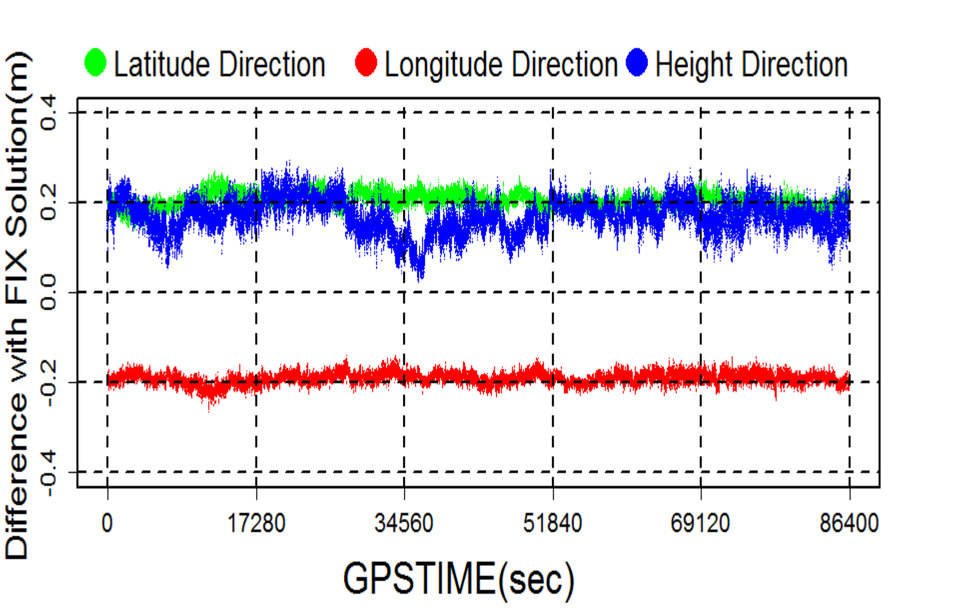


	Latitude (m)	Longitude (m)	Height (m)
Standard Deviation	0.226	0.118	0.387
Average	0.001	0.049	0.170
RMS	0.226	0.128	0.422

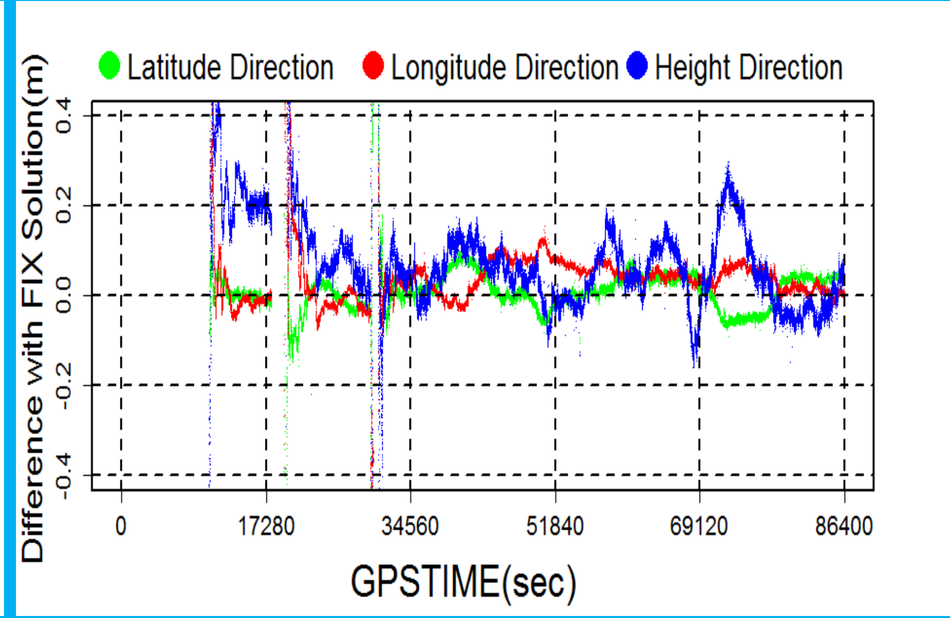
Comparison to Relative Positioning Solution (Post-Processed RTK)

CenterPoint RTX and MADOCA : Anchored State at Japan (24 hours)

PPP by CenterPoint RTX



PPP by MADOCA



PPP by CenterPoint RTX

	Latitude (m)	Longitude (m)	Height (m)
Standard Deviation	0.016	0.013	0.037
Average	0.205	-0.191	0.170
RMS	0.205	0.191	0.173

PPP by MADOCA

	Latitude (m)	Longitude (m)	Height (m)
Standard Deviation	0.106	0.114	0.169
Average	0.005	0.040	0.074
RMS	0.106	0.121	0.184

A New Disaster Prevention System at Sea

- Alternative Data Interpolation of Sea Buoys : Large Ships

Meteorological Equipment

Waves, Tide Level, Tsunami,
Wind Direction and Wind Speed,
Water Temperature,
Current Direction and Flow Speed,
Temperature,
Atmospheric Pressure

Satellite Communication Tools

Transmitting the measurement results to the land

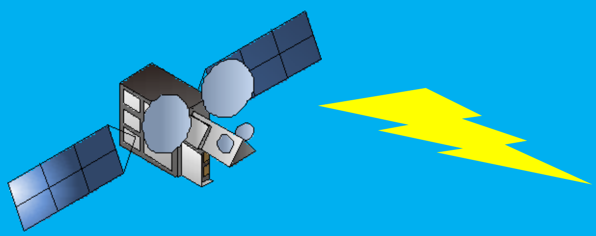
Measurements on Board

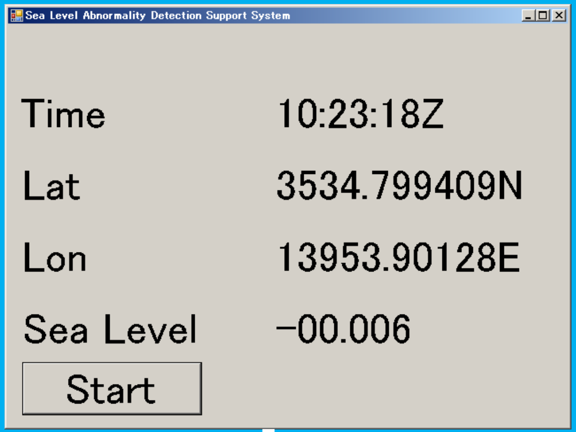
Data Transmission to the Land

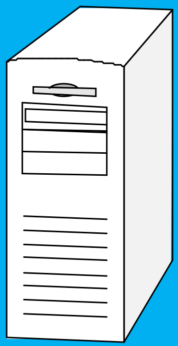
A New Disaster Prevention System at Sea

- **A Disaster Preventing System using Ships in the Anchorage**

We always output the sea-level change data of the ship installed to the computer.







System Server

①When We Detect Abnormal Changes of the Sea

Data Acquisition Continues

Report to the Duty Officer

The Duty Officer Notifies the Alarm at Large Volume

Conclusion

- **Positioning rate of PPP was very high : 95%-100%. Positioning accuracy on board was approximately less than 10cm.**

- **It is possible to measure a wide range of sea area. Analysis of sea level fluctuations are expected.**

- **A disaster prevention system that can be completed in ships is required to protect valuable resources such as ships and sailors.**