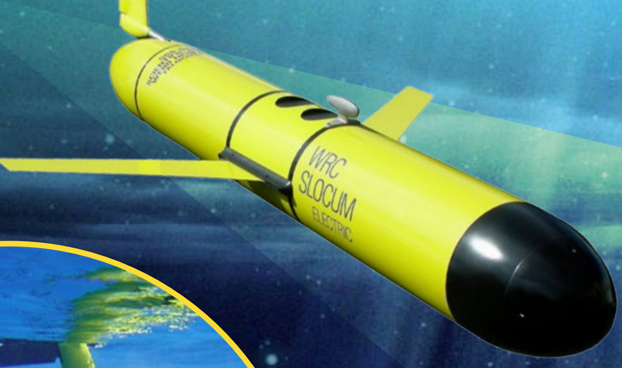
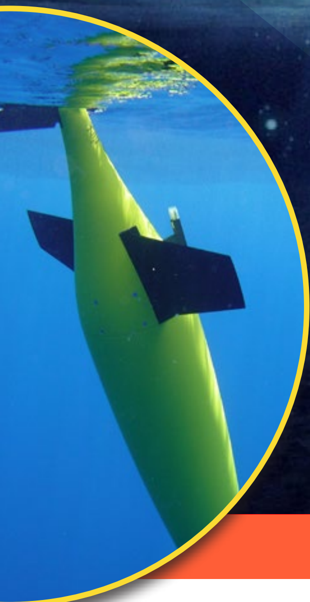




U.S. UNDERWATER GLIDER WORKSHOP REPORT

January 18-19, 2017

INFINITY Science Center, MS

TABLE OF CONTENTS

Meeting Summary 2

Overview. 2

Gliders for Ocean Monitoring 3

Harmonizing Glider Efforts 5

Glider User Group. 6

Workshop Outcomes. 7

APPENDICES (ONLINE):

1. Breakout results
    a. Event monitoring
    b. Sustained monitoring
    c. User Group
    d. Data management
    e. Operational reliability
    f. Interagency coordination
    g. International collaboration
2. Workshop presentations
3. Workshop agenda
4. List of attendees
5. List of poster presentations
6. Survey results

The U.S. Underwater Glider Workshop was publicly announced on the Interagency Ocean Observation Committee's website (www.iooc.us). This public workshop proceeded according to the meeting agenda. A summary of the meeting follows.

OVERVIEW

Autonomous underwater gliders provide an advanced and cost-effective mechanism for collecting essential oceanographic data at spatial and temporal scales that help the United States achieve critical research and operational objectives. In 1989, Henry Stommel and Doug Webb proposed the first Slocum Glider with a buoyancy engine powered by a heat exchanger, which has led to the development of new underwater glider vehicles (e.g. SeaExplorer, Seaglider, Slocum, Spray) and sophisticated data software products. The broad technical and geographic expansion of underwater gliders presents a unique opportunity for greater coordination among the ocean observing community for organizing decision-makers, glider operators, and data users to enhance science, marine services, and maximize societal benefits.

Presented with this opportunity, the Interagency Ocean Observing Committee (IOOC), whose mission is to enhance the efficiency of and motivation for ocean observing networks, commissioned a Glider Task Team comprised of regional and national glider experts and federal resource managers. The Glider Task Team first conducted a survey of the glider community to obtain more information about observing data gaps that could be met with gliders, priority areas for science coordination, and resource sharing opportunities for the glider community. Survey results from 17 agencies and science organizations indicated a need for community-wide scientific collaboration and a desire for resource and information sharing. The opinions of those surveyed reflects the importance of gliders to meet scientific requirements and suggests that most missions are research-based. The survey also indicated that the lack of capacity to respond to events and constrained funding are among the limitations identified by some members of the glider community. To overcome these challenges:

- 92 percent of surveyed agencies and institutions are open to facilitating joint glider missions, including data sharing, deployment/recovery resources, and platform sharing
- 86 percent of the survey takers would use a community forum.

Following the survey, the Task Team convened a U.S. Underwater Glider Workshop attended by 90 national and international glider experts from government agencies, universities, nonprofits, and industry. The workshop provided a platform for:

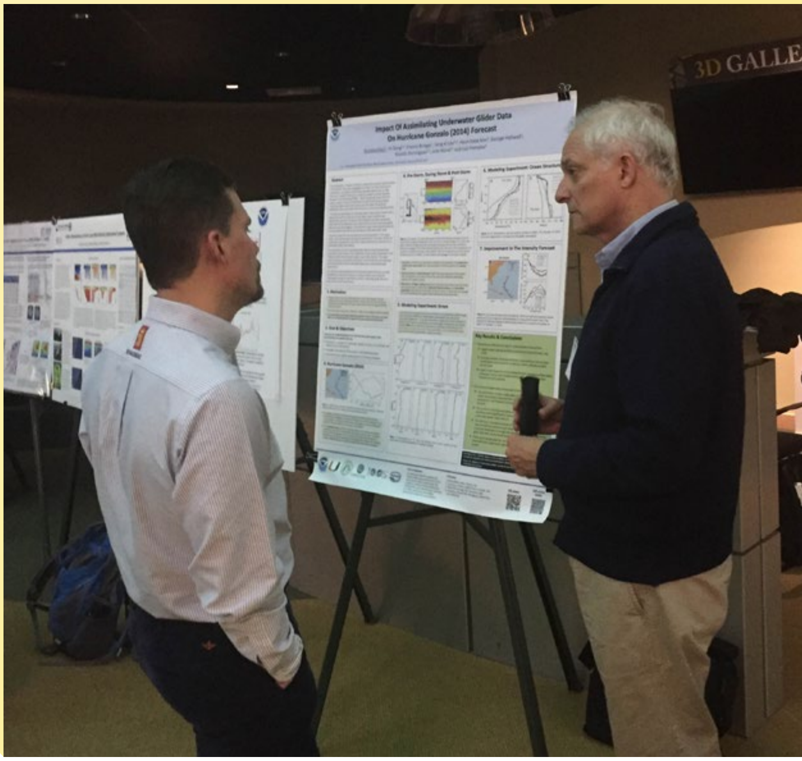
- Exchanging information on advances in glider capabilities, operations, and data processing;
- Exploring how gliders enable new scientific breakthroughs;
- Identifying gaps and coordination opportunities for planning, operations, and resources;
- Assessing best practices for observations, operations, and data management; and
- Designing the scope and aims for a coordination mechanism.

Attendees participated in a high-level plenary by federal agencies, scientific poster presentations, and guided discussion in breakout sessions on Sustained and Event Ocean Monitoring, Harmonizing Glider Efforts, and Developing a Glider User Group. The workshop resulted in diverse ideas broadly presented as:

- Initiate a US Underwater Glider User Group;
- Increase glider data assembly center robustness;
- Explore and encourage asset and platform sharing;
- Improve data and information services; and
- Engage international underwater glider groups.

GLIDERS FOR OCEAN MONITORING

The workshop divided ocean monitoring gliders into two categories: (i) event monitoring, used to target or to respond to specific events and (ii) sustained monitoring, used to establish baseline conditions and to identify trends.



EVENT MONITORING

Operational and scientific glider missions targeting specific features or events covered a wide range of scientific and geographic areas. Example features or events span various disciplines: physical (fronts and plumes, storms, deep water formation, meso- to submesoscale variability, internal waves, the marginal sea ice zone), biological (marine mammal and fish tracking, harmful algal blooms (HAB) and phytoplankton blooms), chemical (eutrophication, hypoxia, acidification), geological (sediment plumes, hydrocarbon seeps). Some events are specifically related to human activity (oil spills, marine pollutants, search and rescue, geopolitical). Event monitoring may begin with low-level detection, progress to more frequent environmental assessments with extensive sensor suites during the event, and continue after its conclusion for persistent impact assessment.

Many workshop delegates identified methods to enhance coordination, addressing science, technical, and data gaps. More effective use of existing glider assets can be improved through:

- Shared data from existing missions via national networks i.e. Integrated Ocean Observing System Glider Data Assembly Center (IOOS Glider DAC);
- Coordinated water space management of glider deployments, flights, recoveries and rescues by multiple groups;
- Shared use of spare glider inventory and sensors, mission planning and analysis software, and technical and regional expertise;
- Dedicated training through glider schools; and
- Enhanced federal and state government coordination and funding with academic, government, and industry glider operators.

Existing gaps in glider capabilities could be improved through:

- Longer duration glider deployments in an even broader range of operating environments
- Development of new low-powered, autonomous sensors;
- Development of rapid all-weather deployment capabilities;
- Development of on-board decision making and improved onshore path planning to reduce human piloting involvement;
- Simplification of glider repairs, refurbishment, and sensor calibrations; and
- Improvement of shared data through standardization, improved quality assurance and control procedures, and assimilation of a wider range of variables into models.

SUSTAINED MONITORING

Sustained glider monitoring missions have been used to collect regional data, to couple with or replace other observational platforms, and provide information to ocean circulation and biogeochemical models. Gliders are most effective at spatial and temporal scales associated with regional processes, which may include the physical circulation of the ocean's boundary currents, marine mammal monitoring and fisheries stock assessment, and ecosystem health (hypoxia, HABs). Many regions already implement sustained glider monitoring in select regions throughout the U.S. and Canada. Sustained glider missions in remote areas are logistically challenging, however implementation is happening at the Ocean Observatories Initiative (OOI) remote Global sites.

In general, workshop delegates provided technical information suggesting that effective sustained monitoring depends on increased collaboration between glider operators and continuous funding pathways. A synopsis of the specific collaboration opportunities includes:

- Facilitation of public/private partnerships;
- Formation of instrument/sensor pools or glider centers with partnering agreements;
- Operator collaboration and resource sharing (glider preparation, deployments, piloting, recoveries);
- Implementation of a user forum to share experiences; and
- Facilitation of data flow through data handling guidelines, data quality assurance and control, and shared pathways to modelers and other customers for the same data.

There are many regions that would benefit from the expansion of sustained glider monitoring (e.g. Gulf of Mexico, high latitudes, multiple Exclusive Economic Zones of the Caribbean/Pacific Islands) with the appreciation of resource limitations and the utility of gliders in certain environments. To address future monitoring activities, some workshop delegates suggested:

- Prioritizing any glider network expansions (in consultation with University-National Oceanographic Laboratory System (UNOLS), National Oceanic and Atmospheric Administration (NOAA), US Integrated Ocean Observing System (IOOS), and academic fleets);
- Determining how to maintain the critical mass of personnel required for sustained operations in more locations; and
- Identifying the best practices for coupling sustained monitoring with event response capabilities.

Cost savings could significantly improve sustained monitoring activities; this could benefit from extending glider deployment durations through energy source enhancement, improving deployment and recovery techniques, minimizing glider loss or the financial implications through insurance, and standardizing additional and/or new sensor integration.

HARMONIZING GLIDER EFFORTS

OPERATIONAL RELIABILITY

The key to glider mission success is often less about the hardware and more about the human interfacing with the hardware. Although some mistakes or errors always happen, many of them are likely preventable. Several key actions for glider operators were suggested that will minimize such errors and improve success:

- A dedicated glider team to develop required expertise and skill sets in operating and piloting gliders- this is not something people can 'jump in and jump out' of. If interns or students are used, clear mentoring and supervision needs to occur.
- A tiered-approach to piloting, used in larger glider operations, where a less-experienced pilot has an experienced pilot to call for assistance and/or advice.
- Knowledgeable glider teams that understand the waters of the area they are flying in. Issues such as currents and shipping lanes may be more obvious than fresh water plumes from rivers, fishing 'hot spots' attracting numerous vessels, and shallow bathymetry, to name a few (see complete list in addendum).

Workshop delegates presented many ideas and opportunities to improve operational reliability. These included:

- Encouraging deployment teams to avoid mistakes by not rushing glider deployments.
- Establishing talent and resource pools, i.e., documenting contacts and local expertise that can be made available when a group is flying in a new area.
- Improving communications with glider producers to provide feedback for strengthening reliability and development of products.

The greatest challenge to achieving these opportunities is a sustained funding source to allow for dedicated personnel and routine missions. Better communication within the glider community, specifically more effective ways to share knowledge, will improve operational reliability. Near-term steps over the next one to three years should include formalizing testing procedures and creating working groups.

DATA MANAGEMENT

Many opportunities were cited regarding glider data management with the need for shared formatting and data integration common themes (see Appendices). Near-term priorities should include standardization across glider operators and a glider data management working group. It was suggested that a glider data management group initially convene in 2017.

INTERAGENCY COLLABORATION

Workshop discussions focused on opportunities to better message the value of collaboration to federal agencies and to encourage them to share mission requirements for gliders. Challenges primarily focused on how to improve communication. Suggestions for moving interagency collaboration forward started with the formation of a Glider User Group. Existing interagency agreements should be reviewed and revised as needed.

INTERNATIONAL COLLABORATION

Sharing best practices will yield significant benefits to international glider operators and users. Moreover, establishing a common set of standards to exchange data would be beneficial to all. There are a number of areas where international planning and coordination of glider missions and linked research would rapidly advance knowledge and glider capabilities. The specific discussion topics should be widely distributed to the international glider community and communicated through the U.S. participants engaged with groups such as OceanGliders, posted on relevant webpages, and included in Glider User Group resources. Several other action items (see appendix) address access to foreign exclusive economic zones (EEZs), and review of existing IOOS and NOAA international agreements to incorporate gliders and glider operations.

UNDERWATER GLIDER USER GROUP (UG)^2

The overarching goal of an Underwater Glider User Group is to establish a community that facilitates sharing and cooperation in the following areas:

- Share experiences related to glider and sensor technology;
- Communicate the most recent scientific and operational accomplishments;
- Share approaches to logistical and operational challenges;
- Compare approaches to handling data collected by gliders, including quality control, formats, and distribution; and
- Disseminate news about opportunities and needs for gliders.

In the context of the mission areas above, (UG)2 might sponsor the following activities:

- Establish a forum for question and answers about gliders;
- Create a "hotline" to contact for help about glider emergencies;
- Host a software exchange for glider operations and data;
- Be a nexus for standards in data services;
- Foster communication between glider groups and users, including modelers;
- Set up a mechanism for sharing of glider resources; and
- Create a site for glider news, including the areas of ongoing operations.

The (UG)^2 would function through the following means:

- Sponsorship and funding should be provided through federal agencies;
- A national steering team would be established;
- Virtual meetings would be held on a regular basis;
- In person meetings could be scheduled with due consideration for other user groups like Everyone's Gliding Observatories (EGO);
- An online forum would allow ongoing communication with archiving for later reference;
- An email list would facilitate broad communication; and
- Training and tutorials could include videos;

If fully successful, (UG)^2 would bring together the glider community to the benefit of operators, data users, and agencies. Operators would benefit from sharing experiences and opportunities, perhaps leading to the development and recommendation of best practices. Data users would realize more uniform standards and services. Agencies would have an identifiable means to broadcast opportunities and assess performance. The (UG)2 may prove to be the legacy of the Glider Task Team.

WORKSHOP OUTCOMES

Many workshop delegates expressed a strong interest in finding opportunities for collaboration and coordination of resources to enable glider missions and subsurface data collection. Discussions also showed broad agreement for connecting the glider community between managers, operators, and data users. The following overarching suggestions below represent a framework for how to meet these goals and begin tackling specific challenges identified by the glider community.

INITIATE THE UNDERWATER GLIDER USER GROUP (UG)2

Initiating the Underwater Glider User Group (UG)2 is the top priority to provide the centralized platform needed to springboard many of the recommended actions. A steering team comprised of national representatives will drive the agenda and activities for (UG)2, maintaining international connections.

IMPROVE DATA AND INFORMATION SERVICES

Improved glider data management results in optimized utility for ocean stakeholders. Sending open glider data through the IOOS Glider Data Assembly Center (DAC) is a method to build on an established platform integrating glider data in the same formats and making the data accessible to all users. There is also a need for a glider data management working group to drive standardization across glider programs and address other data issues, which could serve as a sub-group of (UG)2 and boost Glider DAC activities. These efforts will likely require staff support and additional logistics to facilitate glider data standard development.

EXPLORE AND ENCOURAGE ASSET AND PLATFORM SHARING

Many workshop attendees are eager to leverage resources to expand the reach of the gliders and the data collected. Platform sharing business models, such as the University-National Oceanographic Laboratory System (UNOLS) fleet, Uber/Lyft ride-sharing services, or even a rental car organization, are the types of innovative mechanisms needed to get gliders that are on shelves into the water collecting valuable subsurface data. All of these models would require significant discussions and agreements to ensure fairness and safety to all parties. At a minimum, a forum could be established for operators to share plans and needs. Those with resources could post planned missions to which they are willing to add sensors, while those seeking glider support in the form of deployment and recovery, piloting, and maintenance could solicit help in a shared space.

ENGAGE INTERNATIONAL UNDERWATER GLIDER COMMUNITIES

Many of the international participants in the workshop were interested in working with U.S. operators and data users to expand their glider capacity and networks. Conversely, U.S. glider program managers are eager to learn from established glider operations abroad. The glider community should expand coordination on international forums such as Everyone's Glider Observatories (EGO), Integrated Marine Observing System (IMOS), Ocean Networks Canada, Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) International Steering Team, and potentially others. Beyond strategic planning and information sharing, the U.S. community can seek out specific opportunities to collaborate directly with international glider operators and on shared interest projects.

Ocean Monitoring Breakout

US Underwater Glider Workshop

January 18-19, 2017

Sustained Monitoring Overview:

- **For ocean observing, sustained monitoring is the process of perpetually collecting and analyzing data to determine trends, such as ecosystem health, climate patterns, ocean dynamics, etc.**
- **Purpose of breakout is to assess the scale and potential capability of glider activities**

Event Monitoring Overview:

- **For ocean observing, event monitoring is the process of collecting, analyzing, and signaling event occurrences, such as storms, spills, HABs, etc.**
- **Purpose of breakout is to assess the scale and potential capability of glider activities**

Instructions:

1. **List relevant operational missions and/or scientific objectives**
2. **How can we use existing glider assets more effectively?**
3. **What are the gaps in what we currently do and what are the new capabilities needed to address them?**

Event Monitoring (1/2):

1. **List relevant operational missions and/or scientific objectives**
   a. Storm/Hurricane forecasting
      i. Episodic,
      ii. Isolated,
      iii. Rapid response,
      iv. Strong currents,
      v. Waves
      vi. Seasonal forecasts,
      vii. Improving individual storm intensity forecasts
      viii. Storm surge
      ix. Heat content
      x. Cool wake / productivity response
      xi. Mixing ahead of the eye
      xii. Event is predictable/forecast-able
   b. Disaster response (oil spill, SAR, marine pollutants)
      i. Evolution of oil in the weathering process
      ii. Human health
      iii. Ecosystem response

        iv. Food safety
    c. HABs
        i. Cause toxins or hypoxia
        ii. Fish kills
        iii. Human health
        iv. Fishery closures
        v. Ecosystem response
        vi. Mass strandings for marine mammals
        vii. Beach tourism / economic impact
    d. Hypoxia
        i. Regions of low oxygen in water column due to strong pycnocline, nutrients, and upwelling
        ii. Seasonal, episodic, and permanent (depending on location)
        iii. Shallower water at times
        iv. Near rivers
        v. Commercial fisheries losses
        vi. Recreational issues
        vii. Fisheries assessment interested in predictions on hypoxia and hypoxic events
    e. Ocean Acidification
    f. Eutrophication
    g. Hydrocarbon seepage
    h. Geopolitical incidences / economical (fisherman)
    i. Rapid environmental assessment
    j. Lake sediment plumes
    k. Shelf-break upwelling / frontal dynamics
    l. River plume dynamics
    m. Deep/dense water formation, mixing, deep convection
    n. Meso-, and sub-meso-scale variability
    o. Internal waves
    p. Sea ice advance/retreat
    q. Marine mammal / fisheries migration/detection
        i. regular / seasonal
        ii. intercept choke points
        iii. predictable
        iv. not emergency
        v. variety of species (in mid-Atlantic: everything moving through; whales, stripers, other sport fish)
        vi. tags send a coded message; gliders decode
        vii. effective range is 500 m
        viii. environment changing constantly (in mid-Atlantic)

2. **How can we use existing glider assets more effectively?**
    a. Share data from all existing operating gliders (IOOS Glider DAC)

        i. Enhance data assimilation forecast models
   b. Water space management: integrated command & control (Navy)
   c. Insurance & liability for asset sharing: coordination with regional associations (IOOS)
   d. Sharing knowledge of inventory of excess capacity
        i. Telecommunications line for sharing
   e. Pilots/technician/infrastructure/software for hire
   f. Experience sharing / glider schools (USM model of training)
   g. Leverage regional expert group
   h. Make glider flying easier. Interface glider command & control with optimal path planning or other planning software, improving situational awareness of glider pilots
   i. External vs. internal control; enhancing adaptive sampling & autonomy capability of existing fleet
   j. Dedicate seasonal gliders to areas of interests, deploy gliders with mission specific sensors (Wave, turbulence, ADCP) for rapid response (Hybrid glider for speed)
        i. Utilize operational circulation models to assist with positioning and deployment
        ii. Utilize existing technology to better address and understand seasonal events (oxygen sensors, fluorometers, HFR, operational forecasts)
   k. Enhancing government coordination of mission requirement & funding for event response by glider operators (academic, government, private)

3. **What are the gaps in what we currently do and what are the new capabilities needed to address them?**
   a. Assessment of existing glider capabilities, capacity, and data
   b. Onboard decision making ability
   c. Lack of fundamental background data on where events occur
   d. Sensor development and collaboration
   e. Expanding Operational Capabilities: Adaptive sampling capability of gliders
   f. Work force gap
   g. Rapid all weather deployment (aircraft (C-130))
   h. Delivery of time sensitive glider package/sensors to study sites.
   i. Universal backup systems and more effective data sharing: standardized and QA/QCED
   j. Data assimilation: GTS requires very standardized data, how to get new sensor data into models? On ramp onto the IOOS glider DAC. Regional efforts (IOOS) have been very helpful
   k. Knowledge of deployments (collecting what/when/where)
   l. Sharing innovative use of gliders (methods/algorithms), changing mission files on the fly.
   m. Disaster response: Specialize sensors (radioactive sensor, oil-spill sensors, political issue, water space issues

n. Longer loitering capability for gliders in anticipation of episodic events
o. Improving/simplifying glider turnaround (ballasting/recovery/compass calibration)

Sustained Monitoring (1/2):

1. **List relevant operational missions and/or scientific objectives**
   a. California Network (CALCOFI) – PO observations, some ecological/biological
   b. Gulf Stream – FL straits, currents monitoring
   c. New England—Fisheries stock assessment
   d. Solomon Sea – Pacific/Indian Ocean exchange
   e. OOI Initiatives
   f. SECOORA
   g. CariCOOS—tropical cyclone measuring
   h. Eastern Chukchi Sea—Marine mammal monitoring
   i. Coast of Nova Scotia—Marine mammal surveys, biological sensors)
   j. MARACOOS—HABS, Hypoxia
   k. NOAA Caribbean— bioacoustics (reef fish bio hot spots)
   l. Bermuda slocum missions—BATS augment \
   m. GLOS
   n. Northern California

2. **How can we use existing glider assets more effectively?**
   a. Opportunities for teaming, share/coordinate resources
      i. Forums for collaboration—conferences , list serves, operations forecasting
      ii. Operate like UNOLS, NOAA fleet
      iii. Share pilots, deployment/recovery resources
      iv. Interdisciplinary collaboration— more sensors per glider for mission benefit
   b. Creating a business model to make this work—User group
   c. Data and operational guidelines – sharing pathways / QA-QC
   d. Glider user forum for information sharing
   e. Public / Private partnership facilitation at International / National / Regional governance levels (IOOS to RAs)

3. **What are the gaps in what we currently can do and what are the new capabilities needed to address them?**
   a. Better education of glider use / product delivery
   b. Augment sustained systems w/ event monitoring, best practices for such
   c. Better (user/operator/customer) community communication
   d. Prioritize where network needs to expand
   e. Critical mass of personnel based on operation size
   f. Expansion of training for use, collaboration of users
   g. Standardization of additional integration of sensors

User Group Breakout

US Underwater Glider Workshop

January 18-19, 2017

User Group Overview:

- **The overarching goal of an Underwater Glider User Group is to establish a forum that encourages sharing and cooperation in the following areas:**
  - **Share experiences related to glider and glider sensor technology**
  - **Communicate the most recent science and monitoring objectives accomplished using gliders**
  - **Share approaches to logistical and operational challenges**
  - **Compare approaches to glider data handling, including quality control, formats, and distribution**
  - **Provide a means for ongoing communication about opportunities and needs for gliders**
  - **Collect, develop, vet and communicate recommendations on best practices to a growing glider community and a developing national glider network.**
  - **Purpose of the breakout is to determine the possible User Group that would be most useful to the underwater glider community.**

    Instructions:
    1. **Anything to add to the mission above?**
    2. **What will the group accomplish?**
    3. **What are the activities? (Including scientific contributions)**
    4. **How does the user group function (listserv, virtual meetings, in-person meetings?)**

User Group (1-4):

1. **Anything to add to the mission above?**
   a. Collaboration with existing user groups/for a (EGO)
   b. Add language to display the broad regions, inclusivity, and Interaction with international observing community
   c. Commit to data standards and have interoperability
   d. Organizational structure (subgroups, rotating lead)
   e. Interfacing with agency supporters
   f. International connection
   g. Vendor interaction
   h. Cooperation on analysis tools through a forum that can provide co-development
   i. Add language to show that the group provides input and the leaders will provide content for advocacy

2. **What will the group accomplish?**
    a. Information/Resource sharing--online forum for questions/experiences/trainings
        i. Address immediate/emergency operations and less immediate needs
        ii. Improve communication between glider groups and modeling groups
        iii. Sharing of prep/piloting resources for smaller groups with limited support
        iv. Share knowledge of logistical support including personnel (technicians & / graduate students)
        v. Share calibration best practices
        vi. Share new scientific breakthroughs
        vii. Act as a publication repository
        viii. Share information on engineering and new sensor integration
        ix. Acts as a repository for deployment and mission information in specific areas
    b. Ease in software exchange
    c. Improved data management—raw through mid-level data; past platform-specific data
        i. Help to develop better data standards-- standardization of file formats (DAC, NCEI)
        ii. Innovative ways to visualize data
        iii. Act as a clearing house for glider operations (JCOMMOPS site)
    d. Creation of coordinated network
        i. Reach out to wider group of experts
    e. Identify ways to find additional end-users for a group's product

3. **What are the activities? (Including scientific contributions)**
    a. Recommend and implement standards (data, e.g.)
    b. Define scientific and community priorities
        i. Webinar series (two way exchange, talk with questions and conversations)
        ii. Creative science challenges
        iii. Facilitate groups to develop proposals
    c. Communicate with agencies
    d. Interact/represent with international communities
    e. Sensor training sessions on appropriate topics, include vendors
    f. Organizes periodic meetings
    g. Sharing contacts, ships, infrastructure
    h. Cooperate on analysis tools
    i. Group should have advocacy to establish minimum core mission, to address economy, jobs, security
    j. Set best practices, technical refresh, regional expertise
    k. Provide trainings for data processing and operators
    l.

4. **How does the user group function (listserv, virtual meetings, in-person meetings?)**
    a. Confederation of members overseen by leadership (rotating co-chairs)
        i. Need to identify size of group
    b. Logistical support (website, online forum, travel)
        i. Need to identify resources
    c. Subgroups, data/operators/users/international/manufacturer
        i. Subgroups
            1. Operators, data analysis, data management
            2. Different types of gliders
            3. Deployment focus
    d. Must have charter
    e. Regular cheap meetings/Virtual meetings or webinars (monthly)

h. Risk assessment / insurance
i. Minimize losses
j. Reduce cost investment
k. Permanent deployment
l. Energy source enhancement

4. **Areas that need sustained monitoring:**
    a. Sustained ecosystem monitoring – IOOS Opportunity
    b. Gulf of Mexico
    c. RESTORE funded project(s)
    d. GCOOS/SECOORA Coordination
    e. Great Lakes
    f. Gulf of ME
    g. Caribbean
    h. Arctic
    i. North Atlantic (AtlantOS project, EU – No funds for sustained ops)

U.S. UNDERWATER GLIDER WORKSHOP

Harmonizing Glider Efforts Breakout

US Underwater Glider Workshop

January 18-19, 2017

Operational Reliability Overview:

- **Glider operational reliability measures how dependable the observations are during deployment. Failure occurs due to weaknesses in the design, flaws in the materials, defects from the manufacturing processes, maintenance errors, improper operation, changes in operating concept, etc.**
- **Purpose of breakout is to determine how to implement strategies towards minimizing operational reliability risks**

Data Management Overview:

- **Glider operational reliability measures how dependable the observations are during deployment. Failure occurs due to weaknesses in the design, flaws in the materials, defects from the manufacturing processes, maintenance errors, improper operation, changes in operating concept, etc.**
- **Purpose of breakout is to determine how to implement strategies towards minimizing operational reliability risks**

Interagency Collaboration Overview:

- **Interagency Collaboration among federal agencies, departments, and offices enables many things to be done that no single agency can approach. Ocean scientists, engineers, and decision-makers struggle to synchronize their underwater glider efforts. Enhancing collaboration among U.S. federal agencies can enable powerful new scientific approaches for understanding, predicting, and managing our ocean resources with glider technology.**
- **Purpose of breakout is to determine strategies to advance interagency collaboration, coordination, and cooperation.**

International Collaboration Overview:

- **International Collaboration is essential for optimizing glider activities through fostering engagement with global partners. Overcoming bureaucracies to enable sharing is a major challenge.**
- **Purpose of breakout is to determine how to implement strategies to advance international collaboration, coordination, and cooperation.**

Instructions:

1. **List requirements and/or opportunities**
2. **What are some of the challenges in achieving these opportunities?**
3. **Provide recommendations/next steps**

Operational Reliability:

1. **List requirements and/or opportunities**
   a. **Causes for Failure**
      i. Inexperienced people/lack of available prep time/rush
      ii. Time between deployments
      iii. Deployment team separate from prep team, not focused solely on glider work
      iv. Biofouling or biological impact (shark, remora)
      v. Leaks
      vi. Sensor failure (eg. ctd pump, or a pressure leak)
      vii. Buoyancy (fresh water lens)
      viii. Length of deployment (up to a year difficult, biology happens)
      ix. 90 day cutoff (battery)
      x. Damage in shipping
      xi. Environment challenges (currents)
      xii. Weather
      xiii. Deployment impact (ship hits glider)
      xiv. Loss of steering
      xv. Buoyancy pump
      xvi. Air bladder
      xvii. Ship strike
      xviii. Underwater hazards (crab traps, fishing gear, wrecks)
      xix. Fishermen (pick up)
      xx. New technology impacts time for prep and success rate
      xxi. Software bug
      xxii. Altimeter
      xxiii. Connector issues after significant use
   b. **Opportunities**
      i. Resource pools (local expertise)
      ii. Training courses
      iii. Test early (vendors)
      iv. Guaranteed instrument tests prior to deployment and as new sensors come online (env testing).
      v. Set up standard preparation procedures (users & providers)
      vi. Detailed feedback to glider producers to improve process
         1. Root cause analysis (RCA)
         2. Detailed record keeping by users

2. **What are some of the challenges in achieving these opportunities?**
   a. **Funding/Resouces**
      i. Dedicated personnel
      ii. Training
      iii. Testing
      iv. Technology refresh

        v. Configuration management
    b. Centralized feedback org does not exist (user groups)

3. **Provide recommendations/next steps**
    a. <u>1-3 year goals</u>
        i. Formalized testing procedures
        ii. Procedures/preparation working group (workshops, webex, forum)
        iii. Helium leak testers
        iv. Improved software (data vis and piloting)
    b. <u>4-10 year goals</u>
        i. Current technology needs to become more like commercial
            1. It will never be like operating a r/c car
        ii. Improved power/batteries
        iii. Biofouling improvements (including remora)
            1. Chlorine generation
            2. Snails on a tether
        iv. Improved sensor calibrations
        v. Minimized sensor drift
        vi. sensor/soareft redundancy where available
        vii. Configuration management – shared database of what sensors are used, how calibrated, etc
            1. Cross agency collaboration

Data Management:

1. **List requirements and/or opportunities**
    a. Managing metadata, calibration coefficients, etc.
    b. Ability to integrate different datasets
    c. All data available in same format (automation of conversation to netcdf)
    d. CF compliant data at current standards
    e. CF data need to be converted from cdf to profiles
    f. QAQC– including agency requirements for QAPPs
    g. Archive raw data (time series, delayed mode, real-time)
    h. Create a group of representatives to figure out current state of data management

2. **What are some of the challenges in achieving these opportunities?**
    a. Entry into system for new users/learning curve for building and querying netcdf files
    b. Lack of resources for small shops
    c. Reliance on third party (ERDAP) adds layer of complexity
    d. Inconsistency in metadata between groups
    e. Time/money for personnel at each group to prep data
    f. Inconsistent QAQC
    g. Lack of automation to get files into needed formats (not provided by manufacturer)

h. All gliders output data in different formats
i. Standards change
j. High configurability of gliders means there are sensor data with no standard name, and regularly new types of data
k. Archiving raw data- ownership
l. Coordinating communication between the range of user groups
m. Central location for housing information

3. **Provide recommendations/next steps**
   a. Establish minimum metadata, etc. standard (1-3 year)
   b. Coordinate with EGO and IMOS to develop a unified system (a la ARGO) or improve compatibility – bring together representatives from all 3 groups to work on this (EGO building a team), can also improve QC; include manufacturers in these discussions (1-3 year)
   c. Centralize data management and formatting within the regions (1-3, after initial meeting)
   d. IOOS should develop set recommendations for manufacturers (1-3, after initial meeting)
   e. Recommendation to manufacturers to provide capability to convert data into netcf when they get to shore (Establish minimum requirements to be implemented now, and wish list of further capabilities
   f. Training at the universities (ongoing, coordinate with pilot training programs)
   g. Quantify value of standardized formats – who's using the data? How? Etc.
   h. DOI for each deployment to track use of data (developing this at EGO and OOI, publications are starting to require this)
   i. Include QAQC plan into funding requests
   j. Discussion on archiving raw data and relation to ownership
   k. Data management team –road map, develop standards, implementation, training
   l. Side meetings at major conferences –AGU, Oceans Sciences, etc.
   m. Webinars
   n. Increased support for national glider DAC

Interagency Collaboration:

1. **List requirements and/or opportunities**
   a. Agencies must see value in collaboration
   b. Agencies have mission requirements that gliders can support (e.g., hypoxia, env. monitoring)
   c. Agencies should discuss/ID common areas, aligned goals, exchange mechanisms to examine overlaps, gap areas over a larger glider community

2. **What are some of the challenges in achieving these opportunities?**
   a. Lack of formal agreements in place, long time scales can hinder development
   b. Need high level statement of importance, need for gliders, their contribution to larger issues, quantify impact

c. Making data available, usable, standardized, increase demand, find new users
d. Intra-agency collaboration, communication can improve

3. **Provide recommendations/next steps**
   a. Initial step: stronger agency engagement through user group to identify existing agreements to facilitate asset/expertise sharing, share agency strategic vision, then tailor glider agreements (as needed)
   b. User group driven – grassroots efforts to develop topic areas identified by user group
   c. Review existing agreements, future needs to support collaborations
   d. Representatives to NOPP, other program meetings to share user group needs
   e. Evaluate non-federal opportunities
   f. Formal group
   g. Identify common topics for interagency collaborations. Self-organized task teams with 2+ agencies -> commitment for chair, limited funding to move forward
   h. Biological task team (mainstream observations)
   i. Engagement by all IOOC agencies at regional level
   j. IOOC could support structure, commit funding based on glider user group activity
   k. Strategic planning required
   l. Find ways for money to come together (e.g., NOPP). IOOC as "seed funding" for long term development
   m. Data management requirements, sharing policies
   n. Priority: well-developed glider DAC that operates across agencies
   o. Technology testbed (e.g., Gulf range) as opportunity
   p. Regular communication facilitates, is required for effective leveraging
   q. ID level of commitment in sharing: data of different types, resources, support and have agreements in place
   r. Gliderpalooza as example of past interagency success
   s. Identify forum/mechanism: share logistics, new methods at higher level, but where is repository of information? Grassroots sharing can be most effective, realistic.
   t. Identify formal body to integrate strategic planning, 3/5/10 year plans, weave together by topic (e.g., gliders)

International Collaboration:

1. **List requirements and/or opportunities/challenges**
   a. International best practices
   b. Data sharing, data access
   c. Access to national EEZs
   d. Technology transfer
   e. Collectively addressing science challenges

2. **Provide recommendations/next steps**
   a. Collaborate with International OceanGliders group
   b. Recognize group as the forum for international coordination

    i. ACTION: Pierre to distribute to workshop attendees further information on OG

c. Engage in joint planning of global science challenges for boundary currents, storms, ocean processes, and data management (standards)
    i. ACTION: Distribute information on these activities and additional US participation.
    ii. ACTION: Nominate US participation in future OG activities.
    iii. ACTION: Encourage OG to engage in intergovernmental discussions about access and permission issues.
d. Glider deployment awareness
    i. ACTION: Work with OG and others to improve access to deployment plans and current glider missions.
e. Permissions and access
    i. ACTION: Operators should establish collaborations in countries to encourage access to foreign EEZs and sharing of data
    ii. ACTION: Review IOOS and NOAA international agreements to cover access issues and data sharing for broader US glider community. Share agreements as appropriate as templates for future agreements. Ensure gliders are a part of existing agreements.
    iii. ACTION: Explore potential role of NGOs in enabling collaborative project (scientific and capacity development) with other countries (First step: Collect case studies and target NGO that can help.)

