US GO-SHIP

Review of US GO-SHIP (Global Oceans Ship-Based Hydrographic Investigators Program)

An OCB and US CLIVAR Report
November 2019

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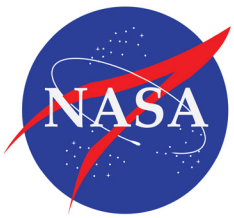

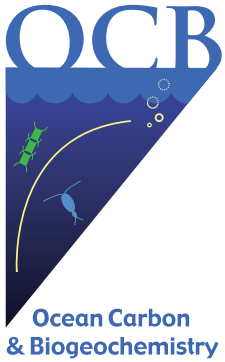

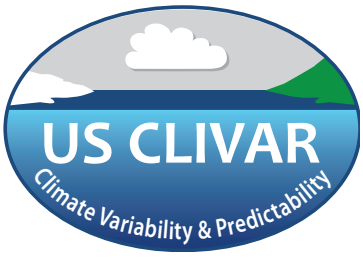

AUTHORS

US GO-SHIP External Review Committee:

Frederick Bingham, Chair
University of North Carolina, Wilmington

Laurie Juranek
Oregon State University

Matt Mazloff
Scripps Institution of Oceanography

Galen McKinley
Columbia University

Norm Nelson
University of California, Santa Barbara

Susan Wijffels
Woods Hole Oceanographic Institution

EDITORS

Heather Benway
Woods Hole Oceanographic Institution

Mai Maheigan
Wood Hole Oceanographic Institution

Mike Patterson
US CLIVAR

Jennie Zhu
US CLIVAR

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COVER IMAGE:

The research vessel *Nathaniel B. Palmer* at sea during US GO-SHIP S04P cruise in 2018. Image Credit: Ted Blanco, https://www.tedblanco.com/

BACK COVER IMAGE:

(Left top) Scripps research vessel *Roger Revelle*. Image Credit: Dr. Hans C. Graber (University of Miami)
(Left bottom) CTD cast during I09N on the research vessel *Roger Revelle*. Image Credit: Steve Baer (Bigelow Lab, now at Maine Maritime Academy)
(Right) NOAA Ship *Ronald H. Brown* at sea. Image Credit: NOAA Office of Marine & Aviation Operations

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1 Executive Summary

The following document constitutes a review of the US GO-SHIP program, performed under the auspices of US Climate Variability and Predictability (CLIVAR) and Ocean Carbon Biogeochemistry (OCB) Programs. It is the product of an external review committee, charged and assembled by US CLIVAR and OCB with members who represent the interests of the programs and who are independent of US GO-SHIP support, which spent several months gathering input and drafting this report. The purpose of the review is to assess program planning, progress, and opportunities in collecting, providing, and synthesizing high quality hydrographic data to advance the scientific research goals of US CLIVAR and OCB.

1.1 Significance of US GO-SHIP

US GO-SHIP is the US affiliate of the international GO-SHIP program. Its observations are carried out in the context of international GO-SHIP as a sustained observing program of the Global Ocean Observing System (GOOS). GO-SHIP provides approximately decadal resolution changes in inventories of heat, freshwater, carbon, oxygen, nutrients and transient tracers in the ocean. It covers the global ocean coast-to-coast and full depth, with measurements of high accuracy. The principal objectives of GO-SHIP are 1) to understand and document large-scale ocean water property distributions, their changes and drivers of those changes and 2) to understand how a future ocean, with a greatly increased burden of inorganic carbon and heat and thus more acidified and stratified, will experience changes in ventilation and circulation due to global warming and an altered hydrologic cycle. GO-SHIP is the international climate community's premier program for measuring long-term changes in the ocean from top to bottom. US GO-SHIP is one of the leading contributors to this international effort.

1.2 Purpose of this Review

The purpose of this external review is to 1) assess the utility of the datasets and the effectiveness of key operational components of US GO-SHIP in advancing the scientific research efforts of the US CLIVAR and OCB communities; and 2) provide input on future directions for the program in advance of the renewal proposals to NSF and NOAA for the next phase of US GO-SHIP. The program review is not intended to supplant or interfere with the proposal review. Rather, this report may help to inform the US GO-SHIP Executive Council in its planning for future activities and operations that can benefit the broad ocean and climate research communities represented by US CLIVAR and OCB. Nor is the review intended to evaluate the effectiveness of International GO-SHIP in meeting requirements set by GOOS for component programs that make up the sustained global ocean observing system. A review with that focus would more appropriately be conducted by Intergovernmental Oceanographic Commission (IOC)/GOOS.

1.3 Scope

The review examined all aspects of US GO-SHIP, including:

- Planning – The basic goals and objectives of the program relative to those of US CLIVAR and OCB
- Implementation – The effectiveness of the program in attaining targets for data collection, quality control, reporting, and access
- Synthesis – The ability of the program to synthesize the data collected for the purpose of understanding 1) heat and freshwater fluxes, 2) carbon system and biogeochemistry, 3) water mass ventilation, 4) model calibration validation and state estimation, and 5) autonomous sensor calibration
- Workforce – Sufficiency of scientific and technical staff
- Ships and instrumentation – Sufficiency of ship and instrumentation resources to carry out the goals of the program
- Coordination – Coordination across the US GO-SHIP projects and with other programs and entities, including international GO-SHIP, Argo, Ocean Observations Panel for Climate (OOPC), International Ocean Carbon Coordination Project (IOCCP), and the US CLIVAR and OCB communities
- Leveraging – New technology and other complementary observations

The major sources of input for this report include a survey sent out to US GO-SHIP-affiliated persons, and two site visits, one in person to Scripps Institution of Oceanography, and another virtual one with NOAA investigators who were unable to attend the Scripps meeting due to a shutdown of the federal government.

1.4 Key Findings

The review committee's findings are overall very positive. We consider the program to be critical, even essential, to ocean and Earth system climate research. The program has provided, and continues to provide, the highest quality data to the oceanographic community through a well-planned and executed observational program that makes good use of available resources. Publications resulting from US GO-SHIP are numerous, wide-ranging, and of high quality and impact. The program is essential to the development and calibration of autonomous sensors and platforms. The review committee wants to emphasize that autonomous instruments cannot be expected to replace the hands-on data collection provided by GO-SHIP, as many parameters essential to understanding of the climate system are not attainable with autonomous platforms. US GO-SHIP has provided career opportunities for many students, postdocs, technical staff, and early-career faculty and researchers, allowing them to gain skill and experience in carrying out and managing field measurements. Finally, US GO-SHIP provides leadership for the international community in terms of effort (about half of GO-SHIP measurements are made by US scientists), quality, development of new measurements, and commitment to the observational program.

Thus, it is the review committee's recommendation that US GO-SHIP be continued and enhanced, with sufficient resources to allow sustained continuation of the observational program and data management system. There are many more specific recommendations detailed in section 5 of this report. A few important ones are given here.

1.5 Recommendations

The report includes specific recommendations, gathered through the survey responses, site visits, and review committee discussion. Overarching recommendations include:

- Centralized coordination – A program of this importance to such a large fraction of the oceanographic community should have dedicated support staff to manage the administrative, coordination, and communication tasks that are critical for the success of US GO-SHIP. The committee recommends designating a full-, or at minimum half-time, project coordinator to support chief and co-chief scientists, enable communication and increased transparency, and formalize program policies and procedures.
- Leadership succession and workforce development – Many of the leaders in US GO-SHIP are at or nearing retirement age. It is urgent that US GO-SHIP develop a plan and begin to carry out a transition to a new generation of leadership, with the requisite transfer of knowledge. US GO-SHIP also needs to more consistently and effectively communicate opportunities for early-career scientists to participate in the program.
- Strategic planning – GO-SHIP would benefit from an overarching international strategic plan to provide cohesive vision for national contributors and justify increased investment for complementary measurement additions, data analysis, and staffing.
- Ships – Global-class research vessels are necessary for the effective operation of US GO-SHIP repeat hydrography. Many of the currently used ships are nearing the end of their useful lives. Regional class research vessels are inadequate to carry out the program's sampling goals. The review committee recommends that US GO-SHIP engage with the University-National Oceanographic Laboratory System (UNOLS) to plan and develop new global-class vessels as these will be critical to its success going forward.
- Data – US GO-SHIP collects high quality data, which is distributed through several closely-allied data centers. Yet, it was perceived that the oceanographic community does not make full use of these. Several recommendations for the data centers and/or US GO-SHIP are made to encourage the community to use these data more fully: publish a regularly updated gridded product; assign DOI's to datasets to better track usage; more accountability from data providers; and others.
- Work environment – US GO-SHIP should work with its science parties, and with NOAA and UNOLS to ensure a positive work environment for all participants in its cruises. All participants, regardless of gender, race, or identity should be respected and have their contributions valued. Clear mechanisms for addressing concerns should be in place and explicitly communicated.

2 Background

The US Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) (https://usgoship.ucsd.edu/), formerly known as the CLIVAR/CO_2 Repeat Hydrography Program, is a systematic and global re-occupation of select hydrographic sections (Figure 1) that was established in the early 2000s. These sections span all of the ocean basins from coast to coast and the full-depth water column, with global measurements of the highest possible accuracy, attainable only with research ships at present and for the foreseeable future. These hydrographic datasets are at approximately decadal resolution, and are the only datasets that support estimates of long-term change in inventories of heat, freshwater, carbon, oxygen, nutrients and transient tracers. As such, they contribute to the following overarching scientific objectives:

1. Understanding and documenting large-scale ocean water property distributions, their changes, and drivers of those changes
2. Addressing questions of a future ocean that will increase in dissolved inorganic carbon, become more acidified and stratified, and experience changes in circulation and ventilation processes due to global warming and an altered planetary water cycle

In addition to directly supporting research on the ocean carbon system, heat and freshwater storage and flux, and deep and shallow water mass formation and ventilation, US GO-SHIP datasets are used for validation of earth system models and for calibration of autonomous sensors. Through the latter, US GO-SHIP supports the Argo Program and other autonomous networks. These science drivers collectively span the research interests of the US Climate Variability and Predictability (CLIVAR) and Ocean Carbon and Biogeochemistry (OCB) communities. US GO-SHIP cruises also provide a platform for synergistic experimental and emerging programs, training of early career scientists, and opportunities for networking and collaboration through post-cruise data analyses and publications.

US GO-SHIP represents the US contribution to international GO-SHIP, bringing together scientists with interests in physical oceanography, the carbon cycle, marine biogeochemistry and ecosystems, and other users and collectors of hydrographic data to develop a globally coordinated network of sustained hydrographic sections as part of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). GOOS defines the Essential Ocean Variables (EOVs) that underpin GO-SHIP observations. With funding from the National Oceanic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), US GO-SHIP supports occupation of one-third to one-half of all of the GO-SHIP sections, depending on the metric of measure (e.g., number of sections vs. days at sea). The sequence and timing for the sections (Figure 1) takes into consideration the program objectives, providing global coverage, and working within resource constraints. Hydrographic sections are selected such that there is roughly a decade between occupations, which is considered optimal for detecting changes in ocean carbon inventory and deep freshwater and heat transport.

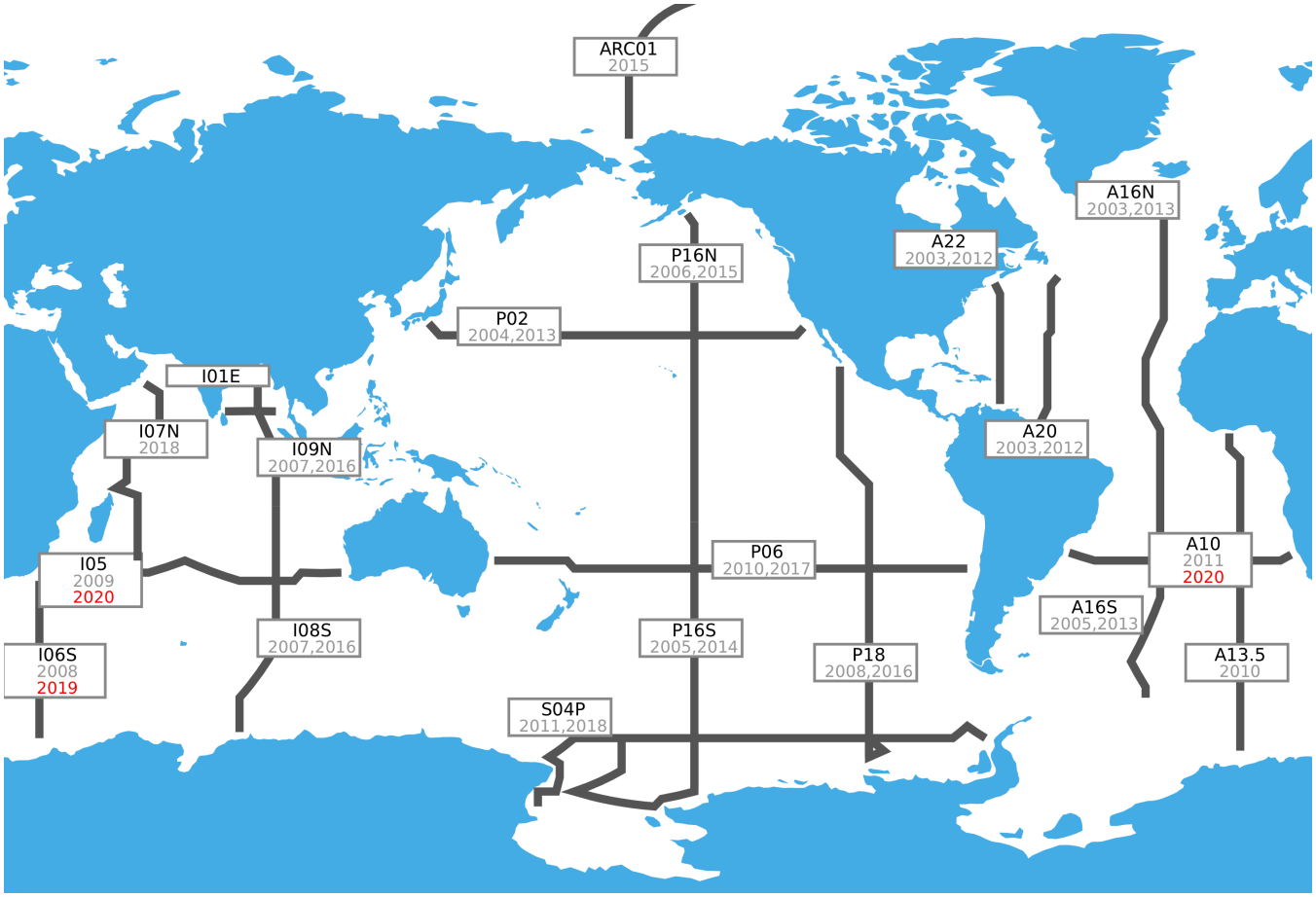


Figure 1. Cruises for US GO-SHIP, 2003-2020 (red indicates a pending cruise, grey indicates a completed cruise) - https://usgoship.ucsd.edu/hydromap/

The program measurements are presently divided into three levels, in order of priority. The levels are also the suggested standard for international GO-SHIP, and should be measured at the highest practical spatial resolution. Level 1 (L1) core measurements are mandatory on all cruises. The criteria for classifying a measurement as Level 1 are based on data required to directly quantify changes in ocean carbon inventory, estimate anthropogenic CO_2 empirically, characterize large-scale water mass ventilation rates, constrain horizontal heat, freshwater, carbon, nitrogen, and oxygen transports and/or net divergence, and provide an on-going basis for model evaluation. Level 2 (L2) measurements are highly desirable and complementary to L1 measurements. They may be collected on coarser spacing and are closely coordinated with the core effort. Within the US, a consortium of funded investigators leads each L1 and L2 observation type. The principal investigators are responsible for data collection, analysis, calibration, documentation, and submission to the data assembly centers. The data assembly centers are responsible for data merging, verification and adjustment of data formats to community standards, online dissemination and documentation, any further quality control (QC), and archiving. Both L1 and L2 datasets have strict data policies that require their funded investigators to submit most of the data within 6 months of a cruise. Level 3 (L3) ancillary measurements are typically proposed and conducted by cruise participants according to opportunity and space available. They should not significantly interfere with Level 1 or 2 efforts,

and may be regional or specific to an individual cruise. L3 data are managed outside of US GO-SHIP, although they are tracked by US GO-SHIP, and are expected to be made available to the community within 2 years of analysis in accord with funding agency requirements.

The NSF portion of the US GO-SHIP project has been funded with six-year grants, and the NOAA portion operates on year-to-year funding that has been sufficiently stable to allow coordinated observations with the NSF multi-year funding. This funding primarily covers the observational program (data collection) and limited shipboard data management, with most of the funding for post-cruise data management and analysis coming from other sources. Internal governance of US GO-SHIP is provided by its Executive Council, which consists of 14 members of the research community spanning career stage and oceanographic discipline, including representation from participating NOAA laboratories. A subset of Executive Council members serve as the principal investigators (PIs) for the NSF- and NOAA-funded US GO-SHIP projects. The lead PIs of these projects report annually to NSF and NOAA program managers. As indicated above, external oversight of US GO-SHIP is driven by the establishment of GOOS EOVs, as well as community-vetted activities and products that enhance GO-SHIP data quality such as laboratory intercalibrations, standard reference materials, and best practices manuals.

3 Review Process Purpose, Scope, Goals, and Process

The purpose of this external review is to 1) assess the utility of the datasets and the effectiveness of key operational components of US GO-SHIP in advancing the scientific research efforts of the US CLIVAR and OCB communities; and 2) provide input on future directions for the program in advance of the renewal proposals to NSF and NOAA for the next phase of US GO-SHIP. The program review is not intended to supplant or interfere with the proposal review. Rather, this report may help to inform the US GO-SHIP Executive Council in its planning for future activities and operations that can benefit the broad ocean and climate research communities represented by US CLIVAR and OCB.

A review committee of six scientists who are knowledgeable in the science, methods, and challenges of monitoring the ocean's response to climate change was established jointly by the US CLIVAR Program's Phenomena, Observations, and Synthesis (POS) Panel and the OCB Scientific Steering Committee (SSC) in Summer 2018, with terms of reference (Appendix 8.1) developed by the US CLIVAR and OCB Project Offices and vetted by these scientific steering bodies, NOAA and NSF agency representatives, and the US GO-SHIP Executive Council leadership. The review committee members are external to US GO-SHIP, having not received funding through the project awards.

While US GO-SHIP represents a significant component of International GO-SHIP, this review is focused on US GO-SHIP's effectiveness in supporting the research of the US CLIVAR and OCB science communities, not the effectiveness of International GO-SHIP in meeting requirements set by GOOS for component programs that make up the sustained global ocean observing system. A review with that focus would more appropriately be conducted by IOC/GOOS.

The review committee evaluated several components of US GO-SHIP, including its effectiveness in the following areas:

- Advancing the scientific knowledge of the US CLIVAR and OCB communities
- Program implementation – including data collection, quality control, data reporting, and access
- Supporting data synthesis efforts (e.g., heat/freshwater storage and flux, carbon system, biogeochemical cycling, water mass ventilation)
- Supporting model validation and state estimation
- Supporting autonomous sensor calibration and new technology development and deployment
- Scientific and technical staff capacity
- Leadership roles and succession
- Training and mentoring
- Ship endurance and deck/lab/berth space to support data collection
- Coordination across the US GO-SHIP projects and with international GO-SHIP, complementary

observing programs (e.g., biogeochemical (BGC)-Argo, Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM), and US-based science programs that utilize the data (US CLIVAR and OCB)

- Communication within and outside the program

The review committee was charged with developing questions for the community survey to assess the perceived effectiveness of US GO-SHIP in the areas defined above; planning and attending a site visit at Scripps Institution of Oceanography (SIO) with US GO-SHIP PIs and Executive Council members; and preparing and delivering a report to the US GO-SHIP leadership, US CLIVAR POS Panel, and OCB SSC that summarizes the perceived effectiveness of US GO-SHIP in advancing the science of the US CLIVAR and OCB communities and provides recommendations to address perceived gaps and shortcomings of the program.

The review was conducted over the course of a year, starting with the identification of reviewers in Summer 2018 via recommendations from the US CLIVAR POS Panel, OCB SSC, NSF and NOAA agency representatives, and US CLIVAR and OCB Project Office leadership. The review committee met regularly via teleconference with US CLIVAR and OCB Project Office staff throughout the review process and in person during the site visit. In Fall 2018, reviewers worked with US CLIVAR and OCB Project Office staff to develop questions for and implement a community survey on the effectiveness of US GO-SHIP in the priority areas listed above. The survey results were compiled and shared with the US GO-SHIP PIs and Executive Council just prior to a Winter 2019 site visit that took place January 17-18, 2019 at SIO. Day 1 of the site visit (Appendix 8.2. Site Visit Agenda) opened with a welcome and introduction from the review committee chair, followed by presentations from lead PIs and Executive Council members on US GO-SHIP goals and objectives, organization and links to international GO-SHIP, US GO-SHIP observations (L1, L2, L3) and associated scientific and synthesis outcomes, cruise organization, and data management. Then the committee gave a summary presentation of the community survey results, followed by a period of group discussion and Q&A. Day 2 of the site visit opened with a SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis presentation by the lead PIs followed by another round of open discussion and Q&A. The site visit was adjourned by the committee chair, and committee members met afterward with US CLIVAR and OCB Project Office staff to discuss and distill key issues raised during the site visit and start planning the report.

4 Community Survey Results

4.1 Introduction

As part of the review process, the US GO-SHIP review committee created and distributed a survey to the oceanographic community, through the US CLIVAR, OCB, and US GO-SHIP mailing lists. The survey remained open over a 6-week period from November 6 to December 17, 2018, and there were 114 unique respondents. The survey was designed to capture the opinions and perceptions of US GO-SHIP from people associated with the program in a variety of ways. This section of the US GO-SHIP review details the results and summarizes some of the comments that the survey elicited.

This section of the report is a summary of the points made by survey respondents. It is not an endorsement of those points or a set of recommendations. A detailed report of the survey results with quotes from respondents has been shared with the Executive Council (EC) and also appears as part of this report (Appendix 8.3). Respondents were engaged with US GO-SHIP in numerous different ways, and a majority had deep connections. They left many constructive and thoughtful comments that the EC should consider – in the opinion of this committee.

The survey was divided into three main sections. Part I was an introductory section for everyone, asking demographic information and overall perceptions of US GO-SHIP. In Part II, the survey was divided into different parts for different affiliations: 1) program leadership, 2) funded investigators, 3) cruise participants, 4) funding agency sponsors, 5) data users, 6) non-US affiliates, and 7) other interested parties. Part III was for everyone, asking a couple of wrap-up questions and providing space for additional observations or perceptions of US GO-SHIP. The survey was designed to elicit statistical information as well as to elicit free-form responses in many places.

4.2 Survey Results Part I

Part I queried demographic information, as well as overall impressions of the importance of US GO-SHIP to the scientific community and its effectiveness in fostering early career development.

There were a large number of separate affiliations, indicating that the survey was taken by a wide variety of people. This included people from the US and abroad, major oceanographic institutions, government agencies, and universities. Respondents indicated a number of different positions, students (9%), postdocs (8%), faculty (37%), research scientists (31%), government employees (6%) and other (10%).

Respondents were asked about the importance of US GO-SHIP in supporting the specific goals of their research. The responses indicated widespread support for US GO-SHIP. "Critical" or "very important" made up 77% of the responses. When asked how important US GO-SHIP is in supporting the broader US CLIVAR and OCB research objectives, again, the responses indicated widespread support. "Critical" or "very important" made up 93% of the responses.

Important outcomes of US GO-SHIP cruises and datasets included:

- Free access to consistently high-quality datasets to monitor interannual to decadal variability
- Full water column (deep) measurements
- Repeat access to remote, under-sampled regions
- Supporting science – ocean carbon cycle, ocean heat content, climate, anthropogenic carbon uptake and ocean acidification, deoxygenation, mapping circulation pathways, monitoring changes in circulation and water masses
- Validation datasets for modeling
- Calibration datasets for autonomous platforms such as Argo floats
- Early career scientist training
- Providing context for planning regional-scale process studies

These responses fit in directly with the goals of US GO-SHIP.

Respondents were overwhelmingly positive with regards to the impact of US GO-SHIP cruises on their early career experiences. The points brought up by the respondents included:

- US GO-SHIP has been a critical, career building component for many, especially those who have had opportunity to serve as co-chief scientist on cruise(s)
- Important learning opportunity for oceanographic data collection techniques, quality control, and science applications
- Cruises represent important networking opportunities
- Post-cruise collaborations lead to high-level publications

Finally, in this introduction section, respondents were asked to identify their connection with US GO-SHIP, which led them to a unique set of questions in Part II based on their affiliation with the program. The total number of respondents for each affiliation broke down as follows: Program leadership (5), US GO-SHIP-funded PI (11), non-funded cruise participant (32), funding agency sponsor (3), data user (41), non-US affiliates (5), and other interested individuals (17). However, it is important to note that a small number of survey respondents have more than one association with US GO-SHIP and thus took the survey more than once, so the sum of the numbers given above is more than the total number of unique respondents.

