Argo Australia National Report 2023 – AST-24

Peter Oke[1], Craig Hanstein[1], Lyudmila Koziy[1], Lisa Krummel[2], Jenny Lovell[1], Pat McMahon[1], Gabriela Pilo[1], Steve Rintoul[1], Tatiana Rykova[1], Christina Schallenberg[1], Roger Scott[1], Dirk Slawinski[1], Peter Strutton[3], Tom Trull[1], Esmee Van Wijk[1]

[1]CSIRO Oceans and Atmosphere; [2]Bureau of Meteorology; [3]University of Tasmania

1. The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2022)

a. Floats deployed and their performance

Between March 2022 and February 2023, Argo Australia deployed 62 floats, including 56 Core floats and 6 BGC floats. All 6 BGC floats include all six BGC sensors, and one also included a UVP. The locations of the floats deployed in 2022 are shown in in **Error! Reference source not found.**. We deployed floats from 8 different vessels[1]. Floats were funded from 6 different sources[2]. Our deployments included 17 floats south of 60°S; 35 floats in the Indian Ocean sector (west of 130°E) and 26 floats in the Pacific Ocean Sector (east of 130°E).

The fleet of core floats deployed in 2022 included 13 Altos, with RBR CTDs; 20 Arvors, 17 Navis, and 12 Apex floats.

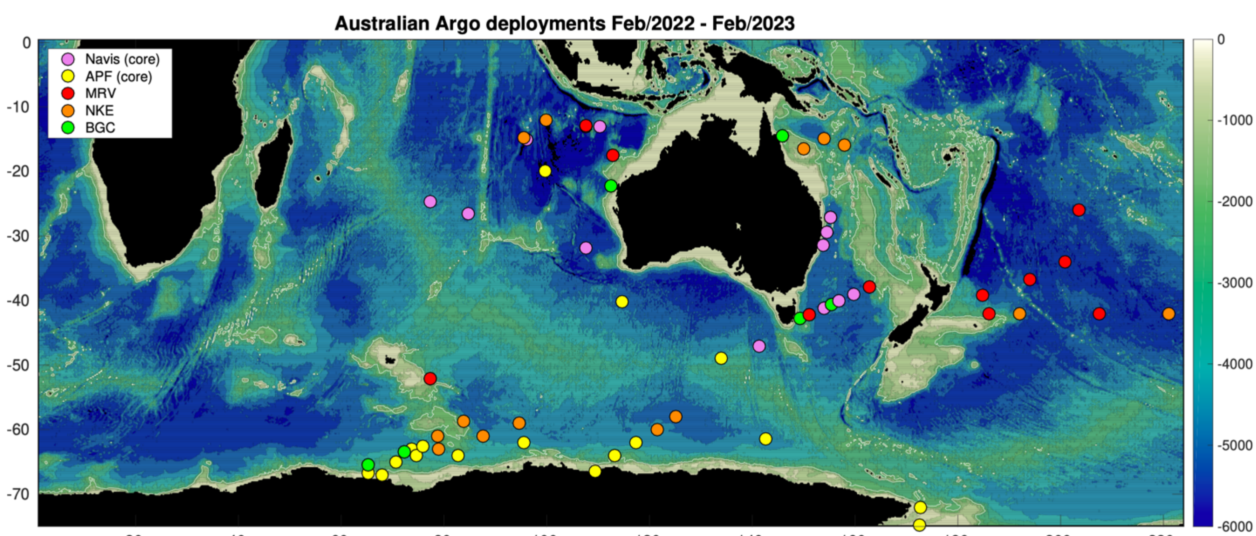

Figure 1: Map showing the deployment locations for floats deployed by Argo Australia in 2023. The colours of the dots denote the float types.

[1] RV Investigator, L'Astrolabe, Antarctic Aurora, RV Kaharoa, Aiviq, Swan River Bridge, Pangaea Ocean Explorer, PMG Pride.

