Mid-scale RI-2 Consortium: Biogeochemical-Argo: A global robotic network to observe changing ocean chemistry and biology

Response to Panel Summaries and Reviews

Introduction

We thank the Proposal Panel, RSV Panel, and individual reviewers for their contributions, which are very positive. Within those positive comments, they have also identified a number of additional questions or requests for clarifications. We believe that several of the responses to the issues they have identified, which are detailed below, will make our program stronger as we incorporate them into the project. In order to ensure that we fully address the primary comments, we have gone through the 72 pages of comments and tabulated all of the questions or requests for additional information. We then prioritized comments by the number of times they were raised in the 14 individual reviews and the two Panel Summaries, with some additional emphasis for topics we thought particularly insightful. Additional priority was given to items that were identified in the Panel Summaries. The comments were then grouped into five main topics and our responses are provided below.

Project Relationship to Other Groups/Agencies

- International Participation and Supply of an Additional 500 Floats

The development of a 1000 float BGC array is predicated on the assumption that the US will provide half of the array and international programs will provide the other 500. The Proposal Panel Summary and R4, R6, R12 and R14 (R# indicates review number) indicate a concern regarding whether the international floats would be deployed, a lack of letters indicating plans, and the impact on the program if they were not available. As we note in the proposal an array with only 500 floats will remain transformational (pg. 11, 25), providing data on seasonal and interannual variability that simply does not exist today in many areas. This proposal can stand alone, therefore. We believe strongly, however, that the success of this proposal would instigate significant international contributions through demonstrated US leadership. These additional floats strengthen the spatial coverage, lead to reduced error limits on fluxes derived from the observations, and increase system redundancy (reduce risk). In addition, our project would drive float prices down by nearly half, based on manufacturer's quotes. The prices quoted for this project would be available to the community if there is an aggregate commitment (including this proposal) for more than 400 BGC, 5 or 6 sensor floats (80% of the 500 float target). This would greatly reduce price as an obstacle that is frequently identified by international colleagues.

With regard to the lack of detail on International commitments, we chose to document (pg. 25) only published national plans, as informal letters from individuals simply cannot guarantee substantive commitments. There are relatively few of these published plans and, by comparison, no published US commitment exists except ongoing research programs such as SOCCOM. A more formal set of commitments, which we did not provide, are found in the annual Argo Commitments Table, maintained by jcommops.org. This documents international commitments for 80 BGC floats in 2019, about half of which have been deployed (and the table lags a bit in time so half is about what is expected). Most of these floats, however, carry only one or two BGC sensors.

- Program/community oversight

The NSF Major Facilities Guide calls for "periodic external reviews that provide advice on the status and anticipated future performance of the facility activities" (Section 4.6.3.2). The US BGC-Argo array will function as a major oceanographic facility and regular review of the program by a committee responsive to community needs should be a feature to ensure broad support and effective performance. There are two options for this; one is a review committee formed for the sole purpose of oversight of this program, the second is utilization of the US OCB Subcommittee on BGC-Argo. In the proposal, we suggested the OCB Subcommittee could be the appropriate group, as this task aligns closely with their function and the Subcommittee is an existing structure. This choice stimulated comments by the Proposal Panel and R12 and R14, in particular regarding personnel conflicts as as many of the committee members are proposal personnel.

It is clear that these conflicts would have to be resolved if the OCB Subcommittee were responsible for review. First, PI Johnson will step down as chair and a new Subcommittee Chair would be appointed. However, we do feel that it is beneficial for some personnel from this project to serve on the Subcommittee to provide expertise and clarification for questions or issues that are discussed. In order to prevent conflict, however, we propose that the review would be performed by Subcommittee members that had no direct overlap with this project. We prefer this oversight structure, as it will ensure an ongoing connection between OCB as a representative of the ocean carbon community and the US BGC-Argo program.

The alternative is an independent review panel to address overall program execution. We suggest, in this case, a panel of at least five members with broad and minimally-overlapping experience. We would suggest one member of the OCB Subcommittee on BGC Argo and one member of the Argo Steering Team with the stipulation that these individuals are neither PIs nor Senior Personnel on the MSRI award. At least one panelist will be targeted based on experience as PI or Senior Personnel of a large federally-funded (NSF or NOAA) oceanography program that is not Argo (e.g. Geotraces, LTER). One or more panelists might be targeted based on experience as PI or Senior Personnel on a previous facility award outside the field of oceanography. To accommodate the following point, membership from other Federal Agencies such as NOAA or NASA may be desirable. Note that many of these characteristics can be found in the membership of the OCB Subcommittee by persons not directly associated with this proposal.

