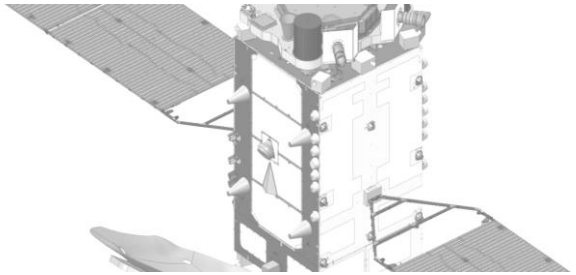
Cabinet Office
National Space Policy Secretariat



2nd ICG Workshop on Interoperability of Precise Point Positioning

QZSS MADOCA-PPP Status Update

March 22, 2023

Yoko SAKAI

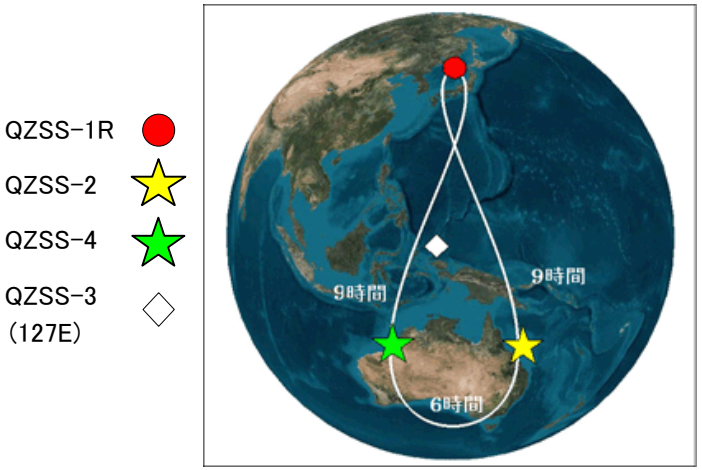
QZSS Strategy Office

National Space Policy Secretariat

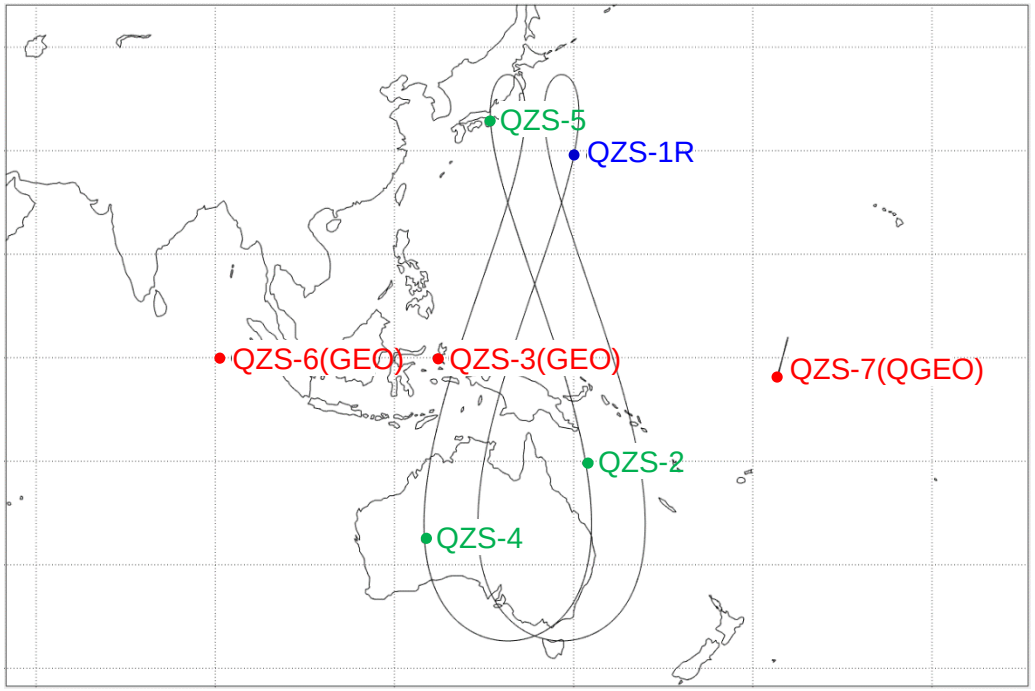
Cabinet Office, Government of Japan

1. QZSS system

- ***Functional Capabilities:***
  - GPS Complementary (Ranging signals)
  - GNSS Augmentation (Error corrections)
  - Messaging Service (Disaster relief, management)
- ***Coverage:***
  - SLAS/CLAS: Domestic
  - MADOCA-PPP: Asia and Pacific region



