Japan Argo Report for Argo Steering Team Meetings, April 2025

1. **The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2024)**
   a. **Floats deployed and their performance**

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) deployed 14 Core, Biogeochemical (BGC) and Deep Argo, and Argo equivalent floats from January to December 2024: 9 for Core Argo (APEX), 4 for BGC Argo (BGC-NAVIS), 1 for Deep Argo (Deep NINJA). The four BGC NAVIS floats equipped with SBE63 DO sensors, Deep SUNA nitrate sensors, and FLBBCD chlorophyll and backscattering sensors were deployed in the western subarctic North Pacific in October-November 2024. The one Deep NINJA float was equipped with AROD-FT (RINKO) DO sensors. Since 1999, JAMSTEC has deployed 1461 Core, Deep and BGC Argo, and Argo equivalent floats. The current positions of all active Japanese Argo floats are shown in Fig.1. Float deployments are usually conducted in collaboration with agencies, institutes, universities, and high schools. In 2024, One float was deployed in the North Pacific Ocean by a voluntary cargo ship of a Japanese merchant ship company, NYK.

The Japan Meteorological Agency (JMA) deployed 17 Argo equivalent floats (4 PROVORs and 13 ARVORs) in the seas around Japan from January to December 2024. All the floats get 2,000 dbar T/S profiles usually every 5 days for operational ocean analysis and forecast. Among 425 floats (18 PROVORs, 194 APEXs, and 213 ARVORs) that JMA has deployed from 2005 to 2024, 51 floats (4 PROVORs and 47 ARVORs) are active as of the end of December 2024, while 17 floats (17 ARVOR floats) terminated the transmission in 2024. JMA deployed 2 PROVORs and 2 ARVORs from January to February 2025.

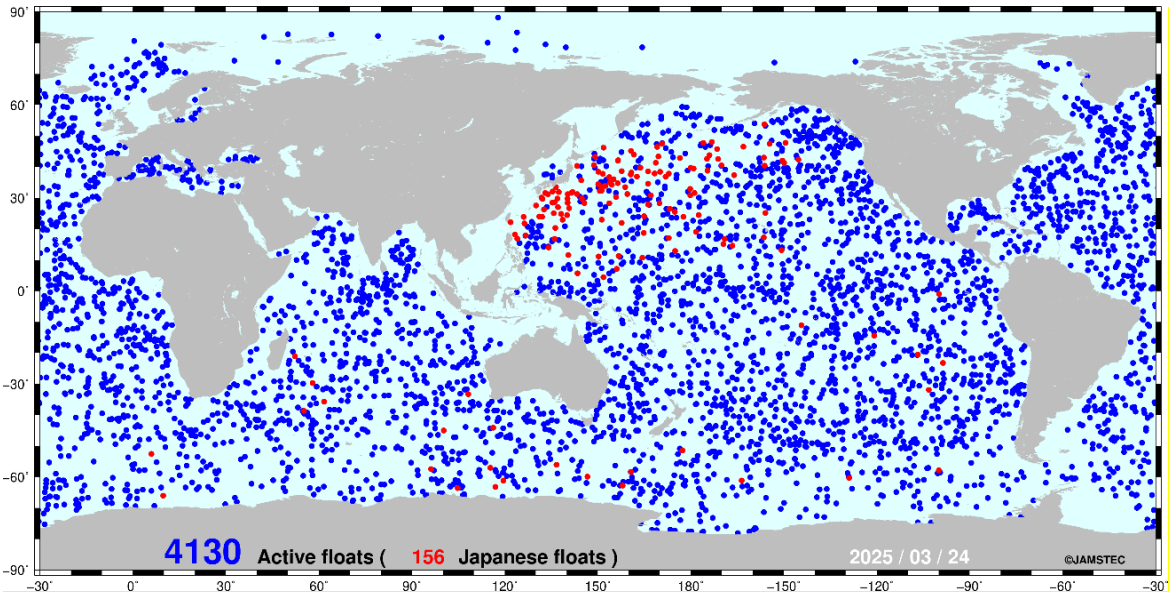

Figure 1: The distribution of active Argo floats. The red dots represent active Japanese floats.