4.3 Survey Results Part II

4.3.1 Program leadership (5 respondents)

According to the survey responses, the strengths of the current EC leadership are:

- Effective execution of the observational program and logistics
- Fair decision making
- Effective outreach and early career scientist development
- Maintenance of a bibliography of project results

Concerns include:

- EC members are busy – need more regular communication among members
- Recruitment of chief scientists could be better
- Need mechanisms to move early careers to next level (e.g., moving early career scientists into the US GO-SHIP EC)
- International coordination could be more robust
- Lack of funding for scientific analysis as opposed to data collection
- Issues with groups that do not submit their data
- Planning for the future of the program not adequately addressed

4.3.2 US GO-SHIP-funded PIs (11 respondents)

Survey respondents were asked about the interface between PIs and program leadership, and offered generally positive responses. The available water from each CTD cast ("water budget") is an issue for adding new measurements, and the EC seemed open to new ideas in operations and science as long as it did not interfere with L1 measurements. US GO-SHIP was seen to be willing and eager to collect samples to accommodate other programs like Argo and GEOTRACES.

Survey respondents were asked about the adequacy of funding for making measurements and post-cruise processing, calibration, and analysis. Two-thirds of respondents indicated that funding seemed adequate for collecting measurements, while one-third were concerned about level-funding and associated inadequacies in staffing. As far as post-cruise processing, there was perceived to be a relatively efficient path from sample collection to data availability. The CLIVAR and Carbon Hydrographic Data Office (CCHDO) was sometimes perceived to be slow to add submitted data to the master file and make quick plots to check for questionable data.

4.3.3 Cruise participants (32 respondents)

Of the 32 people who responded, most had attended 1-5 cruises, but some had been on more, including a few who had been on 10 or more. There was a wide variety of different modes of participation, including faculty, students, postdocs, technicians, chief scientists, and data managers.

From the perspective of those who went to sea as US GO-SHIP chief or co-chief scientists, the feedback was mostly positive regarding support from the ship's captain and crew or from the US GO-SHIP EC. There were complaints about insufficient support and compensation for the required work. Communication of chief scientists with the EC was variable, from full support to minimal support.

Cruise participants were given the opportunity to comment on the work environment on board the ship. They generally found it conducive to achieving their science goals. There was an emphasis on the need for better pre-cruise communication regarding prioritization of measurements, cruise objectives, protocols, coordinated shipping, and loading/unloading procedures. UNOLS ships were found to be better managed than NOAA ships in this regard. A few participants commented on inadequate staffing for around-the-clock sampling of key parameters.

As for the data submission process, cruise participants found this to be painless and very well-managed. Delays in posting data publicly may be a result of poor formatting by data submitters. There were suggestions to better enforce proper formatting of data before submission to make the job of CCHDO easier.

An uncomfortably large number (~30%) of participants commented on inappropriate or unethical behavior on US GO-SHIP cruises. Examples included misogyny and sexual harassment, and devaluing of science priorities of lower level (non-L1) measurements.

4.3.4 Funding agency sponsors (3 respondents)

The three sponsors who responded to the survey said that US GO-SHIP proposals rated consistently very good to excellent. Two of three indicated there was not adequate funding for PIs to carry out their work. All said that US GO-SHIP did not take funding away from other equally worthy projects. There was worry that flat funding is making it harder for US GO-SHIP PIs to conduct the important follow-on data analysis needed to advance the science. One respondent discussed the need for better tracking of data usage.

4.3.5 Data users (41 respondents)

Of the data users who responded, most were using the L1 data, though there was also significant interest in the L2 and L3 data. Most people using US GO-SHIP data accessed it through the CCHDO, though there were other important channels mentioned, including the Biological and Chemical Oceanography Data Management Office (BCO-DMO), NOAA National Centers for Environmental Information (NCEI), the GLobal Ocean Data Analysis Project (GLODAP), and directly from the PI. The data are used for a wide variety of applications, including model calibration, carbon system studies, heat and freshwater fluxes, ventilation, calibration of autonomous sensors, and production of gridded data products.

There was widespread praise for CCHDO and its ability to serve program data. Respondents suggested ways to increase awareness of program data, including special sessions, workshops and town halls at national meetings, undergraduate curricula, acknowledgment of data sources in publications, and tracking of data usage. Respondents indicated that attribution of program data needs improvement, and suggested including citation information in metadata and providing citation guidelines.

Some respondents requested a quality-controlled global dataset as well as a gridded product, with both to be frequently (yearly) updated. In addition, there was a request for machine-readable formats, along with python or MATLAB code for reading and visualizing the data.

Respondents were asked about the importance of US GO-SHIP datasets in the broader framework of the Global Ocean Observing System. It was considered to be a crucial element.

4.3.6 Non-US affiliates (5 respondents)

Of the survey respondents, most had a high regard for US efforts, citing good coordination and communication. There were no complaints about cost-sharing fairness. There was especially positive feedback on data management.

4.3.7 Other interested individuals (17 respondents)

People responding to this part of the survey had a variety of connections to US GO-SHIP, including technical manager, potential users of GO-SHIP platforms, and users of the data and publications. A few had previously submitted US GO-SHIP proposals.

4.4 General Comments

This section of the survey provided open comment space to express additional thoughts or ideas with regards to US GO-SHIP. Thus, the comments were wide-ranging. Overall, there was strong support for the program. Below is a summary of key points emerging from the comments:

- US GO-SHIP will need to transition to new leadership as more experienced people retire and move on. However, care must be taken to ensure that the quality of the measurements does not diminish. This requires better documentation of policies and procedures, especially with regards to measurement protocols, deployment and recovery of rosettes, mobilization and demobilization, and data formats and standards. Additional documentation in this area could make it easier for newer participants to get up to speed quickly and spread GO-SHIP data quality standards further in the field of oceanography.
- A standard introductory packet for students and others experiencing their first GO-SHIP cruise would be a big help.
- US GO-SHIP and BGC Argo should be more directly integrated. (2 similar comments)
- GO-SHIP does not get enough credit for its contribution to science in the Southern Ocean. It provides an important baseline and essential calibration point for SOCCOM floats, as well as a platform for deploying the floats. It is important to give this credit to help sustain US GO-SHIP funding. Better coordination between SOCCOM and GO-SHIP is needed to make use of limited funding and resources in the Southern Ocean.
- There is a need to broaden awareness of and involvement in the program and usage of GO-SHIP data. Better publicizing of US GO-SHIP cruise opportunities is one area where this is needed.
- It needs to be made clear that the US CLIVAR/CO_2 Repeat Hydrography Program and US GO-SHIP are not separate programs.
- Shipping is the most rapidly increasing cost for US GO-SHIP participants. A logistics coordinator is needed to help manage this aspect, to identify shipping agents and coordinate shipments across different teams and thus mitigate cost increases.
- Cruises are too often cut short due to weather and CTD wire problems. More time should be built into cruise schedules to accommodate the fact that US GO-SHIP cruises are going to difficult places. The shortage of global-class vessels limits the ability of US GO-SHIP to take advantage of optimum weather windows. Cruises scheduled outside of these windows should get additional ship time as a cushion. This may cost more in vessel days, and science party time, but sufficient time is needed to accomplish cruise goals. Otherwise, the goals may not be met, or station spacing may be larger than optimal.
- The "Cruise data and schedules" table on the US GO-SHIP website does not provide enough cross-linking to the data collected on each cruise. Not all data are accessible via this interface. Efforts should be made to collaborate with other data repositories that collect underway data

on the program cruises (Rolling Deck to Repository (R2R), BCO-DMO, Shipboard Automated Meteorological and Oceanographic System (SAMOS), NCEI).

- It is difficult to get funds to do analysis of US GO-SHIP data.
- US GO-SHIP co-chief scientist role should be open to non-postdocs, and both chief and co-chief scientists roles should be open to experienced technical staff.
- US GO-SHIP should try to incorporate new types of clean sampling (e.g., trace metals); better coordination between GO-SHIP and GEOTRACES may result from this, offering the opportunity for stations to be occasionally repeated to collect more water and help fill in data gaps.

5 Findings and Recommendations

5.1 General

The review committee finds the US GO-SHIP Program to be essential, even critical, to ocean and earth system climate research. The program has provided and continues to provide the highest quality data to the community by way of a well planned and executed observational program and data system that make good use of available resources. Publications resulting from the field expeditions are numerous, wide ranged, and of high quality and impact. The committee finds that the program remains essential to the development of autonomous research platforms, but that such instrumentation cannot replace the observations of highest quality that can only be provided from a shipboard through a program such as US GO-SHIP. With its comprehensive suite of physical and biogeochemical measurements and its global, full water column coverage, US GO-SHIP provides critical calibration and deployment opportunities for autonomous programs and networks like Argo while also providing an important platform for ancillary experimental measurements. Furthermore, the program has provided hands-on oceanographic training for countless graduate students and early career scientists. US GO-SHIP provides leadership for the international community in terms of data quality, development of new measurements, and commitment to the observational program.

US GO-SHIP was created to advance the scientific goals of US CLIVAR and OCB. These goals include improved understanding of ocean heat and freshwater storage and flux, quantification of ocean carbon uptake that allows for balancing of the global carbon budget, understanding of ventilation of deep and intermediate waters, improving the calibration and validation of climate models and state estimates, and calibrating autonomous sensors. By all accounts, the program appears to be meeting these goals. High quality science has emerged from the data collected by US GO-SHIP (Feely et al., 2014; Talley et al., 2016 and references therein).

It is the recommendation of the review committee that the US GO-SHIP Program be continued and enhanced, with sufficient resources allocated to ensure the continuation of the observational program and the data system. Detailed discussion of each of the topics considered in our terms of reference, and recommendations that result from these, are listed in the sections below. In each section, we have attempted to summarize strengths and weaknesses of the existing program, and challenges and opportunities for the future, along with our recommendations.

5.2 US GO-SHIP Data: Collection, Quality Control, Reporting, Access, Synthesis

5.2.1 Quality control

One of the key features of US GO-SHIP as an observing effort is that the data it collects are of highest quality and systematic. High accuracy is needed for a number of the applications for which GO-SHIP

is used, including water mass changes in the deep ocean and calibration of autonomous platforms. Thus, it is appropriate to consider whether US GO-SHIP is meeting this general goal in its operations and products, and to consider the processes by which US GO-SHIP assesses and maintains the quality of its data. Uniformity of process and continuous training is important for a program that involves multiple ships, multiple PIs and chief scientists, and a program run by a committee.

Quality control on US GO-SHIP cruises is the responsibility of each measurement group, though the NOAA carbon groups work jointly for consistency. Data collection and measurement procedures for GO-SHIP parameters are compiled in a comprehensive series of documents that are collectively known as the international GO-SHIP "Hydro manual" (*GO-SHIP Repeat Hydrography Manual: A Collection of Expert Reports and Guidelines*, available at http://www.go-ship.org/HydroMan.html). This compilation should be continually updated and evaluated in light of changing technology, measurement priorities, and rotating personnel.

One of the main concerns expressed during the site visit regarding US GO-SHIP quality control and data assembly was succession planning. For example, an apparent threat is the retirement of Robert Key (Princeton) and tenuous position of Alex Kozyr (NOAA NCEI), both of whom contribute to quality control, analysis, and management of US GO-SHIP data. There are next generation oceanographers gradually gaining expertise, but there is no formal process, and thus no guarantee, that the excellence of the senior generation that has made GO-SHIP the "gold standard" of oceanographic sampling will be maintained.

5.2.2 Data archival and distribution

US GO-SHIP data are archived and/or served by multiple groups and data management entities:

- CCHDO (https://cchdo.ucsd.edu/) for conductivity, temperature, and depth (CTD) and bottle data, but also
- University of Hawaii Currents Group (https://currents.soest.hawaii.edu/home/ and also https://currents.soest.hawaii.edu/go-ship/ladcp/),
- Lamont Doherty Earth Observatory (LDEO) Carbon Dioxide Research Group (https://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/pCO2data.html),
- Rolling Deck to Repository (R2R) Program (https://www.rvdata.us/),
- BCO-DMO (https://www.bco-dmo.org/),
- Environmental Systems Science Data Infrastructure for a Virtual Ecosystem (ESS-DIVE) for carbon (https://ess-dive.lbl.gov/), and
- NOAA NCEI Ocean Carbon Data System (OCADS; https://www.nodc.noaa.gov/ocads/).

Detailed information is compiled for each cruise in the "hydro-table" that is available on the US GO-SHIP website (https://usgoship.ucsd.edu/hydrotable/), including dates, ship, data collected, chief scientist, ports, links to constituent datasets, and links to cruise reports. This table is a crucial part of US GO-SHIP, as it weaves together the disparate datasets stored in the repositories listed above. However, this sort of compendium is vulnerable to the information and links within it becoming

outdated. Furthermore, as US GO-SHIP data are stored in several different places, the program may be vulnerable in the future to any of them losing funding, interest, and key personnel. The review committee recommends that US GO-SHIP reevaluate the "hydro-table" they are using for managing program data and develop a more stable platform for integrating cruise metadata and pointing to US GO-SHIP datasets that can be easily accessed, maintained, and updated by dedicated staff to ensure up-to-date information at all times.

With funding from an NSF award that is separate from US GO-SHIP, CCHDO takes on the primary task of managing both US and international GO-SHIP hydrographic data, although that funding does not explicitly include data management for non-US cruises. In addition to its director (0.25 FTE), CCHDO has 4 self-funded (100% soft money) staff members and a few students. Sarah Purkey and Jim Swift of SIO serve as CCHDO scientific advisors. The majority (75%) of survey respondents access GO-SHIP data through CCHDO. CCHDO contains >1600 cruises in its archive, in coordination with other data centers like BCO-DMO and OCADS/NCEI, with continual efforts to keep all bottle data up to date and ingest new datasets. US GO-SHIP acoustic doppler current profiler (ADCP) data are managed separately from hydrographic data through the University of Hawaii (underway data) and LDEO (lowered data) components, under subcontract from the SIO NSF data management grant. Non-US GO-SHIP ADCP data are not served by these archives, and there is little coordination between US and non-US ADCP data archival activities. The review committee is concerned that the ADCP data are currently underutilized by the community. Underway pCO_2 data are archived by OCADS/NCEI and SOCAT. SOCAT's funding ends in 2020, and thus their archival activities are at risk.

While the survey respondents were satisfied with data accessibility, there were a few suggestions. One noteworthy request was for a concatenated product of CTD and CTD oxygen data, analogous to what GLODAP has done for bottle data. Providing these data in a readily accessible format (e.g., a CDF file), ideally updated annually, would facilitate better integration into common analysis software (e.g., Ocean Data View). The review panel agreed that a concatenated data product was a straightforward way to increase the accessibility of GO-SHIP hydrography, as many users would like to analyze much of the GO-SHIP repository, and having to download one or more files per cruise can be tedious. An alternative to a concatenated product could be sample code to download and read the data, provided, for example, in the form of a Jupyter notebook.

5.2.3 Data submission

US GO-SHIP PIs are responsible for turning their hydrographic data over to CCHDO when their cruise is finished and quality control is complete. Although the process for submitting data to CCHDO is straightforward, and submitted data are available on the CCHDO webpage within days as 'unmerged' data sets, there are often long delays in finalizing and merging submitted datasets on the CCHDO webpage. This is due to a combination of limited staffing and heavy workloads at CCHDO, and also to data being submitted by PIs in inconsistent formats.

5.2.4 Data citation

The review committee notes the lack of credit given to US GO-SHIP data collection efforts in published papers utilizing US GO-SHIP data. In the future, CCHDO is moving toward assigning digital object identifiers (DOIs) to both current and future datasets to increase the profile and discoverability of GO-SHIP datasets, enabling them to be included in the list of citations in journal articles.

5.2.5 Recommendations

The review committee recommends that careful attention be paid to continually updating standardized protocols for data collection and measurement, as well as the hydro-table on the website, which points users to various locations for obtaining the data. The review committee also supports the recommendation of a concatenated data product for US GO-SHIP hydrography to increase accessibility and broaden applications for these data. To streamline data submission, the committee recommends putting more onus on PIs and chief scientists to submit their data to CCHDO in the recommended formats with appropriate metadata to avoid delays in processing and posting on the CCHDO web page. To increase discoverability and provide opportunities to cite data collection efforts, the committee supports the assignment of DOIs by the allied data centers, including CCHDO, to US GO-SHIP datasets.

5.3 Workforce Development

5.3.1 Mentoring and training of the next generation

The large-scale field effort of the US GO-SHIP program offers a powerful platform for leadership training, mentoring, and career development of early career scientists. As noted in several of the survey responses, participation in GO-SHIP cruises at the undergraduate or graduate level has influenced individual decisions to continue on a spectrum of career paths in oceanography. Some students have pursued and attained advanced degrees, utilizing GO-SHIP data as a critical element of their work; many continue to rely on or be involved in data collection and analysis efforts as they enter postdoctoral and faculty roles. Others have benefited from opportunities to develop technical proficiency in state-of-the-art measurement approaches and have parlayed these skills to technical roles in academic and government labs.

At the heart of this workforce development pipeline are frequent opportunities for interaction and information exchange among scientists from all career stages and a breadth of scientific roles, as well as a sense of community surrounding involvement with the US GO-SHIP program. The most obvious example is embodied in the role of the early-career (typically postdoctoral) co-chief scientist on every cruise leg. While each individual co-chief scientist experience is unique, it is an opportunity in all cases to experience planning and logistics management for major sea-going field campaigns, and in communication and leadership skills necessary for effectively executing and/or adjusting a research plan under often challenging at-sea conditions. Several former co-chief scientists have returned to participate as the chief scientist on subsequent GO-SHIP voyages, accruing more responsibility and additional leadership experience. At all stages, co-chief and chief scientists benefit greatly from a large GO-SHIP community with decades of experience in executing repeat hydrography occupations.

Several other important mechanisms facilitate knowledge transfer and career development for early career scientists. The allocated support for graduate student participation as paid CTD watch-standers provides an important vehicle for student involvement and career development, particularly for those who may be working under the supervisions of PIs not formally affiliated with the US GO-SHIP program. Opportunities for students to participate in collection of Level 1 (core) or funded Level

2 (highly desirable) measurements are also available via individual awards to GO-SHIP-supported or affiliated PIs. A US GO-SHIP cruise will therefore typically involve those undertaking their first scientific voyage working alongside those who have spent many years or even a career in sea-going scientific research. Such experiences can and have been instrumental for those that receive them.

However, in survey results and during the site visit, it was acknowledged that many in the community-at-large and those external to the community are unaware of these valuable career development opportunities, as advertisements are not consistently publicized as broadly as they could be. The cause seems to be a lack of time for the Executive Council to manage these communications in terms of collecting, reviewing, and selecting applications from a potentially large applicant pool. Currently, there is no formalized procedure for this review and selection process. A broad and diverse pool of early career scientists would allow for a sustained flux of new perspectives to the program and also entrain new leadership to facilitate succession planning, and is thus a critical need for US GO-SHIP.

5.3.2 Leadership succession planning

Leadership succession plans within various science components of the US GO-SHIP program range from robust to absent. Carbon system measurements have leadership transition strategies in place. Logistics support based at Scripps Institution of Oceanography, including cruise planning, chief and co-chief scientist support, student support, the website, and data tracking, has recently been transitioned. Several program areas were lacking a clear leadership transition strategy at the time of this review; these include transient tracer observations and NOAA CTD/hydrography management. The Executive Council has recently added new members from NOAA labs, reflecting a transition in leadership there; plans for transition of leadership under the NSF-supported portion should be a focus of the new proposal.

One factor influencing workforce development and leadership transition readiness is the capacity for scientific analysis of US GO-SHIP data by the scientists collecting it. With the exception of limited postdoctoral support, there is no commitment to support within either NSF or NOAA for follow-up data analysis and scientific research. A direct consequence of the lack of funding for science discovery is that the PIs who have the requisite expertise to collect climate-quality data can receive little credit for this work in the publications that ultimately result from the freely available data. Not surprisingly, the areas within the US GO-SHIP program with the most uncertainty regarding leadership transition are those for which funding for science interpretation has been inconsistent. Clearly, a robust leadership transition plan should address the gap in analysis of the data by those collecting it, recognizing this as a barrier for recruitment, professional development, and retention, in order to maintain a healthy, vibrant program capable of making sustained observations into the next decade.

5.3.3 Recommendations

The review committee recommends more consistent and effective communication by US GO-SHIP of opportunities to participate in the program. In addition, explicit plans for leadership succession are needed so as to ensure effective transfer of knowledge and continuation of high-quality measurements. Furthermore, a more consistent process across the US GO-SHIP measurement suite for supporting data analysis and science discovery is needed to ensure that the scientists involved in collecting these valuable datasets have an opportunity to participate in and receive credit for some of the scientific findings that emerge from them.

5.4 Ships

The review committee was charged with considering the suitability of endurance, deck, lab, and berth space for data collection and related research aboard the research vessels in the US fleet for GO-SHIP research purposes. To answer these questions, we considered the results of the community survey, the site visit, subsequent interviews with the US GO-SHIP Executive Council members, and publicly available information.

The primary significant conclusion reached by the review committee was that the current "Global" or AGOR-23 class vessels (*Revelle*, *Atlantis*, *Thompson*, and *Brown*) and the RVIB *Palmer* and USCGC *Healy* are the only vessels in the US research fleet that have sufficient facilities to carry out sampling of the complete Level 1 and Level 2 parameter sets and still have room for Level 3 studies at some level on most cruises. The new "Ocean" class vessels (e.g., *Armstrong*, *Ride*) have trans-ocean-basin capability but insufficient laboratory and berthing facilities to conduct the complete Level 2 parameter sets and also support Level 3 measurements. Therefore, configuration, maintenance, and availability of these five vessels and their successors were the main topics considered by the committee.

5.4.1 Endurance

The review committee understood that the time-at-sea ability of the Global class vessels (ca. 45 to 52 days) is sufficient to carry out the GO-SHIP survey lines and transits currently assigned to the US program. The *Armstrong* and *Ride* have maximum endurance of ~ 39 days at sea, *Sikuliaq* of 45. In recent years individual section legs have been 36 days (P18 Leg 1), 42 days (I8S), 45 days (P06 Leg 2). The longest single legs currently in the program are the ARC01 section occupied on the on the *Healy* in 2015 (64 days) and S4P section plus the Antarctic segments of some Pacific meridional lines (~60 days), which have been occupied twice using the *Palmer* during the current GO-SHIP era. Longer sections (i.e., the current multi-leg sections without port stops) would cause problems with consumables and sample storage space for the PIs, as well as the vessels, and may run up against regulations governing crew continuous time at sea. On a related note, it was also suggested that additional ship days should be budgeted for each section to help account for weather or engineering delays and autonomous vehicle deployments, which could also have implications for sample and consumable storage.

5.4.2 Deck space

The Global class vessels have sufficient deck space and electrical/water supply to support 3-4 20' lab vans, which are sufficient to meet the GO-SHIP requirements, with slots available for other applications (such as storage or hazmat or a level 3 measurement team). Otherwise, the programs require heavy use of the main hydrographic winch and large rosettes. This leaves space (if not time or berths) for Level 2 and Level 3 programs to deploy instrumentation on the cruises. At present, the Ocean-class vessels *Ride* and *Armstrong* do not support moving the rosette in and out of a sheltered area for sampling, as is typically done on the *Revelle* and the *Brown*. There are some conditions where weather conditions may not permit on deck sampling (freezing temperatures, spray) while rosette deployment is possible, which would result in lost cast or sampling opportunities. The *Sikuliaq* and the *Palmer* have Baltic rooms (a staging bay with opening/closing doors for rosette preparation and sampling out of the weather) to help with these difficulties.

5.4.3 Berthing

GO-SHIP cruises frequently sail with a full science complement. The number of berths available for science is not the same for each ship, and can vary for specific missions (Table 1). Foreign observers, when required, can take up to two science berths. This has been a particular issue on the last two I9N sections, where two foreign observers were embarked but the ships were nevertheless not permitted to conduct research in the foreign waters in question. The *Brown* (and the *Thompson*, on long cruises) embark medical officers, whereas on other vessels, some members of the ship's complement have EMT training. On the *Atlantis*, there are some berths that are generally reserved for *Alvin*/*Jason* users, which can severely restrict the number of the science party. The variability in bunk availability has the largest effect upon the Level 3 programs, which may not be able to participate at all in some cruises because of a lack of berthing. However, some of this issue has been alleviated by the departure of some Level 3 programs (i.e., trace metals) for GEOTRACES.

