Australian Argo National Data Management Report prepared for ADMT21, November 2020

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Deployments in 2019/20

Australia has deployed 85 floats between 1 October 2019 and 1 October 2020, including 36 manufactured by Teledyne-Webb, 40 by Seabird, and 9 by MRV. Two Teledyne-Webb floats include BGC sensors to measure pH, oxygen, nitrate, chlorophyll fluorescence and backscatter. The MRV floats include RBR CTDs; the rest are core floats with SBE41 CP CTDs. From the core SBE41 floats, four were deployed in the ice zone over the Antarctic shelf and are parking on the sea floor, and sampling to the bottom. Figure 1 shows a map of deployment locations.

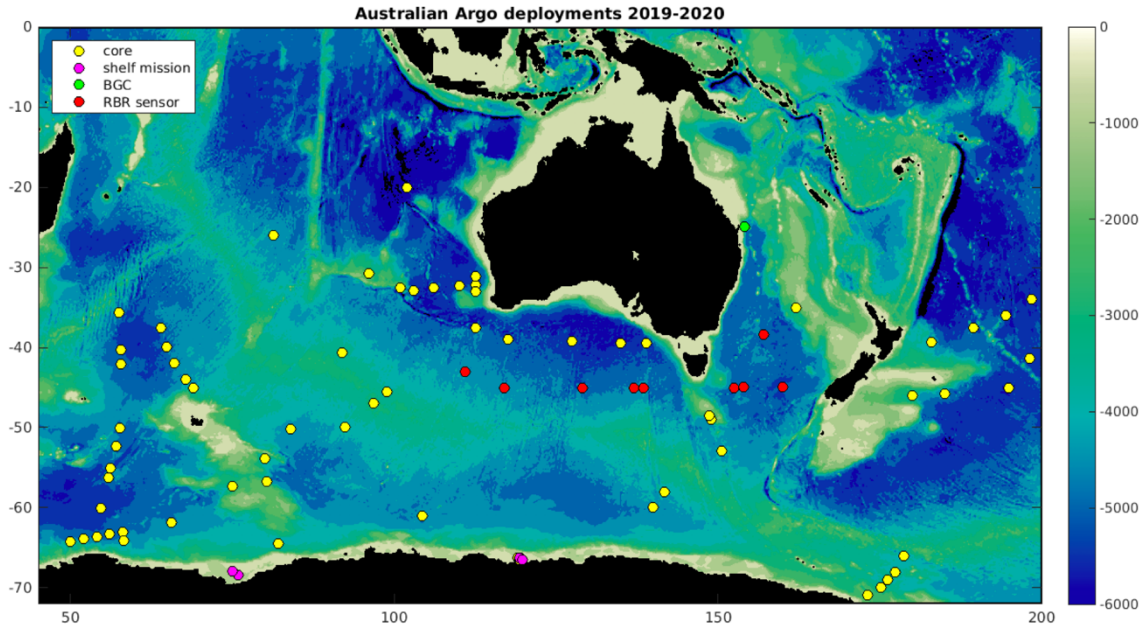

Figure 1: Map of Argo Australia deployments between 1 October 2019 and 30 September 2020; coloured dots indicate deployment location of two Argo-BGC floats (green), four floats in a mission sampling shelf waters off Antarctica (magenta), and nine MRV floats with RBR CTD sensors (red); remaining floats are Argo-Core.

Organization and resourcing

Australian Argo partners include CSIRO, BoM, IMOS, UTAS (Australian Antarctic Program Partnership - AAPP), and the Department of Defence (DoD). Argo Australia is organized as a Facility under IMOS, with the Facility led by Peter Oke (CSIRO), and two sub-Facilities: Deep, led by Steve Rintoul (CSIRO); and BGC, led by Peter Strutton (UTAS). The Facility shares resources for real-time data processing, float testing, float deployment, and software support for real-time operations.

Argo Australia operates with a total of ~5.4 Full-Time Equivalents (FTEs), with ~1.5 FTEs dedicated to DMQC, ~1.0 FTEs dedicated to RT support, ~1.5 FTEs dedicated to technical float support, ~0.9 FTEs dedicated to BGC Argo, and ~0.5 FTEs dedicated to science and leadership.