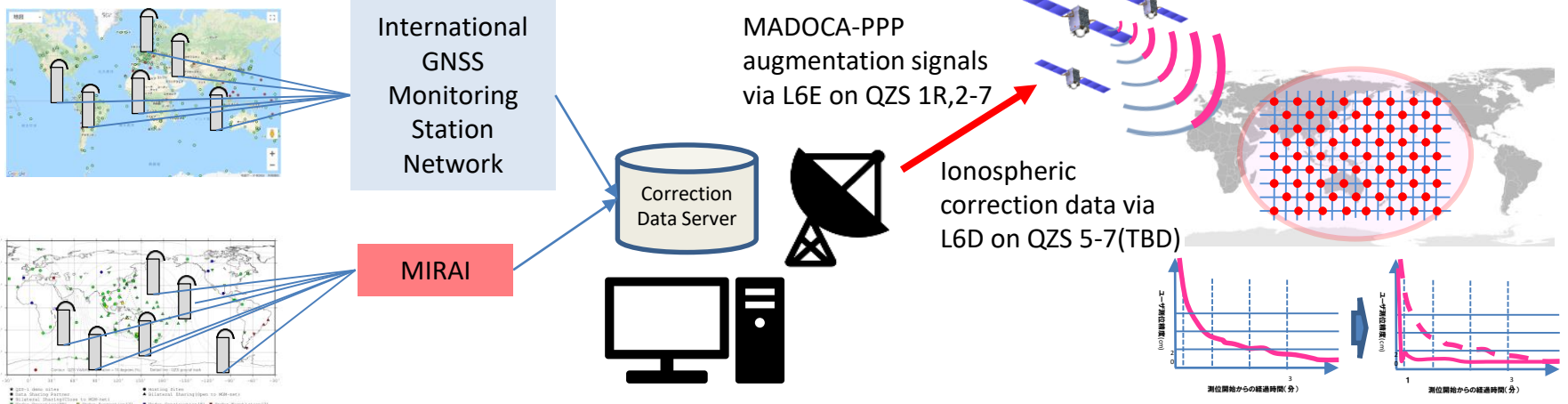
Current 4-QZSS Ground Track



7-QZSS Ground Track

2. Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning (MADOCA-PPP)

- MADOCA-PPP, Multi-GNSS Advanced Orbit and Clock Augmentation - Precise Point Positioning, has begun since September 2022 as a trial service.
- The operational service will start no later than JFY2024.
  - MIRAI, GNSS Monitoring Station Network, has been released since April 2022.
  - To reduce initial convergence time of MADOCA-PPP, the ionospheric correction data for Asia Pacific region will be broadcasted from JFY2024 as an experiment.
- CAO is looking for the opportunity of demonstration in cooperation with partners in Asia-Oceania region to promote technical understanding and consider feasibility to apply MADOCA-PPP to the user applications.



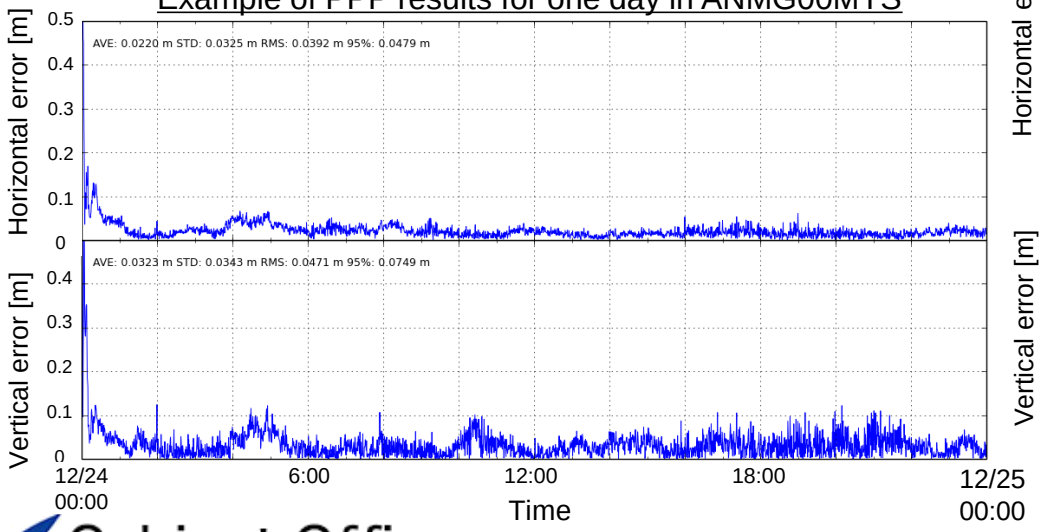
2. MADOCA-PPP -Performance of trial service