Enabling NASA's Mission

Luc Rainville (APL-UW)

Eric Lindstrom (NASA)
Paula Bontempi (NASA)
…and NASA-supported investigators (SPURS, Science Teams)

SPURS campaigns
EXPORTS plans
Enabling Science Teams:

- SWOT Cal/Val *(Farrar et al.)*
- OSTST: Boundary current and eddies *(Castelao et al.)*
- SWOT: Fine-scale dynamical height *(Druska et al.)*

Vision and Mission

Our Vision

We reach for new heights and reveal the unknown for the benefit of humankind.

Our Mission

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

NASA strategic goals are:

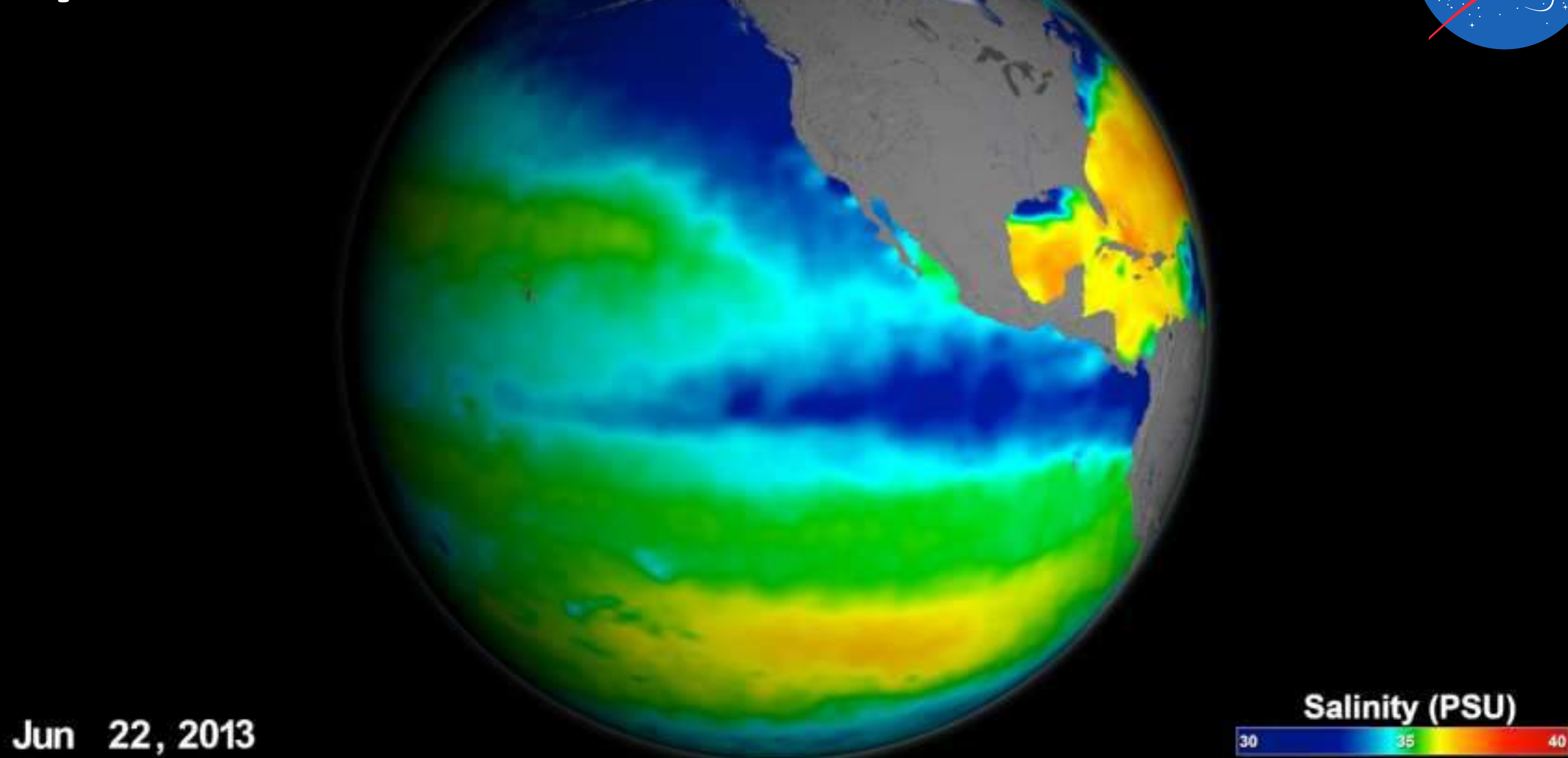
1. Expand the frontiers of knowledge, capability, and opportunity in space.
2. Advance understanding of Earth and develop technologies to improve the quality of life on our home planet.
3. Serve the American public and accomplish our Mission by effectively managing our people, technical capabilities, and infrastructure.

Charles F. Bolden Jr., Administrator

Enabling NASA’s Mission

- Gliders are used as part of long-term autonomous arrays to capture important processes occurring on a variety of time and spatial scales
- NASA has been a supporter of glider technology development, and sensor development, in particular for interdisciplinary science (Ocean Color, etc.).
- Gliders are used as one of the tools to validate satellite and meet mission requirements.
- Glider data are often an important link between the components of large programs (e.g., modeling, Eulerian / Lagrangian arrays, etc.).

Aquarius



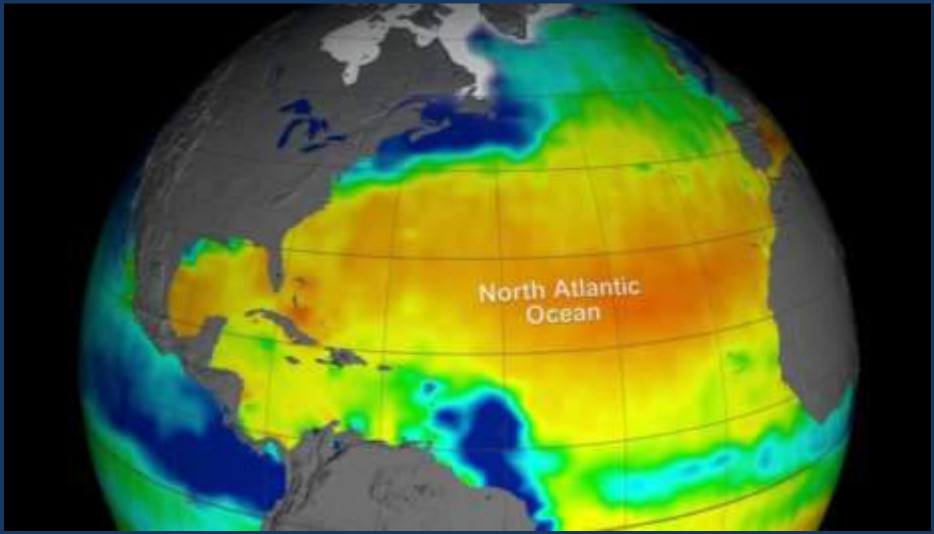
NASA's Goddard Space Flight Center Scientific Visualization Studio

First space-based global observations of ocean surface salinity.
25 August 2011 through 7 June 2015

Currently, global salinity is retrieved from SMAP measurements

SPURS-1

What are the physical processes responsible for the location, magnitude, and maintenance of the subtropical Atlantic sea surface and subsurface salinity maximum?

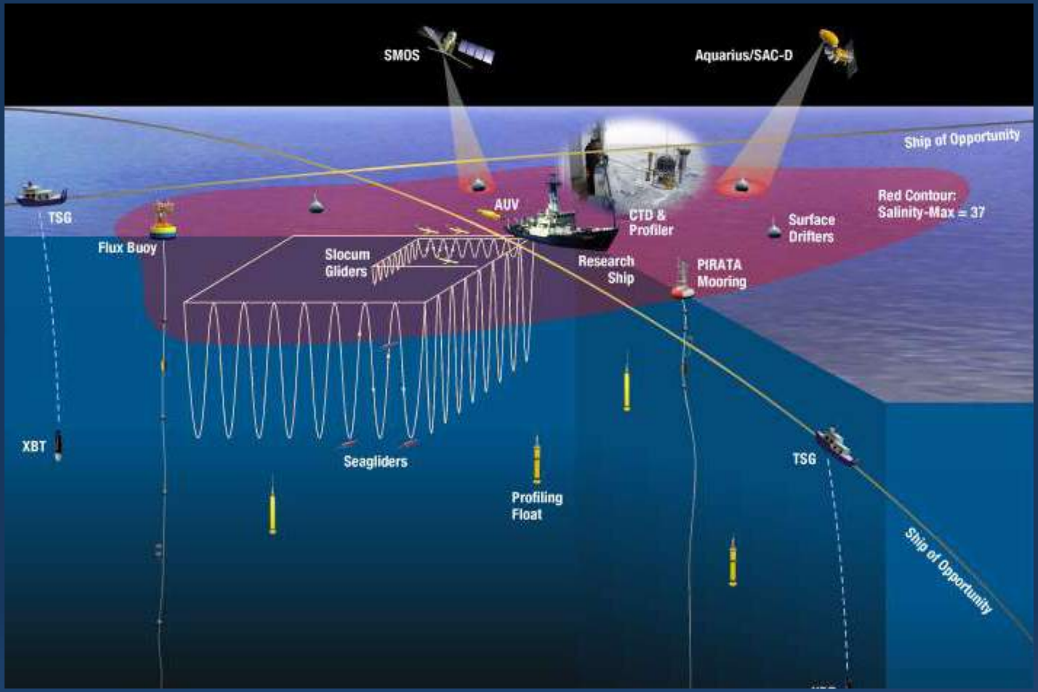


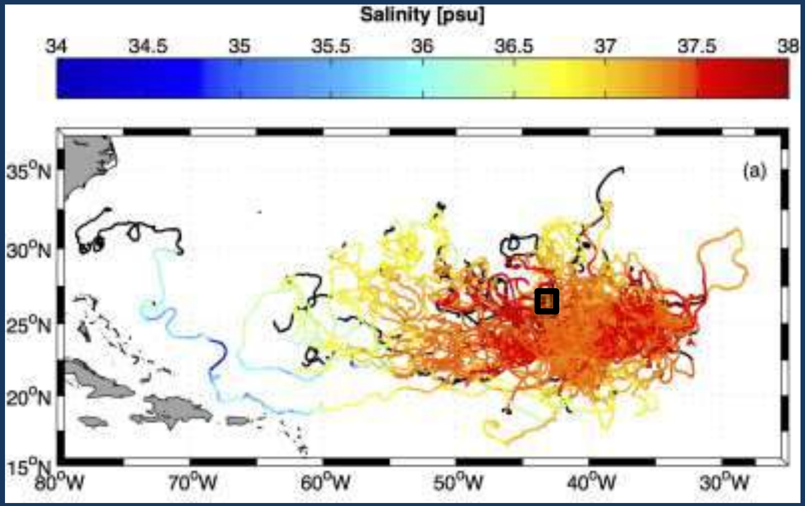
NASA's Goddard Space Flight Center Scientific Visualization Studio

SPURS-1 involves coordinated field work, numerical models, and remote-sensing:

Towed Surface Salinity Profiler, Asher et al., University of Washington
SPURS Data Management System, Bingham et al., University of North Carolina Wilmington
Multi-scale Modeling and Data Assimilation, Chao et al., Remote Sensing Solutions, Inc.
Near-surface Turbulence: Lagrangian Floats, D'Asaro et al., University of Washington
Toward a Salinity Budget (flux mooring), Farrar et al., Woods Hole Oceanographic Institution
Multiscale Autonomous Surveys, Fratantoni et al., Woods Hole Oceanographic Institution
Characteristics SSS Fluctuations, Gordon et al., LDEO, Columbia University
Upper Ocean Salinity from Glider Surveys, Lee et al., University of Washington
Multi-Scale Modeling and Data Assimilation, Li et al., Jet Propulsion Laboratory
Measurements of T, S, Wind Speed, and Rainfall (floats), Riser et al., University of Washington

Microstructure and Mixing, Schmitt et al., Woods Hole Oceanographic Institution (NSF)
SSS Drifters for SPURS, Centurioni et al., Scripps Institution of Oceanography (NOAA)
Prawler Mooring, Kessler et al., NOAA/PMEL (NOAA)
Sustained Ocean Observations, Goni et al., NOAA/AOML (NOAA).



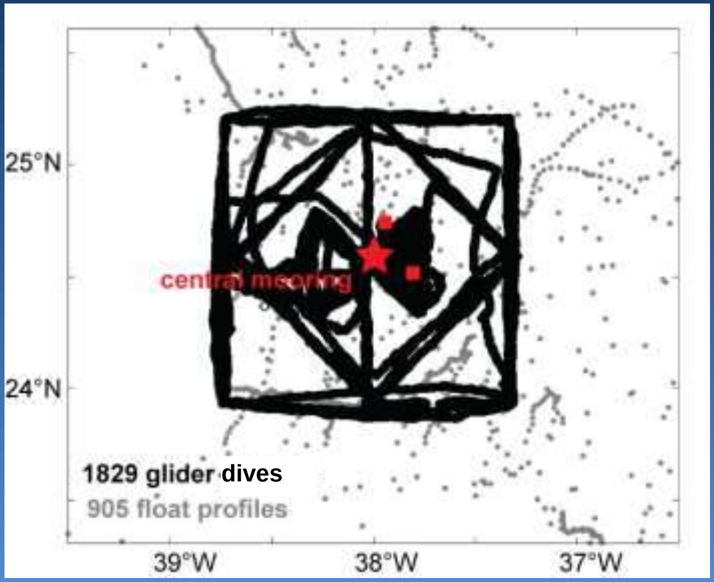


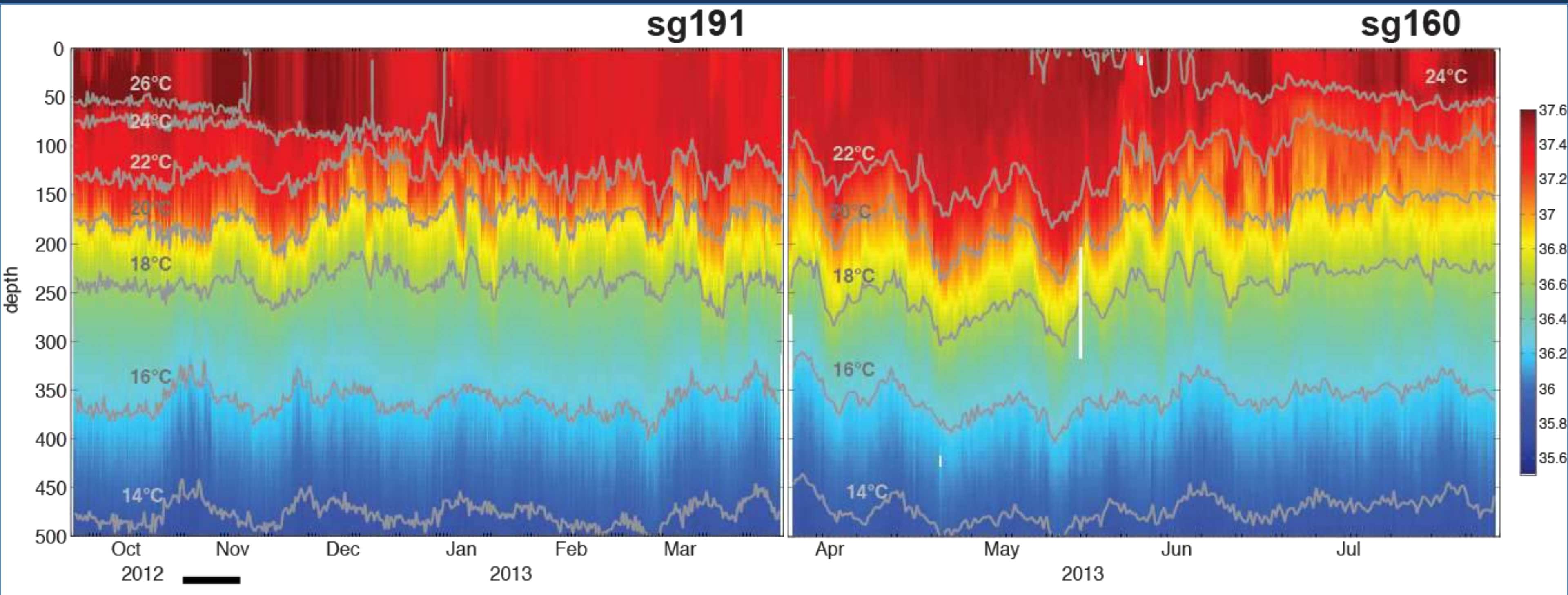
Centurioni et al.: 88 SVP-S and 56 SVP

Hormann et al., 2015

Autonomous platforms (Wave Gliders, floats, drifters, Seagliders) and ships sampled around the central (air-sea flux) mooring array with dense sub-surface measurements.

Unique perspective on the surface and sub-surface evolution of the salinity field.





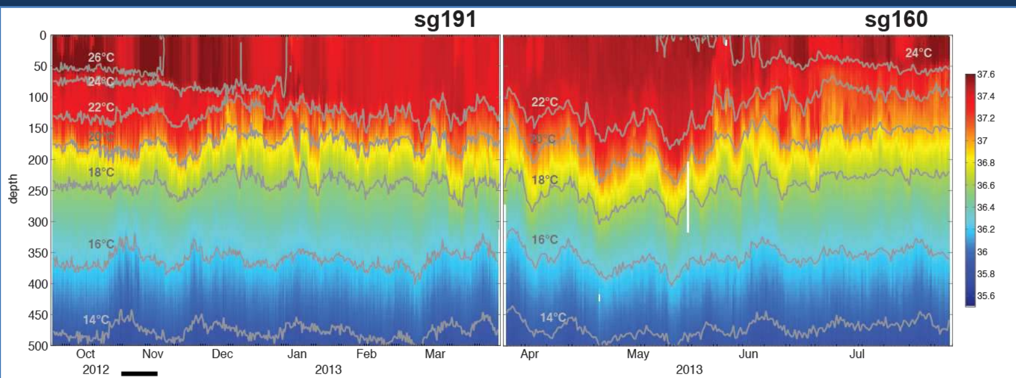
one year

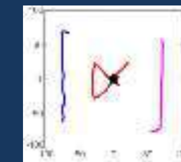
October 2012

September 2013

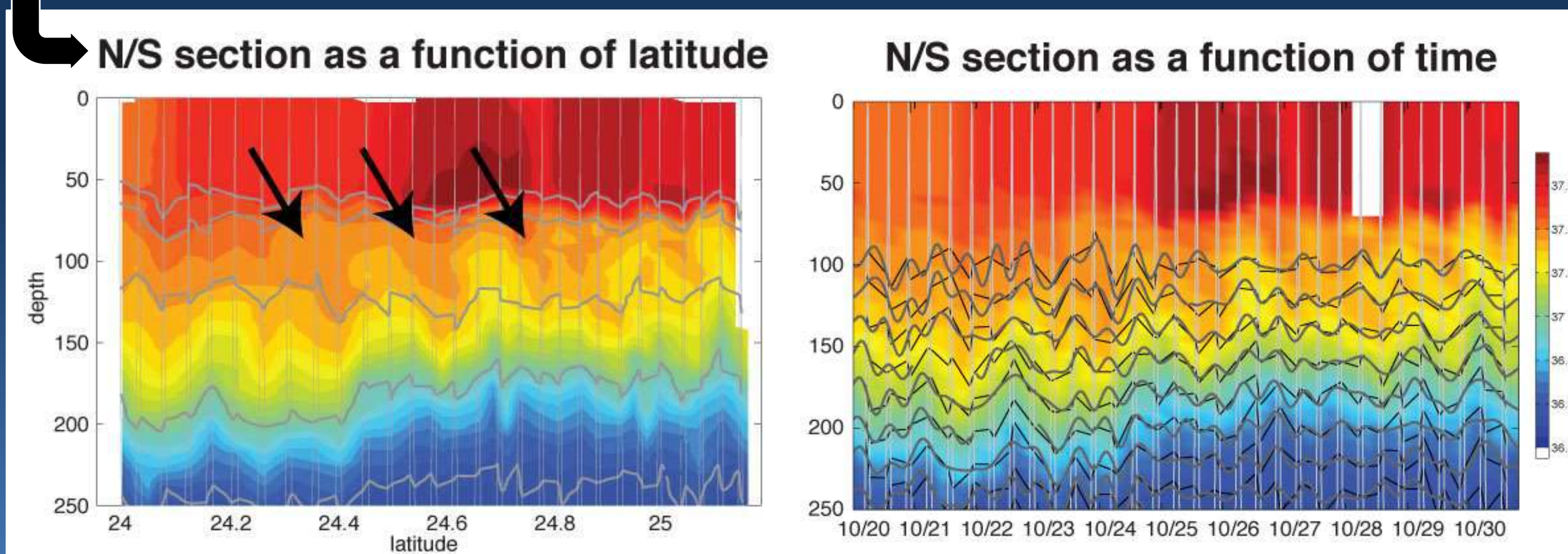
Fall to Winter:
Cooling, deepening of mixed layer.

Spring to Summer:
Restratification. Warming. Evaporation.





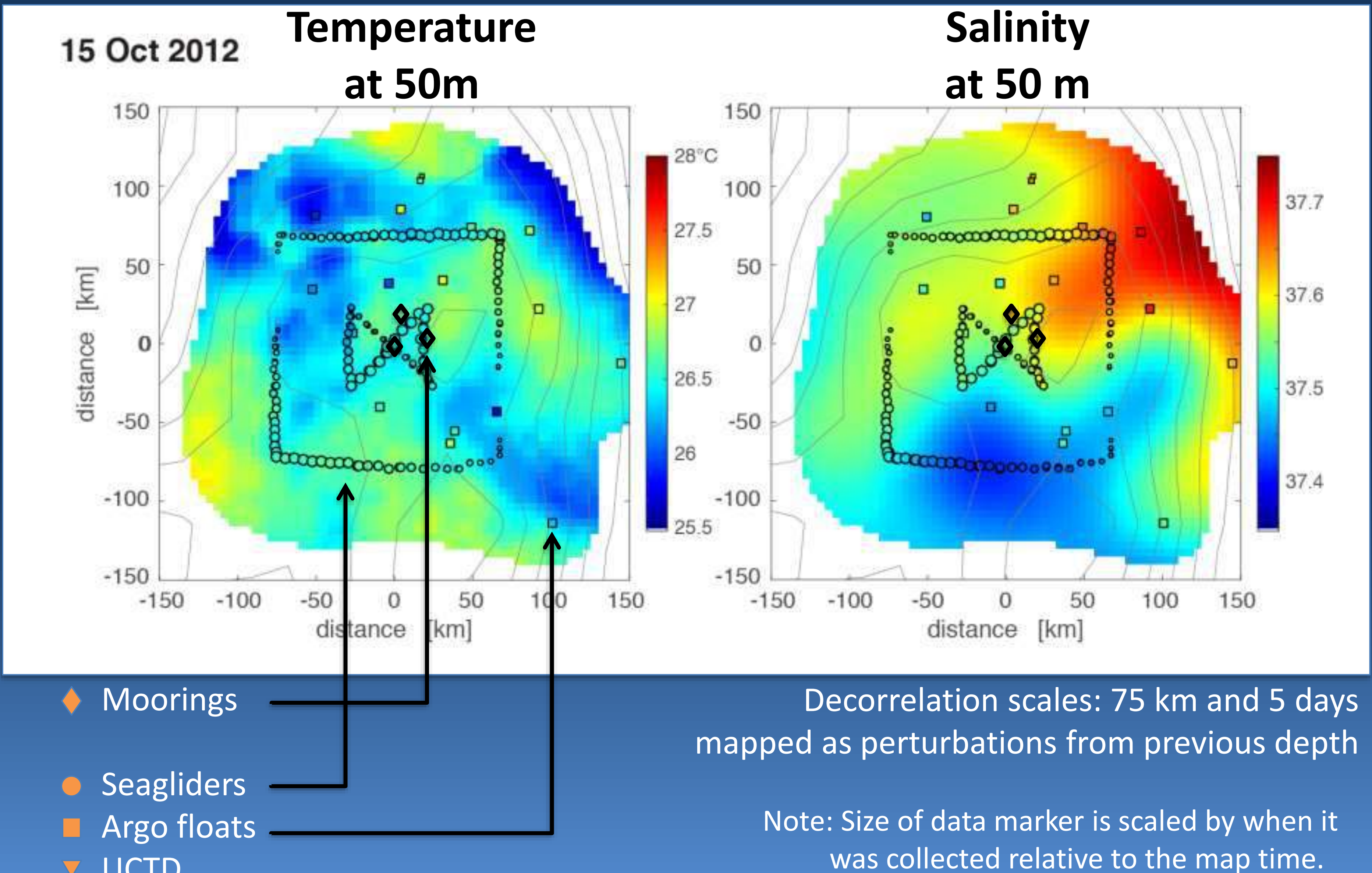
Single section from glider, collected over 1 week, showing complex intrusions, internal waves, mesoscale eddies, etc.



High salinity intrusion at the base of the surface mixed layer.

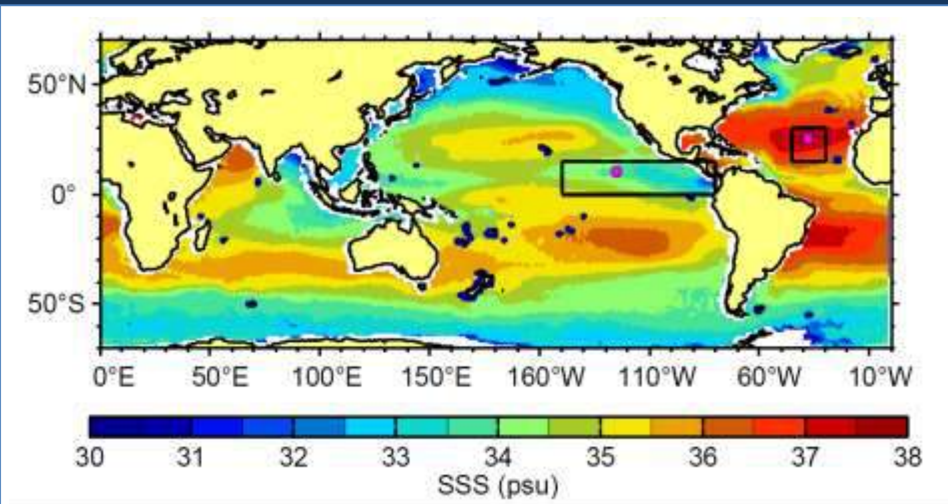
Semidiurnal displacements: +/- 20 m
Inertial displacements: +/- 15 m

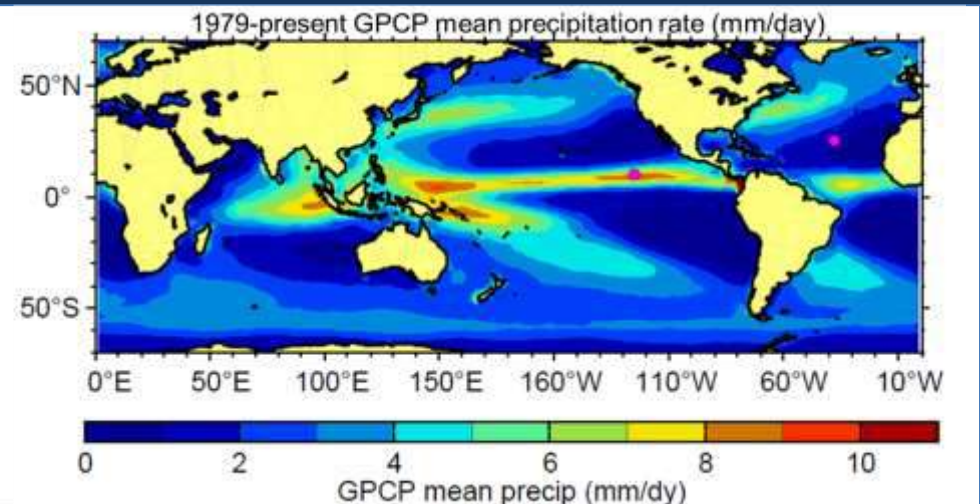
SPURS
Salinity Processes in the Upper Ocean Regional Study



Decorrelation scales: 75 km and 5 days mapped as perturbations from previous depth

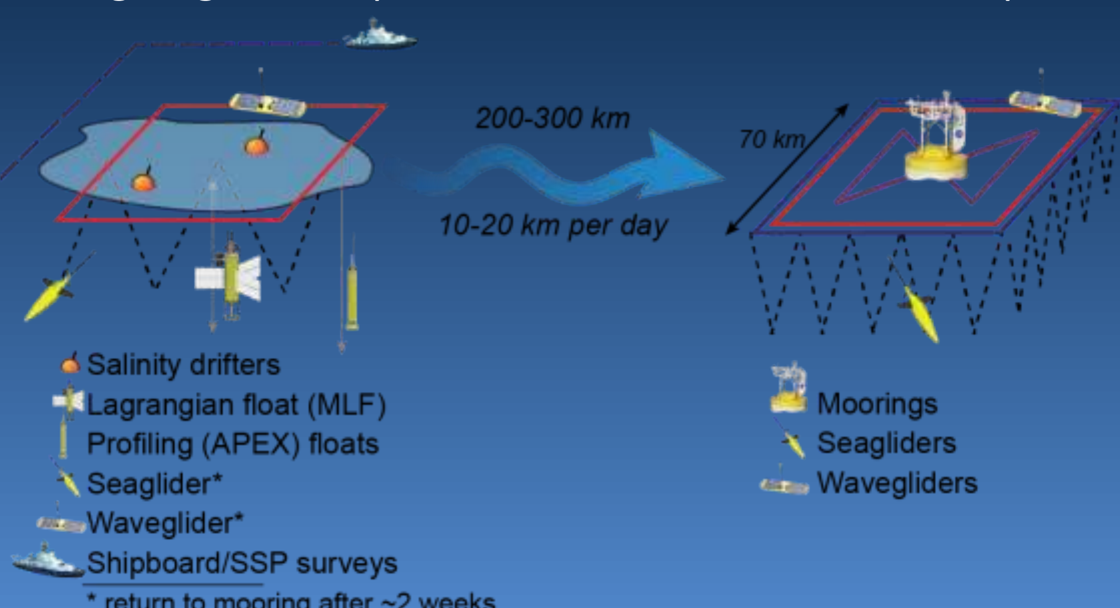
Note: Size of data marker is scaled by when it was collected relative to the map time.





Lagrangian component

Eulerian component



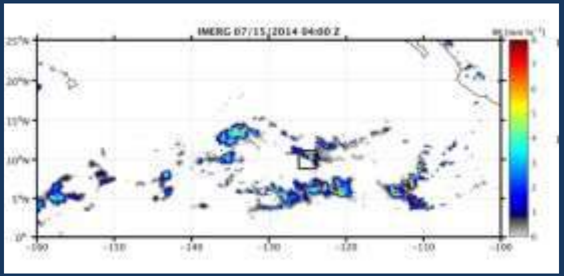
PIs

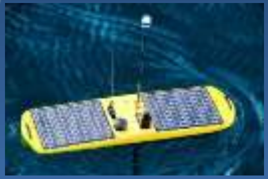
- Andrey Shcherbina, Eric D'Asaro, Ramsey Harcourt, Nikolai Maximenko
- Ben Hodges, Ray Schmitt
- Bill Asher, Andrew Jessup, Kyla Druska
- Carol Anne Clayson, Jim Edson
- Frederick Bingham, Peggy Li, Zhijin Li
- Janet Sprintall
- Julian J Schanze
- Luca Centurioni, Yi Chao, Nikolai Maximenko
- Luc Rainville, Charles Eriksen, Kyla Drushka, Craig Lee
- Steve Riser, Jie Yang
- Tom Farrar, Al Plueddemann, Jim Edson, Chidong Zhang, Jie Yang, William Kessler
- Zhijin Li, Frederick Bingham, Peggy Li
- Billy Kessler

SPURS - 2

Salinity Processes in the Upper Ocean Regional Study

The overall goal of the SPURS-2 field program is to understand the structure and variability of upper- ocean salinity under the ITCZ.





