2020 Argo Canada report of activities

(submitted by Blair Greenan, Fisheries and Oceans Canada)

22nd meeting of the Argo Steering Team (AST-22)
Location: Virtual
22-26 March 2021

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

- *floats deployed and their performance*

From January 2020 to December 2020, Argo Canada deployed 33 NKE Arvor floats (12 in the northeast Pacific, and 21 in the northwest Atlantic). Of these 33 floats, 1 float failed immediately after deployment and another 2 were equipped with dissolved oxygen sensors. The 32 remaining floats are still operational and functioning properly. As of 20 January 2021, Canada has 106 operational floats in the Argo Canada program.

- *technical problems encountered and solved*

One RBR Arvor float failed to initialize just before deployment, and was returned to the manufacturer for repair. The failure turned out to be a communication issue with the CTD, which was diagnosed as an internal component failure by RBR, and was not believed to be a risk for future RBR Arvor deployments.. One DOXY Arvor float also failed to initialize just before deployment, was later reset successfully in the lab, and will be deployed in Feb 2021. Another SBE Arvor float failed during testing in the lab due to low bladder pressure, and is being returned to the manufacturer for repair.

- *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 MEDS DAC continues to acquire data from 106 Argo floats. Data are issued to the GTS and GDACs hourly in BUFR TM315003 and NetCDF formats. Data are available for delayed mode QC as soon as they are sent to the GDACs. The data of all Canadian floats together with some graphics are posted on a website and updated daily: http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/argo/index-eng.html.

From January 2020 to December 2020, 86 % of the data were issued to the GTS in BUFR format within 12 hours of the float reporting. During the month of October and November, the timeliness was dropped to approximately 60% due to upgrade of the mail server and the Argo processes were run manually.

Since AST-21, we have worked on the following:

- Correct DOXY data using the quarterly reports provided by Monterey Bay Aquarium Research Institute.
- Creating a python tool for calculating DOXY gain and performing DMQC on oxygen, based on the Matlab tool SAGE-O2.
- Migrating the current real-time QC tests from Fortran to Python.
- Provide ADMT reports on the performance of Argo data on the GTS in BUFR formats to assist DACs in monitoring the BUFR timeliness transmission.

- *Status of delayed mode quality control process*

As of January 2021, 70% of all eligible floats, active and inactive, had their profiles QC'd visually and adjusted for pressure according to the latest delayed-mode procedures at least once. The salinity component of DMQC had been performed at least once on 72% of eligible cycles. 14% of B-files had been visually QC'd, and 12% were fully DMQC'd. The low percentages of QCed B-files are due to the latest launch of new BGC floats and our work priority on the development of a python package performing DMQC on B-files. The package is now operational and therefore the percentages of QCed B-files are expected to increase significantly in 2021. In addition to DMQC of new profiles, 8 previously-DMQCed floats received either updates to the visual QC or new adjustments in 2020 in response to feedback (e.g., reports of density inversions) or to address known issues (e.g., higher likelihood of salinity drift for salinity sensors in the serial number range 6100-7000 or thermal mass errors).

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)

Financial resources

Argo Canada has ongoing funding for the O&M expenditures related to the International Argo program. Shared Services Canada (SSC) and DFO signed an agreement in late 2019 that resulted in DFO assuming responsibility for all Iridium telecommunications cost for the department, including the Argo program. This has resulted in an extra financial burden being placed on the Argo Canada program.

Ongoing capital for float purchases has not been identified and, therefore, it remains necessary to request capital resources on an annual basis to obtain the funding required to purchase new floats. The Government of Canada (DFO and Department of National Defence – DND) committed $1.33M for purchases of core NKE Arvor-I and Provor CTS4 floats in the Fiscal Year 1 April 2020 to 31 March 2021. The funding will result in acquisition of 36 core Argo floats, 6 BGC-Argo floats (3- BGC sensors) and 4 NKE Arvor floats with RBR CTDs. The Canadian-Pacific Robotic Ocean Observing Facility (C-PROOF) is contributing funding for 7 dissolved oxygen sensors to be added to DFO Argo floats. C-PROOF is based at the University of Victoria (http://cproof.uvic.ca/) and is funded by the Canadian Foundation for Innovation (CFI, https://www.innovation.ca/).

Ocean Networks Canada (https://www.oceannetworks.ca/) has also received funding from CFI to procure BGC-Argo floats (https://www.oceannetworks.ca/canadas-ocean-intelligence-gets-a-boost).

At the G7 meeting in Halifax in October 2018, the Government of Canada announced new funding for the International Argo Program (up to $5.6M over 4 years ending in March 2023). The primary intention of this investment is to support the implementation of the BGC-Argo array with a strong emphasis on having ocean observations benefit Small Island Developing States. This initiative also links to Canada's leadership on the Ocean Observations Action Group under the Commonwealth Blue Charter.