Here is one of the PPP results based on data from IGS monitoring station in Malaysia.

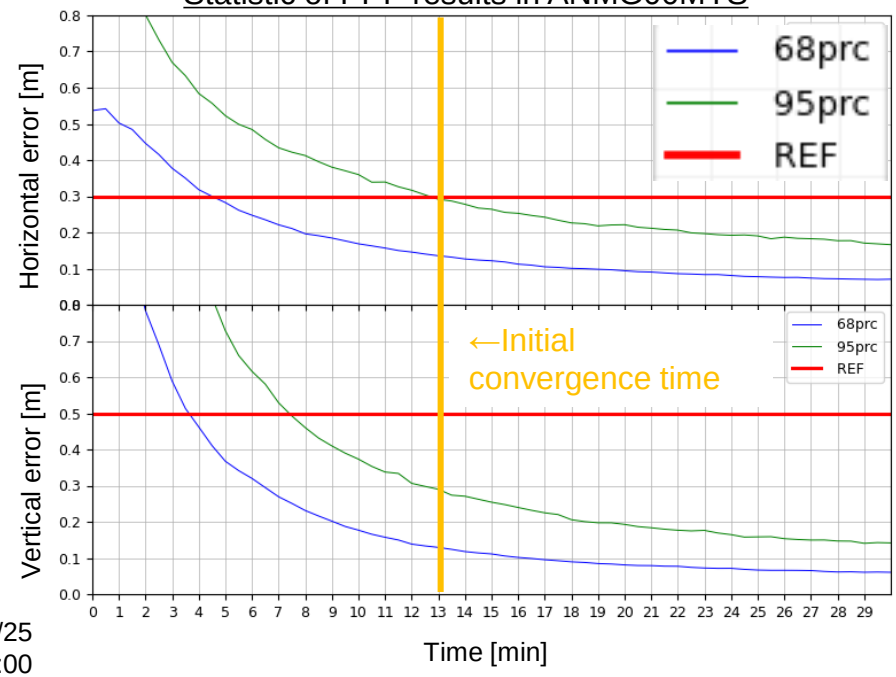
[Evaluation conditions]
Period: Dec. 1 to Dec. 31, 2022
Software: RTKLIB
*1: Statistics in rebooting PPP computation every 15min.
*2: Statistics of every 30s data during a month from 00:30:00 to 23:59:30 (UTC) per day

Name of sites	Initial convergence time to reach H30cm･V50cm of 95% errors*1 [s]	Horizontal accuracy after convergence (95%)*2 [cm]	Vertical accuracy after convergence (95%)*2 [cm]
ANMG 00MYS	780 (1800s in spec)	5.64	9.46

