Argo Australia National Report 2021 – AST-22

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1. The status of implementation of the new global, full-depth, multidisciplinary Argo array (major achievements and problems in 2020)

a. Floats deployed and their performance

During 2020, Argo Australia deployed 78 floats, including 76 Core floats and 2 BGC floats. We also supported the deployment of 2 EM-Apex floats (by UTAS) in the Southern Ocean (although they are not part of the Argo Program). We deployed floats from 9 different vessels[1], over 12 different voyages. The locations of the floats deployed in 2020 are show in in Figure 1. All floats performed as expected, with the exception of 4 ALTOS (described in the next section).

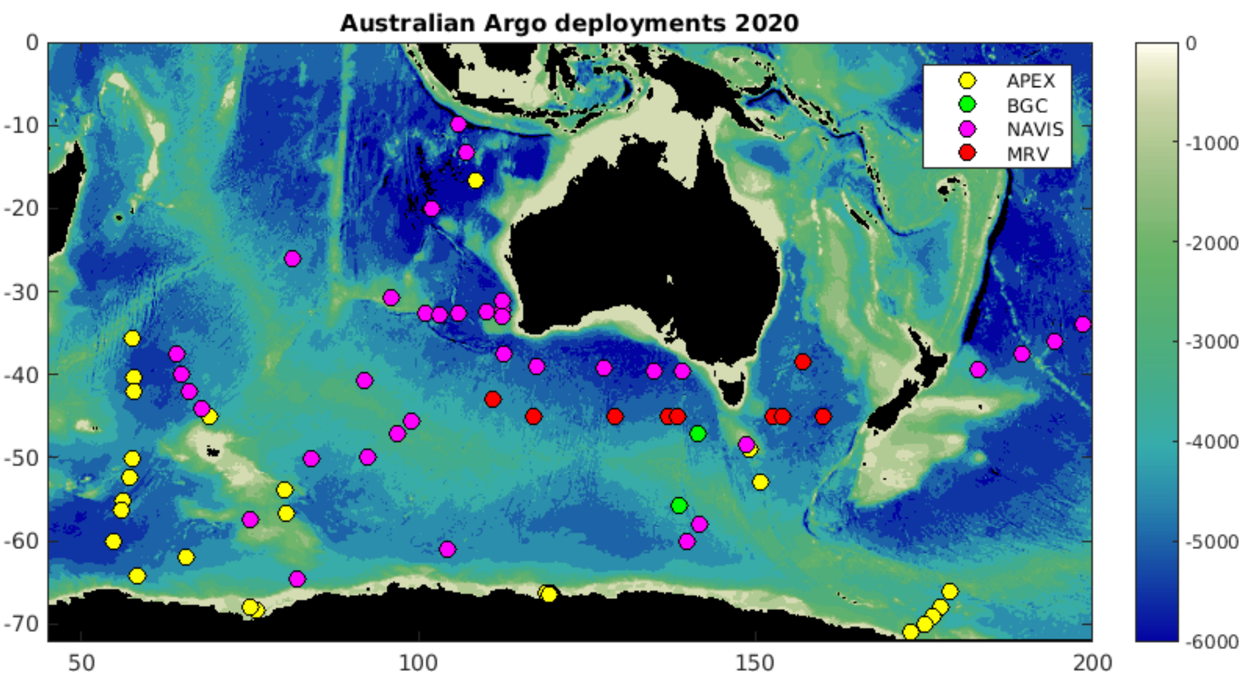

Figure 1: Map showing the deployment locations for floats deployed by Argo Australia in 2020. The colours of the dots denote the float types.

[1] Aurora Australis, RV Investigator, RV Sonne, RV Kaharoa, RV Mirai, RV Laura Bassi, Shirase, MV L'Astrolabe, Swan River Bridge.

b. Technical problems encountered and solved

Possible issue with batteries in 2018 Apex floats

We've noticed a cohort of Apex floats showing a premature drop of battery voltage after 50 to 75 profiles (e.g., Figure 2, right). These are floats purchased in 2018. All of the affected floats have the same firmware.