b. Technical problems encountered and solved

(i) Sensor screening for SBE41 conductivity and pressure sensors

JAMSTEC developed a CT sensor screening system, J-Calibration, for the use of the SBE41 by Sea-Bird Scientific (SBS) and is now in operation (Hosoda et al., 2018). Natural seawater is used for the screening, instead of artificial seawater, to adapt in-situ observation without artificial biases, and the screening is judged based on salinity values instead of conductivity values. As a result, precise temperature control is no longer required, which makes the screening process to be more efficient. In 2024, 29 conductivity (C) sensors were checked by the screening, and one of them was identified as potentially faulty and sent back to TWR(SBS). JAMSTEC also conducted pressure (P) sensor screening using a Deadweight Tester (DWT). A total of 28 pressure sensors were tested, and one of them was found to be questionable. The faulty sensor was returned to SBS for repair. Looking ahead, we aim to improve the screening process for greater efficiency and validate the results by comparing them with actual observations. Also, we are investigating screening methods for RBR CTD sensors to validate using seawater.

(ii) pH sensor failure (Seafet)

Because of the announcement of their pH sensor error by SBS on May 25, 2023, which experienced a high failure rate in 2022, the deployment of JAMSTEC's floats with pH sensors has been suspended. At the end of March 2025, we received the floats with the updated pH sensors. We will deploy the floats in April and beyond.

c. Status of contributions to Argo data management including:

i. Status of Japan DAC

The Japan DAC, JMA has operationally processed data from all of Japan's Argo and Argo-equivalent floats including 160 active floats as of March 17, 2025. 11 Japanese PIs agree to provide data for the international Argo. Almost all core data from those floats are transmitted to GDACs in the netCDF format and also issued to GTS using the BUFR codes after real-time QC on an operational basis. The Japan DAC has completed the Cpcor adjustment for deep Argo floats, the processing of the PROVOR float newly deployed by JMA, and the replacement of the Argo-processing server. JAMSTEC implements real-time salinity adjustment based on the Argo QC Manual ver. 3.8 every cycle and JMA uses it in real-time. Frequent position rotations within JMA and ongoing human resource shortages make it challenging to complete ADMT action items in a timely manner. Additionally, the Japan DAC members lack expertise in biogeochemical (BGC) parameters and their sensors, which makes it more difficult to establish and maintain our data processing chains.

ii. Status of high salinity drift floats

Conductivity sensors of 100 floats with SBE41/41CPs and/or SBE61in Japan, including Core, BGC, and Deep floats, suffered from Abrupt Salty Drift (ASD). 25 of them are still active. They were deployed until 2021. 84 of them have serious ASD and have S profiles unable to be adjusted. About 45% of 100 sensors were within SNs of SBE41cp and SBE61 announced by SBS as compensable. Because of ASD, we have lost about 7,000 salinity profiles since 2015, mainly in the northwestern Pacific Ocean, at a rate of about 800~900 profiles every year. The number of profiles suffered by ASD is equivalent to 10%. SBS offered 20.25 credits of SBE41 as the ASD warranty. We have shared this information with ADMT through the working group. In the Argo QC procedure, most of the salinity profiles with ASD were flagged as probably bad or bad in all layers. Because Japanese active floats suffering from ASD were deployed until 2021, the number of Japanese active floats suffering from ASD and their uncorrectable S profiles is expected to decrease.

iii. Decoding difficulties

JMA finds it difficult to decode the BGC parameters because the Japan DAC members lack expertise in BGC parameters and their sensors. JAMSTEC deals with lots of decode-type floats, APEX, Navis, and Deep NINJA floats, etc. Appropriate decoding programs provided by manufacturers are quite helpful for us to apply our data processing system without creating a decoding program from the float manual. Insufficient provided decoding programs, such as including the wrong format or different code from the float manual, make us waste human resources and time. When a new BGC sensor is delivered for the first time, checking data processing and developing appropriate programs by experts must be required, which can be time-consuming.

iv. Real-time Deep implementation

The Japan DAC has completed the Cpcor adjustment for deep Argo floats.

v. Others

To update the QC procedure of DOXY data better than the existing DOXY QC one, JAMSTEC is evaluating the data quality of ARO-FT and AROD-FT (for deep floats), manufactured by JFE Advantech. The specifications of them are higher accuracy (± 2 µmol/kg or ± 2% of FS) and faster response time (< 1 sec). To achieve accuracy, multi-point calibration was generally conducted in the laboratory before deployment. Further, to check the performance of the calibration, we examined the accuracy of DOXY data obtained from arbitral 10 floats with ARO-FT and 5 floats with AROD-FT. By comparing DOXY values of ARO-FT/AROD-FT with those of ship bottle sampling data at deployment position, we found negative drifts (more than 5 µmol/kg) and biases depending on oxygen concentration. The negative drifts and biases can be corrected by applying a linear relationship of DOXY between oxygen measurements of

