R&D Theme

Development of Virtual Mooring (VM) Technology for Stormy Environments

Progress until FY2022

1. Outline of the project

We develop virtual mooring (VM) drones; sailboat-type unmanned maritime surface vehicles (USVs) that can operate around the center of typhoons and continuously obtain atmosphere-ocean data along their movement based on technologies that enable autonomous navigation and virtual mooring driven by winds and ocean currents.

In the first year (2022), we designed VM function and built hulls which can be navigated in stormy environment with strong wind and high waves around typhoon centers. After improvements by testing prototypes in a lab, full-scale tank, and coastal waters in Japan to prepare a short-term (approx. one week) open-ocean test in 2023 in the east of Philippines, where typhoons are frequently generated, during R/V *Mirai* tropical ocean cruise.

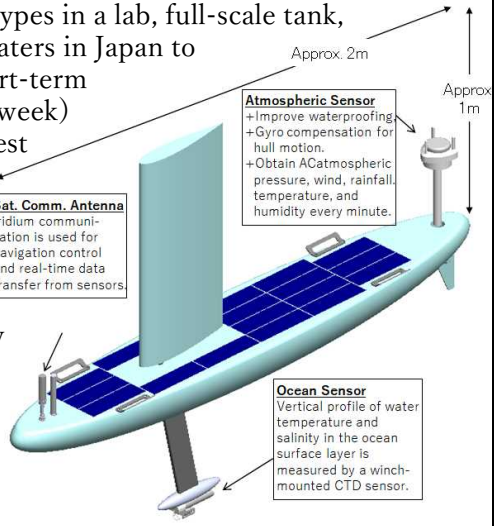

Fig. 1 Overview of the VM drone prototype. Specifications are subject to change by improvement through the project.

2. Outcome so far

The activities and results in 2022 are as follows.

1. We designed a sailboat-type USV based on computational fluid dynamics (CFD) simulations in collaboration with private sectors, and built prototypes #0 (hull structure only) and #1 (with mast, sail, keel, rudder, and electrical components).
2. To confirm the hull strength and the external forces around the hull during sailing under stormy environment with strong wind and high waves, we tested the prototype #0 in a multipurpose water tank (L 40 m x W 4 m wide x D 2 m). For example, it was repeatedly dropped into the tank from a height simulating stormy waves in typhoons to confirm hull deformation and damage, and it was towed in the tank at different speeds and angles to measure wave resistance and hexagonal stress around the mast during sailing.

Fig. 2 Water tank tests using VM drone prototype #0. It was lifted up to the ceiling by a crane (white dashed circle) and dropped into the water tank for a strength test (left). The prototype #0 with six-axis stress sensor equipped to its mast was towed at high speed over the water tank to measure wave resistance and stress around the mast (right).

3. After outfitting prototype #1 with atmosphere-ocean sensors developed by R&D Theme 2, it was tested twice in coastal waters of Suruga Bay (Mitsuhama, Numazu City, Shizuoka) for one weeks in December 2022 and February 2023 to confirm hull and navigation performance. Although both tests were conducted in fair weather and weak wind conditions, we were able to confirm basic sailing performance, hull control by sail and rudder, and radio communication, starting with checking a safety procedure of its deployment (landing on water) and retrieval by using an A-frame crane on the deck of measuring vessel (approx. 17 tons) that transported it from a port to the test area.

Fig. 3 Test in coastal waters by using prototype #1 in Suruga Bay, Japan (left). Operation check on land for sail and rudder control, and communication prior to the test (right).

3. Future plans

In the next year (2023), we build a prototype #2 which is improved based on tests in 2022, and conduct a short-term (approx. one week) open-ocean test in east of Philippines, where typhoons are frequently generated, during R/V *Mirai* tropical ocean cruise which is prepared by R&D Theme 3.

国立研究開発法人 科学技術振興機構 Japan Science and Technology Agency

Development of Unmanned Marine Observation Vehicles to Contribute to Forecasting and Monitoring of Typhoon Artificial Control

R&D Theme

Development of Atomosphere-Ocean Sensors for Stormy Environments

Progress until FY2022

1. Outline of the project

We develop atmosphere-ocean sensors outfitted on virtual mooring (VM) drones which can maintain sufficient accuracy even in stormy environment with large hull motion caused by strong wind and high waves around the center of typhoons and waterproofness enough to withstand temporary submergence and heavy rainfall.

