Japan National Report

(Submitted by Toshio Suga)

1. The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2021)

a. Floats deployed and their performance

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) deployed 40 Core Argo, Deep Argo, Biogeochemical (BGC) Argo and Argo equivalent floats from January to December 2021: 21 floats for Core Argo (APEX), 2 floats for Deep Argo (Deep APEX), 17 floats for BGC Argo (BGC-NAVIS and BGC-APEX). Since 1999, JAMSTEC had deployed 1436 Core Argo, Deep Argo, BGC Argo and Argo equivalent floats mainly in the Pacific, Indian and Southern Oceans. Because COVID-19 influenced cruse plans, the number of our float deployment was largely decreased. The current positions of all the active Japanese Argo floats are shown in Fig.1. Under the limited cruise conditions, collaboration with Japanese voluntary agencies, institutes, universities, and high schools was still ongoing, enabling deployment in 14 cruises. One float was deployed by a voluntary cargo ship owned by a Japanese merchant ship company, NYK. The arrangement of the semi-regular float deployment by cargo ships was made under the cooperative relationship between JAMSTEC and NYK, which was established in 2011 to increase float deployment opportunities. In December 2021, 2 Deep NINJA floats were operated. One Deep NINJA float is planned to be deployed in the Southern Ocean in 2022/23 summer in corporation with CSIRO, Australia. Twelve of the BGC Argo floats are equipped with RINKO ARO-FT oxygen sensor and partly SeaFet pH sensor, which is supported by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, Grant-in-Aid for Scientific Research on Innovative Areas (19H05700).

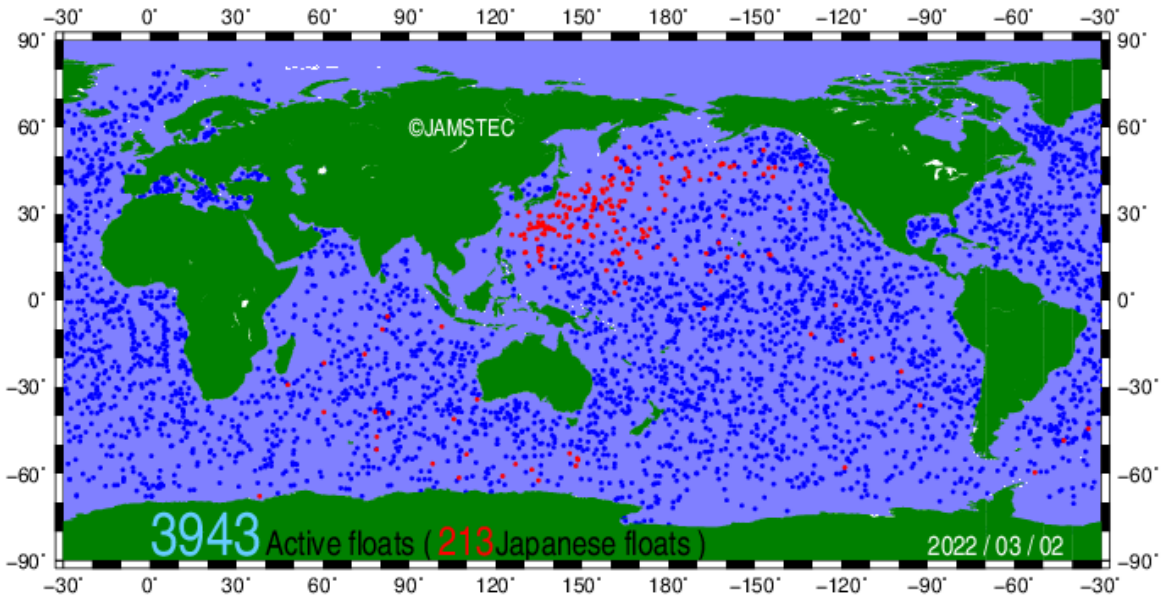

Figure 1: The distribution of active Argo floats. The red dots represent active Japanese floats.