ARO-FT/AROD-FT and bottle data. By checking ARO-FT measurement in-air, the temporal drift of ARO-FT is slightly larger than that of Optode4330 manufactured by Aanderaa, while its individual dependency is smaller in comparison with the Argo DOXY criteria. The carry-over coefficients are relatively large, which may be caused by remaining water drops on the membrane of ARO-FT when the sensor is in the air. Therefore, JFE Advantech improved the film stopper. We also found the temporal drift of AROD-FT, increasing with pressure and oxygen concentration in deeper layers, the amount of which is large in the first 10~20 days and then gradually decreases. The Optode4330 mounted on an APEX Deep float was also found to have a similar tendency of temporal drift. Since slightly large temporal drifts are detected in ARO-FT and AROD-FT during storage before deployment, we are investigating the cause and resolution.

d. Status of delayed mode quality control process

JAMSTEC submitted the delayed-mode QCed Core files of 8,076 profiles in 2024, and the total number of submitted delayed-mode QCed Core data (P, T, and S) to GDACs is 218,349 profiles as of December 2024. About 82.4% of Japanese Core profiles are published in GDAC as delayed-mode QCed profiles as of December 2024. Regarding deep Argo floats equipped with SBE61, we have adjusted the salinity data of deep floats by using optimal CPcor for each Deep float. When our deep float is launched, shipboard-CTD observation with water sampling is basically carried out for estimating individual optimal CPcor. Regarding BGC Argo floats, we submitted BD files with delayed-mode QCed DOXY and pH in 2024. Both account for about 10% of all profiles for each DOXY and pH. Based on the result of the evaluation of ARO-FT's performance, we suggested the correction method of DOXY measured by ARO-FT and updated the data processing manual and the quality control manual for DOXY of ADMT. Now, BGC-ADMT members are reviewing them.

JAMSTEC has started to correct NITRATE by using the SAGE software, which was released by MBARI, after JAMSTEC fixed the issue of garbled characters appearing in SAGE. JAMSTEC has also begun to work on CHLA correction. We plan to submit BD files with dQCed NITRATE and CHLA as well as DOXY and pH. We are also preparing a tool to correct the time of the float clock. We will start to make d-mode trajectory files of Iridium telecommunication floats which are not necessary to correct their position and to submit them to GDAC.

2. Present level of, and prospects for, national funding for Argo including a summary of the level of human resources devoted to Argo, and funding for sustaining the OneArgo mission: Core, BGC, Deep, Polar, Spatial (equator, WBCs)

The level of funding in JAMSTEC is decreasing in FY2025. In FY2025, funding for purchasing float is mostly cut, and funding for sustaining the OneArgo mission is 5-10% less than FY2024 because FY2025 is the last year of the 7-year mid-term plan since FY2019. Deployment floats in FY2025 are provided from stored ones that were previously bought, including Core, Deep, and BGC floats. The level of human resources is 4 persons in FY2025, which is mostly even in the previous

year. However, the amount of dmQC and PARC tasks is increasing, which makes it absolutely difficult to cover OneArgo operational tasks. We are making a new strategy for the next mid-term plan, which starts in 2026.

JMA will allocate an operational budget to purchase 16 Core floats with Iridium communication in FY2025. JMA has a plan to purchase 14 Core floats with iridium communication every fiscal year, after FY2026.

Ongoing and future expected extra funding regarding related OneArgo

The CREST project "Ocean Carbon," funded by Japan Science and Technology Agency (JST), was initiated in October 2023, related to OneArgo for a 5.5-year plan (1.8M USD, https://www.jst.go.jp/kisoken/crest/en/research_area/area2023-2.html). This research project aims to elucidate the carbon exchange process between the atmosphere, land, and ocean, in order to gain an integrated understanding of the ocean-CO2 relationship and create innovations to address climate changes. The team of Tohoku University, JAMSTEC, the University of Tokyo, and the Meteorological Research Institute will develop sensors, evaluate their accuracy, and conduct multi-variable high-precision observations related to next-generation Argo observations. In 2025, one Provor CTS-5 with a UVP sensor will deploy in the cruise of Shinsei-Maru KS25-4 and recover to validate the UVP data.