What governs the structure and variability of upper-ocean salinity near the ITCZ?

Where does the fresh water go, and how does the ocean distribute it from the small scales of the input (clouds) to the regional scale of the east Pacific fresh pool?

What local and non-local effect does the freshwater flux have on the ocean?

How does ocean salinity feedback on the atmosphere?

SPURS - 2

Salinity Processes in the Upper Ocean Regional Study

Use of schooner *Lady Amber* for SPURS-2

A novel and flexible observational approach, motivated by a need to capture the highly dynamical oceanic circulation at the isolated SPURS-2 site.

April 2016 to December 2017

9 cruises, every 2 months for 1.5 years.

- Deploy surface drifters and floats every 2 months,
- Recover, service, and redeploy autonomous instruments (Wave Gliders, Seagliders, MLF, etc.)
- Near-surface and atmospheric measurements during regular visits to the site.

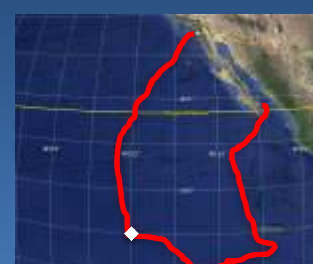
1st cruise:
9 Jun – 5 Jul 2016

- Deployed 15 surface drifters

2nd cruise:
29 Aug – 25 Oct 2016

- Deploy 15 surface drifters
- Serviced Wave Glider
- Underway sampling (T,S, atmos.)

3rd cruise:
1 Dec 2016 – 15 Jan 2017



- Deployed 15 surface drifters
- Recovered Mixed Layer Lagrangian Float
- Recovered 2 Wave Gliders, deployed one.
- Underway sampling (T,S, atmosphere)

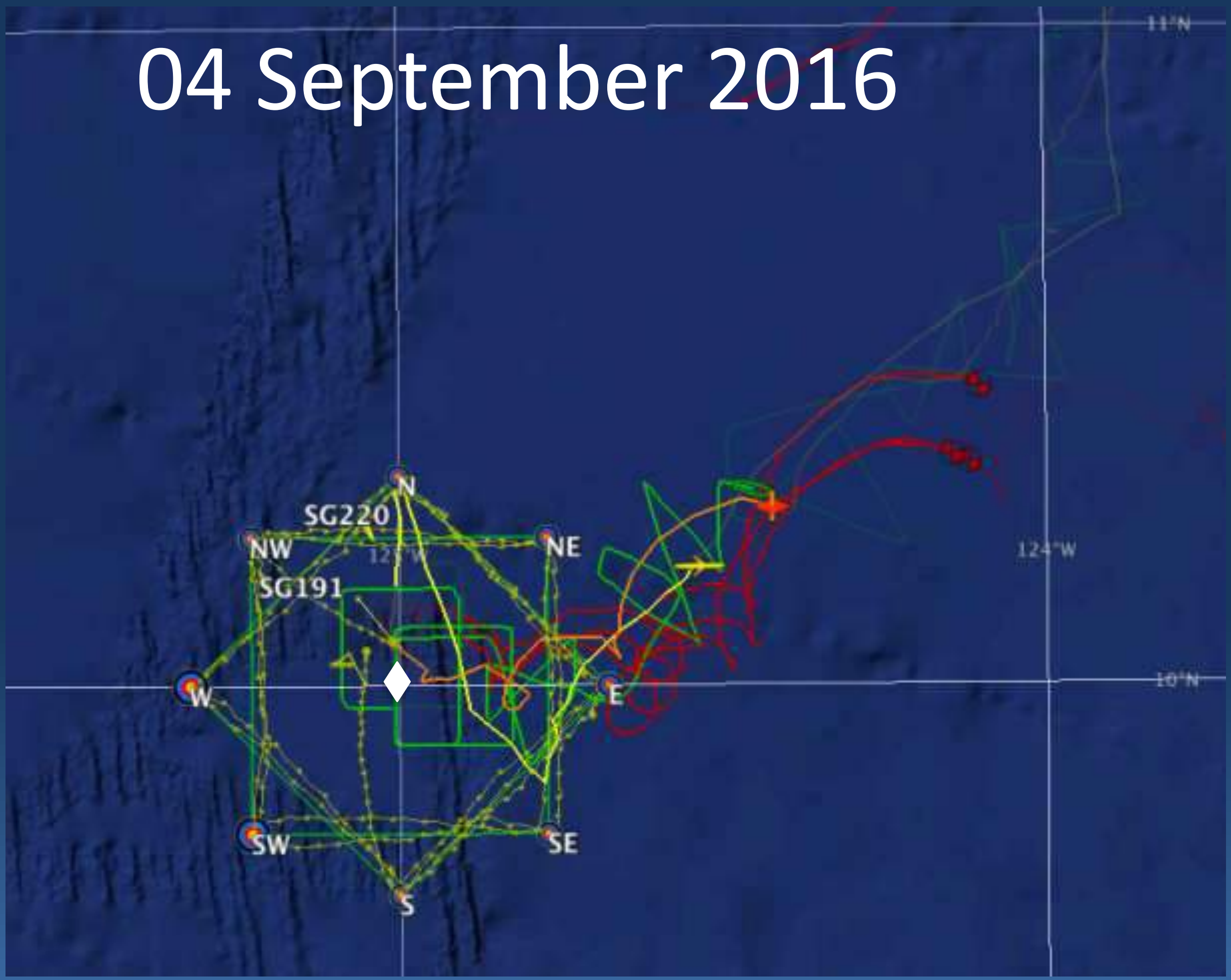
4th cruise:
Feb-March 2017

- **Recover 3 Seagliders**
- **Deploy 3 Seagliders**
- Deploy 15 surface drifters
- Deploy MLF
- Service Wave Gliders

SPURS - 2

Salinity Processes in the Upper Ocean Regional Study

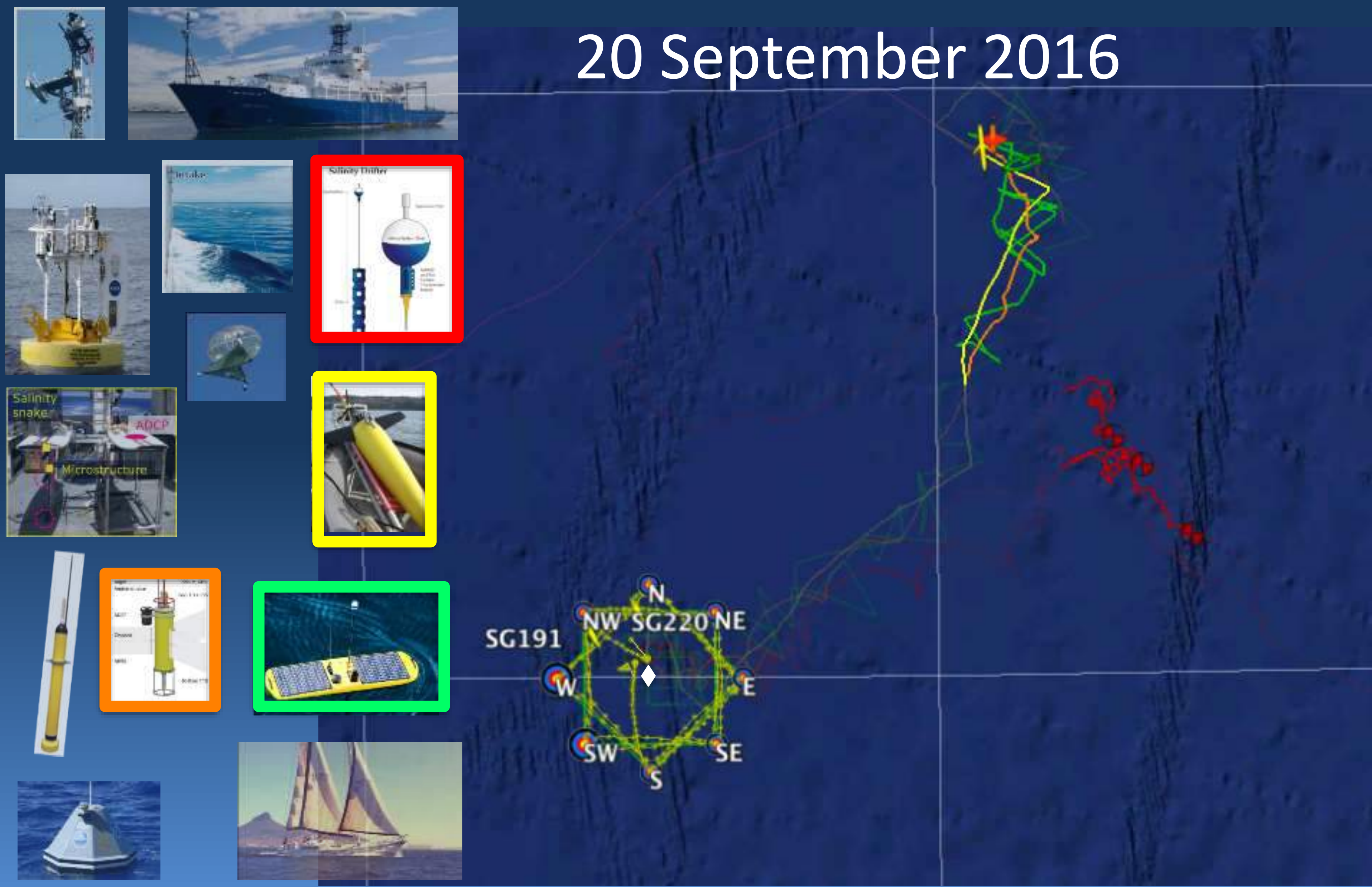
04 September 2016



SPURS - 2

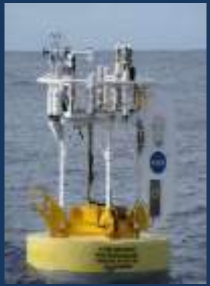
Salinity Processes in the Upper Ocean Regional Study

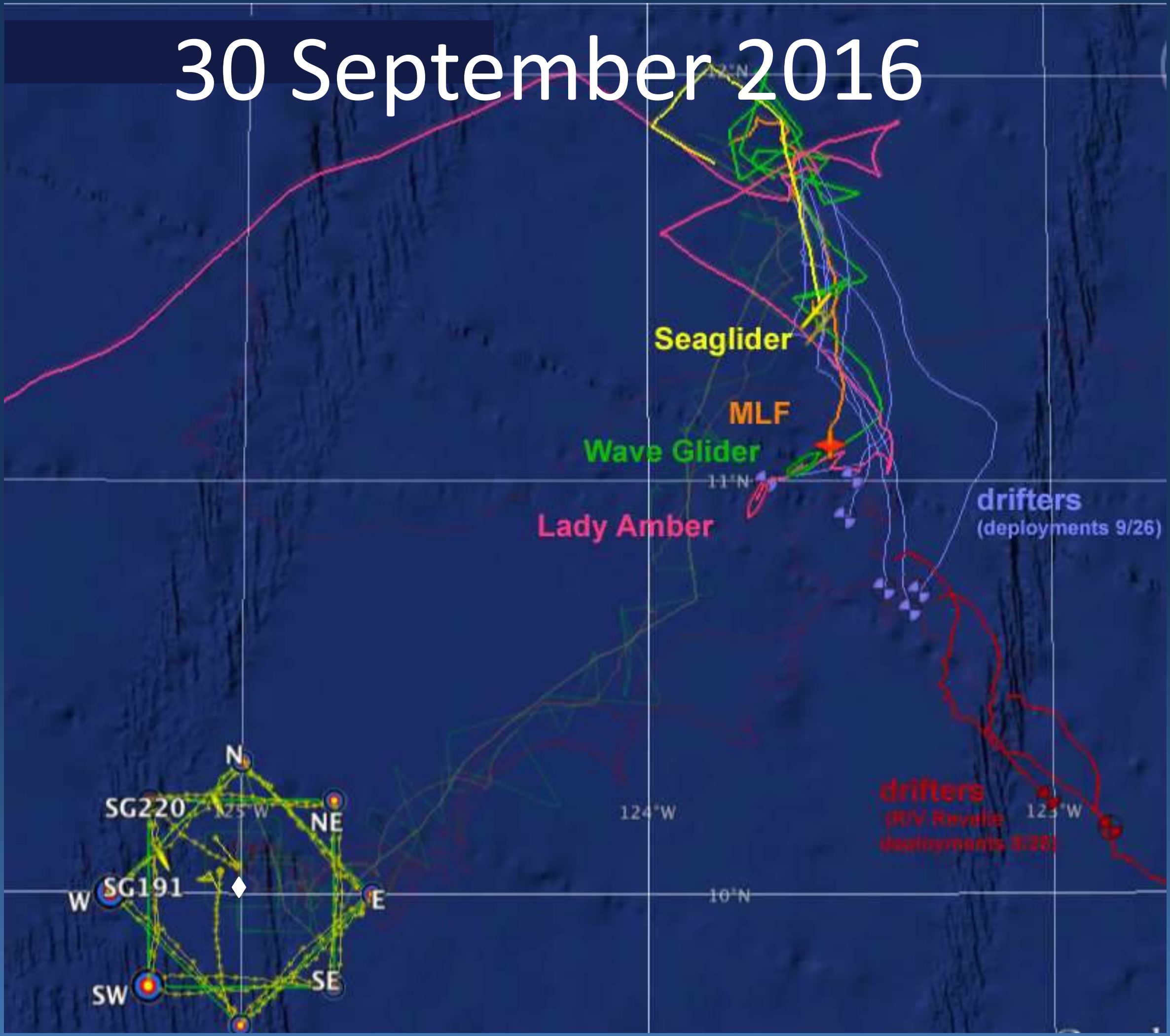
20 September 2016



SPURS - 2

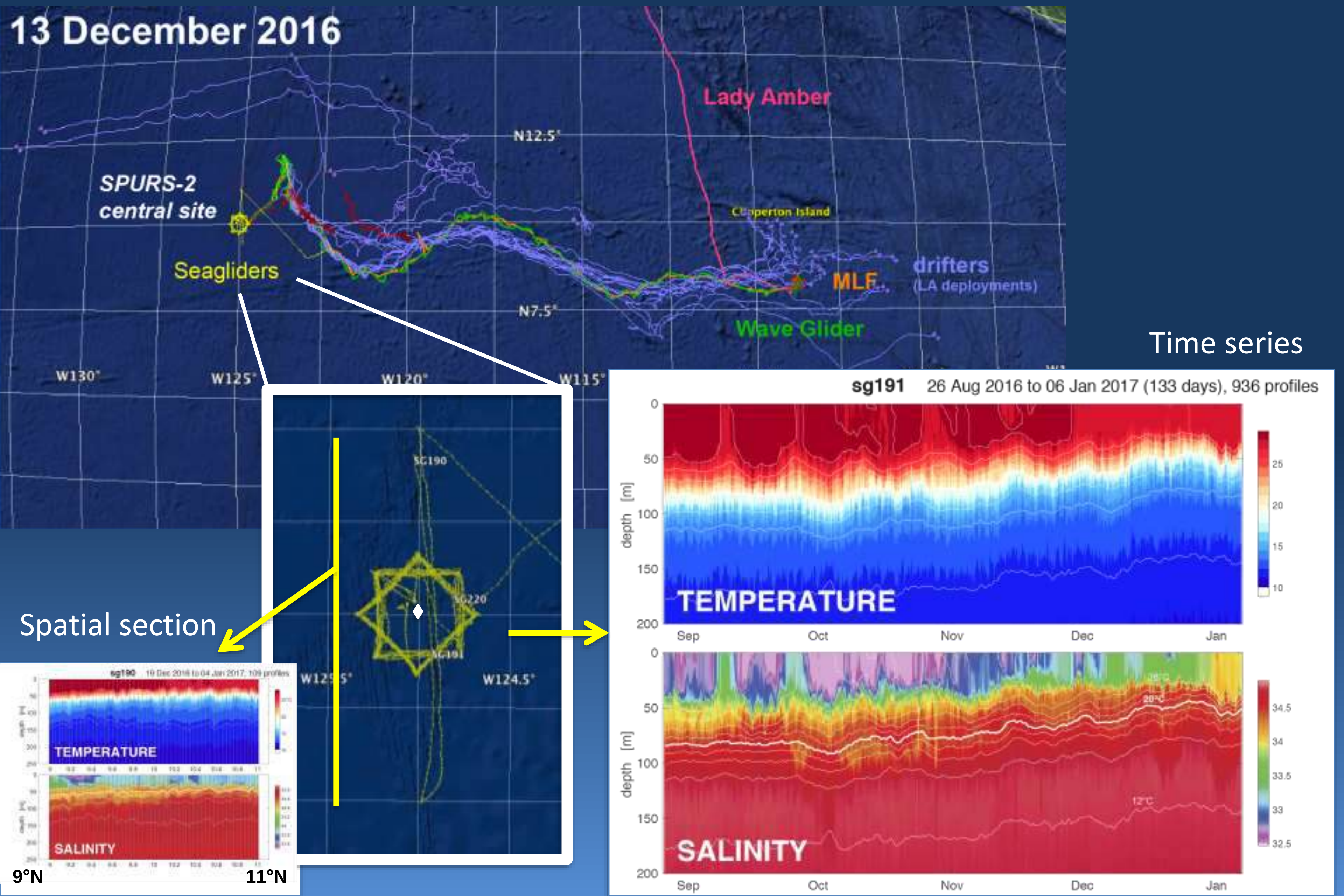
Salinity Processes in the Upper Ocean Regional Study





SPURS - 2

Salinity Processes in the Upper Ocean Regional Study



EXPORTS

EXport Processes in the Ocean from RemoTe Sensing

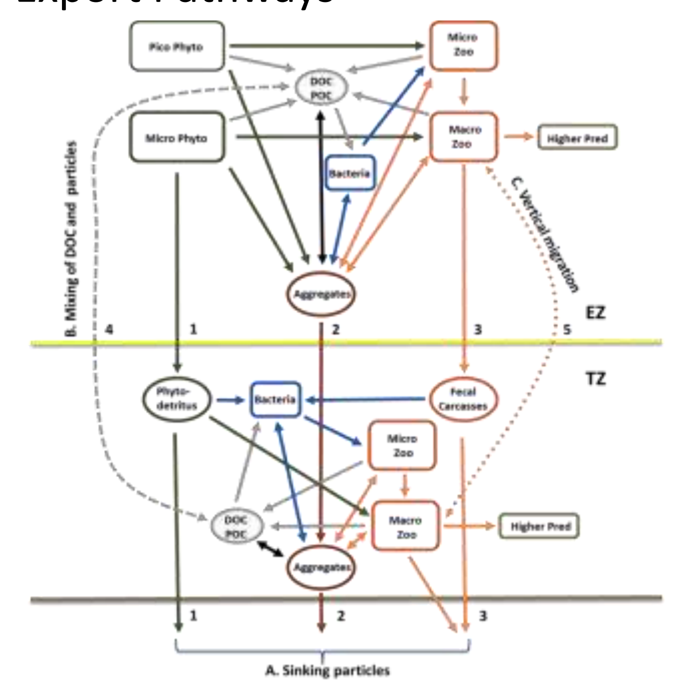
OCEAN BIOLOGY & BIOGEOCHEMISTRY PROGRAM

To develop a predictive understanding of the export and fate of global ocean net primary production and its implications for the Earth's carbon cycle in present and future climates

Plankton ecosystem characteristics include food web structure and their spatiotemporal variability in the environment

Recent advances in the remote sensing of plankton patterns (PFT, PSD, etc.) & autonomous in situ tools make achieving our goal possible

Export Pathways



Q1: How do upper ocean ecosystem characteristics determine the vertical transfer of organic matter from the well-lit surface ocean?

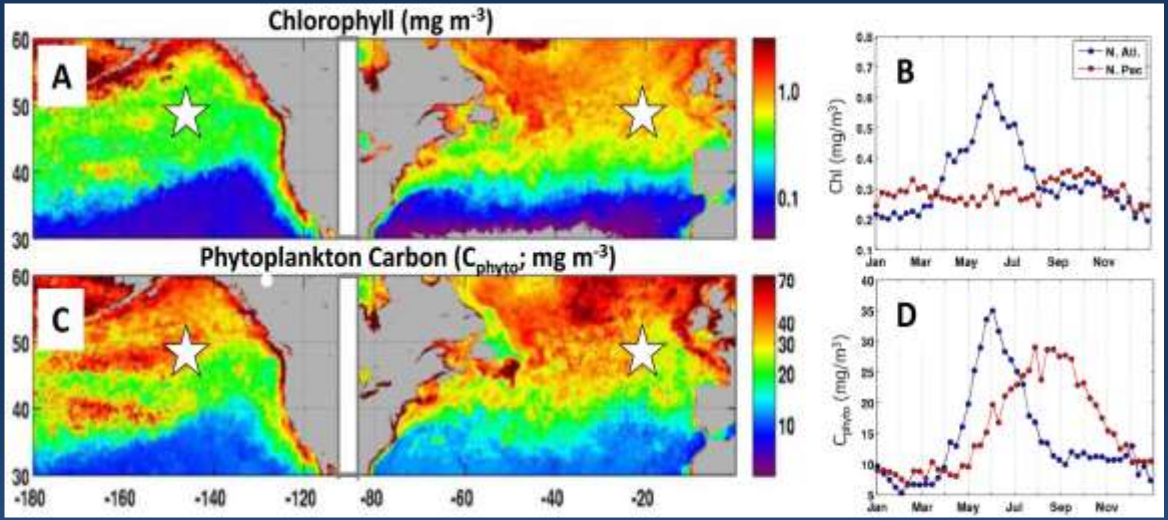
Q2: What controls the efficiency of vertical transfer of organic matter below the well-lit surface ocean?

Q3: How can this knowledge gained be used to reduce uncertainties in contemporary & future estimates of export & fates of NPP?

EXPORTS Science Definition Team

OCEAN BIOLOGY & BIOGEOCHEMISTRY PROGRAM

Suggested field campaign: *2 NE Pacific & 2 NE Atlantic field deployments*



Sites have high signal and variability, increasing the range of ecosystem / C cycling states observed & low mean advection.

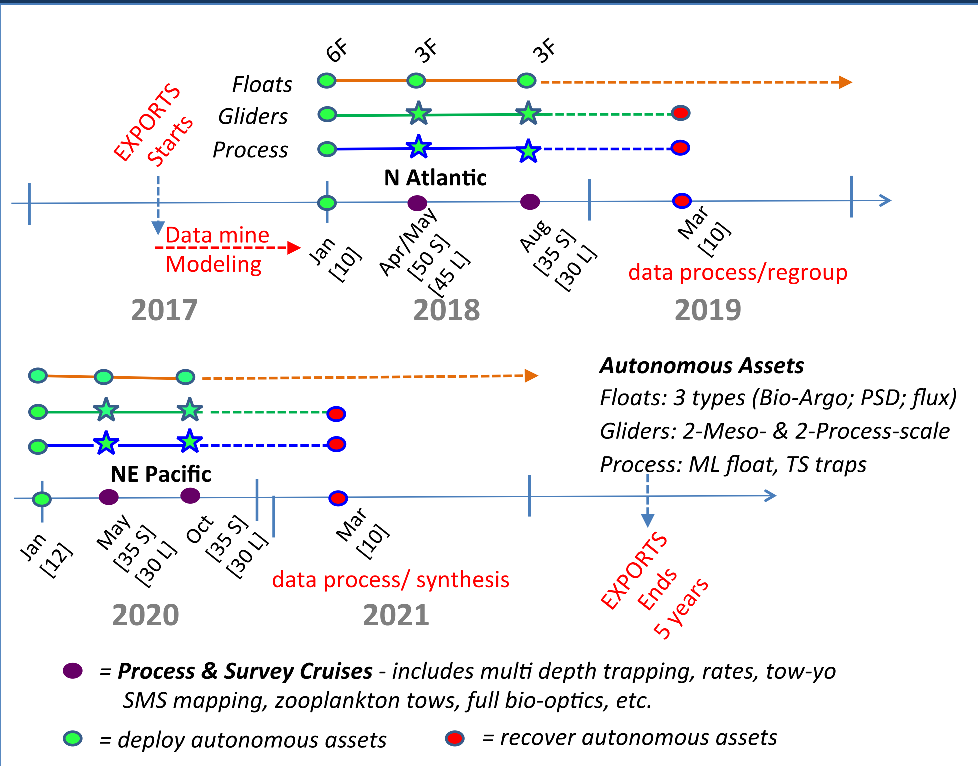
Long-term time-series programs, such as BATS and HOT, provide sufficient data for characterizing end-member conditions for oligotrophic sites.

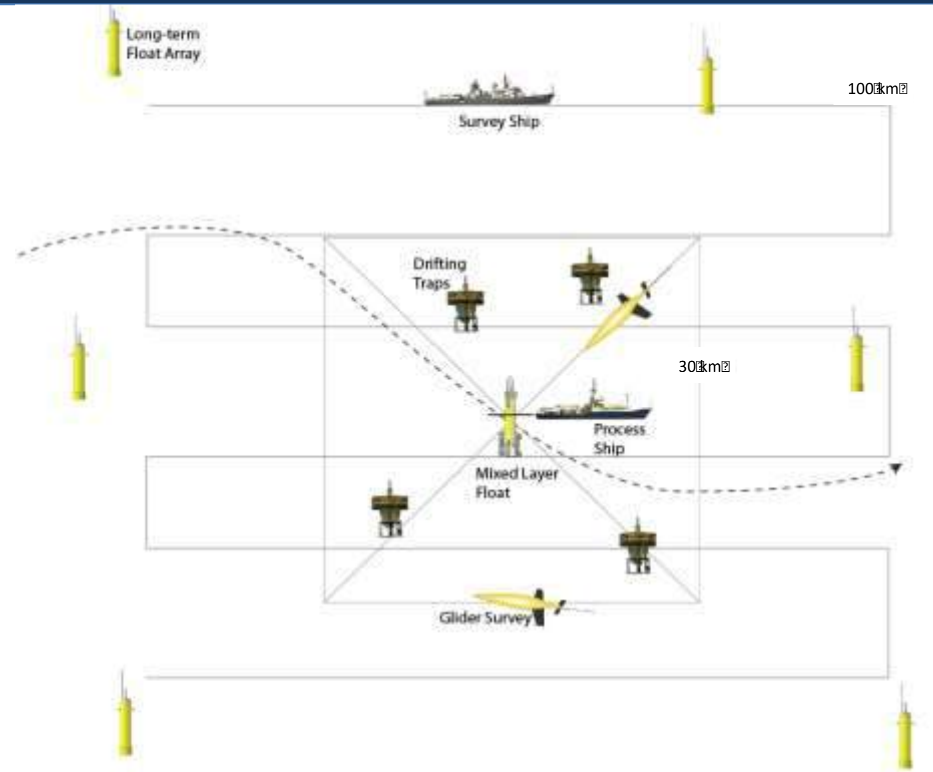
For each cruise…

- A **process ship** measuring rates and time series of stocks following a sub-surface Lagrangian **float**.
- A **survey ship** provides spatial information on biogeochemistry as well as detailed submesoscale physical oceanographic surveys.
- Spatial observations supplemented by **gliders** & **satellites**
- Long-term context from **profiling floats**.

EXPORTS Science Definition Team

EXPORTS Field Program requires multiple ships (process, survey & vehicle launch/retrieval), autonomous platforms (gliders & floats) within a framework of remote sensing & modeling.





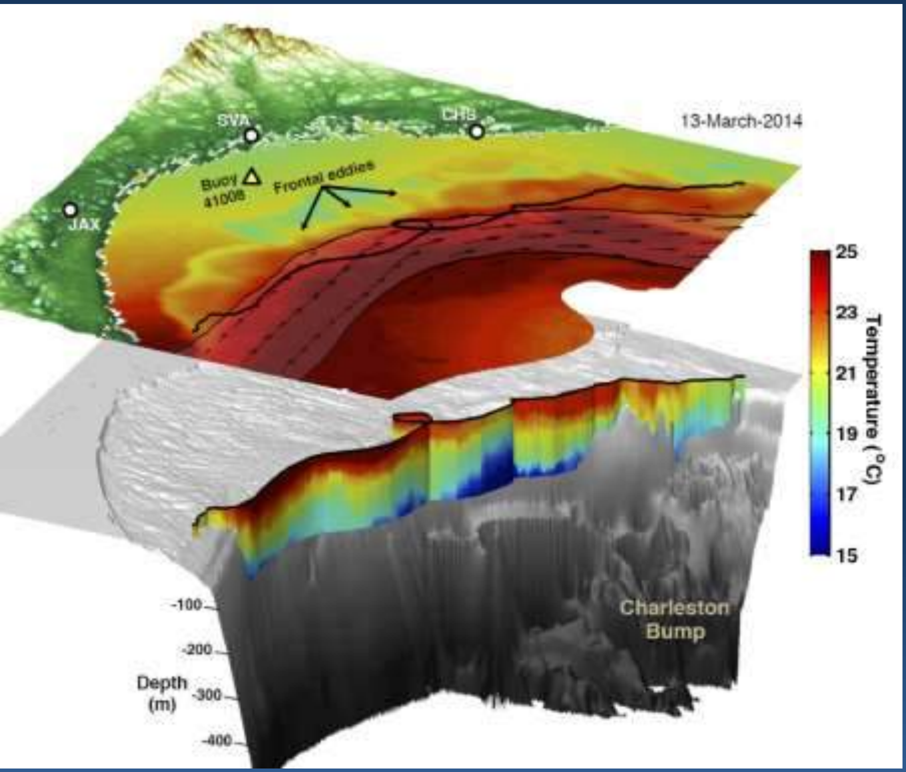
<u>Required Measurements</u>: Water Column Characterization, Food Web Structure, Carbon Flows, Export Paths

- Phytoplankton (C stock, size, PFT, NPP, ...)
- Particles (export w/ vertical profile, PSD, sinking rate, turnover rate, ...)
- Biogeochemistry (O_2, P/DIC, Nuts, P/DOC, ...)
- Food Web Interactions (grazing, fecal flux, sinking particle degradation, energy flow, ...)
- Scales (patch to experimental, trap funnels, ...)
- Context (R_{rs}(l), IOP's, physics, ...)

The Impact of Western Boundary Current and Eddies on the Across-Shelf Exchange in the South Atlantic Bight: an Integrated Study Using Satellite Altimeters Time Series, In-situ Observations, and Data Assimilative Numerical Modeling

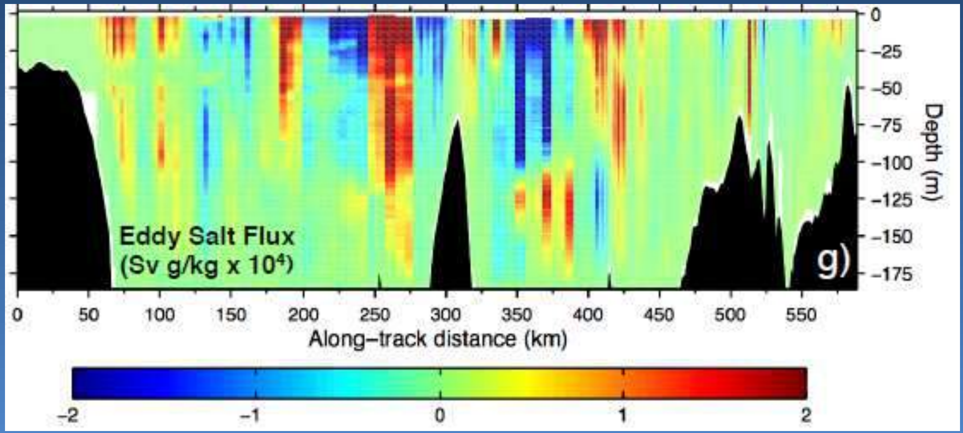
Renato Castelao (UGA) and Ruoying He (NCSU)

Supported by NASA Ocean Surface Topography Science Team



Example of observed potential temperature along the path of a glider in the South Atlantic Bight, March 4-17, 2014. AVHRR SST for March 13th is shown on top panel. Mean location of Gulf Stream core (from altimetry) during deployment is also shown.

- Gliders are providing information about subsurface slope water intrusions onto the shelf
- ROMS 4DVAR implemented assimilating glider data, SSH from altimeters, and SST --> currently being used to investigate along-shelf and cross-shelf exchanges associated with Gulf Stream dynamic



National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Surface Water and Ocean Topography (SWOT) Mission

SWOT Science Team Meeting
January 13-15, 2016

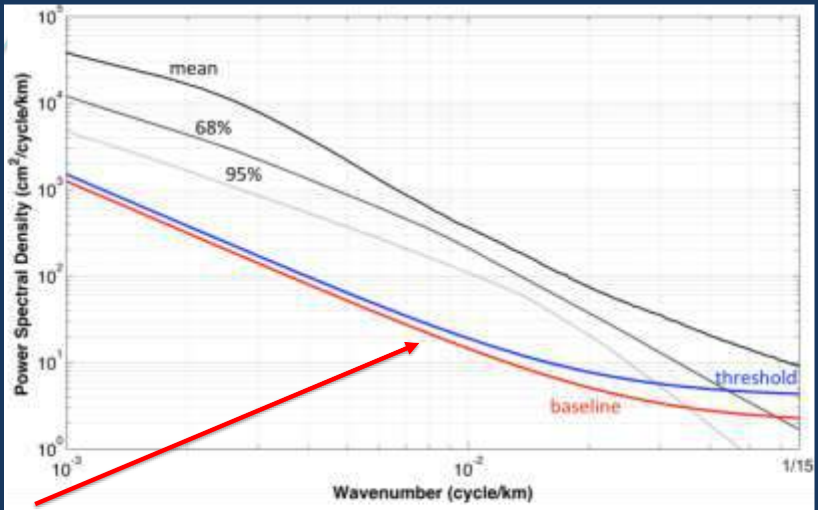
Cal/Val Overview

SWOT Cal/Val Team*!*

SWOT will provide high-spatial resolution, global measurements of ocean surface topography.

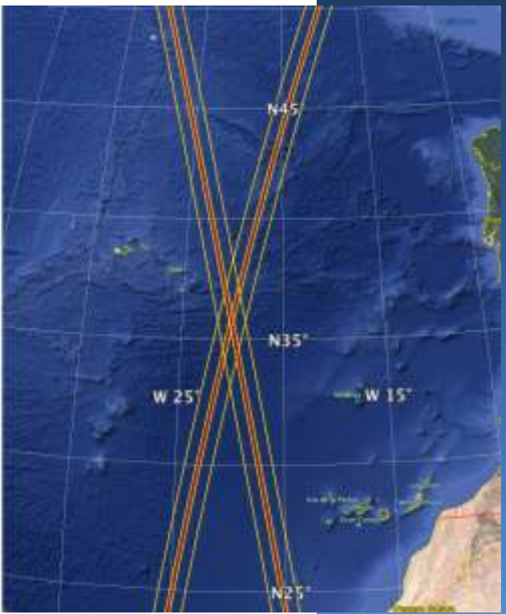
SWOT Validation requires to validate the measurements of entire SSH signature, including tides, internal waves, geostrophic, etc.