The Japan Meteorological Agency (JMA) deployed 23 Argo equivalent floats (23 ARVOR floats) in the seas around Japan from January to December 2021. All the floats get 2,000 dbar T/S profiles every 5 days for operational ocean analysis and forecast.

Among 365 floats (14 PROVOR, 194 APEX and 157 ARVOR floats) which JMA has deployed from 2005 to 2021, 47 floats (47 ARVOR floats) are active as of the end of December 2021, while 27 floats (11 APEX and 16 ARVOR floats) terminated the transmission in 2021. JMA deployed 3 ARVOR floats from January to February 2022.

b. Technical problems encountered and solved

1) Float hardware troubles and updates

One BGC NAVIS float (F0950) was deployed in March 2021, however, it could not send any data, although the activation data was delivered at the deployment. The cause of the trouble is still under investigation in collaboration with SBE.

Some BGC APEX floats with RINKO ARO-FT oxygen sensors were deployed in February 2021. However, one of the floats (S/N 9015) entered the emergency mode and started to drift at the sea surface. Through checking and maintenance remotely by manufacturer TWR, this float started to send healthy data and is now in normal operation. The cause of this drifting is also still unknown. Another float (S/N 9012) sent only science files after the deployment, not the other technical files, thus the data could not be submitted to GDAC due to insufficient data. Based on the manufacturer's analysis, the float needed to modify the buoyancy parameter and to clean all accumulated data. Although TWR and JAMSTEC tried to a large effort, the data could not deliver smoothy and finally the float stopped sending all data.

Data from pH (SeaFet) sensor mounted on BGC Navis floats had a negative bias. The negative bias frequently appears in the other pH sensors mounted on floats in the world, so we will monitor the change of situation and long-term drift of this bias to investigate its cause and resolve.

Two of Deep APEX floats with APF11 controller (S/N: 50 and 53) occurred buoyancy control failure and were necessary to change buoyancy parameters. RINKO AROD-FT oxygen sensor mounted on some Deep APEX floats failed to measure oxygen value, which is in contrast to the Aanderaa Optode sensor which is successfully delivered the data for a long time. The cause of this failure is still unknown, however, it is a possibility that the communication between APF11 and RINKO sensor is not working well.

2) Sensor screening for SBE41 conductivity and pressure sensors

JAMSTEC developed a new CT sensor screening system, J-Calibration, for use with the SBE41 on the Argo float and is now in operation (Hosoda et al., 2018). Although the J-Calibration system requires careful temperature control of the artificial seawater as it is critical to maintain a uniform water temperature, it is suitable for use in laboratory screening prior to deployment. In this year, the J-Calibration has been conducted for 16 C sensors. Based on the screening, we did not find any doubt C sensors. We also conduct P sensor screening using DWT. In this year, 13 pressure sensors were checked All sensors were healthy and passed satisfying the Argo criteria.

3) Recovery BGC float suffering ASD in collaboration with Japan Defence Force and its analyses for temporal drift

One active BGC Navis float (equipped with oxygen, nitrate, and chlorophyll sensors) was successfully retrieved with the cooperation of the Maritime Self-Defense Force (JMSDF), whose salinity sensor was causing ASD, and salinity data were already unavailable. We thank the JMSDF

for their prompt recovery despite the bad weather condition in twilight time. The retrieved BGC Navis float was sent to SBE for verification and repair. SBE reported that the recovered sensors were in very good condition, and each sensor verification work proceeded. As a result, the manufacturer reported that ASD was certainly detected for the C sensor through the SBE calibration process, while long-term drift for the other sensors was quite small within accuracy criteria. The results were reported in ADMT-22 from Dr. Martini in SBE. The BGC Navis is ready for re-launch, by replacing the C sensor, recalibrating all other sensors, and renewing the batteries.