Habitable Japan: 5-year research funding (Grant-in-Aid for Transformative Research Areas (A); 1.5M USD), aiming to “Sustainability of atmospheric and oceanic environment as a survival basis of island country Japan” (https://hotspot3.aori.u-tokyo.ac.jp/en/) was funded in 2024. One of the teams is an ocean observational group and is planning to deploy 3 BGC Argo floats with Oxygen, Chla, pH, and backscatter sensors around the Kuroshio Extension to clarify the physical-biogeochemical relationship associated with biological production/decomposition.

The "Advanced Institute for Marine Ecosystem Change (WPI-AIMEC)" jointly proposed by Tohoku University and JAMSTEC was started in FY2023 as a new center of the World Premier International Research Center Initiative (WPI). The WPI-AIMEC considers the integrated analysis of OneArgo data with other biological data as one of its major research activities and will deploy 2 BGC Argo floats with Chl-a and backscatter sensors in 2025. In addition, 2 BGC Argo floats with UVP sensors and 6 UVP sensors for ship observation will test their performance. Those research activities will contribute to future generation of OneArgo.

In addition, Tohoku University's joint proposal with JAMSTEC and JMA, "Establishment of the Integrated Global Ocean Observing System 'OneArgo' and Promotion of Ocean Interdisciplinary Research" was included in Roadmap 2023 (A basic concept for the promotion of large-scale academic research projects) by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The plan is to conduct observations covering 20-25% of the entire OneArgo area, as well as data management and analysis, over a 10-year period. The inclusion in Roadmap 2023 does not mean that the project will be immediately funded, but it is an endorsement that the project should be given priority. WPI-AIMEC will be the lead institute in moving forward with

the budget request for FY2026. This plan will also include major investments in human resources and relevant facilities.

3. Summary of deployment plans

JAMSTEC will deploy 51 floats for 15 Core, 16 Core+O2, 8 Deep+O2, 12 BGC floats (Core+4~6 params) in 2025. The Deep Argo float is Deep NINJA with RINKO ARO-FT oxygen optode sensor. The BGC Argo floats are BGC Navis and BGC APEX, partly equipped with Oxygen (RINKO ARO-FT, SBE63), pH (SeaFET), Nitrate (Deep SUNA), and Chla/bbp (FLBB2, FLBBCD). Another 4 BGC floats (one for BGC Navis, 3 for BGC APEX; Core+4~6params) are planned to deploy in 2025 depending on the cruise.
JMA plans to deploy 14 Argo equivalent floats (12 floats will be deployed in the western boundary region) around Japan in FY2025. All the JMA floats are identical to the Core Argo floats except that they are usually operated in a 5-day cycle to be synchronized with JMA's real-time ocean data assimilation and forecast system.
JMA continues serving as the Japan DAC. JAMSTEC will continue running the Pacific Argo Regional Center for the upcoming year.

4. Summary of research and development efforts over the past year to try new sensors or improve float technology, including new collaborations with vendors or other partners.

Toward next-generation OneArgo observation (ArgoMIX, MOBY, and FRRF)

JAMSTEC is examining constructing "ArgoMIX" and joining to Argo array as "next generation Argo." To support achieving ArgoMIX, JAMSTEC examined field tests using 3 microALTO with fast response thermistor sensors (FPO7) and/or shear sensors in collaboration with Rockland and MRV in Dec. 2024 and is planning to May 2025. Based on the comparison with ship turbulence measurements (VMP-X and L-ADCP etc.), the performance of floats and turbulent measurements were good, and further analysis is ongoing.

JAMSTEC also deployed two Mermaid-Argo floats with SBE61 CTD in June 2023, called "MOBY", from OSEAN (France) in 2023, as a check of ability for the deep Argo float platform. The floats are still working. Although one of the Mermaid sensors was troubled, their performance is mostly good. The 4000m MOBY float is expected to be a formal deep Argo platform and 6000m MOBY floats will be expected to provide in the future.

The fast repetition rate fluorometer (FRRF) is one of the active chlorophyll fluorescence techniques and can measure a single-turnover fluorescence induction curve in photosystem II (PSII) (Kolber et al., 1998). The PSII parameters derived from this curve provide insights into the physiological state of phytoplankton, such as iron and nutrient limitation, photoacclimation, and photoinhibition. These parameters can also be used to estimate chlorophyll *a* concentration and gross primary productivity. Since 2021, JAMSTEC has been developing the Deep NINJA float equipped with an FRRF, in collaboration with Kimoto Electric and TSK. As part of the experimental phase for this new sensor, a NINJA float with an FRRF was deployed in the Southern Ocean in March 2025. Furthermore, since 2024, JAMSTEC has been developing a power-saving and compact FRRF through a three-year plan with Kimoto Electric and L&F, supported by the CREST program of JST.

