QZSS PPP service MADOCA / CLAS

Training on GNSS, 8 JAN 2020
12:00-12:30

Kaito Kobayashi
Tokyo University of Marine Science and Technology

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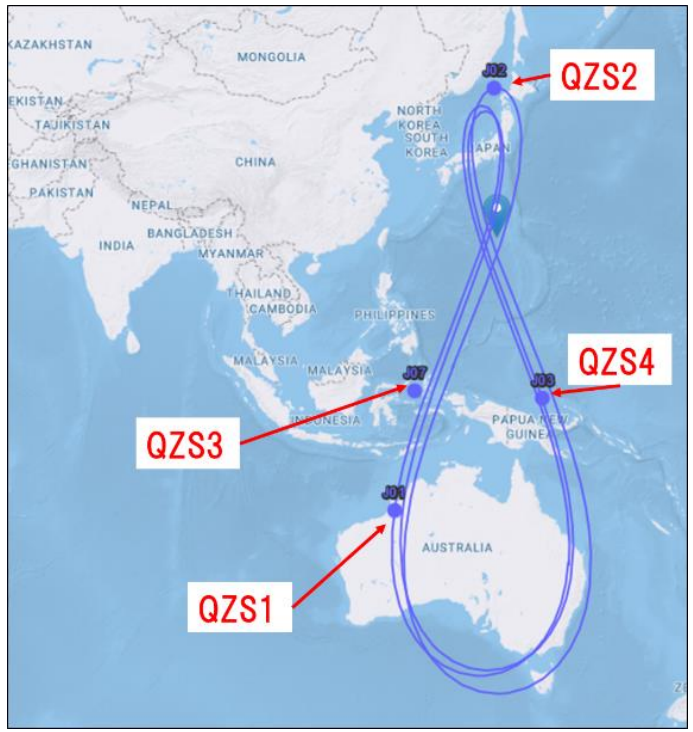
https://1drv.ms/u/s!AidzfXwz4kDK5TGapdiZGWkcFYQD?e=G5zzbv

1. Overview of QZSS

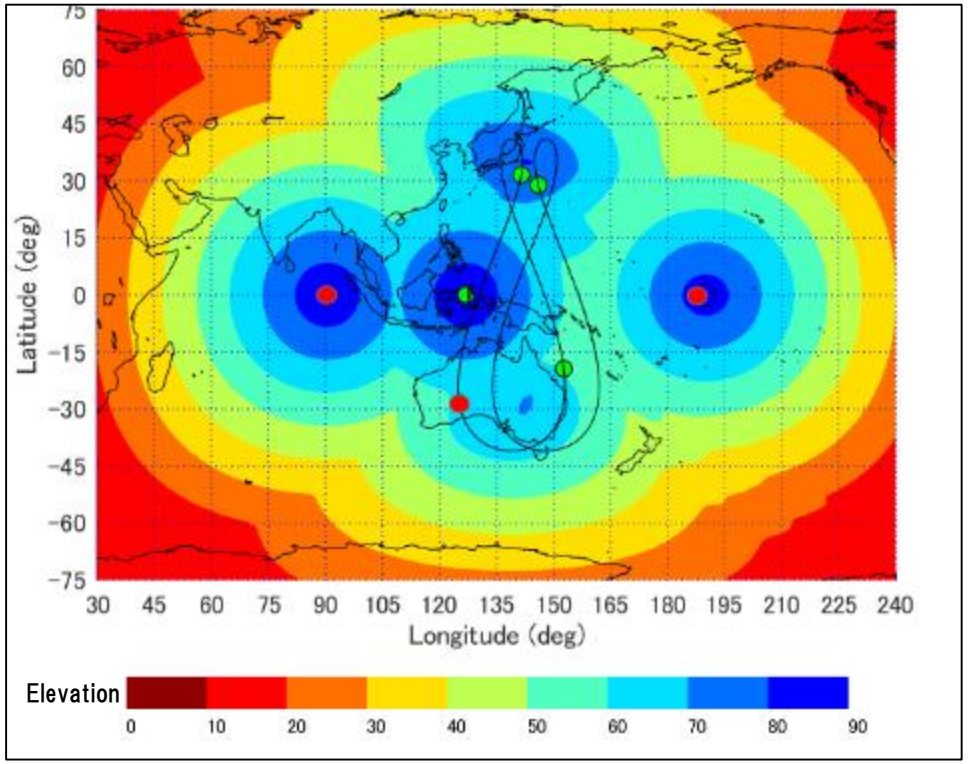
QZSS is Japanese Regional Navigation Satellite System.

4 satellites are available in 2019 and it is planned additional 3 satellite launch until 2023.

Every people in the coverage can use QZSS service freely.



QZSS orbit (2019)

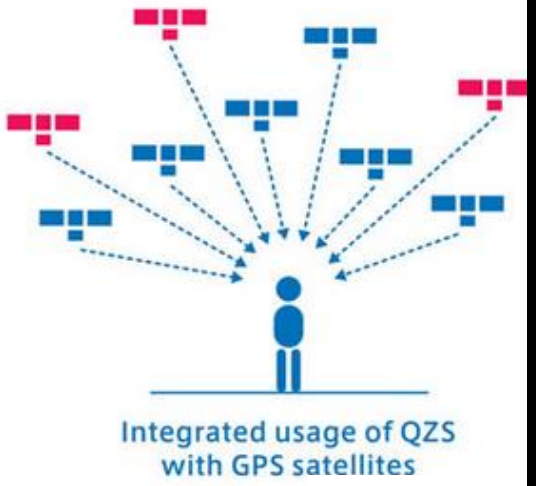


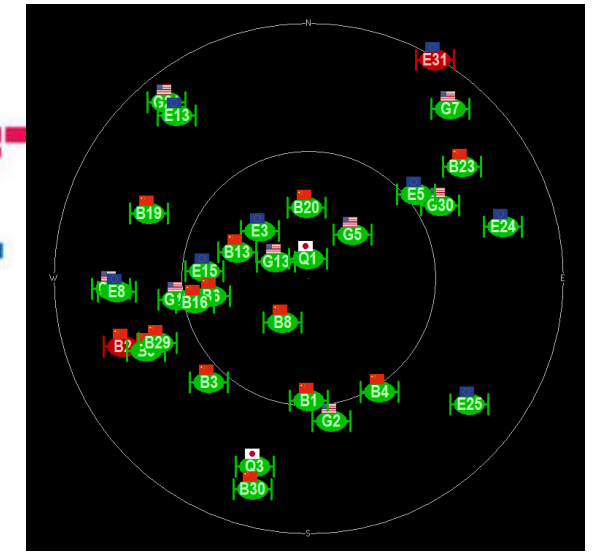
QZSS orbit and coverage (2023)

1. Overview of QZSS

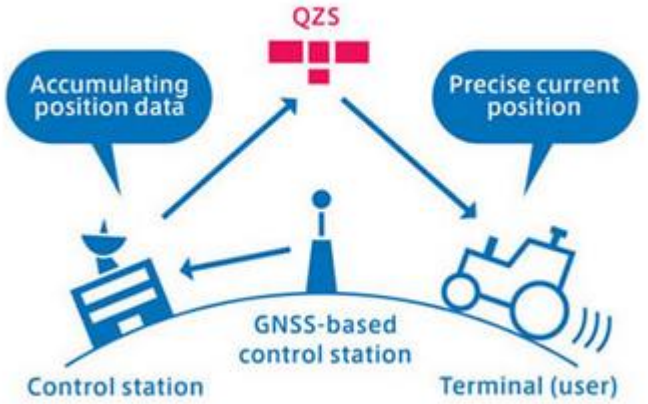
Main objective of QZSS are

1. More robust navigation to complement other GNSS
2. High precise positioning service





Frequency	1176.45MHz		1227.60MHz	1278.75MHz		1575.42MHz			
QZSS	L5	L5S	L2C	L6D	L6E	L1C/A	L1C	L1S	L1Sb
	PNT	Positioning Technology Verification Service	PNT	Centimeter-Level Augmentation Service (CLAS)	Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis (MADOCA)	PNT	PNT	Sub-meter Level Augmentation Service (SLAS)	SBAS
GPS	L5		L2C			L1C/A	L1C		
	PNT		PNT			PNT	PNT		
Galileo	E5a			E6B	E6C	E1			
	PNT			High-Accuracy Service (HAS)	Commercial Authentication Service (CAS)	PNT			

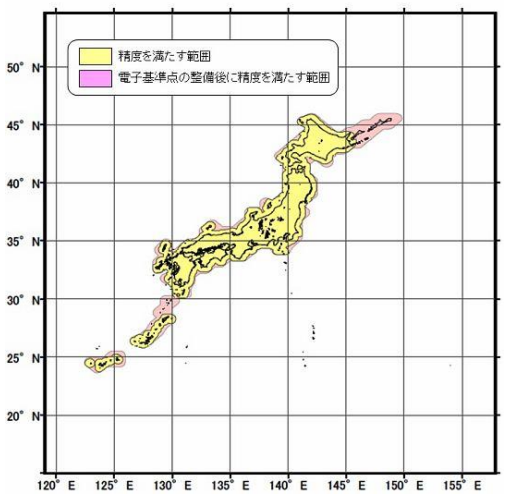


*PNT : Positioning, Navigation, Timing

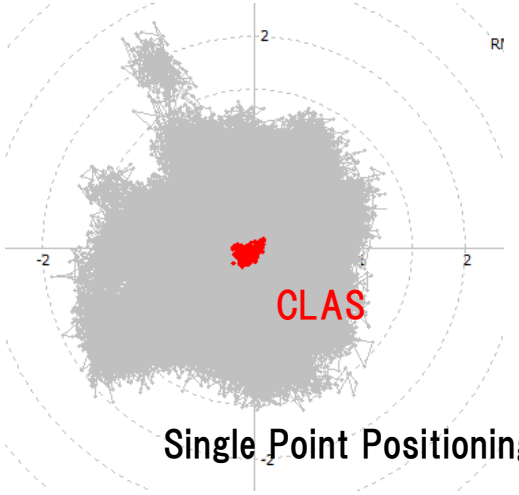
2. PPP service by QZSS

QZSS provides 2 types of precise point positioning (PPP) service.