In the first year (2002), atmospheric sensors were waterproofed and tested alone in a laboratory repeatedly. They were then outfitted on the VM drone prototype #1 for testing in coastal waters, and further improvements were made in preparation for a short-term (approx. one week) open-ocean test in 2023 in the east of Philippines, where typhoons are frequently generated during R/V *Mirai* tropical ocean cruise.

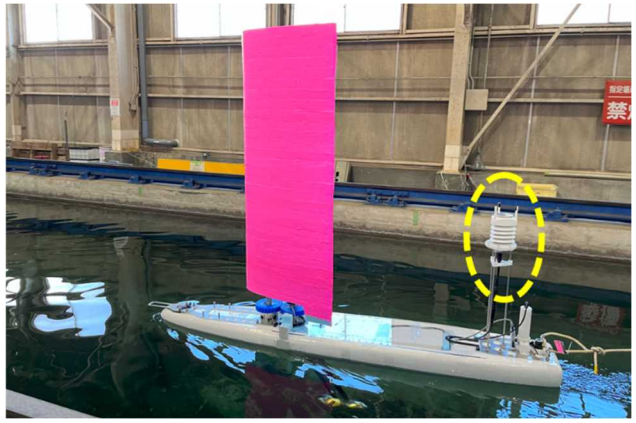

Fig. 1 Modified atmospheric sensor (yellow dashed circle) outfitted with the prototype #1. Prior to the test in coastal waters, it was validated in the multi-purpose water tank.

2. Outcome so far

The activities and results in 2022 are as follows.

1. We modified versatile automatic weather stations to improve their waterproofness, and tested them in a laboratory repeatedly to confirm their accuracy.
2. After outfitting the modified atmospheric sensor with VM drone prototype #1 developed in R&D Theme 1, it was tested in coastal waters of Suruga Bay in December 2022 and February 2023 to confirm its waterproof performance and accuracy. Although both tests were conducted in fair weather and weak wind conditions, we confirmed that data obtained by the modified atmospheric sensor have sufficient accuracy in comparison with that observed by AMeDAS (Mishima) located nearby the test waters.
3. We outfitted an ocean sensor (multipurpose observation float: MOF) on the bottom of prototype #1 at the 2nd test in the coastal waters, and compared its data with that obtained by a drifting buoy (SOFAR Spotter) that was deployed at the same time. The results showed that the MOF has sufficient accuracy though only in small waves.

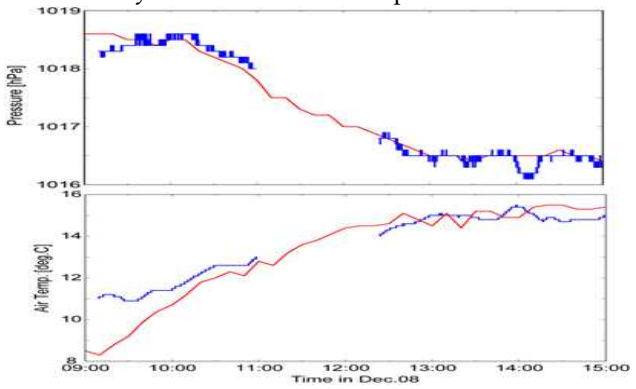

Fig. 2 Comparison of the data acquired by the modified atmosphere sensor outfitted on the prototype #1 during the test in coastal waters (December 2022) with the AMeDAS (Mishima) nearby. Sequential variations of atmospheric pressure (upper panel) and temperature (lower panel). The blue and red lines indicate atmospheric sensor data and AMeDAS data, respectively.

Fig. 3 Simultaneous observations with a Spotter drifting buoy (yellow dashed line) were conducted at the test in the coastal waters to validate the ocean sensor (MOF) outfitted on the VM Drone prototype #1 (red dashed line).

3. Future plans

In the next year (2023), we further improve the atmosphere-ocean sensor outfitted on prototype #2, and conduct a short-term (approx. one week) open-ocean test in the east of Philippines, where typhoons frequently occur, during R/V *Mirai* tropical ocean cruise operated by R&D Theme 3.

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Development of Unmanned Marine Observation Vehicles to Contribute to Forecasting and Monitoring of Typhoon Artificial Control

R&D Theme

Test operation under stormy environment in the tropical northwestern Pacific Ocean

Progress until FY2022

1. Outline of the project

We conduct open-ocean tests of virtual mooring (VM) drone prototypes in the tropical Northwest Pacific Ocean, a region where many typhoons are generated and develop, during R/V *Mirai* tropical ocean cruises in 2023 and 2024 to validate hull control, navigation, communication, and accuracy of atmosphere-ocean sensors in stormy condition with strong wind and high waves around the center of typhoons.