4) Influence of suffering network security incident in JAMSTEC

In March 2021, JAMSTEC suffered unauthorized access to its core network system and leakage of personal information and has completely shut down the network (https://www.jamstec.go.jp/j/about/press_release/20210318_2/). Accordingly, the Argo JAMSTEC data management system and related websites were also shut down, and data submission to GDAC was suspended. As a result, the number of float operations in Japan temporarily dropped below 100 but is now almost back to normal due to the temporary process. However, the impact has been severe, and the delivery of products such as websites, including PARC, and data sets are not working yet because of the re-construction of the data system to be more secure. Currently, Argo-related servers and network security is being addressed, and processing raw data and delayed mode QC will soon be restored to normal.

c. Status of contributions to Argo data management (including status of high salinity drift floats, decoding difficulties, ramping up to include BGC or Deep floats, etc.)

The Japan DAC, JMA has operationally processed data from all the Japanese Argo and Argo-equivalent floats including 216 active floats as of March 1, 2022. 11 Japanese PIs agree to provide data for the international Argo. All the profiles from those floats are transmitted to GDACs in the netCDF format and are also issued to GTS using the BUFR codes after real-time QC on an operational basis. Argo BUFR messages have been put on GTS since May 2007.

JMA and JAMSTEC have converted the almost all of Japanese meta-files, except a few Iridium floats, from v2 to v3.1 and submitted them to GDACs. JMA has converted almost all of Japanese tech-files and submitted them to GDACs. JMA has converted the Rprof-files of Japanese ARGOS floats, except floats with NST sampling scheme and Iridium floats. JAMSTEC has converted all v2 Dprof-files of Japanese floats to v3.1 and submitted them to GDACs. JMA has converted about 30% of Japanese traj-files from v2 to v3.1 and submitted them to GDACs.

JMA has made meta-, tech-, traj-, and Rprof-files v3.1 of the floats newly deployed since March 2016 and JAMSTEC has made meta-files in v3.1 of JAMSTEC's floats newly deployed since October 2015. JAMSTEC has made Dprof-files in v3.1 since January 2016.

Abrupt salty drift floats

Japan has 483 floats with SBE41/SBE41cp whose serial number is larger than 6000, which had been deployed since 2013. 90 floats of them had clearly high salinity drift, and 65 floats of them had differences larger than 0.05 between salinity observed by float and climatology near 2000dbar. The salinity of most of these floats started drifting from about 40-100 cycles. Four floats with SBE41CP whose SN are larger than 11252 have salty drift, and one of them has salty drift that is not able to be corrected. Japanese floats with high salinity drift were mainly launched into the North Pacific, and most of them were deployed in 2017 and 2019. Moreover, 4 Deep APEX floats with SBE61 have clearly high salinity drift. While about 170 active floats with SBE41/SBE41cp whose serial number is larger than 6000 and 22 active Deep APEX floats have not suffered from this issue,

we continue to monitor salinity data of Japanese floats for detecting floats with high salinity drift and understanding features of high salinity drift found in floats. We have shared this information and joined the discussion about this issue through ADMT and the working group of this issue so that we contribute to improving salinity data quality.

As reported last year in our national report, most of the salinity profiles flagged as probably bad or bad in all layers have been "Abrupt Salty Drift" in the past few years, and the number of salinity profiles flagged as probably bad or bad in all layers has been increasing every year. The percentage of global salinity profiles with all layers flagged as probably bad or bad in 2021 was 16%, higher than that in 2020. This is consistent with the results predicted last year. JAMSTEC will continue to monitor the results.

New challenge to quality control for Core Argo profiles

JAMSTEC is now challenging to implement quality control methods using machine learning, developed by Sugiura and Hosoda (2019), for Core-Argo profiles. We performed supervised learning for existing Argo data with quality control flags by using the signature method, We aim to achieve efficient quality control by introducing this.

d. Status of delayed mode quality control process

JAMSTEC has submitted the delayed-mode QCed Core data (P, T, and S) of 175,661 profiles to GDACs as of December 2021. JAMSTEC had submitted D-Core files of 1,476 profiles in 2021. Due to the network security incident that occurred at JAMSTEC in March 2021, our data quality control processing system had to be updated, so the number of DQCed Core profile file submissions was low last year. The system update will be completed soon, so we will be able to increase the number of submissions this year.