CLAS
(centimeter-level augmentation service)

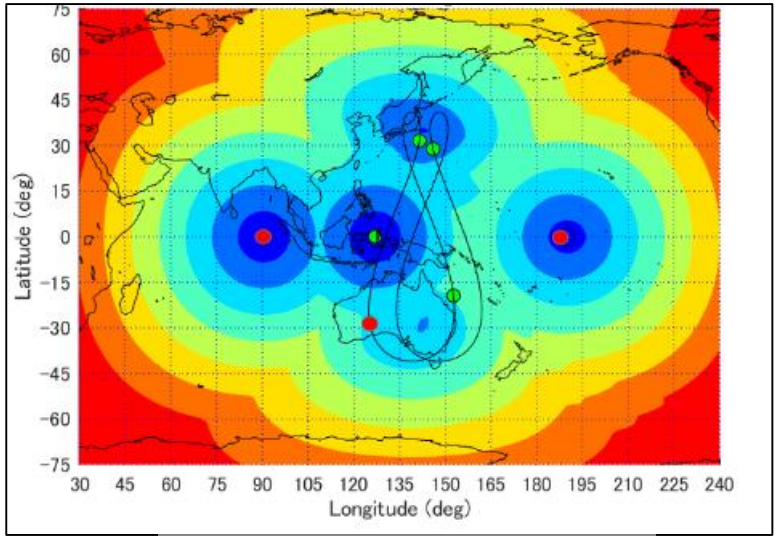


Service Area of CLAS

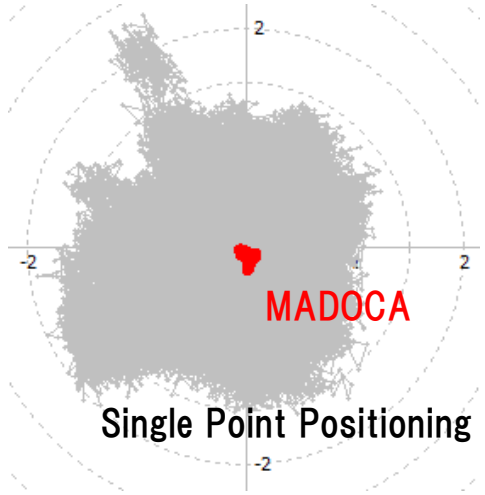


Single Point Positioning

MADOCA
(multi-GNSS advanced demonstration tool for orbit and clock analysis)



Service Area of MADOCA



Single Point Positioning

High accuracy land-based service

Wide coverage PPP service

3. About CLAS

CLAS
(centimeter-level augmentation service)

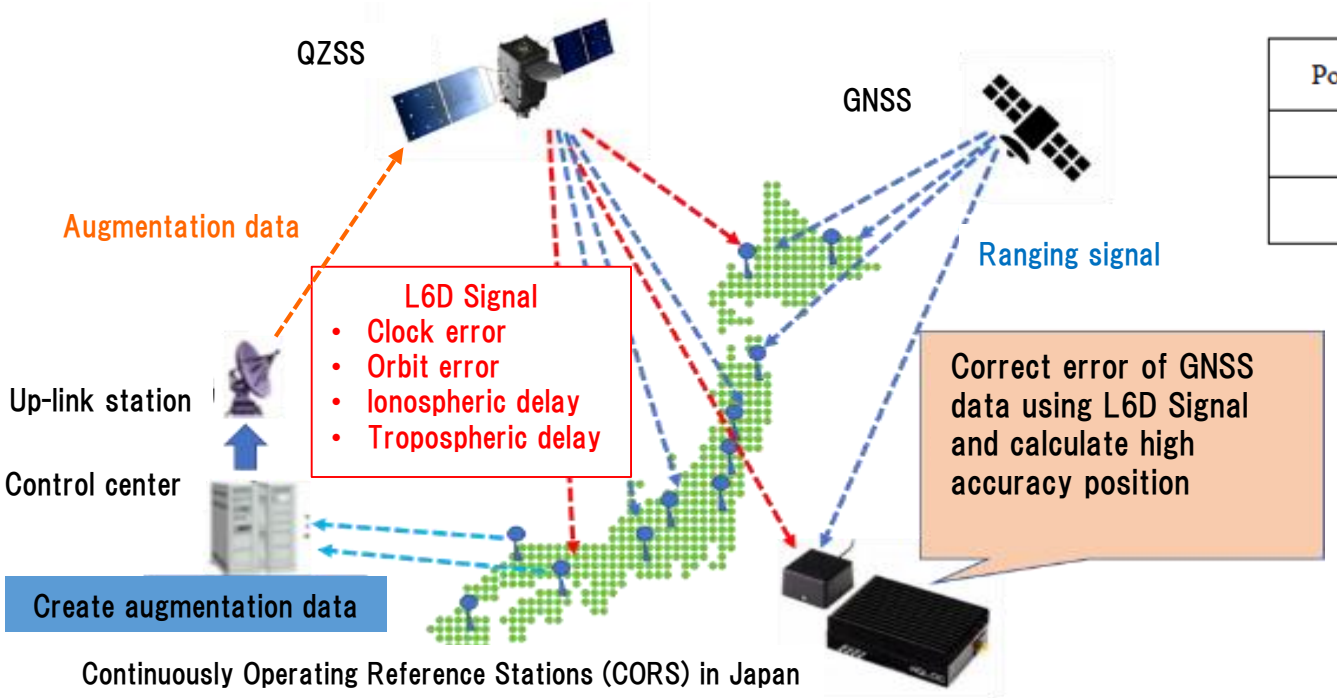
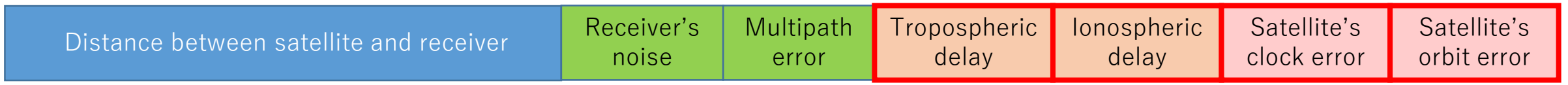


Table. 6.3-1 Positioning Accuracy

Positioning Type	Positioning Error		Remark
	Horizontal	Vertical	
Static	≤ 6cm(95%) (3.47cm(RMS))	≤ 12cm(95%) (6.13cm(RMS))	(*)(**)
Kinematic	≤ 12cm(95%) (6.94cm(RMS))	≤ 24cm(95%) (12.25cm(RMS))	(*)(**)

RTK class performance without base station

GNSS ranging measurement errors

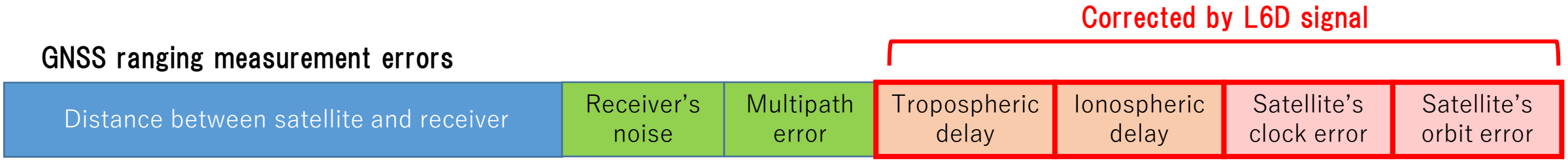


3. About CLAS

◆SSR corrections include clock, orbit, code bias, phase bias, ionosphere, troposphere correction.

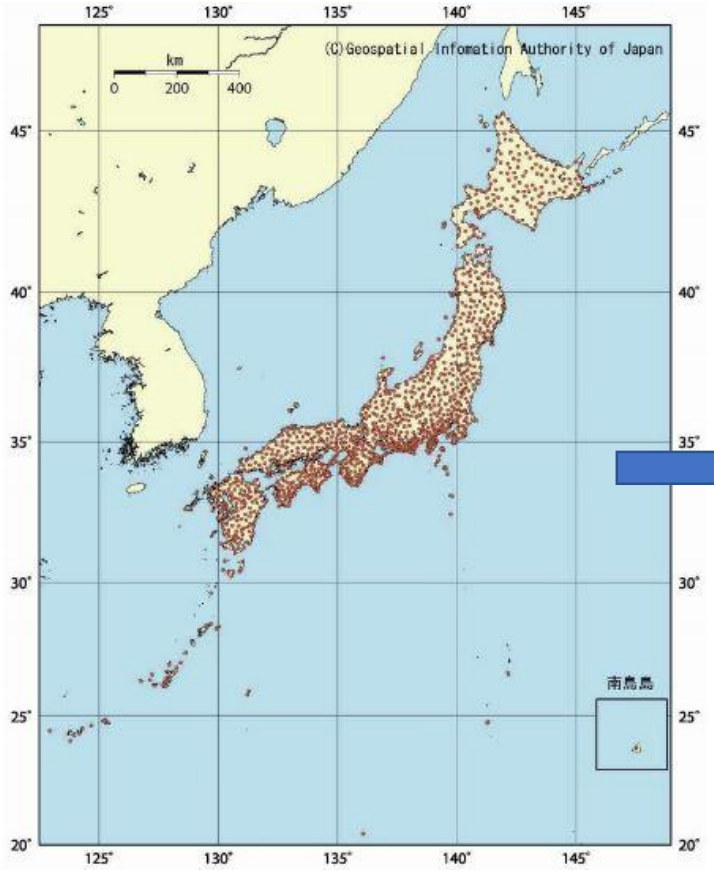
$$CPC_{user}^{PRN}(t) = -\delta C^{PRN}(t) - \delta \mathbf{X}^{PRN} \cdot \boldsymbol{los}_{user}^{PRN}(t) + NET\_BIAS_{k,phase}^{PRN}(t) - I_{user}^{PRN}(t) + T_{user}^{PRN}(t)$$
$$PRC_{user}^{PRN}(t) = -\delta C^{PRN}(t) - \delta \mathbf{X}^{PRN} \cdot \boldsymbol{los}_{user}^{PRN}(t) + NET\_BIAS_{k,code}^{PRN}(t) + I_{user}^{PRN}(t) + T_{user}^{PRN}(t)$$

◆Other corrections such as tide correction, receiver PCO/PCV, and phase windup should be corrected by users themselves.



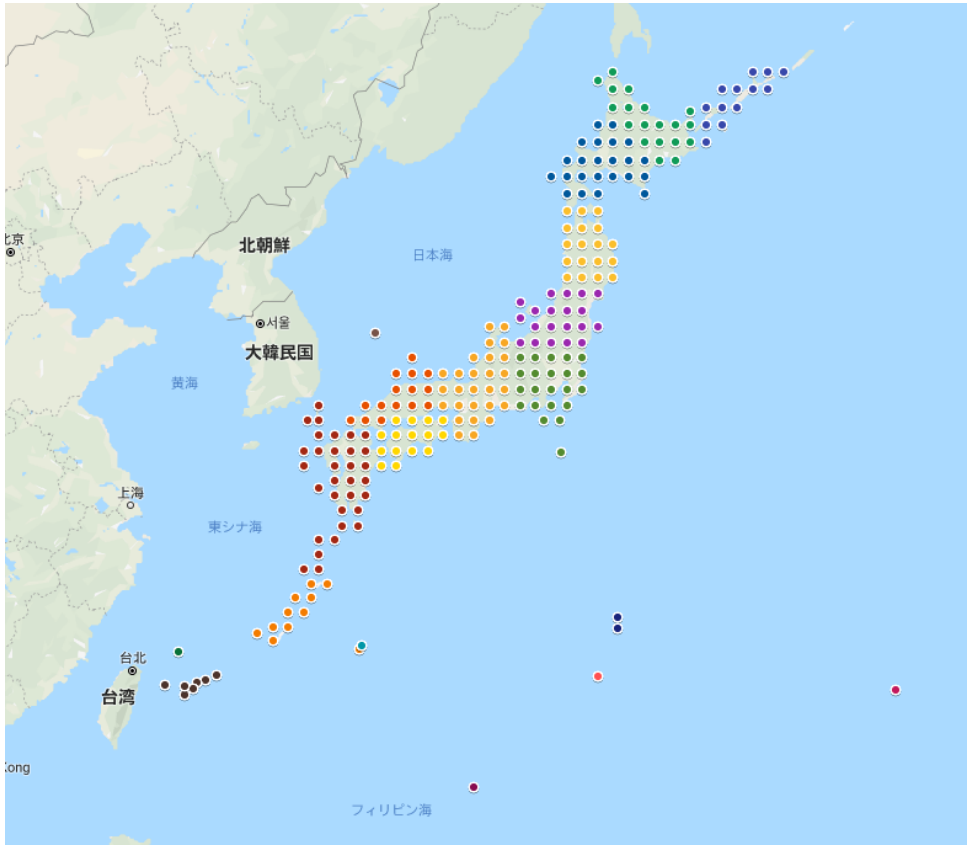
3. About CLAS

CLAS correction data is created using Japanese local CORS(Continuously Operating Reference Stations) observation data.



