# Argo Canada – Report of Activities for 2022

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24th meeting of the Argo Steering Team (AST-24)

Location: Hybrid (Halifax & Virtual)

20-24 March 2023

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

    As of 14 February 2023, Canada has 149 operational floats in the Argo Canada program.

    From January to December 2022, Argo Canada deployed at total of 44 floats in the following Basins, managed by the MEDS DAC:

    - Pacific Ocean (13 floats):
        - 3 NKE Arvor floats (CTD)
        - 10 NKE Arvor floats (CTD + O2)
    - Atlantic Ocean (27 floats):
        - 18 NKE Arvor floats (CTD)
        - 7 NKE Arvor floats (CTD + O2)
        - 2 NKE Provor floats (CTD, O2, Chla, backscatter)
    - Indian Ocean (4 floats):
        - 2 NKE Provor floats (CTD, DO, Chla, backscatter)
        - 2 NKE Provor floats (CTD, DO, Chla, backscatter, pH)

    In the fall 2022, the Takuvik lab (Université Laval) deployed the following floats in Baffin Bay (CCGS Amundsen), managed by the Coriolis DAC:

    - 2 BGC floats (model CTS5-Usea by NKE)
    - Both floats have SBE CTD, Anderaa optode, SBE SUNA, SBE ECO-puck, SBE OCR 504, Biospherical MPE-PAR (new design)
    - One float is equipped with Hydroptics UVP6
    - Two BGC floats have were recovered (Aug. 2022), in the central Baffin Bay as well. These floats were deployed in 2021 in the same area and have been recovered for refit.

b. technical problems encountered and solved

One NKE Arvor (CTD + O2) failed after one cycle. We have not been able to get an explanation from NKE regarding the possible cause of the failure.

One PROVOR float deployed in the North Atlantic reported grounding, despite being in water depths much greater than 2000m. There was no change in data quality, the only notable change is the cycle number jumped from 4 to 7. Again we have enquired with NKE as to why this happened but have not received a response.

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 MEDS DAC continues to acquire data from 149 Argo floats of which 3 floats have had trouble reporting in the last 4 months. 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 2022 to January 2023, on average, 413 messages per month were issued to the GTS in BUFR format, of which 72% of the data were available within 12 hours of the float reporting.

Since AST-23, the following tasks have been completed:

- Implementing of the modules to process and quality control data collected from BGC floats (PROVORBio-II) and publishing BUFR data to the GTS , and meta, profile, technical NetCDF files GDACs.
- Develop the quality control tests and adjustment procedure recommending by ADMT for RBR Argo float and Deep Argo float.
- Develop the decoders for NOVA and DOVA float because MetOcean Telematics is no longer providing this service.
- Continue processing of core Argo variables and DOXY data after they have been delayed mode QC to GDAC and updating the internal database.
- Provide ADMT reports on the performance of Argo data on the GTS in BUFR formats to assist DACs in monitoring the BUFR timeliness transmission.
- Yearly update of the monthly maps and anomaly maps of temperature and salinity along line P in the Gulf of Alaska. For more information on the Line-P products and other uses of Argo to monitor the N.E. Pacific go to: https://www.isdm.gc.ca/isdm-gdsi/argo/canadian-products/Argo-LineP-eng.html

d. status of delayed mode quality control process

In 2022, the regular core DMQC process was interrupted because of short staffing. The shortage was recently filled with two core DMQC operators and the DMQC work was back to normal starting February 2023. The in-house Matlab package for Argo DMQC has been updated to a more accessible and user-friendly version with the following changes:

- Streamlined configuration files and modules
- Maintained version control through Github repository

This year, the thermal mass correction will be integrated to the Matlab package. With a minimum maintenance planned for the Matlab version, a new python version for Argo DMQC will be actively developed utilizing modules from EuroArgo as well as other international partners.

Statistics have been calculated to summarize the DMQC work during the last year. As of February 21, 2023, there is a total of 651 Argo floats from the Canadian DAC. Of these 651 floats, 17 (i.e., 2.6% ) have no profile files reported to the GDAC due to the failure of floats back to surface. 73% of all active floats, had their profiles DMQCed following the latest delayed-mode procedures at least once. About 2559 profiles from 16 active core Argo floats have been DMQCed within the last year. All these profiles have been fully QCed.

