

**Final Report # NA16NOS0120027**

FY 2016-2021 Implementation & Development of Regional Coastal Ocean Observing System:  
Alaska Ocean Observing System (AOOS)

Reporting period June 1, 2016 – May 31, 2024

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**SECTION 1**

**PROJECT MILESTONES:**

The project milestone table is included as attachment 1.

**I. High Frequency Radars (HFRs)**

**Table 1. Summary of High Frequency Radar (HFR) Funding**

Year	Amount	Funding Area	Task
FY16	Arctic Sites: \$156,000  \$101,000  Total: \$257,000	AOOS Core (61%)  Other Partners (Shell Oil) (39%)	Support 4 existing high frequency radar (HFR) at Chukchi Sea/Arctic sites: <i>Names, locations (lat,lon), locations (city, state), Transmit Freq, Operating Institution for each radar:</i> <ul style="list-style-type: none"> <li>• SIMP - 71.0586°N, 154.75056°W - Cape Simpson, AK - 4.66 MHz - University of Alaska Fairbanks (UAF)</li> <li>• PBRW - 71.3784°N, 156.4801°W - Point Barrow, AK - 4.55 MHz - UAF</li> <li>• WAIN - 70.6434°N, 160.0271°W - Wainwright, AK - 4.80 MHz - UAF</li> <li>• ICYC - 70.2850°N, 161.9289°W - Icy Cape, AK - 4.66 MHz - UAF</li> </ul>
FY17	Arctic Sites: \$156,000 \$86,200 Total: \$242,200	AOOS Core (64%)  Other Partners (Shell Oil) (36%)	Support 3 existing HFR in the Chukchi Sea/Arctic (same details as FY16) <ul style="list-style-type: none"> <li>• SIMP</li> <li>• PBRW</li> <li>• WAIN</li> <li>• ICYC: Decommissioned ICYC in 2017</li> </ul> <i>Note: Shell funding used to purchase equipment not allowed on the AOOS Award.</i>
FY18	Arctic Sites: \$156,000 \$15,000 Total: \$171,000	AOOS Core (92%)  Other Partners (Shell Oil) (8%)	Support 3 existing HFR in the Chukchi Sea/Arctic (same details as FY16) <ul style="list-style-type: none"> <li>• SIMP</li> <li>• PBRW</li> <li>• WAIN</li> </ul>
FY18	Bering Strait HFR Initiative:  \$880,000	2018 IOOS Close the Gaps campaign passed through AOOS Core	Purchase CODAR SeaSonde HFR systems for two stations (\$290,000) Purchase components to build a Remote Power Module (RPM) to support off-grid power of 1 HFR system in Wales (\$130,000)

		(One time funding)	Fabrication of a full-scale RPM for use at Wales HFR location. Installation and operational trials of 2 new HFR at Bering Strait sites: <i>Names, locations (lat,lon), locations (city, state), Transmit Freq, Operating Institution for each radar:</i> <ul style="list-style-type: none"> <li>• SHSH - 66.2543°N, 166.0785°W - Shishmaref, AK - 4.80 MHz - UAF</li> <li>• WALE - 65.6110°N, 168.0943°W - Wales, AK - 4.55 MHz - UAF</li> </ul>
FY19	Arctic Sites: \$156,000 \$14,503 Total Arctic Sites: \$170,503	AOOS Core (92%) Other Partners (Shell Oil) (8%)	Support 3 existing HFR in the Chukchi Sea/Arctic (same details as FY16) <ul style="list-style-type: none"> <li>• SIMP</li> <li>• PBRW</li> <li>• WAIN</li> </ul>
FY19	Bering Strait HFR Initiative: \$114,286	2019 IOOS Close the Gaps campaign passed thru AOOS Core (One time funding)	Fabrication of a RPM-Lite for a potential third Bering Strait HFR site Test RPM_Lite
FY20	Arctic Sites: \$156,000	AOOS Core	Support 3 existing HFR in the Chukchi Sea/Arctic (same details as FY16) <ul style="list-style-type: none"> <li>• SIMP</li> <li>• PBRW</li> <li>• WAIN</li> </ul>
FY20	Bering Strait Sites: \$114,286	2020 IOOS Close the Gaps campaign passed thru AOOS Core (One time funding)	Support Bering Strait HFR initiatives, troubleshoot power in Shishmaref, evaluate locations of Bering Strait HFR (same details as above) and ongoing remote field testing for RPM-Lite <ul style="list-style-type: none"> <li>• SHSH</li> <li>• WALE</li> </ul>
FY20	\$95,238	2020 IOOS Close the Gaps campaign passed thru AOOS Core (One time funding)	Refurbish 2 UAF-owned but obsolete HFR systems in order to return them to the operational HFR equipment pool for future Alaska coastal deployments.
Total	\$2,200,513	AOOS Core: \$780,000 IOOS Close the Gaps campaign \$1,203,810	As of 2020, AOOS supports 5 seasonally operational HFR in Alaska: <ul style="list-style-type: none"> <li>• SIMP</li> <li>• PBRW</li> </ul>

		<p>Other Partners (non-IOOS) \$216,703</p>	<ul style="list-style-type: none"> <li>• WAIN</li> <li>• SHSH (new in 2019)</li> <li>• WALE (new in 2019)</li> </ul> <p><i>Note: Remaining funds from “Other Partners (Shell Oil) spent down by end of this project term. Only support starting in 2020 for Alaska HFR comes from IOOS through the AOOS Core award and the Close the Gaps funding in 2020.</i></p>
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**Table 2. Summary of High Frequency Radar (HFR) Stations**

Names of RA’s existing HFR stations	Status	Date of most recent antenna calibration	Date planned for next antenna calibration	Recapitalization needs
SIMP (Simpson)	<p><b>Complete:</b> Reactivated in August, but site was sending empty data files, likely due to a cable connector failure or issue inside receive chassis. Attempts to get corrected in late August and again in early September were weathered out for getting to the site by boat. Site was successfully accessed in late September, but more time was needed to fully rectify issues with remote power system that kept shutting off the radar electronics. <b>Mission was aborted due to large presence of polar bears.</b> After discussions with AOOS, it was deemed this site is longer sustainable. Aging equipment, access challenges, and coastal erosion have also made it an exorbitant drain on time and resources, and plans are in place to decommission in 2024.</p>	4/2021	NA	Site to be decommissioned in 2024.