In the first year (FY2022), we established specific procedures and safety measures as preparation for the short-term open-ocean test (approx. one week) of the prototype #2 outfitted with modified sensors developed by R&D Themes 1 and 2 during R/V *Mirai* cruise in 2023 in the east coast of Philippines.

Fig. 1 R/V *Mirai* used for open-ocean tests of prototypes. A-frame crane on the aft deck (blue dashed circle) and other equipment used for deployment and retrieval of the VM drone prototypes. C-band radar (yellow dashed circle) and various atmosphere-ocean sensors equipped with the vessel are used to validate data obtained by the prototypes.

2. Outcome so far

The activities and results in 2022 are as follows.

1. We submitted a marine scientific research (MSR) application, which is required to prepare about one year prior to a cruise to obtain consent from coastal states if we plan activities in waters under the jurisdiction of a foreign state, to the MEXT (and then, MOFA) for the short-term open-ocean test after international coordination with relevant countries concerning the test in advance,
2. We made a specific test plan of the prototype #2 to obtain sufficient ship time based on discussion among PIs of various projects, such as the Wave Glider and drifting buoys, which are planned during the same cruise.
3. We established safety procedures on the deck of R/V *Mirai* and ocean, including deployment and retrieval the prototype during the test, and coordinated with research safety committee of the representative institution in advance.

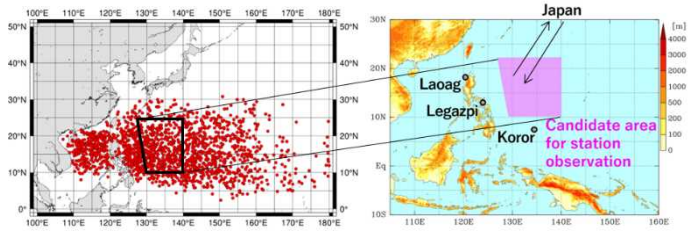

Fig. 2 Climatology of typhoon occurrence locations (red dots), 1951-2021, based on Digital Typhoon*1 (left). Planned route of R/V *Mirai* cruises in 2023/2024 and stationary points for open-ocean tests of VM drone prototypes in the east of Philippines (right).

*1 http://agora.ex.nii.ac.jp/digital-typhoon/reference/birthplace.html.ja

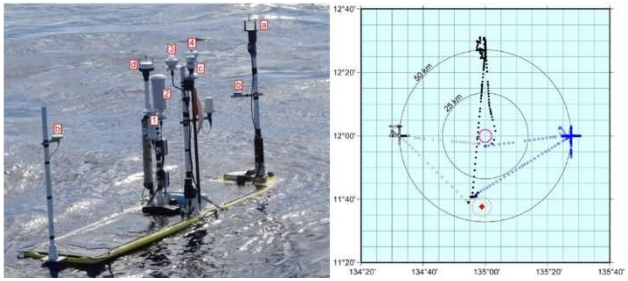

Fig. 3 Atmospheric sensors on the deck of a Wave Glider used for the 2020 R/V *Mirai* tropical ocean cruise (left) and arrangement of three Wave Gliders for their intercomparison (right). They were deployed at 50 km each to the east, west and north of the station point of R/V *Mirai* (red circle at the center) (R/V *Mirai* Cruise Report MR20-E01*2). Open-ocean tests of VM drone prototypes in 2023 and 2024 are planned in a similar configuration which can be intercompared among prototypes, Wave Gliders, and R/V *Mirai atmosphere-ocean sensors.*

*2 https://www.godac.jamstec.go.jp/cr_catalog/external/metadata/MR20-E01_all/file/MR20-E01_all.pdf

3. Future plans

In the next year (2023), we conduct the short-term (approx. one week) open-ocean test of the VM drone prototype #2 in the east of the Philippines during R/V *Mirai* tropical ocean cruise in collaboration with R&D Themes 1 and 2. For this purpose, we prepare for a safety assessment from the research safety committee of the representative institution about the test procedure on the deck and ocean including coordination with vessel crews. In addition, we submit the MSR application for a long-term open-ocean test in 2024 (approx. one month) over the same waters by R/V *Mirai tropical ocean* cruise.

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