5. Summary of national research and operational uses of Argo data as well as contributions to Argo Regional Centers.

JMA issues operational ocean analysis and forecast by using satellite data and in-situ data, including the global Argo BUFR messages. Daily, 10-day mean and monthly products of subsurface temperatures and currents for the seas around Japan and the North Pacific, based on the output of the real-time ocean data assimilation system (MOVE/MRI.COM-JPN), are distributed through the JMA website (in Japanese). Numerical outputs of the system are available from the NEAR-GOOS Regional Real Time Data Base (https://www.data.jma.go.jp/goos/data/database.html) operated by JMA. Monthly diagnosis and outlook of El Niño-Southern Oscillation based on the outputs of the Ocean Data Assimilation System and the Seasonal Ensemble Prediction System (an ocean-atmosphere coupled model) are also operationally distributed through the JMA website (in Japanese) and the Tokyo Climate Center (TCC) web site (https://ds.data.jma.go.jp/tcc/tcc/products/elnino/). These systems were upgraded in Feb. 2022 (for descriptions of the new systems, please refer to https://ds.data.jma.go.jp/wmc/products/elnino/move_mricom-g3_doc.html and https://ds.data.jma.go.jp/wmc/products/model/outline/cps3_description.html. The ocean-atmosphere coupled model is also used for seasonal forecasts of climate in Japan. The model products for seasonal forecast are available from the WMC website (https://ds.data.jma.go.jp/wmc/products/model/).

JAMSTEC provides gridded products of objectively mapped temperature and salinity field data (Grid Point Value of the Monthly Objective Analysis using Argo float data: MOAA-GPV) and gridded mixed layer depth with its related parameters (Mixed Layer data set of Argo, Grid Point Value: MILA-GPV). These products have two versions for each dataset; one is estimated by using mainly real-time QC Argo profiles, and another is by using mainly delayed mode QC Argo profiles. MOAA GPV version 2 will be released soon. The updates since version 1 are 3-dimensional (horizontal and temporal) OI objective analysis and the increase in layers from 25 to 66 layers. The data set is monthly and every 10 days.

JAMSTEC has been providing objectively mapped velocity field data based on YoMaHa'07 (version September 2010), and Argo temperature and salinity profile data put through more advanced automatic checks than real-time quality controls (Advanced automatic QC Argo Data version 1.2a) since October 2014. JAMSTEC has also provided scientifically quality controlled data of Deep NINJA floats for convenient use on scientific or educational purposes. The QC is based on comparisons with highly accurate shipboard CTD observations conducted near float observations.

The Pacific Argo Regional Center (PARC) is operated by JAMSTEC, providing information about consistency checks of float data related to delayed-mode QC through the website. Although it had been operated by IPRC and JAMSTEC since 2006, IPRC terminated to co-operate due to their funding and human resource issues. In 2024, JAMSTEC renewed the PARC website (https://www.jamstec.go.jp/PARC/). JAMSTEC added the statistics of Core and BGC profiles in the Pacific to the sites. Also, JAMSTEC added meta-information on floats in the Pacific, their time section figures, and time series of error magnitude on floats with data that deviate significantly

from MOAA GPV. You can see the activities of the Pacific Deployment Coordination Group on this site, including information on future OneArgo float density maps for deployment plans, past meeting reports, and mailing list members. The maps for the aiming deployment plan show the expected density of the OneArgo array in the Pacific Ocean after 1, 2, and 3 years, using G-YoMaHa, which is objectively mapped velocity at 1000 dbar.