Table 1. Science berths on research vessels

Vessel	# Berths	Comments
Revelle	37	SIO marine techs are science berths
Atlantis	36	2 reserved for Alvin/Deep Submergence Operations Group (DSOG) (only when dives are planned)
Thompson	36	-1 when medic embarked?
Brown	30	28-30 depending on gender distribution of scientists and crew
Palmer	39	
Ride	25	SIO marine techs are science berths
Armstrong	24	
Sikuliaq	24	

CTD operations plus Level 1 and 2 measurements require 32 personnel aboard as illustrated in Table 2, which details the science complement for the 2016 reoccupation of the I8S section, a representative US GO-SHIP cruise, on the *Roger Revelle*. This expedition included one Level 3 project (colored dissolved organic matter (CDOM) for NASA) and was not required to carry foreign observers. The standard science complement for GO-SHIP cruises clearly exceeds the available bunks on the Ocean class vessels, as well as *Atlantis*, if the bunks reserved for Deep Submergence Operations Group users are not released.

Table 2. Science complement for US GO-SHIP cruise I8S 2016 (R/V *Revelle*)

Role	Number	Comments
Chief Scientist/Co-chief	2	
CTD Watchstanders	5	grad students
Data / CTD / Salts	2	Level 1 measurements
O_2 / Data	2	Level 1 measurements
Marine/Comp Technicians	2	
CO_2 System (Dissolved Inorganic Carbon/Total Alkalinity/pH)	5	Level 1 measurements (includes Level 2 pCO_2)
Chlorofluorocarbons	3	
Dissolved Organic Carbon/ Total Dissolved Nitrogen	1	Level 1 measurements (includes Level 2 ^{14}C)
Nutrients	4	Level 1 measurements
Lowered ADCP	1	Level 1 measurements
Salinity / Oxygen	3	Level 1 measurements
Optics & CDOM, Chl, pigments	2	Level 3 measurements
Total	**32**	

5.4.4 Laboratory Space

Laboratory space is comparable across the Global class vessels, but there is considerable variability in individual facilities. For example, *Brown* has a separate temperature-controlled room for salinometer use in the Hydro lab, and a dedicated floor drain for underway instrumentation, which are not found on the other Global class vessels. Spaces listed as "computer" labs available for science are mainly committed to permanent computer infrastructure, so much of this space is not available

for additional science use. The available space and facilities on the Global class vessels are certainly sufficient to carry out GO-SHIP activities, with varying amounts of space available for Level 3 projects. However, the Ocean class vessels *Ride* and *Armstrong* have insufficient interior lab space relative to the Global class vessels (Table 3).

Table 3. Science interior laboratories and sizes

Vessel	# Labs	Size of Lab Space(s)
Revelle	4	4,000 ft^2 (individual spaces similar to *Atlantis*)
Atlantis	4	1,676 ft^2 (main) 549 ft2 (bio) 700 ft^2 (hydro) 234 ft^2 (wet) 836 ft^2 (computer) plus 500 ft^2 (science stores)
Thompson	4	(similar to *Revelle* and *Atlantis*)
Brown	4	1,745 ft^2 (main) 330 ft2 (bio) 693 ft^2 (hydro) 230 ft^2 (wet) 610 ft^2 (computer) plus 358 ft^2 (science stores)
Palmer	6	1,150 ft^2 (computer) 1036 ft^2 (dry) 460 ft^2 (bio) 416 ft^2 (wet) 445 ft^2 (hydro) 298 ft^2 (aquarium)
Ride	3	2,035 ft^2 (similar to *Armstrong*)
Armstrong	3	1,023 ft^2 (main) 398 ft^2 (wet) 311 ft^2 (computer)
Sikuliaq	4	1,000 ft^2 (main) 510 ft^2 (wet) 180 ft^2 (analytical) 410 ft^2 (computer)

5.4.5 Present and future availability

Scheduling and maintenance are important considerations governing availability of the appropriate vessels for the US GO-SHIP lines. The current pace of GO-SHIP line reoccupations is one section annually for a UNOLS (or NSF Office of Polar Programs) vessel and one section annually for the NOAA vessel. A reduction in this pace could threaten the ability of the program to reoccupy each section on the planned decadal time scale, and may have other less obvious consequences, such as making it difficult for PIs to retain skilled personnel, or maintain routine high quality measurements. This in particular applies to the Scripps Oceanographic Data Facility (ODF), which has been an essential part of global hydrography since the WOCE era and for decades prior.

One major routine impact on scheduling is annual shipyard visits. Obviously this part of the schedule affects all potential users of the research fleet. Currently, there is capacity to easily account for potential schedule conflicts (i.e., the *Thompson* is now replacing the *Revelle* on the 2019 I6S section while the *Revelle* is preparing for midlife refit). Reduction in the size of the fleet could make scheduling more difficult even in a year when ships are undergoing routine preventive maintenance.

All of the global class vessels have had issues with maintenance or engineering that have affected scheduling, but it was noted that the *Brown* has had an especially large number of engineering issues

that have significantly impacted US GO-SHIP expeditions while they were underway. Maintenance issues of this sort have downstream effects that impact PI project budgets in particular (i.e., unbudgeted per diem for extended port stays for cruise personnel and the corresponding changes in air travel) and can result in reduction in the number of stations occupied if rescheduling becomes impossible. As the vessels in this class age, maintenance issues are likely to increase. Midlife refits are underway for the UNOLS vessels that should help with this issue. There are currently no plans for a midlife refit of the *Brown*.

Scheduling in the context of competition for ship time is also an important factor governing availability of the critical vessels. The current trend in oceanography is to maximize utilization of vessels on cruises, so demand for time on the UNOLS Global class vessels from other researchers appears to be high for large sectional program expeditions (e.g., GO-SHIP, GEOTRACES). In recent years, NASA has also chartered global class ships for interdisciplinary field expeditions. Because of schedule conflicts on two occasions, the RVIB *Palmer* has been used for research cruises in subtropical waters when another global class ship was unavailable. This led to problems with temperature control, particularly on the first cruise, so this situation is suboptimal. Atlantis is also largely committed to *Alvin* and other deep-submergence operations, so her time available for other research projects is limited. It was stated by the NOAA scientists that GO-SHIP expeditions are the highest priority in scheduling for the *Brown*, so maintaining the pace of NOAA's commitment to GO-SHIP lines in the context of competition for ship time is not an issue.

Finally, all of the Global class vessels are facing retirement on the horizon. They were originally designed for a 30-year service life after delivery in the 1990s. The ongoing midlife refit of the *Thompson*, *Revelle*, and *Atlantis* will extend their lifetimes another 15 years, and there is a current community-driven effort to develop specifications for new Global class vessels. NOAA will not be participating in a future Global class vessel purchase as they did for the AGOR-23 class, so it seems possible or likely that the number of Global class vessels will decrease in the future. UNOLS and NSF Office of Polar Programs have been discussing alternatives for replacement when the *Palmer*'s service lifetime ends in 2022. *Healy's* service lifetime extends through 2030.

5.4.6 Rosettes and profile sampling resolution

The review committee discussed the availability of rosettes with the US GO-SHIP council members during the site visit. Currently, the availability of 36-place, 10L Niskin rosettes is limited, and they are in fact prohibited by NOAA for use on the *Brown*, due to concerns of exceeding wire tension limits. Some discussion of the need for 36 vs. 24 sample profiles ensued, without a clear resolution. It is apparent that for baseline sampling, 24 samples in a profile is sufficient, but increased resolution in areas of stronger gradients is also desirable. One impact this situation may have is with regard to water budgets, particularly in the context of Level 3 measurements. Larger volume samples for particle measurements or biological measurements could be more easily accommodated by having additional bottles available for multiple trips at selected depth horizons. This is more difficult when only 24 bottles are available for a cast.

5.4.7 Recommendations

The review committee recognizes that the Global class vessels are essential for achieving the goals of the US GO-SHIP Repeat Hydrography program, and no other vessels currently in the US research fleet can meet these needs. At present, these vessels can carry out the Level 1 and 2 sampling programs on the current GO-SHIP lines and can accommodate some amount of Level 3 research. Moreover, only the Global class vessels have the endurance to carry out the long GO-SHIP legs. Continued availability of vessels of similar specifications into the future is essential to support the pace of expeditions needed to repeat the global survey every decade, and if Level 3 measurements are to continue as part of the program. The committee supports the development of new Global class vessels to ultimately replace the current fleet, preferably at the same number of ships, to ensure that the pace of the GO-SHIP repeat hydrography program can be maintained. The committee recommends that the US GO-SHIP Executive Council continue to engage with UNOLS to plan and develop new Global class vessels, as this will be critical to the success of the program in the future.

5.5 New Technology and Observing Opportunities

GO-SHIP voyages have a clear track record of facilitating tests of new sensors and enabling researchers (often students and postdocs) to access very remote ocean regions and water samples. These piggyback activities have indisputable value, both for the individuals and the community as a whole. However, the framework and decision process with which 'Level 3' measurements are selected for any particular voyage is ad hoc.

Moreover, an overall framework that rationalizes the "Level" for each parameter is lacking. It appears as if the different parameter ratings in GO-SHIP partly support the concept that parameters/or sensors that would be experimental (Level 3), then globally measured (Level 2) and then of widespread availability and uptake to be required (Level 1). However, this is not well articulated, not very deliberately tracked or discussed. All indicators are that sensor development will continue to accelerate and the biological community will continue to seek broader scale observations. Increased advertising of these opportunities should also be a goal of the program. Thus, demand for access to these opportunities should be expected to increase, and this will require that a clearer process and framework are put in place.

5.5.1 Recommendations

US GO-SHIP should establish a consistent and more transparent framework and set of goals for Level 3 activities, and a process for applying for access to berths at sea. The intent and concept of parameters (or sensors for existing parameters) to move from experimental (L3) to global pilot (L2) to (if sensible) globally prescribed (L1) also be articulated. With such an effort in place, the US Program can be better positioned for advocating a consistent approach for GO-SHIP internationally.

5.6 Program Coordination

Several challenges facing US GO-SHIP center around the themes of coordination, logistics, data and metadata tracking, and outreach. For instance, the GO-SHIP function as an 'access platform to remote parts of the ocean' for Level 3 measurements, appears to be presently run in an ad hoc way with little strategic guidance or a clear application process. Input from Chief Scientists suggests that logistical, clearance, and compliance processes are increasing in complexity, while the staff time to deal with these is decreasing. Tracking data delivery, particularly Level 2 and 3 data, has not been done routinely. For example, the links to shipboard meteorology data are out of date with no access to recent voyages.

The very busy national leadership team is struggling to meet these increasing demands. This will only be exacerbated as internationally GO-SHIP expands the parameters it plans to collect and moves into possible multinational voyages. While the review committee has been immensely impressed with the efficiency and leanness of the US GO-SHIP organization structure, we believe the program is maturing and expanding in a way that requires more support.

One way to solve some of these and other challenges is to establish a US GO-SHIP project office, working under the guidance of the lead NSF and NOAA PIs, and working with the international GO-SHIP committee and its part-time Technical Coordinator. A US project officer could support specific needs of US GO-SHIP and ensure contributions to activities of the international committee. Roles the project officer could take on include:

- Update and maintain the US GO-SHIP website
- Coordinate outreach – blogs, media, image, and video library
- Organize US Executive Council meetings, capture notes, and ensure follow up on action items
- Develop best-practice guides for chief and co-chief scientists
- Organize debriefings of US chief scientists and track any actions resulting
- Support US GO-SHIP chief scientists and contributing teams (such as ODF) with logistics, shipping, clearance, and compliance requirements
- Support cruises by advertising and tracking applications for chief, co-chief scientists and graduate student assistants
- Track papers and theses based on GO-SHIP data, particularly on the less well captured outcomes from Level 2 and Level 3 data; include in international bibliography
- Work to ensure proper citation/acknowledgment of GO-SHIP data, via clear acknowledgment texts and communicate this on the site
- Work with the international GO-SHIP committee and GO-SHIP data access centers to track data flow (early release through final), including Level 2 and Level 3 data
- Expose GO-SHIP data more prominently on the web and keep links up to date
- Write a data FAQ
- Coordinate with US CLIVAR, OCB, the international GO-SHIP committee, and other national and international organizations as needed
- Produce an annual report that summarizes both formal output such as publications as well as

synergistic accomplishments (see Recommendation 5.7.1).

- Support the Executive Council in developing long-range plans for US GO-SHIP and its coordination with international GO-SHIP
- Ensure rotation of the Executive Council occurs according to the Terms of Reference
- Coordinate review of proposed piggyback work and new measurements

5.6.1 Recommendations

US GO-SHIP should create the position of project officer (0.5-1FTE), working under the NOAA and NSF lead PIs and Executive Council, to support smoother operations, bolster the profile of US GO-SHIP and improve coordination with international GO-SHIP.

5.7 Unique Contributions of US GO-SHIP to the Global Ocean Observing System

The review finds that US GO-SHIP, as a major contributor to international GO-SHIP, plays a crucial role in the GOOS by:

- Offering the only broad-scale global repeat deep ocean measurements of key physical and biogeochemical properties. GO-SHIP is the current centerpiece of the Deep Ocean Observing System.
- Collecting data at an accuracy far greater than other networks. This makes it an essential calibration/validation dataset. GO-SHIP data have been routinely used for over two decades to provide highest accuracy for the global data sets used to calibrate core Argo CTD data. The emerging deep Argo and BGC-Argo missions will be even more heavily reliant on GO-SHIP data for this purpose.
- Providing access to remote ocean regions for many networks, deploying over 1,000 profiling floats and also surface drifters.
- Being a key training ground for the next generation of sea-going observational ocean scientists and technicians, essential for the long-term sustainability of many networks, not just GO-SHIP.
- Offering a critical platform for new sensor and laboratory analysis testing via either piggyback mounts on the CTD package or use of excess sample water. This usage is enabled by the unprecedented accuracy of GO-SHIP sensor and analysis datasets.

GO-SHIP provides a platform for several activities that are the backbone of the present and future of oceanographic science. Yet, the ocean and climate community is largely unaware of these critical contributions.

5.7.1 Recommendations

Produce a brief annual report that includes highlights of these synergistic activities. The Executive Council should work with international GO-SHIP and JCOMMOPS to decide what key metrics could be tabulated without excessive additional effort (e.g., the numbers of floats and drifters deployed, the number of piggy-back experiments accommodated, data downloads). More standard metrics of output such as publications and data products should also be presented. These reports should be widely distributed to the ocean and climate communities, including by the US CLIVAR and OCB programs. A more formal report summarizing the outcomes and achievements of US GO-SHIP (e.g., Feely et al., 2014) should also be produced every 10 years.

5.8 Work Environment

A substantial percentage of survey respondents (30%) indicated that they had experienced sexual harassment or misogynistic behaviors; unethical conduct; or the devaluation of science activities not related to Level 1 measurements. During the site visit, the review committee was told that the UNOLS and NOAA Office of Marine and Aviation Operations are implementing updated conduct rules/procedures with respect to sexual harassment, which is a positive step. The concern of devaluing of non-L1 science priorities during a cruise is more unique to US GO-SHIP and deserves attention. Though the review committee finds "unethical behaviors" to be poorly defined, this is also a concern.

5.8.1 Recommendations

US GO-SHIP should work with its science parties, and with NOAA and UNOLS to address community concerns about the work environment aboard its cruises. All participants, regardless of gender, race, or identity should be respected and have their contributions valued.

Extra considerations specific to US GO-SHIP cruises, specifically the concern of devaluing of non-L1 science priorities, must also be addressed with all members of the crew and science parties at the start of each expedition. These discussions should include clear procedures for reporting of misconduct, discussion of the potential consequences, and encouragement to report episodes. Though the review committee finds "unethical behaviors" to be poorly defined, it is clear that all parties should have an established line of reporting with respect to any concern about behavior of others onboard.

6 Conclusions and Overarching Recommendations

US GO-SHIP represents a critical observational cornerstone for the US CLIVAR and OCB research communities. In addition to providing an irreplaceable suite of repeat hydrographic data in support of research on the ocean carbon system, heat and freshwater storage and flux, and deep and shallow water mass formation and ventilation, US GO-SHIP datasets are used for validation of earth system models and for calibration of autonomous sensors. Through the latter, US GO-SHIP supports the Argo program and other autonomous networks. US GO-SHIP also provides a critical platform to accommodate ancillary measurements that support complementary research projects. Overarching recommendations to address program concerns emerging from this review are as follows:

1. Centralized coordination – the program's implementation currently relies on several soft money-supported PIs with many other competing obligations. A program of this stature and importance to such a large faction of the oceanographic community should have dedicated support for at least one 0.5-1.0 FTE project officer to manage the administrative, coordination, and communication tasks that are so critical to the functioning, transparency, and equitability of US GO-SHIP, with key roles as follows:

- *Support chief and co-chief scientists:* The limited salary support that is currently provided for chief scientists does not begin to cover how much time is invested in leading a GO-SHIP cruise. To enable the chief/co-chief to focus on achieving the scientific goals of the cruise, a coordinating body could assist in obtaining EEZ and foreign national clearances, pre- and post-cruise communications with cruise participants, assembly of associated shipboard sample collection and analytical procedures, management of sample shipping, detailed planning of cruise mobilization and demobilization and other ship operations
- *Communication and increased transparency:* Update and maintain US GO-SHIP website, social media presences and other media outlets; advertise US GO-SHIP seagoing opportunities to the broader oceanographic community; support regular teleconferences/meetings of the Executive Council and communications with International GO-SHIP; oversee program reporting and metrics
- *Policies and procedures:* Formalize cruise application and review process, leadership transition, L1/2/3 measurement specifications and progression, harassment policies, and clearly define and communicate duties and expectations of cruise chief/co-chief scientist and participants

2. Leadership succession – The leadership of the program largely consists of mid-senior-level PIs, many of whom are approaching retirement, with few plans for leadership transition. The program needs a formal mechanism for training new people to apprentice and eventually assume leadership of key program components, including parameter sets (e.g., tracer program with loss of J. Bullister, NOAA physics/CTD data), data management (e.g., tenuous support of A. Kozyr at NOAA/NCEI), and data analysis (e.g., retirement of R. Key)

3. Strategic planning – While there have been countless scientific achievements that have emerged from US GO-SHIP, there has been very limited support from NSF and NOAA for science and data analysis, which greatly increase program impact. GO-SHIP would also benefit from an overarching international strategic plan to provide cohesive vision for national contributors and justify increased investment for complementary measurement additions, data analysis, staffing, and scientific analysis.

4. Ships – US GO-SHIP operations heavily rely on the upkeep and availability of global class research vessels. Regional class research vessels are inadequate to carry out this program's sampling goals, and as international vessels become available, there is potential for discrepancies in US vs. international classifications of global vs. regional vessels. Global class vessels in the current UNOLS fleet are aging; while some are undergoing mid-life refit, others are approaching retirement, with no replacements on the horizon. UNOLS vessel planning must consider the endurance, deck, lab space, and berthing requirements of large sectional programs like US GO-SHIP in planning for future research vessels. In addition, NOAA's vessel R/V Brown has no plans for a mid-life refit, can no longer accommodate the larger Niskin rosette that is optimal for sampling, and has historically had a great number of pre-cruise maintenance and clearance delays that have negatively impacted cruise operations. If ships cannot be suitably maintained and/or replaced, then extra days must be added to cruises to accommodate disruptions to cruise operations.

5. Data – US GO-SHIP has a well-established reputation for generating high-quality oceanographic datasets. However, a clear leadership transition for data quality control and analysis is needed to ensure that this community gold standard is maintained. The review committee also supports CCHDO's planned assignment of DOIs to all US GO-SHIP datasets, which will help track data usage and provide a mechanism to credit data providers who aren't necessarily authoring all of the publications that utilize GO-SHIP data. More accountability on the part of data submitters, particularly in meeting data formatting requirements, is needed in order to streamline the data submission process and ensure that data are posted in a timely manner. To increase utility of the datasets, a regularly updated gridded product for CTD and oxygen data (analogous to the GLODAP product for bottle data) is also recommended.

6. Work environment - US GO-SHIP should work with its science parties, and with NOAA and UNOLS to ensure a positive work environment for all participants in its cruises. All participants, regardless of gender, race or identity should be respected and have their contributions valued. Clear mechanisms for addressing concerns should be in place and explicitly communicated.

7 References

Feely, R. A., L. D. Talley, J. L. Bullister, C. A. Carlson, S. C. Doney, R. A. Fine, E. Firing, N. Gruber, D. A. Hansell, G. C. Johnson, R. M. Key, C. Langdon, A. Macdonald, J. T. Mathis, S. Mecking, F. J. Millero, C. W. Mordy, C. L. Sabine, W. M. Smethie, J. H. Swift, A. M. Thurnherr, R. Wanninkhof, M. J. Warner (2014). The US Repeat Hydrography CO_2/Tracer Program (GO-SHIP): Accomplishments from the first decadal survey. A US CLIVAR and OCB Report, 2014-5, US CLIVAR Project Office, 47 pp.

Talley, L. D., R. A. Feely, B. M. Sloyan, R. Wanninkhof, M. O. Barringer, J. L. Bullister, C. A. Carlson, S. C. Doney, R. A. Fine, E. Firing, N. Gruber, D. A. Hansell, M. Ishii, G. C. Johnson, K. Katsumata, R. M. Key, M. Kramp, C. Langdon, A. M. Macdonald, J. T. Mathis, E. L. McDonagh, S. Mecking, F. J. Millero, C. W. Mordy, T. Nakano, C. L. Sabine, W. M. Smethie, J. H. Swift, T. Tanhua, A. M. Thurnherr, M. J. Warner, J. –Z. Zhang (2016). Changes in ocean heat, carbon content, and ventilation: A review of the first decade of GO-SHIP global repeat hydrography. *Annu. Rev. Mar. Sci.* **8**, 185-215, https://doi.org/10.1146/annurev-marine-052915-100829.

https://www.unols.org/sites/default/files/201810rvtap_08.pdf

https://www.nsf.gov/geo/opp/opp_advisory/briefings/nov2010/unols_southeroceanrv.pdf

8 Appendices

8.1 Review Committee Terms of Reference

Terms of Reference for an External Committee Review of the US GO-SHIP Program

- **Why:** The purpose of the Review is to assess the program planning, progress, and opportunities in collecting, providing, and synthesizing quality controlled ocean carbon, hydrographic, and velocity data to advance the scientific research of the US Climate Variability and Predictability (CLIVAR) and Ocean Carbon Biogeochemistry (OCB) Programs
- **Who:** An external review committee (hereafter Committee) of six scientists knowledgeable in the science, methods, and challenges of monitoring the ocean's response to climate change
- **What:** will conduct a review of the progress and plans of the US Global Ocean Ship-based Hydrographic Investigations Program (GO-SHIP) in advancing the goals of the US CLIVAR and OCB Programs; Note that the US GO-SHIP projects are conducted in the context of GO-SHIP internationally as a sustained observing system program of GOOS
- **How:** The Committee, to be selected by the US CLIVAR Phenomena, Observations, and Synthesis (POS) Panel and the OCB Scientific Steering Committee, will provide a review report of its findings and recommendations to these bodies
- **When:** by May 2019

Committee Charge

- Evaluate the adequacy of
  - planning: the **goals and objectives** of the program and their importance to addressing US CLIVAR and OCB program goals
  - implementation: **success and impediments in attaining targets** for data collection, quality control, reporting, and access
  - synthesis: achieving **synthesis of data** (including with ancillary data – e.g., surface radiative, freshwater, and CO_2 fluxes) to **advance understanding** of
    - heat/freshwater storage and flux
    - carbon system and biogeochemical studies
    - water mass ventilation
    - model calibration, validation, and state estimation
    - autonomous sensor calibration

- workforce: sufficiency of **scientific and technical staff** to undertake work as well as **mentoring** of next generation
- ships: suitability of **endurance, deck, lab, and berth space** for data collection and related research
- **coordination** with:
- international partners in implementing international GO-SHIP
- other observing system programs (e.g., OOPC, IOCCP) to addressing GOOS goals
- the US CLIVAR and OCB programs and communities
- leveraging: supporting **new technology** development and deployment (e.g., BGC and deep Argo), accommodating **biological and other complementary observations** (e.g., plankton observing and microstructure sensors) when possible
- Identify **unique, complementary, and/or redundant capabilities** provided by the program within the context of the Global Ocean Observing System
- Identify **challenges, needs, and opportunities** for future directions and implementation approaches
- Prepare a **written report** summarizing its evaluation findings and recommendations

Review Process

- To inform its review, the Committee will
  - review background materials outlining the planning and progress of the program for the period 2003-2018,
  - conduct a survey of scientific networks,
  - conduct a "site visit" at Scripps to meet with PIs, data managers, and members of the US GO-SHIP Executive Council, and
  - conduct follow-up communications with the US GO-SHIP Executive Council, as required.