One argument in favor of the OCB Subcommittee is that it provides the community with a clear, sustained contact point that regularly reports back to the community through OCB Workshops. Involvement of the OCB Steering Committee, as a representative of the ocean carbon community, may be an appropriate step as final decisions on program oversight are made by NSF.

- Relationship to Other Federal Agencies and other NSF Programs

R3, R4, R6, R12, and R14 all expressed concerns regarding the relationship of the project with other Federal agencies, primarily NOAA and NASA (e.g., R4, “it would be great to see additional reach towards ensuring that other agencies are fully utilizing the dataset…”). We agree completely and will strive to ensure that the dataset is compatible with other agency needs within the constraints created by the goals expressed in the proposal. We have been in contact with program managers at NOAA and NASA, including providing copies of the proposal, to ensure that they are fully informed. If funded, we would continue this interaction.

R14 expressed concern about opportunity cost to other NSF programs if this project were funded, disadvantaging other scientists, while R12 was concerned that the proposal included research funds from NSF and this would give the PIs an unfair advantage. We stress that no research dollars are included in the proposal budget and, in some sense, the burden of managing the system puts the PIs at a slight disadvantage. While the facility and operational costs do reduce available funds, the system will provide a tremendous amount of quality data that will enable highly cost effective research, particularly for early career scientists who have not established a sea-going program. We see that as a net gain.

Program Management

- Budget Comments

A particularly insightful comment on budget and schedule was made during the Reverse Site Visit and reiterated in the RSV Panel comments. We had noted that there is a long lead time for float delivery, at least 12 weeks and often more. To facilitate continuous float production, to enable participation on deployment cruises early in each year, and to reduce schedule risk, we noted that it would be helpful to have spending authority 3 to 4 months before each annual start. An RSV Panelist and the RSV Panel Summary asked why we did not just budget for about one third of each year’s capital budget in the prior year so that we could acquire parts and floats well before they were needed, rather than putting all of the money for each year of capital equipment production in the same year budget. This is an obvious program improvement. If the project is approved, this budget modification (shifting about one third of the capital in each year to a prior year) should be considered if we do not have budget authority to order floats and parts well in advance of each year start date. As the panel notes, a no cost extension may be requested if some floats assembled towards the end of Year 5 require deploying into Year 6.

The RSV Panel also noted a minor difference between budget summaries in the proposal and in the cost book supplied to the RSV. For example, the proposal notes that 71% of the budget is allocated to capital expenditures, while the cost book reports 66%. This results from an error in allocating funds to various categories in the proposal. The labor expenditures for float preparation at one institution were erroneously included as capital in the summary tables used in the proposal, slightly inflating capital expenditures and deflating float preparation expenditures. The cost book and its summary tables are correct. Note that the total budget and NSF budget sheets remained accurate, it was the summary categorization that was incorrect.

- Decision Making

Both Panels included comments directed to program decision making, particularly with respect to program scope and contingency. As discussed during the Reverse Site Visit, program decisions will be reached by consensus in the joint Executive Team and Program Office and documented in the Annual Project Implementation Plan. This procedure has worked well in the SOCCOM program, where final authority rests with the Project Director. In the case of significant decisions regarding rebudgeting, scope changes such as changes in sensor types or manufacturer, or use of contingency funds, the Project Implementation Plan will be revised, released and signed by the Project Director (the "owner" of the PIP) with approval by the Chair of the Executive Team per our configuration control procedures.

On an ongoing basis within SOCCOM, Core-Argo, and within the proposed US BGC-Argo program, detailed decision-making is distributed and does not require daily interactive management between the components, as each operating institution (UW, WHOI, SIO) has a large degree of autonomy. This autonomy is based on extensive experience in Core-Argo and the SOCCOM program. Weekly teleconferencing in SOCCOM has permitted discussion of changes in scope within each of the management groups (floats, data processing, deployment organization) to be handled effectively.

- Contingency Funds and Schedule Contingency

Both Panels requested additional clarity on the use of contingency funds, as well as noting a general lack of information on schedule contingency. Contingency funds will be retained by the project office. They can be used to replace floats lost by a particular operator if it is a singular occurrence. If there is an inherent issue with a particular float type, the contingency could be used to replace lost floats with a different model and deploying institution. Use of funds would require concurrence of the Executive Team and discussion and concurrence by the NSF Program Manager. In addition, contingency funds are retained for any additional engineering expenses that might arise. These funds would only be utilized after a similar approval process.

Schedule contingency is addressed above in the Budget Comments, as well as in the Risk section below.

