STATE OF GLIDERS: UPDATE ON CURRENT AND EMERGING BEST PRACTICES

STATE OF GLIDERS: 8th EGO Meeting & International Glider Workshop Meeting Summary

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Appendix A: 8th EGO Meeting & International Glider Workshop Meeting Summary, May 21-23, 2019

B1. Meeting Goal

The goal of the 8th EGO Meeting and International Glider Workshop, held May 21-23, 2019, was to strengthen international collaboration through community dialogue, exchanges of information, sharing of experiences, and development of best practices to support the glider community. For more about the meeting, including the agenda, visit the IOOS or EGO Network sites.

B2. Meeting Objectives

1) Harmonize glider efforts: International data management, leveraging partnerships, documenting best practices, international collaboration.
2) Promote new developments: Sensors, emerging requirements, novel glider applications.
3) Explore extreme environments: Sea ice, currents, severe weather conditions.
4) Refine operational activities: Reliability, sampling strategies, sustained monitoring.
5) Prepare for OceanObs'19: Strategy for the next decade of regional, national, and global ocean observing using glider technologies.

B3. Community

The international glider community is a growing group of manufacturers, scientists, students, funding agencies, universities, and government stakeholders. Individuals from sixteen countries attended the meeting to share ideas and to identify new outcomes and priorities for the community.

Over the past few years, the community has begun to improve coordination and capacity building by developing and sharing best practices. This meeting provided the community a forum for addressing the barriers to coordination and for developing the actionable next steps.

B4. Meeting Components

The meeting offered a mix of presentations, panels, breakout groups, a poster session, and open community dialog.

Oral Presentations. Energetic and captivating speakers educated and informed the community with up-to-date science, practice, and case studies. Researchers and operators, representing the full scope of the international glider community—from federal, state, and local agencies to industry and academia—covered a breadth of examples, methodologies, and general uses of gliders.

Breakout Sessions. Breakout groups created opportunities for participants to interact with colleagues and identify outcomes and priorities in the following areas:

Breakout #1, Glider Coordination Breakouts

- International Cooperation: How do we effectively enable sharing and access across EEZs to collectively address science challenges?
- Exploring Extreme Environments: How do we optimize glider missions to meet scientific objectives in demanding situations (e.g., sea ice, currents, storms, maritime traffic, etc.)?
- Leveraging Partnerships and Collaboration: What types of partnerships have worked and should be models for advancing glider capabilities?
- U.S. Glider User Group: How do we empower a robust and active community of glider users in the U.S.?

Breakout #2, Best Practices Breakouts

- Data Management and New Requirements: What are some near-term, practical implementation strategies towards achieving sound data management for glider activities and meeting new requirements?
- Documenting Best Practices: How can we collect, develop, verify, and communicate best practices most effectively?
- Reliability and Sustained Monitoring: What are the fundamental strategies for minimizing operational reliability risks for sustained glider missions?
- New Sensors and Sampling Strategies: How can new and existing sensors be more effectively deployed on gliders?

Breakout #3, Capacity Building Breakouts

- Training and Education: How do we enhance training and education opportunities for students, operators, managers, and users?
- Asset Sharing and Funding Opportunities: How do we promote collaborative opportunities for glider missions and build the case for more funding?
- Communication Tools: What are the best ways for sharing knowledge about gliders across the community?
- OceanObs'19 and UN Ocean Decade: What is the strategy for the next decade of regional, national, and global ocean observing using glider technologies?

Poster Presentations. Poster presentations showcased research, tools, and information.

B5. The Research

To view the agenda and presentations, visit the IOOS or EGO Network sites. The community heard presentations about the following seven topics:

Topic #1, Studies of Air-Sea Interactions During Storms and Hurricanes. Researchers are using gliders across the globe to collect ocean measurements that inform hurricane research and forecasting. Glider measurements collected internationally have improved understanding of storm intensity changes due to differences in wind shear and water temperature.

Topic #2, Sustained Observations of Boundary Currents. Understanding boundary current processes and variability over time is critical to understanding their influence on atmosphere and climate, especially regional and inter-annual variability. In marginal seas, boundary currents are the major exchange between the open ocean and regional ecosystems, which means that boundary currents provide information about fisheries, recreation, transportation, and, of course, weather. A global network of regional networks totaling at least one hundred gliders that monitor boundary current variability would benefit the world with an improved understanding of earth systems.