Example of PPP results for one day in ANMG00MYS



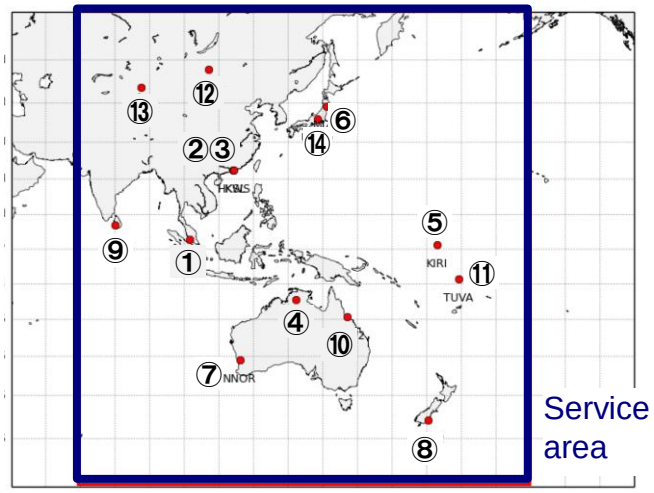
Statistic of PPP results in ANMG00MYS



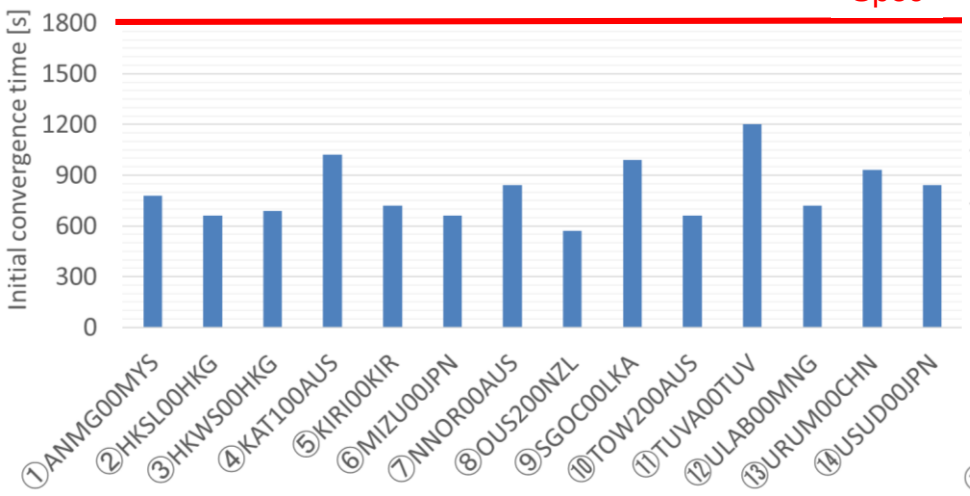
Cabinet Office
National Space Policy Secretariat

2. MADOCA-PPP -Performance of trial service

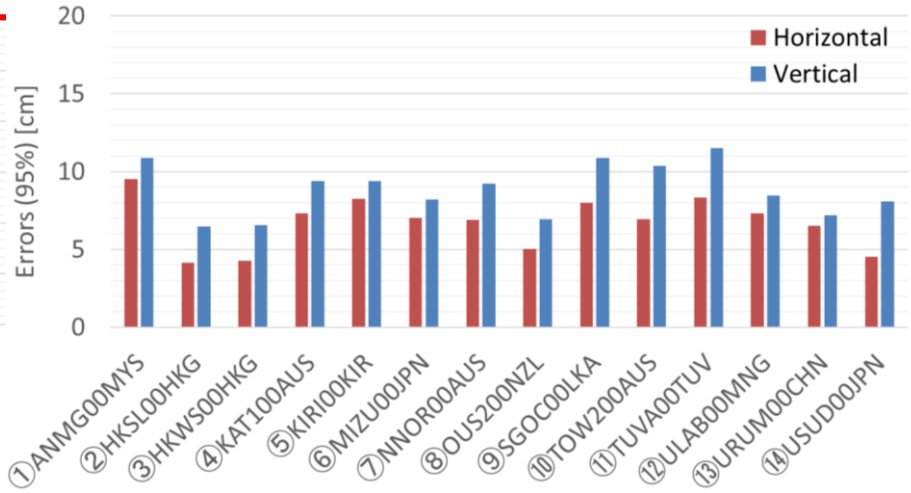
PPP results in last December using other IGS monitoring station are as shown below.
Better initial convergence time than the defined specification and approximately 10 cm of accuracy are confirmed.