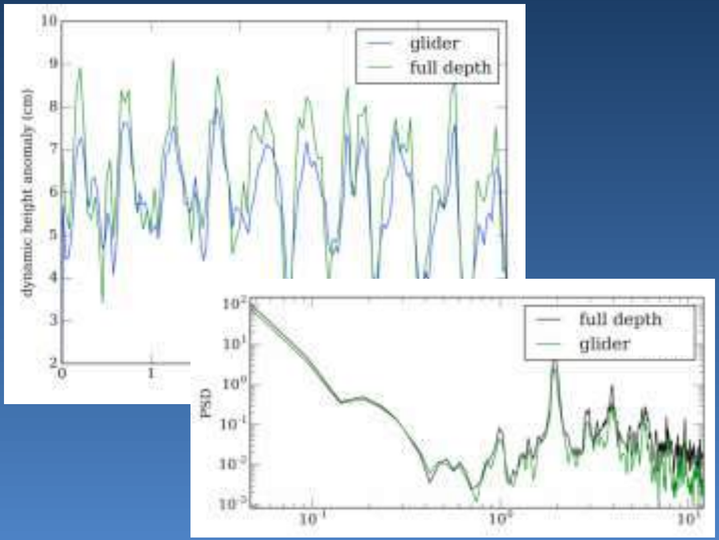
Need to measure the horizontal wavenumber height spectrum.



The spectrum of the ***difference*** between measured and truth SSH needs to be characterized synoptically at scales between 15 km and ~150 km wavelengths

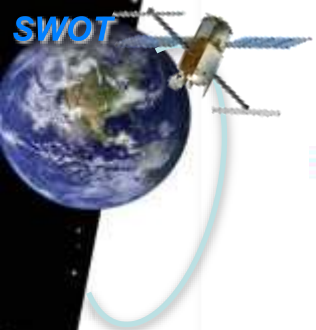
OSSE using high-resolution models, to evaluate sampling strategies



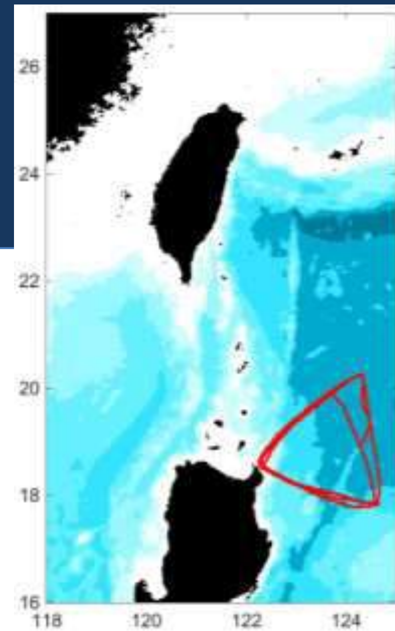


Gliders (time and space)
PIES (mesoscale structure)
Underway-CTD
Towed-body from ship
…

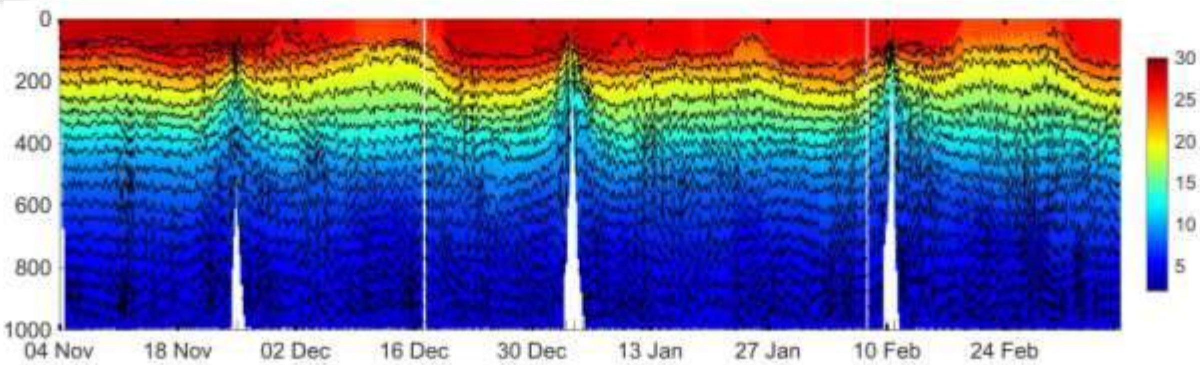
J. Wang, T. Farrar, L. Fu, E. Rodriguez, etc.

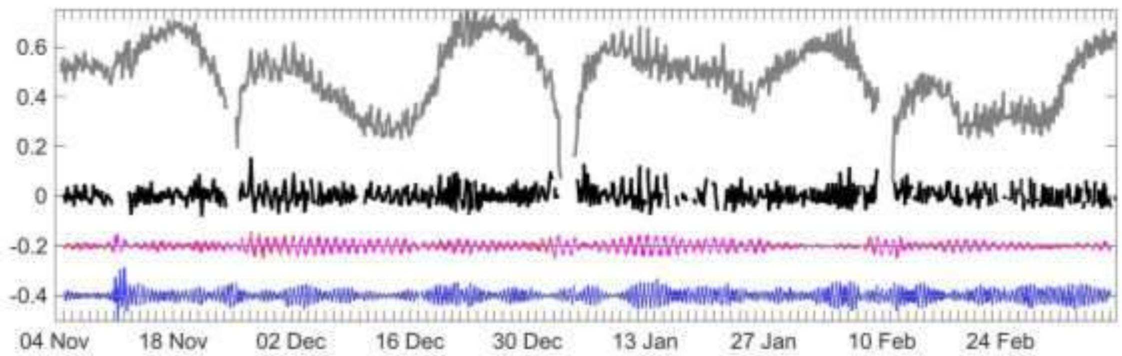


Dynamical height estimates from gliders



Temperature and isopycnal displacements from glider





Total steric height (0 < z < 1000m)

ssh with periods < 3-day

diurnal internal tide ssh

semidiurnal internal tide ssh

The persistence of gliders allows us to estimate the contribution to SSH from internal waves of ***different frequencies***, and of different ***vertical structures***, on a ***regional scale***.

K. Drushka, L. Rainville

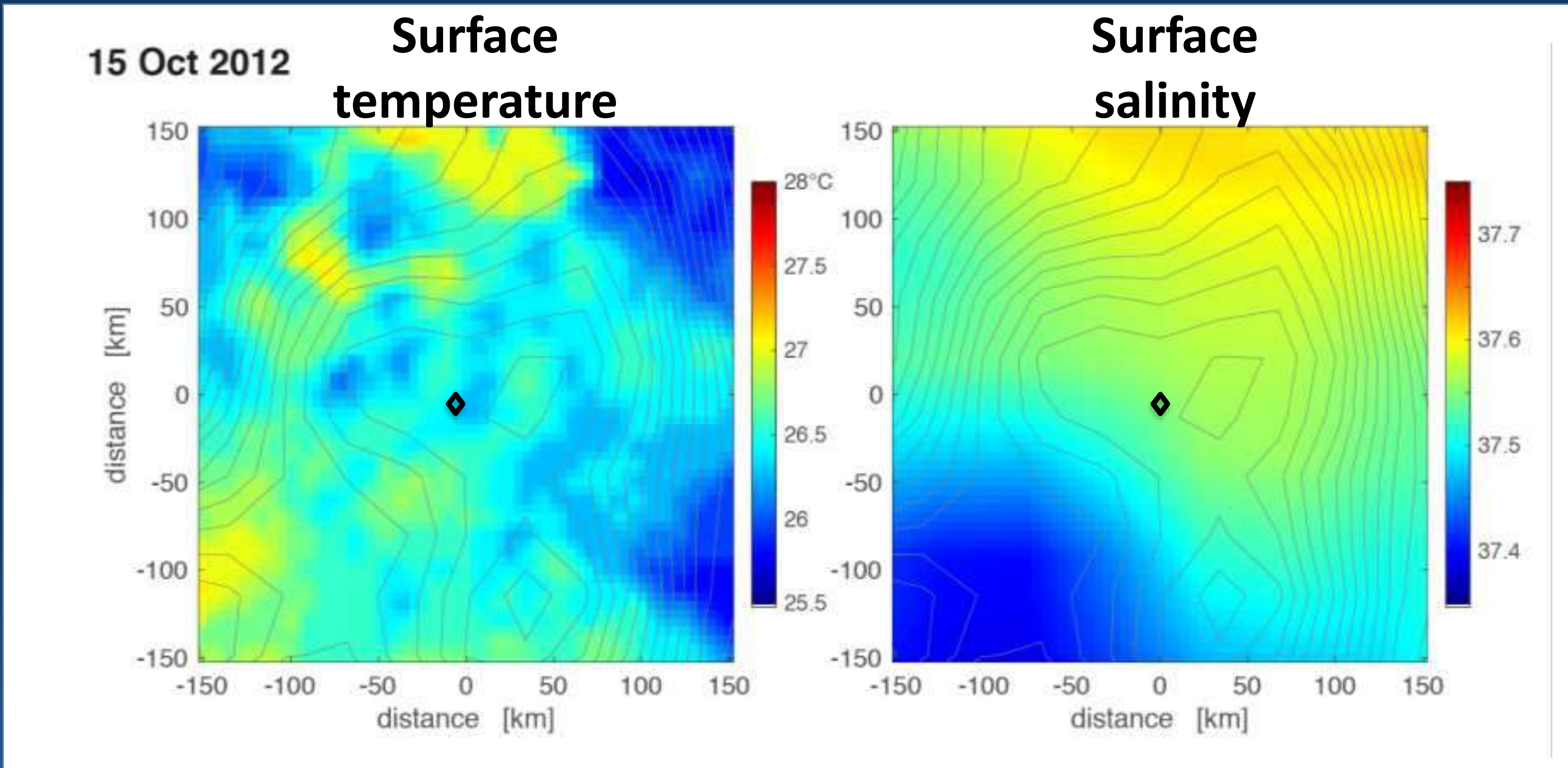
Enabling NASA's Mission

- Gliders are used as part of long-term autonomous arrays to capture important processes occurring on a variety of time and spatial scales

- NASA has been a supporter of glider technology development, and sensor development, in particular for interdisciplinary science (Ocean Color, etc.).

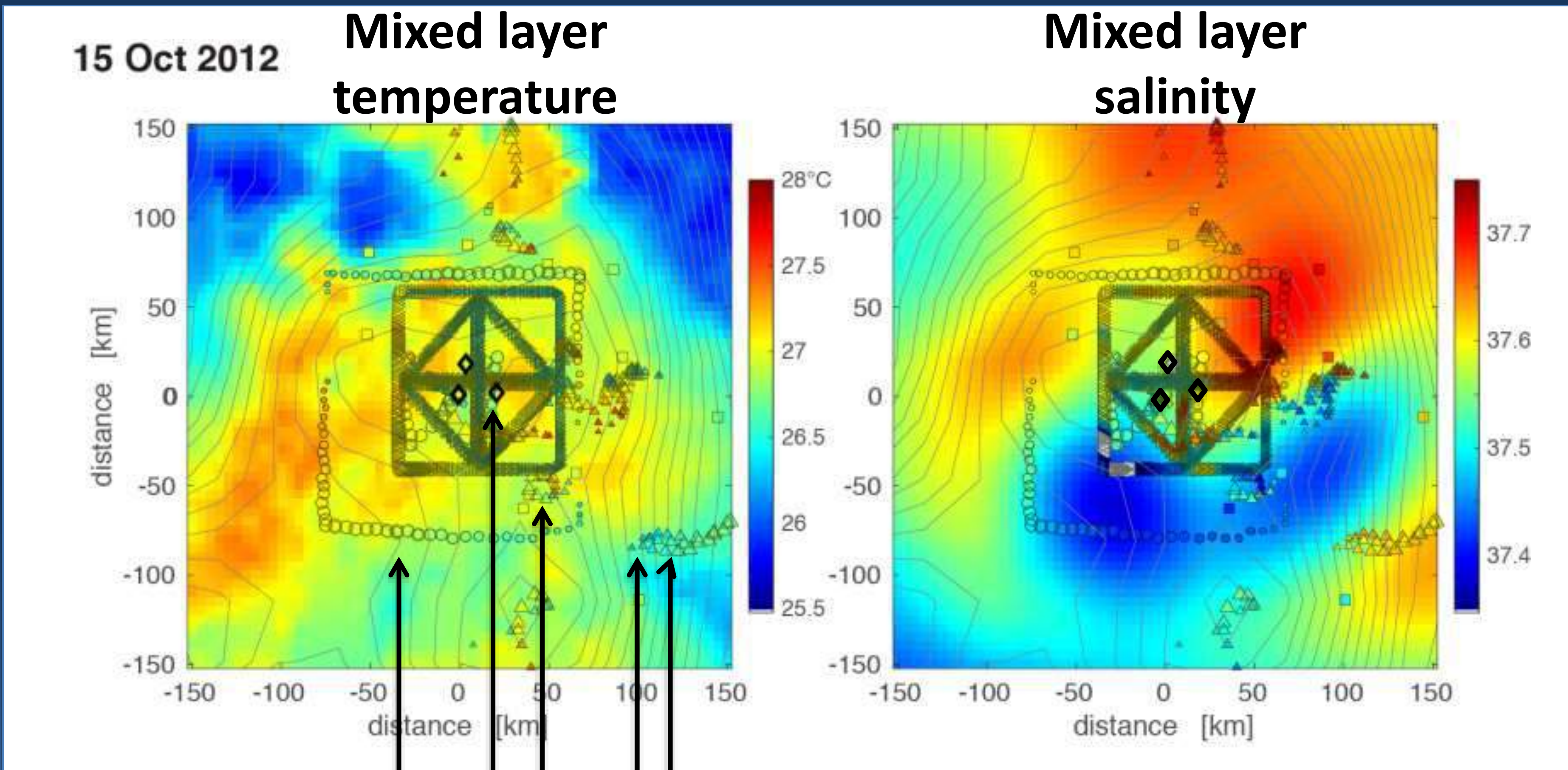
- Gliders are used as one of the tools to validate satellite and meet mission requirements.

- Glider data are often an important link between the components of large programs (e.g., modeling, Eulerian / Lagrangian arrays, etc.).



microwave (MW) and infrared (IR) SST
Optimal Interpolation
(Remote Sensing System)

Aquarius SSS
Optimal Interpolation
(Melnichenko et al.)



- Moorings
- Drifters
- Seagliders
- Argo floats
- Wave Gliders

Decorrelation scales: 75 km and 5 days mapped as perturbations from remote sensing

Note: Size of data marker is scaled by when it was collected relative to the map time.

US Navy Automated Glider Guidance: NRL Glider Optimization Strategies Overview (GOST)

Charlie N. Barron and Lucy F. Smedstad
Naval Research Laboratory

NRL 7320 Ocean Dynamics and Prediction
Stennis Space Center, MS
18 January 2017

Glider Observation Strategies (GOST)

Challenge: Workload for glider pilots

Solution: Automate glider guidance

Purpose of GOST:
Generate an automated Glider Observation Strategy plan using cost functions to identify regions of higher interest, using forecast currents to determine viable paths, and identifying from among these preferred paths that maximize mission-relevant value of glider observations.

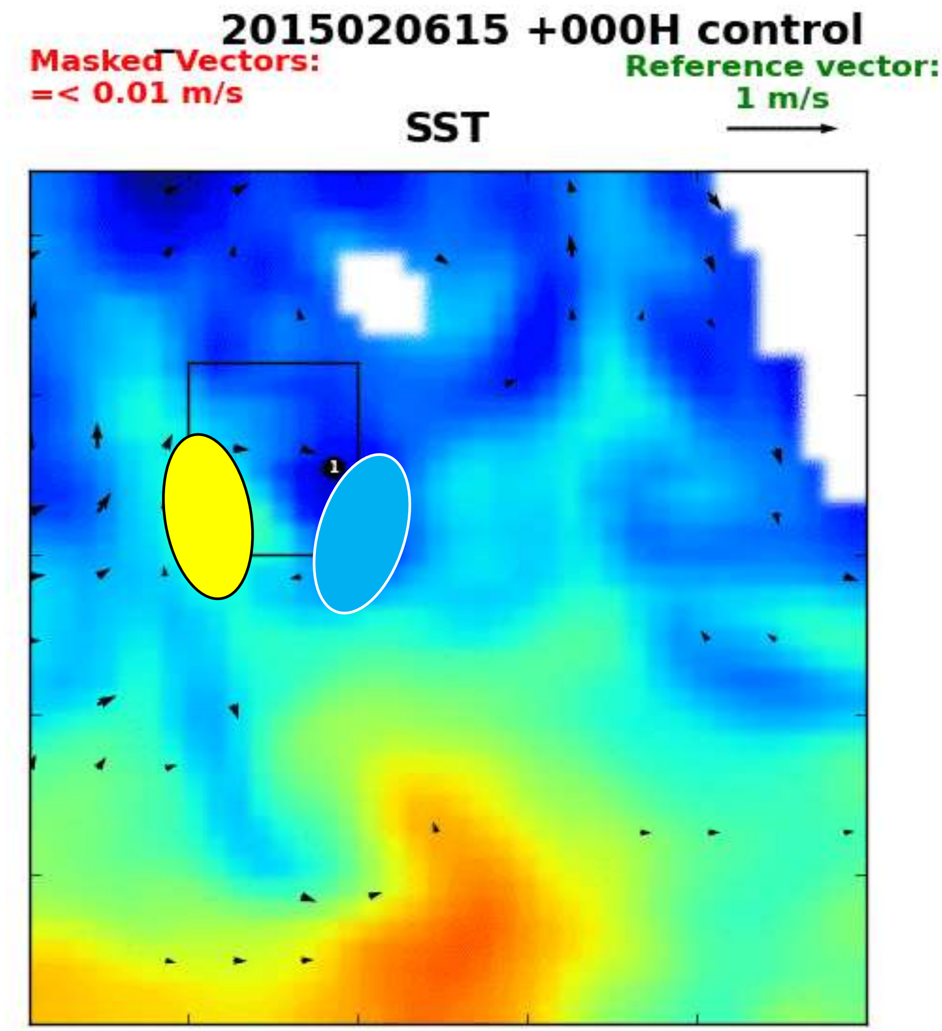
Glider Observation Strategies (GOST)

Challenge: Workload for glider pilots

Solution: Automate glider guidance

Purpose of GOST:
- **Where do I want to go?**
- **Where can I go?**
- **What combination is best?**

Example of active glider observations in the right place: tactically relevant features



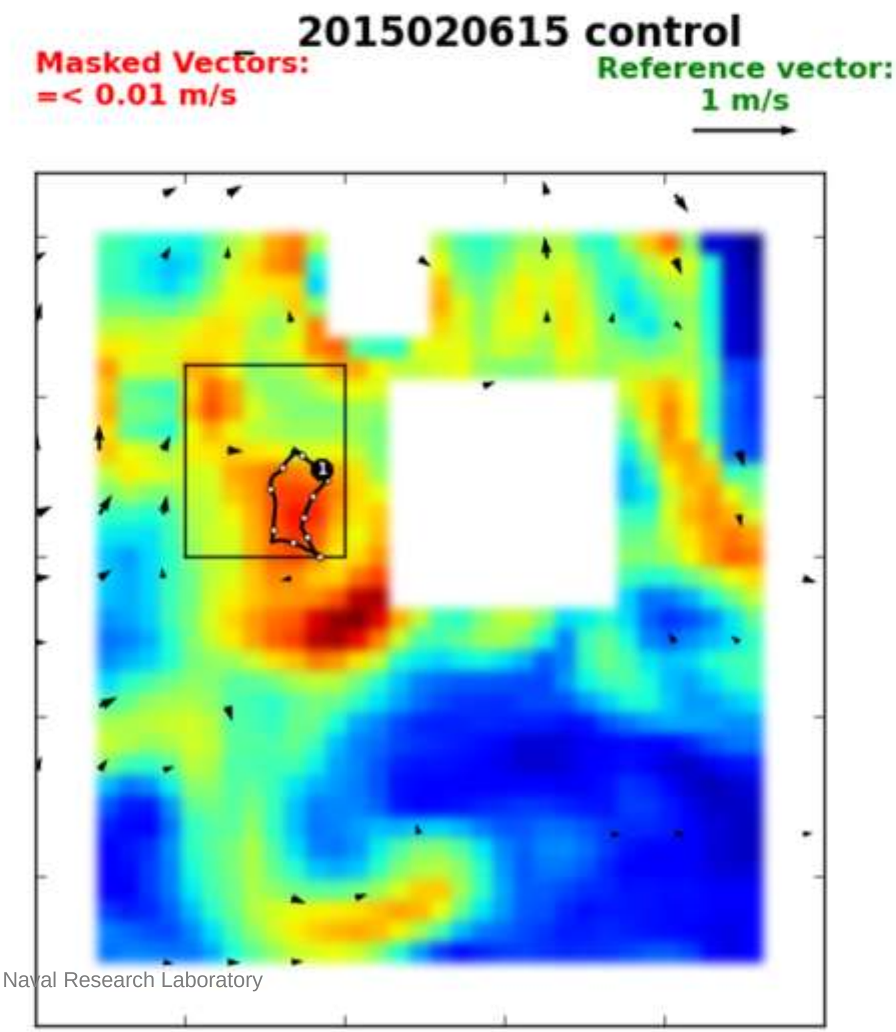
Glider defines boundary between warm and cold eddies

Assimilate glider observations into forecast models

Inform tactical decisions regarding:

- **Acoustic transmission**
- **Mine drift**
- **Special warfare**
- **Small boat operations**
- **Search and recovery**

GOST: Cost function defines relative mission value among different locations

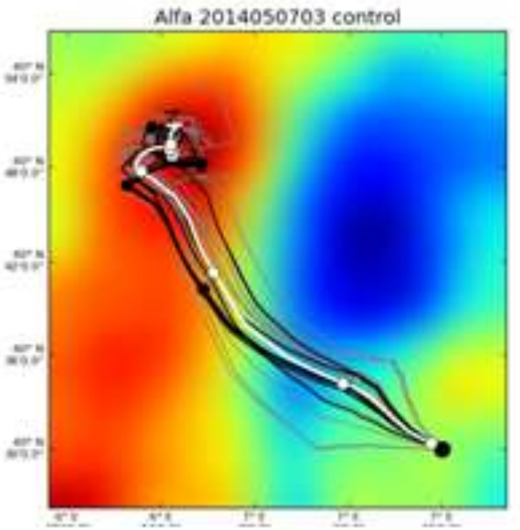


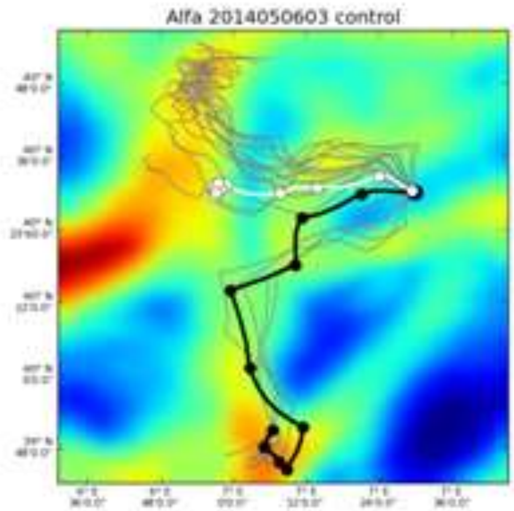
The cost function is a means translate the manual judgment of a subject matter expert into a field used in an automated optimization

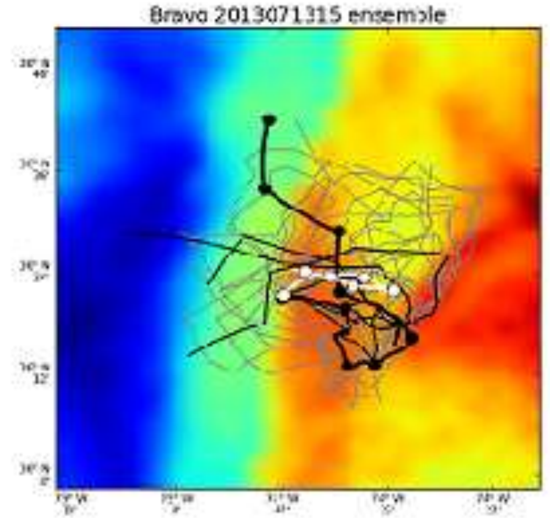
Specific cost functions are designed to quantify preferences relevant for typical Navy missions.

red = more valuable
blue = less valuable

GOST Cost Functions: Of many possible paths, which one is best?



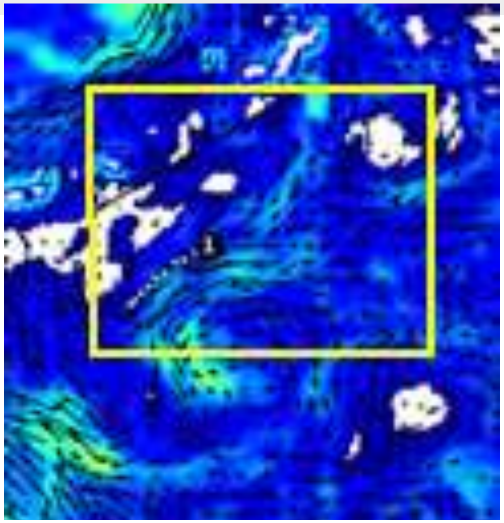




Potential (gray) glider trajectories superimposed on mission cost functions. The preferred waypoints (black) compared with the mean (white) of possible solutions. GOST uses a genetic algorithm to find the preferred path (Heaney et al., 2007)

GOST uses forecast currents to determine waypoints that fulfill assigned glider missions

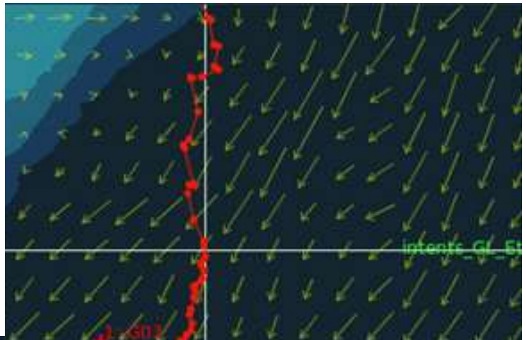
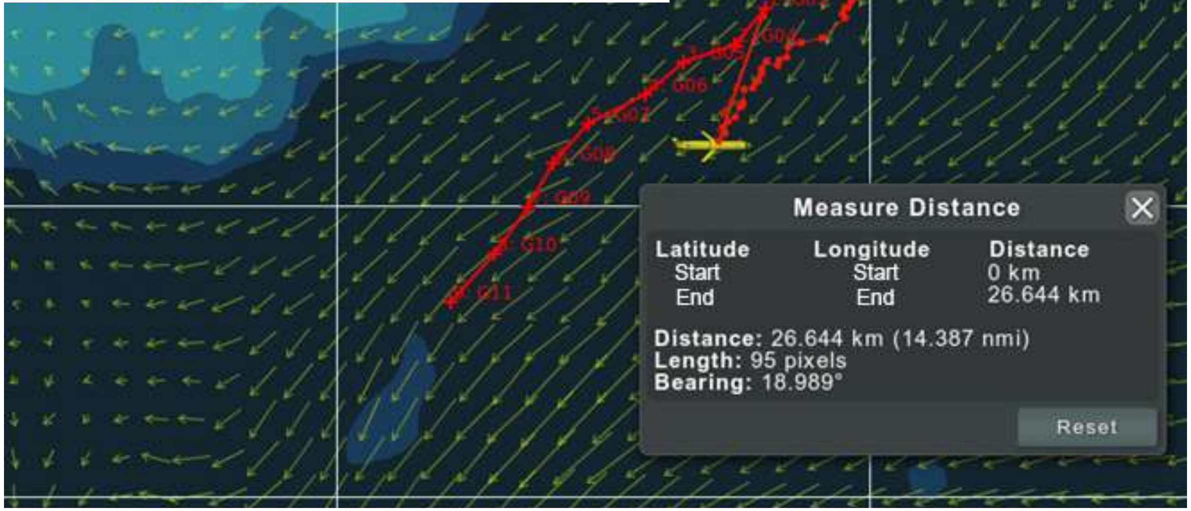
GOST support for UUV operations at NAVOCEANO, developed by NRL 7320



local forecast currents and Glider Optimization Strategies (GOST) mission cost function

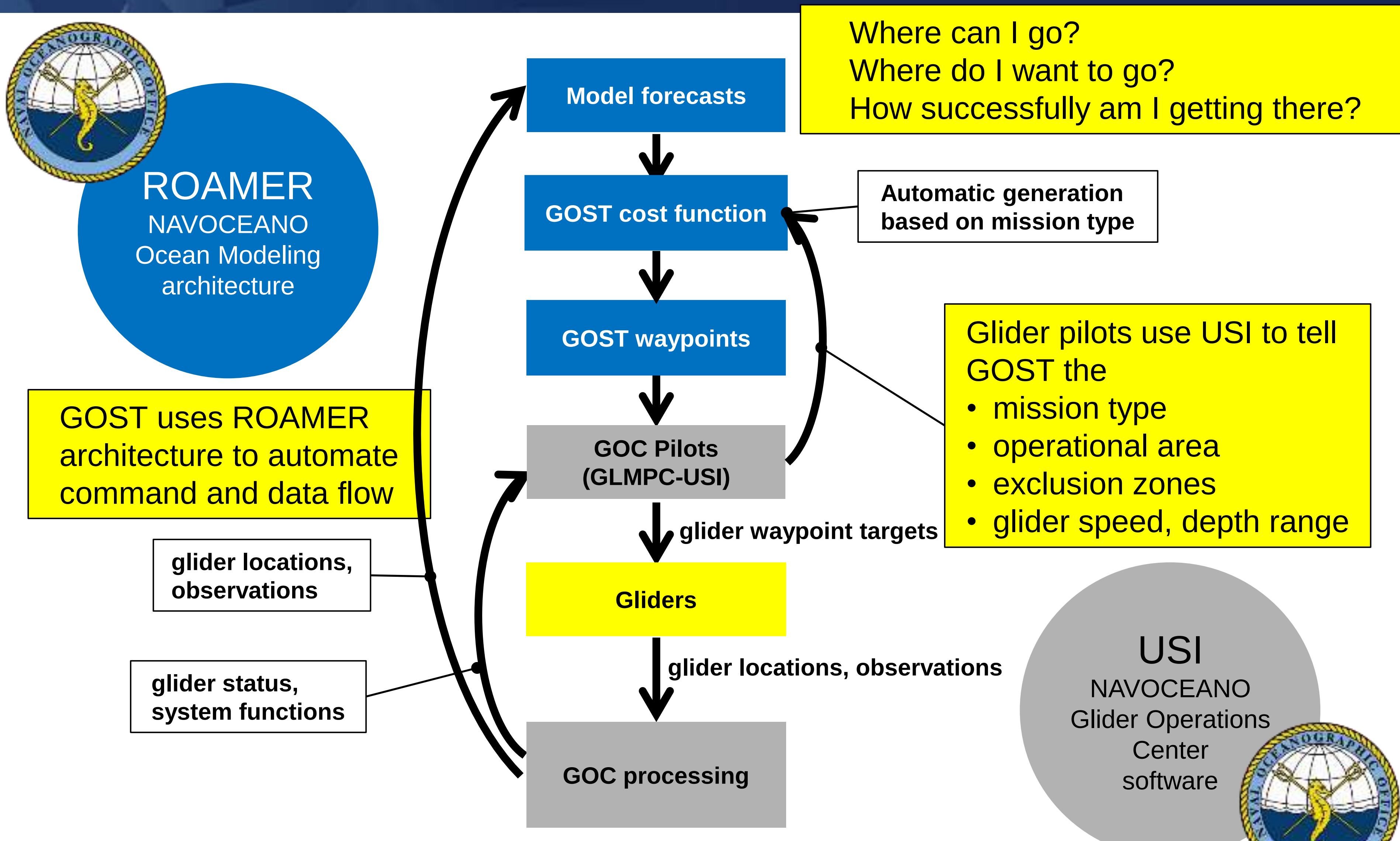
NAVOCEANO glider visualized in USI

- When currents are stronger than predicted, the glider drifts off the preferred GOST path
- Pilots use USI to request a GOST update to guide the response to changing conditions

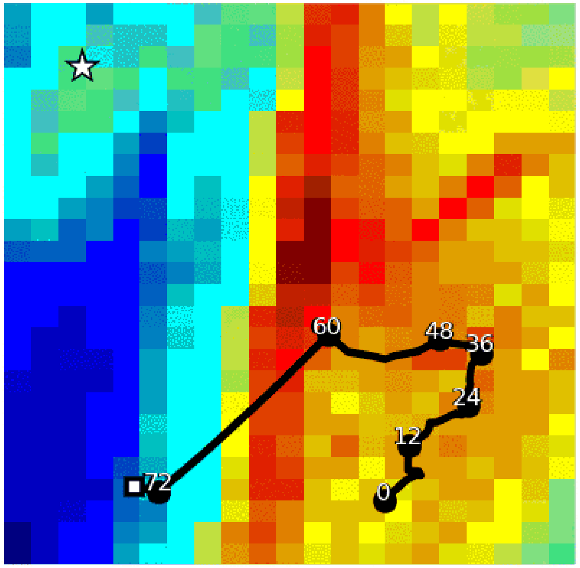
GOST generates an automated glider observation strategy, providing paths to achieve present and future mission goals.

GOST automated commands, data flow, and pilot interaction

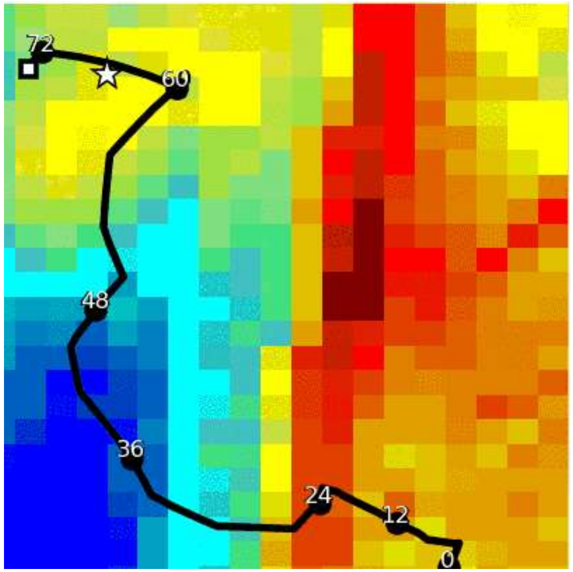


GOST Cost Functions: Finding the right balance between glider observations and recovery

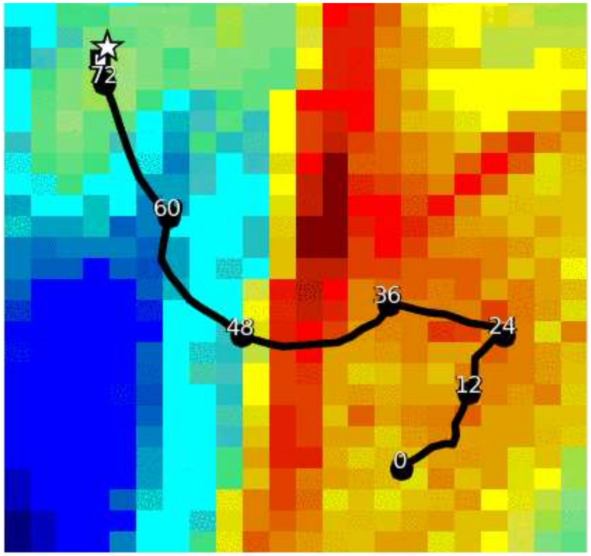
Overemphasize sampling: route fails by missing recovery (☆) location/time



Overemphasize recovery: route fails by missing valuable (red) observations



A successful glider mission finds a path that seeks needed observations and reaches its recovery ☆ location on time



Mission success!