1300 reference stations

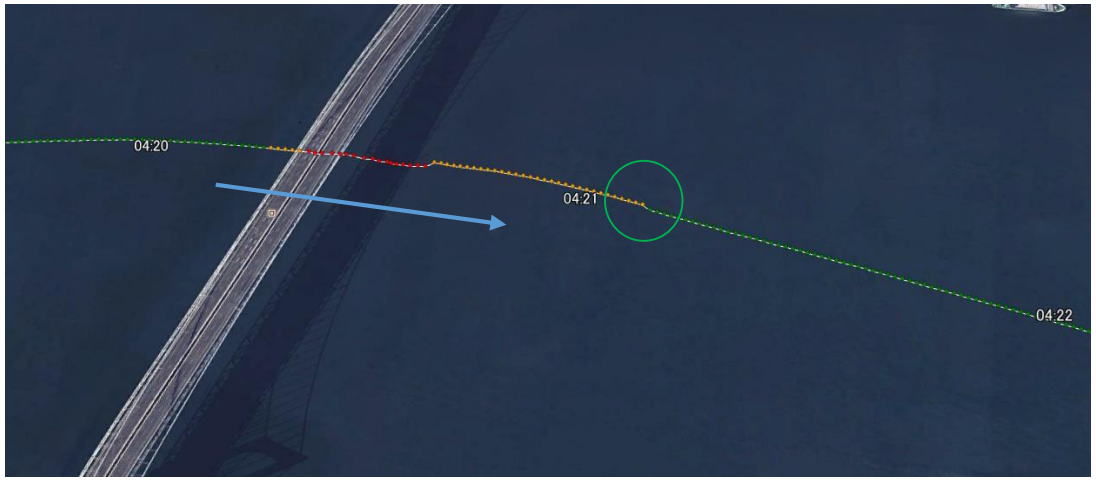
Data center

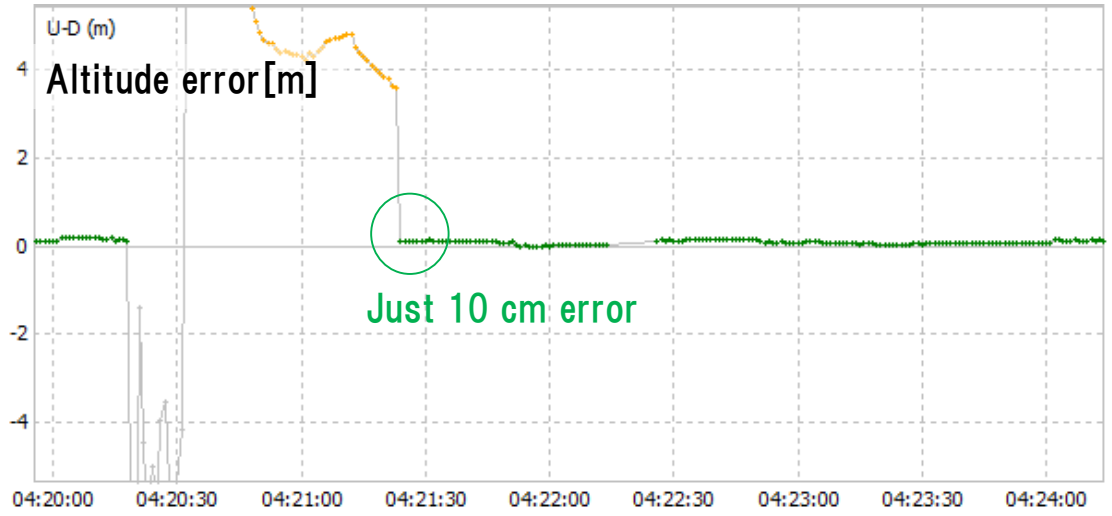


60 km grid of CLAS local correction

3. About CLAS

CLAS receiver get nearest local correction from L6D signal broadcasted by QZSS.
Thanks to this local atmospheric delay correction, convergence time is very short than other PPP service.





3. About CLAS

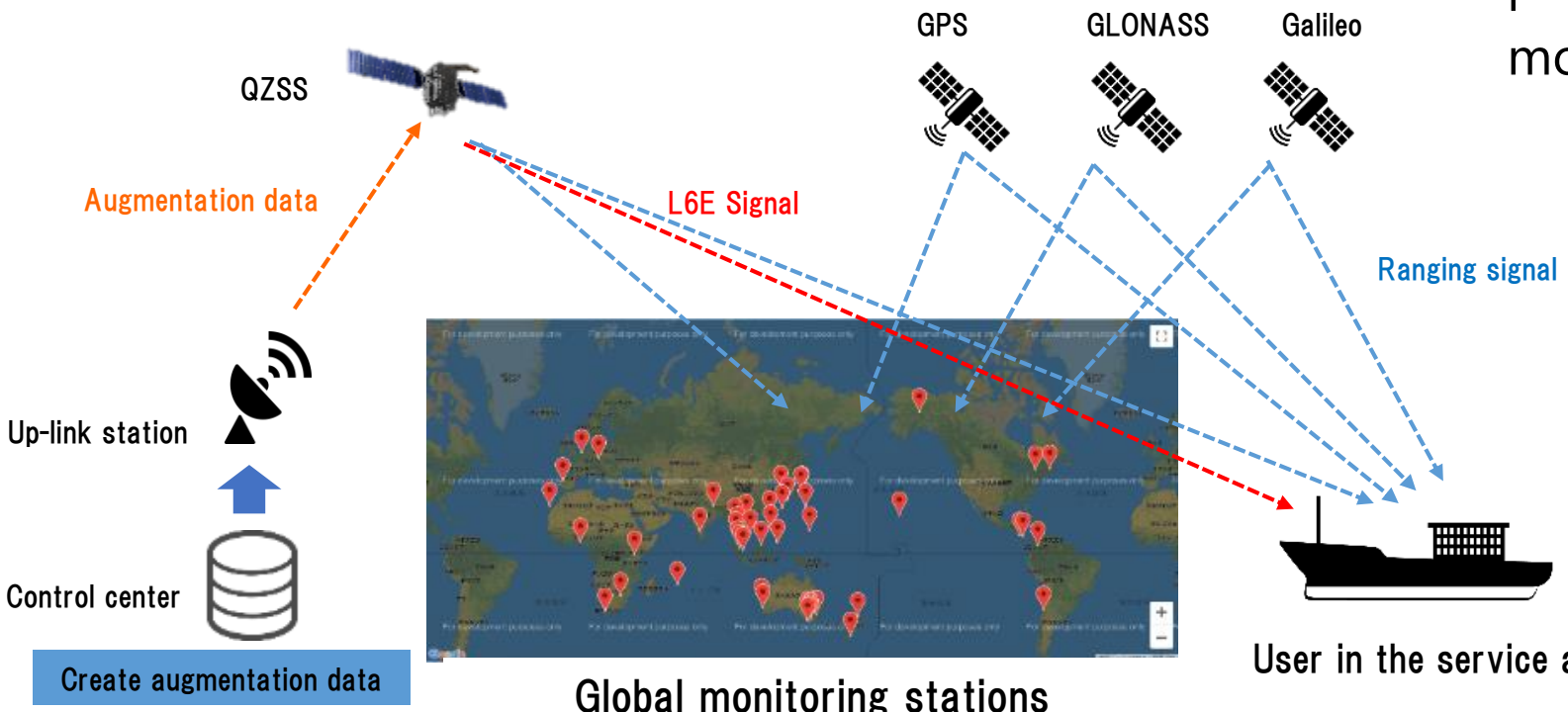
◆Application of CLAS

- ITS(Intelligent Transportation System)
- Agriculture

instead of RTK. Because RTK need network and base station infrastructure.

4. About MADOCA

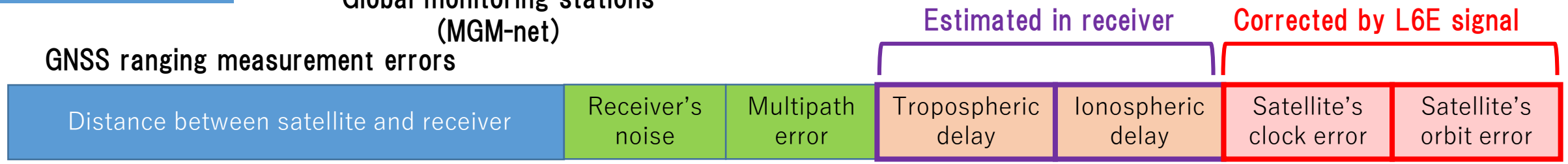
MADOCA
(multi-GNSS advanced demonstration tool for orbit and clock analysis)



Unlike CLAS, MADOCA can't correct propagation delay because its monitoring station is not dense.

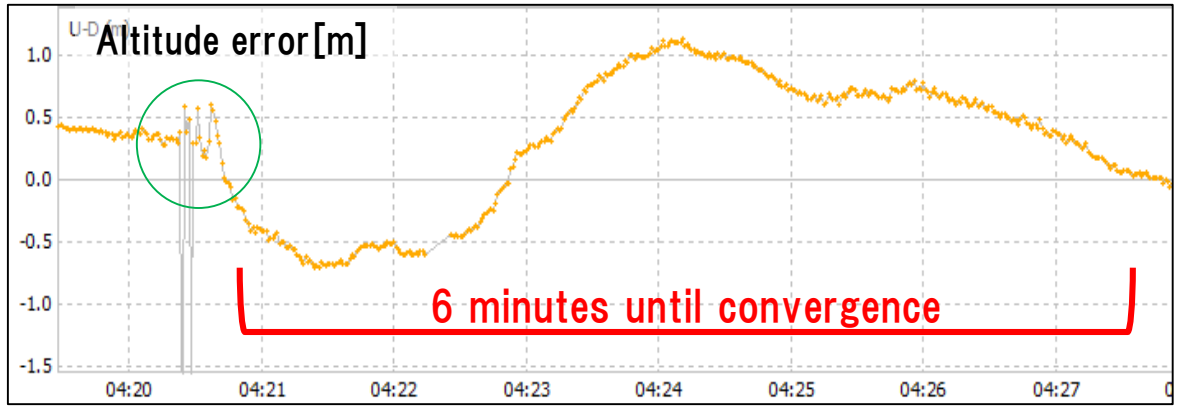
Stand-alone PPP where we can't use RTK

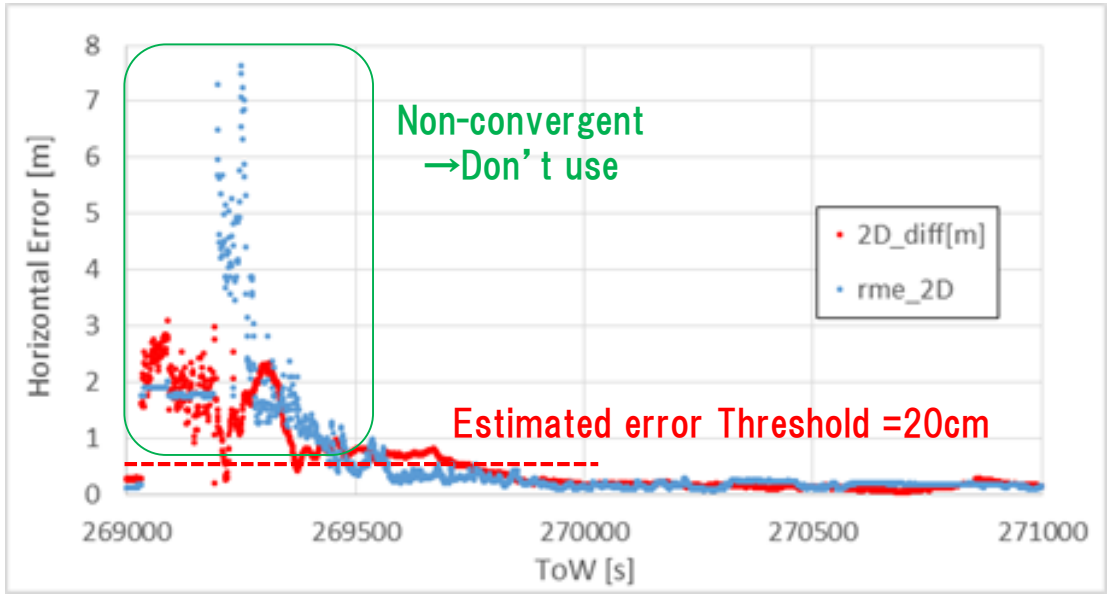
GNSS ranging measurement errors



4. About MADOCA

When L6E signal receiving was interrupted, it needed long time to recover to convergent PPP solution.
This is because atmospheric delay estimation needs some time.