PBRW (Point Barrow)	<b>Complete.</b> After waiting for returned receive antenna hardware from CODAR Ocean Sensors, Point Barrow was reactivated in August 2023 and was operational from August through December 2023, after which sea ice ended data returns. Station regularly telemetering data to CORDC.	8/2022	8/2024	HFR system (2003) end of service life (\$150k) - part of the costs to replace the CODAR Seasonde was Included in the Bipartisan Infrastructure Law (BIL) Y2 fund request at \$116,563, but prices have increased since the BIL proposal was submitted, and the price in the request may no longer reflect the realized cost. Replacement battery bank, end of service life (\$35K)
WAIN (Wainwright)	<b>Complete:</b> After waiting for returned receive antenna hardware from CODAR Ocean Sensors, Wainwright was reactivated in early September, 2023 and regularly telemetered data to CORDC for five weeks, after which the site started having power supply issues (to be addressed before redeployment in Summer 2024).	8/2022	8/2024	HFR system (2009) end of service life, replacement (\$150K)
SHSH (Shishmaref)	<b>Complete.</b> Several maintenance trips were needed to make repairs (i.e., the power outlet, radar transmit antenna, coaxial cable connectors, and the UPS system). This HFR site was operational beginning in early August 2023 and remains so to the present. Station regularly telemetering data to CORDC, but sea ice cover will likely end data returns for the winter.	9/2019	7/2024	Environmental Enclosure (\$10k)

WALE (Wales)	<b>Delayed:</b> After a very late season snow melt, an oceanic inlet filled in between town and the station. Access via ATV alone was no longer possible, and packrafts were used to access site. Wildlife chewing on the satellite internet cable has resulted in inoperable comms until we can get back to the site for maintenance. This will be resolved during a spring 2024 site visit when travel is safer.	8/2022	7/2024	NA
Cook Inlet	<b>Delayed.</b> A test HFR site installed at Hilcorp's Rig Tenders Dock had a sector of data returns where there is low coverage due to a large distance of land over which to transmit and receive data. Plans are to find a new site near to Rig Tenders Dock so that the Canary Loop Field Kasilof Pad can still be used as a companion site. Installation plans for 2 HFRs in Cook Inlet are now planned for spring 2024.	NA	2024	NA

**Table 3. Names of High Frequency Radar (HFR) Information Technology (IT) Systems**

Names of RA's HFR IT Systems	Status	Recapitalization needs
UAF	<p><b>Complete:</b> An offshore Quintillion fiber optic cable break in June 2023 posed an issue for real-time data transmissions for both Arctic and Bering Strait HFR sites. Data started transferring from the field sites when the cable was repaired in September 2023. Chukchi Sea (Arctic) HFR Data <a href="http://research.cfos.uaf.edu/hfradar/">http://research.cfos.uaf.edu/hfradar/</a>                      Bering Strait HFR Data <a href="http://research.cfos.uaf.edu/hfradar/">http://research.cfos.uaf.edu/hfradar/</a>                      AOOS Data Portal (Note, the Bering Strait Radar are not yet reporting on the AOOS Data System) <a href="http://research.cfos.uaf.edu/hfradar/">http://research.cfos.uaf.edu/hfradar/</a></p>	Nothing is needed. New Central Site Computer for UAF with CODAR license upgrade was purchased with BIL Y1 funding.

**II. Gliders and Other Uncrewed Systems (UxS)**

**Summary of glider activities FY16-FY20:** AOOS supported multiple glider initiatives including:

- Continued operation of the Chukchi Glider and completion of four additional annual Arctic marine mammal and oceanographic surveys in the Chukchi Sea, totaling 209 glider days between 2016-2020.
- New glider initiatives to support the *Ecosystem Approach to Fisheries Management* (EAFM) in the northern Gulf of Alaska and Bering Sea.
- New glider sensor payload and sampling improvements that resulted in enhanced glider ecosystem observing capabilities to support glider missions during the International Year of the Salmon (IYS) demonstration for operational readiness of autonomous underwater vehicle (AUV)-based ecosystem monitoring in 2022 and newly planned EAFM glider missions in the Gulf of Alaska and the Bering Sea.
- Newly developed glider-derived real-time indices made accessible through a public facing data dashboard showing key physical and biological parameters, used to inform the North Pacific Fisheries Management Council (NPFMC) EAFM decision-making process and other fisheries management related research activities.
- Glider upgrades to the existing University of Alaska, Fairbanks (UAF) Teledyne Slocum G2 glider fleet, in particular upgraded buoyancy engines needed for profiling in the freshening and warming Alaska coastal waters.
- Successful glider pilot training that increased the number of glider operators for Alaska and improved operational readiness for increasing glider missions.

### **Accomplishments/successes:**

- Chukchi Glider: Since 2013 to 2020, seven annual glider missions spanning the northern Bering and Chukchi Seas have been completed, monitoring the vocal marine mammal occurrence while mapping oceanographic conditions.
- The Chukchi Glider was successfully deployed for 28 days in 2020 despite other sea-going and glider activity delays caused by the COVID-19 epidemic.
- EAFM Glider: Though delayed by COVID-19, multiple EAFM Glider deployments were eventually conducted in Prince William Sound and the northern Gulf of Alaska in 2021-22, including glider deployments as part of the National Oceanic and Atmospheric Administration (NOAA) Ocean and Atmospheric Research (OAR) 2022 IYS demonstration for glider operational readiness.
- An echosounder and auxiliary processor were successfully integrated into an EAFM glider, expanding the glider capability to sample upper trophic levels throughout the water column.
- A newly developed *Echometrics Dashboard* application allows near real-time evaluation of the ecosystem to assess if anomalous conditions are occurring.
- New near-real-time glider data delivery and visualization on the AOOS Ocean Data Explorer better supports operations and allows analysts to redefine glider trajectories and ensures that data are received if the vehicle is not recovered.
- All glider missions in Alaska have demonstrated that an ecosystem monitoring underwater glider can cost effectively supplement and/or replace many components of vessel-based surveys.
- For more details, please see Other Core Observation Activities, section *Autonomous Underwater Vehicles/Gliders for Ecosystem Assessment and Fisheries Management*.