Status of RT Operations

Argo Australia has a team of eight people with fractional allocations to RT operations. In total, we dedicate about 1.0 FTE to RT support. Those individuals involved, and their roles, are:

- Gabriela Pilo: management and trouble-shooting of real-time data streams at CSIRO (with support from Rebecca Cowley)
- Lisa Krummel and Joel Cabrie: management of real-time data streams at the BoM
- Pat McMahon: float procurement and logistics
- Craig Hanstein: technical deployment planning
- Beatriz Pena-Molino: scientific deployment planning
- Craig Hanstein and Pat McMahon: telecommunications
- Roger Scott: Code Support

In October 2019, Argo Australia appointed a new RT operator (Gabriela Pilo). Gabriela was trained and supported by Rebecca Cowley. Since mid-2020, we have maintained two RT systems: a legacy Matlab-based system (operated by Gabriela Pilo), and a new Python-based RT system (developed and operated by Roger Scott). The Matlab-based RT system is still the primary system for floats with Iridium-RUDICS and Argos communications (currently 397 floats). The Python-based system is the primary system for floats with Iridium-SBD communications (currently 33 floats). However, the Python-based system also processes all other floats, as a secondary, backup service. We plan to transition our primary system from Matlab to Python by the end of 2021, and discontinue operation of the Matlab-based system some time thereafter.

Following a denial of service attack on one of our servers in 2019, we installed a secondary, backup RUDICS-server at CSIRO's offices in Perth, Western Australia. This secondary server provides some redundancy, in case of hardware fail, or in case of another malicious attack.

Float data are decoded, processed, and disseminated at CSIRO and BoM every 6 hours – staggered, so that data from the Australian array are processed every 3 hours. The Python RT processing only happens at CSIRO for now, and runs every 3 hours.

At the time of writing (24 November 2020), 98% of eligible data are being uploaded to the GDACs within 24 hours of measurement. The data are issued to the GTS in BUFR bulletins via the Bureau of Meteorology (AMMC). These messages are generated every hour, as data become available. RT performance is summarised in Figure 2. The dip in data delivery between December 2019 and January 2020 was caused by two incidents. First, over this period, we deployed 57 floats and couldn't quite keep up with the attribution of WMO IDs to all floats within 24 hours of deployment. Second, there was a bug in the code when the year changed from 2019 to 2020. As a result, the CLS files

from floats with Argos comms weren't processed. Once we fixed the issue, we processed the backlog of CLS files to restore the complete archive of profiles.

Since 1999, Argo Australia has deployed 977 floats. We currently have 430 floats on our database that we consider to be "alive". This includes floats that are under ice, floats that haven't reported for some time, and 23 floats that are sending suspect data. On 24 November, 2020, 342 floats have reported profiles within the last 90 days. Figure 3 shows a map of the current location of operational floats.

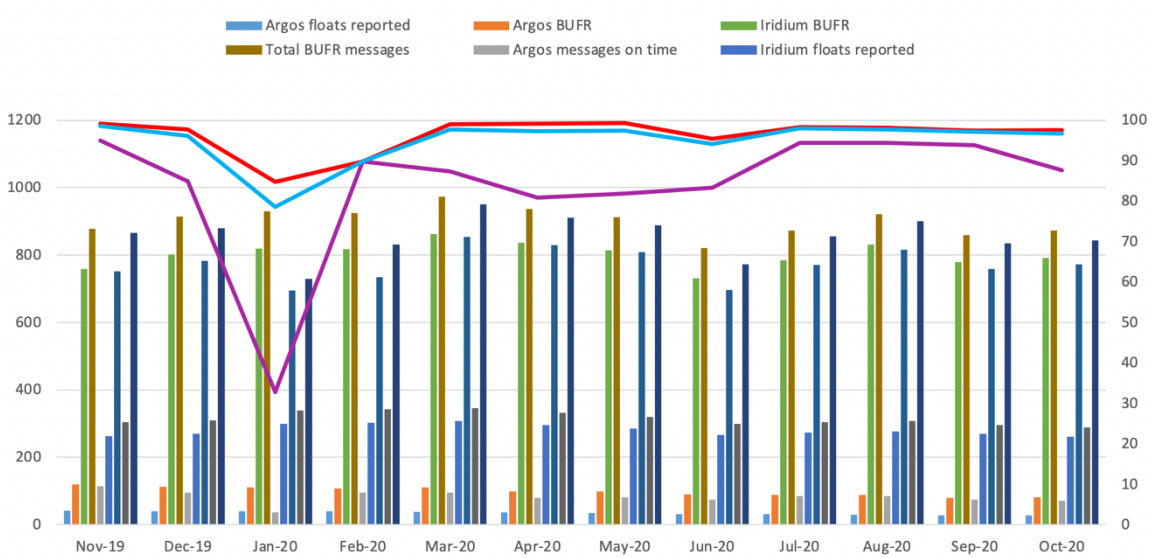

Figure 2: Summary of RT metrics for the Argo Australia operation. The lines at the top indicate the percentage of files delivered to the GDAC within 24 hours for floats with Iridium-RUDICS comms (red), Argos comms (purple) and both (light blue), with percentage axis on the right. The vertical bars indicate the number of floats reported and number of BUFR files sent to the GDAC per month, with axis on the left.