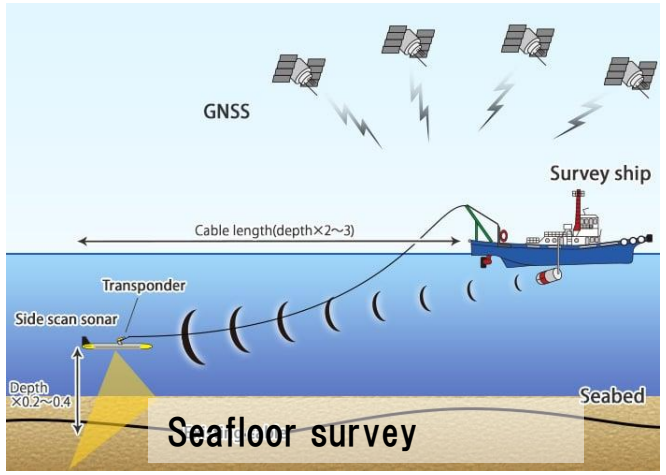




4. About MADOCA

◆Application of MADOCA

Maritime offshore work where RTK can't use.

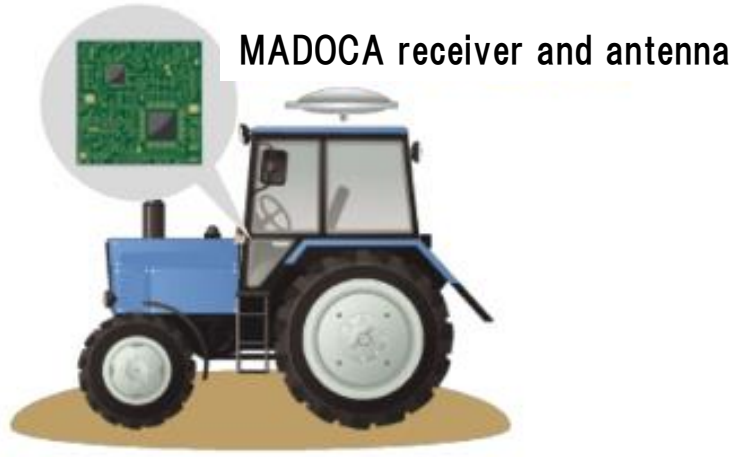


High Cost PPP Service

4. About MADOCA

◆Application of MADOCA

Agriculture where no mobile network service is provided and no cost to install VHF RTK base station.



Agriculture Machinery

Wide area,
networkless farm

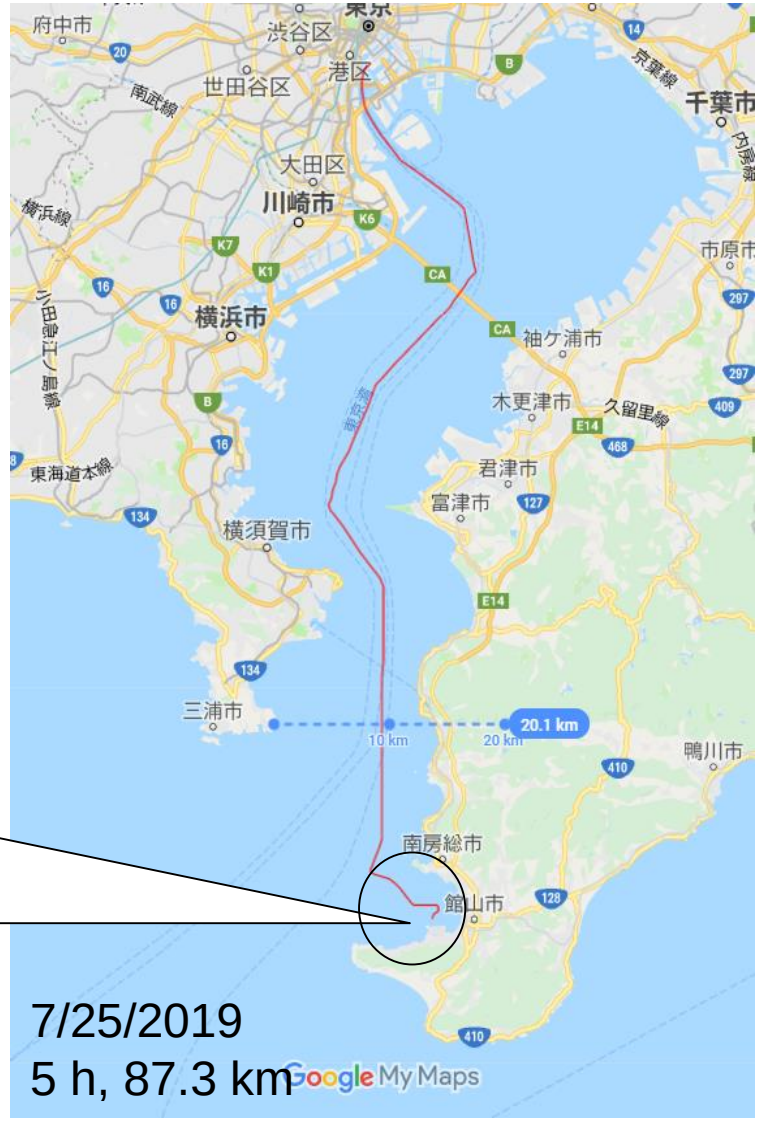
5. Evaluation on the ship

We evaluated CLAS and MADOCA on the training ship of our university.

We show two voyage result near Tokyo bay area.

Training ship Shioji-Maru

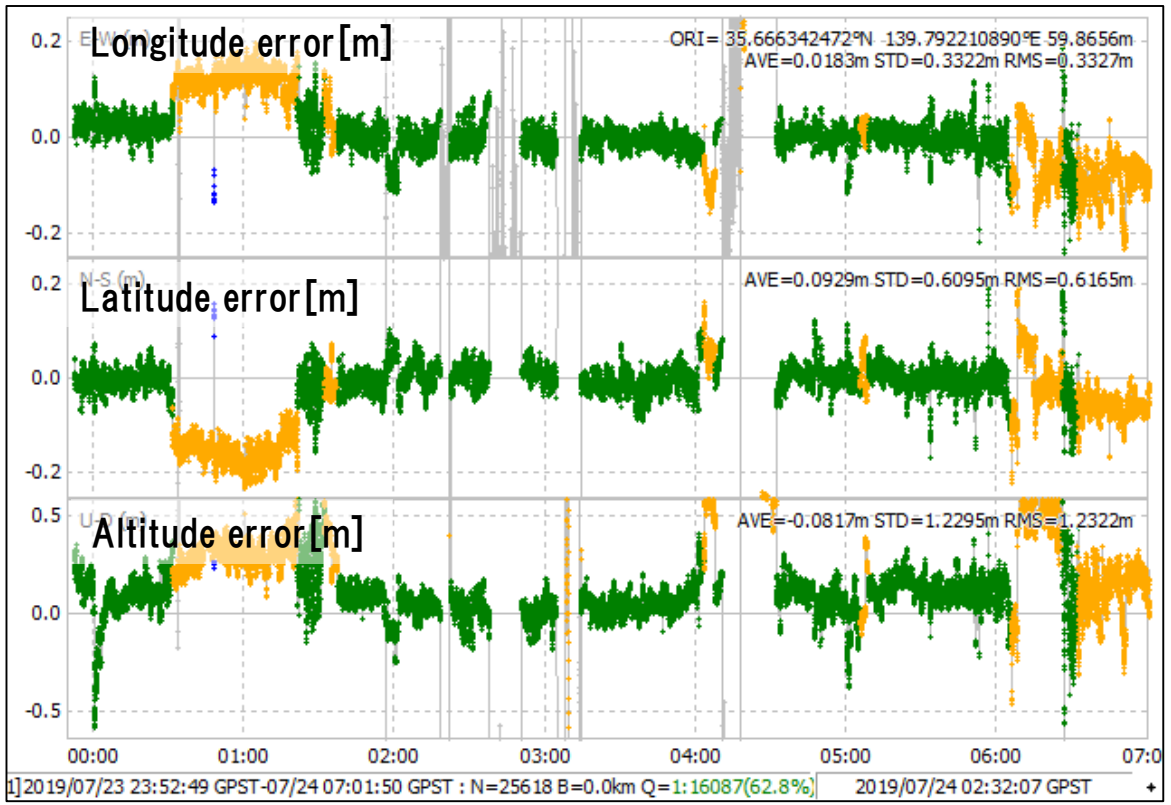
Test voyage 1



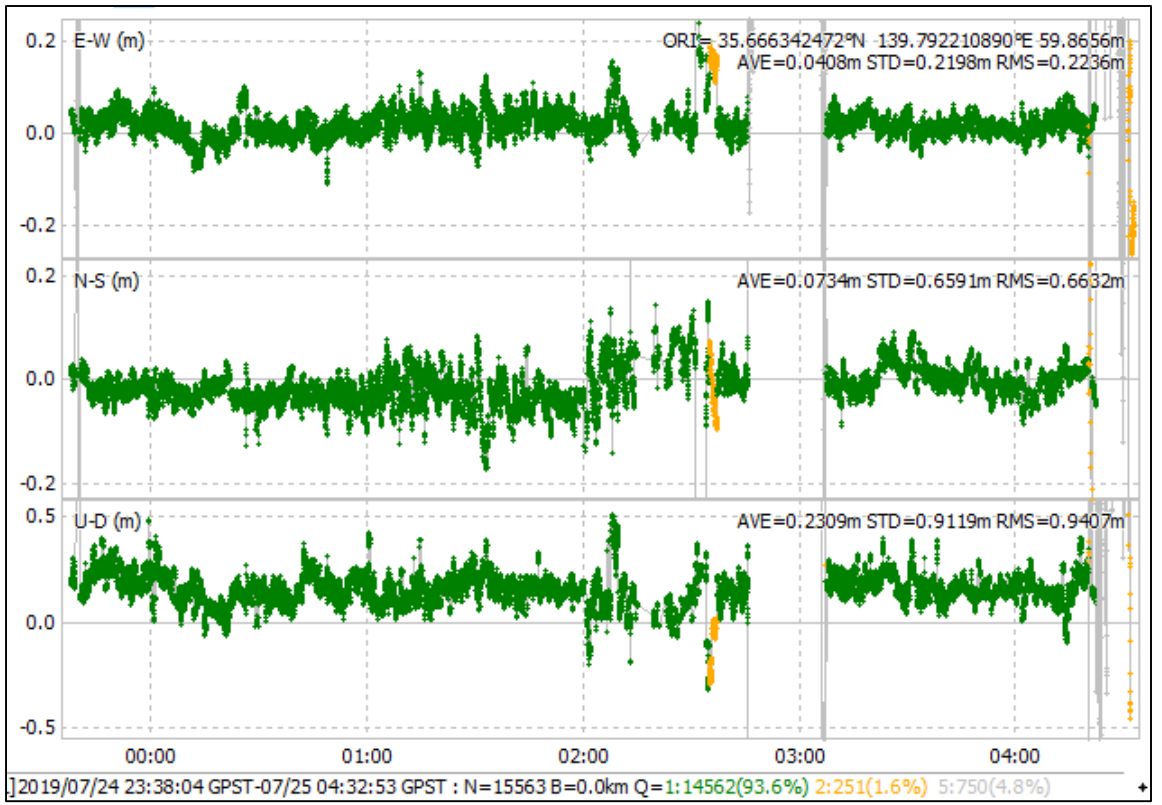
Test voyage 2

5. Evaluation on the ship (CLAS)

- Fix rate of voyage 2 was good.
- Accuracy almost satisfied the official performance standard on land.