We first noticed the problem in floats fitted with N2 Compensators (Figure 2, left). These floats have one less 4DD Li battery pack, and therefore we have seen the voltage drop earlier in the float's life.

We suspect there may have been a batch of faulty Electrochem DD Li cells. We've discussed this with Teledyne and are working with them to try to understand the root cause of the problem.

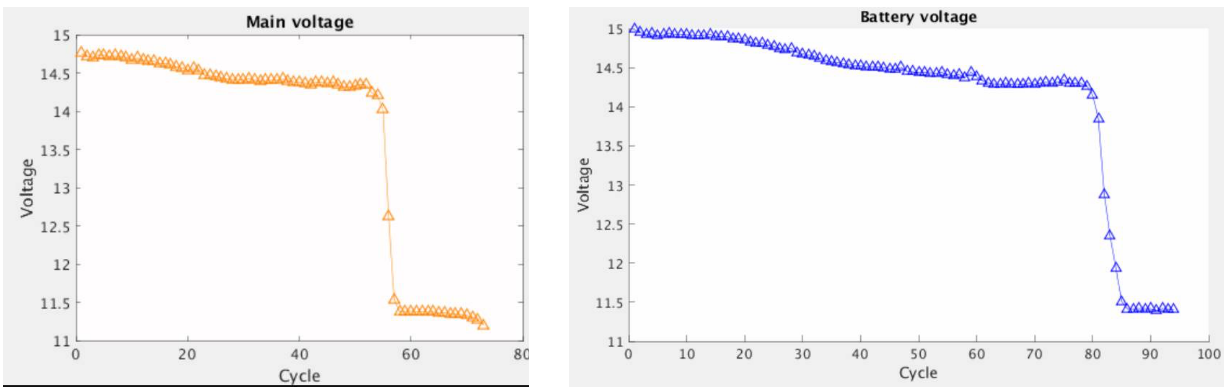

Figure 2: Main voltage as a function of profile number for floats with hull numbers 8428 and 8442. Float 8428 is fitted with a N2 Compensator. To fit the N2 Compensator, 1 pack of batteries are removed, rendering the floats with 25% less stored energy and showing the problem earlier in the float's life.

Faulty Check Valves

We routinely perform 12-hour bladder checks on all of our floats prior to deployment. In 2020, these tests identified 3 Apex floats with leaking check valves (out of 17 tested). The check valves (non-return valves) stop air from leaking from the inflated bladder back into the hull. These leaks were addressed before deployment (TWR sent us replacement valves) and the floats performed as expected. We note that NAVIS floats are built with two check-valves in series. We haven't detected any leaks in check valves in NAVIS floats, and suspect that this may be due to the extra level of redundancy the additional check valve offers.

MRV ALTOs with RBRargo[3] CTDs

We had intended to deploy 18 core floats with RBR sensors (all MRV ALTOs) as our contribution to the RBR global pilot array. However, when we encountered problems with floats, we replanned our deployments to allow the manufacturers time to address the issues identified. To date, we have deployed 9 core floats with RBR sensors. A summary of events relating to our RBR deployments follows:

- Float #11100 (WMO ID: 5905468) was the first to be deployed. It failed to return any profile data. The MRV controller did not properly communicate with the RBRargo[3] CTD. We were using firmware v7.3.5. MRV addressed the issue and provided revised firmware (v8.0.2). The float subsequently failed. The cause of the terminal failure in the float is unknown. MRV have offered to replace this float.