Initial convergence time



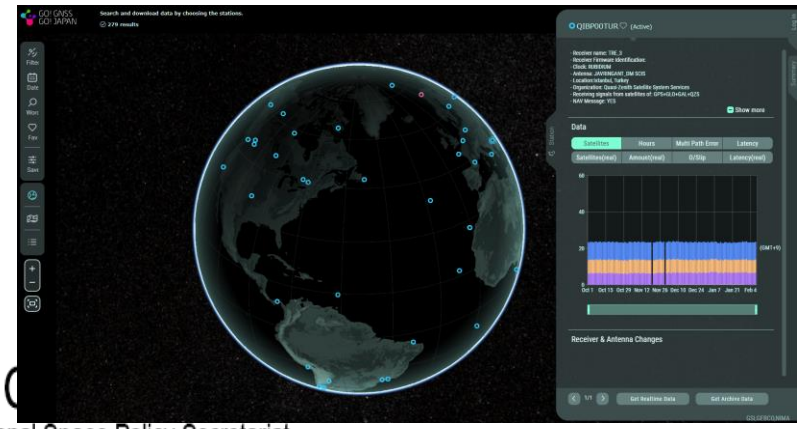
Accuracy after convergence



*The evaluation conditions are the same as on the previous slide.

3. GNSS monitoring station network - MIRAI

- CAO is operating MultI-GNSS Integrated Real time and Archived Information system (MIRAI) with the intention to be a "redundant" data caster on the existing IGS RT infrastructure for operating MADOCA-PPP.
- Partners inside and outside Japan (e.g. GA) kindly provide their data to MIRAI.
- MIRAI shows both real-time data and archive data, and the MIRAI data are shared openly for the benefit of all scientific, educational, and commercial users for peaceful purposes only.
- CAO welcomes direct connection to MIRAI rather than the secondary connection for IGS stations also from the viewpoint of redundancy.



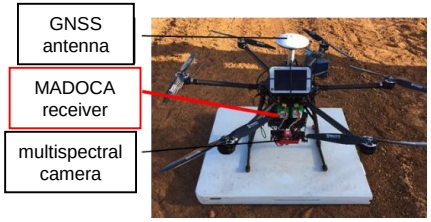
1	Operation Start Date	April 1st . 2022
2	Operation	365 days per year (Charge of free)
3	Signals	● QZSS：L1C/A, L2C, L5, L1C, (L1C/B) ● GPS：L1C/A, L2P, L2C, L5, L1C ● GLONASS：L1, L2 ● Galileo：E1b, E5a ● BeiDou：B1, B2, B3
4	Real-time Output Data Format	RTCM 3 via NTRIP caster
5	Delay (system latency)	< 0.1 s
6	Archiving System	● Archive Period: 1.5 year ● Archive Format: RINEX 3.04 (past 1.5 years. RINEX 4.00 will be available from Oct. 2023)
7	Interface to connect monitoring station	● NTRIP Caster ● MAX 300 stations ● Format : RTCM3 (or BINEX) ● Frequency: 1Hz

4. Demonstration projects using MADOCA

- The experimental signal of MADOCA-PPP was transmitted from QZSS until the start of MADOCA's trial service. In cooperation with private sectors and relevant ministries and agencies, the following demonstration projects were conducted.
- CAO would like to continue to encourage the practical application through demonstration projects with MADOCA-PPP trial service as well.
- CAO believes that some application using domestic augmentation service could also use MADOCA. (Especially maritime application less sensitive to convergence time due to open sky conditions.)

Australia

Tractor's autonomous driving between streets
(by Ministry of Internal Affairs and Communications)



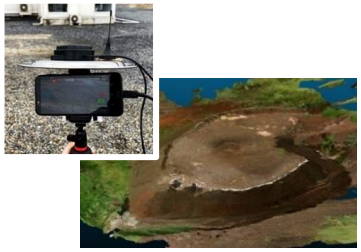
Pinpoint application of herbicide on banana farmland
(by Ministry of Internal Affairs and Communications)

Thailand

Low-speed fully autonomous driving system using micro EVs

Malaysia

Plant observation system by drone



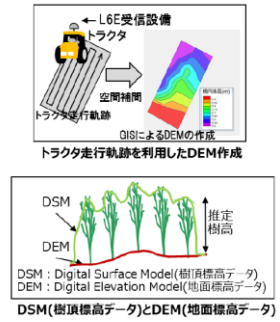
Smart phone soil volume measurement
(by Ministry of Internal Affairs and Communications)