- The US CLIVAR and OCB Project Offices will be responsible for
  - furnishing background materials,
  - facilitating and collating surveys,
  - organizing telecons and arranging meetings to conduct the review, including travel of the Committee members to the meet with the Program Executive Council and other meetings that may be deemed necessary by the Committee, and
  - the preparation, publication, and presentation of the Committee's report.

Review Timeline

March 2018	Revisit draft TOR with program co-chairs and agency sponsors
April 2018	Finalize TOR and share with Program Executive Council Jointly select and invite Committee members (POS Panel & OCB SSC)
Summer 2018	Convene initial Committee meeting with POS/OCB members to review scope and TORs Initiate review, schedule meeting(s)
Fall/Winter 2018	Conduct review and draft report
Spring/Sum 2019	Finalize and publish
Summer 2019	Present report at OCB Summer Workshop and US CLIVAR Summit

8.2 Site Visit Agenda

US GO-SHIP Review
January 17-18, 2019 (Scripps Inst. Oceanography, La Jolla, CA)

Wednesday, January 16, 2019
18:00 Working dinner for Review Committee (La Jolla Shores)

Thursday, January 17, 2019 (Martin Johnson House, Scripps Inst. Oceanography)
8:30 Check-in and Light Breakfast
9:00 Introductions, Purpose, Scope of Review (F. Bingham, UNCW)

US GO-SHIP Goals and Objectives

Program overview
9:15 Program Overview (L. Talley, SIO)

Program Organization
9:40 International GO-SHIP (R. Wanninkhof, NOAA/AOML)
10:00 Data Management (J. Swift, SIO)
10:20 Break
10:40 Cruise Organization (UNOLS & NOAA) (J. Swift, SIO)
11:00 Cruise Organization (Chief/co-chief scientist perspective) (A. Macdonald, WHOI)
11:20 Discussion

Level 1 Observations
11:30 CTD/salt/oxygen/nutrients (L. Talley, G. Johnson, I. Rosso, J. Swift, M. Baringer)
11:50 ADCP (A. Thurnherr, E. Firing, remote)
12:10 DIC, TA, pH, underway pCO_2 (B. Carter, UW)
12:40 Lunch
13:30 DOC, TDN (C. Carlson, UCSB)
13:50 CFC (M. Warner, UW)

Levels 2 and 3 Observations
14:10 Ancillary Measurements ('piggy-back programs') (A. Macdonald, WHOI)
14:30 Committee Questions and Discussion

Survey Results
15:00 Presentations of the community survey results (Review committee members F. Bingham, G. McKinley, L. Juranek, S. Wijffels, N. Nelson, M. Mazloff)
15:20 Break
16:30 Group Discussion
17:30 End of Day 1
18:30 Review Committee Dinner

Friday, January 18, 2019 (Martin Johnson House, SIO)
8:30 Coffee and Light Breakfast Martin Johnson House

Summary and the Future
9:00 Strengths, Weaknesses, Opportunities, Threats (SWOT) analysis & future of US GO-SHIP (L. Talley, SIO)
9:30 Discussion
10:30 Break
11:00 Outstanding issues and follow-up questions (Review Committee)
11:45 Closing remarks (F. Bingham, UNCW)
12:00 Adjourn
Working Lunch: Next Steps for Review Committee (Martin Johnson House)

US GO-SHIP Review – Webconference with NOAA PIs
February 28, 2019

1. Review purpose and scope (F. Bingham, UNCW)
2. SWOT analysis discussion (L. Talley, SIO)
3. Survey results (F. Bingham, UNCW)
4. NOAA-specific questions from Review Committee
    - Funding
    - Coordination between NSF and NOAA
    - Data analysis and research funded through NOAA
    - Succession planning
    - Ship operations
    - Professional conduct
    - Data and data management
    - Community engagement and outreach

8.3 Community Survey Report

US GO-SHIP
External Review Survey Results
Survey dates: November 7-December 17, 2018

Conducted by US CLIVAR and US OCB on behalf of the
US GO-SHIP External Review Committee
Frederick Bingham, U. North Carolina, Wilmington, chair
Susan Wijffels, Woods Hole Oceanographic Institution
Matt Mazloff, Scripps Institution of Oceanography
Galen McKinley, Columbia U.
Norm Nelson, U. California, Santa Barbara
Laurie Juranek, Oregon State U.

Table of Contents

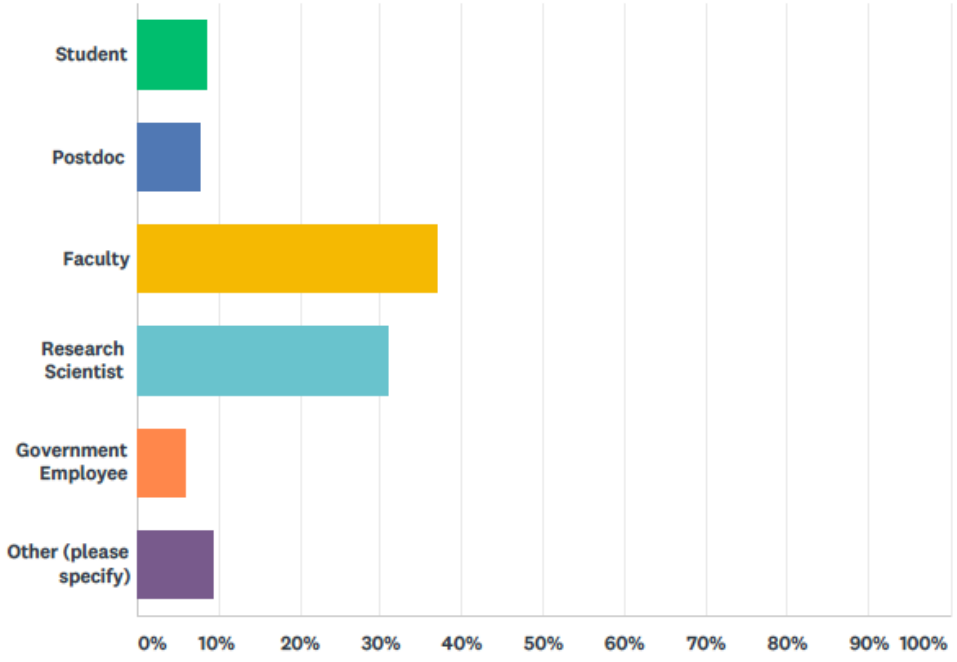
Q1: What is your affiliation?

Affiliation	Count
Arizona State University	1
CNRS	1
Columbia University	1
CSIC Spain	1
CSIRO	2
Department of Geophysics, University of Concepcion, Chile	1
Environment & Peace Foundation	1
ETH Zürich	1
Executive Council and participant	1
Imperial College London	1
Incheon National University, South Korea	1
Lamont-Doherty Earth Observatory of Columbia University	2
Lawrence Livermore National Laboratory	1
Max Planck Institute for Meteorology	1
Monterey Bay Aquarium Research Institute	1
National Institute of Water and Atmosphere (NIWA), New Zealand	1
National University of Ireland Galway	1
NOAA	3
NOAA Ocean Observing and Monitoring Division of CPO	1
NOAA PMEL	1
NOAA/GFDL	1
NOAA/PMEL	2
Oregon State University	1
Princeton University	3
Researcher	1
Scripps Institution of Oceanography	18
Southern Ocean Observing System	1
Texas A&M University	2
UC Irvine	1
UC San Diego	1
UCSB	1
UEA	1

UMD	1
UNH / PML	1
Uni of Miami RSMAS	1
University	3
University of Alaska Fairbanks	1
University of Bremen	1
University of California, Irvine	1
University of East Anglia	1
University of Hawaii	1
University of Maine	1

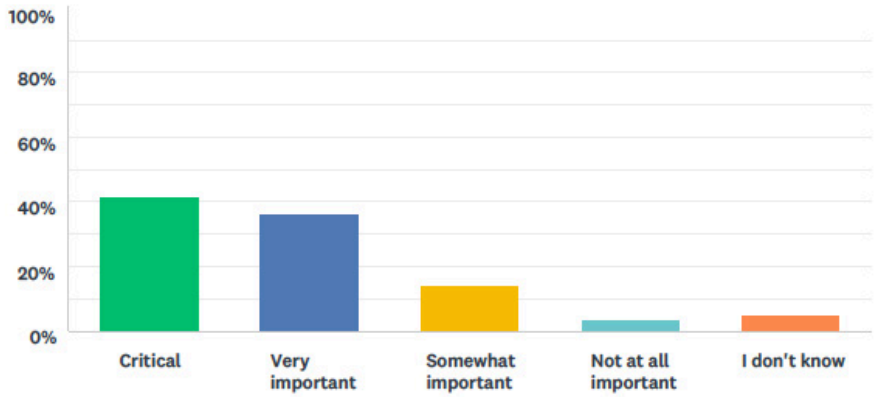
University of Miami	5
University of New Hampshire	1
University of Puerto Rico	1
University of Rhode Island, Graduate School of Oceanography	1
University of Southern California	1
University of Tasmania	1
University of Washington	6
Virginia Institute of Marine Science	3
WHOI	1

Q2 What is your position?



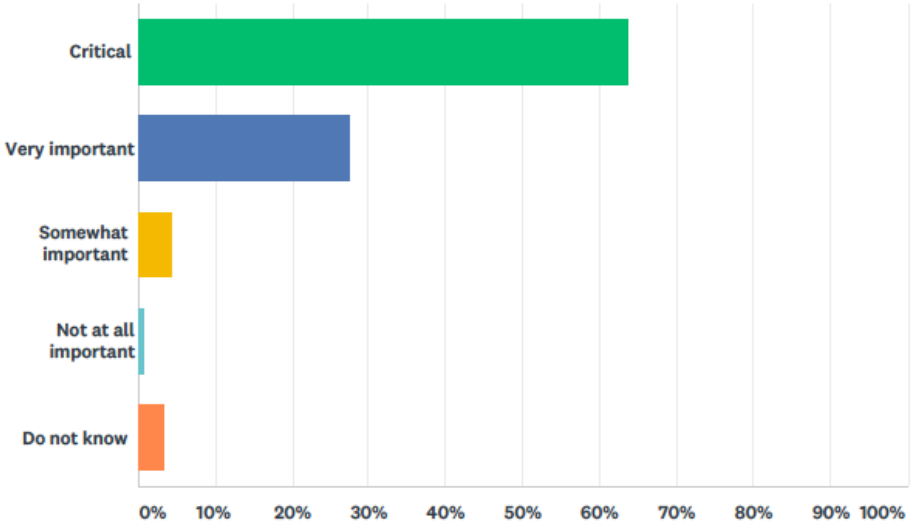
ANSWER CHOICES	RESPONSES	
Student	8.62%	10
Postdoc	7.76%	9
Faculty	37.07%	43
Research Scientist	31.03%	36
Government Employee	6.03%	7
Other (please specify)	9.48%	11
TOTAL		116

Q3 How important is the US GO-SHIP Program in supporting the specific goals of your research?



ANSWER CHOICES	RESPONSES	
Critical	41.38%	48
Very important	36.21%	42
Somewhat important	13.79%	16
Not at all important	3.45%	4
I don't know	5.17%	6
TOTAL		116

Q4 How important do you think the US GO-SHIP Program is in supporting the broader scientific research objectives of the US CLIVAR and Ocean Carbon and Biogeochemistry (OCB) communities?



ANSWER CHOICES	RESPONSES	
Critical	63.79%	74
Very important	27.59%	32
Somewhat important	4.31%	5
Not at all important	0.86%	1
Do not know	3.45%	4
TOTAL		116

Q5 Please list what you perceive to be especially important outcomes of the US GO-SHIP Program's cruises and data sets.

- Long term monitoring of the state of the Earth's Oceans - Enhancing capabilities to determine inter annual and decadal scale variability of the Earth's climate system on the ocean's and vice versa
- studies of long-term trends in the ocean heat content, including in the abyss - basin-scale and global circulation studies using inverse models - global data sets of internal-wave derived turbulence and mixing coefficients from finestructure parameterizations - global data sets of multiple geochemical "tracers" for constraining ocean circulation, air-sea fluxes, and global change - global full depth data sets suitable for providing large-scale context for a wide range of regional and process studies - global data set suitable for constraining circulation models - global data set suitable for autonomous instrument calibration.
(1) Collaboration among physical-chemical-biological oceanographers from different institutions working on the cruises. (2) Comprehensive, spatially-high-resolution datasets from understudied parts of the world's oceans.
1. Decadal-resolution inventories of heat, freshwater, carbon, oxygen, nutrients and transient tracers. 2. The global measurements cover the full water column and provide the only way to quantify these inventories and their changes at depth.
1. Documentation of changes in temperature, salinity, dissolved carbon and dissolved biogeochemical substances along long lines that cross major transport pathways and major basins of the global ocean. This provides critical information on decadal variability and longer term changes that are occurring as the earth's climate warms. 2. All measurements are state of the art and provide a reference for other methods of collecting data, such as gliders and subsurface floats, that can provide greater temporal and special resolution than GO-SHIP.
1. Extensive open source datasets 2. High-quality measurements of the changing carbon system 3. Fostering collaboration across institutions
1. The acquisition and sharing of basic hydrography that can be used with other special parameters to obtain a global understanding of processes in the ocean. 2. Repeat transects along the same tracks decades apart allows assessment of temporal variations of many parameters. 3. Combined with data from previous programs, it has allowed us to connect the distribution and intensity of turbidity in bottom waters with surface water dynamics. Work by physical oceanographers has explained the dynamics of this connection.
1. The collection of global high-resolution data that is not yet attainable by any other methods or technology 2. National and global collaboration as well as network coordination 3. Aids in understanding our largely understudied ocean and addressing future climate and oceanic changes.
1.- High quality data sets to study deep ocean properties and changes. 2.- Scientific papers based on the collected data. 3.- Oceanographic Atlas for direct studies, modelling and educational purposes.

accessibility of high quality data. Easy to read, single data format
All the benefits of free access data since the data nowadays are spread around the scientific world, sometimes impossible to proceed compilation.
Anth. CO_2 inventory growth Heat buildup highest quality data for calibration of float data
Assessing global ocean carbon changes over time.
Basin to Global scale mean circulation estimates, meridional transport estimates, property change estimates (especially T/S/density changes and their effect on sea level rise, and anthropogenic carbon transport and storage), their value as input to assimilative models particularly as they still represent the only means of obtaining repeat basin-scale high quality observations below 2000 m.
Carbon inventory, carbon storage a depth. Dataset of the highest quality to be used for decades to come. The only way as of today to collect high quality samples at depth of the world's oceans.
Carbon storage in water masses and how it is evolving along with ocean acidification. Heat content of oceans. Trace gases and tracers for model testing
Carbon system changes, global heat changes, circulation changes, basic high accurate global data for autonomous instruments including those that measure acidification, nutrients
Changes in the deep ocean. Long time history of properties across the full water column. Super-high quality data as a reference for autonomous systems.
changes in the deep-ocean water masses
Complete sections allow flux calculations
Confident measure of ocean state and change over a critical parameter suite.
consistent, high-quality observations.
coordinated and concurrent sampling of physical and biogeochemical properties; provides data in under-sampled regions like the Southern Ocean
Critical data sets.
CTD & LADCP datasets for looking at global trends in T/S and velocity/shear properties.
Currently the studies of ocean acidification
Data fields of hydrographic variables for model initialization, and estimates of changes between repeat sections.
Data from these cruises allow us to monitor changes in the oceans and their related connections to global warming.
Decadal and climate variability, ground truth for many autonomous measuring systems
Decadal resolution of inventories and distribution of organic, inorganic C as well as O_2 and nutrient. That coupled to the tracer data is critical to evaluate rates of change etc.

Decadal scale changes in carbon storage in the ocean.
Decadal scale global change in oceanic CO_2 inventories and heat content
Decadal snapshots of global ocean state.
Deep ocean data; high quality controlled observations; biogeochemistry observations
Deployment, calibration, and validation platform for numerous programs. Links modern observations to past measurements. Provides anchor for measurements with higher spatial and temporal coverage (and often higher uncertainty). Training ground for young scientists.
Detection of changes in ocean heat content, carbon storage/ ocean acidification, oxygen, and major circulation pathways and variations leading to the changes.
Extraordinary high quality of data, mapping properties and documenting their changes of both the upper, and the deep and bottom waters
full depth high quality temperature and salinity data
Global context for all ocean science (of seawater itself); invasion of anthropogenic heat into the ocean; invasion of anthropogenic CO_2 into the ocean; acidification in the ocean; deoxygenation of the ocean; stratification of the ocean; new illuminations of the deep ocean based on data sets that are otherwise too few
Global hydrography based on high quality measurements
Global perspective is critical.
GO-SHIP provides critical measurements with calibrated sensors that we rely on to validate everything else. Assessments of deep warming.
High quality repeat hydrography. Validation data.
High quality shipboard data from GO-SHIP provides essential information for validating data products from autonomous platforms (floats!).
Higher quality data sets of key biogeochemical and physical parameters.
Highest quality BGC tracer measurements.
Hydrographic sections of global ocean repeated each decade with community accepted and quality assured methods
I'm new to US GO-SHIP. I would like to be involved in the future
International Cruise plan coordination Quality data procedures
Is necessary to assure the collection of self-consistent, high-quality data

It is a very long list, but in no particular order: - Anthropogenic CO_2 uptake estimates -Monitoring deep ocean warming -Monitoring de-oxygenation of the ocean -Support of the Argo Program through reference data and deployments -Critical support of BGC Argo AND Deep Argo for reference data - these programs would not work with out GO-SHIP - Understanding the MOC and it's variability from Geostrophic transport estimates. - A platform for new ocean measurements ranging from ocean mixing (such as Chi-pods) to measuring DNA of bacteria through out the water column
It provides adequate datasets to assess global warming effects on oceans physical and chemical budgets, specifically carbon, heat and freshwater content.
Just the availability of high quality observational data. There is no substitute for this!
Large scale patterns of ocean properties and processes. Novel discoveries about how the ocean is changing over time and its role in the earth system.
Large-scale processes, identification of regions of different biogeochemistry, the free-availability of data, where scientists from different backgrounds use the data to answer different questions.
Maps showing that broad areas of the ocean are becoming deoxygenated. Also it is hugely important when I am able to show students that direct measurements are showing that the ocean is warming, becoming fresher in some areas and more acidic.
Monitoring oceanic uptake of heat and carbon
Monitoring oceanic uptake of heat and other dissolved constituents into the deep ocean
Ocean heat content change over time, which can in principle place constraints on the planetary energy budget imbalance, and hence the climate sensitivity at the low end of the range. (the high end is uncertain for other reasons, e.g. poorly known aerosol forcing)
ocean nutrient distributions, carbon uptake, oxygen & temperature changes, global ocean circulation
Protocols
Quantification of the ocean carbon sink Quantification of the progression of ocean acidification
Quantification of: 1. Deep ocean warming, 2. Antarctic Bottom Water freshening, and 3. Ocean carbon uptake.
Reference data sets to quality control BGC-Argo data.
Reference data sets with known and documented accuracy, used as de facto calibration standards for e.g. Argo and other programs. Long-term changes evident in comparing earlier and recent cruises.
Reference grade/gold standard data, immediately available preliminary data sets once the cruise is done.
Reference quality data that is the gold standard to calibrate all other ocean data (floats, moorings, etc.)

Repeat monitoring of specific hydrographic sections along with periodic sampling in very remote/ undersampled ocean regions.
repeat occupations (time series)
Repeated occupations of the same regions of the oceans allows large lead times for planning purposes. Visiting the open ocean allows researchers to collect auxiliary datasets, not part of the core GO-SHIP mission, but difficult and expensive to obtain otherwise.
Standardised, high-quality, long time series of key variables and open access to data
Surface fluxes of energy/moisture/momentum. Deep ocean diffusion of heat/density.
Sustained biogeochemical and physical data of world's oceans. Long-term monitoring. Commitment to examine remote or poorly-accessible ocean regions. Management protocols for delivering consistent, clear and compatible data. Reliable archives of latest and historical data sets. Freedom to engage with GO-SHIP data to pursue new research. Innovative research and collaborations are encouraged. Opportunities to expand ocean science community and awareness through student positions, internships, subcontractors, and teachers-at-sea.
Sustained high-quality inter-calibrated oceanographic data. GO-SHIP (and its predecessors) are absolutely critical instrument for our ability to monitor changes in ocean properties.
Synthesis dtasets and collations
The climate-quality data, incredible documentation, and quick turnaround time for public datasets.
The data contribute to understanding of the cycle of bioactive chemicals in the ocean and the anthropogenic transient.
The decadal surveys are instrumental in maintaining calibration for the Argo and upcoming Deep Argo autonomous platforms
The excellent quality of the data, the soon public release, the amount of essential and other not so essential but important variables measured. The opportunity given to young people to participate. The stability of the program.
The high data quality is a major outcome of the program.
The US GO-SHIP program is only truly global program that provides critical oceanographic biogeochemical data to the international scientific community.
The wide geographic distribution of the measurements.
To determine the role of the oceans in the global carbon cycle and its changes over time.
Unbiased coverage of large areas in the ocean, especially the "boring" regions such as sub-tropical gyres. The ability to build up data bases of baseline conditions and inter-annual changes.
Very high quality oxygen & nutrient data sets

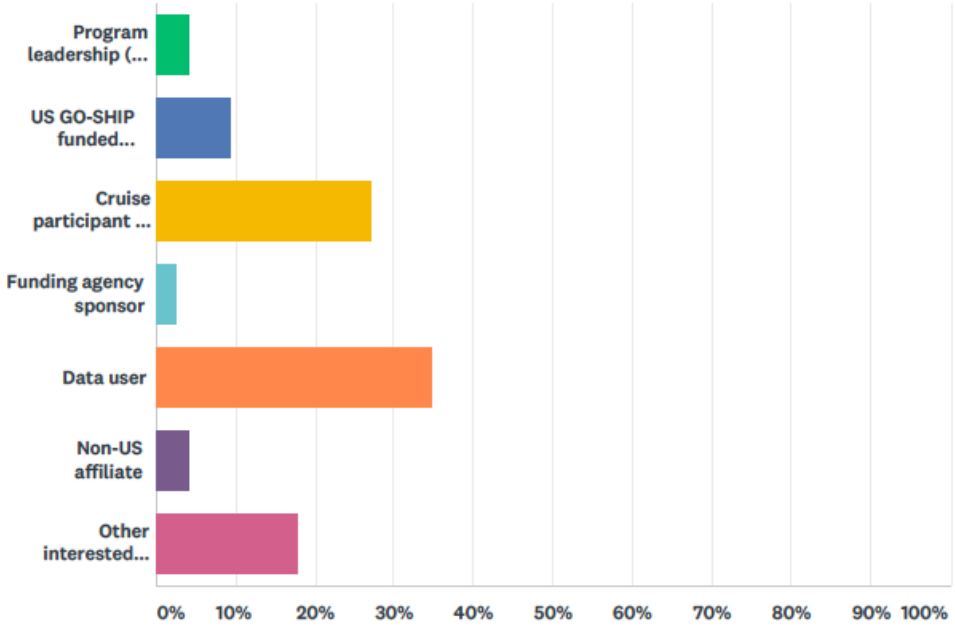
Q6 If you are a student, postdoc, or previously participated on a cruise as a student or postdoc please comment on how US GO-SHIP has impacted your early career experiences, both positively and negatively.

It provides unparalleled opportunities to train graduate students working at sea alongside world experts.
(I am not a student or post-doc, but I'd like to note that I am proud of what we have accomplished in terms of involving students, post-docs, and early career scientists in the sea program.)
All positive. I wouldn't be in oceanography without it. It provided critical research opportunities, generated data that has enabled >90% of my research efforts, funded my early graduate work, and the cruise work provided the impetus to study oceanography (before I was more intrinsically motivated by the research).
amazing experiences and the best networking available. So great to meet scientists and students from all levels onboard the ships.
As a post-doc I participated as a co-PI on a CLIVAR repeat-hydrography cruise. This provided excellent training for my own future cruises.
As a student who participated, I was not a part of the GO-SHIP core program, but an ancillary project on three cruises. Each chief scientist was very supportive in accommodating our requests within the water budget constraints.
Field experience should be a key component of any graduate or postdoc program in climate/ocean sciences - I recommend that US GO-SHIP continues to call for early-career participation in all US-based (and international) cruises
Following protocols from GO-SHIP
GO-SHIP has been a major component of my career for over 30 years.
GO-SHIP has greatly impacted my career. First, I've been trained as a co-chief scientist, a wonderful opportunity for an ECR observational oceanographer (I'm a postdoc). Second, with the data we have collected I published with colleagues a paper in a prestigious journal. Last but not least, based on the observations we made I had new ideas for proposals.
GO-SHIP provided a diverse and welcoming scientific network that aided my understanding of my own scientific and career interests. Through my GO-SHIP experiences I made many helpful connections that plugged me into position openings and created job references. My involvement with GO-SHIP has opened several career pathways and has expanded my scientific niche from local to national.
Going on a GO-SHIP cruise made me definitively want to become a seagoing oceanographer, and also taught me about the logistical details that go into collecting data. This knowledge of logistical details has improved my ability to plan fieldwork and projects.
Having cruise experience is very valuable for everyone focusing on marine sciences. Not only is it a challenging yet fun experience, but you also realize and appreciate how much work the CLIVAR, GO-SHIP, etc., datasets require.
I did participate on a WOCE voyage in my early career- it was a wonderful opportunity to learn about how the data were collected.