- Float #11154 (WMO ID: 5905482) was the first float we deployed with the revised firmware (v8.0.2), but the RBRargo³ CTD failed. The float's operation went as follows:
  - float 11154 with RBRargo³ C.T.D S/N 203995 behaved correctly up to cycle 9, and returned data that looked reasonable.
  - at beginning of cycle 9, the CTD stared reporting higher temperatures than expected for the internal temperature of the conductivity cell
  - during ascent, around 1000 dbar, the CTD started reporting salinity lower than 6 PSU
  - at the surface, the float controller was unable to communicate with the CTD
  - for subsequent cycles (10+), the float controller reported identical stale values for the "fall/rise" series. This is because the float controller stores old values of time and pressure in its volatile memory and used those 'most recent' values since it was unable to acquire a response from the CTD.
  - a float reset was attempted in order to power cycle the CTD, unsuccessfully. #11154 has not called in since the reset attempt.
  - MRV has confirmed that if the ALTO controller does not get a response from the RBRargo³ CTD, it returns a previous value (e.g., on each dive cycle the struct that holds this data is not reset, but is populated with data as soon as it is read from the CTD). MRV has been unable to replicate this issue during bench tests, but after a close inspection of the controller code and analysis of the packets returned in dives 9 and 10, there is convincing evidence that the CTD on #11154 did not return data after dive 9.
  - This sequence of failure on an RBR instrument, either RBRargo³ CTD or standalone instrument, has never been observed in the field nor at the RBR factory. RBR is still actively looking for a potential explanation. It is highly unlikely that the pressure sensor of the RBRargo³ CTD is at fault.
- Float #11155 (WMO ID: 5905483) performed 3 profiles, and then failed to report again. The root cause of the failure is unknown. There is no evidence of any issue with the RBRargo³ CTD on this float.
- Float #11159 (WMO ID: 5906619), with firmware v8.02, is still operating, but encountered an issue. The float reset to dive 0. This has been explained to us as "rarely-exercised code path that would result in a float reset", but we can't yet confirm that it is the root cause of the problem.
  - Other MRV floats have reset in the field before, with SBE sensors. It is apparently a rare event, and doesn't preclude further normal operation of the float. For example, we understand that WHOI's ALAMO float #9245 encountered a similar reset and went on to profile for an additional 1043 cycles. (v8.0.2)
  - We have experienced problems with the float building up a backlog of SBD packets and we are working with MRV to resolve the problem.
- Floats #11105 (WMO ID: 5905483), 11099 (WMO ID: 5906615), 11103 (WMO ID: 5906616), 11157 (WMO ID: 5906617) and 11156 (WMO ID: 5906618) seem to all be performing well. All are running with firmware v8.0.2.
  - Some profiles where high-resolution sampling was attempted ran into encoding limitations on the MRV controller side. MRV has developed a post-processing tool that can recover the data from these high-resolution sampling dives.

Of the 9 ALTOs deployed by Argo Australia so far, one failed to communicate with the RBRargo³ CTD (with firmware v7.3.5), and of the 8 floats deployed with firmware v8.0.2, 2 are lost, and 1 had a reset that is rare and recoverable (with an admittedly large impact on shoreside processing), and 5 encountered no serious problems.

Regarding the RBRargo[3] CTDs, which we are motivated to assess under the global pilot, we note that only one RBRargo[3] CTD has shown suspicious behaviour. The 6 operational ALTOs look to be returning reasonable data. We suspect that the issue observed with RBRargo[3] CTD S/N 203995 (on #11154) is an outlier.

We understand that MRV is currently bench- and tank-testing v8.04 of the float controller firmware, which addresses a known (but rare) cause of the float reset issue discovered by reviewing the controller code. We also understand that MRV are working on a White Paper to describe and address the root cause of the reset condition.

Argo Australia are waiting on the abovementioned White Paper, and on results of the v8.0.4 tank tests, before deciding on a path forward for deployment of the 9 ALTOs with RBRargo[3] sensors that we have in the laboratory.

At the outset of this activity, we knew that we should expect some issues. Although there were a few more issues than we had hoped, we commend the MRV team for their transparency and responsiveness to the issues we encountered. At times, we were in daily contact with engineers from MRV, and participating in weekly video-conferences to identify how best to proceed. This level of collaboration, engagement, transparency, and honesty is important, and gives us confidence to continue contributing to this important global pilot program.

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)

Decoding

We currently maintain a Matlab- and Python-based Real-Time (RT) system for decoding float data. We're currently in the process of implementing some new tests in our RT system, at the request of the ADMT. These include the global range test on Rtraj files (completed in January 2021), MEDD test (started), and adding the new grounded flags to the Rtraj files (planned).