### **Problems/delays:**

- Chukchi Glider: 2019 was the only year a Chukchi Sea glider deployment was not completed. Upon deployment, it was discovered that the buoyancy engine in the glider could not overcome the fresher and highly stratified water conditions experienced in the Bering Strait region in 2019. This motivated the upgrade of all three UAF Gliders with improved and more powerful buoyancy engines.

The 2020 COVID-19 epidemic delayed some of the planned EAFM glider missions beyond the 2016-2020 end-date. However, the planned missions were completed in 2021 and 2022.

## **III. Other Core Observation Activities**

### **A. Marine Operations**

#### **Weather Observations**

*Subaward to Prince William Sound Science Center (PWSSC) - Service Snow Telemetry stations in Prince William Sound.*

- **Purpose of the project:** To maintain long-term observations of meteorological conditions at eight priority Snow Telemetry (SNOTEL) stations around Prince William Sound and Cook Inlet.
- **Key outcomes:** This project maintained SNOTEL observing assets and provided real-time web accessible weather information, primarily for safe vessel operations in the Prince William Sound, lower Cook Inlet, and near two large hatcheries that require significant vessel and aircraft support throughout the year.
- **Who used the information and for what purpose:** Station data were streamed in real-time on the AOOS Data Portal and the SNOTEL website (managed by the U.S. Department of Agriculture) and utilized by regional mariners and aviators, recreational users (e.g., kayakers, fishermen, skiers, backcountry outdoorsmen), ocean and atmospheric science researchers and forecasters (e.g., NOAA National Weather Service [NWS]); hatchery managers; hydrological resource managers (e.g., precipitation and snow depths); and climate modelers.

*Subaward to Marine Exchange of Alaska (MXAK) - Increase access to weather observations using AIS.*

- **Purpose of the project:** To improve maritime safety by installing real-time weather sensors in areas experiencing data gaps and to disseminate the weather information in a more timely, accurate and comprehensive way to mariners via the Automated Information System (AIS) vessel tracking network and through multiple website services.
- **Key outcomes:** The MXAK weather project enhanced maritime safety across Alaska by adding 26 new real-time reporting weather stations to the MXAK AIS weather observing network, and repairing/upgrading 14 existing MXAK weather stations. By project end, 68 real-time weather stations were operational with real-time data being shared directly with vessels through the AIS and smartphones to more efficiently transmit weather information to mariners. real-time data were also made publicly available through the AOOS Data Portal, the MXAK website, and the National Data Buoy Data Center (NDBC) website.
- **Who used the information and for what purpose:** Primary users are mariners who require current and hyper-localized weather information while operating at sea. Making weather information available through the AIS is a more direct way for on-the-water mariners to obtain local conditions, rather than listening to broadcasts over VHF radio networks that are difficult to hear and have limited coverage. Other data users include harbormasters and port authorities, recreational boaters, passenger vessel operators, marine pilots, tugboat operators, and fishermen. The NWS and other forecasters rely on the MXAK weather stations to make more accurate regional forecasts. The NWS continually displays MXAK weather data in their VHF weather broadcasts.

### **Waves and Surface Current Observations**

*Internal AOOS project - Sustain and increase wave observations for forecasting, coastal planning and navigation safety.*

- **Purpose of the project:** To maintain existing and initiate new wave buoy operations in partnership with the Coastal Data Information Program (CDIP), a U.S. Army Corps of



Engineers (USACE) program that partners with Integrated Ocean Observing System (IOOS) Regional Associations (RAs) to sustain real-time coastal wave buoy observational capacity.

- **Key outcomes:** Provided operational support to sustain year-round real-time CDIP wave buoy 204 observations in Lower Cook Inlet 2016-2020; operated a real-time seasonal CDIP wave buoy 241 off the Port of Nome 2018-2020; assumed operational maintenance of the National Renewable Energy Laboratory (NERL) CDIP buoy 236 offshore of Kodiak for two years 2019-2022.
- **Who used the information and for what purpose:** The CDIP wave buoys in Alaska help fill data gaps in critical coastal areas that can benefit from real-time wave information, including parts of the state where NDBC buoys are not possible or are cost prohibitive. The buoys provided reliable, publicly-accessible data for use by coastal engineers and planners, scientists, storm surge modelers, mariners, coastal communities and the interested public. The USACE is the primary program sponsor, as they require reliable, long-term wave measurements for use in planning, designing, and operating coastal projects, such as increasing the size and operational capacity of ports and harbors.

### **Map Surface Currents with HFRs**

*Subaward to UAF - Operation and maintenance of three Arctic HFR sites on the Chukchi and Beaufort Seas.*

- **Purpose of the project:** To operate and maintain three existing HFR sites that provide surface current data in the Arctic region covering the northern Chukchi Sea to the western Beaufort Sea. Stations are located in the communities of Wainwright, Utqiagvik (Point Barrow), and at Cape Simpson (east of Utqiagvik). The Icy Cape HFR station was decommissioned in 2017 due to lack of funding.
- **Key outcomes:** UAF installed and has been maintaining a grid of remotely powered HFR sites in various configurations on the northeastern Chukchi and western Beaufort coasts during ice-free seasons since 2009. This HFR array has been recording hourly surface currents and displaying measurements in real-time on the internet via the HFR Data Assembly Center (DAC), the AOOS Data Portal, and more locally via the UAF-CFOS website. During this project effort, three of the original four HFR were operational for most of the open water season each year (July through December). They provided hourly, real-time surface current measurements at 6 km spatial resolution, covering an area up to 150 kilometers (km) offshore.
- **Who used the information and for what purpose:** The data are primarily used now for oceanographic research and modeling activities. These systems were originally installed with funding from the oil exploration companies working in the Arctic and the Bureau of Ocean and Energy Management (BOEM) for modeling, circulation studies and ice forecasting. Data are made available in appropriate formats for the United States Coast Guard (USCG) to assist Search and Rescue Operations (SAR) and assist routing of commercial vessel traffic; the NOAA Office of Response and Restoration (OR&R) for contaminant spill response; and the NWS to aid in improving weather and marine forecasts and sea ice coverage analysis. Local subsistence hunters may also access the information for improved maritime safety.