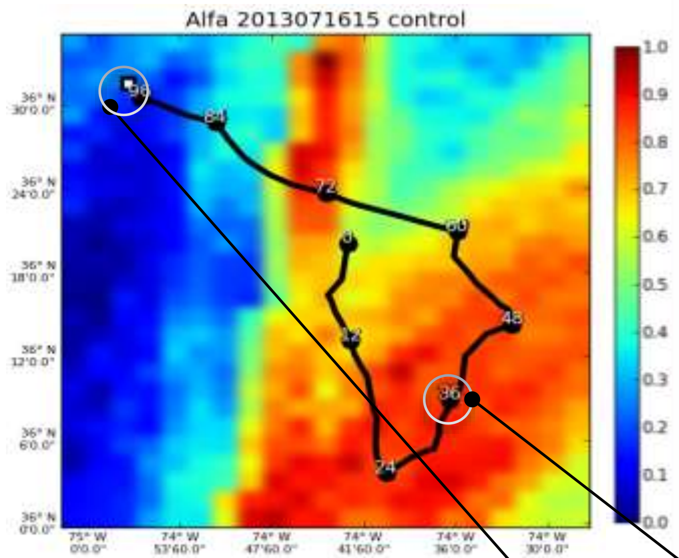
Measurements are more valued in warmer (redder) areas, but glider must reach recovery in 72 hours.

Waypoints from GOST are guidance for glider pilots

GOST conveys normalized value of observations at different waypoints

Pilot can prioritize more valuable waypoints

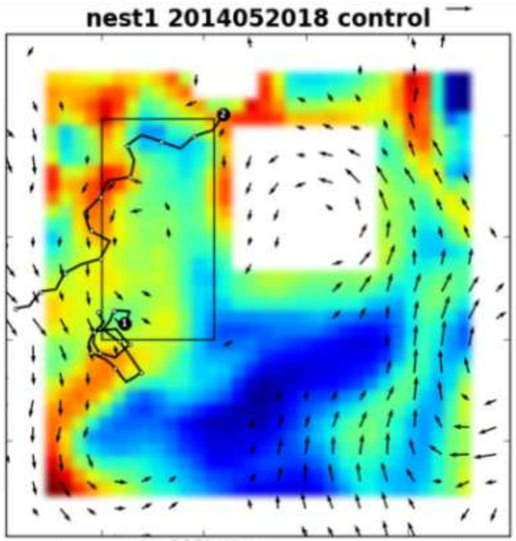
More flexible vs less flexible

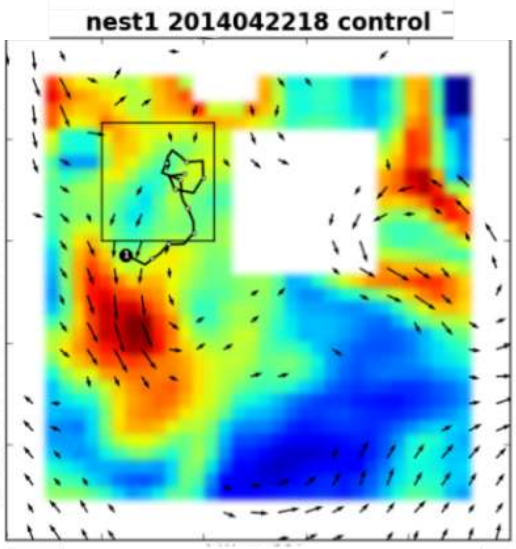


Normalized cost function or observation value

Time	Latitude	Longitude	Platform	Out Of Bounds?	Too Close?	Weight
000	36 N 20'03.840"	74 W 43'01.920"	Alfa	Clear	Clear	0.6130
012	36 N 13'06.960"	74 W 42'50.760"	Alfa	Clear	Clear	0.6566
024	36 N 03'36.000"	74 W 40'29.280"	Alfa	Clear	Clear	0.8428
036	36 N 08'51.000"	74 W 36'21.240"	Alfa	Clear	Clear	0.8720
048	36 N 14'15.720"	74 W 32'20.760"	Alfa	Clear	Clear	0.8563
060	36 N 20'53.880"	74 W 35'52.800"	Alfa	Clear	Clear	0.5604
072	36 N 23'40.560"	74 W 44'25.080"	Alfa	Clear	Clear	0.8669
084	36 N 28'42.600"	74 W 51'38.160"	Alfa	Clear	Clear	0.3714
096	36 N 30'32.760"	74 W 56'33.720"	Alfa	Clear	Clear	0.1499
098	36 N 31'33.600"	74 W 57'21.240"	Alfa	Clear	Clear	0.1499

How is GOST guidance used by pilots?

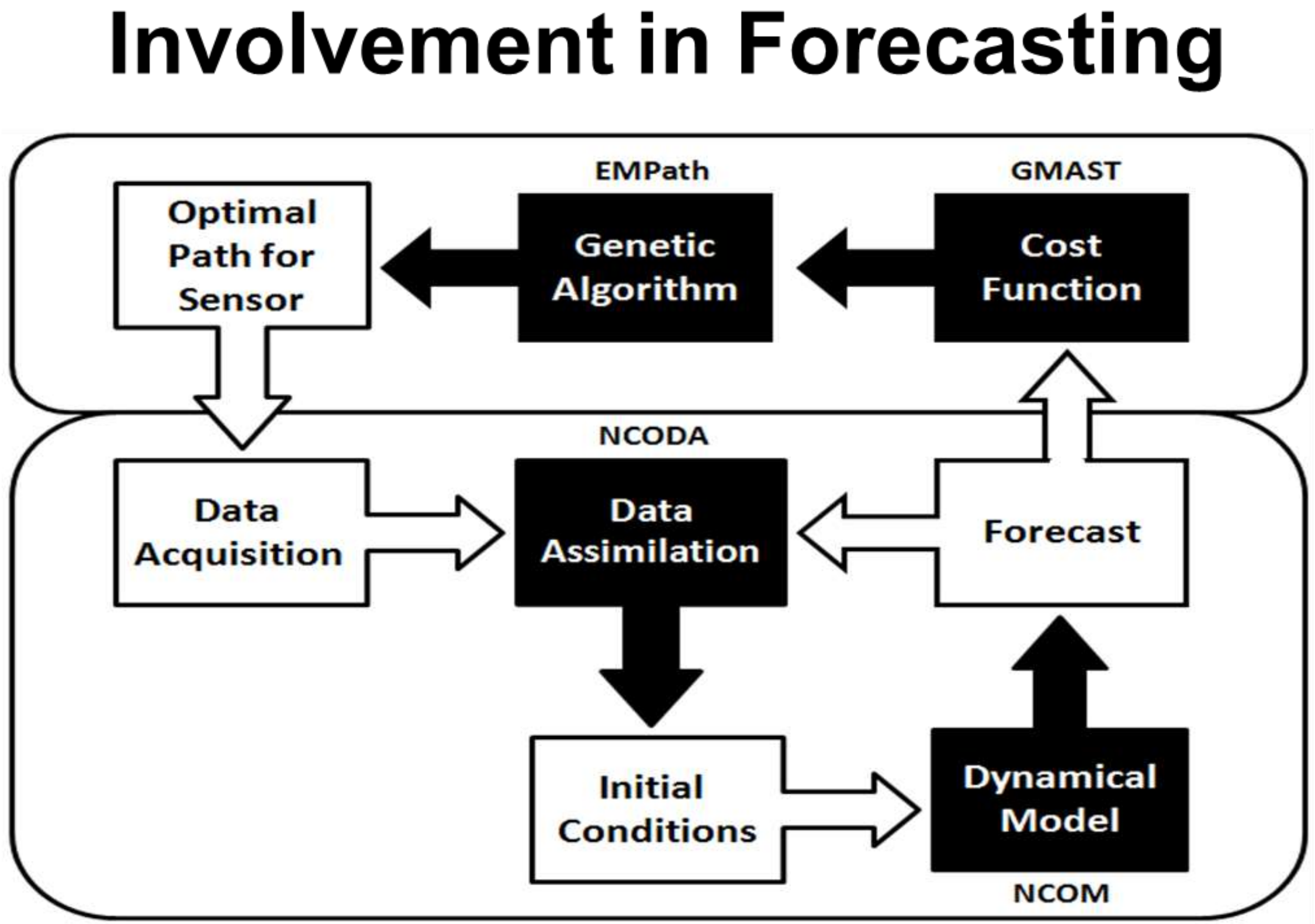




How are GOST waypoints typically used?
(evaluation over 10 months)

41.9% Used As Is	**39.8% Adjusted** **(change a few points near boundaries or to accommodate how a glider identifies its next waypoint)**
9.7% Not used **(manual control just before recovery, points outside of OpArea)**	**8.8% non-guidance issues** **(Hardware Issues, file transfer issues, format issues)**

GOST as part of Ocean Forecast System



GOST

OCEAN FORECAST SYSTEM

Glider Observation Strategies (GOST)

Result: Glider pilots have increased efficiency

Solution: Automated glider guidance

Purpose of GOST:
Generate an automated Glider Observation Strategy plan using cost functions to identify regions of higher interest, using forecast currents to determine viable paths, and identifying from among these preferred paths that maximize mission-relevant value of glider observations.

Enabling NOAA's Mission with Glider Technology

Office of Oceanic and Atmospheric Research (OAR)

David M. Legler

(with input from Derrick Snowden (NOS/IOOS), Becky Baltes (NOS/IOOS), Gustavo Goni (OAR/AOML) Chris Meinig (OAR/PMEL), and Chris Beaverton (OAR/OER)

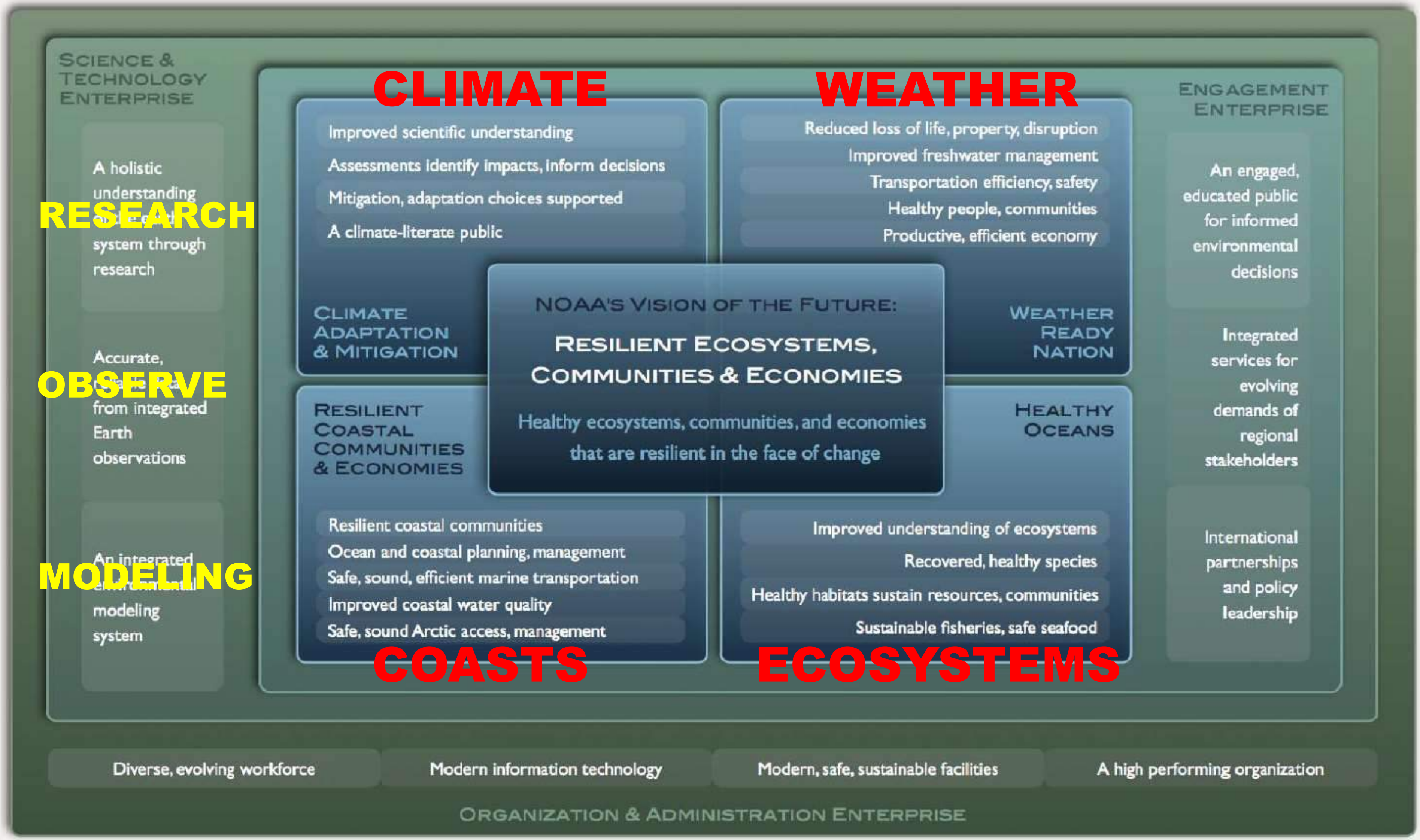
Director, Ocean Observing and Monitoring Division

Climate Program Office | OAR

January 18, 2017

NOAA's Mission:
Science, Service & Stewardship

To understand and predict changes in climate, weather, oceans, and coasts,
To share that knowledge and information with others, and
To conserve and manage coastal and marine ecosystems and resources



Role of Underwater Gliders in Meeting NOAA's Mission Goals

WEATHER READY NATION

1. Environmental Modeling Prediction
2. Hurricane/ Tropical Storms

HEALTHY OCEANS

1. Ecosystem Monitoring, Assessment & Forecast
2. Fisheries Monitoring, Assessment & Forecast
3. Habitat Monitoring & Assessment
4. Protected Species Monitoring
5. Science, Services and Stewardship

RESILIENT COASTS

1. Coastal Water Quality
2. Planning and Management

CLIMATE

1. Climate Science and Improved Understanding
2. Ocean monitoring

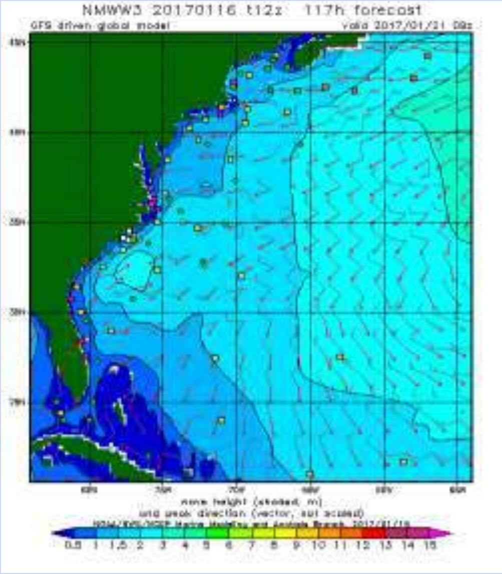
Glider Missions Completed:

- Ecosystem dynamics monitoring
- Fish stock mapping
- Harmful Algal Bloom (HAB) mapping
- Hydrographic mapping
- Ocean acidification sampling
- Climate monitoring
- Listening to tagged fish, whale acoustics
- Sustained and targeted ocean observations for improving tropical cyclone intensity and hurricane seasonal forecasts
- Oil spill response and restoration

What is NOAA's role in the glider enterprise?

NOAA is a developer of glider technology

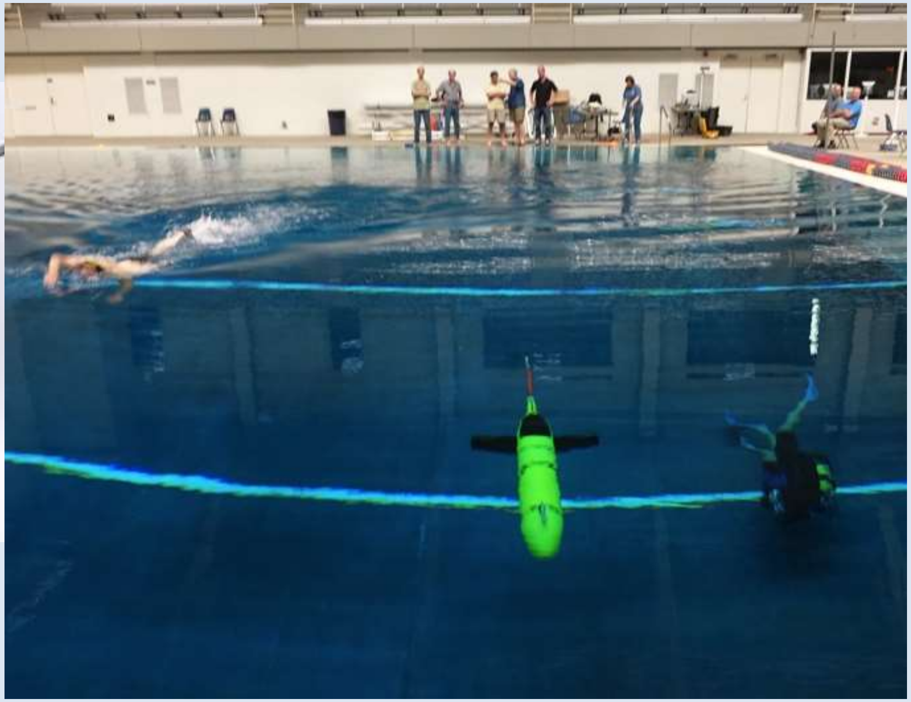
NOAA is an operator and sponsor of gliders



NOAA is a consumer of glider information

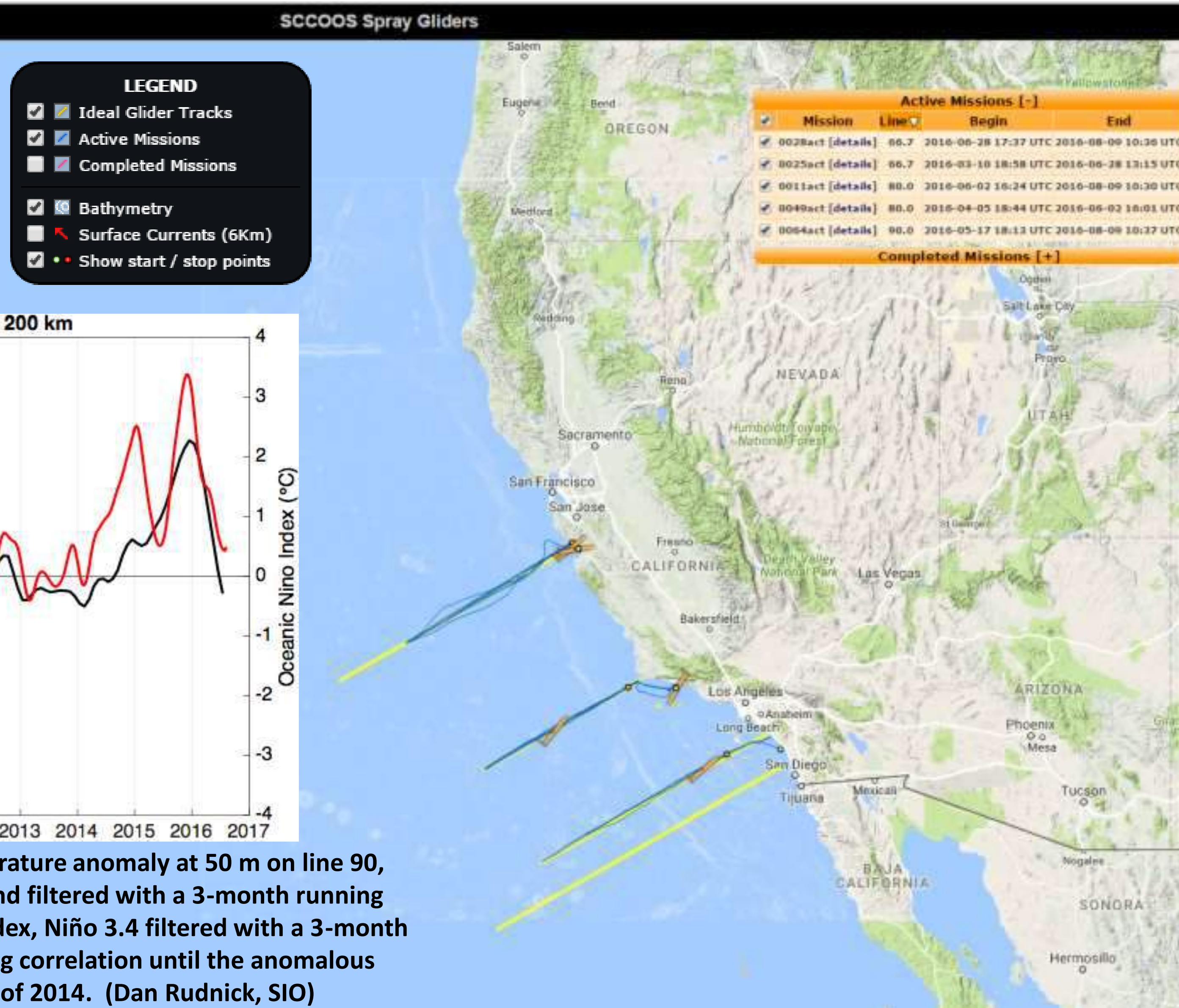
Oculus Coastal Glider

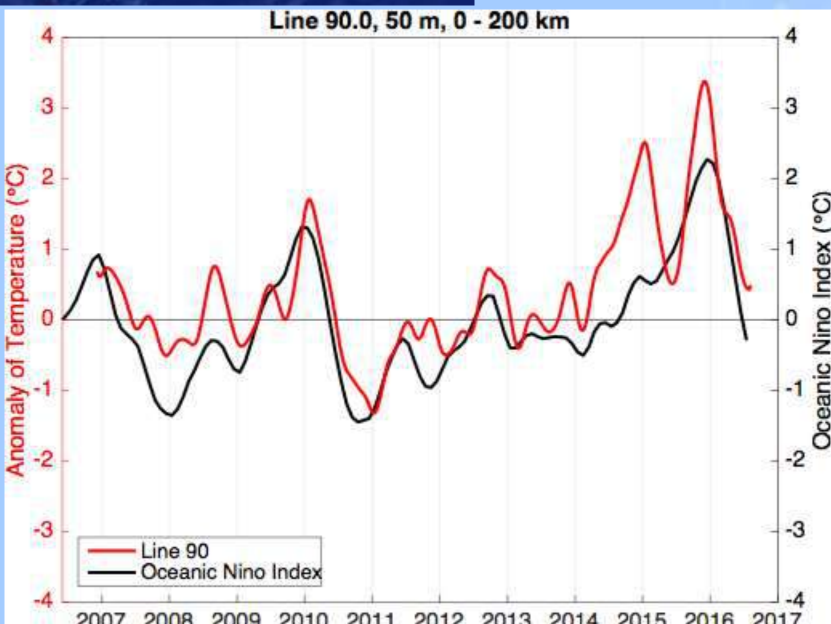
- **Catered to the shallow depths of the Arctic**
- **Uses a rapid buoyancy system - can change speed and angle faster that any other glider on the market - allowing for a more efficient and adaptive Arctic survey, but transferable to a variety of markets**
- **Field testing (Seattle, WA) in fall 2016 and field mission in 2017 (US Arctic)**



A video plankton recorder is being incorporated into this platform

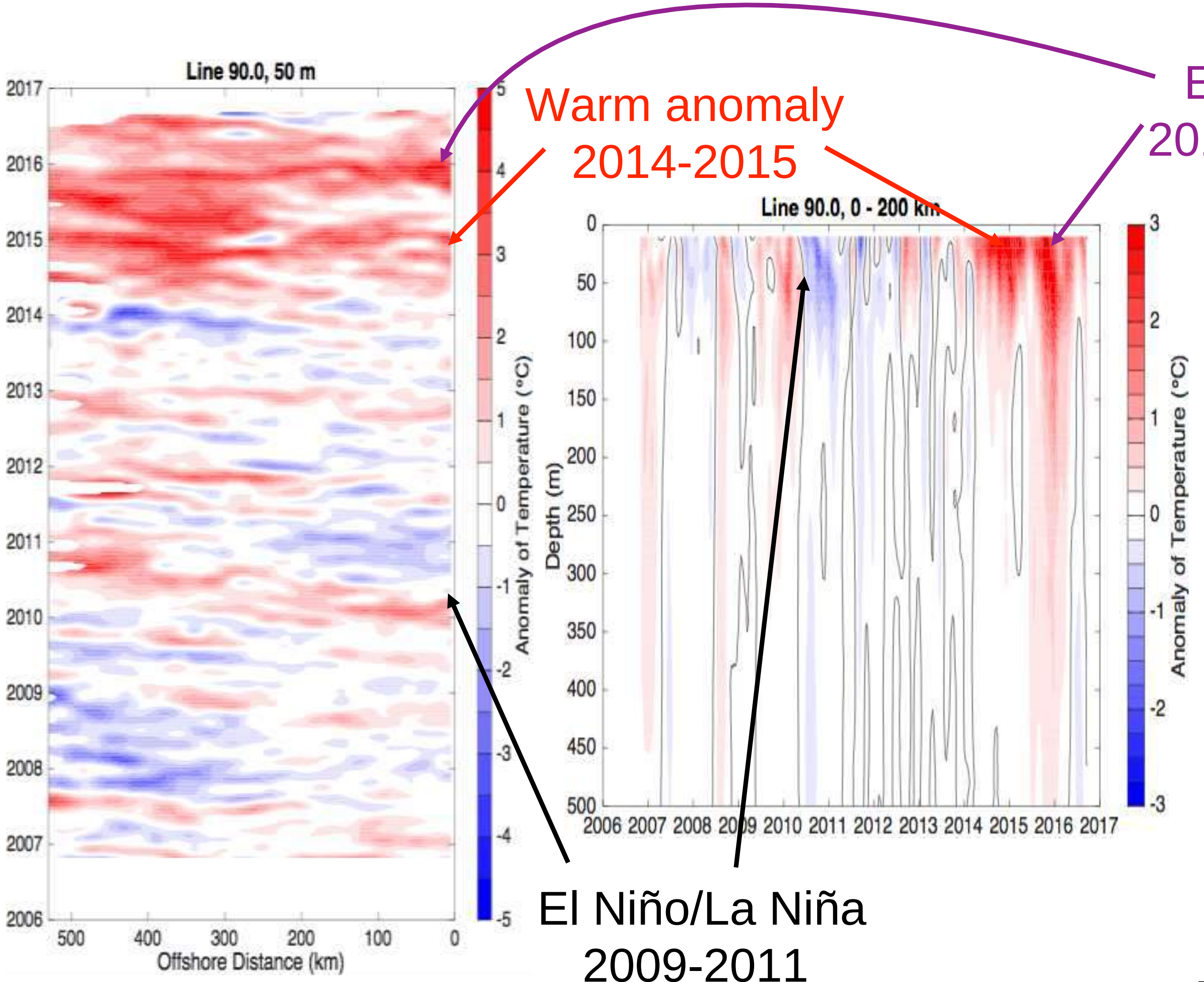
California Underwater Glider Network





The SoCal Temperature Index, temperature anomaly at 50 m on line 90, averaged over the inshore 200 km, and filtered with a 3-month running mean (red), and the Oceanic Niño Index, Niño 3.4 filtered with a 3-month running mean (black). Note the strong correlation until the anomalous warming starting near the beginning of 2014. (Dan Rudnick, SIO)

Interannual Anomaly of Temperature

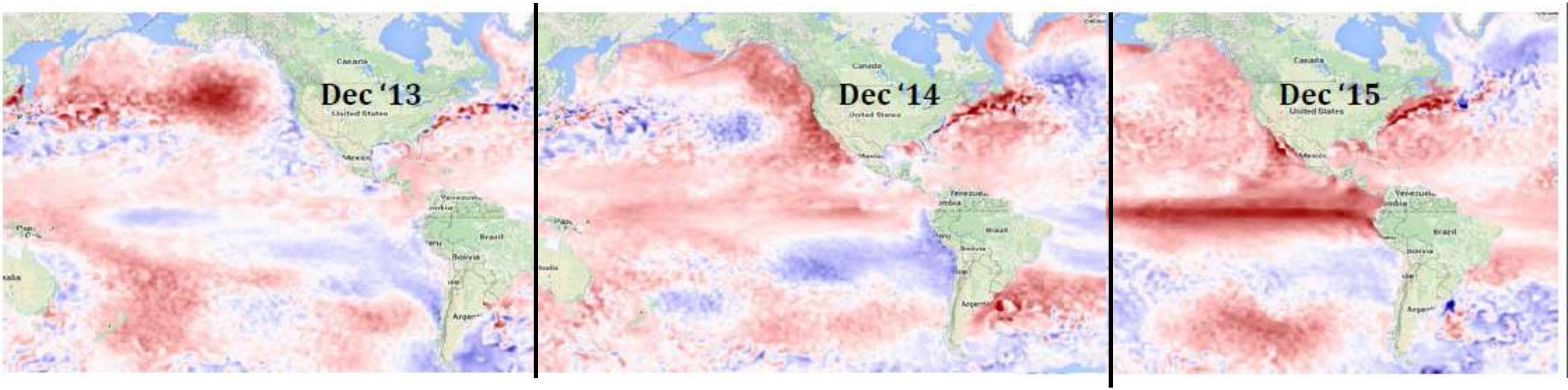


Climate events of last decade

Dan Rudnick, SIO

Pacific Anomalies Workshop 2 Report

Summary and Recommendations of the
Second Pacific Anomalies Science and Technology Workshop
University of Washington, Seattle, WA
January 2016



"In the Southern California Current System (SCCS), anomalous surface warming started at the beginning of 2014, and with the onset of El Niño conditions in 2015, this surface warming extended into the subsurface."