BGC efforts

One of the challenges for BGC Argo this year has been the fact that we bought floats from different suppliers, with differing programming and decoding requirements. As a result, programming and decoding efforts (and ancillary questions) have taken up a lot of time. However, looking ahead, we are now in a position where we can decode a number of different floats, so less time should be needed to get new floats into the system, leaving more time for fine-tuning of RTQC efforts.

So far, RT Quality Control (RTQC) is implemented for new floats (except for the CHLA variable, as the protocol for RTQC is currently being revised, see below), but has not been retro-actively applied to legacy floats in our system. Nearly all our DOXY data is either in "A" or "D" mode, and systems are in place to adjust DOXY on newly deployed floats within ~2 months. Efforts are also underway to adjust NITRATE and

PH, using the SAGE system. We expect this to be achieved for all live floats by April 2021. Real-time flagging to QC=3 for raw data of DOXY, CHLA, NITRATE and PH has been implemented for live floats but will still need to be addressed for legacy floats.

Around 88% of eligible DOXY profiles have been Delayed-Mode Quality Controlled (DMQC-ed), with BD-files uploaded to the GDACs. None of the other BGC variables have received DMQC, but the CSIRO BGC operator has led the effort to update the CHLA RTQC documentation, with final decisions on crucial aspects of the QC process to be decided very soon. The BGC operator will subsequently incorporate the decisions into an updated CHLA RTQC document for the BGC Argo community, and DMQC of CHLA (and BBP) will commence shortly thereafter, followed by DMQC on other BGC variables.

Deep efforts

Real Time processing: We are looking into the implementation of the RT corrections for Deep floats recommended in the most recent release of the manual.

Delayed Mode processing: Initial modifications to the DMQC software have been made to allow deep floats to pass through our system, so that data can be viewed. At this stage, it only includes removing the maximum pressure check so that deep data can pass through the software, however the data is not yet QC'd. Once DMQC recommendations are made available to the community, we will also begin to implement these in the DM software.

Analysis of high salty drift floats

We have submitted information on 28 floats (out of 304 in our fleet with CTD SN≥6000) that meet the criteria for Fast Salty Drift (FSD) as described in the ADMT-21 meeting report. This addresses action item 39 from ADMT.

The report below was submitted to ADMT in November 2020, and is presented again here, with updated numbers. We aim to perform the first DMQC on floats six months after deployment, with a 3-month lag; and we then aim to perform DMQC every year, with a 6-month lag. We assess PSAL against CARS09 and nearby-Argo at multiple theta levels. If after assessment, it is decided that the PSAL drift or offset is real, we run OWC and apply piece-wise, linear adjustments where necessary. If the required adjustment in DMQC is large, we greylist the float for PSAL in RT QC (QC3 if PSAL is well-behaved and we expect we can correct the data with DMQC, QC4 if un-correctable).

We performed an assessment on our fleet to assess the percentage of floats showing a salty drift prior to the 2020 ADMT. At that time, of our entire fleet (846 floats), 77 had not yet been assessed, 658 (78%) showed no drift; 177 (21%) showed a salty offset or drift; 12 (1.4%) showed a fresh offset or drift; and 38 returned bad PSAL data (these were not included in the percentages reported here). These results are summarized in **T**able **1**. Based on experience, we expected to find the percentage of salty drifters to be closer to 10-12%. We repeated this analysis for floats with SBE41 CTDs with SN6000-7100, and SN8000-8999. The results are in Table 2 and 3. We find that there is a much higher percentage of salty drifters with SN6000-7100 (Table 2). But we find no evidence (in our small sample) for more than usual salty drifters with SN8000-8999 (Table **3**).

Table 1: Analysis of PSAL drifts in SBE41 CTDs for all floats deployed by Argo Australia.

Code	Meaning	Frequency	Percentage
0	Not assessed	77	
1	No drift	658	77.7%
2	Salty drift	177	20.9%
3	Fresh drift	12	1.4%
4	Bad PSAL	38	
		Total assessed: 847	

Table 2: Analysis of PSAL drifts for SBE41 CTDs with SN6000-7100. Of those not assessed, one has a problem being processed through our DMQC system (software issues) and six are from floats in the high latitudes with sparse reference data that need further analysis.