*Subaward to UAF - Install new HFRs in the Bering Strait Region.*

- **Purpose of the project:** To test, install, operate and maintain two HFR stations in the Bering Strait Region in western Alaska. This project also supported fabrication and testing of a new, low-power remote power module system design (RPM Lite) for its feasibility to add a third, more remote off-grid HFR site to the Bering Strait HFR array as funding becomes available.
- **Key outcomes:** The testing of two grid-powered HFR sites in the Bering Strait region in 2019 demonstrated HFR could provide surface mapping coverage completely across the Bering Strait. The COVID-19 pandemic caused many delays in the timeline. Sites were finally permitted and HFR installed in summer of 2021. One site was grid powered in Shishmaref, and the other remotely powered by an RPM ~15 miles northeast of Wales. Both installations have been intermittently operational for periods of the open water season since 2021. Unfortunately, neither were both operational and online concurrently to derive real-time surface currents during this project period. The original HFR site in the Native Village of Wales was relocated in 2022 to improve spatial coverage and was operational during open water seasons starting in September 2022. The successful fabrication and testing of the RPM-Lite makes a third remote HFR system in Alaska more rapidly deployable and with a smaller footprint.
- **Who used the information and for what purpose:** Primary motivation for the Bering Strait HFR was the increasing vessel traffic that necessitates improved maritime domain awareness and navigation safety. The data collected from these systems when operational will be made available in appropriate formats for the USCG to assist SAR and assist routing of commercial vessel traffic; the NOAA OR&R for contaminant spill response; the NWS to aid in improving weather and marine forecasts and sea ice coverage analysis; subsistence hunting and other boating activities for improved maritime safety and awareness; and researchers (e.g., those tracking fate and distribution of harmful algal blooms [HABs]).

*Subaward UAF - Upgrade out-of-date HFR systems.*

- **Purpose of the project:** To upgrade two out-of-date 13 MHz HFR SeaSonde systems owned by UAF that are no longer operable, so that they may be utilized for future projects, thereby increasing coverage along the Alaska coastline and contributing to the U.S. IOOS Fill the Gaps campaign.
- **Key outcomes:** Two SeaSonde systems were sent to CODAR (manufacturer) for equipment upgrades to make these operationally viable for new HFR installations in Alaska. The site footprint is now significantly reduced, as the new antenna design requires only one combined transmit/receive antenna at each site, rather than separate transmit and receive antennas.
- **Who used the information and for what purpose:** The two refurbished HFR SeaSonde systems are targeted for deployment in Cook Inlet in southcentral Alaska to acquire surface current maps to be used by resource managers and agencies, including the Cook Inlet Regional Citizens Advisory Council (CIRCAC), USCG for SAR, NOAA OR&R for spill response, the NWS for improved marine forecasts, scientific researchers working to improve circulation models (e.g., NOAA's Cook Inlet Forecast System [CIOFS]), and

commercial and recreational boaters who benefit from improved maritime domain awareness.

### **Sea Ice Observing**

*Subaward to UAF - Repair and sustain the sea ice radar system in Utqiagvik.*

- **Purpose of the project:** To repair and return to operation an existing ice radar system operating in Utqiagvik (formerly Barrow), Alaska in order to sustain real-time ice observing capabilities, and transition data processing and management tasks to Axiom Data Science (Axiom)/AOOS.
- **Key outcomes:** This project supported replacement spare parts, technical support and travel to Utqiagvik to repair and attend to routine system maintenance tasks on the aging Fuguro ice radar system. The ice radar data stream was restarted prior to freeze-up and returned to operation on November 17, 2017. At the time, this was the lowest-cost option available to attempt to bring this ice radar back online for continued operation, and repairs enabled continued operation for a short period before additional failure modes occurred. Recommendations were to replace the radar using a modern, solid-state system; however, funding to achieve this was not available at the time. The plan to transition data processing and management to Axiom was not completed due to the radar going offline.
- **Who used the information and for what purpose:** As a research instrument, the radar had been used to monitor near-shore ice conditions and evaluate the stability of landfast sea ice. Local subsistence hunters and analysts at the NWS Anchorage Ice Desk routinely used the sea ice radar to assess ice conditions in the Utqiagvik area. Commercial and civilian mariners also used the sea ice radar imagery available on the UAF website and associated animations for navigational purposes during periods of the year when mobile sea ice poses a potential threat to their vessels. With support from Department of Homeland Security (DHS), the processed data feeds were made available to USCG District 17, NOAA's Arctic Environmental Response Management Application (ERMA), and the Arctic Domain Awareness Center (ADAC) Arctic Information Fusion Capability (AIFC). Since this project ended, the Principal Investigator was able to secure alternative (non-AOOS) funding support to replace the sea ice radar in Utqiagvik.

*Subaward to UAF - Build and deploy an ice detection buoy at the Chukchi Sea Ecosystem Observatory (CEO).*

- **Purpose of the project:** This project was a contribution of funds IOOS and AOOS made to continue freeze-up detection buoy trials started during an IOOS Ocean Technology Transition (OTT) project: *A Real-Time Sensor System for Detecting Freeze-up on Arctic Shelves*, and to deploy a third, newly built Ice Detection Buoy (IDB) at the Chukchi Ecosystem Observatory (CEO) in 2018. The data from a series of IDB buoys were purposely being collected to test the operational capability and viability of the real-time data shared through the global telecommunication system (GTS) from this prototype mooring for ice detection and sea ice modeling activities. The NWS in 2017 and IOOS in 2018 (this project) wanted to continue to evaluate the prototype buoy system for its potential as an operational asset following the successful IOOS OTT 2015 deployment.
- **Key outcomes:** IOOS and AOOS invested to build a third IDB for deployment in 2018. With this subaward for equipment support only, a new IDB was built, which was

deployed in August 2018 during the CEO moorings and IDB turn-around cruise. This project did not cover the entire cost of the effort, but contributed to the 2018 IDB equipment and hardware. Data collected during deployment were successfully shared through the GTS.

- **Who used the information and for what purpose:** As in 2017, the 2018 real-time data streamed via the GTS and was made available to sea ice modelers to use and evaluate the data for their modeling activities. Unfortunately, shortly after its deployment, the 2018 IDB mooring was dragged by ice and the top float flooded, rendering the real-time transmissions inoperative. The mooring and equipment were recovered in September 2018 and returned to UAF for salvage of mooring hardware and subsurface sensors. This was the last IDB deployed.