Newton, J.A., M. Jimenez Urias, L. Li, L. Li, K. O'Brien Beaumont, A. Shao, and H.B. Stone. 2016

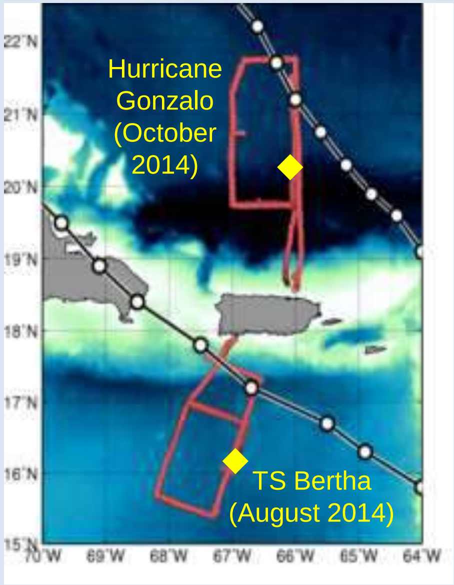
http://www.nanoos.org/resources/anomalies_workshop/workshop2.php

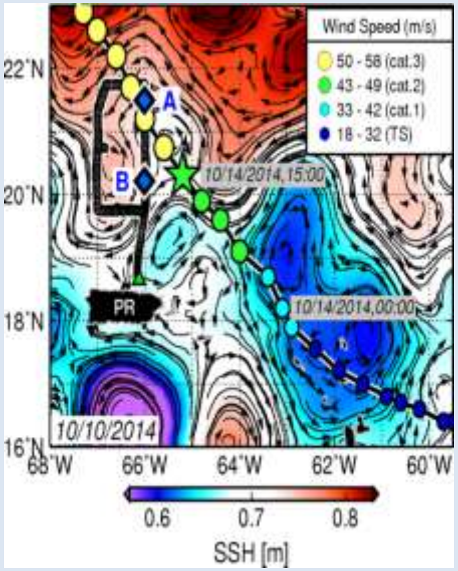
NOAA Underwater Gliders - Underwater Glider Observations in the Caribbean Sea and Tropical North Atlantic Ocean in Support of Tropical Cyclone Studies (AOML/CariCOOS)

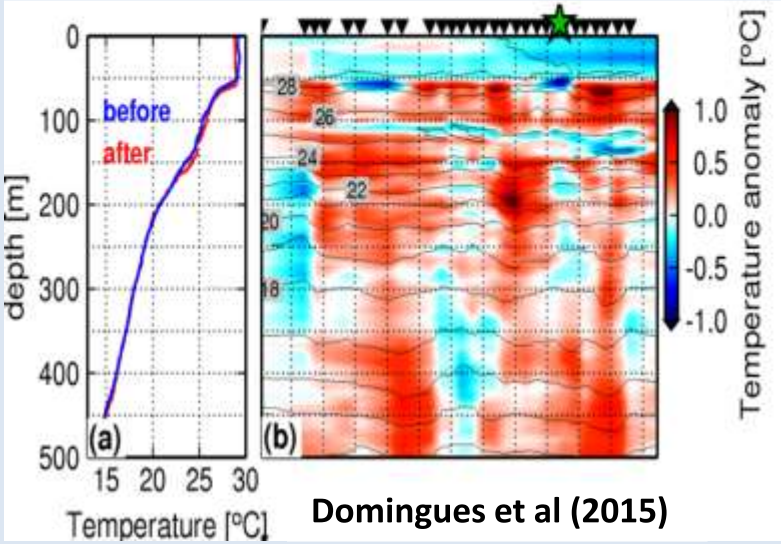
- Successful operations under hurricane force winds
- Unique time series
- Glider observations provides ocean initial conditions for models
- All data transmitted into the GTS (real-time) to be assimilated by operational forecast models, and submitted to the IOOS Glider DAC (delayed-mode)

Domingues et al., (2015), Goni et al. (2015)

Hurricane models overestimated upper ocean cooling; salinity effects were absent







Domingues et al (2015)

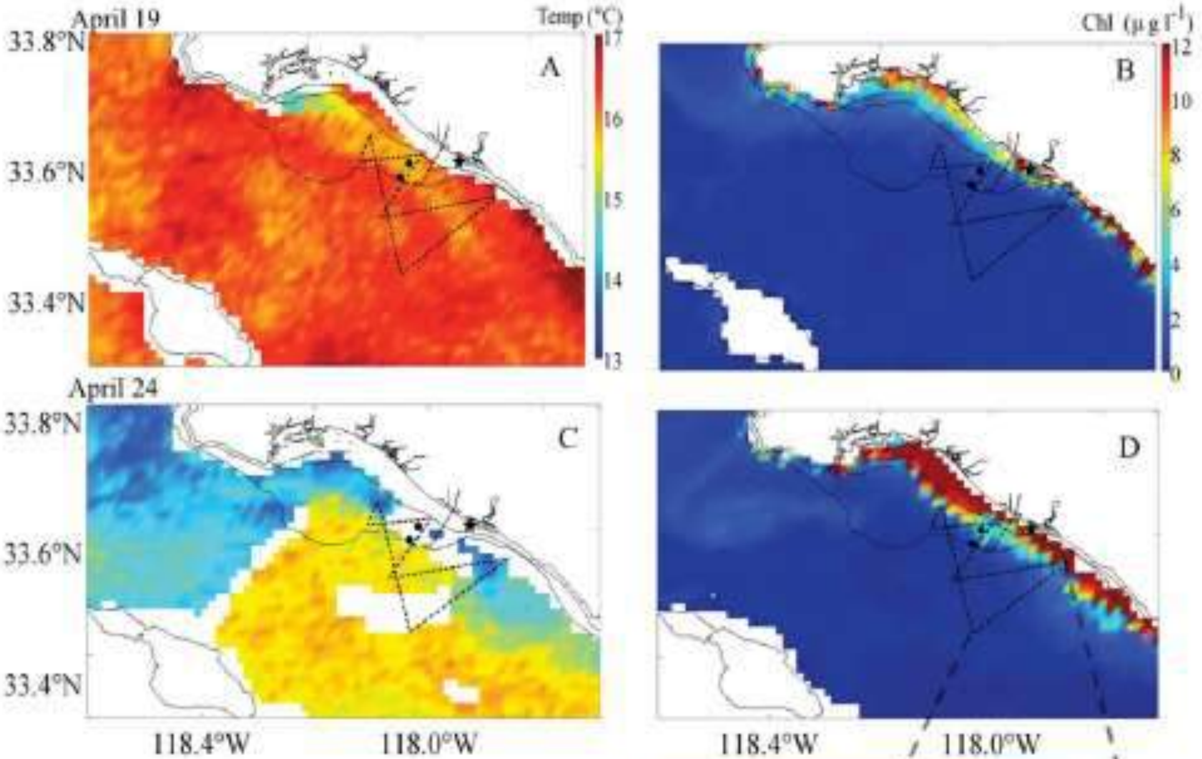
Harmful Algal Blooms

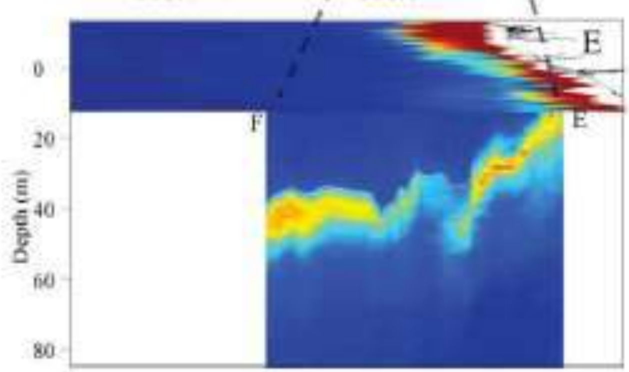

LIMNOLOGY and OCEANOGRAPHY

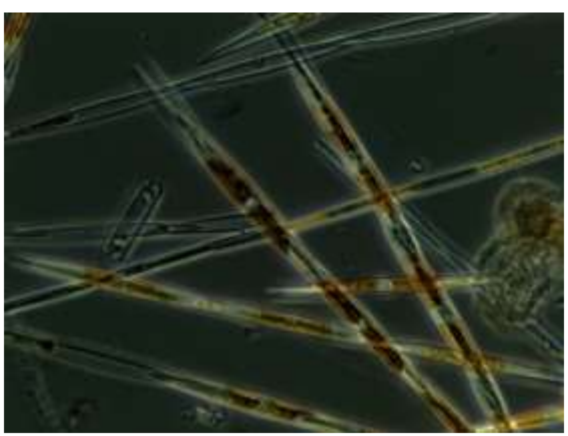
ASLO

Subsurface seeding of surface harmful algal blooms observed through the integration of autonomous gliders, moored environmental sample processors, and satellite remote sensing in southern California

Bridget N. Seegers,*[1] James M. Birch,[2] Roman Marin III,[2] Chris A. Scholin,[2] David A. Caron,[1] Erica L. Seubert,[1] Meredith D. A. Howard,[3] George L. Robertson,[4] Burton H. Jones[1,5]
[1]Department of Biological Sciences, University of Southern California, Los Angeles, California
[2]Monterey Bay Aquarium Research Institute (MBARI), Moss Landing, California
[3]Biogeochemistry Department, Southern California Coastal Water Research Project, Costa Mesa, California
[4]Ocean Monitoring Program, Orange County Sanitation District, Fountain Valley, California
[5]Red Sea Research Center, King Abdullah University of Science and Technology, Thuwal, Kingdom of Saudi Arabia







MODIS images of SST (A, C) and chl a (D, E) from San Pedro Bay for 19 April and 24 April. The glider track and the OCSD outfall are indicated by dashed black lines, black dots indicate ESP mooring locations and the Newport Pier is indicated by the star symbol. Panel E shows the MODIS chlorophyll image overlaid three-dimensionally on the southernmost glider transect, line E–F, from 27 April.

Blooms can develop offshore and subsurface prior to their manifestation in the surface layer and/or near the coast.

Seegers et al, 2015

Fish Tracking

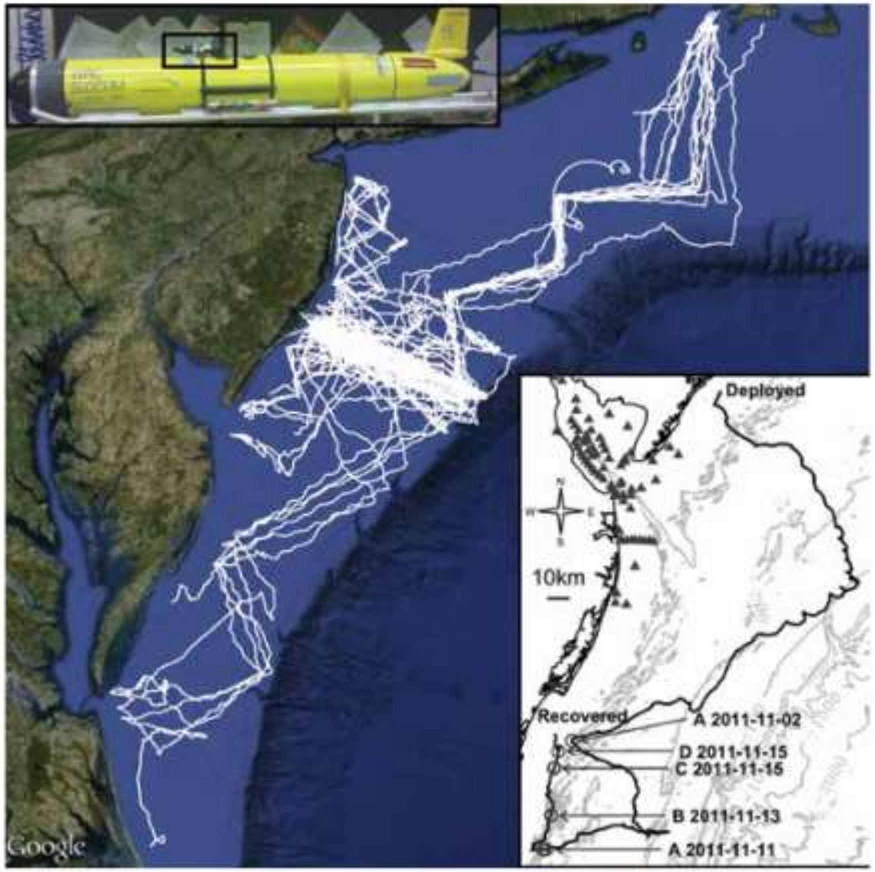


Figure 1. Tracks of the 71 Slocum glider missions between 2005 and 2011 (white lines) show the potential to develop mobile listening assets in the Mid-Atlantic. A VMT was attached to the dorsal side of a Slocum glider (upper inset) and deployed for 1 month. Telemetered Atlantic Sturgeon were detected in nearshore coastal waters along the Delmarva Peninsula (lower inset). Triangles represent the location of ACT hydrophones during the glider deployment.

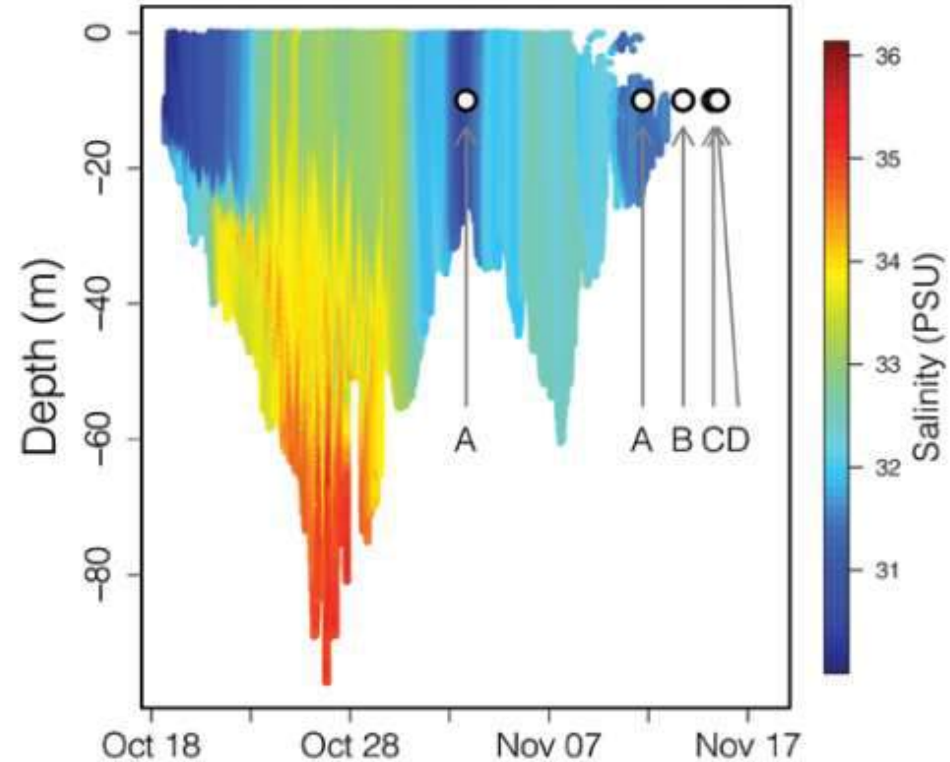
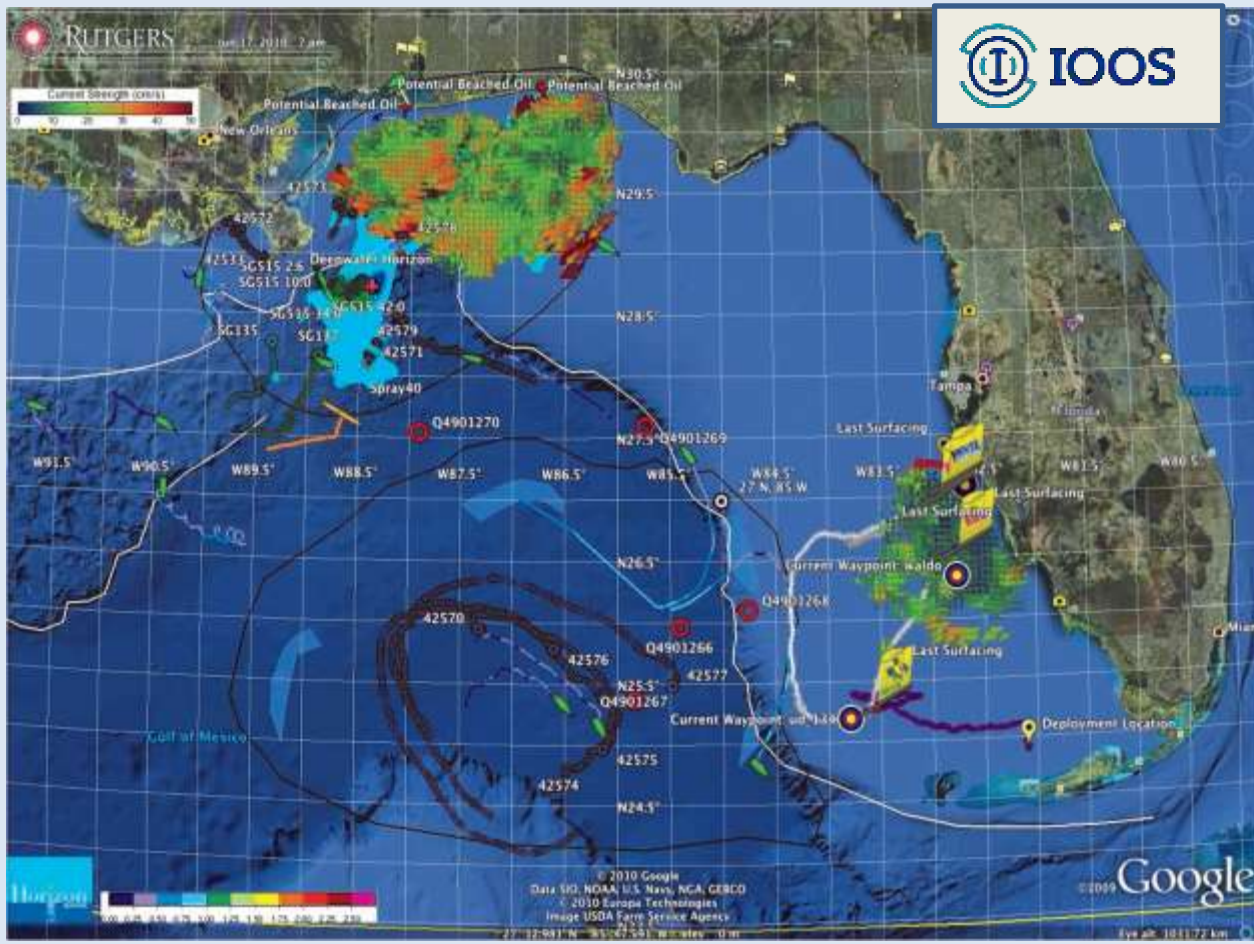


Figure 2. In situ salinity profiles from the glider show that Atlantic Sturgeon detections occurred in fresher, well-mixed coastal water.

"Therefore, AUVs can be used in a dynamic seascape to explore the relationship between Atlantic Sturgeon and the specific water masses they encounter." (M. J. Oliver et al., 2013, Fisheries)

U.S. IOOS Underwater Gliders - Part of a coordinated support effort during Deep Water Horizon

- 7 gliders w/ sensors to indicate presence of oil in water column
- IOOS RAs (Mid-Atlantic, Gulf Coast, S. California, Southeast) offered gliders
- Narrowed search zone and answered questions about potential oil movement
- Measured add'l variables for use in ocean models for emergency response teams
- DWH was first U.S. oil spill to apply this technology



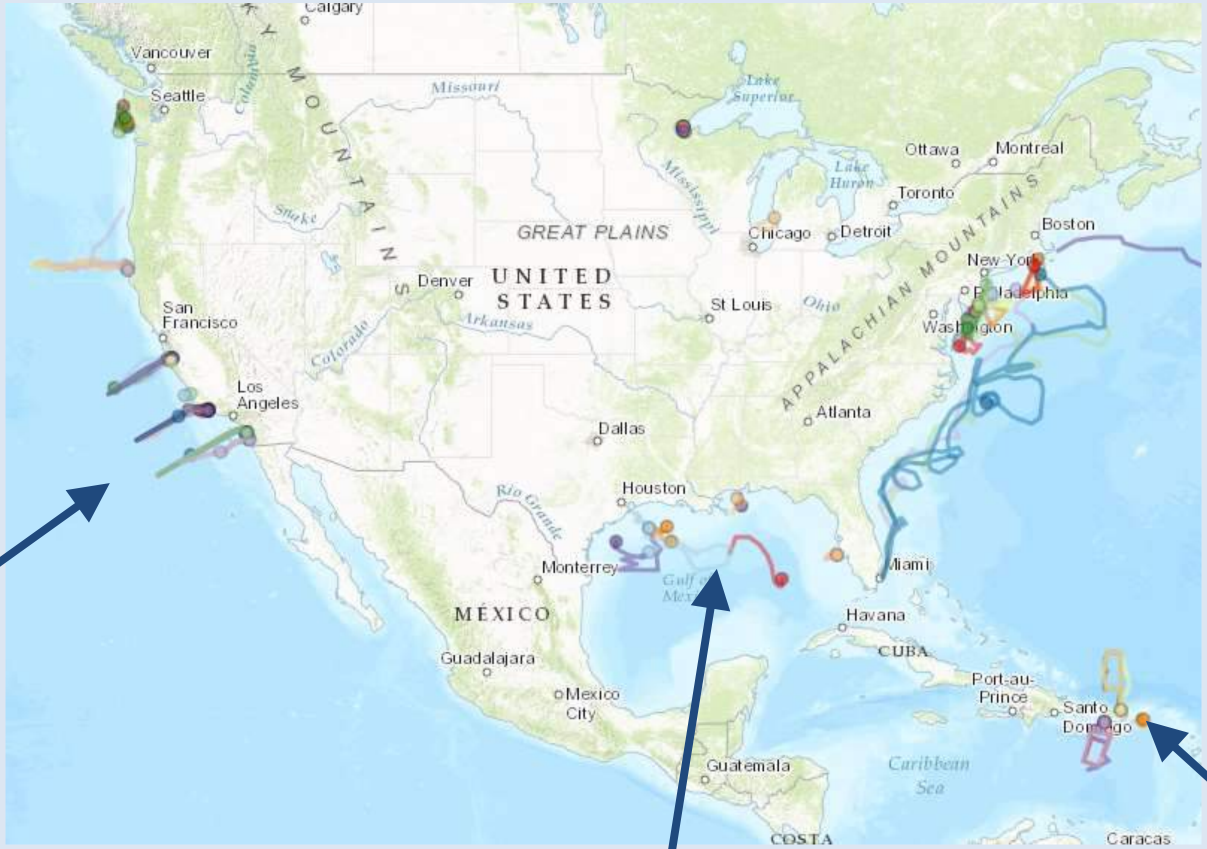
IOOS | Integrated Ocean Observing System

IOOS: Glider Program

- Regional Associations provide glider observations and presence
- In 2013 Established a National Glider Data Assembly Center (NGDAC)
- In 2014 Released a Glider Network White Paper

NOAA Underwater Gliders – A flexible platform with an established coordination network in place

> 45000 glider days with capabilities in all 11 IOOS regional associations



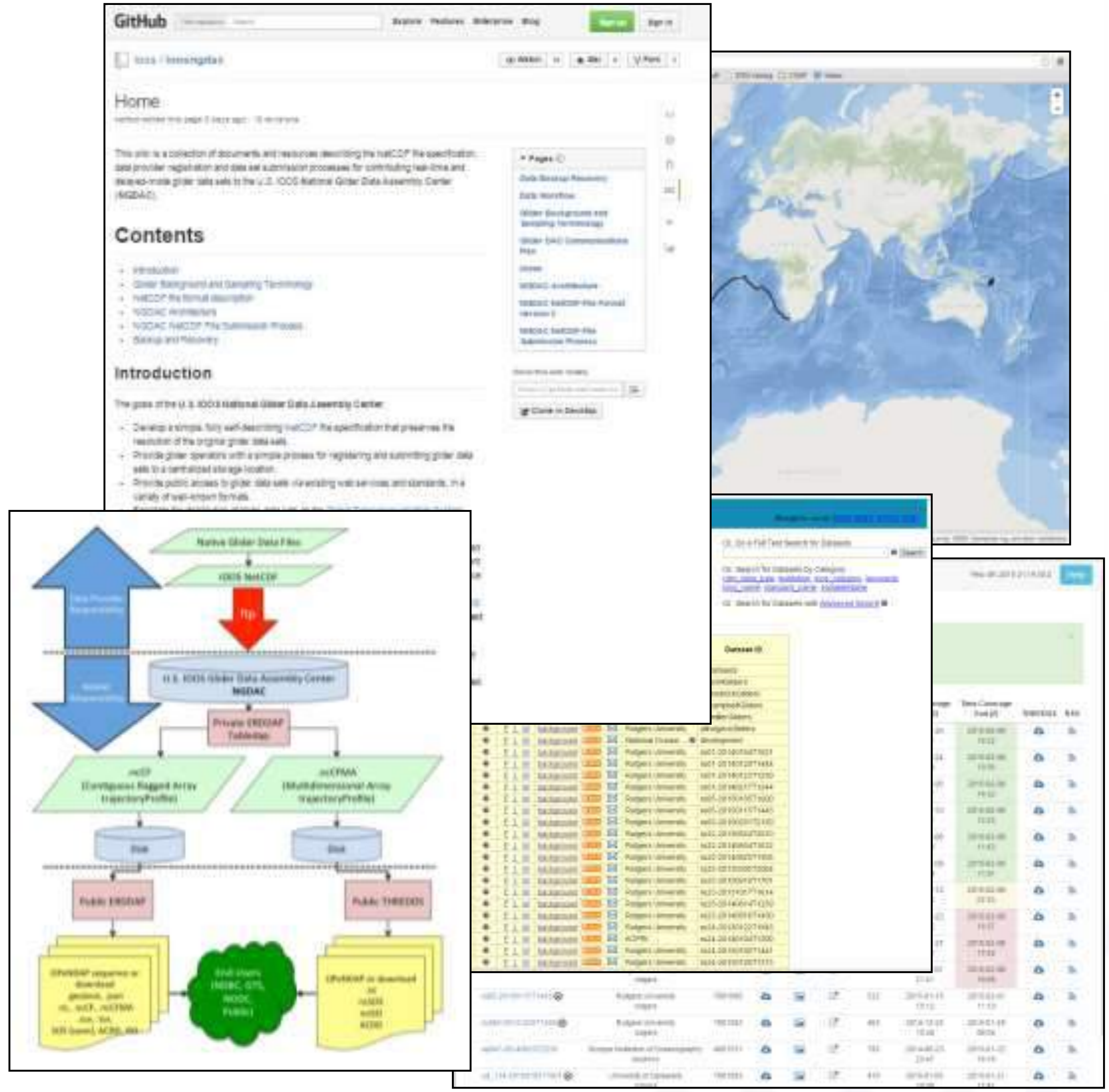
Sustained ocean and ecosystem monitoring

Fast response to crisis: Deepwater Horizon

Understanding the ocean's role in hurricane intensification

Glider DAC

- National standards to ease exchange of data from regional glider operators
- Real-time distribution to non-federal and federal partners (GTS)
- Archiving (NCEI)
- QC processing
- Share your data!



IOOS EYES ON THE OCEAN

Future Activities

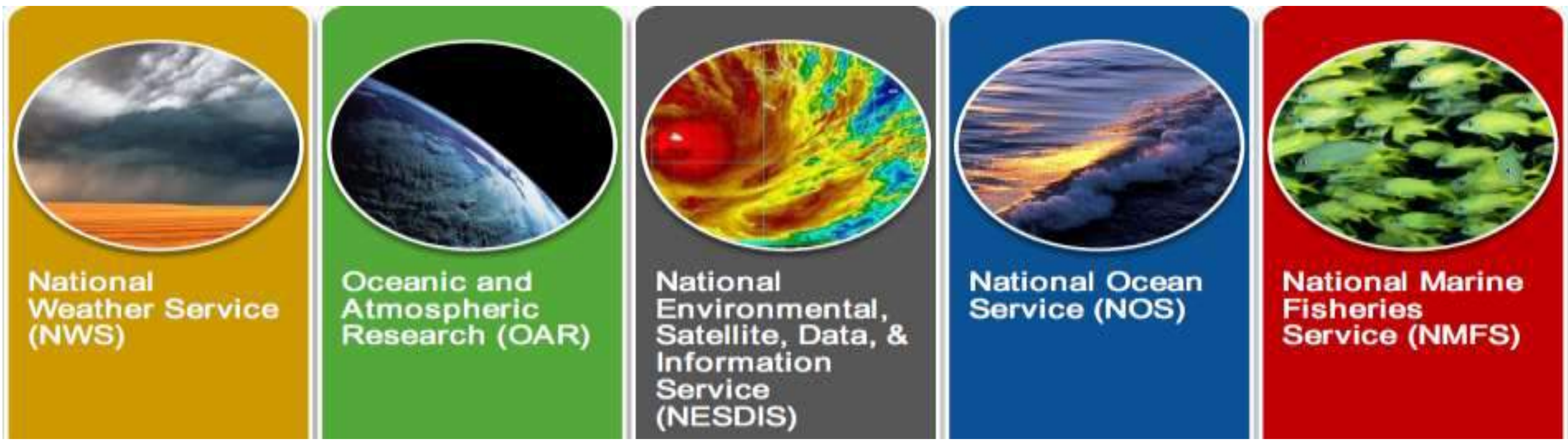
- NOAA will continue to assess the integration of gliders into its observing strategies, identifying the best uses of gliders to address its goals
- NOAA will increase collaboration with the national and international community to develop global standards for the assembly and exchange of data and address territorial issues (e.g. EEZs) to improve access to important regions
- NOAA will continue to develop and explore new glider technologies (e.g., sensors) and capabilities
- NOAA will continue to improve data system for gliders to enhance data access and discoverability

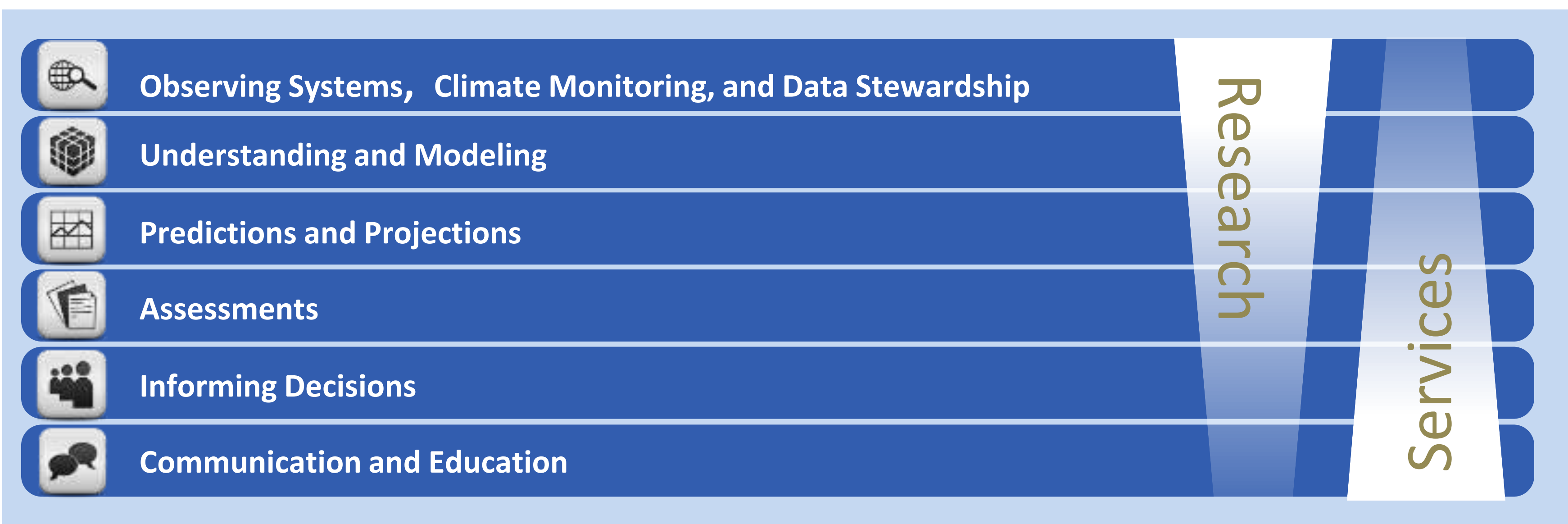
Many challenges and opportunities ahead…

Thank You

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

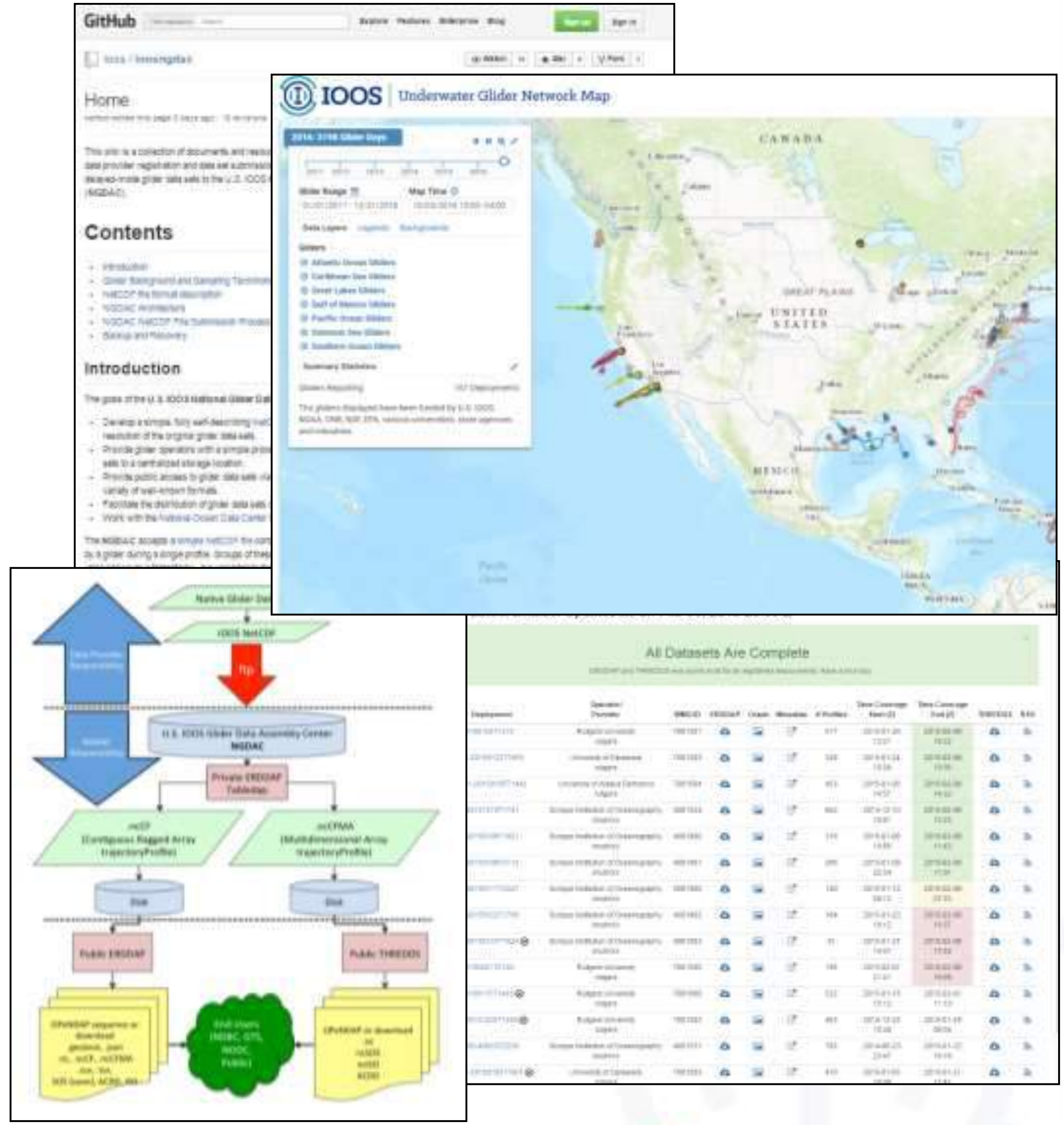
Capabilities linking environmental intelligence to resilience





Glider DAC FY17 Outlook

- Complete initial implementation of QC using QARTOD standards
- Improve visualization. Add analysis tools for operators
- Maintain real-time distribution (GTS), access, Archive (NCEI)



IOOS EYES ON THE OCEAN

Enabling Agency Missions with Glider Technology

The National Science Foundation

Jack Barth, Oregon State University,
jack.barth@oregonstate.edu

U.S. Underwater Glider Workshop

January 18, 2017

INFINITY Science Center, Pearlington, MS

NSF "where discoveries begin"

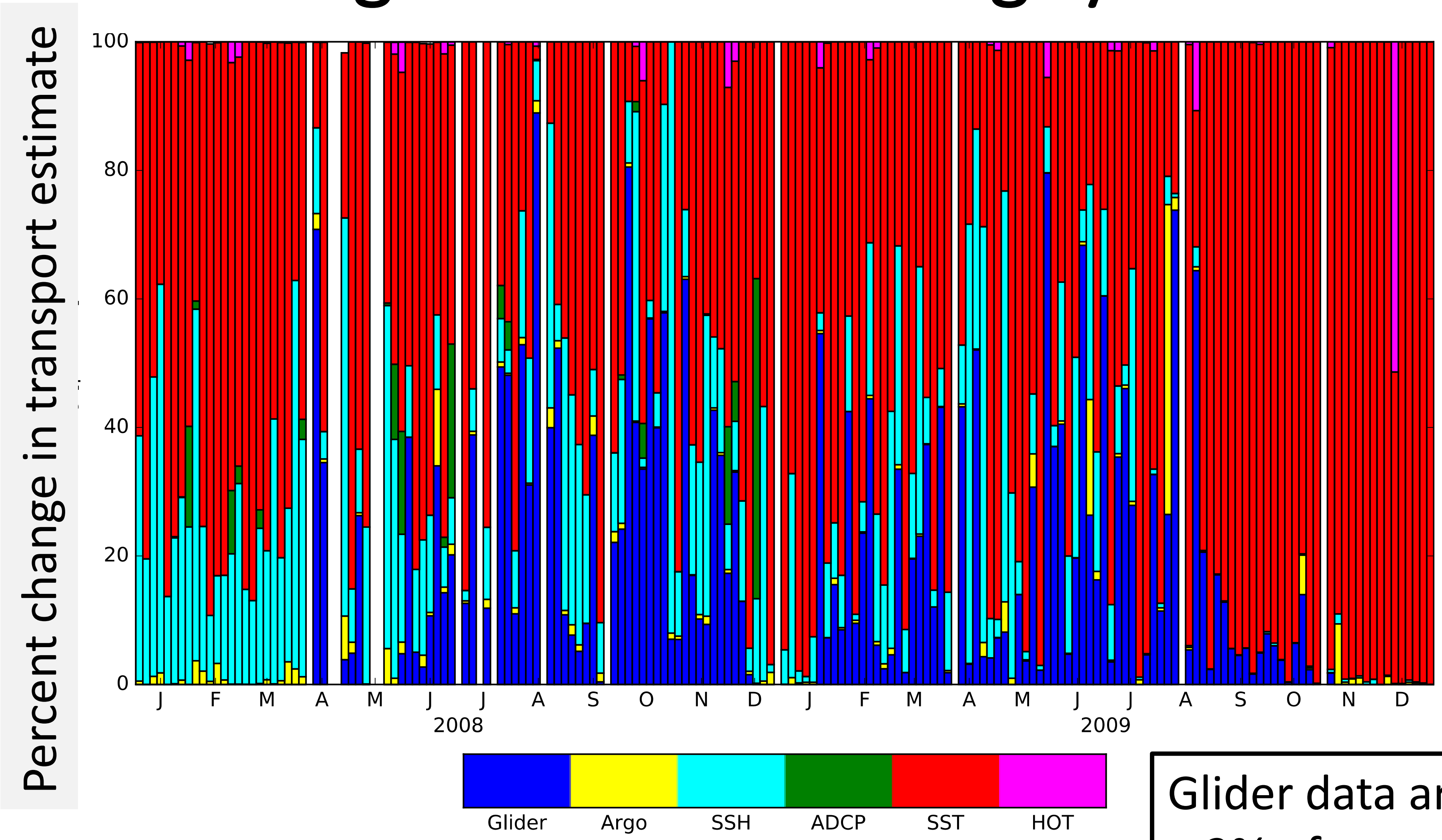
Goals:

- advance the frontiers of knowledge
- cultivate a world-class, broadly inclusive science and engineering workforce and expand the scientific literacy of all citizens
- build the nation's research capability through investments in advanced instrumentation and facilities
- support excellence in science and engineering research and education

How:

- Limited-term grants (~3 years)
- Research centers and long-term ecological research
- Major research equipment and facilities

Assessing the value of underwater glider data using a data assimilating system



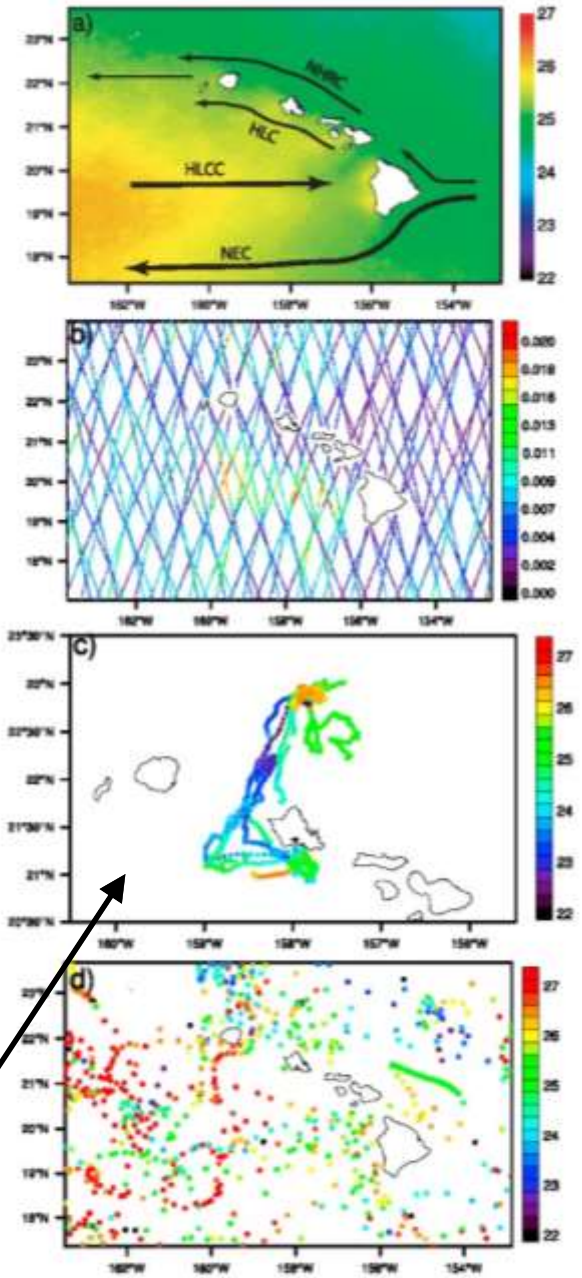


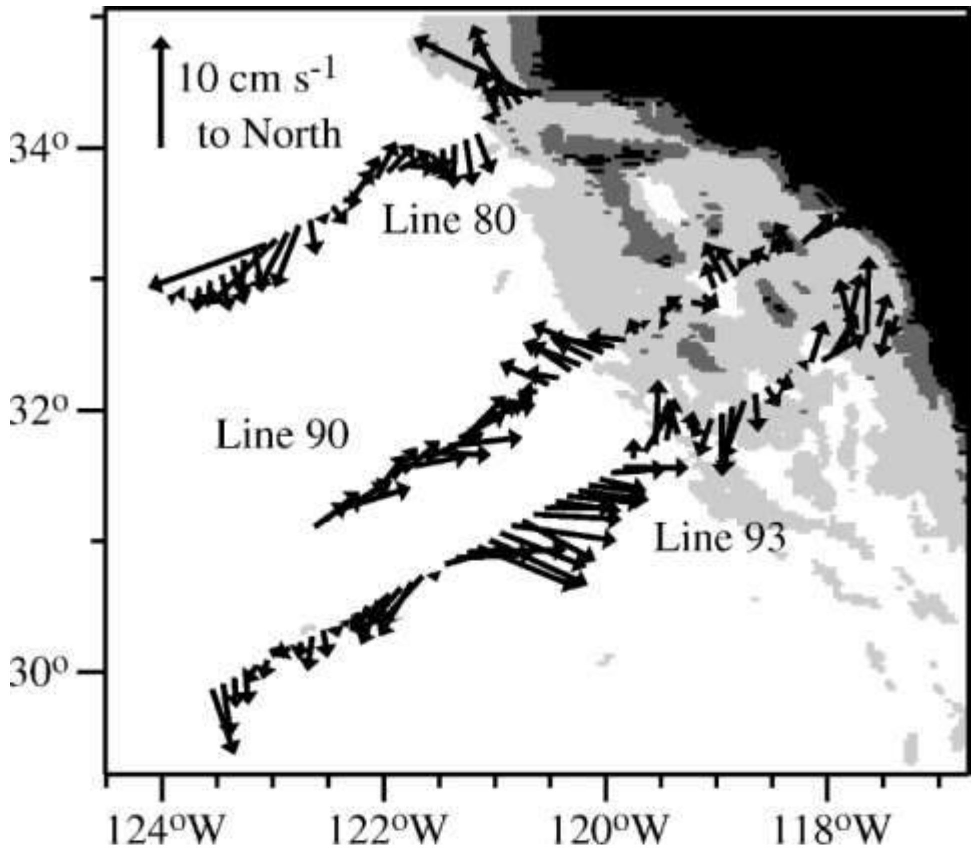
Figure 1. (a) Time-averaged map from satellite observations of SST at the model grid and (b) temporal variance of SLA observations, (c) temperatures above 20 m depth layer from Seagliders, and (d) Argo and shipboard profiles.

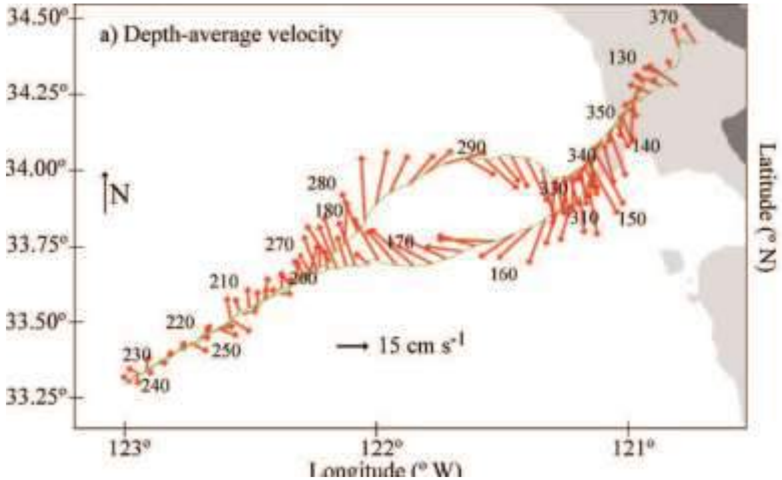
Glider data are < 2% of observations

(Courtesy of Brian Powell, U. Hawaii; Matthews et al., JGR, 2012)

Physics & biology of an Eastern Boundary Current

The southern California Current System



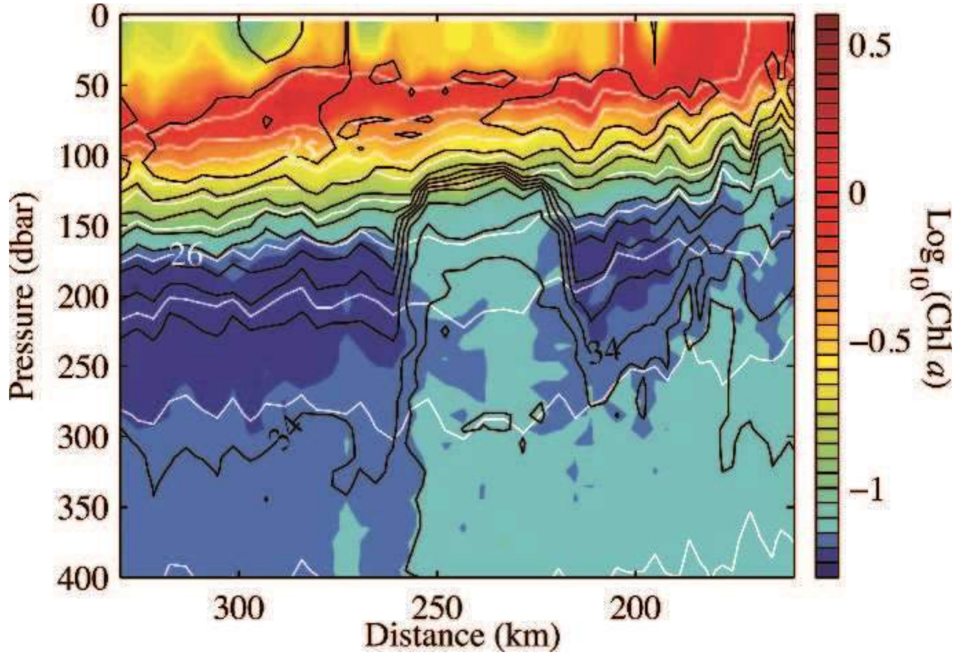


Eddies

Intrusions

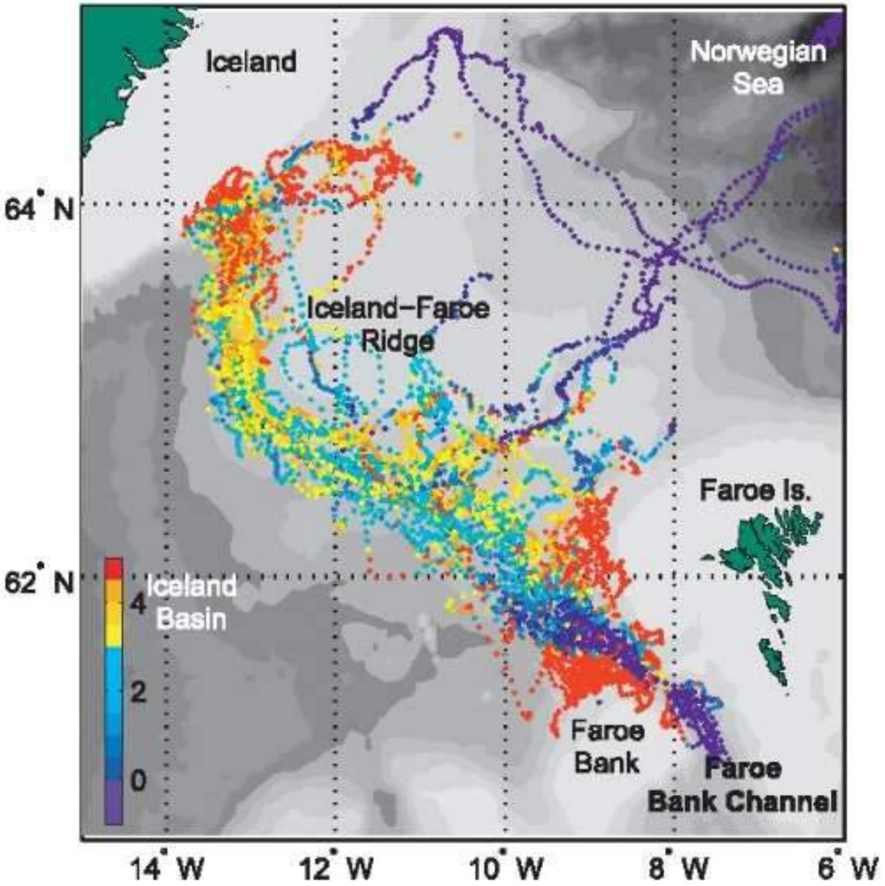
salinity contours – black

chlorophyll - color



Davis, Ohman, Rudnick, Sherman and Hodges, L&O, 2008

Turbulent mixing in deep overflows
Eastern Nordic Seas



Turbulent dissipation rate $\log_{10}(\varepsilon)$ [W kg^{-1}]

Temperature

JOURNAL OF PHYSICAL OCEANOGRAPHY

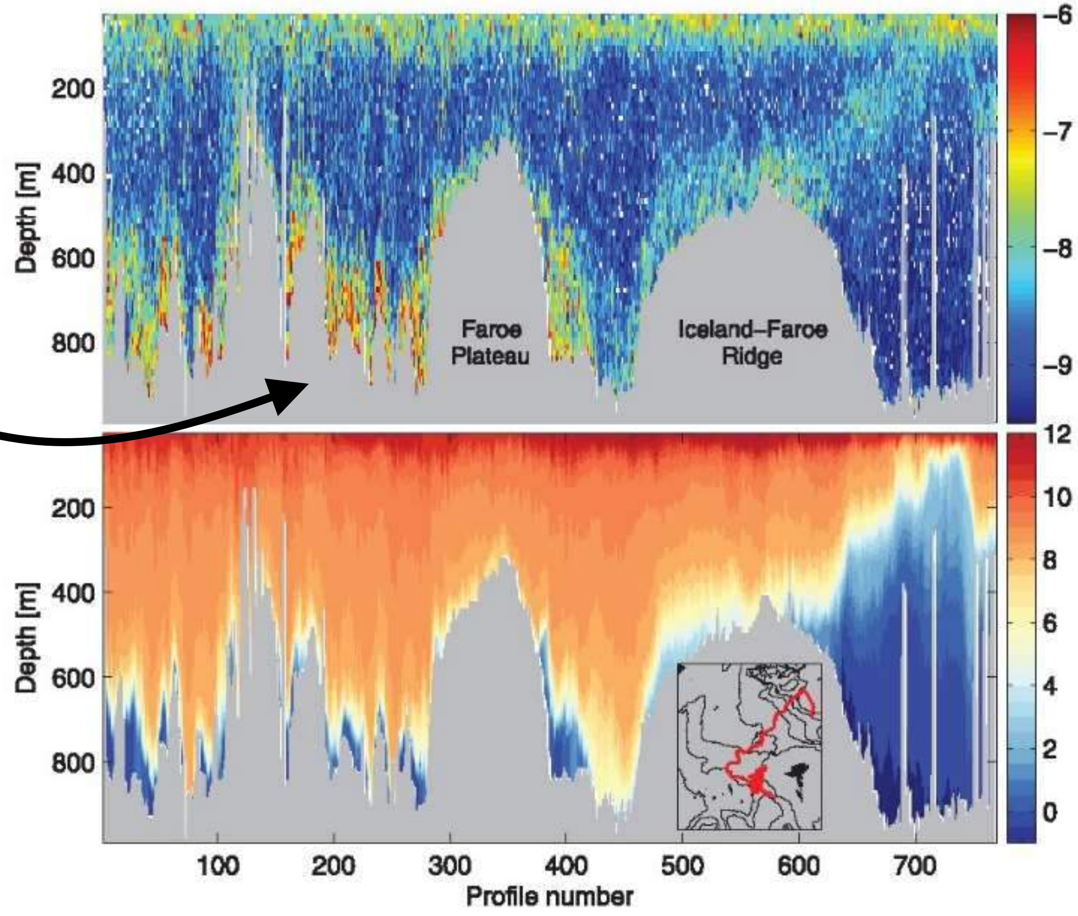


FIG. 9. (top) Depth vs profile number section of dissipation, $\log_{10}(\epsilon)$ [W kg^{-1}], from the entire sg005 deployment for which where each dive and climb is counted as a profile, and (bottom) corresponding temperature section (°C). Inset map shows the dive locations in red; the FBC dives may be seen in more detail in Fig. 2.

Beaird, Fer, Rhines and Eriksen, JPO, 2012

Horizontal scales of variability

Shelf-slope front in the Middle Atlantic Bight

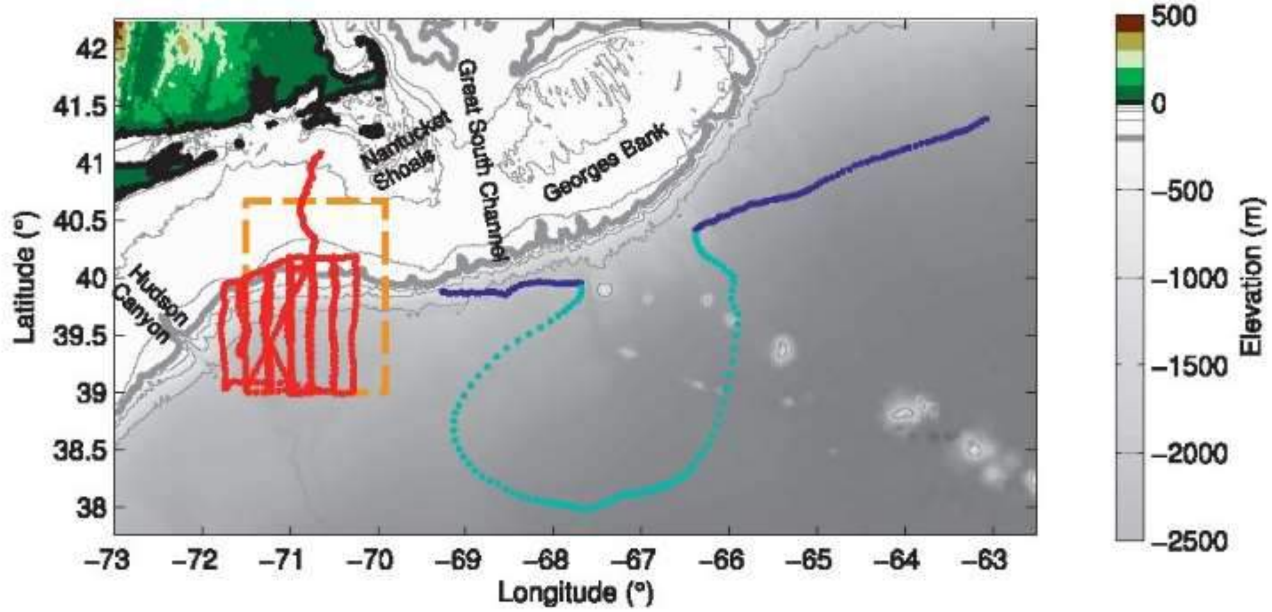
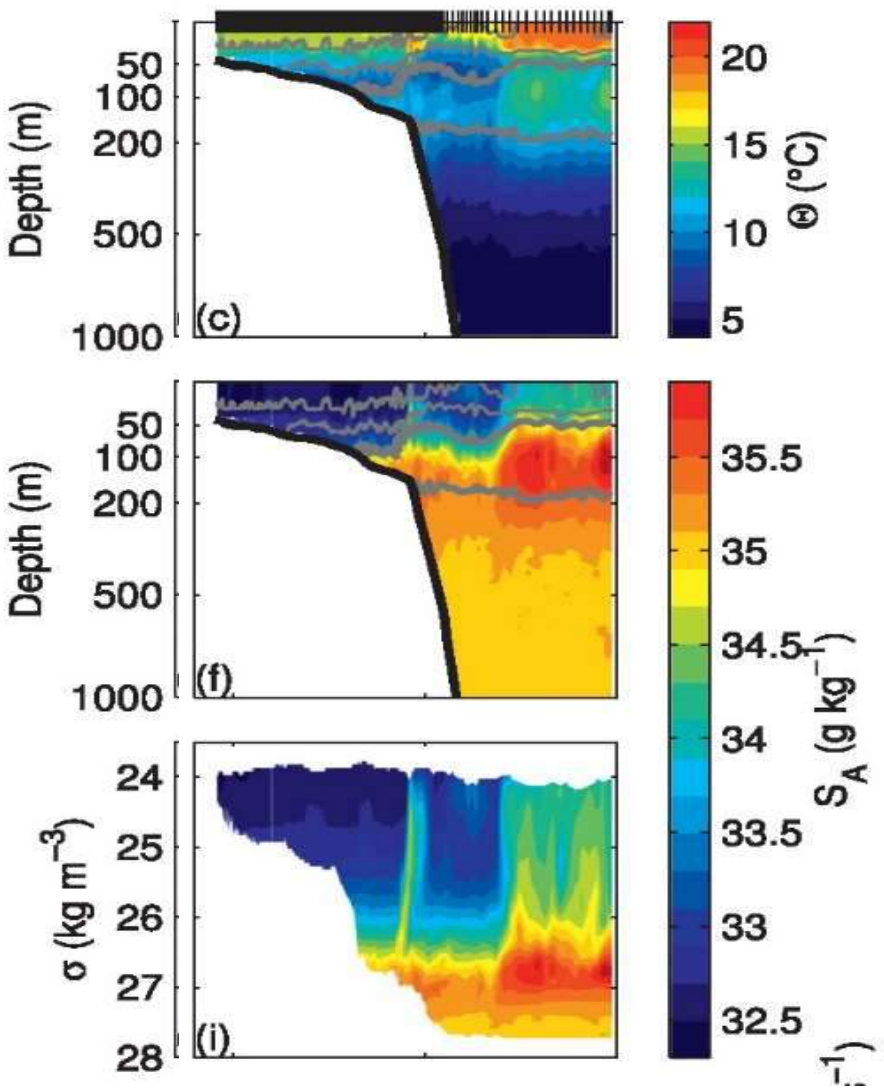


TABLE 1. Exponential (*e*-folding) scales for least squares fits of an exponential function to selected structure functions shown in Fig. 5. Shelfbreak and slope sea subregions for cross-shelf scales are as defined in the text.

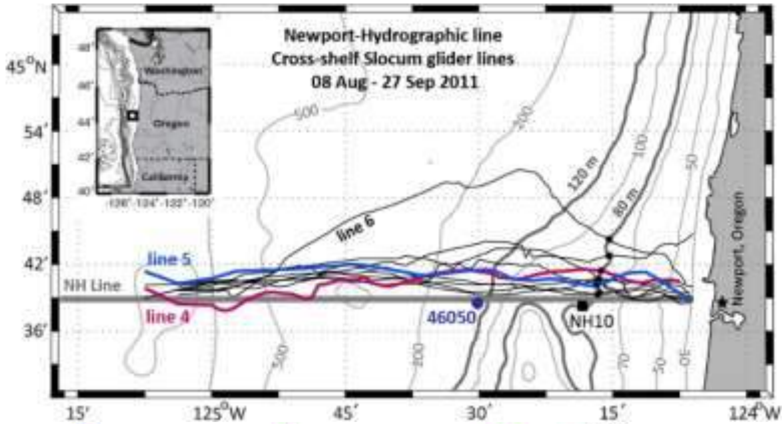
Variable	Cross-shelf scale (km) Shelf break	Cross-shelf scale (km) 39.0°–40.2°N	Cross-shelf scale (km) Slope Sea	Alongshelf scale (km) Shelf break	Alongshelf scale (km) Slope Sea
Θ, 0–50 m	12	24	20	10	35
S_A, 0–50 m	13	23	29	8	35
Spice, 25.0–27.0 kg m^{-3}	12	21	36	—	—

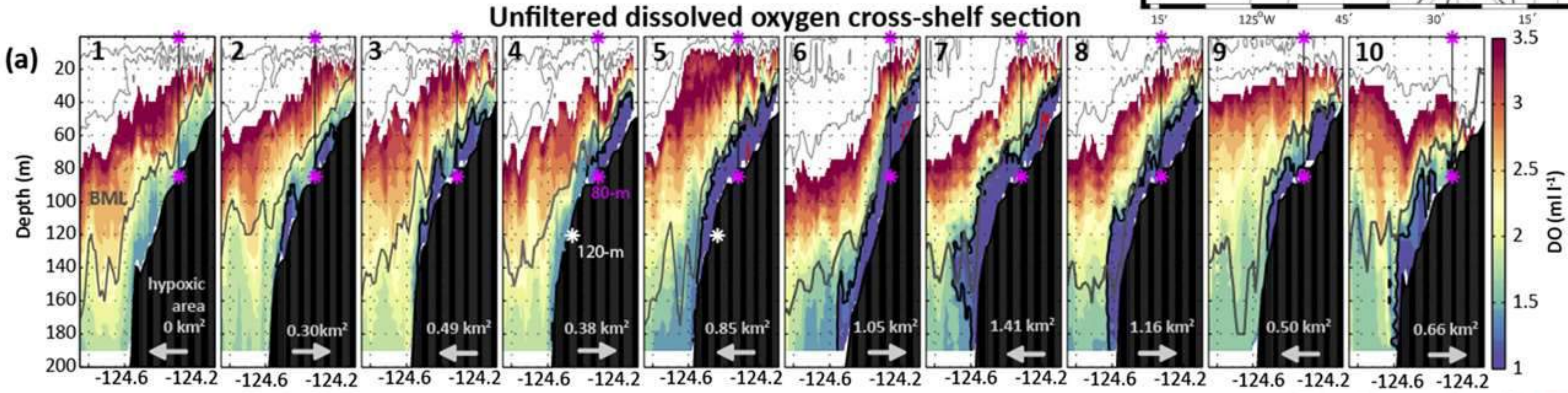


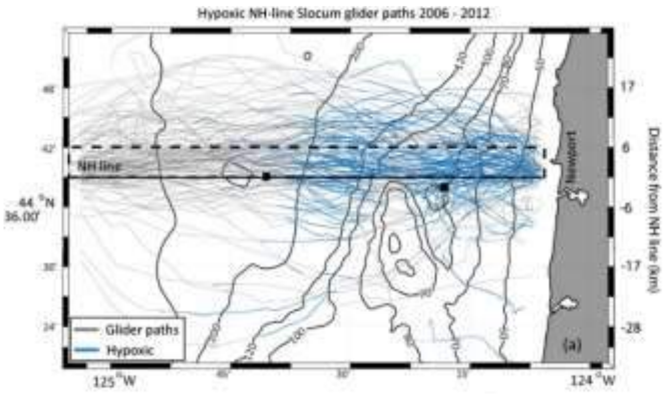
Todd, Gawarkiewicz and Owens, JPO, 2012

Upwelling and Near-Bottom Hypoxia

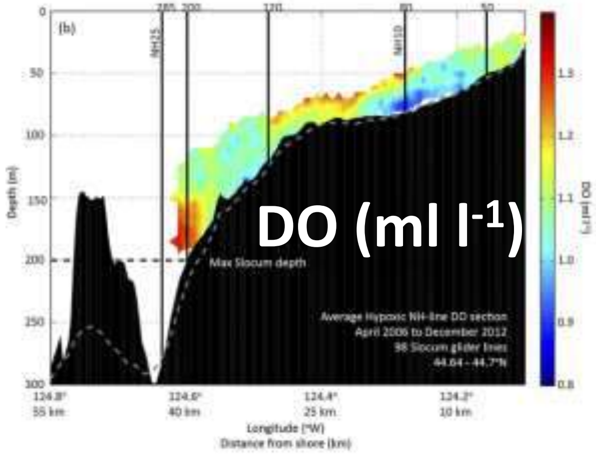
Northern California Current -- Oregon





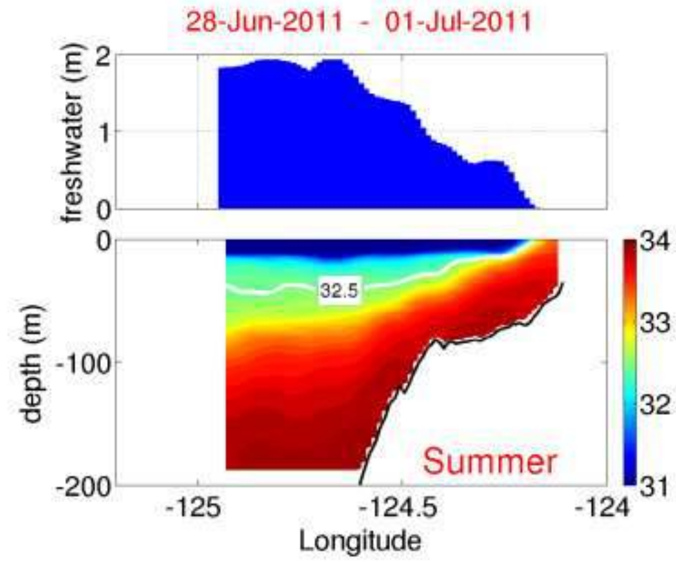


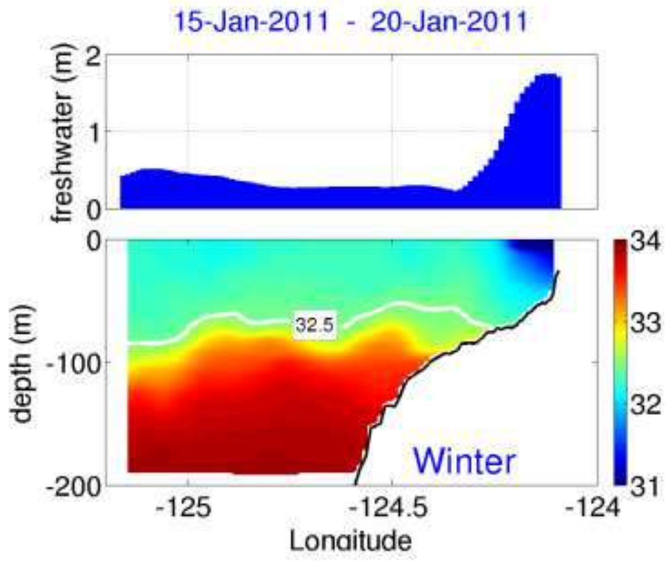
133 sections reveal details of near-bottom oxygen distribution