In addition, funding for "A BGC Argo Program for the NW North Atlantic Ocean" led by Dalhousie University and the Memorial University of Newfoundland, is conditionally approved by CFI for a total cost of $8.8M. Final approval is contingent on a confirmation of provincial matching funds, on finalization of lab renovation plans at Dalhousie, and on a final agreement with Compute Canada for hosting of IT infrastructure supported by the project. The plan is to acquire about 40 BGC-Argo floats for deployment in the NW North Atlantic.

The development of close links between the Argo Canada program and both the operational meteorology and operational oceanography R&D activities at the Canadian Meteorological Centre (Dorval, Québec) has been beneficial. An inter-departmental (Environment and Climate Change Canada, Department of National Defence, Fisheries and Oceans) Memorandum of Understanding entitled CONCEPTS (Canadian Operation Network of Coupled Environmental PredicTion Systems) has provided strong advocacy for the Argo program.

Human resources

Since 1 April 2015, Blair Greenan of the Bedford Institute of Oceanography (BIO) has acted as national leader of the Argo Canada program. The logistics related to float deployments and satellite data transmission has been handled by Ingrid Peterson, also at BIO. On the west coast, Tetjana Ross (DFO, Institute of Ocean Sciences) is responsible for Pacific deployments for Argo Canada.

The following people contribute to the logistics and data management for Argo Canada:

Anh Tran (DFO, MEDS, Ottawa) – DAC lead, RTQC Operator
Zhimin Ma (DFO, MEDS, Ottawa) – DMQC Operator (core Argo)
Jenny Chiu (DFO, MEDS, Ottawa) – RTQC support
Andrew Stewart (DFO, OSB, Ottawa) – National Manager, Ocean Monitoring and Observing
Tyler Emmott (DFO, OSB, Ottawa) – Float procurement, contracting
Blair Greenan (DFO, BIO, Halifax) – AST member, Argo Canada lead
Ingrid Peterson (DFO, BIO, Halifax) – deployment planning, logistics, performance monitoring

Chris Gordon (DFO, BIO, Halifax) – DMQC Operator (BGC)
Clark Richards (DFO, BIO, Halifax) – Research scientist, RBRArgo data task team member, ArgoFloats R package development
Jaimie Harbin (DFO, BIO, Halifax) – ArgoFloats R package developer
Igor Yashayaev (DFO, BIO, Halifax) – Atlantic deployment planning
Adam Hartling (DFO, BIO, Halifax) – Field support
Tetjana Ross (DFO, IOS, Sidney) – Pacific deployment planning
Lindsay Mazzei (DFO, IOS, Sidney) – Field support

Katja Fennel (Dalhousie University, Halifax) – Canadian member of the International BGC-Argo Steering Committee

In addition to the above persons, we benefit from the technical support of many sea-going staff that follow pre-deployment protocols and perform the float deployments.

National Coordination
With increasing participation in the Argo program within Canada, both in core Argo and BGC-Argo, it was decided to establish a new governance structure in 2018. The Canadian Argo Steering Team (CAST) provides scientific leadership and oversees the development and implementation of the Canadian contribution to the International Argo Program. The CAST is chaired by Blair Greenan.

The Canadian Biogeochemical-Argo Committee facilitates the implementation of the Canadian contribution to the Biogeochemical-Argo program by coordinating and advising national efforts, and acting as liaison to the International Biogeochemical-Argo Steering Committee. The Committee is chaired by Katja Fennel.

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.

Here is a link to the commitments table at OceanOPS. If you cannot edit the online table, please send a list of deployment plans for each of the columns in the table as needed.

Argo Canada (with financial contributions from Fisheries and Oceans Canada and the Department of National Defence) will procure the following by March 2021 (end of fiscal year):

- 22 NKE Arvor-I with SBE41 CTD
- 14 NKE Arvor-I with SBE41 CTD + DO
- 4 NKE Arvor with RBR CTD
- 6 NKE Provor CTS4 with SBE41 CTD + DO + chla + backscatter

In 2021 and early 2022, Argo Canada plans to deploy about 40 of the floats (firm commitment). Fourteen will be deployed in the Northeast Pacific, and about 25 in the Atlantic. Seven Arvors with DO will be deployed in both the Pacific and Atlantic Oceans.

Of the 25 floats planned for the Atlantic, we are currently planning to deploy 12 Arvor floats on a dedicated charter if NOAA and WHOI are successful in securing a vessel. We also plan to deploy some of the Atlantic floats in Baffin Bay in the summer 2021 which will provide under-ice capability. This deployment is planned to be on the CCGS Amundsen. We are seeking deployment opportunities for the Arvor-RBR floats, with a planned deployment of one float in the Caribbean on the A20/A22 GO-SHIP cruise departing Woods Hole in March 2021.