### **Maritime Operations Data Products and Services**

*Subaward to UAF - International Arctic Research Center (IARC) Update Historical Sea Ice Atlas.*

- **Purpose of the project:** To maintain an updated Historical Sea Ice Atlas, which synthesized Alaska sea ice concentration information into a digital database spanning 1850-2014 at a monthly time resolution.
- **Key outcomes:** The database was kept current at UAF and annual updates were provided to AOOS to maintain the Sea Ice Atlas data layer for access and display via the AOOS Data Portal. Axiom maintained this data layer/product on the portal through the annual AOOS Core Data Management and Assembly (DMAC) subaward. The visualization tool was expanded to include the option for users to select from a menu of more than 50 Alaska coastal communities and an additional 70 Arctic coastal communities in other countries. The atlas itself is unique in that it incorporates historical ship captain logs to provide estimates for location of the historical ice edge and ice thickness dating back to 1850. Graphics and other information from the Historical Sea Ice Atlas have appeared in various reports, including outreach publications as well as journal papers.
- **Who used the information and for what purpose:** A survey of users of the Historical Sea Ice Atlas by the Goldstream Group (funded by the Alaska Center for Climate Assessment and Policy [ACCAP]) generated responses from users in the following categories (# of respondents in parentheses): management (23), planning (21), policy (16), education (29), outreach (33), coordination (29), natural resources (34), and research (44). Employer categories included the federal government (25), state government (6), university (24), industry (7), non-profit agency (7), and various “others”. The most common use type was “general information”, followed by research, management and policy. The historic data is particularly useful for observing long-term sea ice trends in the Arctic dating back to the 1850s.

### **B. Coastal Hazards & Inundation**

*AOOS Geospatial Coordinator Position - Alaska Department of Natural Resources (ADNR) and AOOS.*

- **Purpose of the project:** To support a two-year, part-time Alaska Geospatial Coordinator position to provide guidance, coordination and leadership in the development of a

cohesive statewide strategy for prioritizing baseline geospatial data collection in the Alaska coastal and nearshore areas.

- **Key outcomes:** ADNR contributed funds to AOOS for a part-time Alaska Coastal Mapping Strategist position based in the ADNR Anchorage office 2018-2019. This position was an AOOS employee.
- **Who used the information and for what purpose:** This position worked with established mapping committees, agency liaisons, Native Corporations, non-government organizations (NGOs), the private sector, and academia to organize the diverse coastal mapping needs in Alaska by location, quality-level, partner, capacity, feasibility, and refresh-rate, with the overall objective of developing a long-term strategy for prioritizing coastal mapping activities.

*AOOS Hydroball(™) Equipment Acquisition: Crowd-source non-NOAA hydrographic (water depth) survey data.*

- **Purpose of the project:** To acquire shallow water bathymetry measuring equipment for filling gaps and improving the nearshore bathymetry in remote Alaska communities. Data collected using the equipment is aimed at improving navigation safety, but also to provide up-river and nearshore bathymetric information for storm surge modeling. Funding to purchase the equipment was provided by the IOOS Fill the Gaps campaign and from pass through funds from NOAA Office of Coast Survey (OCS).
- **Key outcomes:** AOOS purchased the equipment and maintains the software licenses and insurance on the assets, and the Alaska Navigation Manager helped coordinate the crowd-sourcing activities and partnership, in particular, getting the data processed and shared with NOAA National Center for Environmental Information (NCEI). AOOS now owns two Hydroballs(™) and continues to make equipment available to the Alaska observing community for use in filling critical, nearshore bathymetric data gaps. The system was demonstrated to be easy to use and deploy from small boats and was specially developed for and has been tested and implemented in shallow water areas, like river mouths and shallow coastal lagoons. AOOS partnered with the NOAA Alaska Region Navigation Manager, ADNR, and NOAA OCS to pilot this technology, which continues to be used by multiple partners across the state. AOOS continues to support the equipment for loan to many projects beyond this project end-date. By 2023, raw data files (RDFs) of bathymetry data collected with community participation in five communities have been published.
- **Who used the information and for what purpose:** NOAA partnered with AOOS on this project to help assess data quality and processing protocols for this specific technology, which was demonstrated during the project award period. ADNR and the UAF Alaska Center for Energy and Power (ACEP) now manage the equipment and continue to work with communities and researchers on data collection activities. Mariners for safe navigation, federal and state resource managers and researchers working on storm surge models and flood assessments, local communities, and others who need information on the nearshore bathymetry of coastal Alaska. Many small native communities spread along the coastline will benefit from data from Hydroball(™) survey efforts for improving safe navigation, especially for barge traffic bringing fuel and supplies into and out of communities.

## **Water Level Observations**

*Subaward to ADNDR - Facilitate an integrated, interagency water level network for Alaska - Alaska Water Level Watch (AWLW).*

- **Purpose of the project:** To improve the quantity and quality of Alaska coastal water level observations and Alaska coastal flood and flood communication mapping products.
- **Key outcomes:** This project supported coordination of the newly formed Alaska Water Level Watch (AWLW) regional collaboration network for improving access to and increasing water level capacity in Alaska; developed and maintained the AWLW webpage; guided the development of the AWLW Data Portal (hosted by AOOS and Axiom (<https://awlw.aos.org/>)). Maintained five operational real-time water level sensors in western Alaska communities; installed tide staffs for the documentation of maximum storm water levels; published 17 color-indexed flood maps in communities where tide datums, community infrastructure, and elevation information were available (<https://dggg.alaska.gov/pubs/id/30160>); developed a statewide database for coastal storm flood documentation (<https://dggg.alaska.gov/pubs/id/30573>); updated the NWS annually on potential flood impacts in advance of seasonal storm events; tested real-time coastal hazard observing camera systems suitable for remote, off-grid, cold region deployments.
- **Who used the information and for what purpose:** The Alaska State Emergency Operation Center and NWS Offices during pre- and post-storm assessment of community flood impacts. Additionally, a few community-specific information requests were received throughout the project that required data transmission or interpretation. These requests came from small Alaska Native communities and engineers contracted to the communities to assess flood or erosion vulnerability. Other users include fisheries resource managers, storm surge modelers and coastal researchers working on community flooding, erosion, melting permafrost and other climate related changes.