- Earned Value Management

The absence of a formal Earned Value Management system was noted by both Panels. We noted in the Project Execution Plan that the structure of this project, with repeated annual cycles of float deployments, greatly reduced the need for formal EVM. The RSV Panel then agreed with this conclusion, stating "This experienced team has been collaborating on very similar activities under a different funding mechanism and different funding sources for a few years for a BGC-Argo prototype network in the Southern Oceans (SOCCOM) to a few decades for Core-Argo (with more limited sensor packages). No special EVM system is required for performance measurement, as a simple approach based on counting floats produced, deployed, and transitioned to operations would be adequate." We agree and our intent would be to not formally implement EVM. Progress is tracked through success in meeting the objectives of float production and deployment on individual cruises and the annual cumulative targets for float deployment, as well as data quality. The project integrated master schedule (IMS) gives us the ability to and we will track actual costs and progress against the baseline budget and baseline schedule in enough detail to identify issues before they become serious problems.

- Work Breakdown Structure (WBS)

The RVS Panel noted that "a complete WBS does not exist" and "NSF should require a more detailed WBS...as a condition of the award". The first quote is an accurate statement with several caveats at our end, and we are ready to comply with the second comment immediately. While a finalized WBS does not exist, the WBS in our IMS is sufficiently complete to allow us to identify the critical path and project milestones in enough detail that we can track actual costs and progress against budgeted costs and the baseline schedule.. Our current IMS is sufficiently large (200+ WBS elements) that there was no effective way to show it in the Project Execution Plan and it did not occur to us to submit the Microsoft Project file as a supplementary document, if that was possible. We showed only a rolled up version in the

PEP, which we agree does not illustrate sufficient detail, and likely precipitated the panel comment. We noted in the Project Execution Plan (Section 4.2), “Following approval of this project, a pre-funding team meeting will be held with the institutional partners to complete the WBS in full detail. This will enable the detailed monitoring of program progress.” This remains our intent. However, the functional, but preliminary, version is available now.

- Risk (Including Schedule Risk)

Several comments on program risk were raised by both Panels and R4 and R10, particularly schedule risk. Much of the schedule risk could be alleviated by the budgeting change (or early spending authority) discussed above in the Program Management section. The RSV Panel also noted that “Little attention has been paid to the possibility of unanticipated issues”, and the Risk Management Plan “is not properly connected to the project management procedures and therefore does not enable the necessary monitoring [of] the project risks during implementation.” We agree that unanticipated issues were not discussed, but they are a potential risk. The primary mechanism to detect unknown risks is vigilant monitoring of array status, a core function of the program task teams. The mitigation, if significant unanticipated issues arise, is the presence of significant engineering capability within the project personnel as well as engineering contingency funds.

????????? discuss the last quote, Risk not connected to project management???? (I’m not sure I get this either, maybe we can talk about it tomorrow before the telecon).

- Staff Workload

The RSV panel expressed a concern for staff overload and noted that many of the project personnel have multiple roles that are identified in the organizational chart. We agree that many personnel will have multiple roles. This, in part, is a reality of a relatively lean staffing level that requires the engineering and technical staff to handle multiple tasks. We are also cognizant that this lean staffing can lead to overwork. When complete, the IMS will have specific staff assigned to each task in the WBS and the IMS software (Microsoft Project) will identify overloaded individuals. As this project comes on line, and personnel take on additional tasks, the possibility of overload becomes more likely. As new hires come on line, this pressure will ease, but management will have to be particularly vigilant during any transitional period. There is also significant multi-tasking occurring with the Senior Personnel. Some of that simply reflects their eagerness to be involved in all phases of the project. Again, careful mentoring is required as the project establishes itself.

A separate comment by R11 about small salary requests for some of the co-PIs is best answered by noting that those with academic positions cannot request more than limited summer salary. In addition, significant effort will be cost shared, which we did not enumerate per instructions in the solicitation.

- Metrics for Success

The Proposal Panel and R10 requested that the program develop quantitative metrics, similar to Earned Value Management, which will allow program success to be determined. Evaluation of the program will occur through multiple mechanisms. (1) Annual internal evaluations by project personnel on the Data Team and Float Production Team will assess and report on data quality as well as float and sensor reliability. Metrics for reliability and sensor performance are available and will be used to quantify program performance. If technical issues are apparent, a plan will be implemented to address them. Contingency funding is included to support engineering if significant problems arise. (2) Annual internal assessments of program data utilization by the community in research publications. Citable DOIs will be provided to facilitate this along with a recommended statement for the acknowledgments. We have not developed metrics to evaluate this, but will consider doing so. The Argo achievement of one paper for each float operating is a potential target goal. (3) Annual in-person project meetings will serve as a mechanism to report to program managers, the oversight committee, and BGC-Argo colleagues. The program oversight committee will be asked to provide an annual external review to the Executive Team and the community for this meeting. (4) Assessment of broader impacts and training success will involve tracking: the number and demographics of scientific workshop participants (local and remote); the number of community members participating remotely in annual meetings/program reviews; the number of teachers who continue to use course materials developed during educator workshops; classroom metrics for the adopt-a-float program; and the number of people and demographics for MATE and maker space participation.