Error plot of Voyage 1

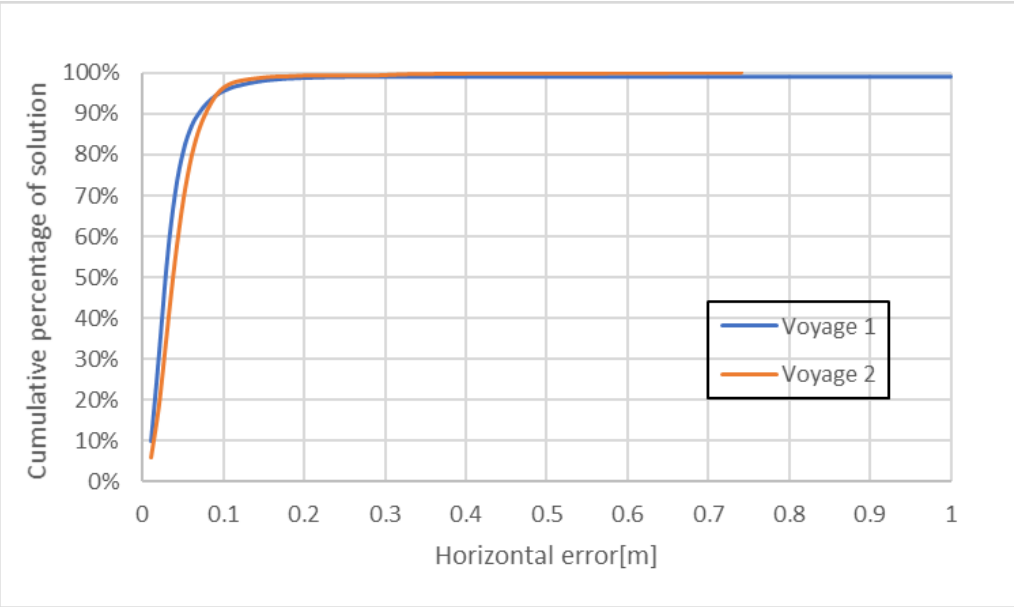


Error plot of Voyage 2

- Fix : Reliable cm-level solution
- Float : Corrected by CLAS but not reliable solution
- SPP : CLAS is not used

5. Evaluation on the ship (CLAS)

- Fix rate of voyage 2 was good.
- Accuracy almost satisfied the official performance standard on land.



Cumulative frequency graph (only Fix solution)

CLAS	Fix rate	Horizontal 2DRMSE	Vertical 2DRMSE
7/24 Voyage1	62.80%	9.06cm	25.76cm
7/25 Voyage2	93.60%	13.26cm	34.78cm

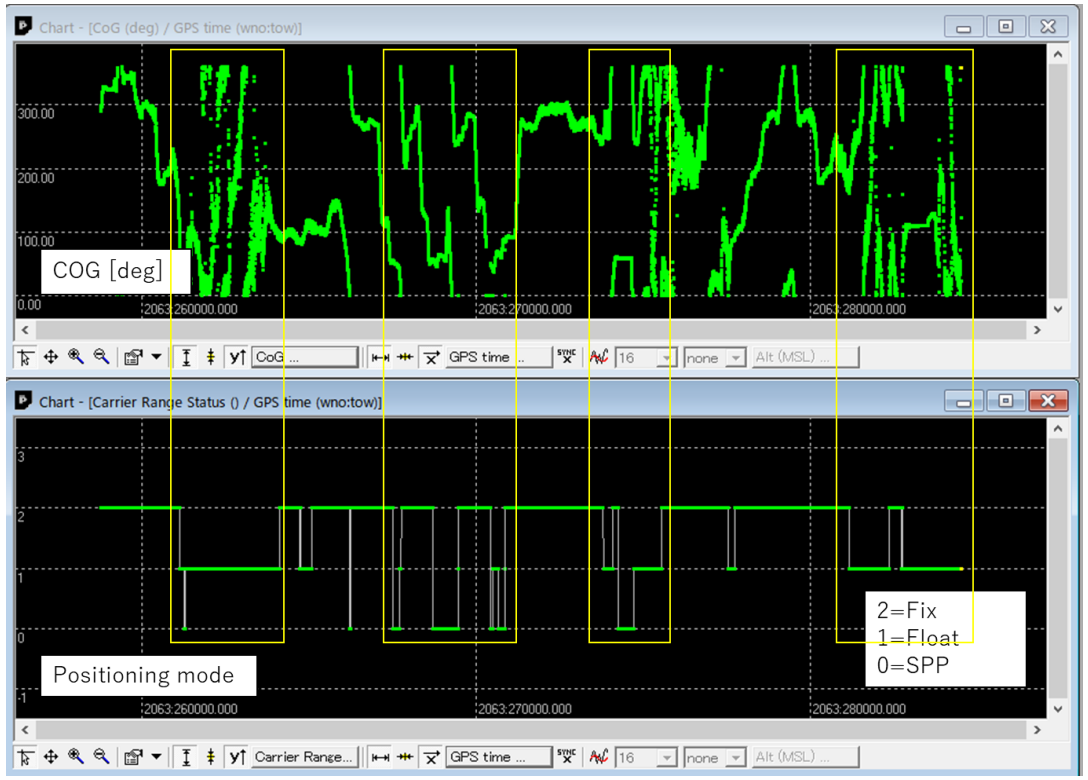
Official performance standard
Horizontal : <12cm
Vertical : <24cm

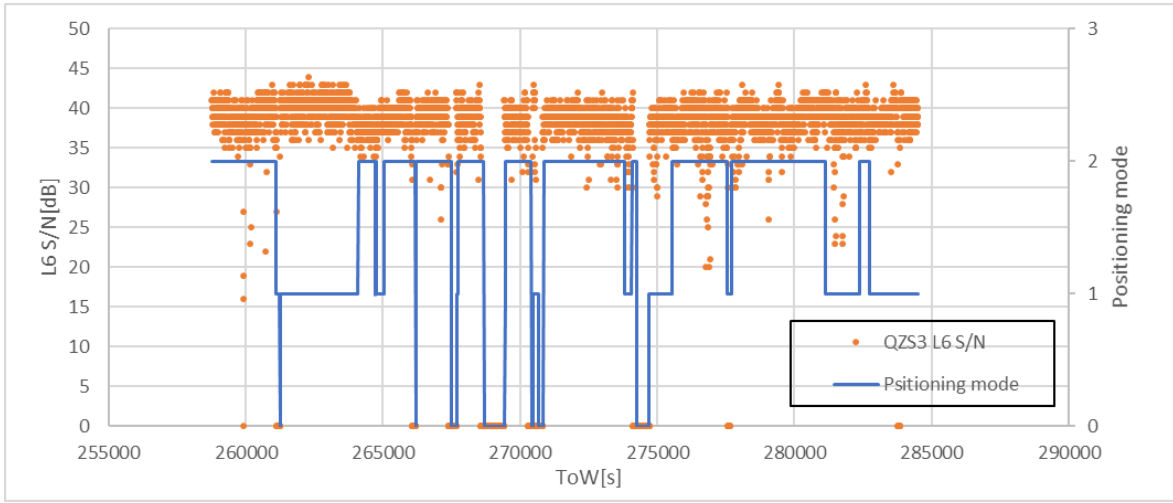
＊RMSE : Root Mean Squared Error

5. Evaluation on the ship (CLAS)

In voyage 2, the ship cruised with quick maneuver and Fix solution could not be calculated during the high COG rotation. This reason is assumed that L6D signal from QZS-3 was blocked by the mast.

When we changed L6 tracking selection mode to “Auto” (select good condition satellite automatically from QZS-1~QZS-4), the Fix rate was improved to 91.7% from 62.8%.



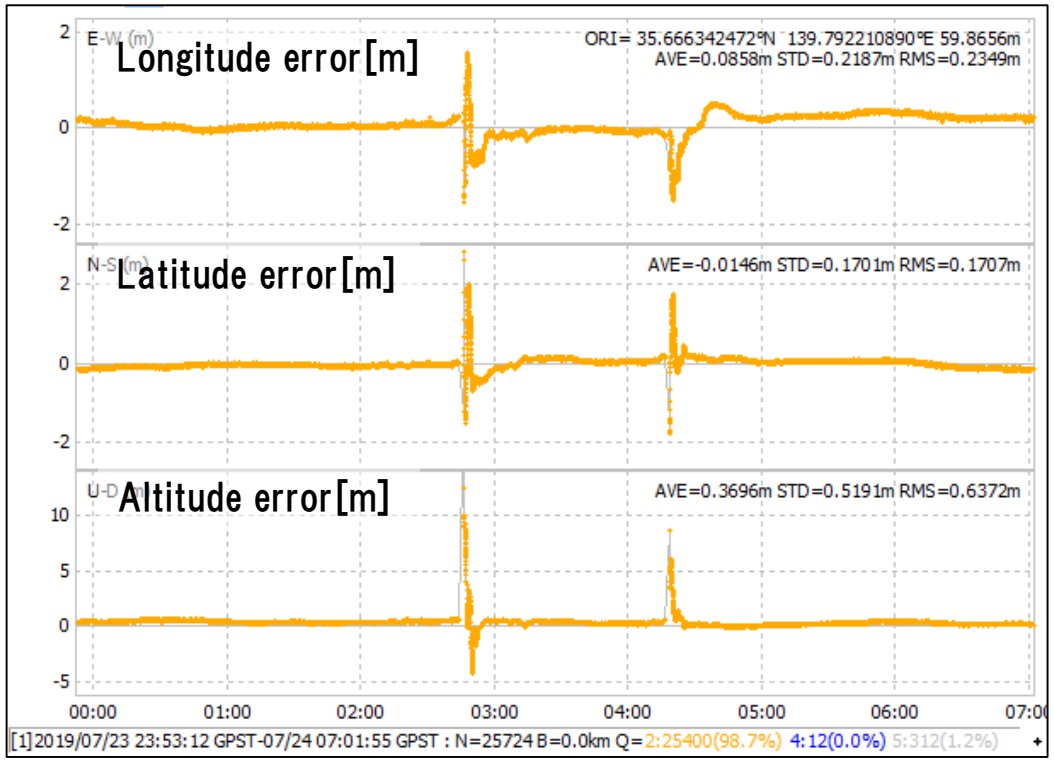


Relation ship between L6D signal S/N (Signal to Noise ratio) and positioning mode.