Australia/Philippines, Indonesia

Road surface information provision/prediction service, motorcycle theft prevention service
(by Ministry of Internal Affairs and Communications)

Indonesia

Creation of 1/5000 topographic maps by high-precision surveying



Tree-planting management
(by Ministry of Internal Affairs and Communications)

4. (1) Autonomous navigation vessels

CLAS

内閣府
宇宙開発戦略推進事務局

- Eight knot Inc. announced the launch of "Eight knot AI CAPTAIN," an autonomous navigation platform for small vessels under 20 tons. They began offering some functions that are still available under the current law as automatic ship-handling assist functions.
- CLAS is used for automatic vessel navigation and berthing.
- Through social implementation of autonomous navigation technology, it is expected to support ship crews, save labor, improve safety, and contribute to cost optimization.

Robotic AI Cruiser with AI CAPTAIN
「Eight Knot I」

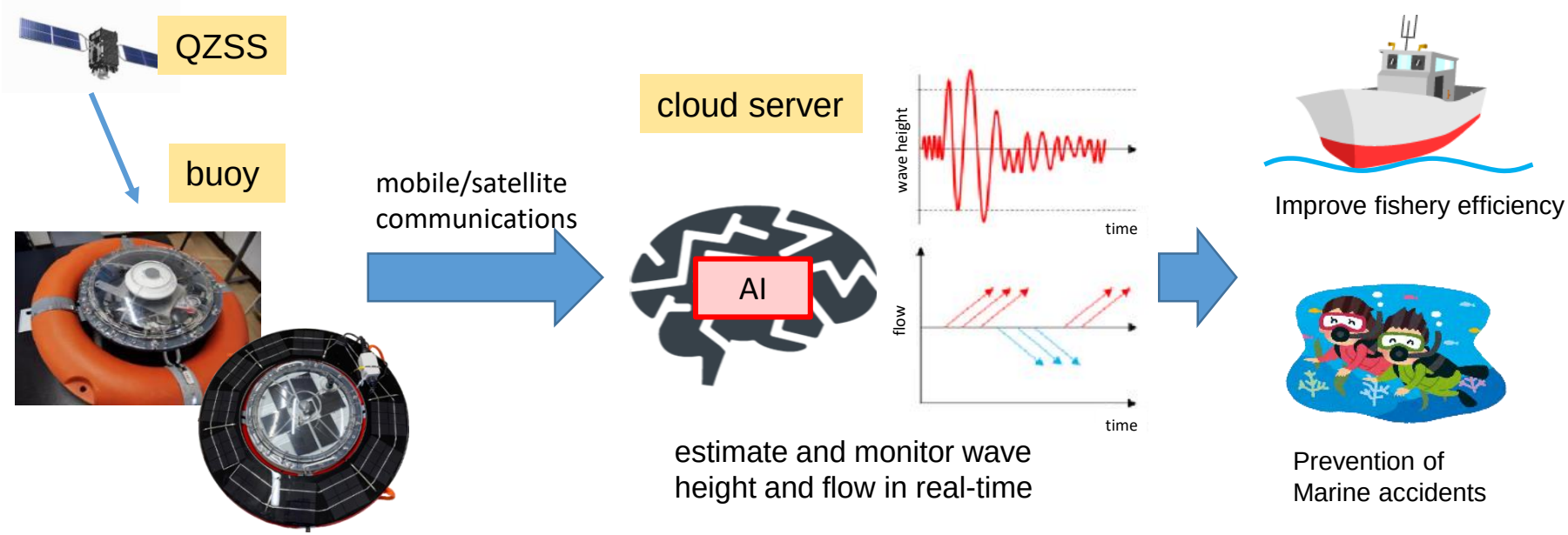
Navigation display (sample)

4. (2) Buoys for real-time oceanographic observation

SLAS

内閣府
宇宙開発戦略推進事務局

- Blue Ocean Research Institute, Inc. has developed a wave height estimation system using SLAS.
- The system is now being produced on a build-to-order basis.
- The system uses buoys equipped with SLAS receivers to observe XYZ, and uses AI to estimate wave heights (10 cm accuracy) and flow directions (16 directions) in real time.
- Maintenance-free operation is possible at offshore with solar panels and cellular/satellite communications together.
- Real-time monitoring of the oceanographic is possible, contributing to improving fishery efficiency and prevention of marine accidents.