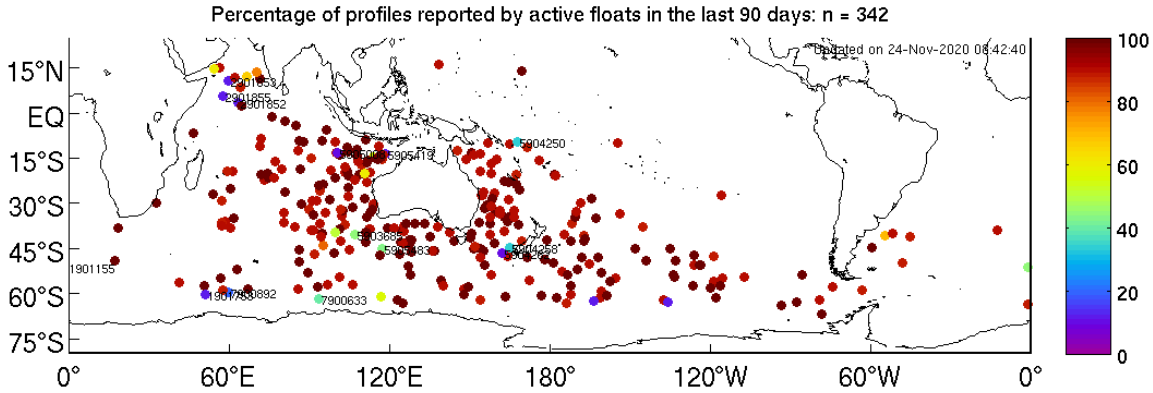

Figure 3: Map of the current locations of operational floats managed by Argo Australia. The colour of each dot indicates the percentage of data return over the last 90 days; with 100 indicating that 9 out of 9 profiles have been returned. Floats that have reported profiles fewer than 5 times in the last 90 days are labelled with their WMO ID (used by the Argo Australia team to identify floats that may be dead and that need to be checked and monitored).

Status of DMQC Operations

Argo Australia has a team of six people with fractional allocations to DMQC operations (with only five active for most of the past year). In total, we dedicate about 1.5 FTEs to core DMQC and about 0.5 FTEs to BGC DMQC. Those individuals involved, and their roles, are:

- Core DM Operators: Catriona Johnson, Jenny Lovell, Tatiana Rykova (on maternity leave)
- BGC DM Operator/Specialist: Christina Schallenberg
- DM Consultant: Esmee Van Wijk
- Software support: Dirk Slawinski

At the time of writing (19 November 2020), 95.8% of eligible core profiles have been DMQC-ed with D-files uploaded to the GDACs.

We are using OWC-V2 to make salinity adjustments for floats with PSAL drift and plan to soon upgrade to OWC-V3. Out of the whole fleet (both active and dead), we find that close to 20% of floats require PSAL adjustment for some profiles. For floats with CTD serial numbers (SN) in the range 6000-7100 this percentage is 50%. There are 71 floats with CTDs in this SN range; two have not been assessed for drift due to RT data issues, and these have RTQC of 2 applied to PSAL in recognition of the higher likelihood for PSAL drift.

CSIRO hosted a DMQC Operator from China (Xiaofen Wu) during Aug-Oct, 2019 and delivered the CSIRO DMQC system to her. During this time some improvements were made to the structure of the system to make it more easily portable to external users. We maintain a collaborative relationship with Xiaofen, providing some code-support to accommodate different float characteristics, although our capacity to provide full code-support is limited.

In the past, our core DMQC operators performed DMQC on DOXY parameters. This is now handled separately by our BGC DMQC specialist. Some changes are underway to ensure accurate documentation and delivery of DMQC information and meta-data between the two efforts, as well as some changes to the software to facilitate the independent export of D-files and BD-files. At the time of writing, 90.9% of eligible DOXY profiles have been DMQC-ed with BD-files uploaded to the GDACs.