Topic #3, Water Transformation Phenomena, Vertical and Horizontal Mixing Processes. The use of gliders allows researchers to collect multi-year high-resolution observations that allow for the study of a wide array of ocean processes. Work presented at the meeting demonstrated improved understanding of the gulf stream and other extreme ocean events.

Topic #4, Observing the Ocean Geochemistry and Biology. An emerging area of research for gliders is the detection and measurement of the oceans' bio- and geochemistry. Through the maintenance of the CalCofi lines off the coast of California, researchers examined chlorophyll fluoresces and matched that to satellite data. Other researchers have developed the capability of identifying the species of biological organism floating in the ocean, which improves understanding of how these creatures change throughout the seasons. These measurements can also be used as early warning signs for the health of the ocean ecosystem and to improve our understanding of a changing world.

Topic #5, Glider Data Management. The community is in the process of identifying new standards and best practices for data management. In particular, there were presentations from the National Data Buoy Center and multiple Data Assembly Centres outlining the current processes for data management. The Ocean Best Practices system was reviewed by the community as a mechanism to catalog and share best practices for data management and other glider-related methodologies.

Topic #6, Operations and Infrastructure. The focus of this section was on the development of glider pilot training programs, establishing glider operations in new regions, and the difficulties with off-shore water-quality monitoring. These presentations highlighted the need for improved coordination and collaboration within the community to develop frameworks for prioritizing investment in operational and infrastructure capacity.

Topic #7, Glider and Sensor Technology. The community heard from a number of researchers implementing and developing new sensors to be attached to gliders. These new technologies ranged from the development of the Zooglider to identify marine organisms to new methods for sediment sensing and measuring hypoxia.

B6. Summary

Scientists, engineers, students and industry exchanged knowledge and experience on the development of glider technology, the application of gliders in oceanographic research, and the role of gliders in ocean-observing systems.

Appendix B. Technical Summaries: 8th EGO Meeting & International Glider Workshop

Table B1. Opportunities for Glider Coordination

Subtopics [numbers refer to the sections, above]	**Gaps**	**Opportunities**	**Impact if Addressed** [notional; low, medium, high]
1.0 Exploring Extreme Environments	Polar environment ● Compass variation ● Ice imagery/ ice detection ● Inability to do an emergency recovery ● Greater autonomy ● Trade-off with staying longer under ice and generating data versus getting the glider safely out of ice	● Need a community-focused approach for sharing information, tools, and techniques. Offering community-based funding is one idea to facilitate the sharing of information ● Partner with manufacturers to solve issues common across the community ● One solution for the inability to do an emergency recovery in this environment is to transmit as much data as possible when the glider surfaces	Medium
1.0 Exploring Extreme Environments	Human-built structures. Particularly challenging areas: ● West coast of California ● Mid-Atlantic ● Baltic Sea ● Gulf coast Primary technical and logistic challenges: ● Ship traffic and shipping lanes ● Lack of Automatic Identification System (AIS) data ● Pipe lines ● “Good Samaritans” picking up gliders ● Recreational boating- shrimpers and longline nets; ● Shipwrecks ● Offshore energy structures	● Swim shallow (at least 10 meters) across ship channels ● Make AIS tracking available for avoidance ● Make current maps available for locating structures ● Surface frequently in shallow water ● Improve ballasting to limit time at the bottom	High