Code	Meaning	Frequency	Percentage
0	Not assessed	7	
1	No drift	35	50%
2	Salty drift	35	49%
3	Fresh drift	1	1%
4	Bad PSAL	3	
		Total assessed: 71	

Table 3: Analysis of PSAL drifts for SBE41 CTDs with SN8000-8999.

Code	Meaning	Frequency	Percentage
0	Not assessed	0	
1	No drift	28	76%
2	Salty drift	6	16%
3	Fresh drift	3	8%
4	Bad PSAL	0	
		Total assessed: 37	

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 used OWC-v2, and we will soon upgrade to OWC-v3. We are using the ARGO_for_DMQC_2020V03 reference database. We currently have three DMQC Operators regularly performing DMQC on our data, and one software engineer supporting the code.

To date, we have processed about 94% of eligible T/S/P data.

Our over-all capacity in DMQC is temporarily reduced for 2021, as staff effort has shifted between projects. This may impact our through-put. We will likely need to recruit a new DMQC Operator.

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)**

Argo Australia has secured funding for salary and operating costs to support our Argo operations until June 2022 from the Australian Integrated Marine Observing System (IMOS). We expect this funding to continue until at least 2028 at an equivalent level. This includes support for salary and operating costs for the Australian Argo Program.

In 2021, we expect to acquire 40-45 Core floats, 3 Deep floats, and deploy 7 BGC floats (as shown in Table 4). Core floats are funded from a strong partnership between IMOS (likely until 2028), CSIRO (reviewed annually), the Australian Department of Defence (reviewed annually), BoM (reviewed annually), and AAPP (funded until 2029). BGC floats are funded by IMOS, CSIRO, UTAS, and AAPP. Deep floats are funded by AAPP and CSIRO.

Of the 7 BGC floats we plan to purchase, we will likely deploy only 3 or 4 floats in 2021, and will deploy the final 3 or 4 in 2022. A summary of our efforts to obtain and deploy BGC Argo floats is presented in Table 4.

Table 4: A summary of our efforts to obtain and deploy BGC-Argo floats are increasing are presented below; * indicates that floats have been ordered; and "?" indicates deployments are pending funding, choice of float/type, and/or voyage allocations.

Date	Quantity	Deployment region	Float Type	Sensors	Purchasing Partners	Status
Oct-19	2	Tasman Sea	APEX	5	IMOS	certain
Dec-20	2	Southern Ocean	NKE	6 + UVP	IMOS, UTAS	certain
Feb-21	3	Southern Ocean	TWR*	6	IMOS, AAPP	certain
May-21	2	Tasman Sea	NKE*	6	IMOS	certain
Jun-21	1	Coral Sea	NKE*	6	IMOS	certain
Oct-21	1	Eastern Indian Ocean	TWR*	6	IMOS, CSIRO	certain
Feb-22	1-2	Southern Ocean	NKE*,?	6	IMOS, SOTC, AAPP	expected
Jun-22	2-3	Southern Ocean or Tasman	??	??	IMOS, CSIRO, AAPP	expected

All 3 Deep floats that we plan to purchase will be deployed to enhance the pilot array in the Australian Antarctic Basin.

Argo Australia has (some fraction of) two technical officers; one scientist running real-time operations and maintaining our Matlab-based RT system; one programmer developing a new Python-based system and doing most of the decoding; six scientists contributing to the delayed-mode operations (including one scientist dedicated to BGC and one programmer dedicated to software development and maintenance). Our operational team supports activities of Core, BGC, and Deep Argo. Argo Australia also has (some fraction of) two scientists working on Core Argo, two scientists working on BGC Argo, and two scientists working on Deep Argo – although the lines distinguishing between these efforts is becoming blurred – something that our program is embracing. In total, Australian Argo draws on ~6 FTE, with ~4.5 FTE for operations; ~0.5 FTE for Core Argo leadership and applications, ~0.5 for BGC Argo leadership and applications, and ~0.5 FTE for Deep Argo leadership and applications.

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. This funding has been secured until June 2022, but we expect it to continue until 2028.