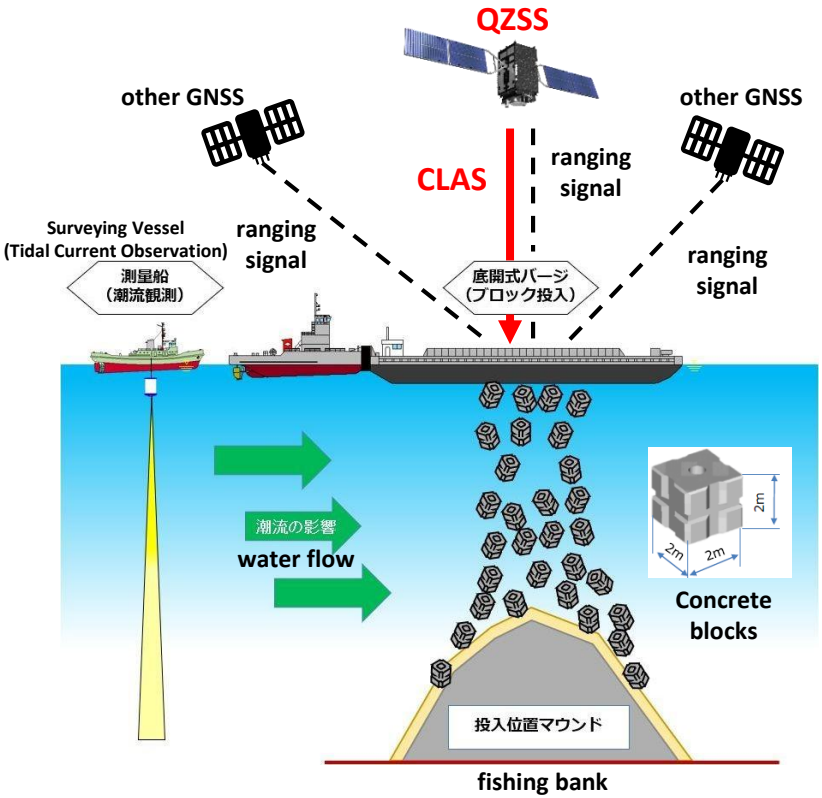


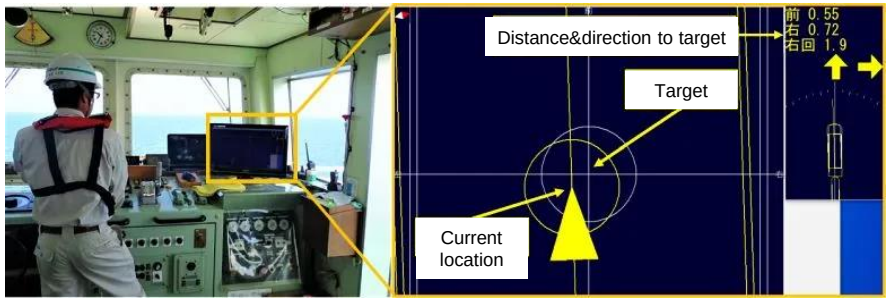
4. (3) Artificial Fishing Reefs Construction on Seabed

CLAS

内閣府
宇宙開発戦略推進事務局

- Toyo Construction Co., Ltd. has developed a system to visualize offshore construction conditions using CLAS.
- Although RTK was not available offshore where the construction site was located, CLAS showed no loss of accuracy even when 20+ km away from the coast.