The backlog of core DMQC is persistent and will still be the priority this year. To clear the backlog for core DMQC, efforts will be made to collect floats information from monthly anomaly reports and OCEANOPS altimetric checks. Floats will be geographically assigned to the two DMQC operators for QC.

Of all BGC floats, 824 of 5974 profiles (13%) have been DMQC'ed. 2581 (43%) profiles have oxygen in 'A' mode. It should be noted that DMQC only applies to DOXY for Argo B-profiles. Clearing the backlog of now inactive floats requiring DMQC and fixing historical DOXY_QC flags that are '1' when they should now be '3' remains the main priority. Implementing real-time adjustment of DOXY following sufficient profiles to calculate a gain is also a priority.

Development of a BGC-Argo DMQC tool written in python (https://github.com/ArgoCanada/bgcArgoDMQC) has continued and is now the primary method for visualizing, calculating gain, and exporting D-mode files for the MEDS DAC. The software was presented at the BGC-Argo DMQC workshop and the results are in good agreement with existing tools such as SAGE-O2.

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 OneArgo mission: Core, BGC, Deep, Spatial (Polar, equator, WBCs)

*Financial resources*

Argo Canada has ongoing funding for the O&M expenditures related to the International Argo program. The majority of these expenditures are related to Iridium telecommunications costs which are managed by Shared Services Canada (SSC) and paid for by DFO.

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 $1.2M CAD for purchases of core NKE Arvor-I, NKE Arvor-RBR, and Provor CTS4 floats in the Fiscal Year 1 April 2022 to 31 March 2023. The funding will result in acquisition of 17 core Argo floats, 4 CTD+O2 floats, 10 BGC-Argo floats (3 BGC sensors) and 4 NKE Arvor floats with RBR CTDs for a total of 35 floats.

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, the project "A BGC Argo Program for the NW North Atlantic Ocean" led by Dalhousie University and the Memorial University of Newfoundland, has been funded by the Canadian Foundation for Innovation (CFI), Research Nova Scotia (RNS), and the province of Newfoundland for a total cost of $8.8M. The current plan is to acquire 33 BGC-Argo floats for deployment in the NW North Atlantic. 5 NKE CTS5 floats with oxygen, backscatter, chlorophyll, and irradiance sensors have been ordered to date.

CFI funding held jointly by the Universities of Victoria and British Columbia (C-PROOF, see details in Section 4) that has been providing additionally oxygen sensors for floats deployed in the Northeast Pacific. In the Fiscal Year 1 April 2022 to 31 March 2023, UVic has purchased four O2 sensors to be added to DFO Arvor floats and five SUNA (nitrate) sensors plus the jumbo option for DFO Provor floats being delivered to the Institute of Ocean Sciences in Sidney, BC in March 2023.

In 2022, Ocean Networks Canada (ONC) was successful in obtaining funding for the procurement of 18 Deep Arvor floats equipped with CTD + O2. Two of these floats were delivered to ONC in Victoria, BC in December 2022, and the remaining floats will be delivered in the first half of 2023.

Since 2016, Takuvik has deployed 22 BGC Argo floats (funding being provided by French and Canadian projects, each up to 50 %), which have acquired more than 2,500 profiles (temperature, salinity, backscattering coefficient at 700 nm, radiometric data along 4 channels,

as well as concentrations of a) dissolved oxygen, b) chlorophyll-a, c) colored dissolved organic matter, d) nitrate.

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*

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)
- Trajce Alcinov (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
- Chris Gordon (DFO, BIO, Halifax) – DMQC Operator (BGC), deployment planning, logistics, performance monitoring
- 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 and Commonwealth Blue Charter training coordinator
- Igor Yashayaev (DFO, BIO, Halifax) – Research Scientist
- Adam Hartling (DFO, BIO, Halifax) – Field support
- Tetjana Ross (DFO, IOS, Sidney) – Pacific deployment planning, Canadian member of the International Deep Argo Mission Team
- Lindsay Mazzei (DFO, IOS, Sidney) – Field support
- Katja Fennel (Dalhousie University, Halifax) – Canadian member of the International BGC-Argo Steering Committee
- Dan Kelley (Dalhousie University, Halifax) – ArgoFloats R package developer
- Kohen Bauer (Ocean Networks Canada) – Principal Investigator, Deep Argo
- Richard Dewey (Ocean Networks Canada) – Principal Investigator, Deep Argo
- Herminio Folio Neto, Jeannette Bedard, and Kohen Bauer (Ocean Networks Canada) – DMQC Operators, Deep Argo

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, BGC-Argo and Deep 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 and meeting annually prior to the Argo Steering Team meeting.