*Subaward to UAF - Install rapid deployment inundation platforms (RDIPs) and pressure sensors in coastal communities.*

- **Purpose of the project:** To test a prototype Rapid Deployment Inundation Platform (RDIP), which was a new mounting system community members could use to rapidly deploy water level sensors ahead of pending storms.
- **Key outcomes:** The UAF-Institute of Northern Engineering (UAF-INE) developed a mounting system for residential use in vulnerable coastal communities to rapidly deploy water level sensors for measuring storm surge and wave height during storms. RDIP mounting systems were deployed in three coastal villages in Western Alaska: Shishmaref, Shaktoolik, and Kivalina. Successful storm data from the fall 2017 storm season were collected from Shaktoolik and are available in WGS84 and NAVD88 format along with the raw data. Storm surge data collection was unsuccessful in Kivalina and Shishmaref due to the storage limitations of the loggers and the availability of people in communities to safely reset the loggers before storm events. This project was not continued.
- **Who used the information and for what purpose:** RDIP assemblies were intended to address the lack of appropriate infrastructure in most coastal Alaska communities that complicates the deployment of shore-based water level and inundation sensors. Water level data were provided to AOOS and the NWS for use in improving their storm surge

forecasts. Data and metadata from the Shaktoolik deployment were uploaded to the AOOS Research Workspace, and data were also shared with the ADNDR Division of Geological and Geophysical Survey (ADNDR-DGGS) coastal hazards group, and the NWS.

*Contracts to ASTRA, LLC - Pilot ASTRA GPS telemetered satellite receivers for water level monitoring, develop automated data processing approaches for GPS-R water level computations, and install permanent GPS-R in Utqiagvik.*

- **Purpose of the project:** To continue a technology trial initiated in 2017 and complete a permanent installation in Utqiagvik with Atmospheric and Space Technology Research Associates, LLC (ASTRA; renamed Orion Space Solutions). The ongoing trials were to demonstrate the performance of ASTRA's land-based GPS receivers for the application of global positioning satellite (GPS) satellite reflectometry (GPS-R) for making water level measurements. This project also supported development of automated data processing approaches for deriving water level measurements from various GPS/global navigation satellite system reflectometry (GNSS-R) sites. The Fill the Gaps campaign supported an upgrade to one of the ASTRA/Orion Space Solutions GPS receivers owned by AOOS for permanent installation in Utqiagvik (Barrow). The NWS originally supported these efforts by providing funds to purchase and test the original two ASTRA GPS receivers in 2017.
- **Key Outcomes:** Three new water level observing stations (1 permanent) and two water level sites via data services were added to the AWLW observation network: (1) 2017 Seward, completed one-year GPS-R trials using two co-located ASTRA receivers; (2) 2018 Homer, completed a one-year trial using one ASTRA receiver; (3) 2021 Utqiagvik, completed a permanent water level GPS-R installation. The NWS Alaska Office supported trials in Seward and Homer informed on best practices and conditions suitable for using this methodology. ASTRA also developed automated processing algorithms to derive water level measurements from two UNAVCO GNSS installations (St. Michael and Cape Spencer), adding those two additional water level sites to the AWLW.
- **Who used the information and for what purpose:** This effort responded to the priority in the AOOS Coastal Hazards portfolio to increase real-time water level observations in Alaska using new and cost effective, innovative technologies and methodologies. ASTRA projects demonstrated the efficacy of using GPS/GNSS-R methods for making water level observations in remote Alaska. The systems proved to require little if any maintenance, and once installed were shown to be very cost-effective, especially when using cellular modems (versus iridium satellite) for data filtration. Users of data from both the test sites and the newer permanent station in Utqiagvik include researchers, coastal hazards mitigation planners, the NWS forecasters, numerical modelers. real-time water level data resulting from these projects continue to be publicly accessible via the AOOS Data Portal, and several papers and publications came out of these efforts.

*Contract to UNAVCO (Earthscope Plate Boundary Observatory) - Install a permanent GPS/GNSS telemetered satellite receiver for water level monitoring in St. Michael.*

- **Purpose of the project:** To partner with UNAVCO and implement a permanent GNSS geodetic and GNSS-R water level co-installation in the under sampled region of western Alaska. A memorandum of understanding between UNAVCO and AOOS fostered

cooperation, coordination and partnership between the two organizations in support of the long-term operation of the National Science Foundation (NSF) funded Earthscope Plate Boundary Observatory GPS network and the mission of AOOS.

- **Key Outcomes:** A permanent GNSS-R water level station was installed in the community of St. Michael in Norton Sound, western Alaska, in May 2018. This is one of the few reliable and accurate water level systems in this critical AWLW region, and has remained operational for over six years with no added investment on AOOS' part. The limited operations and maintenance requirements further demonstrated the cost effectiveness of this technology for remote Alaska. The real-time water level data feed from this GNSS-R station continues to be made available through the AOOS and AWLW Data Portals. UNAVCO supports the public satellite data feeds, but does not convert data to water level. A data processing algorithm for water level conversion using RINEX data from the UNAVCO data feed was developed under a separate project with ASTRA and implemented by Axiom during this project period.
- **Who used the information and for what purpose:** This effort was supported by the NWS Alaska Office and responded to the priority in the AOOS Coastal Hazards portfolio to increase real-time water level observations in Alaska using new and cost effective, innovative technologies and methodologies. Data users include resource managers, researchers, coastal hazards mitigation planners, numerical modelers. 2019 data were specifically used by Jacquelyn Overbeck (ADNR) in a report on a storm surge event in Unalakleet, Alaska during the winter of 2019. Data were also extensively used for model validation assessments during the IOOS OTT Western Alaska Storm Models project (IOOS OTT Project Grant NOAA # NA18NOS0120164).