1.0 Exploring Extreme Environments	Ocean dynamics. Primary technical and logistical challenges: ● Deep ocean canyons ● Strong stratification ● Boundary currents ● Storms/ hurricanes that make operating gliders difficult ● Lack of guidance for piloting through areas of high uncertainty ● Lack of autonomy; fleet of gliders need more autonomy to scale up ● Shark attacks	● Improve models for guidance ● Create more common tools for use within the community ● Hold higher-level community discussions for solving problems ● Share solutions/information/data throughout the community ● Facilitate, especially by manufacturers, the development of community discussions to develop common best practices	Medium
1.0 Exploring Extreme Environments	Long endurance flights. Primary technical and logistic challenges: ● Power supply ● Large displacement vole to overcome density variation ● Biofouling	● Develop environmentally-powered gliders (e.g., thermal engine allows to run in half of latitudes (not polar)) ● Use deep gliders and not surface as often to avoid biofouling ● Deploy paint and seam tapes to minimize biofouling ● Develop improved batteries and rechargeable batteries ● Develop better pumps and auto-ballosting ● Develop more autonomous gliders for fleets ● Build community fora for sharing information and solutions (e.g., biofouling and different methods for avoiding/dealing)	High
4.0 International Cooperation	Coordination and leveraging of international resources	● Relate one-on-one by scientist and by country ● As above, but simplify the country processes ● As above, but in multiple countries ● Aggregate processes through IOC or similar (broaden ARGO representation) ● Leverage OceanGliders	High
4.0 International Cooperation	Demonstrating the value of ocean gliders	● Choose domains: tropical cyclones, boundary currents (e.g., contaminant transfer), ocean acidification ● Identify impacts: make the general value case and then share specific success stories	Medium

		• Separate the data from the platform • Leverage Safety at Sea	
4.0 International Cooperation	Developing international capacity	• Train and develop • Provide the data to the country of collection; share as widely as feasible • Encourage the in-country scientists to collect and share • Invite a Steering Committee to lay the groundwork for training and expectations in-country and establish the funding mechanisms	High
4.0 International Cooperation	Unified protocols	• Write and continuously update the data management plan • Balance timing and depth of the dataset • Specify the consistency of measures • Specify the metadata • Set and enforce the protocols • Communicate consistently • Build trust (e.g., show the logos) • Demonstrate transparency	High
4.0 International Cooperation	Open questions	• Dealing with drifters • Working with uncooperative countries (e.g., getting equipment in and back out) • Change in one-on-one relationships changes the agreements	Low
4.0 Leveraging Partnerships and Collaboration	Lack of awareness of global glider missions	• Establish a mechanism to consistently compile a list of past and existing partnerships • Figure out how to meet GOOS objectives • Build mechanisms to improve international collaboration	High

4.0 Leveraging Partnerships and Collaboration	Lack of clarity when establishing partnerships	• Framework for collaboration
		  ○ Identifying a lead organization or person
		  ○ Minimum expectation
		  ○ Passion
		  ○ Collaborate with the next generation
		• Funders mandate partnerships (NOPP as an example)
		  ○ Ensure alignment of priorities amongst partners
		  ○ Formalize the partnership and include buy in for all partners
		• Prioritize opportunities to centralize operations and maintenance
			Medium

4.0 U.S. Glider User Group	Demonstrating the value of ocean gliders	• Highlight successes (e.g., website, interactive tools like Slack, Twitter) • Identify sustained funding to build a website and robust email list (including the operations and maintenance) • Continue in-person meetings every 12 or 18 months • Support early career by providing fast answers to hard questions, mentorship,	High

		travel support, stipends to contribute to the website, email list, etc. • Create a Steering Committee that includes international and U.S. participants, scientists, glider operators, data users, early career, mid career, and late career	

Table B2. Techniques and Technologies to be Developed

Subtopic [numbers refer to the sections, above]	**Gaps**	**Opportunities**	**Impact if Addressed** [notional; low, medium, high]
2.0 Data Management and New Requirements	OceanGlider1.0 (primarily real-time)	• Speak with manufacturers with a unified voice • Use findability, accessibility, interoperability, and reusability (FAIR) as a guiding principle • Communicate the process of OceanGlider1.0 to facilitate community development • Establish and update guidelines • Make everything backwards-compatible • Remember: It is all about metadata • Invite Joint Technical Commission for Oceanography and Marine Meteorology in situ Observations Programme Support Centre (JCOMMOPS) to play a large role in the implementation of all of the above	High
2.0 Data Management and New Requirements	Quality control (real-time)	• Focus on the Data Assembly Centres (DACs) • Produce best practices and socialize those with the community early and often • Focus on flagging the data as an initial step • Establish two-way communication channels between users and DACs	Medium
2.0 Data Management and New Requirements	Quality control in general	• Host annual quality control meetings as in the Argo Program. Focus the discussion around key issues to produce best practices and train the next generation. Currently exists in the United Kingdom • Invite manufactures to the meetings	Low
2.0 Data Management and New Requirements	BUFR	• Support Binary Universal Form for the Representation (BUFR) • Ask the BUFR working group reach out to the United Kingdom Meteorological Office for feedback	Low
2.0 Data Management and New Requirements	New requirements	• Develop a user-friendly, documented process for real-time data submission (new format) • Track deployment planning with estimation of mission likelihood, which also supports JCOMMOPS development of community services	High
3.0 Reliability and Sustained Monitoring	Openly and publicly available data	Make sure the data are publicly available and findable with a Document Object Identifier (DOI) associated for tracking the usage. Some is sent to a central system and then is engrossed by a variety of operational systems that may not be attributing sourcing	High