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.

The Government of Canada CONCEPTS initiative (Canadian Operational Network for Coupled Environmental Prediction Systems; http://science.gc.ca/eic/site/063.nsf/eng/h_97620.html) uses observations from the Argo array for a variety of operational and research applications. These include direct assimilation into operational weather and environmental prediction systems, monitoring of forecast quality (verification), and well as detailed research to improve model physics (e.g. further development and optimization of model parameterizations) and data assimilation (e.g. Observing System Experiments). The CONCEPTS Global and Regional Ice Ocean Prediction Systems (GIOPS and RIOPS) provide daily estimates (analyses) of ocean and sea ice properties using a multi-variate data assimilation system assimilating Argo observations together with other sources of in situ temperature and salinity, satellite altimetry, and sea surface temperature data. GIOPS analyses are used to initialize the ice-ocean components of the coupled Global Deterministic Prediction System (GDPS), responsible for providing operational medium-range weather forecasts for Canadians. GIOPS analyses are also used to initialize the operational forecasts from the Canadian Seasonal-Interannual Prediction System (CanSIPS). RIOPS analyses are produced in a model that includes tides and provides daily three-dimensional state of the ocean estimates for Canada's three coastlines on a domain covering the North Pacific, Arctic, and North Atlantic Oceans. Coastal forecasts are produced for the east and west coast of Canada at 2km resolution using a spectrally nudging to RIOPS analyses. RIOPS analyses are also used to initialize the oceanic component of the pan-Arctic high-resolution Coupled Canadian Arctic Prediction System (CAPS) put in place for the Year of Polar Prediction (2017-19).

Argo data is used in the verification of Canadian and international prediction systems to enable predicted and observed profile comparison. Part of OceanPredict Inter-comparison and Validation Task Team. Comparisons of Argo based class 4 is visible on https://navigator.oceansdata.ca under the class 4 tab.

The Department of National Defence scientists, operational oceanographers and sonar operators routinely use real time Argo vertical profiles to assess model performance and in some instances use as data to compute acoustic range predictions (both at sea and in the Meteorology and Oceanography Centres (Esquimalt and Halifax)). DND uses the web-

based Ocean Navigator tool (http://navigator.oceansdata.ca/public/) to assist with these activities.

Argo data are used in the preparation of Fisheries and Oceans Canada's State of the Ocean reporting (e.g. https://www.dfo-mpo.gc.ca/oceans/publications/soto-rceo/2019/index-eng.html).

The Canadian-Pacific Robotic Ocean Observing Facility (C-PROOF, http://cproof.uvic.ca/) is funded by the Canadian Foundation for Innovation (CFI) and B.C. Knowledge Development Fund (BCKDF) to build ocean observing capacity off the British Columbia coast. C-PROOF is based at the University of Victoria. A fleet of autonomous gliders, Argo floats, and moorings will provide ocean scientists with long-term monitoring of the ocean at the small scales important to resolve upper ocean physical and biological properties. C-PROOF will add dissolved oxygen sensors to 7 of the DFO core Argo floats that will be deployed in the Northeast Pacific in 2021. This project is planning to deploy BGC-Argo floats along Line P in future years.

The Argo Canada web site is maintained by Fisheries and Oceans Canada at http://www.isdm.gc.ca/isdm-gdsi/argo/index-eng.html.

The Canadian BGC Argo website is maintained by Katja Fennel at http://bgc-argo.ocean.dal.ca/.

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.

Nothing to report this year.

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.

CCHDO currently acquires Line-P data up directly from the https://waterproperties.ca/linep website. MEDS will send CTD data collected by other DFO institutions to NOAA NCEI and then the data will be available to CCHDO.

7. Keeping the Argo bibliography (Bibliography | Argo (ucsd.edu)) up to date and accurate is an important part of the Argo website. This document helps

demonstrate the value of Argo and can possibly help countries when applying for continued Argo funding. To help me with this effort, please include a list of all papers published by scientists within your country in the past year using Argo data, including non-English publications.
There is also the thesis citation list (Thesis Citations | Argo (ucsd.edu)). If you know of any doctorate theses published in your country that are missing from the list, please let me know.
Finally, if you haven't already sent me a list of Argo PIs in your country, please do so to help improve the statistics on how many papers are published including an Argo PI vs no Argo PIs.