[2] IMOS, CSIRO, AGO, BoM, AAPP, IMAS.

b. Technical problems encountered and solved

Argo Technical Community of Practice

Argo Technical Community of Practice (CoP) continued to meet in 2022. The Argo Technical CoP is a forum for collaboration, knowledge sharing and coordinated action between Argo Technicians to establish, review, and refine best practice procedures for pre-deployment testing of floats to eliminate premature deaths and performance-debilitating failures for core and BGC Argo. Recent meetings have included discussion of Argo deployment methods and MBARI coastal float development.

The group nominally meet each quarter. Founding members are Pat McMahon (CSIRO, Founding Chair), Deb West-Mack (WHOI), Ryan Anderson (WHOI), Rick Rupan (UW), Elizabeth Steffan (PMEL), and Chanelle Cadot (PMEL). A website containing more information is at:
http://www.cmar.csiro.au/argo/dmqc/html/ArgoCop.html

Recent Alto-RBR performance

CSIRO purchased 30 Alto floats with RBRL3 loggers over two financial years as a contribution to the RBR Pilot array. We have deployed 22 of these floats, with 14 early failures. Six floats had problems communicating with the CTD. These floats continued to operate but returned no CTD data. We regard these floats as dead. Of the 30 floats deployed, only four have had no known technical problems.

In FY2019-20 CSIRO purchased 18 Alto floats with RBR sensors. We deployed 16 of these floats and have returned 2 with a CTD fault. Of the 16 floats deployed, 12 are dead. All floats from this order were impacted by a hardware fault that mean the Bluetooth module was constantly powered, resulting in early battery depletion. Four floats died from early battery depletion between Profile 110 and Profile 123. We expect four more floats from this order to exhaust the battery packs by Profile 125. We have been unable to determine the failure mode of 4 floats from this order.

In FY2020-21 we purchased 12 Alto floats with RBR sensors. We have deployed six of these floats, and two are already dead. One float stopped communicating with the CTD at profile 6, and one developed a hydraulic valve fault shortly after deployment.

Despite the issues we've had with these floats, our communication with Manufacturers has always been productive and open. We hoped to demonstrate good performance of the RBR CTDs and extended floats life. But the problems we encountered hampered our efforts.

Processing data with unconventional sampling

Several BGC floats were programmed for continuous sampling above 1000m and sparser sampling below. The data were initially recorded with a short primary profile and a full-depth secondary profile. This caused problems in DMQC as PSAL drift analysis systems are built with the assumption that deep PSAL data will be available in the primary profile. This problem has been rectified by creating a merged profile, recording data to 2000m in the primary profile.

Deep float malfunction and recovery

We deployed an MRV Deep SOLO float (WMO# 7900923) in December of 2021 and it began to malfunction soon after. The CTD fouled when the float was stuck at the surface. Salinity readings went from ~34 to ~7 psu (cycle 10), before continuing to profile in subsequent cycles. Further, the humidity inside the float increased by ~8% and then ~25%, indicating a leak (cycles 32 and 40, respectively). The float then remained on the ocean surface sending "abort" messages. The float was recovered by a nearby ship (FNS L'Astrolabe) and returned to Hobart in February 2022. On closer inspection by MRV, it was revealed that the float could not be repaired. The top glass was cracked and water droplets were found on the inside of the glass; the antenna was broken; there appeared to be a leak path to the communications board; and the CTD suffered a leak. Although the root cause could not be confidently determined, all lines of evidence indicate some sort of impact that broke the CTD, glass, and antenna. We suspect impact with sea ice.