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.

*Float Testing Facility*

In partnership with Defence Research and Development Canada (DRDC), DFO has established a testing facility on the DRDC Barge in Bedford Basin. This facility will enable us to do short-term testing of floats and sensors to evaluate performance. This is a low-current environment that facilitates tethered profiling to a water depth of 35 m.

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 the link isn't working, visit OceanOPS and choose 'commitments' from the farthest right icon at the top of the page). If you cannot edit the online table, please send a list of deployment plans for each of the columns in the table as needed.

   In 2023, Argo Canada plans to deploy approximately 28 floats in the Northeast Pacific and North/South Atlantic:

   - 14 Core Argo (9 SBE CTD, 5 RBR CTD)
   - 8 BGC-Argo (2 O2 only, 4 O2 + bio-optical triplet, 2 O2 + bio-optics + pH)
   - 2 Dalhousie BGC -Argo (O2 + bio-optics + radiometry)
   - 4 ONC Deep Argo (Arvor with CTD + O2)

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). Temperature and salinity from GIOPS analyses are also used to represent the baroclinic effects in the Global Deterministic storm Surge Prediction System (GDSPS). 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. An observing system experiment is underway to assess the impact and potential benefits of assimilating seasonal Argo floats from the Arctic Ocean into RIOPS. Coastal forecasts are produced for the east and west coast of Canada at 2km resolution using a spectrally nudging to RIOPS analyses.

DFO also extensively used the GLORYS global ocean reanalysis product from Mercator-Ocean International, produced with assimilating Argo data. The applications of this include providing lateral open boundary condition for regional models, and analyses for interpreting observations and understanding ocean variability.

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 (DND) 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 to assist with these activities.

The Argo Canada web site is maintained by Fisheries and Oceans Canada at http://www.isdm.gc.ca/isdm-gdsi/argo/index-eng.html. A repository of Argo-related code under development through DFO has been made available on Github at https://github.com/argoCanada. Repositories include the under-development python BGC DMQC tools, the argoFloats and argodata R packages, a new python package for finding and working with Argo data (argopandas), and an informal blog used to highlight interesting floats and issues encountered when working on Argo DMQC.

Argo data are used in the preparation of Fisheries and Oceans Canada's State of the Ocean reporting (https://www.dfo-mpo.gc.ca/oceans/publications/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.

Dalhousie University and the University of Newfoundland are leading an infrastructure project for implementation of a regional BGC Argo array in the northwest North Atlantic with funding from the Canada Foundation for Innovation, Research Nova Scotia, and the province of Newfoundland. Research questions to be addressed include the sensitivity of carbon sequestration and ocean ventilation in the Labrador Sea to changing atmospheric and oceanic conditions, new approaches to biological rate measurements using Argo measurements (e.g., NCP, vertical carbon flux), assessment of the skill of climate models in the region, and implementation of a data-assimilative physical-biogeochemical ocean model for the region. As part of the project, a Canadian adopt-a-float program was launched (https://adopt-a-float.ocean.dal.ca/). The Canadian BGC Argo website is maintained by Katja Fennel's research group 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 OceanOPS, 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. Also, during the AST-24 plenary, each national program will be asked to mention a single highlight or issue via a very brief oral report.

   Argo Canada would like to thank the leads for the Basin Planning Working Groups. This has improved information-sharing among the groups deploying floats and is helping to identify deployment opportunities.

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*

Chomiak, L. N., Yashayaev, I., Volkov, D. L., Schmid, C., & Hooper, J. A. (2022). Inferring Advective Timescales and Overturning Pathways of the Deep Western Boundary Current in the North Atlantic through Labrador Sea Water Advection. Journal of Geophysical Research: Oceans, 127(12), e2022JC018892.