From a project management perspective, success is measured throughout each year as tasks in the IMS are completed without signficant changes to the float deployment schedule.

Project Design

- *Floats*
  - Recovery of Floats at End of Life

The Proposal Panel and R3, R7, R12, and R14 expressed concern regarding the effects of not recovering floats at their end of life. We appreciate their concern and share their fundamental consternation about not recovering floats. We also recognize that we did not adequately identify the issues that are involved with float recovery. These issues make recovery both unaffordable and environmentally unsound.

Floats can be efficiently deployed from ships making transits or cross-basin sampling trips such as GO-SHIP cruises without having the ship deviate from its planned route. However, once the floats drift away from these fixed lines, dedicated cruises are generally required to recover them, as finding the floats would require a cruise such as a GO-SHIP line to make excessive diversions, which is not possible. The environmental and monetary cost of such recovery cruises would greatly outweigh the benefit of recovering the float. For example, the amount of protons (as CO_2) flowing to the ocean generated from the fuel burned by a one month oceanographic cruise of the R/V Revelle would create an ocean acidification signal 1500 times greater than the acidification created by acid released from batteries in the 125 BGC floats deployed by this program each year.[1] Because of a global distribution of floats, many cruises would be required to recover 125 floats each year at a dollar cost much higher than the annual operating cost for the array, resulting in a large opportunity cost for science.

Although more difficult to quantify, the information and knowledge gained from the float array could result in modifications to environmental policy that would create environmental gains that are far greater than the very modest effect of the float loss.

For these reasons, we do not believe it to be sound policy to recover floats using ships, except in exceptional circumstances. We have encouraged, unsuccessfully, groups such as the X-Prize Foundation to have challenges leading to the development of robotic methods to recover floats using platforms with lower environmental impact, such as WaveGliders or SailDrones. We will continue to consider other alternatives to minimize environmental effects.

  - Why 3 Float Operating Groups

The Proposal Panel and R1 raised concerns about having three operating institutions. This distributed model for float production and deployment, with multiple centers supplying and deploying floats, is based on the successful US Core-Argo program. It maximizes success through internal competition, innovation, and technical exchange. By utilizing this model, US Core-Argo float performance greatly exceeds that attained by most international Argo partners. It minimizes risk by greatly reducing the probability that a single point of failure associated with an institutional operating group will impact the entire array. It also permits each of the three institutions to be more regionally specialized, which permits more informed scientific oversight of the float array. We expect similar advantages for BGC-Argo, for which regional responsibilities will be roughly aligned with each institution’s Core-Argo program. Finally, the available space and facilities generally limit the number of floats that a group can handle and this also forces the diversification of production.

Having 3 operating groups and 3 float types also mitigates concerns (R2, R4) about whether we can produce enough floats. Using only a single group and float type simplifies some issues, but raises many additional concerns about single points of failure and the large jump in production capability at one institution.

  - Why 3 Float Types

A variety of comments were made regarding float types and choices. R7 comments on cost/benefit of various float types is difficult to assess. R14 notes some float types are still in development. R1 wonders why we don’t use more SOLO-II floats. A related set of comments concerned

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[1] Ship - 275,000 liters of fuel/month * 700 g C/L * 1 mol CO_2/12 g C * 25% enters ocean = $4x10^6$ mol CO_2 into the ocean = $4x10^6$ mol H^+/cruise (and multiple cruises per year to recover 125 failing floats)
Floats - 125 floats/y *16 Li cells/float * 1.3 mol Li/cell * 1 mol H^+/mol Li = 2,600 mol H^+/year

the ability of float types to carry all 6 of the desired sensors. As noted by the Proposal Panel, “not all the float designs can carry all the sensors”.

All of these are legitimate comments, but often in opposition to other requirements and a compromise solution is required. This is our approach. For example, there are compelling reasons to deploy radiometers (see Bio-optics section below), but the most robust platform available to us will not easily carry a radiometer. We will, therefore, introduce new floats into the array, while working with the manufacturers to ensure their reliability. The compelling rationale to begin global observations now, in a changing ocean, require the compromise of multiple float types, some with 5 BGC sensors, some with 6. While the SOLO-II is an extremely capable platform, the risk of depending exclusively on it, while it is adapted to carry BGC sensors is too high. Thus, we are left with our present, compromise choice.