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)

We are currently not able to issue v3.2 Traj files (including BGC variables) because it seems that the file checker isn't ready to accept them. This is a problem because the v3.2 Traj file is needed for the in-air oxygen calibration that is the recommended QC procedure for Aanderaa 4330 oxygen optodes. Without v3.2 Traj files (and their incorporation into the relevant QC programs such as SAGE), we can't do this recommended DOXY QC, and we are therefore stuck with using other DOXY adjustment methods that have a larger error bar. We are waiting for the file checker to accept the new v3.2 Traj files in order to start producing these, and in order to start in-air calibration of DOXY. To be clear, we are still processing DOXY data. But we wish to apply the in-air corrections to improve data quality – and this requires v3.2 Traj files.

d. Status of delayed mode quality control process

Our Matlab-based DMQC system is actively maintained to ensure that all of our data can be processed efficiently. Our system now uses OWC-v3. We currently have three DMQC Operators regularly performing DMQC on our data (Tatiana Rykova, Jenny Lovell, and Lyudmila Koziy), and one software engineer supporting the code (Dirk Slawinski). We lost a long-term DMQC Operator (to holier pastures – she became a church minister) in June 2023, and recruited a replacement (Lyudmila Koziy) in April 2023.

We have submitted Dfiles for the first of our RBR-sensor floats and are now ready to process several more. To do this we needed to implement code for QC of TEMP_CNDC (Matlab GUI), incorporate the compressibility coefficients and thermal lag (short and long timeframe) code provided by RBR into our workflow. In addition there were some modifications to the ingest and output stages.

We are waiting on updated compressibility coefficients for 5 RBR sensors and have provided RBR with the wmoid of buddy floats and reference CTDs.

We have some problems in handling core DMQC of BGC floats where there are more than 2 profiles of data per cycle. We have done extensive testing of our workflow to discover which stages need modification and expect this to be addressed in 3-4 months.

We have identified three ASD floats in the SBR recall and sent that information to SBR. Updates are made to the ASD google spreadsheet at least twice per year.

We are starting to see data in DM from floats that have known hardware issues (e.g. valve problem, stuck bladders) and have had modified missions in attempts to rectify the issues. To ensure these are correctly handled, we continue to improve communication between RT and DM systems e.g. floats that exhibit the stuck bladder problem tend to have intermittent communication and thus deliver partial log files. The RT updates the Rfiles as more data are received and maintains a record of the cycle number beyond which the Rfiles may not be complete so that DM does not ingest them.

As we have diversified our fleet (including floats with RBR sensors, Deep Argo floats, and BGC floats) we are finding more float-specific processing is required, some of which would ideally be done on-board the float. RBR are progressing in this direction with their new individually calibrated compressibility coefficients being handled on-board, but the user still needs to be able to accommodate older units. A more wide-spread example is surface pressure correction which may be done on-board or in post-processing and in the latter case the SP value may be delivered with the current profile or with the subsequent profile depending on the float controller.

We continue to support Argo-China with updates to DMQC software (Matlab system) and provide advice when requested.

We currently use the most up-to-date reference databases for OWC (ARGO_for_DMQC_2022V03, CTD_for_DMQC_2021V02) and are using the Matlab OWC V3.

Table 1: GDAC status as of 7 March 2023.

Number of R-files (NR)	15331
Number of R-files > 365 d (NN)	4845
Number of D-files (ND)	193960
Raw percent D 100*ND/(NR+ND)	92.7%
Percent of Elligible D-files (100-100*NN)/(NN+ND)	97.6%
Number of D-files submitted in previous 365 d	46888
Number of floats submitted in previous 365 d	342

The DMQC Discussion series that started in January 2022 has continued. Tatiana Rykova has organised these meetings, with virtual meetings every other month. Topics covered have included DMQC of Deep floats (Meeting 2), Southern Ocean floats (Meeting 3), DMQC of floats with RBR sensors (Meeting 4), Difficult floats (Meeting 5 and 6), and Demonstrations of DMQC systems (Meeting 7). Meetings are typically attended by 15-20 people from more than 10 different countries. There seems to be strong interest in maintaining this discussion series, with future meetings planned. This discussion series is intended to promote collaboration between Argo DMQC Operators and interested members of the Argo Community. This forum is an opportunity for newer Operators to learn from more experienced Operators, to ask questions, seek second opinions, to promote a sense of community, and to promote consistent DMQC practices. The meeting is open to anyone interested. A record of meetings and speakers is maintained at: http://www.marine.csiro.au/argo/dmqc/html/ArgoDM-Disc.html.