3.0 Reliability and Sustained Monitoring	Increase redundancies	Some programs purchase two-three gliders for every one in the water. Some day, maybe, move to quick-swapping already-calibrated sensors or other forms of modularity, bearing in mind the largest cost is the ship cost (could lower with prop-powered from coast). Reliability requires a full reset in the laboratory. Increase reliability with redundancy	Low
3.0 Reliability and Sustained Monitoring	Record reliability data	Begin recording reliability data at the sensor level to answer consistent questions (e.g., Got the glider back? Got the data back? Denote the failure mode (e.g., power, software, black box, biofouling, ballasting). Denote time out of water, track length (as a function of faster and longer). Related, share this feedback with manufacturers (e.g., this failure, this improvement request (e.g., for buoyancy))	Medium
3.0 Reliability and Sustained Monitoring	Work with manufacturers	Coordinate with glider and other sensor manufacturers to make the components more reliable. Share reliability information in near-real-time through strong advocates	Low
3.0 Reliability and Sustained Monitoring	Build technical support capacity	Develop a coordinating structure for local, organizational, community, and manufacturer technical support and best practices	High
3.0 Reliability and Sustained Monitoring	Build the value argument	Note data usage and utility by stakeholders. Identify and share the success stories	Medium
3.0 Reliability and Sustained Monitoring	Build national coordination of glider efforts	For example: (1) Initiate a community review of the reliability, points of failure - with strong user leadership to raise systemic issues to manufacturers; (2) Consider detailing the requirements for a universal black box; and (3) aggregate best practices (e.g., calibration facility, backups, seasonal accommodations, track the sensor in every dataset)	High
3.0 New Sensors and Sampling Strategies	Note: Every decision involves trade-offs. Best practices are nuanced. Major need for community resources	Develop three to five Grand Challenges for the international community	High
5.0 Documenting Best Practices	Need for a centralized best practices repository	Endorse the Ocean Best Practices website	High

		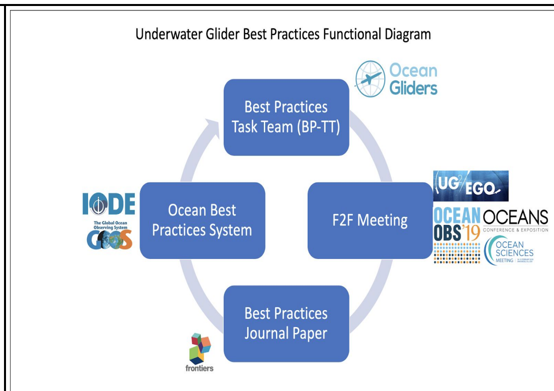	
5.0 Documenting Best Practices	Documenting best practices	● Form a task team on this topic under the Ocean Gliders; Pierre Testor and Mark Bushnell agreed to be on the team and develop a paper that describes the various categories of best practices ● Document best practices, lessons learned, and common mistakes (worst practices)	Medium
5.0 Documenting Best Practices	Community building through in-person technical meetings	● Co-opt other meetings (e.g., OCEANS, UG2/EGO Meetings, OceanObs'19, Ocean Sciences, etc.) ● Host webinars and other remote/virtual gatherings	Low
5.0 Documenting Best Practices	Choosing the appropriate communication tool for this community	Establish technical listservs, Slack channels, Twitter hashtag, hotline	Medium