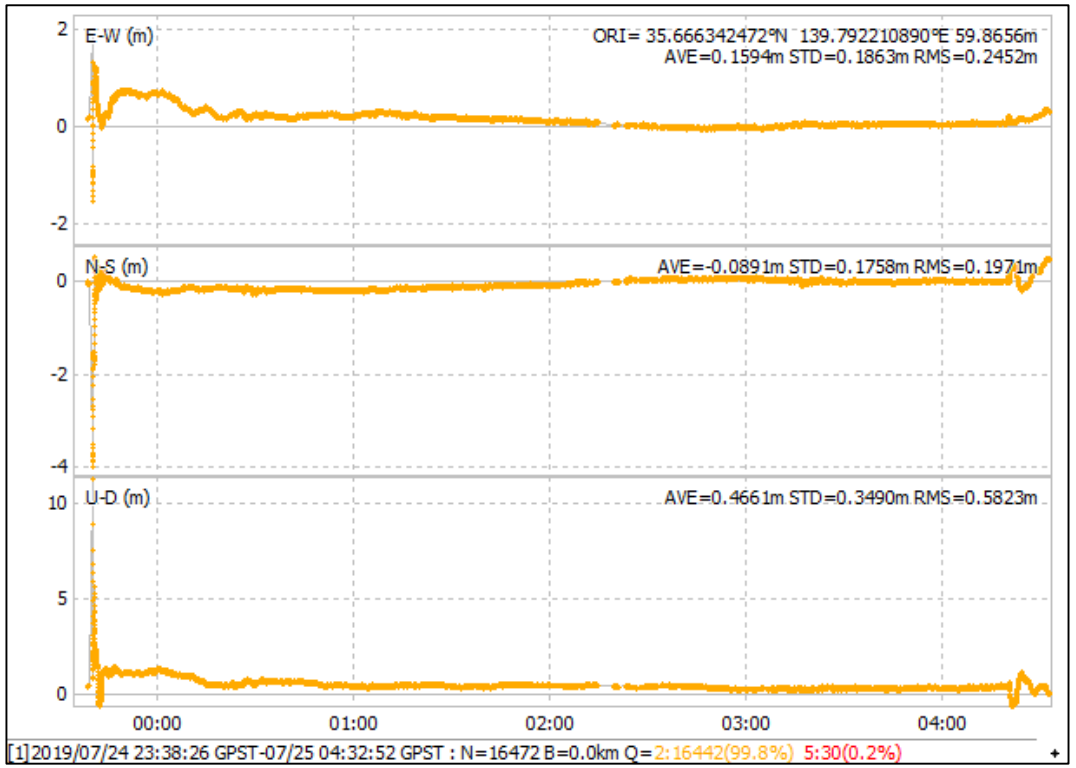
5. Evaluation on the ship (MADOCA)

◆MADOCA solution includes large error that caused by interruption of L6E correction data receiving.

◆ Availability was high, but accuracy was worse than CLAS.



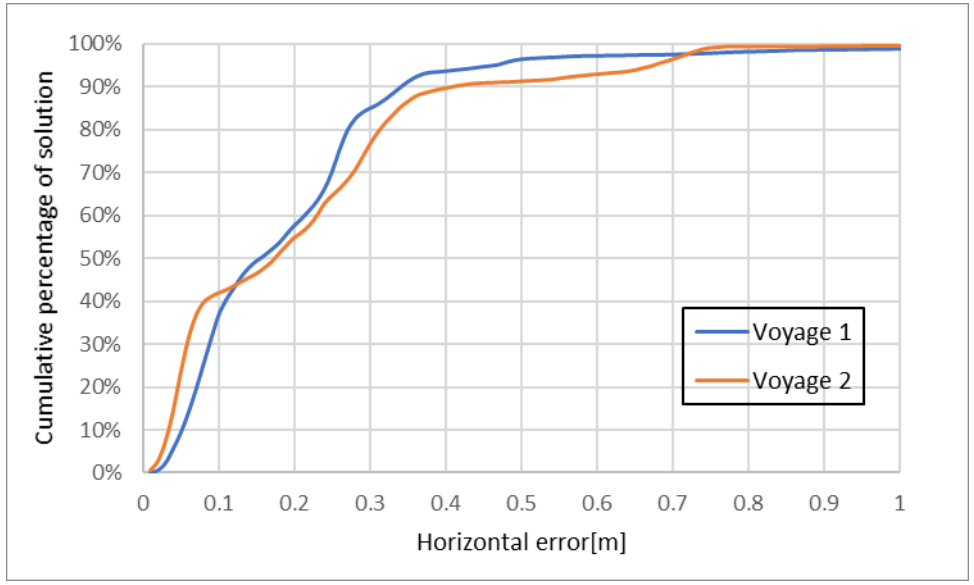
Error plot of Voyage 1



Error plot of Voyage 2

5. Evaluation on the ship (MADOCA)

- MADOCA solution includes large error that caused by interruption of L6E correction data receiving.
- Availability was high, but accuracy was worse than CLAS.



Cumulative frequency graph (only PPP solution)

MADOCA	PPP rate	Horizontal 2DRMSE	Vertical 2DRMSE
7/24 Voyage1	98.80%	58.07cm	127.44cm
7/25 Voyage2	99.80%	62.92cm	116.46cm

＊RMSE：Root Mean Squared Error

6. Conclusion of the evaluation on ship

CLAS

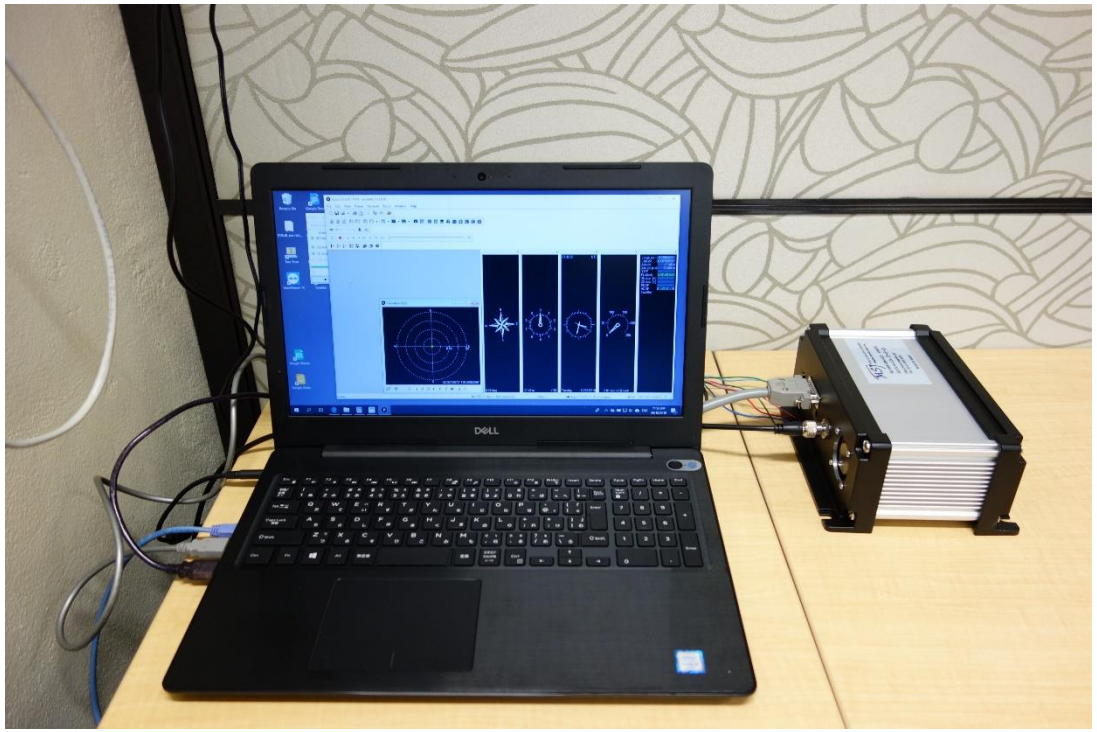
- Accuracy satisfied expectation and it was better than MADOCA.
- There is no accuracy and availability degradation in the coastal area 5~10km away.
- Mast or other object on the ship blocked L6 signal and it caused low fix rate.
  We should consider antenna install position or more robust L6 tracking selection algorithm.

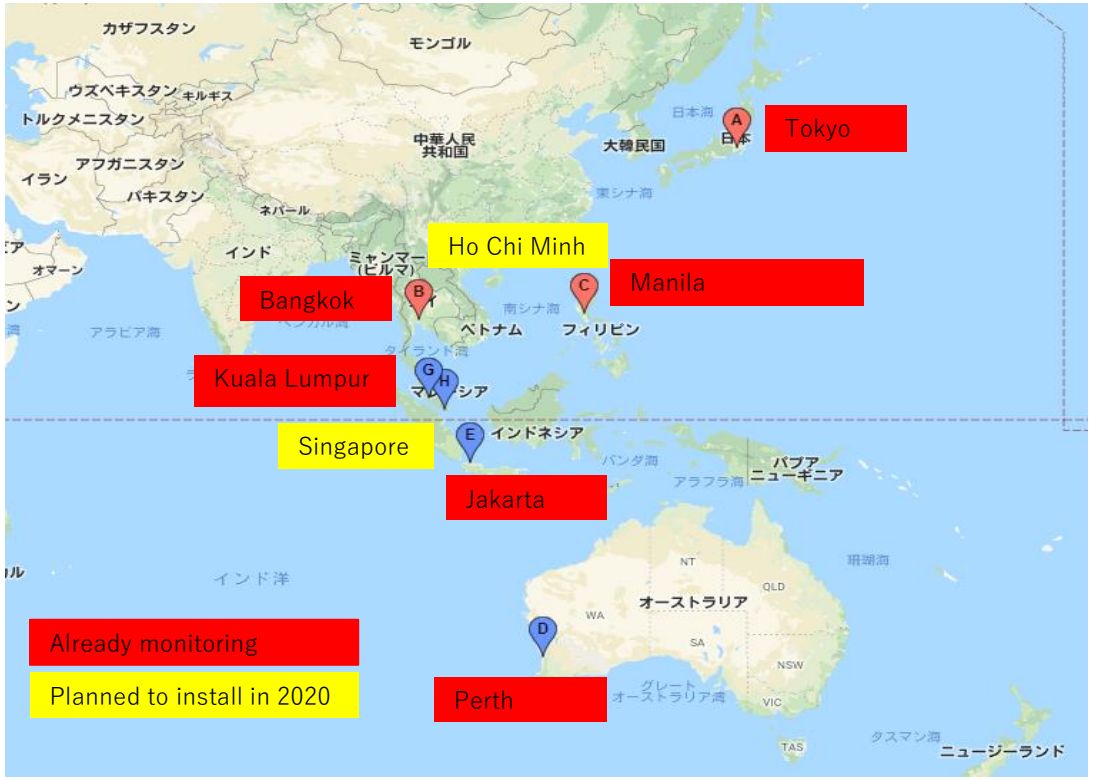
MADOCA

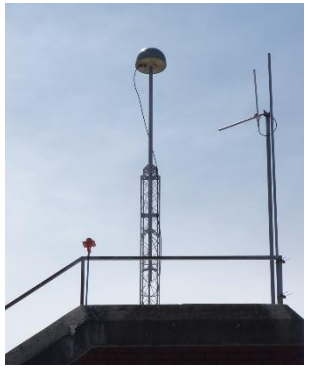
- By monitoring estimated error, we can use 40cm level position solution constantly in the wide QZSS coverage area.
- Influence by ship object is lower than CLAS.
- Future tasks are
  - conduct more evaluations in different regions and environments.
  - Performance improvement to achieve faster solution convergence and eliminate vertical bias.