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)**

Contracts funding Argo Australia will end in June 2023. We have been assured by funders that funding will continue, but contracting has not started. We're also hopeful of expanding our program to include new funding for Deep Argo (hopefully 4 Deep floats per year, plus additional funding for salary).

Argo Australia has (some fraction of) two Technicians (1.1 FTE); two real-time Operators (0.5 FTE); seven delayed-mode Operators (2 FTE), and several people in leadership and science roles (0.9 FTE). Our technicians and real-time operators support activities of Core, BGC, and Deep Argo. Our delayed-mode team includes only one person working on BGC data.

Argo Australia intends to continue providing AUD$100K funding to support operations of the RV Kaharoa (and its successor), and AUD$30K funding to support OceanOps. We continue to receive scrutiny over these budget items, but we will work hard to maintain this level of support.

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.**

We plan to deploy 47 floats in 2023-2024, including 4 BGC floats and 43 core floats.

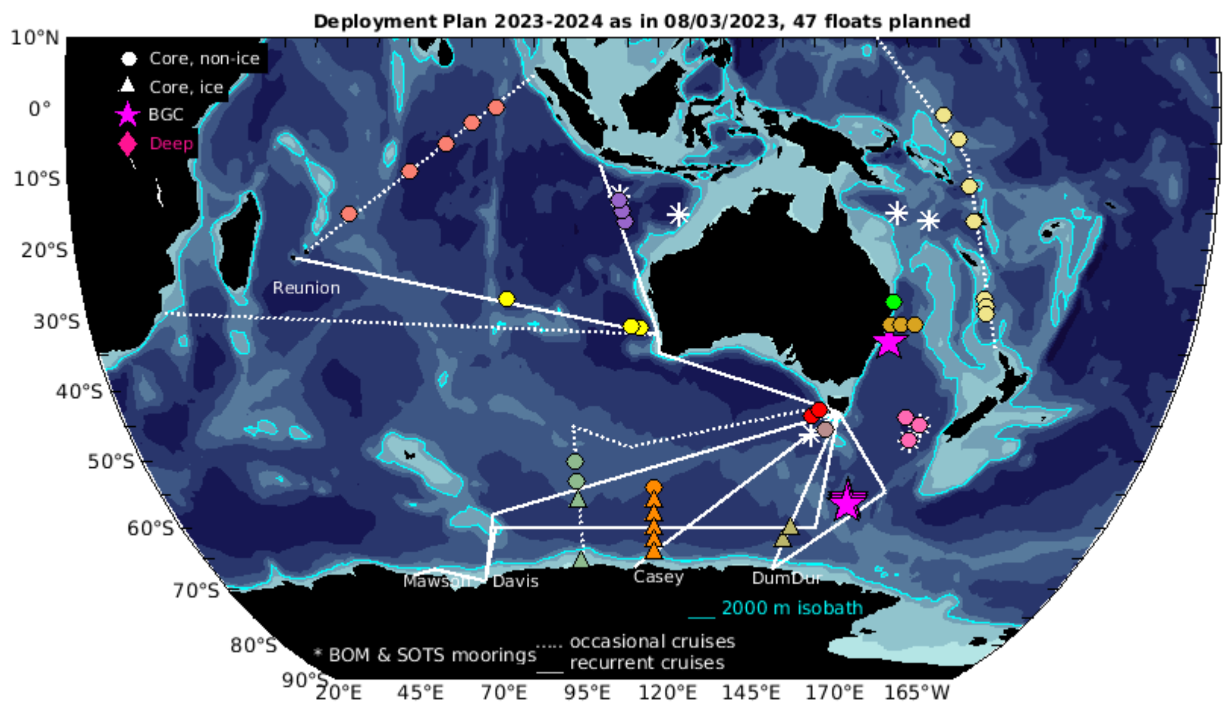

Figure 2: Approximate locations of planned deployments for 2023-2024.