I have sailed on several GO-SHIP/CLIVAR cruises and this experience has taught me about how to operate a field campaign. It has also provided me with invaluable networking that will continue to benefit me throughout my career.
I participated in a GO-SHIP cruise as an undergraduate student, serving as a technician running samples. This experience catalyzed my interest in the oceans and the professional opportunities that exist to study it. This experience served as the basis for new ideas and possibilities that became the foundation for a successful NSF CAREER award that I received to collect data as part of the GO-SHIP cruises.
I participated on a CLIVAR line and it was an incredibly positive and informative experience.
I participated on a Pacific cruise as a first year graduate student. This experience cemented my desire to not only pursue a M.S. in Oceanography but to make this my career.
I participated on WOCE cruises as a student and a postdoc (a long time ago). Those experiences helped me to understand how the data were collected and calibrated. They got me interested in regional and global research questions. They helped me to connect with other members of the oceanographic research community.
I participated to few US GO-SHIP cruises, collected and analyzed data, used these data to validate model output and to understand the ocean environment when compared to observations from Argo floats. Participating on a cruise has always been more than rewarding and has determined the path of my career in many ways. Not only I had the first opportunity to look at real data and learn how to interpret them, but these cruises gave me the chance to create collaborations that are very important for my present work.
I was a co-chief scientist on a cruise (A66 in 2012), and it made me much more aware of this type of data in general and in particular about the measurements made around the Caribbean. I still have a project idea related to this work that I want to pursue finding for.
It really improved my fieldwork experience, I made contacts and collaborations with fellow scientists in the ship and could develop my own research apart of the regular go-ship plan.
Learned tons from being Co-Chief Scientist on a GO-SHIP cruise
networking/connections with observational oceanographers; data collection onboard provides context to data usage in research; newfound appreciation for sea-going oceanographers
Not yet effected by US GO-SHIP.
Participating in the GO-SHIP cruises as a grad student impacted my early career experience in the most positive ways. I'm so grateful for that first-had experience in collecting ocean science data and trouble-shooting at sea. These cruises were also a welcomed respite from my grad-student bubble. They forced me to flex my leadership skills and allowed me to interact with researchers across the gamut from newbies to well-known professors.
Participating on a cruise as a student 3 years ago was a very positive impact on my career. I learned about all of the other types of data collection going on and the questions that all of that data was helping to answer. The cruise helped me understand the nature of oceanographic research, and I have already used what I learned or experienced for my own research, teaching, and even outreach.

Participation on GO-SHIP cruises has had the utmost impact on my early career. The first field work I ever participated in was a GO-SHIP cruise prior to attending graduate school. I loved the experience so much, I decided to pursue a career in observational oceanography. I went on to graduate school, where I participated in another GO-SHIP cruise, followed by a postdoc where I participated in yet another GO-SHIP cruise as Co-Chief scientist through the GO-SHIP postdoc program, and eventually on to be faculty at SIO where I still interact heavily with the GO-SHIP community. Through the three GO-SHIP cruises I have participated in, I have learned an extraordinary amount about how we measure the physical properties and biochemistry of the ocean. In addition, other GO-SHIP students and GO-SHIP PIs that I met on cruises continue to be extremely influential on my career. Many of my research interest have and continue to rely heavily on GO-SHIP data. Having the chance to participate in these cruises both promoted my interest in the data as well as allowed me to have a deeper understanding of the data I use, which I believe is critical.
Positively
US GO-SHIP (and i'm not base din the US) benefited me greatly in allowing me to participate in its expeditions and collect samples. My students are now using these samples. In that sense, GOSHIP has been absolutely critical for my early career as a faculty.
US GO-SHIP data has been critical to my postdoctoral research and has had a significant, positive impact on my early career experiences. Our laboratory has participated in 3 GO-SHIP transects, which provided the basis for our understanding of diel particulate organic matter and microbial growth fluctuations. Personally, I will be the first author or a co-author on six or more publications due to the US GO-SHIP program.
US GO-SHIP data has been extremely vital for me to pursue my research goals as a graduate student pursuing a PhD. The data has been instrumental in writing up my thesis research. Further, US GO-SHIP provided me with significant field experience on their research cruises and building connections and contacts with fellow oceanographers across disciplines and institutions.

Q7 What is your primary connection with US GO-SHIP? If you identify with >1 role you are welcome to take the survey >1 time to give different perspectives.



ANSWER CHOICES	RESPONSES	
Program leadership (US GO-SHIP Executive Council)	4.24%	5
US GO-SHIP funded principal investigator	9.32%	11
Cruise participant who is not GO-SHIP funded PI	27.12%	32
Funding agency sponsor	2.54%	3
Data user	34.75%	41
Non-US affiliate	4.24%	5
Other interested individual	17.80%	21
TOTAL		118

PROGRAM LEADERSHIP (EXEC COUNCIL): Q8-Q12

Q8 How do you believe the Executive Council has been most impactful or influential?

The Executive Council has been impactful in coordinating cruises, recruiting postdocs, and providing input on making changes to cruise schedules when needed.
organizing the program over the years including writing the proposals that fund it, interacting with international GOOS leadership and international GO-SHIP leadership
Facilitate international coordination and collaboration
coordination of the logistical aspects of the program - keeping track of GO-SHIP related literature

Q9 What challenges have you faced in your leadership capacity and how do you think they could be effectively addressed?

Sponsoring a part-time international program coordinator at JCOMMOPS
One large issue with the ex council is that everyone is busy with multiple programs, so it is not always easy to get the attention of the members. Having regularly scheduled calls could help with that. Bringing in the next generation could also help.
1. biggest challenge is lack of funding beyond that to collect the data and therefore lack of continuity and scientific analysis 2. most important challenge for the data sets is how to convince some groups to actually submit their data. We have just a few groups who simply do not believe that it is required. We have not applied the leverage needed through the funding agencies to weed out these recalcitrant groups, or to find a way to recoup the data. I fear that we will just start losing more and more data, which is already happening.
there has not been much discussion about the future of this project, including challenges

Q10 What is your impression of how decisions are made (fairness, effectiveness, etc.) by the Executive Council?

The executive council decision making process can be a bit ad-hoc, but it attempts to be fair, and is generally effective.
I cannot judge because I am on the council. I think we do not have enough discussions/meetings in general.
Note, I'm assuming this is the international executive council. There are few binding decision made by the international council, it is mostly about coordination and outreach
the decisions that have been made since I joined the council have all been reached by consensus

Q11 From your perspective, how effective has the Executive Council been in cruise planning (cruise scheduling, core measurements, filling berths, identifying chief/co-chief scientists, etc.)?

The ex council has been pretty effective at cruise planning, if a bit ad-hoc. We could have done better in advertising the chief/co-chief scientist positions to the wider community in some instances.
I think we have been very successful. Each cruise has gone forward and collected all the data needed. I don't know how much to attribute that to the council or to the excellent interaction of the whole team.
This is mostly done by the chief scientist with assistance of the national exec
very effective (it's what the council does best, IMO)

Q12 From your perspective, how effective has the Executive Council been in fostering broader community participation in US GO-SHIP, including with early career participation and mentoring?

Us council: very good
These topics are frequently discussed during conference calls, so the council is proactive about them. Cruise co-chief scientists have typically been early career, so I consider this effective.
Given the very small amount in the budget for this (i.e. restricted to hiring students for watch positions on the cruises, finding co-chief scientists, and in the last funding round, having funding for 1 postdoc), I think we have been very successful. Many of the students have continued with this type of work. Many of the co-chiefs have continued on and moved up to leading their own cruises. We have had much less mobilityu in terms of laboratory leadership, with younger scientists rarely moving up to leadership because of the longevity of the labs.
I think we have done a good job with students and postdocs, the big challenge is moving them into the next level. Some of that will and should be done during the next big proposal.

FUNDED GO-SHIP PIs: Q13-Q17

Q13 As a funded US GO-SHIP PI, please comment on your experiences (positive and/or negative) working with Executive Council to incorporate new (Level 3) measurements into cruise planning.

My experience has been positive
From my perspective the system has worked well to add new measurements as appropriate.
The Level 3 measurements are carefully considered.
I do not have experience with this
Level 3 measurement should be added.
No complaints
I have not had a particular issue with adding a new measurement - especially since it requires no additional water
Back in the mid 2000 I was involved with programs that incorporated level 3 measurements. The executive committee and chief sci were accommodating and easy to work with. The biggest constraint was water budget but that is understandable and we adjusted to those constraints.

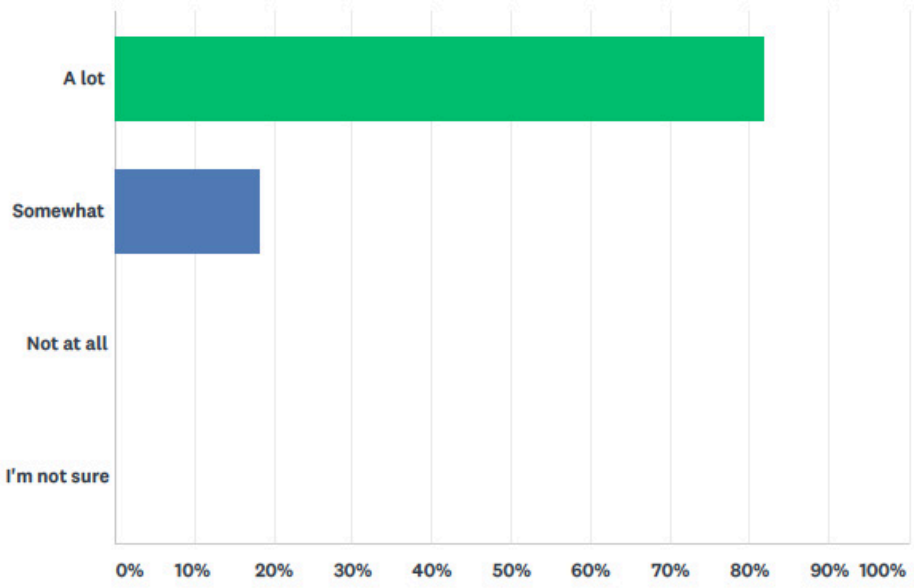
Q14 Is US GO-SHIP receptive to new ideas in operations and science?

The Executive Committee has been receptive to new ideas and approaches to address the carbon cycle in the oceans and support other national projects (i.e., Argo, BGC Argo, Geotraces, etc.
I believe so
Yes
Yes
All new ideas receive a fair hearing.
to the extent that it doesn't interfere with the Level 1 measurement program
I havent pitched any ideas so I cant comment.
Yes
Yes

Q15 Please comment on the process of obtaining funding to perform measurements on US GO-SHIP cruises. Did this process seem fair and straightforward? Was/is the level of funding adequate to achieve your proposed objectives?

A flatted funding over years will affect the success of program.
Funding was obtained outside the normal GO-SHIP proposal.
I am involved in the core program. NSF funding has been straightforward (considering the substantial budgets), with productive working relationship with NSF program officers.
It has been very difficult to obtain steady funding for synthesis and analysis of the data. Nevertheless, significant achievements shave been made through collaborations at the international level.
My funding comes from NOAA and I have been level funded for many years and this is becoming a problem.
My laboratory receives inadequate funding for the measurements we are asked to make; I am understaffed. As such, our data delivery time is up to 3 times beyond what the program asks of us. We get it done, but we are getting further and further behind.
The funding is adequate for making the measurements and producing a final set. Funding for interpretation is much more difficult to obtain.
The GO-SHIP program and its predecessors involved a lot of planning by a large number of investigators and most of these investigators were funded to participate in the program. Investigators negotiated with each other regarding who would do what prior to proposal submission. This was done in a fair and straightforward way. The funding was adequate to produce a final data set that could be used by the scientific community, but, by design, was not sufficient for detailed interpretation of the data.
yes
Yes it was fair and (relatively) straightforward; the level of funding was OK

Q16 To what extent did the data sets you are/were funded to collect support the ancillary science objectives of other researchers?



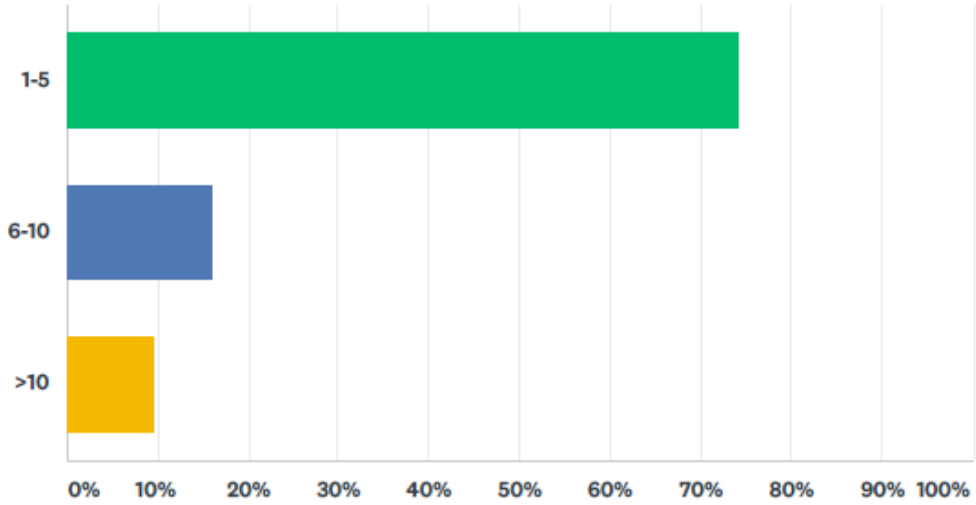
ANSWER CHOICES	RESPONSES	
A lot	81.82%	9
Somewhat	18.18%	2
Not at all	0.00%	0
I'm not sure	0.00%	0
TOTAL		11

Q17 Please comment on your perceived effectiveness of the post-cruise sample and data processing and how it could best meet your needs.

Handled well
I complete all of my analyses at sea and final data processing and submission to CCHDO for archival is completed within 6 months.
I have noted that some questionable data has not been identified by the measurement PIs. It would be useful to have someone at CCHDO plot the data up quickly to identify questionable data
It is a bit slow. I delivered data to CCHDO about two months ago, but they are still not integrated into the master file that is made available to the public. Perhaps they are underfunded relative to what would be needed to expedite data integration.
It is cumbersome to do significant post-cruise activity, but it's OK.
Preliminary shipboard measurements were quickly made available to GO-SHIP PIs. T, S, Oxygen and nutrients were quickly finalized and made available to the community. CFCs/SF6 took several months to be finalized, but were generally available within a year. Some shore based measurements took a year or two for completion. Updates were posted on line as soon as they occurred. There was some frustration with some data taking too long to be submitted, but problems do occur in shore based labs that cannot be foreseen.
There are some delays in post-cruise processing - moving to so-called "final" data, and then in getting them unambiguously on line at the CCHDO. (They are there, but not always fully merged.)
We have been able to complete all of our post-cruise data processing obligations after each cruise.
World class for U.S. and Japanese led cruises. I wish we could get the rest of the world up to this level.

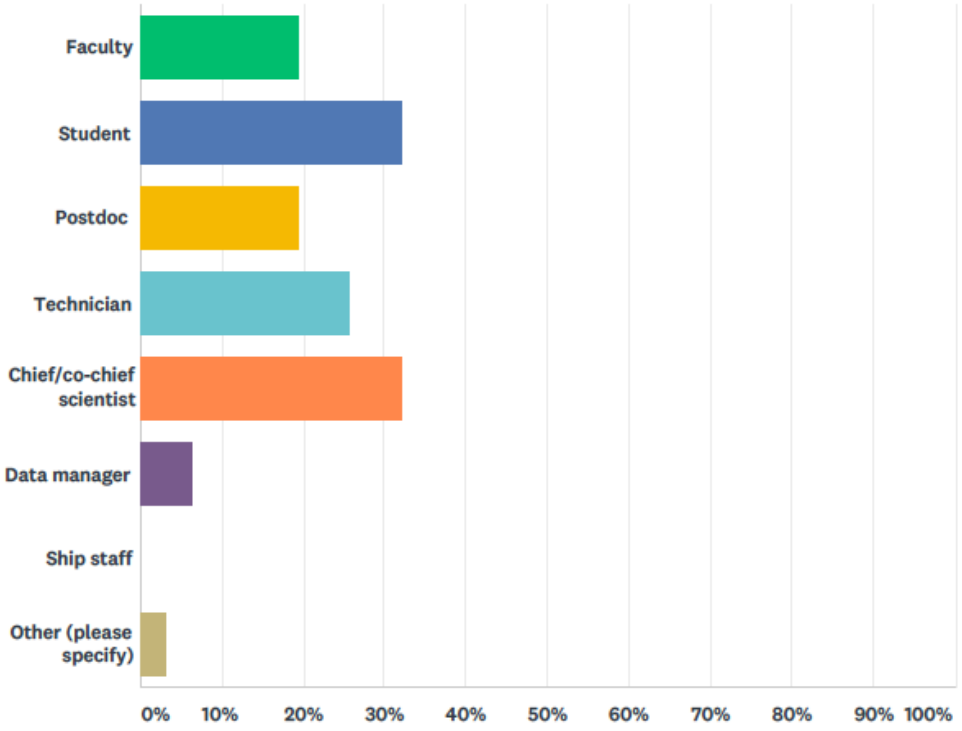
CRUISE PARTICIPANT NON-PI: Q18-Q24

Q18 How many US GO-SHIP cruises have you participated in?



ANSWER CHOICES	RESPONSES	
1-5	74.19%	23
6-10	16.13%	5
>10	9.68%	3
TOTAL		31

Q19 In what capacity did you participate on the cruise(s)? Check all that apply



ANSWER CHOICES	RESPONSES	
Faculty	19.35%	6
Student	32.26%	10
Postdoc	19.35%	6
Technician	25.81%	8
Chief/co-chief scientist	32.26%	10
Data manager	6.45%	2
Ship staff	0.00%	0
Other (please specify)	3.23%	1
Total Respondents: 31		

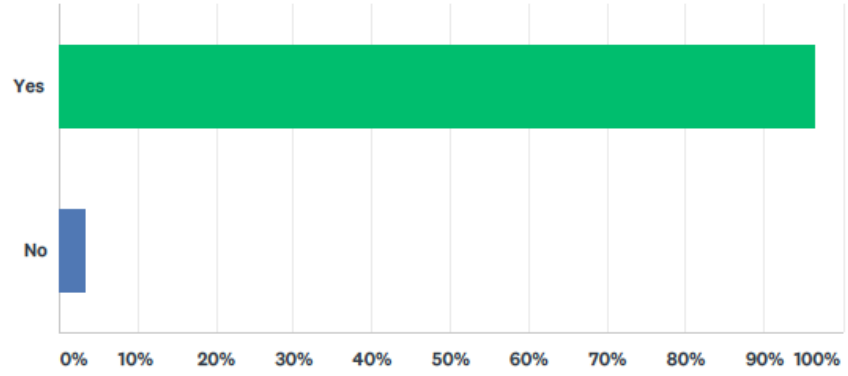
#	OTHER (PLEASE SPECIFY)	DATE
1	Provider of instruments for cruises and user of the data collected. Not a shipboard participant.	11/8/2018 10:28 PM

Q20 If you have ever sailed as a chief or co-chief scientist, please comment on your experiences (positive and negative) as a co/chief scientist (e.g., level of support from Executive Council, working with ship's staff to achieve cruise goals, etc.).

All my experiences with the Executive Council have been very positive, and I cannot recall having any communication problem with the Chief Scientists either.
I had a great experience as co-chief scientist. The communication, planning, and running the cruise together with the chief scientist have been very positive and a rewarding learning experience. I found that working with the ship's staff has been equally positive, and we had worked together to find the best solution to achieve the cruise goals, despite the issues that we had encountered (e.g. weather related or technical)
I had a very positive experience overall. The Executive Council was very supportive with timely help when needed and recommendations. The cooperation with the ship's crew was also great.
I participated as a co-chief scientist shortly out of grad school. Though many operations were happening at once (eg, various deployments at a station), in general, I felt that all onboard (the chief scientist, ship's staff, and other science members) were working in cooperation to achieve the cruise goals. I felt free to communicate and clarify concerns with the chief scientist and ship's staff at all times. This experience provided me with many insights into mentoring and leadership overall.
I was exec council due to be a chief sci, so arguably my work was exec council work. Mostly, excellent support particularly with finding co-chief and watchstanders. However, much of my day to day support was provided by NOAA (NOAA led on a NOAA vessel).
In the two cruises that I was the co-chief scientist the ship's staff was exceptional. They worked hard to make everything works, especially when the problems showed up. A frequent criticism that I heard from members of the science party was that the communication about the logistics and the cruise objectives were not always clear. I believe that improving communication is the key to successful GO-SHIP missions. I had not much contact with the Executive council so I can't evaluate.
My experiences on the whole have been excellent, however more recently, it has become clear that funding is an issue, so I have had to limit my requested time. J. Swift has been extremely helpful trying to take over tasks that might normally go to the chief scientist (e.g. clearances), but in the end the c.s. has to be knowledgeable about the whole cruise and everyone involved, so it is not a task one can come to at the last moment unprepared. The net result is that one spends a great to deal more time (particularly, but not only) on the cruise prep that one is compensated for.
No, but I would like to. Sadly, i am not based in a US institution so this seems not possible for me at this time.

Not on a GO-SHIP cruise, no.
On NSF-led cruises excellent support from Scripps for EEZ clearance requests and logistics for chief-sci party. Ship's crew on the Roger Revelle was knowledgeable and reliable. On NOAA-led cruises less support for EEZ-related issues. Rotating NOAA corps on hips means less experienced ship's officers. In both cases, having access to previous cruise reports was extremely useful for planning and scheduling.
This was an incredibly useful experience to me, to learn about the data streams, quality control, and management of such a cruise.
was 18 years ago, but the ship was well run

Q21 Was the work environment aboard the ship (during loading, at-sea work, and unloading) conducive to meeting your sample collection and science goals, and completing those tasks successfully during the cruise?



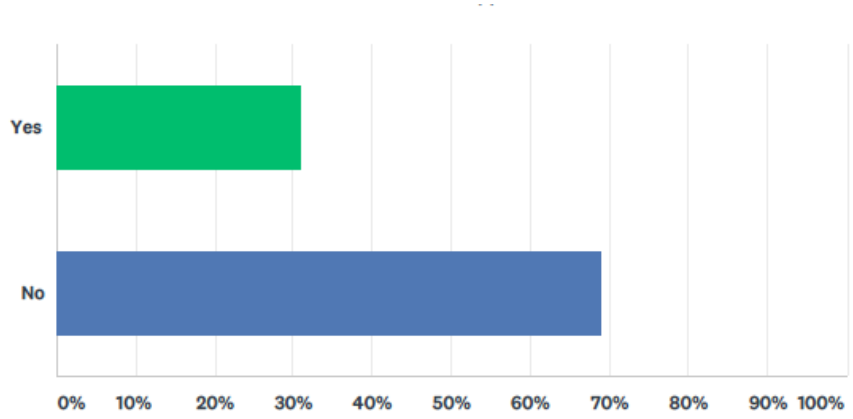
ANSWER CHOICES	RESPONSES	
Yes	96.55%	28
No	3.45%	1

Please elaborate further:

Although I felt that some of the decisions that were made during the cruise with regards to which stations to cancel due to weather were not always judicious.
As a technician, I hope and believe that my presence on the cruise makes it conductive to work for others.
But, cramped shared quarters with roommates on conflicting shifts definitely impacts safe and efficient operations due to lower levels of awareness caused by inadequate rest.
But, I believe that better communication before and at the beginning of the cruise is needed. Some of the problems we faced in our cruises could be avoided just with a better communication. For example, water budget and sampling order can be a potential problem especially when there is only a 24-bottle rosette. I believe that arrangements and agreements between all PIs should be done before sampling starts, avoiding compromising the cruise goals. My observation is that the unloading phase seems to be the most stressful part of a GO-SHIP cruise since many PIs that don't sail forget to send material for preparing for unloading. This fact can potentially cause some disagreements with the crew. I believe that non-present PIs should be reminded that before each cruise.
generally yes, although I had some issues related to the maintenance of ship's equipment (e.g. winches) onboard

I was the pH operator, and while the answer to this question is largely "Yes", currently GO-SHIP only funds one person to collect samples and analyze for pH which is very challenging. It is also the only chemical parameter, measured onboard, that doesn't have two shifts associated with it. That means the success of the pH science goals is only achievable as long as other cruise participants are willing to share their time and help out with e.g., sample collection. In my opinion this is not sustainable, as the success of measurements shouldn't rely on the goodwill of other people.
It was the best work environment aboard a ship I have ever experienced! Very high level of collaboration, support, communication, and interest in one another's work.
More experienced personnel on UNOLS vessels makes for smoother execution of cruise objectives. A clear directive of core, level 1,2 etc parameters is very helpful when issues come up and activities need to be cut down.
mostly but not 100%
Overall we were able to complete our intended research. However, significant delays of the R/V Ronald Brown negatively impacted the at-sea work environment. Additionally, CTD water budgets were extremely limited compared to other cruises.
The space and the people involved were beneficial for completing tasks successfully.
The vast majority of the people who go to sea regularly on GO-SHIP cruises are dedicated, enthusiastic professionals.
The work prior, during and post the cruise was conducted professionally by both the science party and the ship's crew, and has allowed to reach the sample collection and the science goals.
Vessel had numerous readiness issues, but, ultimately, the work got done. (See the cruise reports.)
Yes, we received appropriate lab space, and the ship's staff has been available to accommodate further requests.