Table B3. Opportunities for Capacity Building

Subtopic [numbers map to the sections, above]	**Gaps**	**Opportunities**	Impact if Addressed [notional; low, medium, high]
4.0 Asset Sharing and Funding Opportunities	Unclear how you get access to some resources	• Invite JCOMMOPS to start a group for communications /societal impacts • Leverage centers and/or JCOMMOPS for the collaboration, knowledge sharing, and deployment. Who funds? • Permissions and funding by EEZ, across EEZ	High
4.0 Asset Sharing and Funding Opportunities	Uncertainty surrounding Insurance	Work with insurance providers to develop a system for cooperative agreements for gliders that allow for distributed liability	Medium
4.0 Asset Sharing and Funding Opportunities	Unstable governments		Low
4.0 Asset Sharing and Funding Opportunities	Insufficient collaboration/ innovation with manufacturers	Make a platform for researchers to announce a glider deployment in a particular sector, with particular sensors: becomes an opportunity for funding or collaboration	Medium
4.0 Asset Sharing and Funding Opportunities	Sector overlap: public, academic, private	• Speak with a strong and collective voice, especially about societal benefits and why one project over another • Make the case for philanthropic funding (as in deep Argo)	High
4.0 Asset Sharing and Funding Opportunities	General recommend-ations	• Think ahead to operations and maintenance of equipment, software, and data assets; Same for service and training. Plan for those costs with acquisition • Aggregate the community's requirements and requests and choose strong leaders/advocates: for technology/funding requests, cloud high-performance computing, manufacturer requests/feedback • Develop a formalized software and community model that acknowledges the shared resource and the need for services, technical support	Medium
4.0 Communication Tools	Knowing where to go for information when joining the community	Hoste face-to-face meetings with networking (and meet again in November 2020). Include a session entitled, "It didn't go right"	Low
4.0 Communication Tools	Getting help when things go wrong	• Glider 911 • Twitter hashtags • Help hotline	High

4.0 Communication Tools	Understanding what communications tools should be deployed and when	Develop a series of quick-start guides: ● Outline which lines of communication to use for different scenarios ● Summarize the "Quick Start" to glider operations	Medium
4.0 Training and Education	Training tracks required	Develop certification or accreditation for operators that includes these topics, at a minimum: ● Maintenance ● Piloting ● Data management, analysis, use, QA/QC ● Sensor calibrations ● Battery management ● Risk management, including near misses ● Engage broader community ● Life-cycle training	High
4.0 Training and Education	Finding training opportunities (internships/ scholarships)	● Incorporate training opportunities at conferences ● Share standard operating procedures ● Develop training videos/ YouTube videos ● Document failures ● Host virtual meetings	Medium
4.0 Training and Education	Funding/costs	Educate the non-science community of successes	Medium
4.0 Training and Education	Multiplatform software management system	Develop a multiplatform software management system	Low
4.0 Training and Education	Turnover of students, technicians, and senior users	● Incorporate training opportunities at conferences ● Develop certification or accreditation for operators	High

4.0 OceanObs'19 and UN Ocean Decade	General recommend-ations	● Use OceanObs'19 as a strategic opportunity
		  ● Be prepared!
		  ● Develop talking points, two-pagers, large visuals, maps. Participate in sessions strategically (e.g., coastal hazards and modeling)
		  ● Invite meteorologists to participate (e.g., Joint Typhoon Warning Center and southern hemisphere meteorologists)
		● Engage with modelers. Be another set of eyes to validate their models
		● Coordinate with other countries by building off of effective bilateral and regional relationships (e.g., "land and expand")
			Medium