*Subawards to JOA Surveys, LLC - Install water level stations and provide data services for GPS/GNSS telemetered satellite receivers for water level monitoring.*

- **Purpose of the project:** As part of the coastal hazards portfolio aimed at increasing water level observing capacity in critically under sampled regions, multiple AOOS projects were contracted with JOA Surveys (JOA) to install water level stations and provide water level data services from five Alaska data gap regions.
- **Key Outcomes:** JOA added five new real-time water level stations to the AWLW: (1) 2019 Naknek - hardened and converted for year-round observing a temporary summer installation of two bubbler gauges which were part of a NOAA Center for Operational Oceanographic Products and Services (CO-Ops) project; (2) 2021 Dillingham - installed a dual-system water level observing station, including a bubbler and a downward looking radar at the City Dock as part of the 2020 IOOS Fill the Gaps funding and using contributing funds from the UAF; (3) 2021 Peterson Bay (PBAY), developed real-time processing algorithms for computing GPS-R (reflectometry) water level data for the UAF-owned GPS installation near Homer; (4) 2022 Whittier, installed tide gauge equipment provided by the State of Alaska in the small boat harbor using a downward looking Judd acoustic sensor, and tied the data to the network of existing tidal benchmarks via differential leveling; (5) 2021 Utqiagvik, assisted with site reconnaissance and installation of the Utqiagvik GPS-R (reflectometry) station and determined the MLLW (Mean Lower Low Water) tidal datum correction for level-corrected data based on five area benchmarks. JOA also worked on deriving tidal datums



for other GNSS-R systems used for water level at St. Michael and Cape Spencer GNSS-R. All data from new installations report to the AOOS and AWLW Data Portals.

- **Who used the information and for what purpose:** This effort responded to the priority in the AOOS Coastal Hazards portfolio to increase real-time water level observations in Alaska using new and cost effective, innovative technologies and methodologies. Users of data include researchers, coastal hazards mitigation planners, the NWS forecasters, numerical modelers. real-time water level data resulting from these projects continue to be publicly accessible via the AOOS and AWLW Data Portals.

### **Tsunami Warnings**

*Subaward to the Alaska Earthquake Center (ACE) at the Geophysical Institute of the UAF - Enhance seismic and tsunami monitoring capabilities in Alaska.*

- **Purpose of the project:** To sustain seismic observing capacity needed for NOAA tsunami warnings in Alaska by supporting the operations and maintenance of 18 geographically-dispersed, broadband digital seismic stations operated by UAF Alaska Earthquake Center (AEC).
- **Key outcomes:** This project helped AEC achieve annual site maintenance and data delivery from 18 critical seismic stations that required site maintenance but that were no longer supported. AEC made all data collected from the sites available in real-time without cost to other organizations either directly, through the IRIS Data Management Center (DMC), or through the warning centers. Data were archived at the IRIS DMC.
- **Who used the information and for what purpose:** This project supported NOAA's Weather-Ready Nation initiative by providing earthquake observing capacity needed for tsunami warnings that would otherwise not exist in Alaska. The data from these stations also helped enable a more thorough understanding of how, when, and where large subduction zone earthquakes, and the tsunamis they cause, occur.

### **Coastal Hazards Data Products and Services**

*Subaward to Axiom - Develop the AWLW Data Portal.*

- **Purpose of the project:** To develop a prototype data management system and associated interface to house the various water level data and products being collected statewide. The AWLW Data Portal will increase and add to the already existing NOAA National Water Level Observing Network (NWLON) coastal water level observation products (real-time station data, short-term time series, and high-water mark measurements). Development of a robust data management system that parallels the CO-OPS Tides & Currents online system was and remains critical to ensuring that these complementary coastal hazards products are well understood, consistent and readily accessible, specifically because NOAA CO-OPS is not accepting non-NWLON water level data for inclusion on their Tides & Currents System. The first phases of this development were to get the AWLW Data Portal infrastructure scoped and established to achieve data sharing priorities. Portal enhancements were to follow.
- **Key outcomes:** The AWLW Data Portal was launched and accommodates a wide range of observational water level data acquired from external sources. Data types include NOAA NWLON real-time in situ water level observations and predicted tides, and all

non-NWLON real-time water level data external providers share publicly with the AWLW. The portal also hosts a historical database of flood events across Alaska (measurements of high water marks and photographs of impacted areas). A standardized data submission process was implemented, and links to the original station definition forms submitted by the provider are available on the station pages to provide critical information related to datums and other station information and history. A service was developed to tag water level stations ingested into the database with data tier codes (A, B, and C) that stipulate NOAA data accuracy requirements for specific applications. Many of the scoped functionalities have yet to be implemented and were not completed during this project period as planned.

- **Who used the information and for what purpose:** Development start-up funds came from the NWS Alaska Office, and later was cost-shared through the IOOS Fill the Gaps campaign, and the AOOS core program. The key audience for the water level data available through the AWLW portal is the AWLW, composed of state and federal agencies, local governing entities, non-profits, private businesses, and communities. Once functioning as scoped, the AWLW Data Portal will provide a common tool where water level data can be tracked to support decision-making related to flooding, erosion, and permafrost degradation in Alaska.

### C. Ecosystems, Fisheries & Climate Trends

#### Ship-based Sampling

*Subaward to UAF - Support sampling along the long-term Seward Line transect.*

- **Purpose of the project:** To contribute to a consortium of funders led by UAF School of Fisheries and Ocean Sciences (SFOS) (now College of Fisheries and Ocean Sciences (CFOS)), to support sampling along the Seward Line, the longest multidisciplinary oceanographic time series in Alaska. This project helped sustain long-term observations of ecosystem conditions made seasonally year-round in one of Alaska's Large Marine Ecosystems (LMEs) that contribute to the pan-regional series of ecosystem observations spanning the Northern Gulf of Alaska to the eastern Beaufort Sea.
- **Key outcomes:** Sampling along the Seward Line continued a critical long-term data time series on interdisciplinary oceanographic conditions in the Gulf of Alaska, making multi-seasonal observations to monitor how the marine ecosystem and diverse biology may be changing due to climatological changes. The Seward line has been sampled continuously since October 1997, with some measurements (station GAK1) going back to the late 1970's. AOOS support helped bring this sampling program through its 23rd year. The importance of oceanographic data collection and time series analysis from this project was emphasized by the dramatic warming of the northeast Pacific starting in late 2013 and continuing through 2016 (the Pacific marine heat wave known as the "Blob"). Data are publicly available for both visualization through 2013 on the AOOS Data Portal and for download through 2016 via the AOOS hosted data portal for the [Gulf Watch Alaska Program](#), the long-term ecosystem monitoring program of the Exxon Valdez Oil Spill Trustee Council (EVOSTC) for the marine ecosystem affected by the 1989 oil spill. The NSF Northern Gulf of Alaska long-term Ecological Research Program (NGA LTER) joined the consortium co-sponsoring the Seward Line in 2018. Cross calibration of ocean acidification (OA) data at a subset of Seward Line stations were also used to assess

comparability of methodologies between the two high-precision analytical groups and Burk-o-Lator (BoL) run discrete samples, evaluate and determine accuracy limits of both high precision laboratory and BoL methods, and provide a better understanding of how OA data can be integrated and compared across the region, given the diverse methodologies being employed.