Q22 Did you experience any negative or unethical behavior during your cruise(s) that interfered with your ability to conduct your work? Describe if possible. Remember, comments are not attributed.

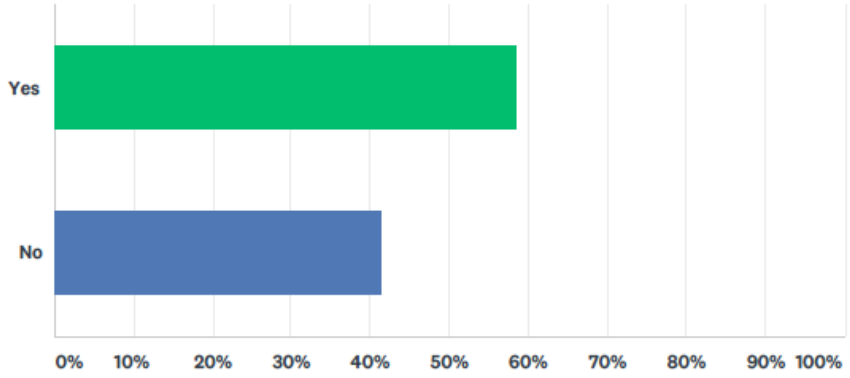


ANSWER CHOICES	RESPONSES	
Yes	31.03%	9
No	68.97%	20

I don't recall any negative or unethical behavior during the cruise
Misogyny still exists and can be particularly harsh whether done by a chief scientist, student, or anyone in between. Differing expectations of standards at sea can lead to friction, especially between those that are participating for the first time and those that have done 5, 10, 20+ cruises.
Negative behavior regarding the hierarchical nature of data priorities on GO-SHIP lead some scientists to devalue the presence, priorities, and research of other scientists on the cruise (i.e., refusal to wear nitrile gloves when sampling the CTD because it wasn't required by first-level priority science).
Not personally to me, but I saw some unethical behavior such as: 2 males that are boyfriends staying in a same cabin, working in the same project and not shifting work with other fellows from the project correctly. I aso saw unethical behavior from one scientist towards the other.
Not that interfered.
On one cruise a scientist was very disrespectful toward the crew, chief scientist, and fellow members of the science party. This was handled correctly by GO-SHIP and the NOAA command.
Once a crewmember sent me an unsolicited inappropriate email, which left me feeling very uncomfortable. I discussed my frustrations with a female friend onboard and my work-ability was not impaired. However, I imagine if there were fewer females onboard, the anxiety would have persisted.
Some crew refused to wear hard hats when needed

The issue is that not everybody perceives a particular behavior in the same light, but as chief scientist one eventually becomes privy to all sides. I am not going to describe details, but what I can say is that in all cases straightforward discussion/intervention seemed to work well, as in the end we all had the same goal.
The person in charge of IT was inappropriate with women on board several times, making comments mostly. When we got to port he tried to hit on many female scientists.
The primary objectives being to measure heat, salt, carbon and nutrients, there is a well-established routine around the rosette. This makes the sampling process efficient, but there is also a degree of reticence for ammending the established sampling protocols to accomodate new people with new objectives - in my opinion, it will be necessary to accomodate these objectives to help sustain the sampling effort. Given some of the new measurement capabilities regarding DNA, microbes or trace elements, some of the core sampling protocols may have to be amended somewhat (i.e. make an effort with wearing gloves, or work more cleanly).

Q23 Did you submit data to a US GO-SHIP data system (CCHDO, BCODMO, etc.)?



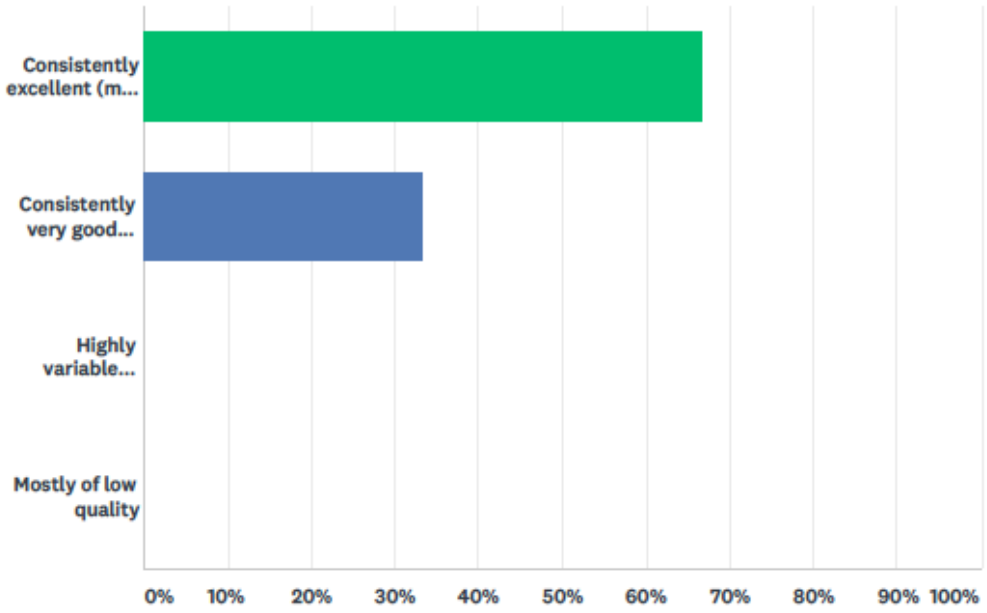
ANSWER CHOICES	RESPONSES	
Yes	58.62%	17
No	41.38%	12
TOTAL		29

Q24 If yes, please comment on your experience with the data submission process.

A representative from CCHDO was onboard, which made data submission really easy.
BCO-DMO was relatively easy system to access and use.
CCHDO data submission has improved significantly in recent years. They have been very helpful. BCO-DMO has also been very helpful.
CCHDO data submission is streamlined and easy to use. Data generally appears on the CCHDO website in short order after being submitted. Have not submitted to other data centers.
Easy. Painless.
Instructions for submission were clearly outlined on website. Data manager sent confirmation of data-received email.
It works.
Mostly great, but took some nagging to get data finalized.
Smooth, good email responses.
Unbelievably easy. I can't imagine it being any easier. That being said if we didn't have the ODF people onboard that would all change in an instant.
Very easy and straightforward, nothing to complain
Very positive
We submitted data to BCO-DMO without any hassle.

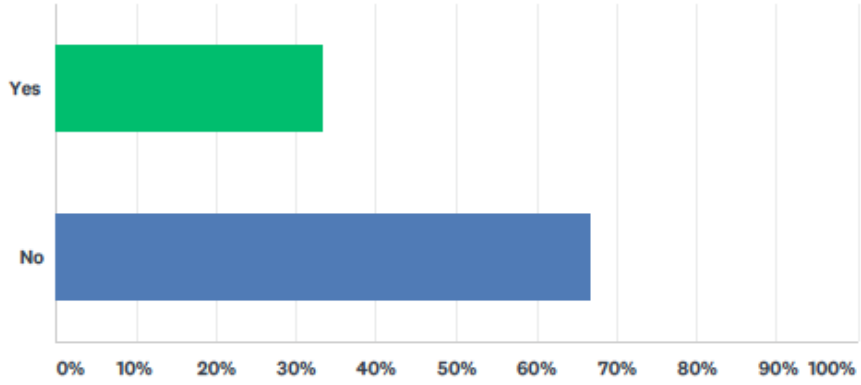
FUNDING AGENCY SPONSOR Q25-Q29

Q25 How do you perceive the quality and competitiveness of US GOSHIP proposals relative to other proposals that are submitted to your agency?



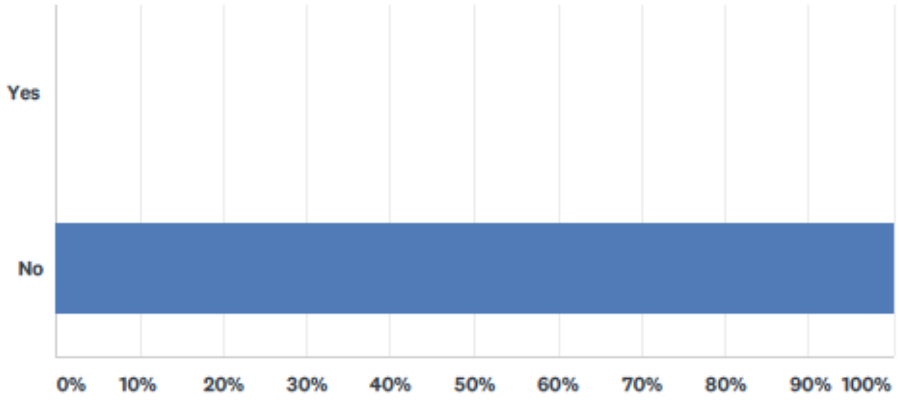
ANSWER CHOICES	RESPONSES	
Consistently excellent (more competitive than other proposals, higher than average success rate)	66.67%	2
Consistently very good (competitive but not always at the top of the pile)	33.33%	1
Highly variable (ranging from excellent to poor)	0.00%	0
Mostly of low quality	0.00%	0
TOTAL		3

Q26 Do you think there is adequate funding for US GO-SHIP PIs to carry out their work?



ANSWER CHOICES	RESPONSES	
Yes	33.33%	1
No	66.67%	2
TOTAL		3

Q27 Do you think that funding for US GO-SHIP often takes away from funding for other equally worthy projects?



ANSWER CHOICES	RESPONSES	
Yes	0.00%	0
No	100.00%	3
TOTAL		3

Q28 How can the current US GO-SHIP funding model be improved?

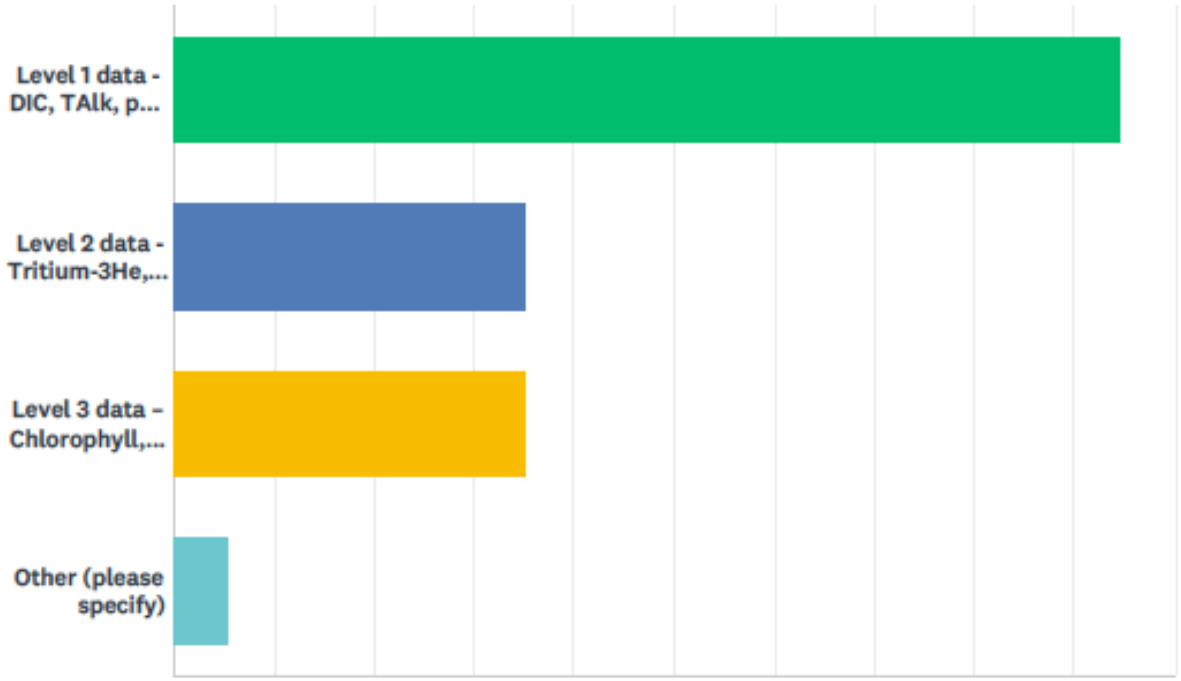
The NOAA-funded portion is impacted by flat funding affecting the ability of the PIs to - replace service equipment -write papers -engage in follow-on activities (e.g. modeling efforts) Most of the funding supports salary, cruise and analysis costs will little left over if there are issues with instrumentation or for further research or modeling efforts.

Q29 What is your perception of US GO-SHIP data discoverability and usage by the ocean sciences community? Can you suggest other metrics we could track to quantify the community impact of this program?

US GO-SHIP data are available in a timely matter as required by international GO-SHIP. Data are available at NOAA OCADS (NCEI) and CCHDO via FTP, and browser-based Live Access Server (http://ferret.pmel.noaa.gov/LAS) access that offer the user the ability to define, visualize and download custom subsets. I am not sure if usage is tracked but perhaps something similar to the tracking done by the Argo program would be helpful.

DATA USER: Q30-Q35

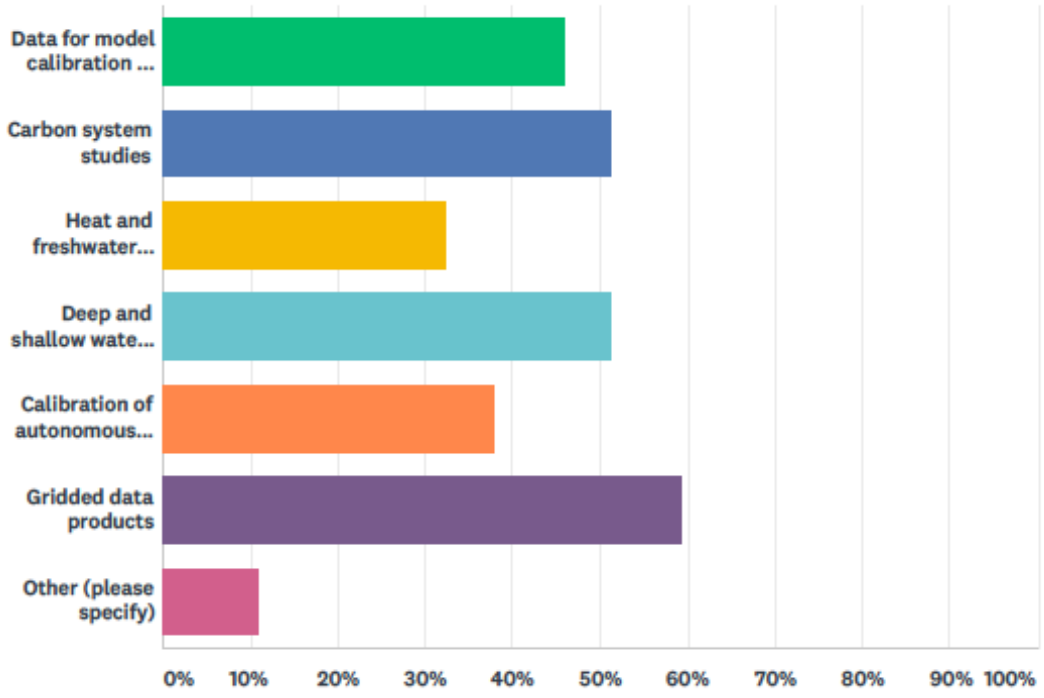
Q30 Which data sets do you primarily use? (select all that apply)



ANSWER CHOICES	RESPONSES	
Level 1 data - DIC, TAlk, pH, CTD (T, P, S, O2), bottle S, nutrients by standard autoanalyzer (NO3/NO2, PO4, SiO3), DO, CFCs, SF6, DOC, DON, surface underway data (T, S, pCO2), ADCP (shipboard, lowered), underway navigation and bathymetry, meteorological	94.59%	35
Level 2 data - Tritium-3He, discrete pCO2, 14C by AMS, CCl4, d13C of DIC, Fe/trace metals, CTD transmissometer, surface underway system (nutrients, O2, Chl, skin temperature)	35.14%	13
Level 3 data – Chlorophyll, primary production, HPLC pigments, experimental continuous analyzers, d 15N, NO3, 32Si, d18O of H2O, NH4, low-level nutrients, total organic P, upper ocean optical, isotopes of O2, N2-Ar-O2, methyl halides, DMS	35.14%	13
Other (please specify)	5.41%	2
Total Respondents: 37		

#	OTHER (PLEASE SPECIFY)	DATE
1	Chipods	12/17/2018 7:15 PM
2	Synthesis products like GLODAP and WOA	12/17/2018 3:47 PM

Q31 How have you used US GO-SHIP data? (select all that apply)

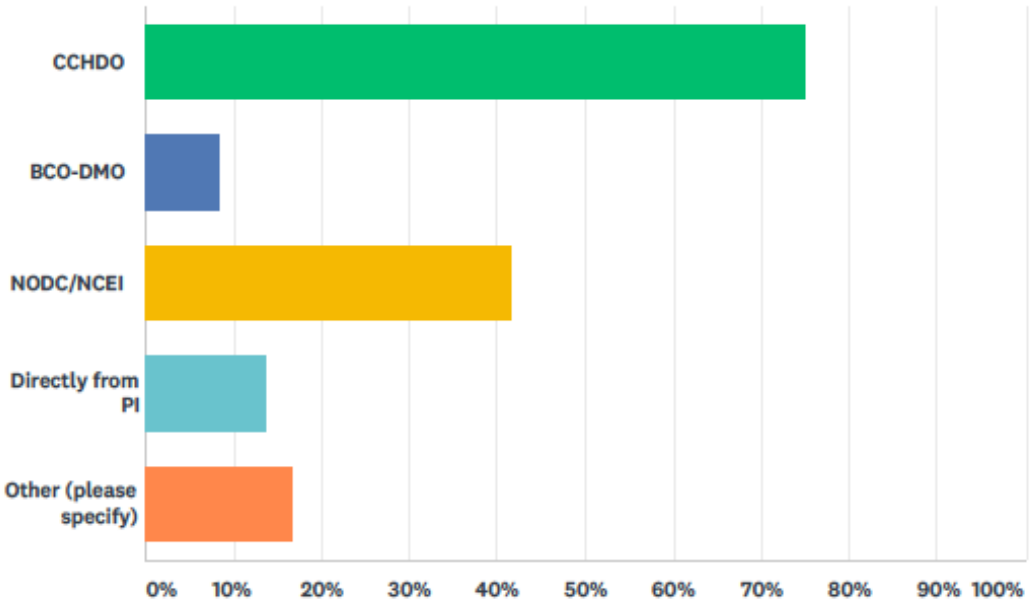


ANSWER CHOICES	RESPONSES	
Data for model calibration and validation	45.95%	17
Carbon system studies	51.35%	19
Heat and freshwater storage and flux studies	32.43%	12
Deep and shallow water mass and ventilation studies	51.35%	19
Calibration of autonomous sensors	37.84%	14
Gridded data products	59.46%	22
Other (please specify)	10.81%	4
Total Respondents: 37		

#	OTHER (PLEASE SPECIFY)	DATE
1	Biogeochemical studies, comparison with GEOTRACES data	12/1/2018 2:13 PM
2	surface ocean and upper mesopelagic biogeochemical fluxes of C, N, P, O2	11/29/2018 3:27 PM
3	Anthropogenic carbon inventory change calculations	11/6/2018 11:40 AM
4	global inventories and fluxes	11/6/2018 10:45 AM

Q32 How do you access US GO-SHIP data (check all that apply)?

Answered: 36 Skipped: 82



ANSWER CHOICES	RESPONSES	
CCHDO	75.00%	27
BCO-DMO	8.33%	3
NODC/NCEI	41.67%	15
Directly from PI	13.89%	5
Other (please specify)	16.67%	6
Total Respondents: 36		

#	OTHER (PLEASE SPECIFY)	DATE
1	GLODAP and WOA	12/17/2018 3:47 PM
2	glodap, socat	12/17/2018 2:52 PM
3	CDIAC, OCADS	12/14/2018 12:41 PM
4	as part of larger, amalgamated datasets such as GLODAPv2	11/19/2018 11:55 AM
5	GLODAP	11/6/2018 1:38 PM
6	I know lots of acronyms, but I'm afraid that some of these are beyond me.	11/6/2018 10:11 AM

Q33 Regarding US GO-SHIP data management, please comment on the accessibility, documentation, data quality, and support. Can you suggest improvements to make their use easier?

Accessibility seems fine.
According to my own experience: Very easy internet access and well documented metadata.
CCHDO has been very easy to use and to find data.
CCHDO is great!
Data are easy to access and use. CCHDO has been responsive to queries.
Data are very accessible.
Data has been easy to access through CCHDO.
Easy to use.
Excellent data management overall.
fabulous documentation and quality. No suggestions for improvement.
GO-SHIP data is clearly defined, easy to access and in a standardized format - all perfect.
Head and shoulders better than anything on the planet. A bit of extra equipment funding for the labs doing the lion's share of the measurement is needed
I haven't interacted much with the newer CCHDO, I primarily obtained data from CDIAC and found the map of lines with data behind the hyperlinks very user friendly.
Instructions for submission of data is clear and access is easy. We appreciate that units and formats have been made consistent over the years.
It would be amazing if all data was machine readable and if there were sample code to download and read the data. For example python / R / Julia notebooks that go through the whole process from acquiring the data to plots.
Its very well organized and easy to access.
Sometimes data sits in CCHDO's "Unmerged Data as Received" for a long time. Data under "Unmerged Data as Received" is not downloaded when doing an advanced search. Files should be processed quickly and put into "Dataset" so the files can be found in a search and will be in Exchange format
Sometimes, within my expertise ... the CO_2 system in seawater, I see that the reports are copy/paste without some detailed issues properly regarding the cruise analysis.
the US leads the way in its commitment to making datasets publicly available within a few years of data collection.
Wonderful. A major improvement would be better integration into ODV. Another would be to include all repeat hydrography on the GOSHIP site in a couple of easily accessible formats.

Q34 Please comment on the importance of US GO-SHIP data sets in the broader Global Ocean Observing System (GOOS) framework?

A critical component of GOOS
Absolutely zero level critical
Essential backbone dataset
First, may of the biological, chemical and tracer parameters measured on the ship can not be measured any other way. The repeat sections allow for assessment of climate variability that we could not do with any other part of the GOOS system. Second, GO-SHIP data acts as a reference set to many other GOOS platforms, without which, those platforms (such as Argo, Deep Argo, and BGC Argo) would be much less effective.
For biogeochemistry it underpins interpretation of the wider GOOS framework.
Highest importance. GO-SHIP is the gold standard. Argo needs GO-SHIP for ground truthing and calibration
I don't know what the GOOS is.
I'm not aware of all GOOS, but US GO-SHIP, as a major component of GO-SHIP, is a key component to have high-quality oceanographic data, and also a wider set of deep ocean observations.
It allows a continues overview of the world's oceans.
It is a critical part of the GOOS framework that ties many other programs (SOCAT, BGC-Argo, satellite obs) together.
It is essential for EOVs still not so well measured and calibrated using sensors at profiles floats r gliders
Its a cornerstone of our open ocean observing. If one goes to NODC and checks recent data entries in the open ocean, GO-SHIP is now about the only data source. Without GO-SHIP we won't have ship-based validation for processes such as ocean deoxygenation.
The repeat hydrography is a key and instrumental piece of the GOOS
The wealth of parameters from a GO-SHIP cruise makes it worthwhile compared to autonomous resources. There are different science questions to be answered using different approaches.
There are things measured on the GOSHIP cruises that cannot be measured in other ways. They are also a useful platform for deploying autonomous vehicles.
they are critical for the GOOS framework.
US GO-SHIP data are a critical element of the GOOS
US GO-SHIP data are an important component.
Very important. Ship-based observations are getting harder to collect because of costs. The US effort is greatly appreciated.