Construction status diagram

fishing ground construction system screen

Barge(vessel) and GNSS antenna

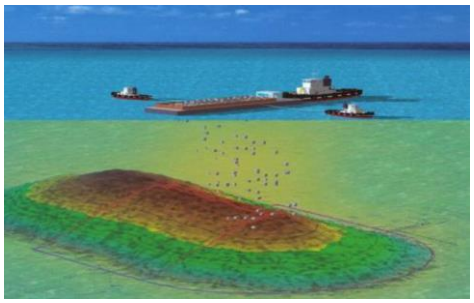
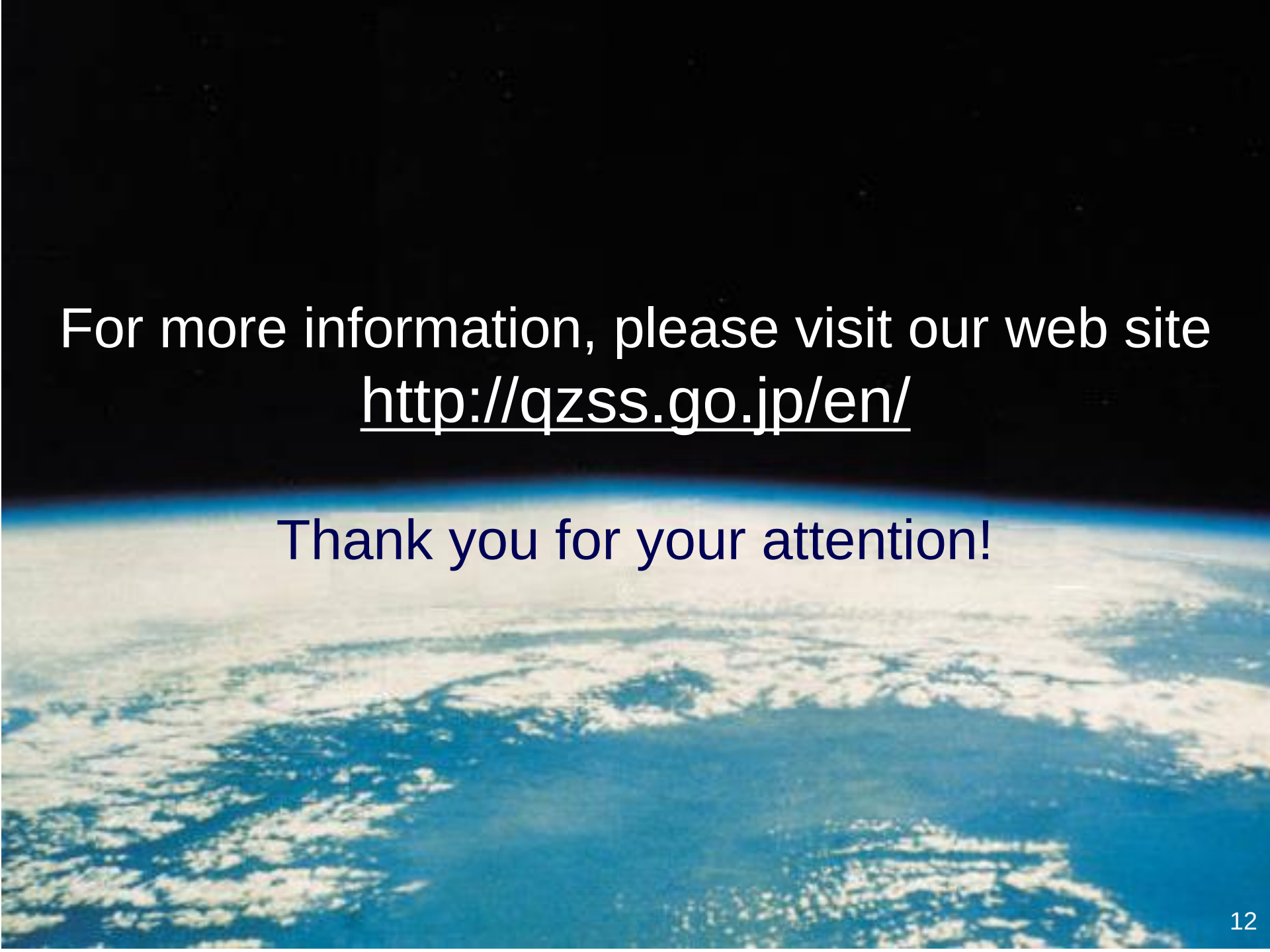


Image of block input by barge

5. Comments on PPP interoperability

- Message format of MADOCA-PPP is based on Compact SSR as same as CLAS considering a certain degree of interoperability.

- CAO continues to suggest that providers clarify and standardize the assumptions and definitions of the items like positioning accuracy and convergence time in the 3PITF report, as commented in ICG-16.



For more information, please visit our web site
http://qzss.go.jp/en/

Thank you for your attention!