- NOPP status

Reviewers and the Panels recognized that three float types provide resiliency to the network, but also had some questions and comments on the status of the final engineering stages that are currently underway on the Seabird Navis and MRV SOLO II floats. Both of these platforms are mature with proven (>95%) survival rates in Core-Argo. Two funded National Ocean Partnership Program (NOPP) projects are underway at UW and SIO to complete sensor integration and platform testing to enable these two platforms to carry all six BGC sensors. Additionally, the WHOI group will deploy a total of four NAVIS BGC floats in the Atlantic in 2020 and 2021 as part of a NOAA OOMD funded project that will build expertise with this platform within the WHOI float group. Together, these activities will ensure readiness for the Navis and SOLO II floats to contribute to MSRI as outlined in the float production schedule.

- *Chemical Sensors*
  - Oxygen

R1 and R14 expressed concerns about the performance of oxygen sensors on floats. R1 correctly pointed out the need for SBE-63 to be able to conduct air calibration, and this modification is currently underway through a funded NOPP project. This is a relatively minor engineering effort, and progress is on track to complete and fully test this modification by summer, 2020. We respectfully disagree with R14 regarding the need for improved precision of the oxygen optodes, as they are excellent and at a similar level or better than the standard Winkler titration. R14 also noted the slow oxygen sensor response. Published methods now exist to largely remove artifacts due to slow response in steep gradients using numerical methods (Bittig et al. 2017, doi: 10.5194/os-13-1-2017). The SOCCOM program has experimented extensively with these numerical corrections and recommended to the BGC-Argo Data Management Team at their Oct. 2019 meeting that the methods be routinely implemented for all floats that record the necessary timing information. The needed timing information is standard for the floats that will be used here. This will greatly mitigate the problem with slow oxygen response rates. This recommendation is under consideration.

  - Sensor Improvement

The Proposal Panel noted that “there is still some development of sensors” required. R5 specifically noted that continued development of the pH sensor should be encouraged. We agree that continued assessment of all sensor performance and subsequent improvement will be an essential activity. These improvements will come via two mechanisms. One is close collaboration with manufacturers to inform them on the performance of their instruments and necessary improvements. An example of this is our work with Sea-Bird to enable their oxygen sensors to perform air calibrations. Without this close collaboration, manufacturers generally do not have the data available to assess performance and refine operation.

Secondly, as developers of the nitrate and pH sensors used on floats, the Chemical Sensor Lab at MBARI will continue to work to improve their designs using institutional support. These improvements are regularly shared with the manufacturer. This should address the concern of R5.

  - Sensor Intercomparison

R1 and R4 raised concerns about the lack of a plan for intercalibration between floats. We would like to point out that while the floats themselves are different, the sensors equipped on them will be the same, with slight variations for the oxygen and nitrate sensors (although they utilize the same sensing technology and components). Therefore we do not expect different sensor performance between float types. However, in order to verify this, as done in SOCCOM, we will continue to compare float performance to hydrographic casts taken at the time of deployment of more than half of the floats to ensure that no biases exist among different float types.

- Sensor Performance, Stability and Use of GLODAP to Assess Performance

R5 was concerned that we did not fully understand sensor accuracy and stability, particularly for oxygen and pH. We acknowledge the importance of independent assessments of sensor calibration and performance through co-located hydrographic casts. In SOCCOM, this has taken the form of co-located profiles at the time of float deployment and comparison to GLODAP data when floats pass near stations in the database; the resulting comparisons have been essential for validating our calibration approaches for each sensor, which are independent of individual co-located hydrocasts. In BGC-Argo, we will continue this practice to the extent possible with deployments from quality research cruises that collect the specific data sets relevant to these sensors; GO-SHIP is the core of this effort and there are also routine, high quality opportunities in regions with sustained observing systems (tropical Pacific, multiple latitudes in the Atlantic, etc). We have not proposed that every float deployment include a complete co-located hydrographic profile because we have shown in SOCCOM that this is not necessary for high quality calibration, specifically because sensor calibrations do drift, and therefore the calibration process must be and is independent of very sparse shipboard measurements. However, the more co-located sampling that occurs, the more robust our assessment of the float data set quality.