Appendix C: Acronyms List

AIS: Automatic Identification System
ANFOG: Australian National Facility for Ocean Gliders
AOP: Annual Operating Plan
ASA: Applied Science Associates
ASAP: Adaptive Sampling and Prediction
AUV: Autonomous Unmanned Vehicle
BOON: Boundary Ocean Observing Network
BUFR: Binary Universal Form for the Representation [of meteorological data]
CalCOFI: California Cooperative Oceanic Fisheries Investigations
CEQ: Council on Environmental Quality
CONUS: Continental United States
CO-OPS: Center for Operational Oceanographic Products and Services
CTD: Conductivity, Temperature, Depth [sensor]
DAC: Data Assembly Centre
DO: Dissolved Oxygen
DOE: Department of Energy
DOI: Digital Object Identifier
DMAC: Data Management and Communication
DOD: Department of Defense
EEZ: Exclusive Economic Zone
EGO: European Gliding Observatories —or— Everyone's Gliding Observatories
EOC: Education, Outreach and Communication
EPA: Environmental Protection Agency
EuroGOOS: European Global Ocean Observing System
FAIR: findability, accessibility, interoperability, and reusability [data principles]
FTE: Full Time Equivalent
ftp: File Transfer Protocol
GCCS: Glider Coordinated Control System
GCOOS: Gulf of Mexico Coastal Ocean Observing System
GENIOS: Glider Environmental Network Information Operating System
GLOS: Great Lakes Observing System
GMT: Greenwich Mean Time
GOOS: Global Ocean Observing Systems
GPM: Glider Program Manager
GPS: Global Positioning System
GTS: Global Telecommunications System
HAB: Harmful Algal Bloom
HFR: High Frequency Radar
ICOOS: Integrated Coastal Ocean Observing System
IMOS: Integrated Marine Observing Systems

IOC: Intergovernmental Oceanographic Commission
IOOC: Interagency Ocean Observing Committee
IOOS: Integrated Ocean Observing System
IPO: IOOS Program Office
JCOMMOPS: Joint Technical Commission for Oceanography and Marine Meteorology in situ Observations Programme Support Centre
JSOST: Joint Subcommittee on Ocean Science and Technology
MARACOOS: Mid-Atlantic Regional Association Coastal Ocean Observing System
MODIS: Moderate Resolution Imaging Spectroradiometer
NANOOS: Northwest Association of Networked Ocean Observing Systems
NCCOS: National Centers for Coastal Ocean Science
NCEP: National Centers for Environmental Prediction
NDBC: National Data Buoy Center
NESDIS: National Environmental Satellite and Information Services
NetCDF: Network Common Data Form
nFLH: normalized Fluorescence Line Height
NGDC: National Geophysical Data Center
NHC: National Hurricane Center
NJDEP: New Jersey Department of Environmental Protection
NOAA: [United States] National Oceanic and Atmospheric Administration
NODC: National Oceanographic Data Center
NOP IP: National Ocean Policy Implementation Plan
NOPP: National Oceanographic Partnership Program
NRC: National Research Council
NSF: National Science Foundation
NSG: Network Steering Group
NSTA: National Science Teachers Association
Glider Network: National Underwater Glider Network
NWS: National Weather Service
O&M: Operations and Maintenance
OG1.0: OceanGliders 1.0 [unified data format]
ONR: Office of Naval Research
OOI: Ocean Observatories Initiative
OPeNDAP: Open-source Project for a Network Data Access Protocol
OSSE: Observing System Simulation Experiments
OSTP: Office of Science and Technology Policy
PacIOOS: Pacific Islands Ocean Observing System
QA: Quality Assurance
QA/QC: Quality Assurance/Quality Control
QAPP: Quality Assurance Project Plan
QARTOD: Quality Assurance/Quality Control of Real-Time Oceanographic Data
QC: Quality Control
PI: Principle Investigator
RA: Regional Association

RCOOS: Regional Coastal Ocean Observing System
RHIB: Rigid Hull Inflatable Boat
RMS: Root Mean Square
SCCOOS: Southern California Coastal Ocean Observing System
SECOORA: Southeast Coastal Ocean Observing Regional Association
SOS: Sensor Observation Service
ssh: Secure Shell
SSS: Sea Surface Salinity
SST: Sea Surface Temperature
SOP: Standard Operating Procedure
THREDDS: Thematic Realtime Environmental Distributed Data Services
UNFCCC: United Nations Framework Convention on Climate Change
UG2: U.S Glider User Group
UNESCO: United Nations Educational, Scientific and Cultural Organization
UNOLS: University-National Oceanographic Laboratory System
US: United States
USGS: United States Geological Survey
WMO: World Meteorological Organization
WMS: Web Map Services
WRF: Weather Research Forecast

Appendix D: Resources

1. 2017 U.S. Underwater Glider Workshop Report (available online).
2. DRAFT State of Gliders Presentation (available online).
3. Kamensky, John M., and Thomas J. Burlin. 2004. *Collaboration: Using Networks and Partnerships*. In Leveraging Networks: A Guide for Public Managers Working across Organizations. Lanham, Maryland: Rowman & Littlefield Publishers.