7. Monitoring of MADOCA in Asia

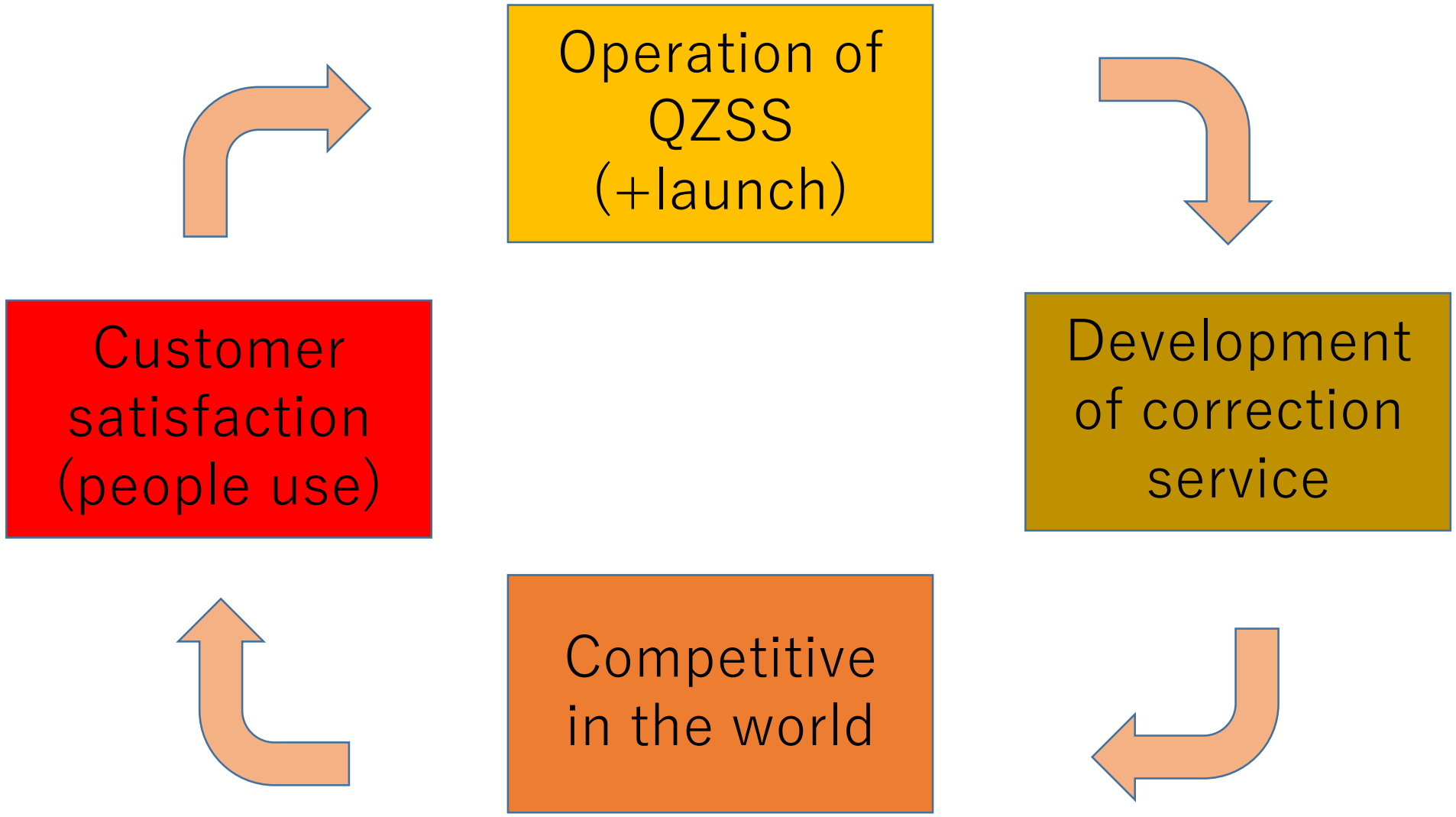
Now, we are monitoring MADOCA-PPP accuracy and reliability in some university in Asia and Oceania.





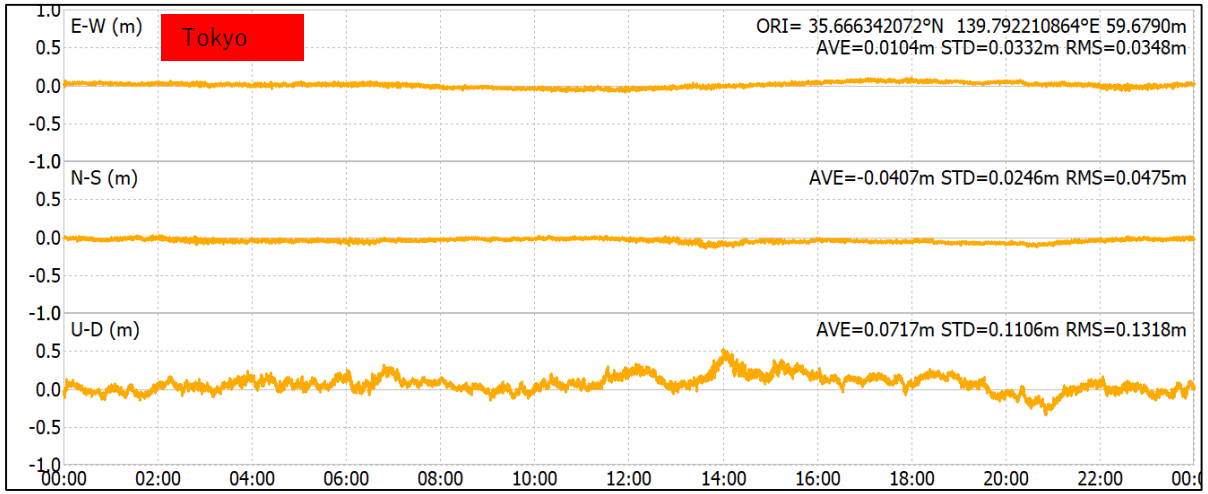


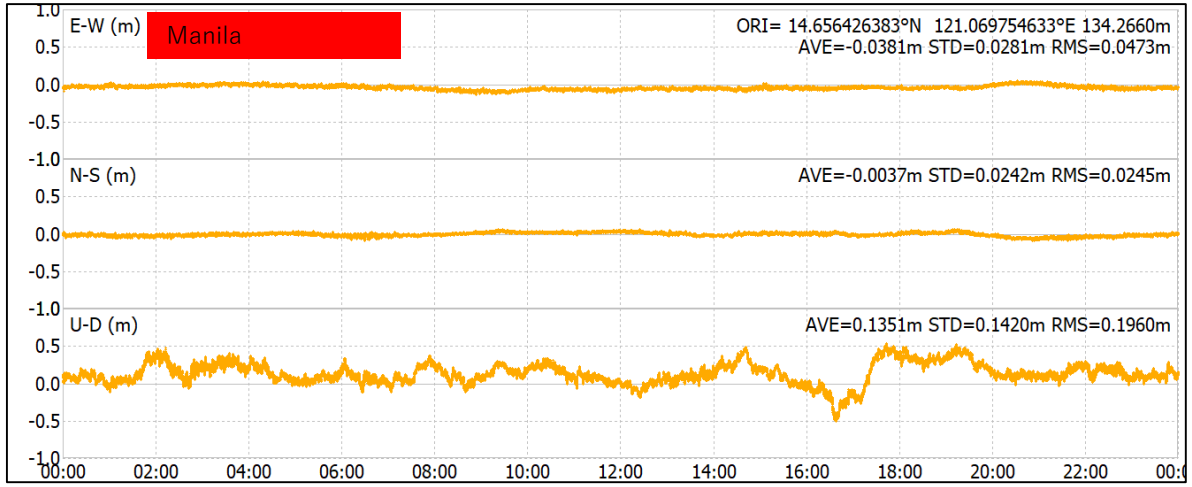
7. Monitoring of MADOCA in Asia

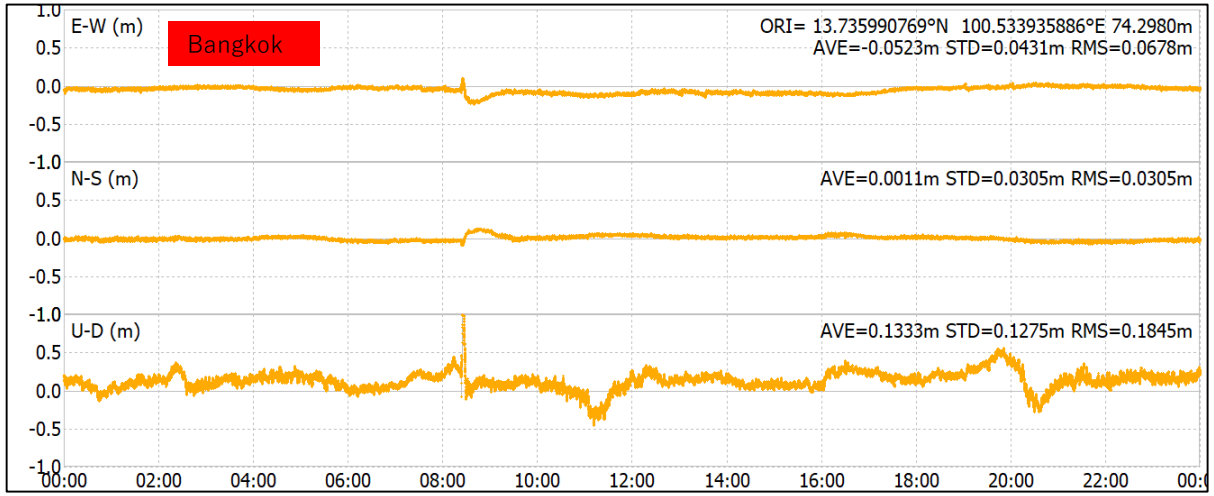


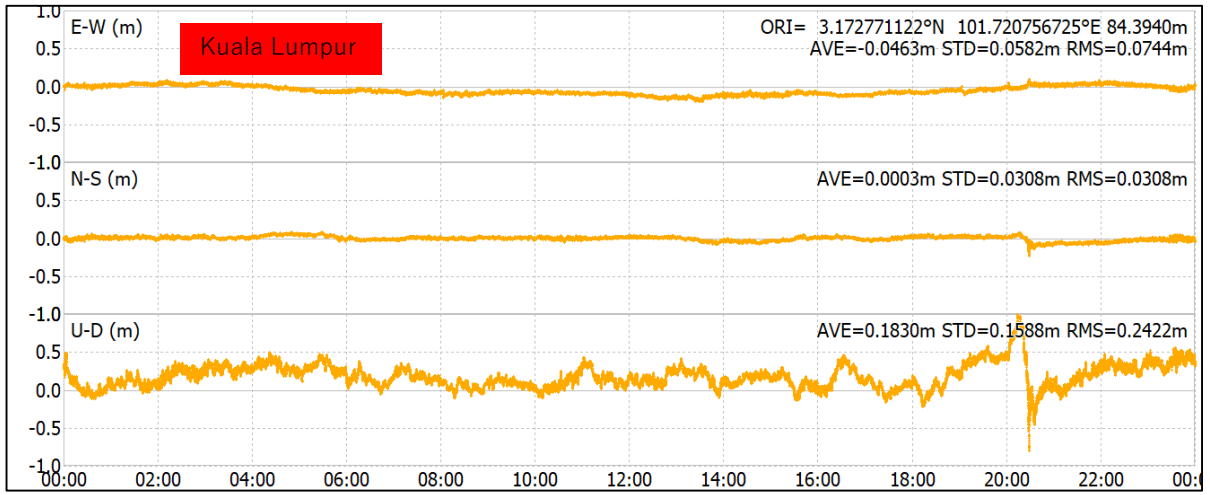
7. Monitoring of MADOCA in Asia

Real time MADOCA-PPP solution in each station.