There is currently 0.9 FTE available for BGC-related tasks, with about 0.5 FTE to BGC DMQC. Other BGC tasks include sensor selection, pre-deployment decisions, and RTQC (including the “adjusted” mode for several BGC variables). To date, only the DOXY variable has received DMQC, as indicated above. However, several issues related to QC of the DOXY_ADJUSTED variable have been solved in the past year, and all our DOXY data are now in “adjusted” mode. We have responded to float issues that have come up in the DOXY audits and after the most recent improvements have been completed, we should have no more than ~15 DOXY profiles outside of the expected bounds.

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 at ADMT-21. The BGC operator will

subsequently incorporate the decisions into an updated CHLA RTQC document for the BGC Argo community, and DMQC of CHLA will commence shortly thereafter. The next variables to receive DMQC will be BBP and IRRADIANCE/RADIANCE/PAR, which are the most common variables present in our data set (after DOXY). It is expected that these variables will be up to date with DMQC by mid 2021. The remaining variables (PH and NITRATE) are expected to follow in the second half of 2021.

Analysis of PSAL drifts

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 expected we can correct the data with DMQC, QC4 if un-correctable). We have performed an assessment on our fleet to assess the percentage of floats showing a salty drift. At the time of this analysis – of our entire fleet (846 floats), 77 have 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 Table 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	78%
2	Salty drift	177	21%
3	Fresh drift	12	1.4%
4	Bad PSAL	38	
		Total assessed: 846	

Table 2: Analysis of PSAL drifts for SBE41 CTDs with SN6000-7100. Of those not assessed, two have problems 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	8	
1	No drift	35	50%
2	Salty drift	34	49%
3	Fresh drift	1	1%
4	Bad PSAL	3	
		Total assessed: 69	

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

Code	Meaning	Frequency	Percentage
0	Not assessed	0	
1	No drift	29	78%
2	Salty drift	5	14%
3	Fresh drift	3	8%
4	Bad PSAL	0	
		Total assessed: 37	

Web pages, products, and papers

Argo Australia have developed a new product, called Blue Maps. Blue Maps is a gridded product of temperature, salinity, and sea-level, constructed by mapping observations from Argo, satellite altimetry, and satellite sea surface temperature. The mapping method is based on the ensemble-based data assimilation system routinely used under Bluelink – an ocean forecasting effort in Australia. Results from a prototype of Blue Maps is at: www.marine.csiro.au/~oke060/Argo/ArgoMaps.html.

Once the system configuration is finalized and documented, data will be made available to the community via OPeNDAP. This is expected in early 2021.

Other products generated in Australia using Argo data include:

- OceanMAPS: operational, short-range ocean forecasts produced by the BoM (summarised by Schiller et al. 2019);
- BRAN: Bluelink ReANnalyses produced by CSIRO (summarised by Schiller et al. 2019). The latest version – BRAN2020 – was completed in October 2020. Once assessed and documented, data will be made available to the community via OPeNDAP; and
- OceanCurrent (http://oceancurrent.imos.org.au): a product based mostly on satellite data, but includes Argo data in graphics.

Argo data in Australia continues to be used to underpin many different scientific studies. These are captured on the Argo Bibliography webpage. Some studies coming out of the Australian Argo team include a couple of papers on the oceanography of the East Australian Current region (Oke et al. 2019a,b), a study of Antarctic Bottom Water (Silvano et al. 2020); a study of biomass in the Arabian Sea (Wojtasiewicz et al., 20210), an analysis of ocean warming in the Indian Ocean (Beal et al. 2020), a study of changes in Antarctic ice sheets (Noble et al. 2020), and others. The Argo Australia team are also working on a paper to analyse the fail modes of all of our floats. This study is led by Jenny Lovell, and aims to identify why some floats fail early (before their power is exhausted), with a view to eliminating avoidable failures in our future fleet.

Assessment of Impact

One of our funders (IMOS) recently undertook an assessment of impact of each of their facilities. This may be of interest to the International Argo Community. For the Argo facility, this focussed on the impacts of Argo Australia, rather than the International Argo

effort. Some results are summarised below. It is estimated that between 2006 and 2019, data collected and disseminated by Argo Australia:

- Informed 430 publications, delivering societal benefit to four main areas (with roughly equal distribution), including food security; coastal populations; maritime safety, security and sovereignty; and biodiversity conservation and management;
- Informed 103 publications that were related to Sustainable Development Goals (mostly to SDG 13: Climate Action);
- Informed 42 publications taken up into policy documents;
- Informed 601 uses/applications, including application to publications (430); Reports (59); Products (35); Projects (55); and Postgraduate projects (22); from Australian Institutions or Australian Industry.

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