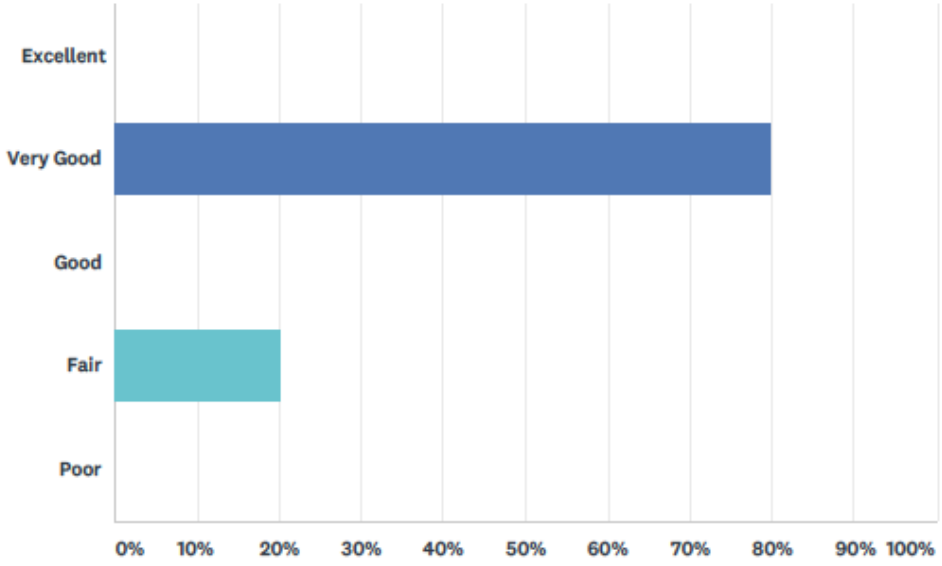
Q35 How aware do you think the community in general is of the GO-SHIP data resource? What could be done to increase utilization?

Awareness is high and adequate
Build high quality curriculum for undergraduate studies that use the data. For example an entire lab /data analysis component where students train in downloading and interpreting he data. Why not include some nice videos and photos from the cruise as well, and maybe even contact information for the grad students?
Data coverage is too poor to be very useful.
Fairly aware.
Fairly aware. I think the status quo is probably fine.
Fairly low. It would be useful if any researchers using these datasets are recommended to acknowledge all programs that have contributed data (most often Argo* and GO-SHIP)
Generally aware...perhaps a town hall or booth in non-traditional workshops (e.g. MTS Oceans meeting) would be helpful.
Given the broad use of Argo data, GO-SHIP data might be more widely used if the data were available in an Argo-like format---though it's hard to imagine that data formatting is holding people back. Air-sea flux data would benefit from some work on ship flow distortion and sensor placement.
I think awareness is a big problem for GO-SHIP and I do think the data set is under utilized. I think combining all the data into a global data set would be useful.
I think for biological oceanographers is not that well known.. maybe GO-SHIP PIs or representatives can attend particular meetings and present the results / opportunities given by GO-SHIP to other programs
I think that specialized people and oceanographers (ocean researchers) are well aware about GO-SHIP data resources. We could increase the utilization showing those resources to our graduate (and advanced undergraduate) students, given special assignments where they have to use those resources.
I'd say a majority of researchers are aware of the data resource. To increase utilization, maybe providing the complete dataset as a QA/QC package immediately openable in Ocean Data View or other visualization software.
In the general ocean obs community, many may be aware of the data but not necessarily the program - increased utilization could come about from having all users acknowledge the data source as GO-SHIP in published works and in talks. Often modellers just say it is a compilation of data when it is really a single GO-SHIP expedition.

Scientists using gridded data products such as GLODAP or WOA should be made more aware of the data source. Many could benefit from using the original datasets instead of the gridded products.
Sessions at OCB summer workshops
The scientific community is very well aware of the data resource and relies on it.
Very aware.
Well aware.

NON-US AFFILIATE: Q36-Q38

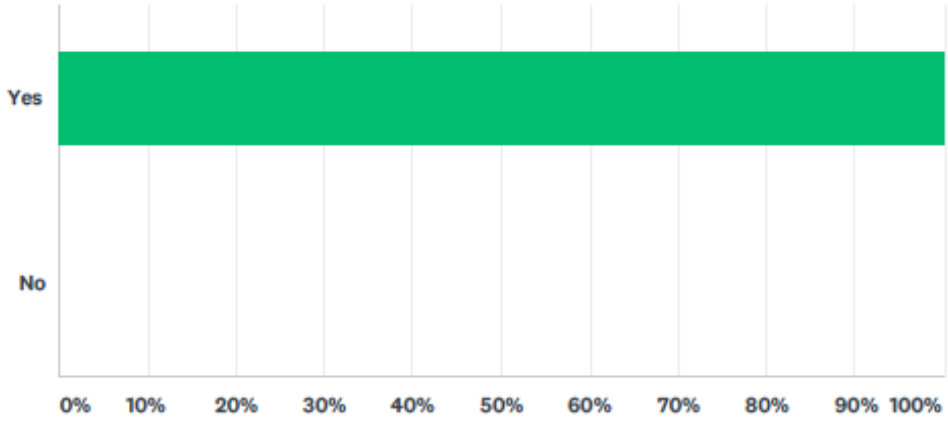
Q36 How would you rate the level of coordination and collaboration by US GO-SHIP to help the goals of the international GO-SHIP program?



ANSWER CHOICES	RESPONSES	
Excellent	0.00%	0
Very Good	80.00%	4
Good	0.00%	0
Fair	20.00%	1
Poor	0.00%	0
TOTAL		5

#	PLEASE ELABORATE FURTHER:	DATE
1	Not particularly well coordinated, but everyone is busy. The exception is the help on our cruises with CFC measurements, which is exceptional. The US program also supports some other tracer collections, but this is more opportunistic and welcome. It is on a cruise by cruise basis, when the section is in a useful location, and this is very welcome and we are happy to help, although it is more or less us filling bottles with seawater.	12/17/2018 5:20 PM
2	It could be improved, but it works well	12/17/2018 2:49 PM

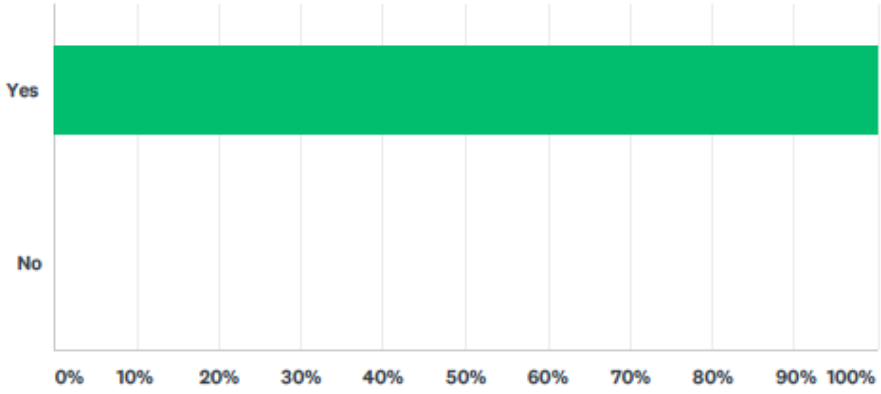
Q37 Are international cost sharing mechanisms fair and effective?



ANSWER CHOICES	RESPONSES	
Yes	100.00%	4
No	0.00%	0
TOTAL		4

#	OPTIONAL COMMENTS FIELD FOR FURTHER ELABORATION	DATE
1	Countries cover their own costs	12/17/2018 5:20 PM
2	I am not familiar with the cost-sharing mechanisms	12/17/2018 2:49 PM

Q38 The US is primarily responsible for GO-SHIP data management through CCHDO and BCO-DMO. Do you have confidence that the data are effectively served, managed and safeguarded?



ANSWER CHOICES	RESPONSES	
Yes	100.00%	5
No	0.00%	0
TOTAL		5

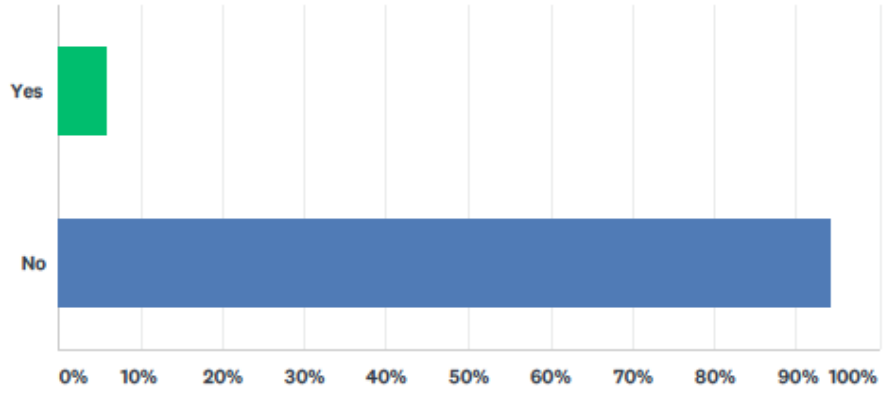
#	OPTIONAL COMMENTS FIELD FOR FURTHER ELABORATION:	DATE
1	I am particularly familiar with BCO-DMO and their efforts to serve Go-ship data prove very effective	12/17/2018 2:49 PM

OTHER INTERESTED INDIVIDUAL: Q39-Q42

Q39 Please define your connection with US GO-SHIP

Carbon/Tracer Data quality evaluation Chief of mission in non US GO-Ship line
Coordination of a key end-user community
I have helped coordinate the US academic sea program and the international hydrographic data office since the inception of the program. Previously I was involved in similar capacities with WOCE and with CLIVAR repeat hydrography.
I have no direct connection but I am a member of the broader community of US scientists conducting biogeochemical research
manager of technical group that provides support
no relation
none at this point
Provider of quality controlled datasets from GO-SHIP cruises. Collaborator with GO-SHIP steering team via JCOMM working groups/teams.
Trough SOCCOM I am responsible for the optical sensing. I am co-chair of a SCOR committee looking to add biological measurements to GO-SHIP.
User of data and of publications based on the data.

Q40 Have you submitted a proposal for funding to participate in US GOSHIP?

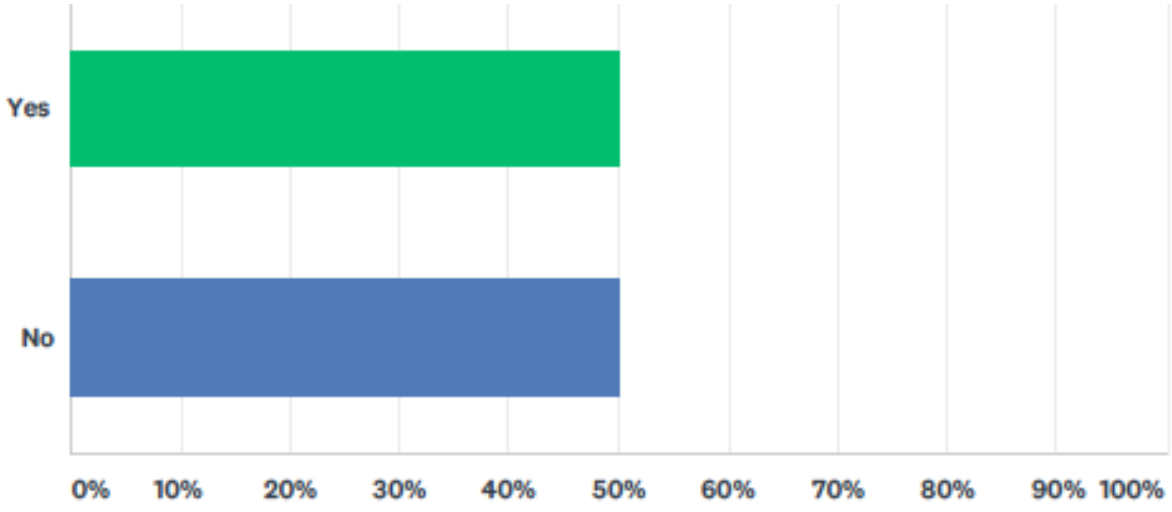


ANSWER CHOICES	RESPONSES	
Yes	5.88%	1
No	94.12%	16
TOTAL		17

Q41 If yes, to which funding agency?

NSF (also data office proposal to NOAA)
N/A

Q42 Do you believe your proposal was treated fairly?



ANSWER CHOICES	RESPONSES	
Yes	50.00%	1
No	50.00%	1
TOTAL		2

#	PLEASE ELABORATE FURTHER	DATE
1	N/A	12/17/2018 1:51 PM
2	I have found the review process and the subsequent agency implementation process fair and effective.	11/19/2018 1:22 PM
3	does not apply	11/10/2018 6:13 PM
4	n/a	11/6/2018 7:03 PM
5	N/A	11/6/2018 12:13 PM

GENERAL: Q43

Q43 Please use this space to comment on any additional aspects of the US GO-SHIP Program that were not addressed in this survey.

A lot of the GO-SHIP community is near retirement age. Recruitment of younger scientists needs to accelerate beyond current activities
As a student based at a university that does not operate blue water cruises, the opportunity to go to sea with GO-SHIP was invaluable to me.
As stated earlier, I think that for the future, GOSHIP should look on how to try to incorporate new types of "clean" sampling. Given the existence of GEOTRACES, there seems to be quite a few opportunities for both programmes to work together. Synergies already exist given that many of the people involved are the same, but it could also be nice to allow for some GOSHIP stations to be ocasionally repeated (i.e. every 10-15 degrees) so as to collect more water, and therefore help fill in data gaps for the other programme if at all possible. In any case, a programme like GOSHIP needs to continue to exist and if I can help in any ways, I will be very happy to contribute.
At least 12 countries participate in the international GO-SHIP effort with the US serving as one of the major contributors. GO-SHIP has several requirements including a data policy timeline (by data level), temporal and spatial requirements (decadal, coast-to-coast or coast-to-ice). The program also updated the WOCE hydrographic manual to promote standardized methods for a core set of parameters measured on the GO-SHIP hydrographic reference sections.
Based on the Cruise Data and Schedules table on the U.S. GO-SHIP website, additional work is needed within U.S. GO-SHIP to cross-link and relate datasets collected on GO-SHIP cruises. Many data types are known to be made on all GO-SHIP cruises, but not all are accessible via this interface. Likely a resource issue, but efforts should be made to collaborate with other data repositories focused on underway data from U.S. cruises (e.g., R2R, BCO-DMO, SAMOS, NCEI).
For outsiders sometimes it seems that CLIVAR and GO-SHIP are 2 different programs that run on the old WOCE lines independently, so the message about GO-SHIP being part of CLIVAR isn't quite getting out there. This may be because the perception often is that CLIVAR is predominantly physical oceanography and GO-SHIP emphasizes more the C system.
Future integration of GO-SHIP with BGCArgo is next
GO-SHIP is great and an essential partnership for autonomous sensor programs such as BGC-Argo.
How do I join US GO-SHIP Program to participate in Voyages & research . How do I get affiliated to the program to contribute substantially.
I believe that the US GO-SHIP cruise opportunities need to be better publicized and possible in advance. Many people had complained to me about that.

I have two concerns. One is the difficulty in getting projects funded that do the basic analysis of the data sets (it is work that has to be done, but it is not part of the GO-SHIP). Second, I would like to see the practice of having any educated talented person have the opportunity to be co-chief, that this position not be reserved only for those in post-doctoral positions. If that had been case back when I first started going on GO-SHIP cruises, I never would have become involved.
I regularly use data from GO-SHIP cruises in my teaching, as is fundamentally shapes our understanding of ocean biogeochemistry.
I will take the survey again to comment on ship support issues.
Information about this program and opportunities associated with its cruises need to be distributed more broadly.
It would be nice to add POC and pigment (chlorophyll) data
N/A
NSF and NOAA need to build up their global class vessels to keep programs like GOSHIP and GEOTRACES going.
Overall, I feel that the US GO-SHIP program is utterly invaluable to our understanding of the global ocean. However, I also feel that the program would significantly benefit from increased flexibility in terms of the types data that are measured on the cruises.
Please keep it, I do deeply envy this program. I wish Spain could have such a coordinated and funded program.
Shipping is the most difficult component of these cruises. The expense has skyrocketed and it may be more efficient and cost effective to have a logistics coordinator for each cruise to help identify agents, coordinate shipments among various teams etc.
Sometimes I think that non-scientific considerations played too large a part in deciding what was tier 2 or tier 3 measurements. I"m also strongly biased on this one.
The program needs to find a means to best relate its findings on phyiscal/chemical ocean change to whatever ecosystem responses to those changes may be taking place. I am a little disturbed that in our efforts to be most efficient in terms of ship time, we have cut some of the cruises too short to allow for weather and wire problems. Yes, NSF is reasonable on these matters, but maybe we should talk about a tad more ship time, especially where higher winds/seas may take place. Also, we are having increasing difficulty getting cruises scheduled in the optimum data windows. Certainly this is partly due to the reduction in global-class ships. Perhaps the ship time request system could be modified to note that for cruises scheduled outside the optimum data window, extra days at sea will be required. This will not only cost more for the ships, but also for the science teams, but one way or the other we need to be able to field our teams with sufficient time to accomplish the cruise objectives. I think we are getting by for now, more or less, but perhaps the scientific leadership could weigh in on how longer station spacing affects scientific results?
This is an important program that should be continued.
This survey did not ask the most important question which is how this work contributes to essential sustained observations, in addition to how it might contribute scientificially and to early career development.

US GO-SHIP appears to be in a transition period, where a number of the older seagoing folks seem to be moving on while their replacements are slowly filtering in. This is good for the program in the long run, as new blood is needed, but care must be taken to ensure that enough support is available to ensure the data quality does not drop. More documentation for GO-SHIP participants is better - most of the usual seagoing teams are made of specialized experts that know their area excellently, but there can be a lack of broad knowledge available in the team while at sea, leading to basic misconceptions of what happens at each step - multiple black boxes except for the step they know. While the GO-SHIP hydro manual explains the science and how to do it, there is less available documentation for deployment and recovery of rosettes and CTDs, mobilization/ demobilization, data formats and standards. Additional documentation in this area could go a long way towards flattening the learning curve for new participants on cruises, and help to spread GO-SHIP quality data across other programs, improving oceanography as a whole. While I have not seen what student introduction packets look like, students frequently find themselves on their first cruise ill prepared for time at sea. A standardized introduction packet to provide a baseline for chief and co-chief scientists to customize could be helpful to new students at sea.
We are often asked to collect samples for the US SOCCOM float group while on sections. This is an increasing burden when there is other section work put aside to help. This SOCCOM group relies on sections and the people in the field for calibration data to make their sensor data useful. From my perspective, they give little credit to the importance of GO-SHIP or other groups that get in the field, deploy their floats, and collect or provide essential calibration data. I am not sure we can sustain funding to support efforts like sections as long as SOCCOM continues to downplay the importance of the sections in order to promote their own work. This may not be the case in the USA (I don't know). However, if the response is that it is not a problem in the USA, it may be an indication of a failure to adequately communicate the links of sections and the float effort outside the USA. This communication should be both from SOCCOM and GO-SHIP. It may come down to a choice of floats or sections for countries with limited resources and this is likely to impact the ability of those countries to contribute to the sections work.
Well, I'd just say that some of the questions, plus your use of all the acronyms, means that you are thinking about your users in a very restricted way.
Why is this survey on US GO-SHIP alone? Other organisations outside US also collect high quality data. I am puzzled by this survey.

8.4 Strengths, Weaknesses, Opportunities, Threats (SWOT) Slides

Strengths

Overview

- Reference-quality, global data set collected and provided for public use
- Vital for carbon inventories, vital for deep ocean change estimates
- Vital for Argo (core, deep, and BGC) both calibration and deployment

International GO-SHIP

- GO-SHIP has name recognition as an outstanding program with the best data
- Best way to get a global coordinated survey at decadal intervals
- International agreements on measurements (EOV, Levels) and Best Practices
- Links to international operational entities through JCOMM and GOOS/IOCCP
- Part of international grand vision (e.g. Sustainable Development Goals) and addressing acute GOOS issues (de-oxygenation, warming, acidification, eutrophication)

Data Management

- CCHDO serves easy to use reference-quality, global data; US ADCP/LADCP & pCO_2 data are in good hands.
- At-sea data and documentation management on US academic GO-SHIP cruises (via ODF) remains strong.
- Effective CCHDO US GO-SHIP data management; good relationships with seagoing teams and data users.

Cruise Organization

- Productive working relationship with UNOLS schedulers, academic ship operators, and NSF ship support.
- Academic cruise planning is explicitly supported by the NSF grant; Isa Rosso nearly in place (replacing Swift).
- Planning (scheduling, science & measurement teams, and data responsibilities) has resulted in successful cruises.
- The long experience of the expert seagoing teams greatly assists pre-cruise planning.
- Executive committee provides advice, has process in place to consider requests for additional science programs.

Chief/Co-chief

- Assistance from: Chief Scientists, GO-SHIP leadership and Ship Support (NOAA onshore DM support)

- ODF and Ship Techs
- S, O2, TALK and Ancillary sampling & deployments provide experience for students
- Provides excellent leadership training for CS and Co-CS
- Data reporting reminders from SIO GO-SHIP

CTD/O2/nuts/S

- On-time production of reference quality CTD/O2, bottle oxygen, salinity, and nutrient data
- Incorporation of ancillary sensors on CTD (transmissometer, FLBB) & rosette (LADCP, chipods, UVP)
- Contributed to international protocols for nutrient measurements (SCOR WG 147 leadership)
- Contributed to global assessment of heat, freshwater, oxygen, sea level change
- Publications on ocean circulation, mixing, climate and climate change

ADCP

- Ocean current profiles are available at sea, and in archives ashore.
- SADCP and LADCP provide the high-resolution context for all other GO-SHIP observations.
- SADCP and LADCP are essential for geostrophic referencing in some regions.
- LADCP Vertical Kinetic Energy parameterization provides new mixing estimates.

DIC/pCO2

- Reference-quality, global carbon, biogeochemistry and tracer data set
- Success in quantifying decadal changes in carbon inventories and transport calculations,
- Success in quantifying de-oxygenation and acidification estimates and attribution
- Vital for BGC Argo both cal/val and deployment and model validation

ph/Alk

- Measurement of discrete samples, on-board ship, by skilled personnel, in standardized ways, leads to very consistent data sets

DOC/TDN

- Production of the most extensive and highest quality DOC and TDN profile data to date
- Quantitative estimate of largest pool of reduced C necessary for mass balance understanding of Ocean C cycle
- Data used by ancillary groups for interpretation of DOM character, transformation, export and age estimates
- Data contributed to high profile and high impact publications on the understanding of DOM biogeochemistry

CFC

- Production of highest quality tracer data, met data management requirements
- Incorporation of SF6 measurements not only enhanced temporal information provided by tracers, but its measurement required larger samples that resulted in increased precision for CFCs
- Tracer invasion into the ocean is a important analogue for anthropogenic carbon uptake
- Contributed to high profile publications on ocean circulation, mixing, climate

Level 2, 3

- Provides funded professional core observations useful to experimental programs (level 3)
- Organization and high quality shipboard measurements support floats and drifters programs
- Level 2 provides test grounds for future Level 1
- Level 3 provides test grounds for future Level 2 or 1
- Provides opportunities for early career scientists and students to take the lead on specific sampling

Weaknesses

Overview

- All PIs quite busy, hard to meet regularly for oversight
- Need to regularize selection of seagoing science party
- Data management could use some fine-tuning
- GO-SHIP investigators without science funding have minimal opportunities to analyze data, negatively impacts recruitment of chief and co-chief scientists

International GO-SHIP

- It is a largely volunteer effort: requires time from SC members, and no means to enforce requirements
- Need national resources to implement common components such as central data depositories
- TORs and requirements need to be clarified & codified

Data Management

- At-sea data and documentation management on the NOAA-led cruises is working at a functional but rudimentary level commensurate with funds available.
- While DOIs are minted on request, comprehensive minting/versioning is not yet implemented (difficult issues).

- Staff support (from CCHDO) for US GO-SHIP web site is ad hoc and relies on over-subscribed personnel.
- International: Insufficient support for full CCHDO data management; must now use triage approach.
- International: Data discovery and contacts with data originators are ad hoc, lacking in official sanctions.

Cruise Organization

- Timing for UNOLS pre-cruise planning can be irregular.
- Long lead time needed for added programs which require ship time. Difficult and expensive to add ship days.
- Process/timing for selecting cruise leaders and students is not as open and regular as it might be, and available positions are not always advertised widely (e.g., if exec or cruise leaders already have persons in mind).