What has not been feasible in SOCCOM, due to the remoteness of the Southern Ocean and the cost of ship time, is extensive co-located sampling some years into float lifetime, to assess sensor stability. As a result, we have focused on using the GLODAP data set to assess stability long after deployment. R5 was critical of the dependence on GLODAP to assess stability and wanted more direct comparisons. As the BGC-Argo program extends to the global scale, we anticipate opportunities to conduct such comparisons to arise, especially in basins like the North Atlantic where more research cruises occur. We plan to take advantage of such opportunistic ‘crossovers’ to assess long term sensor performance.

In summary, we will continue efforts from as many avenues as possible to assess and validate sensor performance.

- *Bio-optics*
  - Bio-optics Expert.

R4 and the Proposal Panel commented on an apparent lack of bio-optics expertise on the project team and suggested that a bio-optics expert be added. We respectfully suggest that adding a senior member is not required: The bio-optical float data that we have generated in the SOCCOM program are of the highest quality found in the BGC-Argo program and are widely used in publications, with all calibration and QC functions carried out at MBARI by the senior personnel and support team proposed herein. Moreover, concerns were expressed (e.g., R13) that the Executive Team was too large. We have generally opted for a large team to ensure that early and mid-career personnel are trained in program management, but we recognize that expanding the team too far will make this approach unwieldy. We do acknowledge a small shortcoming in staffing to replicate SOCCOM’s shipboard data collection and archiving in support of the bio-optical float sensors, and will include additional expert staff at SIO.

R4 was concerned that “optical sensors are much less stable”. In fact, optical sensors have generally been the most stable sensors (other than CTD) in the SOCCOM program, independent of the methods used for evaluation. The relationship between optical sensor data and biogeochemical state variables such as chlorophyll or particulate organic carbon are more complicated, but that is an issue for the research community to resolve and generally beyond the scope of this proposal.

The essential issue is that we generate high quality bio-optical sensor data and we are doing that, as exemplified by the use of SOCCOM bio-optical data in numerous papers. We coordinate closely with the Biogeochemical Argo Data Management Team, which includes several international experts in bio-optics, to ensure that our data are of the highest quality. We note that our floats suffer an order of magnitude fewer sensors failures than found in other programs, ensuring high quality results that are widely used. A few examples of papers from 2019 using SOCCOM bio-optical data, several with authors who are bio-optical experts, are listed here:

Arteaga, L. A., Pahlow, M., Bushinsky, S. M., Sarmiento, J. L. (2019). Nutrient Controls on Export Production in the Southern Ocean. Global Biogeochemical Cycles 0: | DOI: 10.1029/2019GB006236

Bellacicco, M., Cornec, M., Organelli, E., Brewin, R.J.W., Neukermans, G., Volpe, G., Barbieux, M., Poteau, A., Schmechtig, C., D'Ortenzio, F., Marullo, S., Claustre, H., Pitarch, J. (2019). Global variability of optical backscattering by non-algal particles from a Biogeochemical-Argo dataset. Geophysical Research Letters 46: | DOI: 10.1029/2019gl084078

Bisson, K.M., Boss, E., Westberry, T. K., Behrenfeld, M. J. (2019). Evaluating satellite estimates of particulate backscatter in the global open ocean using autonomous profiling floats. Optics Express 27: | DOI: 10.1364/OE.27.030191

Uchida, T., Balwada, D., Abernathey, R., Prend, C. J., Boss, E., Gille, S. T. (2019). Southern Ocean Phytoplankton Blooms Observed by Biogeochemical Floats. Journal of Geophysical Research: Oceans | DOI: 10.1029/2019JC015355

Given the conflicting tension of making the Executive Team too large, and the successful operations that we have achieved, we again suggest that it is not necessary to add additional senior personnel.

- Radiometer

Concern was expressed by R1 that radiometers would not be available on APEX floats, and R3 commented that the rationale for adding radiometers was not provided. R3 also suggested removing the radiometers as they were unproven. We acknowledge that we did not provide adequate justification for utilization of radiometers or the impact of not providing them on all floats.

There are multiple, strong reasons for having a global array of radiometers. These devices observe the vertical distribution of light in the ocean when floats profile during daylight. They have been used extensively on profiling floats, although not in the SOCCOM program for technical reasons noted in the proposal. The attenuation lengths for light energy that are obtained from these observations are fundamental inputs to data assimilating ocean models, which otherwise use default estimates of attenuation scales to assess where light energy absorption and subsequent heating occur. The attenuation of light is also a fundamental measure of the integrated chlorophyll stock and this can greatly increase the accuracy of chlorophyll estimates. Variations in the attenuation scale over time are probably our most accurate tool to assess long-term changes in phytoplankton stocks. These factors are demonstrated in many publications using BGC floats, and clearly justify the addition of radiometers. As a risk management tool, however, our initial float deployments will be dominated by the proven APEX floats, which do not carry radiometers. This creates some penalty, by not providing light attenuation observations across the array. We feel the penalty is balanced by the readiness and proven performance of the APEX float. The light attenuation observations that are made by the subset of floats with radiometers will provide significant scientific benefit.