4. **Summary of national research and operational uses of Argo data as well as contributions to Argo Regional Centers. Please also include any links to national program Argo web pages to update links on the AST and AIC websites.**

Argo data are used operationally to underpin Australia's short-range ocean forecast system (OceanMAPS; www.bom.gov.au/oceanography/forecasts/), ocean, and seasonal prediction systems (POAMA; www.bom.gov.au/climate/ocean/outlooks/). Science applications include the investigation of decadal prediction, climate studies, biogeochemical response to dust and smoke, and some studies into mesoscale variability around Australia.

5. **Issues that your country wishes to be considered and resolved by the Argo Steering Team regarding the international operation of Argo. These might include tasks performed by the AIC, the coordination of activities at an international level and the performance of the Argo data system. If you have specific comments, please include them in your national report.**

We are seeking clarity on the status of the file checker. It seems that we are currently not able to issue v3.2 Traj files (including BGC variables) because it seems that the file checker isn't ready to accept them. This is stopping us from applying in-air corrections to DOXY data.

6. **To continue improving the quality and quantity of CTD cruise data being added to the reference database by Argo PIs, it is requested that you include any CTD station data that was taken at the time of float deployments this year. Additionally, please list CTD data (calibrated with bottle data) taken by your country in the past year that may be added to the reference database. These cruises could be ones designated for Argo calibration purposes only or could be cruises that are open to the public. To help CCHDO track down this data, please list the dates of the cruise and the PI to contact about the data.**

Details of the following CTD profiles have been included in the floats' meta files.

- CTD cast with BGC sampling at time of deployment of float 7900947: RV Investigator, voyage IN2023_V01, 03 CTD, Station 4; PI Alix Post (Geoscience Australia)
- CTD cast with BGC sampling at time of deployment of float 5905519: RV Investigator, voyage IN2022_T01, CTD cast #001
- CTD cast with BGC sampling at time of deployment of float 5905501: RV Investigator, voyage IN2022_V02, CTD cast #001; PI Martin Jutzeler (University of Tasmania)
- CTD cast with BGC sampling at time of deployment of float 5905505: RV Investigator, voyage IN2022_V02, CTD cast #002; PI Martin Jutzeler (University of Tasmania)

7. **Bibliography**

We use the Argo Bibliography, maintained by UCSD, as the definitive source of papers that use Argo data. We know of no additional publications that should be included.

We understand that this isn't the place to report interesting science results, but we can't resist sharing some results that we hope might provide relief from the dryness of National reports. Last year we published a "fun" paper on the merging of two eddies in the Tasman Sea (Rykova and Oke 2022, JGR-Oceans). The analysis used Argo data to show that when these two eddies merged (Figure 3a), the smaller, deeper eddy (that we called Tom, after the authors' littlest boy) wrapped around and subducted beneath the bigger, lighter eddy (that we named Bob, after the authors' second littlest boy) and spiralled in towards the eddy centre. The result of the merging was Bob stacked on top of Tom, with multiple layers that penetrated to about 800-m depth (Figure 3b,c). The eddies were sampled by two Argo floats. As the eddies were merging, the floats were 11 km apart (Figure 3d), and the sub-ducted water is seen on the outer-most profile, but not on the inner-most (compare the pink and green profiles in Figure 3e, when only the green has multiple layers that is clearest in salinity). About twenty days later, the sub-ducted water is seen on the inner-most profile, but not the outer-most (compare the green and cyan profiles in Figure 3g, when only the cyan has multiple layers). The dynamics of a smaller eddy "spirally" around a larger eddy when they merge is well-documented in theory – but not previously observed in the field. Who said that Argo doesn't resolve eddies?!? The authors of this paper found it fitting that after an energetic interaction, Bob ended up on top of Tom … just like their boys.