ESTOC (Estimated state of ocean for climate research) is a JAMSTEC product, an integrated dataset of ocean observations, including Argo data by using a four-dimensional variational (4D-VAR) data assimilation approach. ESTOC is the open data that consists of not only physical but also biogeochemical parameters for 60 years from 1957 to 2016 (See the website in JAMSTEC, https://www.godac.jamstec.go.jp/estoc/e/). The dataset was updated for physical parameters for 65 years from 1957-2022

JCOPE is a research project for the prediction of oceanic variation using ocean models with the assimilation of remote-sensing and in-situ data, which is managed by JAMSTEC. In 2019, JCOPE2M, which is an updated version of JCOPE2/FRA-JCOPE2 reanalysis covering the Northwestern Pacific, was released. The Argo data are used by way of GTSPP. The hindcast data 6 months back and the forecast data 2 months ahead are disclosed on the following website: https://www.jamstec.go.jp/jcope/htdocs/e/home.html. More information is shown at https://www.jamstec.go.jp/jcope/htdocs/e/distribution/index.html. In 2022, JCOPE-FGO, a reanalysis product covering a quasi-global ocean, was released: https://www.jamstec.go.jp/jcope/htdocs/e/distribution/fgo.html.

FRA-ROMS is the nowcast and forecast system for the Western North Pacific Ocean developed by Japan Fisheries Research and Education Agency (FRA) based on the Regional Ocean Modeling System (ROMS). FRA-ROMS was operated from May 2012 to March 2022. In March 2022, FRA began operating FRA-ROMSII, a system based on FRA-ROMS with improved model performance in the Japan Sea. FRA-ROMSII was updated to FRA-ROMSIIv2 in January 2025, improving the accuracy of the reanalysis data in the Oyashio area and the East China Sea, and extending the data period to 30 years. The outputs of FRA-ROMSIIv2 are used primarily for fisheries resource surveys and are provided every week through the website: https://fra-roms.fra.go.jp/fra-roms/index.html/.

Tohoku University has released a gridded dataset of subsurface chlorophyll maximum depth, using Chl-a measurement data in the World Ocean Database 2018 (Boyer et al. 2018) and the Global Ocean Data Analysis Project version 2.2019 Release (Olsen et al., 2019). The Chl-a measurement data includes Argo profile data as well as bottle samples, CTD fluorescence, gliders, and so on. This gridded dataset can be downloaded on the websites (http://caos.sakura.ne.jp/sao/scm/).

6. Issues that Japan Argo wishes to be considered and resolved by the Argo Steering Team regarding the international operation of Argo.

EEZs clearances for the Marine Scientific Research (MSR) procedure for Argo float deployed had been simplified following IOC Resolution XLI-4, which is performed by OceanOPS. Most coastal

states have simplified their procedures regarding Argo deployment and drifting in the EEZ by providing information through the NFP. However, in some cases (especially for tropical Pacific island countries), the fee was demanded for applications if floats deploy in EEZs where MSR applications are required (in the case of Japan, drifting into the EEZ of a coastal state that has not established an NFP). It is necessary to work with the Argo community and OceanOPS to promote a better understanding of the Argo program in these coastal states.

7. Outreach and communication

A national program Argo webpage works for them and has recently been updated as a site to exchange information between domestic and international programs (https://www.jamstec.go.jp/J-ARGO/?lang=en). Some JAMSTEC researchers contributed to the Japanese translation of "Keeping an Eye on Earth's Oceans With Argo Robots" published in Frontiers for Young Minds (https://kids.frontiersin.org/articles/10.3389/frym.2023.943491).

8. CTD station data that was taken at the time of float deployments this year and CTD data (calibrated with bottle data) taken by Japan in the past year that may be added to the reference database.

After the last upload of CTD data to the CCHDO website in February 2024, which was included in the national report the year before last, we have uploaded 226 CTD cast data as "Private for Argo" in the western North Pacific.

9. Papers published by scientists within Japan in the past year using Argo data, including non-English publications.

(1) Articles

2024

- Doi, T., S. K. Behera, T. Yamagata (2024), Seasonal predictability of the extreme Pakistani rainfall of 2022 possible contributions from the northern coastal Arabian Sea temperature, npj Climate and Atmospheric Science, 7, 13 (2024). https://doi.org/10.1038/s41612-023-00557-2
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- Ohnishi, S., T. Miyoshi, and M. Kachi (2024), Impact of atmospheric forcing on SST in the LETKF-based ocean research analysis (LORA). Ocean Modelling, doi:10.1016/j.ocemod.2024.102357
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(2) Doctorate thesis

N/A

10. Deployment plans for RBR floats in the next couple years

In 2025, JAMSTEC will deploy 1 RBR APEX float for Argo equivalent. The RBR Argo equivalent floats will be deployed in the western equatorial Pacific region, observing the air-sea interaction regarding MJO and ENSO. In 2026 and after, we do not have fixed plans to get them yet.