- *Float Mission and Distribution*

R3 raised a number of concerns about the proposed basic float mission cycle: 10 day cycles to 2000 m. R3 includes a comment that a 10 day cycle time is too long to adequately observe processes such as the biological carbon pump and it will not benefit NASA as there will be few satellite matchups. Another comment suggested that floats only go to 2000 m depth infrequently. A final comment was that we had not reported the surfacing time for floats.

The float mission parameters represent a set of compromises that are necessary to achieve overall science goals. Shortening the cycle time reduces float lifetime proportionately (halving cycle time halves life) and any significant change would make sustaining a global array nearly impossible from a deployment perspective and impossibly expensive. While a shorter cycle time would improve resolution of many biologically mediated processes, significant science is possible with the proposed mission cycle. Numerous papers using BGC-Argo float data have reported on the biological carbon pump, beginning with Martz et al. (2008). These include novel mechanisms of carbon export (Dall'Olmo et al, 2016). The Arteaga et al. (2019) reference shown above is another good example. A depth of 2000 m on each profile, as well as the 10 day cycle time, will allow the floats to contribute to Core-Argo assessments of ocean heat and freshwater content and the deep data are essential to assess sensor performance (Johnson et al., 2017b).

Numerically significant matchups with ocean color satellites signals have been achieved and the results used to validate chlorophyll algorithms (Haëntjens et al., 2017) also confirming the 10 day cycle time produces a useful complement to remote sensing data.

We did not report the float surfacing times, as noted by R3, which has implications both for satellite matchups and for use of the radiometer. Our protocol is to set floats on an ~10.25 day cycle, so that the sampling captures all phases of the day/night cycle. As a result, about half the radiometer profiles are in the dark and don't yield useful data. However, having the floats surfacing at independent times of day enables the determination of broad-scale diel cycles from other parameters if one considers the entire network as a single array of sensors. For example, preliminary work shows that the diel oxygen cycle can be extracted. This approach has been validated by Sarah Gille's work, which shows that one can extract diel temperature cycles from the Argo data set (Gille et al., 2012, doi:10.1029/2012JC007883).

R1 and R8 both expressed concerns that the relatively coarse spacing of floats would not enable regional scale science. Our primary goal is achieving a global assessment of ocean biogeochemistry. However, this is not inherently incompatible with regional scale studies. The array will provide a global-scale framework within which regional process studies can be embedded, much like regional scale ocean models are often embedded in a coarser resolution global model. We anticipate that the success of a global array may stimulate more focused, regional scale float deployments, perhaps in regions such as an Oxygen Minimum Zone, where the global array provides boundary conditions.

Data

- Cybersecurity

The RSV Panel raised significant concerns regarding cybersecurity and have suggested that a revised cybersecurity plan be a condition of an award. We are grateful for their insightful comments and we agree that a complete cybersecurity plan is required. Following discussions with our institutional cyber infrastructure experts after our first Panel interview, we identified the Trusted CI group as an expert advisory body and the RSV Panel indicated that was an appropriate resource during our second interview. We have contacted Trusted CI and understand that the next window for applications will be opening around March 2020 for engagements to take place in the second half of the year, which would coincide with the beginning of an MSRI-2 award.

In the meantime, we have begun consultations with our institutional security officers, who in some cases are already engaged with NSF's cybersecurity programs. In preparation for an audit, we will undertake internal steps within the multi-institutional structure of the proposed project, including a computer inventory, data storage inventory, data flow diagrams, list of people associated with the project, and summary of pertinent local policies and security frameworks.

- Non-proprietary Software

The Proposal Panel suggested that the program consider conversion of computer codes developed in Matlab to non-proprietary software, which would increase its use. We agree and acknowledge the importance of converting the current software infrastructure (e.g. SAGE as well as the entire float data processing stream) to an open-source language such as Python. However, significant effort over multiple years was required to develop such software, and similar efforts will be required to develop a Python-based infrastructure, especially because such expertise is not a core competence within the data team. Therefore we plan to keep this as a long-term objective of this program. It should be noted that the current software is openly accessible through GitHub, and can be adopted by any float deployer. At the Argo Data Management Team meeting in October, six of the national Argo Data Assembly Centers acknowledged using the SAGE tools developed in Matlab by the SOCCOM project, as well as several individual scientists. We have, and will continue, to provide support for BGC-float deployers who wish to utilize SAGE.