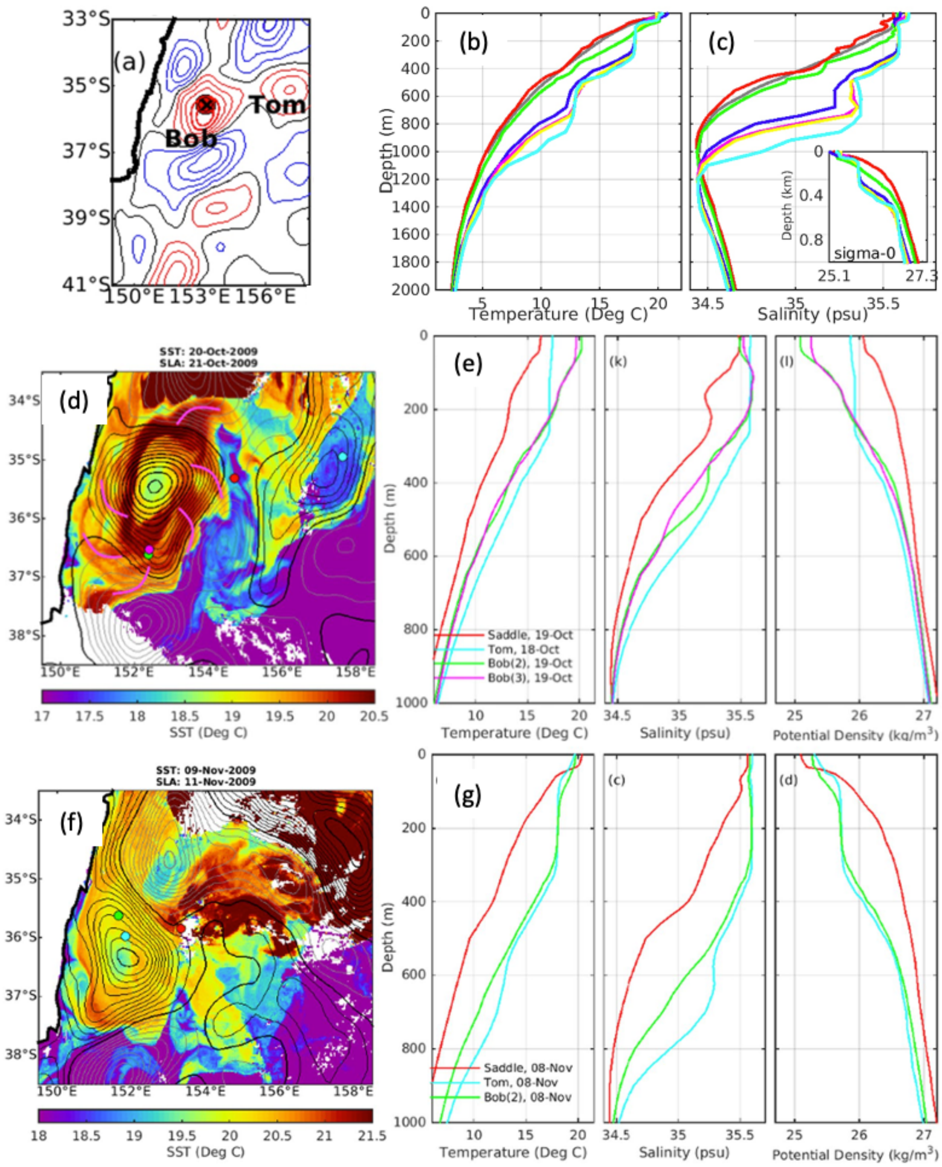

Figure 3: Figures adapted from Rykova and Oke (2022; JGR-Oceans), showing (a) a map of sea-level anomaly where two eddies (Bob and Tom) are evident in close proximity; (b,c) profiles from within eddy Bob, before and after the merging event; (d,f) SST images as the eddies merge, showing the location of Argo floats (coloured dots), and (e,g) profiles from within the merged eddy.

8. 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.

Nothing to report.

9. 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 2021 and 2022 (if known) and where they might be deployed.

We report on the performance of floats with RBR sensors in section 1b, above.