Dever, M., Owens, B., Richards, C., Wijffels, S., Wong, A., Shkvorets, I., Halverson, M., & Johnson, G. (2022). Static and Dynamic Performance of the RBRargo3 CTD, Journal of Atmospheric and Oceanic Technology, 39(10), 1525-1539. Retrieved Feb 16, 2023, from https://journals.ametsoc.org/view/journals/atot/39/10/JTECH-D-21-0186.1.xml

Gillard, Laura C., Clark Pennelly , Helen L. Johnson c, Paul G. Myers. The Effects of Atmospheric and Lateral Buoyancy Fluxes on Labrador Sea Mixed Layer Depth. Ocean Modelling 171 (2022) 101974 https://doi.org/10.1016/j.ocemod.2022.101974

Izett, R. W., Castro de la Guardia, L., Chanona, M., Myers, P. G., Waterman, S., & Tortell, P. D. (2022). Impact of vertical mixing on summertime net community production in Canadian Arctic and Subarctic waters: Insights from in situ measurements and numerical simulations. Journal of Geophysical Research: Oceans, 127, e2021JC018215. https://doi.org/10.1029/2021JC018215

LaBrie, R., Péquin, B., Fortin St-Gelais, N., Yashayaev, I., Cherrier, J., Gélinas, Y., ... & Maranger, R. (2022). Deep ocean microbial communities produce more stable dissolved organic matter through the succession of rare prokaryotes. Science Advances, 8(27), eabn0035.

Steffen, K., Indraningrat, A. A. G., Erngren, I., Haglöf, J., Becking, L. E., Smidt, H., ... & Sipkema, D. (2022). Oceanographic setting influences the prokaryotic community and metabolome in deep-sea sponges. Scientific Reports, 12(1), 3356.

Stoer, A. C., Fennel, K., Retrieval of net primary productivity from daily cycles of carbon biomass measured by profiling floats, Limnology and Oceanography Letters, https://doi.org/10.1002/lol2.10295, 2022

Tesdal, J. E., Ducklow, H. W., Goes, J. I., & Yashayaev, I. (2022). Recent nutrient enrichment and

high biological productivity in the Labrador Sea is tied to enhanced winter convection. Progress in Oceanography, 206, 102848.

Wang, B., Fennel, K., Biogeochemical Argo data suggest only a minor contribution of small particles to long-term carbon sequestration in the subpolar North Atlantic, Limnology and Oceanography, , https://doi.org/10.1002/lno.12209, 2022

Wang, Z., Yang, J., Johnson, C., & DeTracey, B. (2022). Changes in deep ocean contribute to a "see-sawing" Gulf Stream path. Geophysical Research Letters, 49, e2022GL100937. https://doi.org/10.1029/2022GL100937

*Ph.D./M.Sc. Thesis*

Bin Wang, BIOGEOCHEMICAL (BGC) ARGO IMPROVES UNDERSTANDING AND QUANTIFICATION OF THE OCEAN'S BIOLOGICAL CARBON PUMP, Dalhousie PhD thesis, 2022

*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.

   Deployments for 2022 were impacted by a combination of COVID-19 and vessel availability issues. The primary platform for oceanographic research on the east coast of Canada has been the CCGS Hudson. In January 2022, DFO announced that the 59 year-old Hudson would be decommissioned after it had deemed the ship "beyond economical repair" following a catastrophic mechanical failure. This resulted in a loss of opportunity to deploy Argo floats. A replacement vessel is under construction with delivery expected in 2025 (https://www.seaspan.com/press-release/canadian-coast-guard-offshore-oceanographic-science-vessel-achieves-important-construction-milestone/) . DFO has committed to find solutions for the gap before the replacement vessel arrives, but at this time the future remains uncertain and presents challenges for Argo float deployment planning.

9. 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 2023 and 2024 (if known) and where they might be deployed.

   Argo Canada is committed to deploying additional floats equipped with RBR CTDs. The procurement plan for 2023 is not known at this time, but we expect to procure about 50% of our core Argo floats with RBR CTDs. We had encouraged NKE to consider upgrading the Arvor float firmware to enable sampling and transmitting RBR CTD data at ~1 Hz to allow for further

research on the CTD response characteristics in a range of oceanographic conditions. In late 2022, NKE confirmed that this capability would be available in future Arvor float shipments.

Dalhousie University and the Memorial University of Newfoundland are interested in procuring BGC Argo floats with the RBR CTD and possibly other RBR sensors.