JAMSTEC has adjusted salinity data of Deep floats by using optimal CPcor for each Deep float. When our Deep float is launched, shipboard-CTD observation is often performed. Therefore, the optimal CPcor for each Deep float is estimated by comparing its first profile with shipboard-CTD data at its deployment.

JAMSTEC has started performing delayed mode QC for our BGC floats. We are now preparing to process programs for DOXY-DMQC. We are also testing whether Nitrate and pH observed by our BGC floats in the North Pacific are corrected well by SAGE. We aim to start to submit D-mode DOXY_Adjusted of our BGC floats to GDAC this year.

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

Japan Argo had been conducted in a 5-year program from FY1999 to FY2004, as a part of Millennium Project implemented under cooperation among the Ministry of Education, Culture, Sports, Science and Technology (operation: by JAMSTEC), the Ministry of Land, Infrastructure and Transport, JMA and Japan Coast Guard. After the Millennium Project terminated in March 2005, JAMSTEC has continued the operation until FY2013 nearly on the same scale (about 80 floats to be deployed every year and associated delayed-mode data management) under its two consecutive mid-term programs for FY2004-2008 and FY2009-2013. JAMSTEC continues the float deployment and delayed mode data management but in the scale somewhat lower than before under its recent mid-term program FY2014-2018. Because of budget cuts in FY2014-2015, the number of technical staff devoted to delayed mode QC and PARC activities has been decreased from 5 to 4 since FY 2015 and the number of purchased floats had been reduced to about 12-15. In FY2016,

owing to ocean monitoring enhancement recommended by G7 Ise-Shima Summit, especially its Science and Technology Ministers' Meeting in Tsukuba, the additional fund for Core Argo and Argo extensions (Deep and BGC Argo) was allocated for aiming to sustain Core Argo array and to enhance Deep and BGC Argo. Furthermore, following its communique and our original research plans, JAMSTEC had got extra research funds to purchase 50 Core, 25 Deep and 10 BGC Argo floats in FY2017, and are being deployed in the Pacific, Indian and Southern Ocean in FY2018-19.

From FY2019, JAMSTEC has started new mid-term programs for 7 years. In FY2021, 25 Argo floats were deployed, including 19 Core, 4 Deep and 2 BGC floats, following JAMSTEC's research purposes. In FY2021, the level of human resources for Argo deployment and QC is the same as in FY2021 (3 persons) including temporal staff. However, because of dmQC complexity including core, deep, BGC Argo, the number of technicians is insufficient. The deployment plan for Core, Deep and BGC Argo floats in FY2022 is not yet fixed but will be decided soon.

JAMSTEC is also planning to examine "next generation Argo" toward constructing a higher valuable observing system, including ArgoMIX. The construction of the observing system is already addressed a load map of ocean science in Japan as "Global deployment of deep-sea Argo floats for more accurate prediction of climate and ecosystem change" and consensus among the Japanese ocean science community. To achieve the load map, JAMSTEC examine a validation of Argo float equipped with turbulence sensor (RBR fast-response CTD) in nearshore field test, in collaboration with Rockland and MRV. Also, JAMSTEC will purchase Mermaid-Argo floats from OSEAN in France, which is equipped with SBE61 and hydrophone sensors in 2022. The float will be examined to apply Argo data flow as well as planning toward a next generation observing system.

JMA allocates operational budget for 27 floats in FY2022.