Chief/Co-chief

- Timing of announcements and determining who is involved
- NOAA & ASC Medical (as it relates to backup personnel)
- Foreign National Clearance requirements limit NOAA's choice of students
- Specifics in Guidelines need more emphasis (do not assume the CS comes with experience)
- Not all co-chief experiences are created equal
- Ancillary sampling can become overwhelming, outbound shipping can be an issue

CTD/O2/nuts/S

- Senior PIs all busy with other programs (promotes connections but little dedicated attention)
- Data management on NOAA cruises under-supported.

ADCP

- SADCP: might be under-utilized in GO-SHIP.
- SADCP and LADCP: characterization and estimation of uncertainty is complex.
- SADCP and LADCP: US GO-SHIP is not closely connected with non-US contributors.

DIC/pCO2

- Succession plans not obvious, especially for carbon and tracers
- Need to replace and/or upgrade aging instrumentation
- Misalignment of ship time requests and scientific funding

ph/Alk

- Insufficient attention paid to characterizing measurement uncertainty for GO-SHIP data
- Inadequate planning for long-term sustainability of measurement programs
- Need to improve ease of post-cruise data quality assessment (by improving on-board system?)

DOC/TDN

- Aging instrumentation impacts throughput of sample analyses
- All analyses must be performed at shore based lab; thus presents challenges of how to partition highly trained technical personnel btw sea going collection vs highly technical analyses, given funding level.
- Coordination of logistics issues such as shipping, securing agents could be more efficient
- Limited water budgets limit other types of supporting ancillary data, DOP, microbial rates, experiments etc.

CFC

- Science analyses for NSF-based participants unsupported by the funded grant
- No consistent DQ process
- Analytical difficulties still result in missing measurements (i.e. not a routine measurement)

Level 2, 3

- Can be a significant effort in terms of organization, water budget and time for the science team
- Lack of funding priorization for Level 2 measurements
- Following data submission requirements are more acute than for Level 1
- Ad-hoc framework for US GO-SHIP decision making for Level 2 and 3 parameters

Opportunities

Overview

- Emerging needs for biological observations, microplastics, turbulence, etc
- Increasing BGC and Deep Argo needs for deployments and reference quality cal/val data
- Opportunities for increasing syntheses of GO-SHIP and Argo data
- Opportunity for increased collaboration with emerging BGC Argo

International GO-SHIP

- Further multinational collaborations: "Global programs should have global participants"

- JCOMMOPS provide unique opportunity of metadata tracking and cross-program linking (programs/projects, cruises, EOVs, bibliography) [see JCOMM OCG network slide]
- JCOMM/WMO/IOC efforts with EEZ issues (Marine Research Clearance) following Argo

Data Management

- Bi-weekly data manager telecons continue to enhance interoperability, coordination, and innovation.
- NSF is funding several CCHDO technical improvements, e.g., improved data standards compliance, search and download of data "by profile" (in addition to "by cruise"), and improved Google "findability".
- CCHDO working with BCO-DMO should be able to handle new bio/ecosystem parameters as that develops.

Cruise Organization

- Wide community demand for reference-quality data helps to assure sea program support.
- Public high quality hydro/tracer/CO_2 data & global/repeated coverage inspire science program enhancements.
- Involvement of new science interests (e.g., ecosystem assessment) may increase funding & scheduling priority.
- US GO-SHIP seagoing teams are available to help complete Level 1 parameter suite on other GO-SHIP cruises.

Chief/Co-chief

- There is a desire to share cruise planning and water budget software
- To share strengths and weakness and previous issues
- Leg 1 CS has the opportunity to include both Leg 1 & 2 co-chiefs in planning
- Interaction with students provides lasting relationships

CTD/O_2/nuts/S

- Expand rosette/CTD operations to include routine optical/biological/mixing measurements
- Seek modest, periodically reviewed science analysis funding for PIs.
- Improve linkages with Argo with upcoming Deep and BGC Argo (operations, QC, science)

ADCP

- Global study of geostrophic referencing methods with GO-SHIP cruise data.
- Increased collaboration with non-US GO-SHIP SADCP and LADCP programs.
- Make external magnetometer/accelerometer package a standard part of LADCP.

DIC/pCO_2

- Emerging need for biological observations to determine biological responses to changing biogeochemistry
- Increasing need for BGC Argo validation studies and cal/val data for new sensors
- Opportunity for increased collaboration with emerging BGC Argo

pH/Alk

- Should spend more resources on upgrading measurement approaches to ensure that high-quality data can be obtained more cheaply (on a per measurement basis)

DOC/TDN

- Allows for the evaluation of DOM removal rates and mechanisms on times scales otherwise impossible to obtain
- DOM research is still in relatively early phase of understanding; each occupation reveals new features & info
- Only just finishing 2nd global sampling- additional occupations should reveal long term changes
- Opportunities for student and Post Doc training; Share archived samples with ancillary programs
- Continued improvement in analytical procedures and DOM quality

CFC

- Incorporation of measurement of N2O on a subset of the cruises at insignificant cost
- Tracer concentrations and their changes within the ocean interior continue to be recognized as important tools for understanding changes in ventilation/circulation
- Collaborations with Australians

Level 2,3

- Provides basis for synthesis and future collaboration
- Opportunity for emerging science (e.g. microplastics, biology, autonomous instruments)
- Biological sampling (e.g. net tows, trace elements, inherent/apparent optical property casts) are complementary to GO-SHIP objectives
- Reaching out for collaboration with groups working on Environmental DNA samples --> eDNA samples seem highly compatible with GO-SHIP sampling and would benefit form decadal repeats

Threats

- Lack of funding for science (reduces impact of data sets, makes transition from co-chief to chief difficult)
- Increasing costs of sea-going work with level (in 2003 dollars) funding on NOAA side
- Level 2 and 3 data sets that are essential for climate monitoring: very fragmented funding (ex. del18O)

International GO-SHIP

- Difficult to gain long term commitments from different nations
- Part Time (3 mo/yr) GO-SHIP coordinator funded through ad hoc and voluntary funding (Australia, Horizon 20/20, Japan)

Data Management

- CCHDO workload to manage international CTDO/bottle data and docs exceeds its funded staff capability.
- Retirements of key personnel (Swift, Key, Kozyr) may significantly worsen international data discovery and flow.
- Long-term international ADCP/LADCP data management issues still not settled.
- International support for sea surface carbon data management is at risk fiscally, though has good PI support.

Cruise Organization

- Becoming more difficult to schedule cruises in optimum weather windows (= missed/ incomplete stations).
- Reductions in total US/UNOLS sea work (and changes in the NSF proposal process for PIs to use ODF) negatively impacts the stability and technical evolution of the seagoing teams (some may be below a sustainable level already).
- Flat NOAA funding impacts NOAA cruise schedule and lab support. Also: need succession plan for senior/key personnel.
- ODF funding is fragile and uncertain; also ODF needs SIO action on new scientific advisor (to replace Swift).
- ODF GO-SHIP rosette is nearly 'maxed out' and is thought to be operating near the limits of present CTD cables.

Chief/Co-chief

- When timing and/or allowed cost means that SIO does more of the planning, CS may not be prepared
- Limited salary funding & lack of science funding – may end up limiting who is willing to

expend the time & effort

- When the ship is not prepared (e.g. winches, wires and techs)
- Timing and readiness of EEZ clearances, as this can bring to extensive port and at-sea delay

CTD/O2/nuts/S

- Rosette re-design to optimally incorporate some Level 3 instruments (e.g. UVP)
- Science analysis for CTD/oxygen/nutrients PIs is not supported
- NOAA CTDO-rosette operations flat funded since 2003
- Succession plan for PIs not apparent (especially on NOAA side)

ADCP

- Reliability of present standard LADCP instrumentation (especially WH150) is poor.
- LDEO tech support: Bruce Huber has retired.
- Funding for taking advantage of opportunities?

DIC

- Declining numbers of global class vessels while number of parameters to measure increases
- Lack of funding for data synthesis efforts (GLODAP) and science
- Increasing costs of sea-going work with level (in 2003 dollars) funding on NOAA side

pH/Alk

- Increasing costs of sea-going work (salaries & OT, shipping, . . .)
- Insufficient resources to train new personnel effectively

DOC/TDN

- Lack of funding for data synthesis efforts (GLODAP) and scientific interpretations of data
- DOM research is Level 1 in US program; still very hit or miss support on the international level

CFC

- Ageing expertise – no young analysts in the pipeline!
- Reduction of NOAA commitment to tracer program?
- Loss of innovator in analytical techniques and leader in calibration efforts

Level 2,3

- Lack of succession for some Level 2 measurements
- Smaller ships with fewer berths --> more sampling requests for CTD-watch - impacting how much could actually be done, because Level 1 always takes precedence

8.5 US GO-SHIP Executive Council comments on the US GO-SHIP review

September 9, 2019

This comprehensive and positive review of US GO-SHIP by US CLIVAR and OCB is of great value and importance for the future of GO-SHIP. We are already acting on some of the recommendations and will be incorporating the major suggestions in our planning for the proposed next 6-year funding cycle of US GO-SHIP.

The following comments from the US GO-SHIP Executive Council are in response to the review, highlighting strengths and raising additional concerns or highlighting major issues for which the review committee did not propose solutions, but which should be addressed in the next cycle of US GO-SHIP.

1. Organization and funding

The NSF and NOAA components differ in structure, funding, management. Some of the unique issues are mentioned in the review but not expanded upon.

US GO-SHIP is self-governing as there is no formal program oversight for US GO-SHIP because GO-SHIP is a program of GOOS, and GOOS does not have a central US structure/program management. Leadership is drawn from funded PIs, and the funded PI structure is based on historical structure because it is rooted in labs with long-term experience. Perhaps this is appropriate. US GO-SHIP should tend to leadership transitions more proactively.

International vs. U.S. organization.
There is no international GO-SHIP project office. International organization is handled through JCOMMOPS, with 3 months/year support for Martin Kramp, and assumption of input from the international GO-SHIP co-chairs.

Suggestions for approaches to funding expansion of ADCP data archiving to international GO-SHIP would be very valuable. Similarly, if CCHDO expands to vigorously incorporate data quality and data products including all international GO-SHIP contributions, there would need to be additional personnel.

Within international GO-SHIP we are looking hard at creative means to share resources (e.g. this is already done for CFCs with the US covering Australian cruises) including shiptime. One option would include NSF and NOAA chartering international ships.

Funding mechanisms for data analysis and synthesis, to ensure continued leadership
The current and past cycles of the US GO-SHIP funding contain little funding for science analysis. The most recent 6-year cycle has one postdoc position, but no funding for the scientists involved in the program to analyze the data they have collected on behalf of GO-SHIP.

The US GO-SHIP Executive Council perceives this to be a fundamental weakness in the GO-SHIP structure, if only because it leads in the long-run to problems with expert succession, for this sustained observations program that will likely endure for some time.

The following comments in the review on the lack of funding support for data synthesis are crucial and are a bit buried in the leadership succession subsection. The issue is broader than just leadership succession and workforce development and gets to the return on investment for NSF and NOAA. It would benefit from being called out as a separate subsection in Section 5.2 on US GO-SHIP Data: Collection, Quality Control, Reporting, Access, Synthesis. Currently in that section, "synthesis" is only addressed in terms of succession planning for two specific personnel.

Section 5.3.2 Leadership succession planning

> "With the exception of limited postdoctoral support, there is no US GO-SHIP project support for follow-up data analysis and scientific research. A direct consequence of the lack of funding for science discovery is that the PIs who have the requisite expertise to collect climate-quality data can receive little credit for this work in the publications that ultimately result from the freely available data."
>
> "Furthermore, a more consistent process across the US GO-SHIP measurement suite for supporting data analysis and science discovery is needed to ensure that the scientists involved in collecting these valuable datasets have an opportunity to participate in and receive credit for some of the scientific findings that emerge from them.".

In the past, one argument has been that synthesis and science proposals could be submitted to NSF core programs, but there is a sense in the community that such proposals do not do well in panel. I am not sure if we have any hard data on this, and one suggestion is to ask NSF to assess the aggregate statistics (anonymously) of GO-SHIP synthesis and science proposals.

2. Levels 1, 2, 3 data

Level 1 data and quality

A difficult aspect moving forward is ensuring the data quality of the various Level 1 measurements given turnover of the individuals involved in making these measurements at sea. The US CO_2 groups have found this to be problematic.

A key difficulty is to ensure that the methodology is subject to sufficient continuous improvement so as to make it more reliable, faster, and cheaper - while maintaining (or improving) the level of measurement uncertainty.

Level 2 data

The review report focuses on opportunities for Level 3 variables and does not address challenges with the Level-1/Level-2 distinction. The current system for funding and planning Level-2 has weaknesses, and we were hoping to see an explicit recommendation for careful reevaluation of the Level 2 variables in: Section 5.2 US GO-SHIP Data: Collection, Quality Control, Reporting, Access,

Synthesis, 5.2.5 Recommendations

-There is no "consortium of funded investigators" leading each Level 2 observation type. For instance, with Level-2 tritium-3He, funding that exists requires independent, ad-hoc proposals by individual PIs for sampling and analysis. At least for tritium-3He, there is no longer a fully coordinated program, in part because of retirements and people moving away from the field.

There are some misconceptions about Level 2 data in the review text (Section 2).

-It is not simply that Level 2 "may be collected on coarser spacing". In fact some of the Level 2 variables are not collected at all on some of the U.S. funded sections, their funding has to be obtained independent of the core proposal for the Level 1 variables, and there is no coherent plan for which sections to target for specific Level 2 data types.

-The data policy for Level-2 data is based on time after analysis, not the cruise, as is also the case for Level 1 data.

Level 3 data
While from a US funding agency perspective, Level 3 data and protocols are of high importance, they are less so for international GO-SHIP. GO-SHIP is set up to address the core questions outlined in the review with the level 1 measurements following the exacting protocols. This remains the absolute priority.

We are not aware of level 3 requests being turned down by the US GO-SHIP Executive Council or the US GO-SHIP chief scientists, unless we could not accommodate them with respect to shiptime requirement, water volume, or specialized equipment. The council and chief scientists do consider each request seriously and whether it is feasible. The most common avenue for Level 3 measurements is that a Level 3 PI will contact us about a proposal they are writing, and ask about whether we can accommodate the measurement. If we can, then we provide a letter of support signed by both co-chairs, on letterhead. Of course not all proposals are funded. A second common avenue is for someone who is already part of the science party, for instance a PhD student or postdoc, to request to do additional sampling. Again if it is possible to accommodate this, we do, with the understanding that the sampling will be of lower priority than Level 1, followed by Level 2.

In all cases, we expect the Chief Scientist to work with the Level 3 programs and the core shipboard measurement team in advance of the cruise, and throughout the cruise, to ensure that their program needs are being met; we are aware that we have not always achieved this ideal.

3. Data practices and management

The real value of GO-SHIP Level 1 data is as an absolute reference dataset. It requires all of GO-SHIP, not just US GO-SHIP, to acquire this global dataset. The gridded products proposed would be of greater value if they included all GO-SHIP reference sections, which would require additional funding.

The rapid and open release of data is a unique part of GO-SHIP.

The US GO-SHIP committee and PIs have been leaders in advocating Best Practices, and rapid and open data sharing. This has been a mind change in the oceanographic community. In WOCE/WHP in the 1990s, there was a strict two-year embargo on data sets (which caused all sorts of issues for data that needed to be corrected - such as alkalinity needing nutrient info etc., causing delays longer than 2 years). Beginning with the first round of CLIVAR repeat hydrography cruises in the 2000s, the US adopted the current, liberal data sharing guidelines, in which Level 1 and 2 data sets are to be made public at the earliest reasonable time given the data types; deadlines were set for each type of data. These data sharing guidelines were expanded to the international program with the formation of GO-SHIP after OceanObs09. US GO-SHIP laboratory heads have mostly done an excellent job meeting those deadlines.

To ensure timely data submission, US GO-SHIP exec council should have an agreement with the NSF and NOAA program managers that provides information to NSF/NOAA about very tardy PIS/groups, after a given protracted lapse (define time scale) and routine requests from US GO-SHIP for data submission. If it is a matter of insufficient funding for data processing/QC prior to submission, then it is useful for NSF/NOAA program managers to know this. This should extend to Level 3 as well as Levels 1 and 2.

The GO-SHIP data quality, best practices, and open release are now being propagated in two new efforts in GO-SHIP: "Frequently repeated" and "affiliated lines". These are not mentioned in the review report, likely because the US GO-SHIP program does not at present include these types of sections.

Data quality examination (DQE) is an ongoing, tough issue. There is no doubt that primary DQE is best carried out at sea. This requires time and expertise. If we have the expert techs running ragged to keep up with sampling and running samples, we are missing out on the best DQE opportunity. [This is an ancillary benefit of having another program on board that uses ship time but generates a minimum of the present GO-SHIP parameters. An hour a day of wire time for a hypothetical eco-bio team may be a godsend for the GO-SHIP technicians in terms of DQE and maintenance.] We might consider - just musing here - offering a “science DQE spot” on the cruises - or a month of support post-cruise - that would be open to community scientists, and supported competitively for each US GO-SHIP cruise. This may be more economical and perhaps in some ways superior to supporting a full-time DQE person for the program.

US GO-SHIP does not have its own data management system other than its internal data tracking system to ensure that measurement groups meet deadlines for submission, and so responding to the recommendations in bullets 2 and 5 is complicated. It is true that US GO-SHIP is deeply intertwined with data management entities, particularly the CCHDO and ADCP/LADCP center, but these are funded separately from US GO-SHIP. CCHDO has much wider scope than just US GO-SHIP, and CCHDO serves international GO-SHIP in addition to US GO-SHIP. In order to deal with the review committee recommendations, US GO-SHIP would need to be much more directly involved in the management of these external data management systems. As a major user of these systems, perhaps US GO-SHIP should greatly increase its formal influence and direction.

There are advantages if the CCHDO were more directly subject to external scientific oversight. During WOCE, the WOCE Hydrographic Program Planning Committee and, after that, the WOCE Data Products Committee provided valuable guidance to the WHPO and CCHDO, plus there was the considerable advantage that if the WHPPC or DPC directed a change, NSF was more likely to support any extra funding required for it.

Directions that US GO-SHIP can consider:

1. US GO-SHIP improve/modernize its one formal data management function, e.g. data tracking.
2. US GO-SHIP institute a central data quality control process for each of its Level 1 and 2 data sets.
3. US GO-SHIP should engage formally at least annually with its principal data management centers: CCHDO and ADCP/LADCP, and underway data (currently R2R and NCEI).

4. Ships and work environment

In section 4.3.3, there is this statement:

> "An uncomfortably large number (~30%) of participants commented on inappropriate or unethical behavior on US GO-SHIP cruises. Examples included misogyny and sexual harassment, and devaluing of science priorities of lower level (non-L1) measurements."

This matter is taken very seriously by US ship operators, UNOLS, and the funding agencies. For example there is a major, productive conversation within UNOLS, with a number of initiatives well underway, including production of videos (to be viewed by all parties) dealing with shipboard life, including harassment issues. NOAA has taken the lead on the videos, and UNOLS is making progress, too. There has been in the past few years a considerable upgrade in the content and visibility of materials dealing with harassment, including reporting, and how incidents must be dealt with. Also, there has been a major change in how special events, such as crossings, must be handled. US GO-SHIP should reaffirm its total commitment to these anti-harassment policies, and meanwhile for every cruise directly point all of the participants to the materials and measures that are in place and coming into place.

Two current US GO-SHIP PIs (Jim Swift and Dennis Hansell) are on UNOLS committees. This type of engagement should be maintained. To help keep visibility and communication going in the long run, US GO-SHIP should encourage its academic participants to volunteer for UNOLS assignments and committees within their general fields of interest. Vacancies on UNOLS committees are widely advertised (and there is good community response).

Scheduling is a big issue for US GO-SHIP and there is no science community membership on the scheduling committee (nor will there be, we presume). For GO-SHIP cruises on UNOLS, USAP, and USCG ships, it will be important for the project logistics coordinator to work 1-2 years in advance of each cruise with the schedulers, armed with a short, very to the point letter from the US GO-SHIP Exec listing the scientific priorities of the cruise as related to logistics. It will also be good to have such

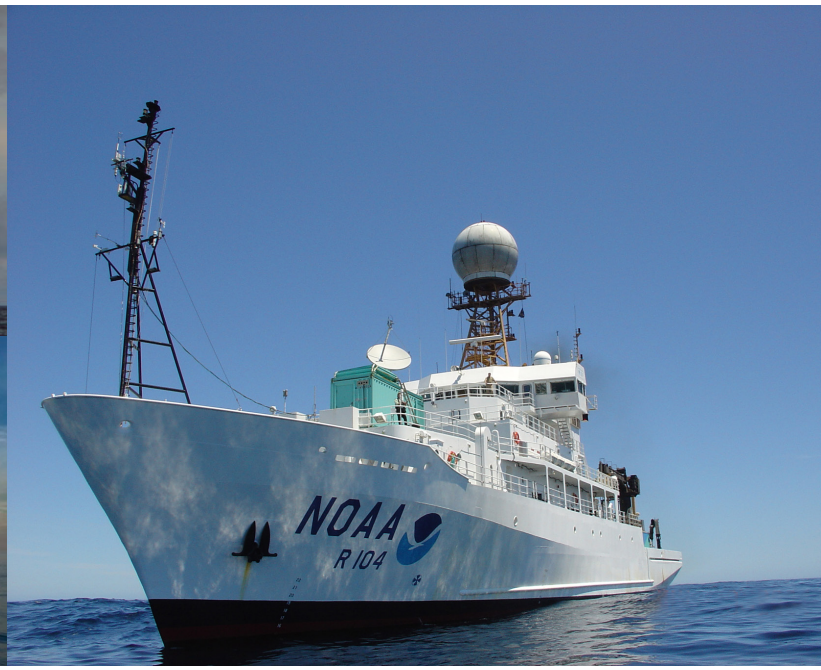
statements like this directly in the Ship Time Request (STR) form. The STRs are a key document used by the schedulers. They are submitted with the proposal but can be modified (to a degree) along the way, as each cruise approaches. We know enough now about the sensitive points of each US GO-SHIP cruise to be clear about what we need and what the scientific costs are of logistics problems. The more clearly a science program can elucidate the logistics required to meet its reviewed, funded goals, the better its chances are to have its logistics needs met.

That said, it is clear in the latest UNOLS Fleet Improvement plan (available soon from the unols.org web site) that NSF OCE may be level funded for years, perhaps with minimal (or even no) inflation adjustment. NOAA is likely in a similar situation. In addition, there are no plans in NOAA to replace their single, ageing, global class vessels. Meanwhile ship operation costs will likely continue to rise somewhat faster than overall inflation. Therefore there may well be continual erosion in the number of ship operating days annually supportable by NSF and perhaps other Federal science sponsors, and also in the number of ships in the academic research fleet. Hence it may become even more competitive for US GO-SHIP to get the global class ships it wants in the years and seasons it wants, and with the cruise durations it needs. Hence refer to the previous paragraph about the importance of clearly elucidating the logistics required to achieve science goals.

US GO-SHIP Executive Council membership:
https://usgoship.ucsd.edu/ under 'People'
The executive council for US GO-SHIP sees that the program of repeat hydrography, ocean carbon, and tracer measurements is completed to fulfill the scientific objectives of GO-SHIP.

- Leticia Barbero National Oceanic and Atmospheric Administration (NOAA)/AOML
- Molly Baringer National Oceanic and Atmospheric Administration (NOAA)/AOML
- Craig Carlson University of California, Santa Barbara
- Brendan Carter National Oceanic and Atmospheric Administration (NOAA)/PMEL
- Andrew Dickson Scripps Institution of Oceanography (SIO)
- Scott Doney University of Virginia
- Richard Feely National Oceanic and Atmospheric Administration (NOAA)/PMEL
- Gregory C. Johnson (Co-chair) National Oceanic and Atmospheric Administration (NOAA)/PMEL
- Alison Macdonald Woods Hole Oceanographic Institution (WHOI)
- Jim Swift Scripps Institution of Oceanography (SIO)
- Lynne Talley (Co-chair) Scripps Institution of Oceanography (SIO)
- Andreas Thurnherr Lamont-Doherty Earth Observatory
- Mark Warner University of Washington
- Rik Wanninkhof, ex officio (GO-SHIP co-chair) National Oceanic and Atmospheric Administration (NOAA)/AOML

For more information visit
https://usgoship.ucsd.edu/



Ocean Carbon & Biogeochemistry Program

Woods Hole Oceanographic Institution
266 Woods Hole Road MS#25
Woods Hole, MA 02543
508.289.2838 I hbenway@whoi.edu
www.us-ocb.org I @us_ocb

US Climate Variability & Predictability Program

1201 New York Ave NW, Suite 400
Washington, DC 20005
uscpo@usclivar.org
www.usclivar.org I @usclivar

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