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 currently have 82 Core floats, 8 BGC floats, and 2 Deep floats either in our laboratory or on order. Of the Core floats 76 have been assigned to specific cruises for deployment (see Figure 4), but the target locations for 9 Apex floats that are intended to be deployed from the September 2021 Kaharoa Cruise are yet to be determined. We will coordinate with others involved in the cruise to identify the most suitable locations.

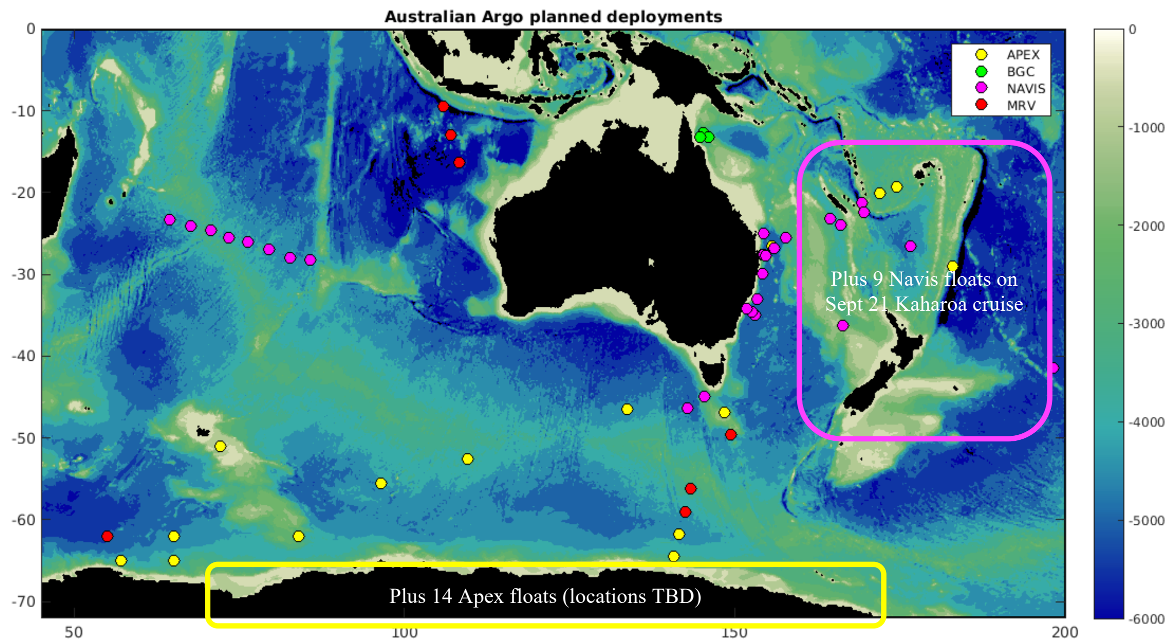

Figure 3: Map of planned deployments for 2021.This includes 20 Apex floats, 40 Navis floats, 7 ALTOs (with RBR sensors), and 3 NKE BGC floats. We also have an additional 9 Navis floats that we plan to deploy in the South Pacific on the September 2021 RV Kaharoa Cruise (to be coordinated with others), plus 15 additional Apex floats: 14 ballasted for under ice, and one ballasted for 25S.

We also have 15 Core floats (Apex floats) that have not been assigned to cruises (their original cruise was cancelled). Of these floats, 14 are ballasted for ice conditions, and will likely be deployed next Austral summer, and one is ballasted for 25S and will be deployed in the South Pacific (off the Tangaroa in May 2021).

We have 2 Deep floats that we have not yet assigned to a cruise. The Deep floats will be deployed to enhance the pilot array in the Australian Antarctic Basin. Options we're considering for 2021-22 include: AAD resupply mission, L'Astrolabe, Japanese vessel, or Investigator trip to Cape Darnley. Only the last two of these options will allow CTD on deployment.

Plans for BGC floats are shown in Table 4.

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.

A new ocean reanalysis, called Bluelink ReANalysis 2020 (BRAN 2020), has just been completed and will soon be made publicly available (once the paper describing the reanalysis has been submitted). BRAN2020 assimilates Argo data, altimetry, and satellite SST data, plus other in situ data sources.