3. Summary of deployment plans (level of commitment, areas of float deployment, Argo missions and extensions) and other commitments to Argo (data management) for the upcoming year and beyond where possible

To maintain the Argo array and to achieve the research purposes, JAMSTEC will deploy 19 floats mainly in the North Pacific for 11 Core, 1 Deep, 3 BGC, and 4 Argo equivalent floats. The 11 Core Argo includes 2 RBR Argo floats. For the Argo equivalent floats, 3 RBR CTD Argo floats will be deployed in the western equatorial Pacific for the purpose of the air-sea interaction study, and "hotspot2" research team of special research fund "Grant- in Aid for Scientific Research in Innovative Area", being supported by JSPS KAKENHI, will deploy one BGC Argo equivalent float with RINKO oxygen sensor around the subtropical region south of the Kuroshio Extension in 2022.

JMA plans to deploy 27 Argo equivalent floats (12 floats are deployed in the western boundary region) around Japan in FY2022 and in the coming years. All the JMA floats are identical with the core Argo floats except that they are operated in a 5-day cycle, synchronized with JMA's real-time ocean data assimilation and forecast system.

JMA continues serving as the Japan DAC. JAMSTEC continues running the Pacific Argo Regional Center for the upcoming year.

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

Many groups in JAMSTEC, JMA, FRA, and Japanese universities are using Argo data for oceanographic research on water mass formation and transport in the Pacific Ocean, the mid-depth circulation, the mixed layer variation, the barrier layer variation, and tropical atmosphere-ocean interaction in the Pacific and the Indian Ocean and so on. Japanese fisheries research community is

conducting their biogeochemical studies using Argo floats equipped with chlorophyll and/or oxygen sensors.

JMA issues operationally 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 North Pacific, based on the output of the real-time ocean data assimilation system (MOVE/MRI.COM-JPN), are distributed through the JMA web site (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 El Niño Prediction System (an ocean-atmosphere coupled model) are also operationally distributed through the JMA web site (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 tohttps://ds.data.jma.go.jp/tcc/tcc/products/elnino/move_mricom-g3_doc.html, andhttps://ds.data.jma.go.jp/tcc/tcc/products/model/outline/cps3_description.html). The ocean-atmosphere coupled model is also used for seasonal forecast of climate in Japan. The model products for seasonal forecast are available from the TCC web site (https://ds.data.jma.go.jp/tcc/tcc/products/model/).

JAMSTEC is providing a variety of products including objectively mapped temperature and salinity field data (Grid Point Value of the Monthly Objective Analysis using Argo float data: MOAA-GPV), objectively mapped velocity field data based on YoMaHa’07 (version September 2010), and gridded mixed layer depth with its related parameters (Mixed Layer data set of Argo, Grid Point Value: MILA-GPV). JAMSTEC has released 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 nearby float observations.

The Pacific Argo Regional Center (PARC) is operated by JAMSTEC, providing information about consistency check of float data related to delayed-mode QC through the web site. Since 2006, PARC and its website had been operated by JAMSTEC and IPRC in collaboration with several coastal states of the Pacific region. JAMSTEC mainly operates PARC, and will construct a new PARC website soon as the mentor of the Pacific Ocean. Float PIs and DMQC operators can exchange various information about the deployment and technical information, data quality of floats, DMQC, scientific products, etc. to improve the status of the Pacific Argo array.

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. It is upgraded to version 04a in April 2020 to cover 58‐year period during 1957‐2014 (See the web site in JAMSTEC, http://www.godac.jamstec.go.jp/estoc/e/top/). Version 04a added two observational elements of ocean mixing and geothermal heating. Deep and BGC float data can be assimilated into the system after 2016. We plan to release a 60‐year state estimation (version 4b). Some scientific papers related to the ESTOC were published (e.g., Osafune et al, 2020, Masuda and Osafune 2021).

JCOPE2M (Japan Coastal Ocean Predictability Experiment 2 Modified) is the model for prediction of the oceanic variation around Japan which is operated by Application Laboratory of JAMSTEC. JCOPE2M is the updated version of JCOPE2, developed with enhanced model and data assimilation schemes. The Argo data are used by way of GTSPP. The reanalysis data 29 years back (from 1993 to

present) and the forecast data 2 months ahead are disclosed on the following web site: http://www.jamstec.go.jp/frcgc/jcope/. More information is shown in http://www.jamstec.go.jp/frcgc/jcope/htdocs/jcope_system_description.html.