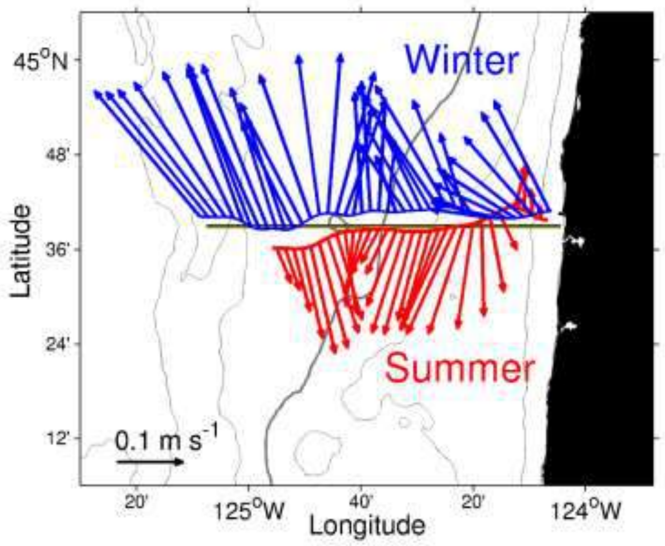


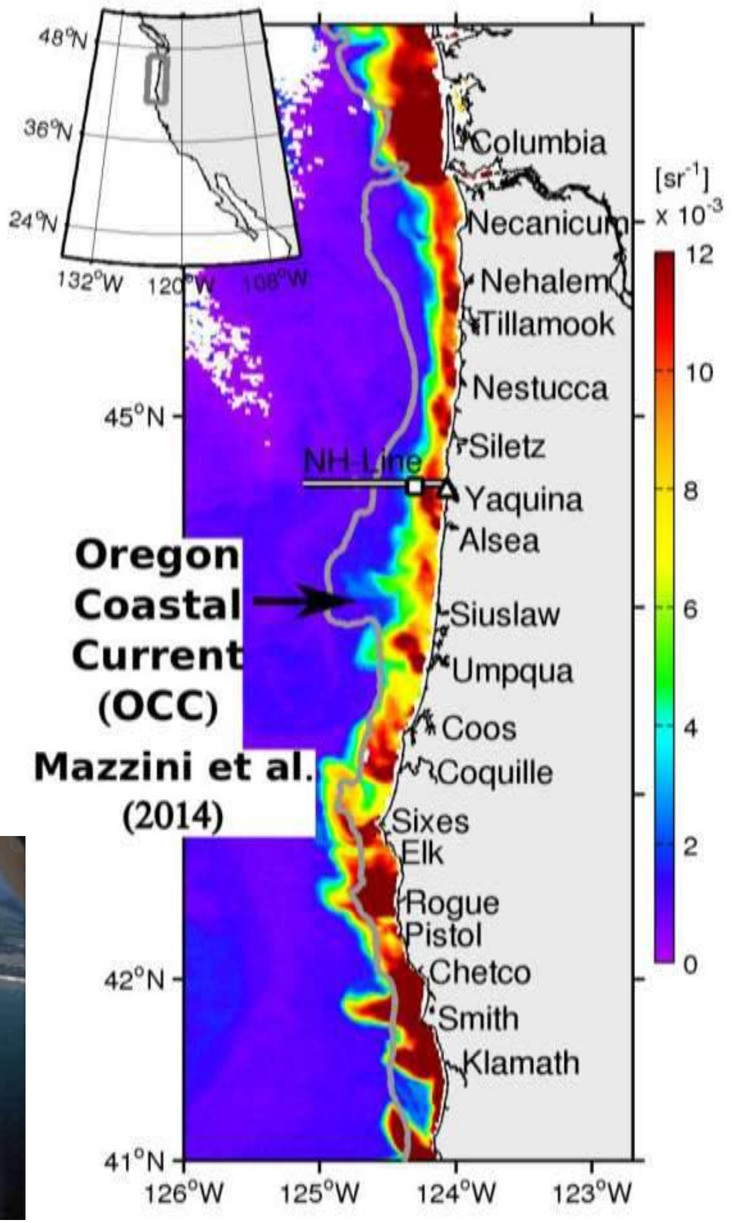
Adams, Barth and Shearman, JPO, 2016

Buoyancy-Driven Coastal Currents during Winter





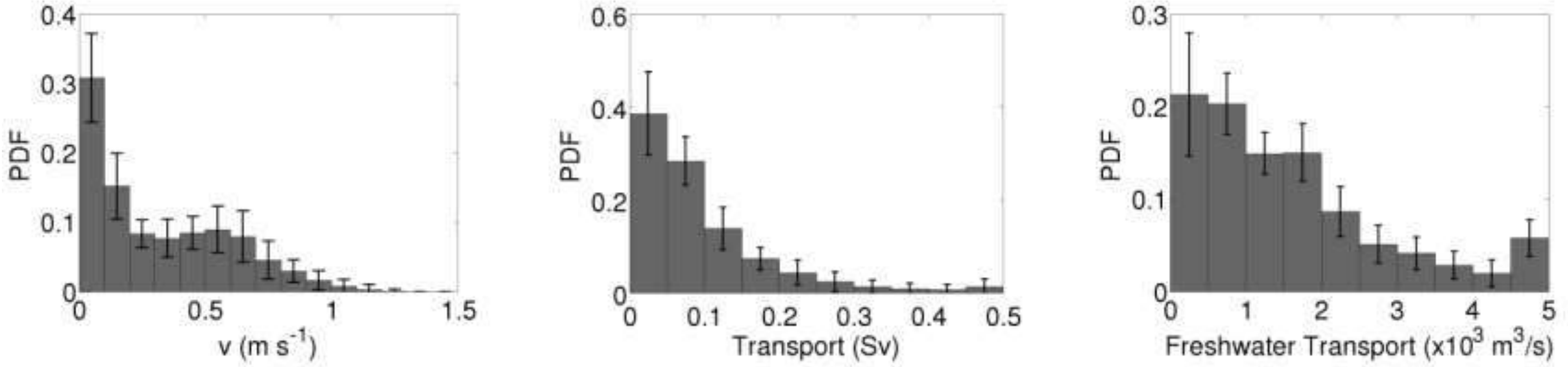


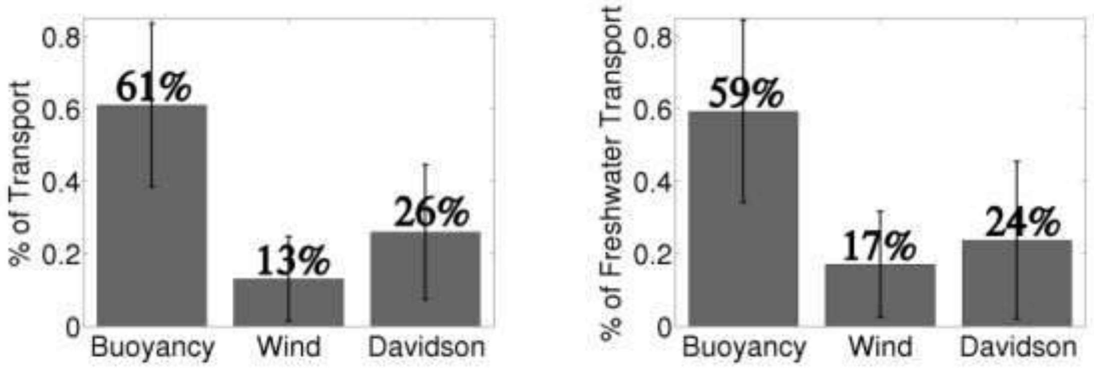


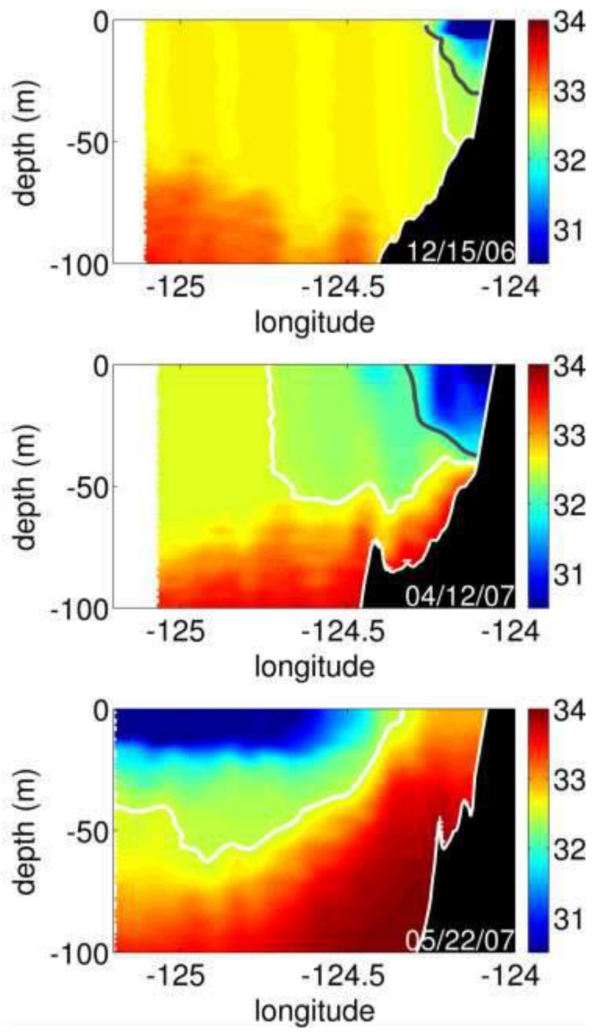
Mazzini, Barth and Shearman, JPO, 2016

Calculate velocity/transport due to different forcing mechanisms

$$v(x) = \underbrace{\frac{g'H}{fR}\, e^{-\left(\frac{x+W_p}{R}\right)}}_{\text{buoyancy-driven}} + \underbrace{\frac{\tau_o^y}{\rho_o r}}_{\text{wind-driven}} + \underbrace{v_D}_{\text{Davidson Current}}$$







Mazzini, Barth and Shearman, JPO, 2016

Palmer Long-Term Ecological Research (LTER)

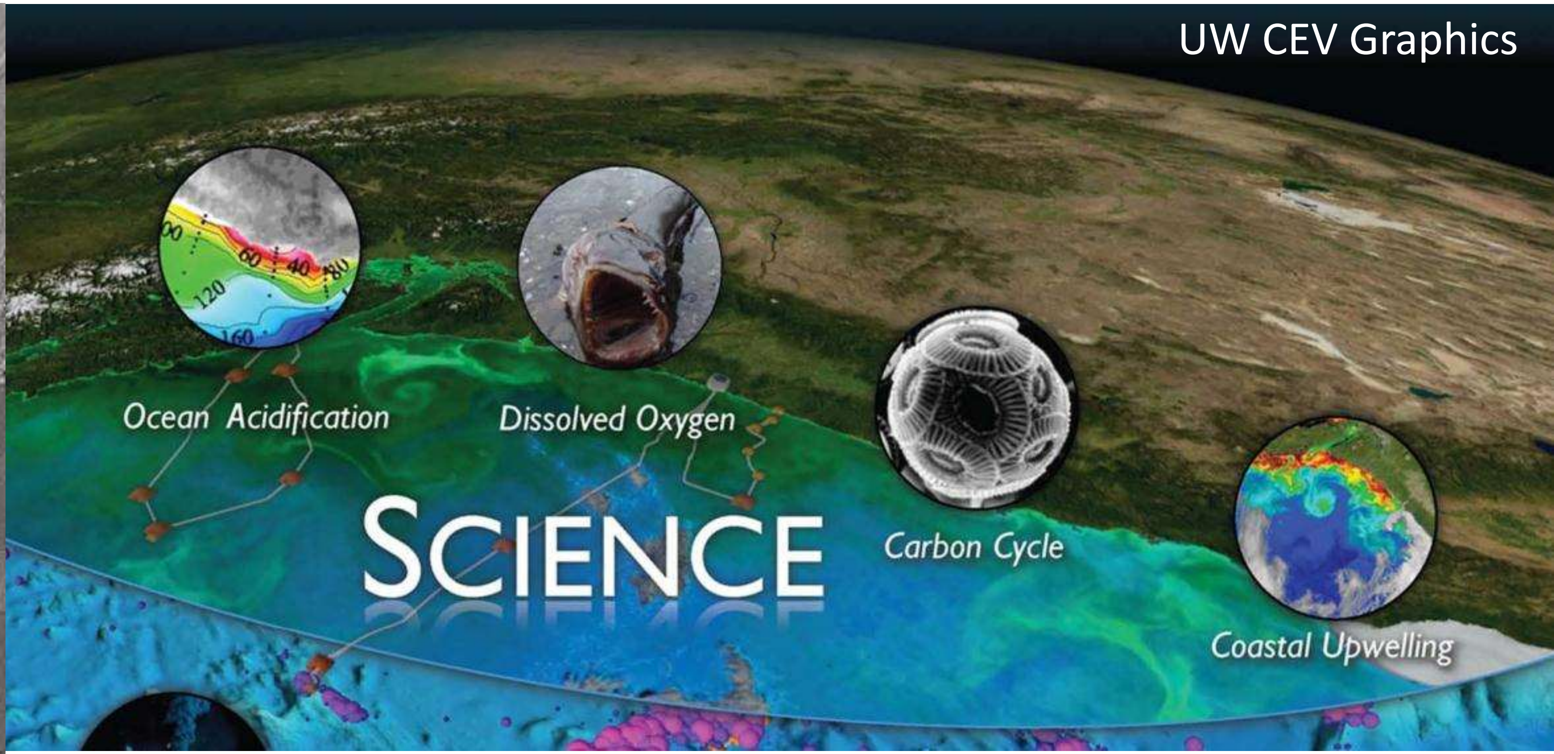
(Photo Credit: Zach Swaim)

(Photo Credit: Beth Simmons)

Algae and diatoms (Photo Credit: Grace Saba / Rutgers University)

Ocean Observatories Initiative (OOI)

Major Research Equipment and Facilities Construction



Coastal:

- Endurance Array – Pacific Northwest
- Pioneer Array – Middle Atlantic Bight

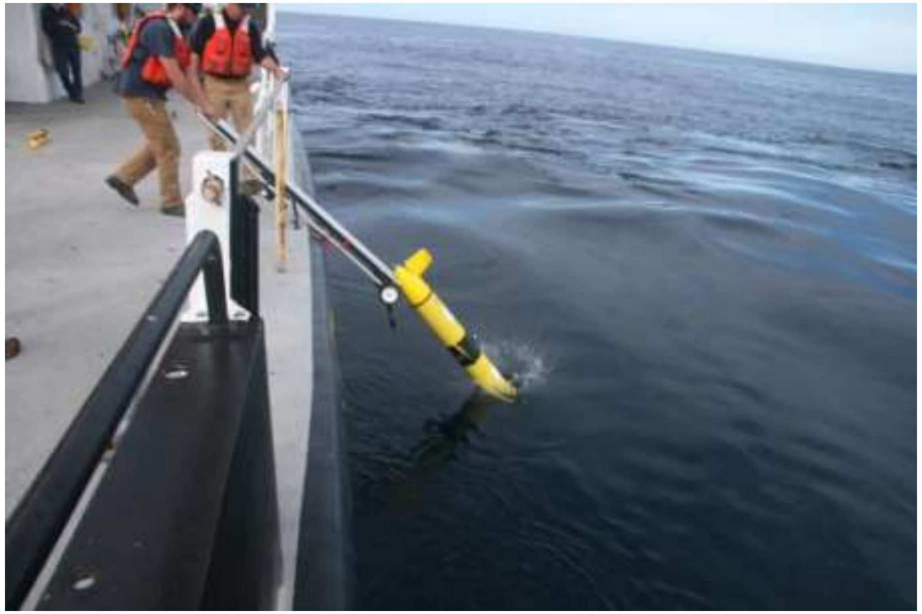
Global: Irminger Sea, Papa, 55 South, Argentine Basin

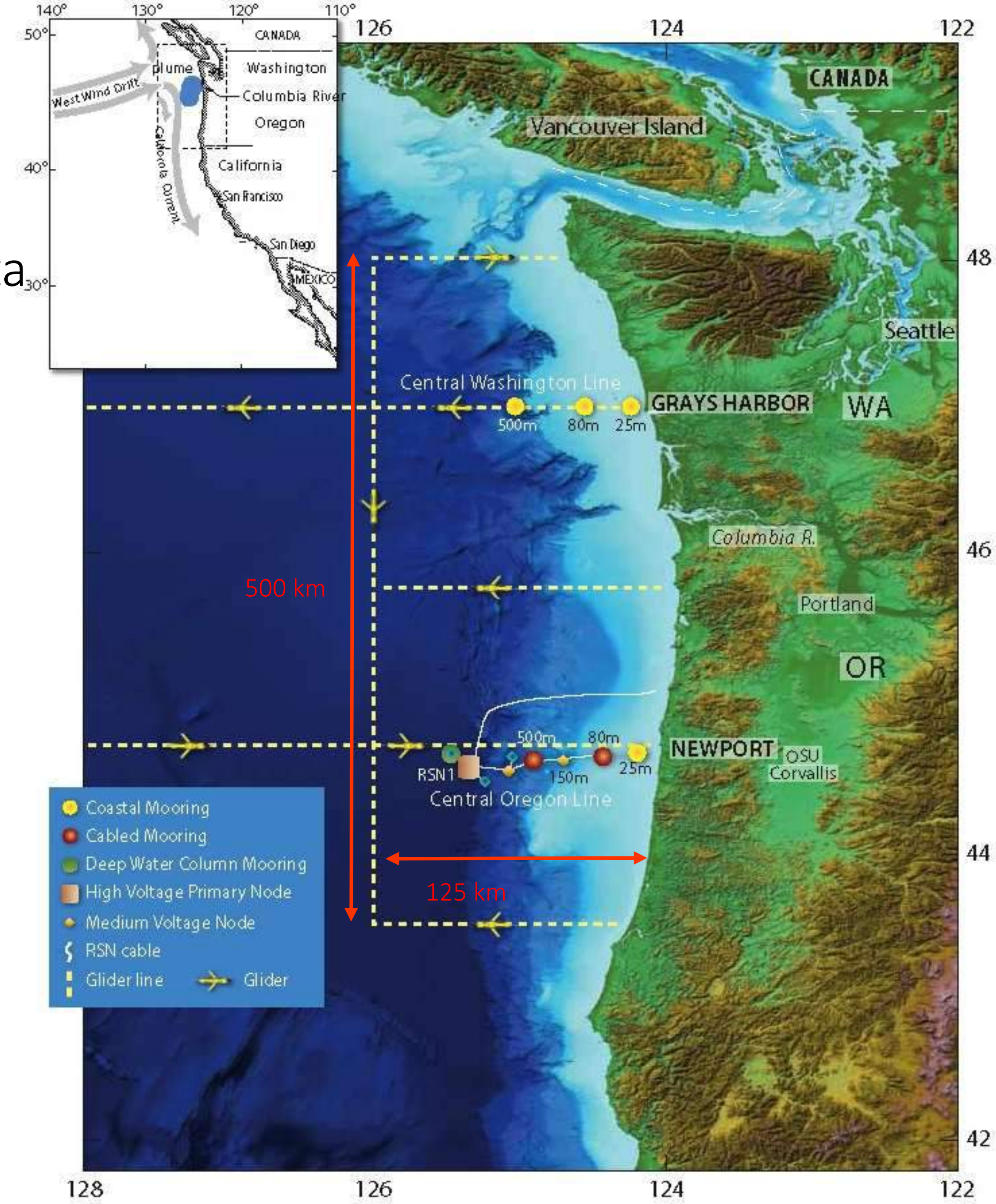
OOI Endurance Array

- Cross-shelf mooring lines at Newport, Oregon, and Grays Harbor, Washington
- Locations chosen based on existing long-term data
- Oregon Line connected to the Cabled Array
- 20 platforms:

  EA ~240 sensors

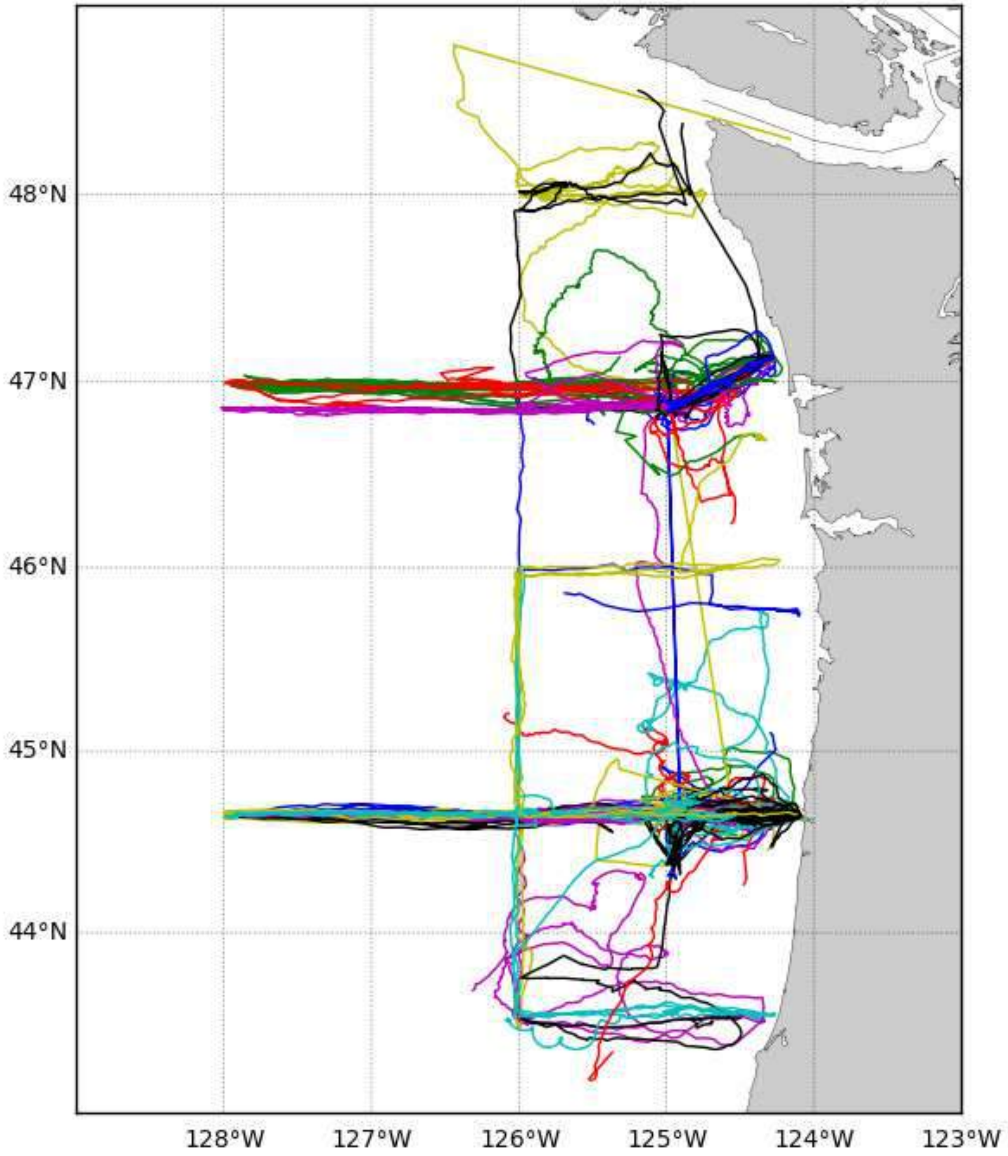
  Cabled EA ~39 sensors
- 6 deployed gliders year-round





OOI Coastal Glider Tracks since early 2014

Endurance Array



Pioneer Array

Courtesy of Peter Brickley (WHOI)

Courtesy Stuart Pearce (OSU)

What might aid NSF researchers use of underwater gliders?

- Streamline procurement and service
- Make entry of new users easier
- Increase glider “uptime” through shared experience with glider maintenance and operation
- Facilitate data processing, curation and sharing of data
- gliders purchased for an NSF project to be available to reduce the costs of the next project wherever it might be
- “preserve the flexibility of individual PIs” (Mete Uz, NSF)

Workshop Agenda

US Underwater Glider Workshop

January 18-19, 2017

INFINITY Science Center, 1 Discovery Circle, Pearlington, MS

DAY 1: WEDNESDAY JANUARY 18, 2017

Time	Agenda Item	Person	Allocation
8:00	**Breakfast**		
8:30	**I. Welcome**	P. McDowell	15 mins
8:45	**II. Keynote Address**	W. Burnett	30 mins
9:15	**III. Workshop Overview**		30 mins
	a. Mission and Objectives	D. Legler	
	b. Glider Workshop Deliverables		
	c. Participant Roles and Responsibilities	B. Kirkpatrick	
9:45	**IV. Enabling Agency Missions with Glider Technology**	S. Harper	60 mins
	a. Luc Rainville (NASA) b. Charlie Barron (Navy) c. David Legler (NOAA) d. Jack Barth (NSF)		
10:45	Q&A	Audience	15 mins
11:00	**V. Ocean Monitoring Breakout Sessions**	S. Glenn	15 mins
11:15	**Break**		
11:30	*Event Monitoring (2)*	S. DiMarco S. Glenn	60 mins
	Sustained Monitoring (2)	R. Todd D. Rudnick	

Workshop Agenda

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12:30	**Lunch**		
1:30	**VI. Ocean Monitoring Breakout Reports**	Breakout Leads	40 mins
	a. Event Monitoring		
	b. Sustained Monitoring		
2:10	**VII. Glider User Group Concept**	S. Glenn	15 mins
	a. Overview	D. Rudnick	
	b. Q&A	Audience	15 mins
2:40	**VIII. User Group Breakout Sessions**	L. Rainville	60 mins
	4 Breakout Groups: User Group	J. Barth	
		C. Lembke	
		A. Thompson	
3:40	**Break**		
4:00	**IX. User Group Breakout Reports**	Breakout Leads	40 mins
	a. User Group		
4:40	**X. Day 1 – Wrap-Up**	B. Baltes	20 mins
	a. Recap Findings		
	b. Prep discussion items for Day 2		
5:00	**Poster Session & Reception at INFINITY Gallery** **Sponsored by Teledyne and GCOOS**		

Workshop Agenda

US Underwater Glider Workshop

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DAY 2: THURSDAY JANUARY 19, 2017

Time	Agenda Item	Person	Allocation
8:00	**Breakfast**		
8:30	**I. Day 2: Objectives**	D. Legler B. Kirkpatrick	15 mins
	a. Review Requirements		
	b. Reassess Potential Deliverables		
8:45	**II. Harmonizing Glider Efforts Breakout Sessions**	B. Kirkpatrick	15 mins
9:00	*Data Management*	J. Kerfoot	60 mins
	Operational Reliability	M. Crowley	
	International Collaboration	D. Legler	
	Interagency Collaboration	B. Houtman	
10:00	**Break**		
10:15	**III. Harmonizing Glider Efforts Breakout Reports**	Breakout Leads	40 mins
	a. Data Management		
	b. Operational Reliability		
	c. International Collaboration		
	d. Interagency Collaboration		
11:00	**IV. Roundtable Discussion on Next Steps**	Audience	60 mins
12:00	**V. Closing Remarks**	Co-Chairs	

12:00	**Workshop Adjourned (Lunch provided)**		
12:00	**Navy Glider Operations Center Tour Schedule**		
	1200 - Load group 1 at Infinity **1215 - Drop group 1 at OSB** **1230 - Load group 2 at Infinity** **1245 - Drop group 2 and load group 1 at OSB** **1300 - Drop group 1 and load group 3 at Infinity** **1315 - Drop group 3 and load group 2 at OSB** **1330 - Drop group 2 at Infinity** **1345 - Load group 3 at OSB** **1400 - Drop group 3 at Infinity**		
12:30	**V. Glider Task Team-CLOSED SESSION**	Workshop Organizers	60 mins
	a. Summarize Deliverables		
	b. Review Action Items		
	c. Identify Next Steps		
	d. Outline Report		

Workshop Participants

US Underwater Glider Workshop

January 18-19, 2017

INFINITY Science Center, 1 Discovery Circle, Pearlington, MS

Jay	**Austin**	*University of Minnesota Duluth*
Becky	**Baltes***	*National Oceanic and Atmospheric Administration*
Charlie	**Barron**	*United States Navy*
Jack	**Barth***	*Oregon State University*
Mark	**Baumgartner**	*Woods Hole Oceanographic Institution*
Jordon	**Beckler**	*Mote Marine Laboratory & Aquarium*
Landry	**Bernard**	*University of Southern Mississippi*
William	**Boicourt**	*The University of Maryland Center for Environmental Science*
Jeffrey	**Book**	*United States Navy*
Francis	**Bringas Gutierrez**	*National Oceanic and Atmospheric Administration*
Wendell	**Brown**	*University of Massachusetts Dartmouth*
Danielle	**Bryant**	*United States Navy*
William	**Burnett**	*United States Navy*
Yi	**Chao**	*UCLA Joint Institute for Regional Earth System Science and Engineering*
Adam	**Comeau**	*Dalhousie University*
Liz	**Creed**	*Kongsberg Underwater Technology*
Mike	**Crowley**	*Rutgers University*
Ruth	**Curry**	*Bermuda Institute of Ocean Sciences*
Fraser	**Dalgleish**	*Florida Atlantic University*
Richard	**Davis**	*Dalhousie University*
Kruti	**Desai**	*Consortium for Ocean Leadership*
Richard	**Dewey**	*University of Victoria*
Steven	**DiMarco**	*Texas A&M University*
Karen	**Dreger**	*Texas A&M University*
Catherine	**Edwards**	*University of Georgia*
Christopher	**Gledhill**	*National Oceanic and Atmospheric Administration*
Scott	**Glenn***	*Rutgers University*
Donglai	**Gong**	*Virginia Institute of Marine Science*
Gustavo	**Goni**	*National Oceanic and Atmospheric Administration*
Monty	**Graham**	*University of Southern Mississippi*
Ken	**Grembowicz**	*United States Navy*
Karen	**Grissom**	*National Oceanic and Atmospheric Administration*
Scott	**Harper**	*United States Navy*
Philip	**Hoffman**	*National Oceanic and Atmospheric Administration*
Todd	**Holland**	*United States Navy*
Bauke (Bob)	**Houtman**	*National Science Foundation*
Matthew	**Howard**	*Texas A&M University*
Stephan	**Howden**	*University of Southern Mississippi*
Clara	**Hulburt**	*Teledyne Webb Research*
Reyna	**Jenkyns**	*University of Victoria*

Workshop Participants

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Clayton	**Jones**	*Teledyne Webb Research*
Laurie	**Jugan**	*MIST Cluster*
John	**Kerfoot**	*Rutgers University*
Barbara	**Kirkpatrick***	*Gulf of Mexico Coastal Ocean Observing System*
Josh	**Kohut**	*Rutgers University*
Chad	**Kramer**	*United States Navy*
Gerhard	**Kuska**	*Mid-Atlantic Regional Association Coastal Ocean Observing System*
David	**Legler***	*National Oceanic and Atmospheric Administration*
Chad	**Lembke**	*University of South Florida*
Alan	**Lewitus**	*National Oceanic and Atmospheric Administration*
Hank	**Lobe**	*Sonardyne/Severn Marine Technologies*
Atle	**Lohrmann**	*Nortek International*
Kevin	**Martin**	*University of Southern Mississippi*
Andrea	**Mask**	*United States Navy*
Pam	**McDowell**	*National Oceanic and Atmospheric Administration*
Bryan	**Mensi***	*United States Navy*
Russ	**Miller**	*University of Michigan*
Robert	**Moorehead**	*Mississippi State University*
Mike	**Morley**	*University of Victoria*
Ru	**Morrison**	*Northeastern Regional Association of Coastal Ocean Observing Systems*
Laura	**Nazzaro**	*Rutgers University*
Amanda	**Netburn**	*National Oceanic and Atmospheric Administration*
Matthew	**Oliver**	*University of Delaware*
Rich	**Patterson**	*Kongsberg Underwater Technology*
Chari	**Pattiaratchi**	*University of Western Australia*
Stuart	**Pearce**	*Oregon State University*
Ruth	**Perry**	*Shell Exploration and Production*
Dawn	**Petraitis**	*National Oceanic and Atmospheric Administration*
Luis	**Pomales**	*University of Puerto Rico*
John	**Quinlan**	*National Oceanic and Atmospheric Administration*
Josie	**Quintrell**	*IOOS Association*
Luc	**Rainville***	*University of Washington*
Rodeny	**Riley**	*National Oceanic and Atmospheric Administration*
Nick	**Rome**	*Consortium for Ocean Leadership*
Dan	**Rudnick***	*Scripps Institution of Oceanography*
Grace	**Saba**	*Rutgers University*
Lucy	**Smedstad**	*United States Navy*
Scott	**Smith**	*United States Navy*
Joe	**Swaykos**	*National Oceanic and Atmospheric Administration*
Chris	**Taylor**	*National Oceanic and Atmospheric Administration*

Pierre	**Testor**	*Le laboratoire LOCEAN*
Charles	**Thompson**	*National Oceanic and Atmospheric Administration*
Andrew	**Thompson***	*California Institute of Technology*
Jim	**Todd**	*National Oceanic and Atmospheric Administration*
Robert	**Todd**	*Woods Hole Oceanographic Institution*
Jerry	**Townsend**	*United States Navy*
Victor	**Turpin**	*Le laboratoire LOCEAN*
Sofie	**Van Parijs**	*National Oceanic and Atmospheric Administration*
Hemantha	**Wijesekera**	*United States Navy*
Thomas	**Wims**	*Consortium for Ocean Leadership*
Freda	**Zifteh**	*Nortek International*

**Glider Task Team Members*

Poster Presenters

US Underwater Glider Workshop

January 18-19, 2017

INFINITY Science Center, 1 Discovery Circle, Pearlington, MS

Title	Presenter
Gliders in the Great Lakes; data inventory and preliminary results	**Austin**
Hypoxia off the Oregon coast from 10 years of glider data	**Barth**
Near real-time detection of marine mammals from autonomous platforms	**Baumgartner**
Improvement of glider operation efficiency through partnership with IOOS Regional Associations	**Beckler**
AOML-CARICOOS underwater glider operations in support of tropical cyclone intensification studies	**Bringas**
Investigating Mid-Atlantic Cold Pool Dynamics	**Brown**
Impact of glider data assimilation on the California coastal ocean nowcast/forecast system	**Chao**
Glider Observations of Tropical Storms and Submesoscale Biogeochemical Cycles near Bermuda	**Curry**
Lidar sensors deployed on gliders	**Dalgleish**
Ocean Observations on the Scotian Shelf using Autonomous Vehicles	**Davis**
Gulf of Mexico: Hypoxia, OA, Upper Ocean Heat Content	**DiMarco**
Autonomous navigation of gliders, interdisciplinary glider science	**Edwards**
Storms	**Glenn**
Glider Observations of Arctic and Mid-Atlantic Submarine Canyons	**Gong**
Impact of assimilating underwater glider data on Hurricane Gonzalo (2014) forecast	**Goni**
Heat content	**Howden**
Glider based water quality monitoring along the New Jersey coast	**Kohut**
Navy Glider Sampling Plans and Piloting Strategies	**Kramer**
Fisheries	**Lembke**
TBD	**Martin**
Acoustic Biotelemetry for Slocum Gliders	**Morell**
Development and operation of a national ocean glider facility in Australia	**Oliver**
Long-term Gulf of Mexico Loop Current Monitoring Supported by a Public-Private Partnership Model	**Pattiaratchi**
Gliders in the Great Lakes; data inventory and preliminary results	**Perry**
Passive acoustics monitoring, oil spill work, coastal ocean monitoring	**Quinlan**

Poster Presenters

US Underwater Glider Workshop

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Title	Presenter
IOOS Association	**Quintrell**
Sustained observations of boundary currents	**Rainville**
California Underwater Glider Network	**Rudnick**
Developing a profiling glider pH sensor for high resolution coastal ocean acidification monitoring	**Saba**
Integrating passive and active acoustic sensors in glider payloads	**Taylor**
Topographic closure of the overturning circulation in the Southern Ocean: Glider observations from Drake Passage	**Thompson**
Cross-Gulf Stream surveys between Miami and New England	**Todd**
EGO network and global glider data management	**Turnip**
Integrating active and passive acoustics on gliders to detect and protect spawning fish aggregations	**Van Parijs**
Glider Performance and reliability/Long term glider deployment - operational successes	**Wims**

- Reponses from 5 Federal Agencies and 11 Regional Associations (respondents affiliated with 10 different departments and agencies).

Federal	# of respondents	RAs	# of respondents
NOAA	12	MARACOOS	10
EPA	4	AOOS	4
BOEM	3	NANOOS	2
NAVY	3	CeNOOS	2
USACE	1	GCOOS	2
NSF	1	CariCOOS	2
		PacIOOS	3
		SECOORA	1
		NERACOOS	1
		SCCOOS	1
		GLOS	1
TOTAL	24		29

- Salinity, Temperature, and DO are the most required measurements.
- Most geographic regions were evenly collected from (Low standard dev. - 0.06)
- 66% of respondents said they were able to meeting the requirements laid out by their funding agency.
- 96 % of respondents said gliders would help improve meeting their subsurface observing/data requirements.
- Salinity, Temperature, DO, and Colored Dissolved Organic Matter are the most collected variables.
- 86% of respondents said that they utilize gliders (44 % <50%; 42% >50% of the time) to meet their subsurface requirements.
- 81% of respondents said that they have flexibility when sending or receiving funding to modify glider missions or sensors to accommodate collaboration and leveraging of resources.
- 34% of respondents said that if acting as a funder, they would NOT participation in a glider user group if one existed.
- 85% of respondents said that funding was the major limitation in collecting subsurface data.
- 82% of respondents ARE aware of the IOOS National Glider DAC.
- 94% of the data collected by respondents is public.

- **57% of respondents said they would require operators to submit data to the Glider DAC.**
- **90% of respondents said they would use collected subsurface glider data to improve model output.**
- **83% of the primary subsurface data collection missions are research-based.**
- **60% of respondents said they do NOT glider capacity to respond to unplanned events (i.e. oil spills, hurricane, etc.).**
- **49% of respondents said they do NOT have adequate resources for maintenance and launch/recovery.**
- **Slocum gliders are the most operated by respondents.**
- **Collaboration types most interesting to respondents were data sharing, deployment/recovery resources, and platform sharing.**
- **92% of respondents are open to adding sensors, or modifying sensor location or sampling strategy to facilitate joint glider missions.**
- **86% of respondents said they would use a community forum such as an email listserv that informs the community about deployments and serves as a platform to describe needs.**
- **81% of respondents said they would participate in a glider user group.**
- **66% of respondent think a standardized interface in glider trainings would be useful.**