A new gridded product, called Blue Maps, has been developed. Data from Blue Maps – likely to span 2005-present, will soon be made publicly available (once the paper describing the methods employed has been submitted). Blue Maps grids data from Argo, satellite altimetry, and satellite SST.

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.**

It appears that the practice of only sampling with Deep Argo floats on descent is inconsistent with the spirit of the OneArgo array. This will mean that Deep floats are not equivalent to Core floats. Core floats report profile data within 24 hours of measurement. However, when Deep floats perform 10-day missions and only sample on descent, they report data 10-11 days after measurement. This renders Deep floats – at least the shallow measurements from Deep floats – irrelevant to operational systems that typically use data from T-3 days until present. With the current mode of operation, data from Deep floats will not be assimilated into operational models. Shifting the Argo design from ~4000 Core floats to 2700 Core, 1200 Deep, and 1000 BGC floats will effectively mean that the array of floats for operational applications will be diminished to 3700 floats. If that is acceptable to the AST, then it is suggested that this implication is clearly explained to the operational community.

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.**

Many deployments included accompanying high-quality CTD profiles. All of those cruises are listed in the first section of this report. However, we have failed to routinely including the details of CTD station data in the float's metadata. But we will try to find the resources to address this gap in our program. However, details for the four BGC floats deployed off the RV Investigator Cruise (on INV2019_T01 and IN2020_V08) are included in Table 5.

Table 5: Details of CTD casts accompanying deployments of BGC floats in 2019 and 2020.

WMOID	Date deployed	Ship	Voyage #	CTD #	P/mts	POC	Alk	DIC	Nutrients	Oxygen	Salinity
5905441	4.10.2019	R/V Investigator	IN2019_T02	1	x	x	x?	x?	x	x	x
5905442	4.10.2019	R/V Investigator	IN2019_T02	1	x	x	x?	x?	x	x	x
5906623	12.12.2020	R/V Investigator	IN2020_V08	23	x	x	x	x	x	x	x
5906624	27.12.2020	R/V Investigator	IN2020_V08	53	x	x?	x	x	x	x	x

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.

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.

COVID-19 has impacted all areas of our operation, but we have actively adapted to restrictions to maintain the overall performance. Impacts on each area of our work is summarized below:

- Deployments
    - Some deployment opportunities were lost, when cruises were cancelled or postponed. In those instances, we changed our deployment plans and shifted floats to other opportunities. This resulted in deployments in locations that were not our first choice. But we tried to make sensible choices that would positively contribute to the global array.
    - Our usual practice has been to ship floats to their final port, and then one of our Argo Technicians travels to that port to perform final pre-deployment checks. This wasn't possible. Instead, we recruited suitably-skilled technicians near each final port, and worked with them to perform the final tests for us. This turned out to be a significant cost saving, and is something we may consider continuing in the future, regardless of travel restrictions.
- Data processing
    - Our work-force was not directly impacted by COVID-19. However, staff all worked from home for most of 2020. This had mixed impacts on productivity. For some, it resulted in greater productivity, but for some it posed a challenge. One of our team members encountered one work-place incident (a serious back injury that required surgery and extended time of work for recovery) that took her out of action for 3 months. Although this is not a direct result of the pandemic – had the pandemic not interrupted our lives, it may not have occurred.
- Budgets
    - Our travel budgets were all frozen. We adapted to this, as noted above, but it's possible that post-pandemic travel budgets may be lean.
- Pre-deployment script/Application further development
    - COVID-19 travel bans encouraged us to continue developing pre-deployment scripts and applications to simplify final shipside tests so any person can perform a thorough test and

identify outliers. We see it as an opportunity to further adapt our operations to reduce our dependency on travel.

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.**

Despite the challenges we've faced during our initial deployment of ALTOs with RBR sensors, it is our intention to include some portion of floats with RBR sensors each year. We still have 11 floats with RBR sensors in our labs that are awaiting deployment, so we may not order floats with RBR sensors this year. But once we have ironed out the issues with manufacturers, we will purchase floats with RBR sensors each year – perhaps 4-8 floats per year (representing ~10-20% of our annual investment).