- Application of Intercalibration, Calibration, and Uncertainty

The Proposal Panel found that it was not clear how intercalibration, calibration, and uncertainties are applied and reported. Due to length limitations in the proposal, this topic was treated with brevity. Extensive work on these topics has been done and reported in research publications such as Johnson et al. (2017, Biogeochemical sensor performance in the SOCCOM profiling float array. Journal of Geophysical Research-Oceans 122: 6416-6436 | DOI: 10.1002/2017jc012838). More important, these protocols are detailed in technical publications of the Argo Data Management Team, such as "Processing BGC-Argo pH data at the DAC level" (Johnson et al., DOI https://doi.org/10.13155/57195). The technical documents outline the full process for producing quality controlled and validated data, including usage of software validation tools and computation of uncertainties. Also note that it is the Argo policy that all measurements are reported with an associated uncertainty, which is computed following these published procedures.

Broader Impacts Section

- Diversity Plan

R13 specifically commented about a lack of gender diversity in the MATE program, which however is characterized by significant ethnic diversity. It should be noted that the data discussed by the reviewer represents a summary of MATE's GLOBAL ROV competition participants. Looking at gender diversity at a regional level, the numbers are more encouraging. For example, 44, 44, 49, and 50% of the participants competing in MATE events in the Mid-Atlantic, Chicago, IL, the Great Lakes, and Oregon, respectively, were female. Further, through its recent partnership with the Motorola Solutions Foundation, the MATE ROV Competition is proactively addressing its "gender gap," with funding from the foundation specifically geared towards the recruitment and retention of girls and young women. It is also working with its Pennsylvania partners who are involved with the National Girls Collaborative Project to engage and inspire girls in STEM. We will continue to work with MATE on diversity issues as well as seek broader representation with the EARTH professional development program and the Adopt-A-Float program.

The Panel asks about workforce diversificationxxxx

- Detail on Broader Impacts

The Adopt-A-Float program is already running and will be able to continue for the duration of the project. We will make an effort to reach out and diversify the schools/groups that are adopting the floats beyond the broad geographic scope that we have already attained. The EARTH professional development program will focus on this program in years 1, 3, and 5 of the program. At this point we have proposed conducting these workshops at Univ. of Washington but we will include this program in workshops in the off years in different geographic areas as we look to try and increase our diversity in terms of student body and educators. The summer intern working with MBARI and MATE will be a targeted intern recruitment (under-represented group and/or first generation college). We will create competition scenarios and design mission tasks that align with and incorporate biogeochemical-ARGO related research and technology into the competition. For example, in Year 1:

- ➢ Teams build a float that uses a variable buoyancy system (no propellers/thrusters allowed) to descend to and hold at a given depth (e.g. 2.0 meters) for one minute before returning to the surface.
- ➢ Teams design one sensor (e.g. temperature) and deploy that sensor on their ROV to collect data at a specific location/depth.
- ➢ Teams use their ROV to collect water samples at specific depths then either bring the samples to the surface to measure specific parameters or use sensors to measure those parameters in situ.

MATE is highly effective in terms of increasing interest in STEM. The results of post-program surveys showed that 86% (N=1919) wanted to learn more about STEM and that 77% (n=1933) were interested in a STEM career! 87% (N=1923) felt that the ROV program helped them learn how to apply STEM to solving real world problems. 99% of educators (N=345) saw an improvement in their students' STEM knowledge and skills. 67% (N=432) of the alumni surveyed in 2015 credited MATE with influencing their educational/career path and help the alumni with jobs (37%), getting into an education program (36%), internship (30%), awards (21%), and scholarships (21%).

- Postdoctoral Mentoring Plan

Our proposal does not directly fund any postdoctoral scholars, but we have included a Postdoctoral Researcher Mentoring Plan as we were likely to interact with postdocs through their utilization of this data set and our Broader Impacts workshops. As noted by the Proposal Panel, that plan does not include a specific statement regarding how grievances by postdoctoral researchers might be handled. Normal, institutional protocols concerning workplace grievances are in place at each of the consortium institutions. However, the National Academies Report, “The Postdoctoral Experience Revisited”, finds that many postdocs feel that such protocols may not provide adequate mechanisms to deal with their particular situation, which is rather unique compared to most employees. Such policies are in place at the academic partners, but not at MBARI, where a single grievance policy applies to all employees. The PI will ask for an institutional review of this situation. Given that this project will not have direct supervision of postdoctoral researchers, it is most likely that our interactions will be primarily an advisory one and not directly supervisorial and this situation is manageable if careful attention is paid to postdoctoral interactions.