Journal Publications

Atamanchuk, D., J. Koelling, U. Send, and D.W.R. Wallace, 2020. Rapid transfer of oxygen to the deep ocean mediated by bubbles, *Nature Geosciences*, **13(3)**, 232-237, https://doi.org/10.1038/s41561-020-0532-2

Chai, F., K.S. Johnson, H., Claustre, X. Xing, Y. Wang, E. Boss, S. Riser, K. Fennel, O. Schofield and A. Sutton, 2020. Monitoring ocean biogeochemistry with autonomous platforms, *Nature Reviews Earth & Environment*, **1**, 315-326, https://doi.org/10.1038/s43017-020-0053-y

Courtois, P., Y. Garcia-Quintana, X. Hu and P. G. Myers, 2020. Kinematic subduction rate of Labrador Sea Water from an eddy-permitting numerical model. *Journal of Geophysical Research*, **125**, e2019JC015475. https://doi.org/10.1029/2019JC015475

Gordon, C., K. Fennel, C. Richards, L.K. Shay, J.K. and Brewster, J. K., 2020. Can ocean community production and respiration be determined by measuring high-frequency oxygen profiles from autonomous floats?, *Biogeosciences*, **17**, 4119–4134, https://doi.org/10.5194/bg-17-4119-2020 , 2020

Lin, H., W. J. Merryfield, R. Muncaster, G. C. Smith, M. Markovic, F. Dupont, F. Roy, J.-F. Lemieux, A. Dirkson, S. Kharin, W.-S. Lee, M. Charron, A. Erfani, 2020. The Canadian Seasonal to Interannual Prediction System Version 2 (CanSIPSv2). *Weather and Forecasting*, **35**, 1317-1343. https://doi.org/10.1175/WAF-D-19-0259.1

Nezlin, N. P., M. Dever, M. Halverson, J.-M. Leconte, G. Maze, C. Richards, I. Shkvorets, R. Zhang, and G. Johnson, 2020. Accuracy and Long-Term Stability Assessment of Inductive Conductivity Cell Measurements on Argo Floats. *Journal of Atmospheric and Oceanic Technology*, **37**, 2209–2223. https://doi.org/10.1175/JTECH-D-20-0058.1

Pennelly, C., and P. G. Myers, 2020. Introducing LAB60: A 1/60degree NEMO 3.6 numerical simulation of the Labrador Sea. *Geosci. Model Dev.*, **13**, 4959–4975, https://doi.org/10.5194/gmd-13-4959-2020

Randelhoff, A.. L. Lacor, C. Marec, E. Leymarie, J. Lagunas, X. Xing, G. Darnis, C. Penkerc'h, M. Sampei, L. Fortier, F. D'Ortenzio, H. Claustre and M. Babin, 2020. Arctic mid-winter phytoplankton growth revealed by autonomous profilers. *Science Advances*, **6**, https://doi.org/10.1126/sciadv.abc2678

A. Randelhoff, J. Holding, M. Janout, M. Kristian Sejr, M. Babin, J.-É. Tremblay and M. B. Alkire, 2020. Pan-Arctic Ocean Primary Production Constrained by Turbulent Nitrate Fluxes. *Frontiers in Marine Science*, **7**. https://doi.org/10.3389/fmars.2020.00150

Wang, B., K. Fennel, L. Yu and C. Gordon, 2020. Assessing the value of biogeochemical Argo profiles versus ocean color observations for biogeochemical model optimization in the Gulf of Mexico, *Biogeosciences*, **17**, 4059–4074, https://doi.org/10.5194/bg-17-4059-2020 , 2020

Ph.D./M.Sc. Thesis
Nothing to report

Books
Nothing to report

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.

In 2020, COVID-19 restrictions did put pressure on our procurement process with delivery of floats in March 2020 being delayed, but ultimately all floats were delivered before the end of our fiscal year (31 March 2020). Deployments of floats were impacted by the cancellation of some cruises (e.g., DFO Maritimes Region Atlantic Zone Monitoring Program on the Scotian Shelf, March-April 2020). However, overall the impact of COVID-19 on deployments was limited and Canada deployed 33 Arvor floats, which is within our normal range. COVID-19 has not had an impact on data processing at the MEDS DAC. The impact on our budget was minimal for 2020 and going forward will not be known until after the Federal Budget is released in March 2021.

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.

Argo Canada is still interested in piloting the RBR CTD. We have purchased 3 Arvor floats with the RBR CTD in 2020 and are expecting delivery of 4 additional floats before the end of March 2021. The plan for procurement of floats for 2022 is yet to be determined by we will likely purchase 2-4 additional floats in the upcoming fiscal year. In terms of deployment plans, one float is planned for deployment on the upcoming GO-

SHIP A20/A22 mission departing Woods Hole in the spring 2021. The deployment locations for the remainder of the floats is open for discussion.