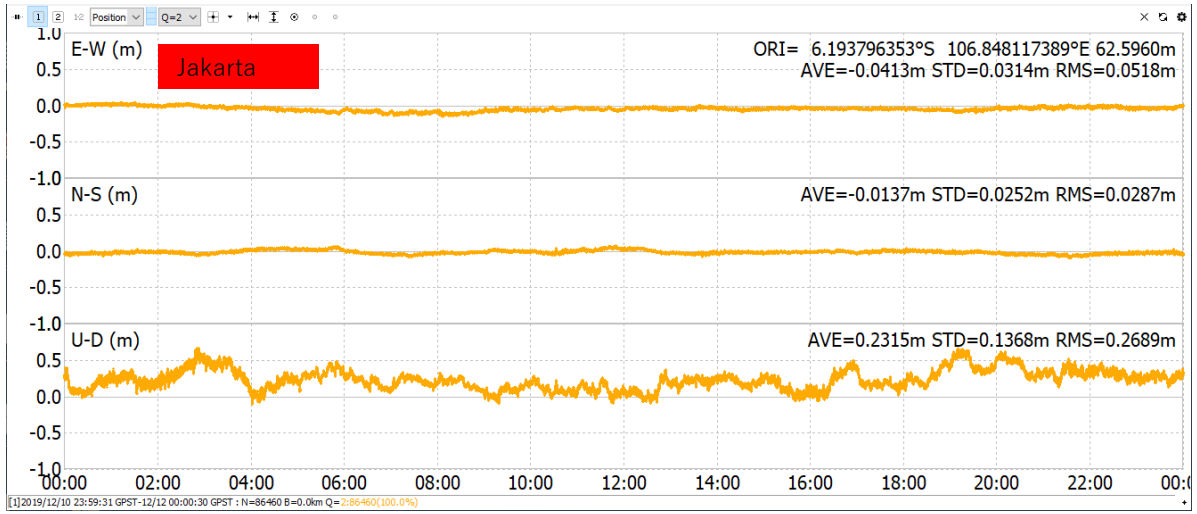


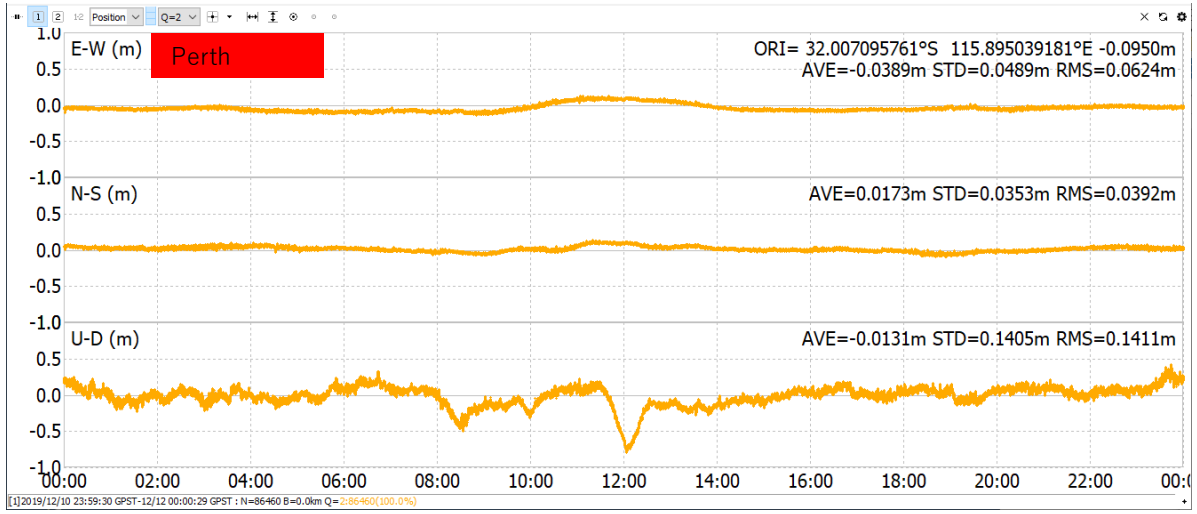




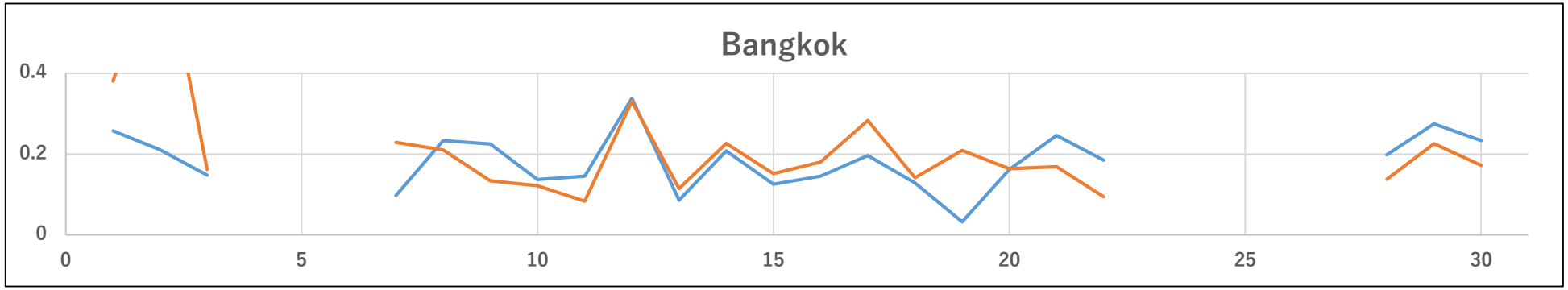
7. Monitoring of MADOCA in Asia

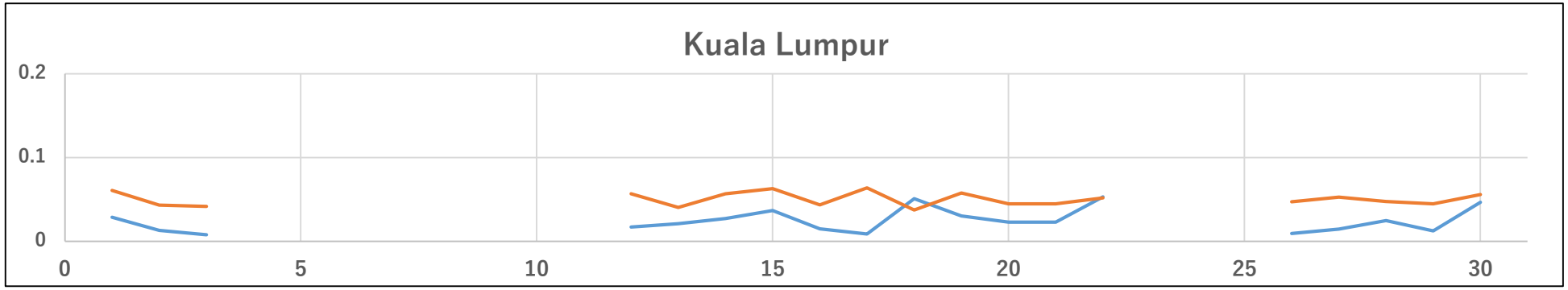
Real time MADOCA-PPP solution in each station.

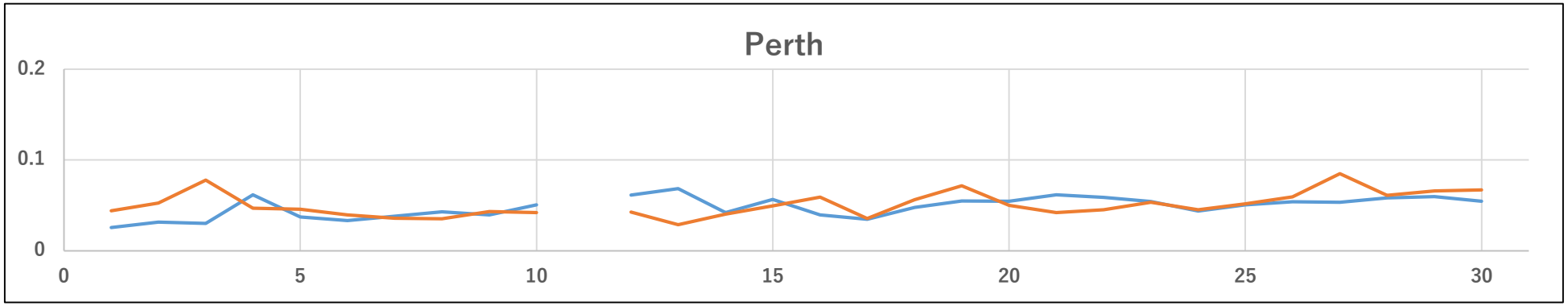




7. Monitoring of MADOCA in Asia







- Average of the horizontal error
- Standard deviation of the horizontal error

8. Promotion of MADOCA/CLAS

Consumer receiver release was started nowadays.

Mitsubishi (CLAS)

AQLOC-VCX

AQLOC-VCX II

19年春発売予定

Magellan Systems Japan (CLAS,PPP)

Core (CLAS,PPP?)

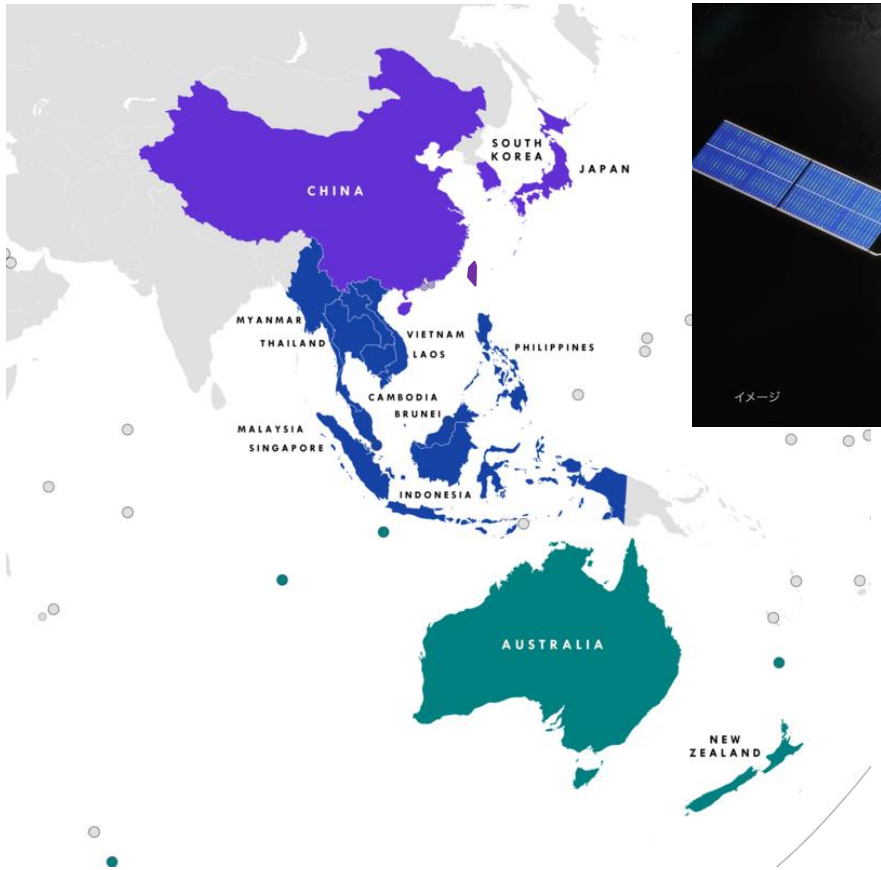
Chronosphere-L6

JRC (CLAS)

8. Promotion of MADOCA/CLAS

We hope more QZSS use in Asia region.

Please let us know if you are interested in MADOCA-PPP. We will help you solve your problem by QZSS-PPP service.



QZSS official home page : https://qzss.go.jp/en/

Prof.Kubo : nkubo@kaiyodai.ac.jp
Kaito Kobayashi : d650efrmm@outlook.com