JCOPE-T DA, a downscaled version of JCOPE2M, has been recently developed by the collaboration of JAMSTEC and JAXA. It is designed for real-time (daily-basis) assimilation of satellite and in-situ data including the Argo data and 10-day lead forecast updated every day. The latest available forecast information is available from: https://www.eorc.jaxa.jp/ptree/ocean_model/index.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). Instead of FRA-JCOPE, which was the previous system of providing the hydrographic forecast information around Japan, FRA started the FRA-ROMS operation in May 2012. Argo has been one of important sources of in-situ data for the FRA-ROMS data assimilation system. The forecast oceanographic fields are provided every week on the website http://fm.dc.affrc.go.jp/fra-roms/index.html/.

Tohoku University has released 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/).

5. Issues that our country wishes to be considered and resolved by the Argo Steering Team regarding the international operation of Argo

As reported in 2011, EEZ clearance procedure for Argo float deployed had been simplified following IOC Resolution XLI-4. This change reduced our time and effort for the process of EEZ clearance. However, the traditional EEZ clearance is still needed for some key countries because Argo national focal points (NFPs) of those countries are not registered on the list at AIC. Japan Argo hopes for more NFPs, especially of nations in and around the Pacific Ocean to be registered to facilitate more timely and optimal deployment of Argo floats, especially about the southern islands in the Pacific Ocean. This could be also helpful for smooth implementation of any future extension of Argo and less trouble with the countries.

6. CTD cruise data being added to the reference database

After the last upload of CTD data to the CCHDO website in January 2020, which was included in the national report the year before last, we have uploaded 485 CTD cast data as "Private for Argo" in the western North Pacific.

7. Outreach activity

Online event "One Ocean Science": In advance of the 26th United Nations Conference of the Parties on Climate Change (COP26, Nov. 1-12, Glasgow, UK), the online event "One Ocean Science" was held by IFREMER of France in recognition that "ocean science is the key to predicting and addressing climate change. Digital World Tour of Science". JAMSTEC contributed to provide a video message. The objective of this event is to raise awareness of the importance of the oceans by communicating from scientists to the general public, industry, non-profit

organizations, etc., how the science they are doing is important for our future. Short videos were created by major ocean science institutions in Japan, France, and other related countries, and made available online via Twitter and YouTube. JAMSTEC provided an explanation of the importance of the BGC Argo.
Certificate of appreciation for volunteer deployments: JAMSTEC's Argo deployment requires the cooperation of lots of volunteers from related organizations. As contributions to the SDGs, are becoming more common, certificates of appreciation were presented to 7 organizations for their cooperation to express gratitude for the FY 2019 VOS input. JAMSTEC will continue providing such certificates of appreciation for the voluntary groups to be more recognizing Argo and ocean environment problems.

8. Argo bibliography

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(2) Doctorate thesis
None,

9. How has COVID-19 impacted your National Program's ability to implement Argo in the past year? This can include impacts on deployments, procurements, data processing, budgets, etc.

Due to COVID-19, some of the cruise plans were canceled or modified, mainly going to the far area from Japan. That must modify JAMSTEC's deployment plan, and we suffer difficulty to fill in the gap of the global Argo array.

10. Argo is still interested in piloting the RBR CTD. Does your National Program have any deployment plans for RBR floats in the next couple years? If so, please indicate how many floats will you be buying in 2022 and 2023 (if known) and where they might be deployed.

In 2021, JAMSTEC did not have any plan to deploy RBR Argo float. However, we will purchase totally 5 RBR APEX floats, 2 for Core Argo and 3 for Argo equivalent in 2022. The 2 RBR core Argo floats will be deployed in the western North Pacific, and the 3 RBR Argo equivalent floats will be deployed in the western equatorial Pacific region, observing the air-sea interaction regarding MJO and ENSO. The shipboard CTD cast will be carried out at all deployment points.