- **Who used the information and for what purpose:** The scientific community and researchers utilize this information to understand marine climate variability and ecosystem change in the long-term, as well as how conditions affect ocean circulation and productivity in the short term. Fisheries managers tasked with performing EAFM are also using this information to complete their annual indicators reports for setting fishing quotas for the Gulf of Alaska.

*Subaward to NOAA National Centers for Coastal Ocean Science (NCCOS) Kasitsna Bay Laboratory - Collect oceanographic data along repeat shipboard transects in Kachemak Bay and lower Cook Inlet.*

- **Purpose of the project:** To maintain oceanographic observations in Kachemak Bay and lower Cook Inlet, Alaska that monitor seasonal and interannual oceanographic variability, provide data to assess risks from harmful algal blooms, climate change, oil spills and ocean acidification, and facilitate development of decision support tools for coastal planners and resource managers. Observations from more hyperlocal nearshore areas in the northern Gulf of Alaska contribute to the pan-regional series of ecosystem observations spanning the Gulf of Alaska to the eastern Beaufort Sea.
- **Key outcomes:** The importance of oceanographic data collection and time series analysis from this project was emphasized by the dramatic warming of the northeast Pacific (including Kachemak Bay) starting in late 2013 and continuing through 2016 (the Pacific marine heat wave known as the “Blob”). Ocean monitoring in Kachemak Bay was used with observations across the northern Gulf of Alaska to help understand changes in fish, seabird and marine mammal populations during the marine heat wave, along with increases in toxic algae and paralytic shellfish poisoning events. This project also assisted on multiple occasions (+2) on recovery and deployment operations of the Lower Cook Inlet CDIP Program wave buoy managed by AOOS.
- **Who used the information and for what purpose:** Key support for these efforts came from the EVOSTC, who is interested in the recovery of resources from the 1989 spill affected regions in the northern Gulf, and NOAA NCCOS Kasitsna Bay Laboratory. Users include researchers and resource managers. Data provide a long-term observing baseline for the region and aid development of decision support tools for resource and coastal management. Data are being used to validate Cook Inlet ocean circulation models (e.g., NOAA NOS operational CIOFS). Oceanographic, nutrient, and OA data are improving understanding of spatial and temporal variability in oceanographic conditions, carbonate chemistry and nutrients in the subarctic estuary of Kachemak Bay Alaska.

## Ecosystem Moorings

*Subawards to UAF - Continue incremental build-out of a moored Gulf of Alaska Ecosystem Observatory (GEO) and the Chukchi Ecosystem Observatory (CEO) and sensor acquisition.*

- **Purpose of the project:** Two moored ecosystem observatories (EOs) in Alaska were under development during this project period to support the Arctic Marine Biodiversity Observing Network and other programs. Both EOs are funded through a consortium of partners. As one of the funding partners, AOOS provided annual support to continue the incremental build-out of the GEO (Gulf of Alaska) and the CEO (Chukchi Sea) moored EOs by providing funding for equipment purchases, sensor maintenance, and operations. These moored observatories record ecosystem conditions continuously year-round in two of Alaska's LMEs, and are part of a pan-regional series of ecosystem moorings spanning the Northern Gulf of Alaska (GEO) to the eastern Beaufort Sea (BLE LTER).
- **Key outcomes:** These efforts resulted in the development, build-out and deployment of multi-instrument and multi-disciplinary moorings: (1) CEO initially deployed in 2014 near Hanna Shoal in the northeast Chuck Sea; and (2) GEO initially deployed in 2019 near the Seward hydrographic line in the northern Gulf of Alaska. After eight years of mooring deployments, the CEO program is now featured in more than 15 published, in-review, or nearly submitted peer-review manuscripts. The GEO program, with fewer years of data, is just beginning to see published results. Novel equipment additions included an AguaMonitor water sampler (GreenEyes) that provides eDNA samples used for detection of fish species, and a benthic time-lapse camera systems (Sexton) to observe benthic invertebrates, making year-round images of the seafloor to assess changes in assemblage, structure, and movement rates of mobile benthos. Another system quantifies marine gas exchange dynamics. Some deployments involving sensors on surface floats have resulted in both success and failures, but on balance the EOs have achieved great returns. Select datasets from these moorings are available for viewing and download on the AOOS Data Portal.
- **Who used the information and for what purpose:** Baseline and temporally-indexed measurements are essential for understanding long period, time-dependent marine and ocean-atmosphere interactions. As the Northeast Pacific continues to undergo transformative changes over the century as warming continues and episodic El Niño and marine heat-wave events amplify temperature effects on the ecosystem, changes in the physical environment will likely initiate a cascade of biological consequences that reduce an ecosystem's resilience (ability of the system to withstand disturbances) and increase its vulnerability to detrimental impacts (extent of harm from stressors). As the EO data series lengthen, these data sets will become more valuable to scientific research and societal applications. Numerical modelers are already using the CEO data to validate biogeochemical and ecosystem models, and data are valuable for Alaska-regional management and indicator reports used for fisheries management efforts.

*Subaward to NOAA Pacific Marine Environmental Laboratory (PMEL)/Alaska Fisheries Science Center (AFSC) - Build-out Ecosystem Observatory at Bering Sea Mooring Site M8.*

- **Purpose of the project:** To continue the incremental build-out of moored EOs in the Bering Sea and enhance multi-instrument and multi-disciplinary moorings that record ecosystem conditions year-round in one off Alaska's LMEs. This project specifically

supported nutrient and optical water properties sensor acquisition to build-out existing NOAA PMEL Ecosystems and Fisheries Oceanography Coordinated Investigations (EcoFOCI) mooring M8, establishing a more complete northern Bering Sea Ecosystem Observatory as part of a pan-regional series of ecosystem moorings spanning the Northern Gulf of Alaska (GEO) to the eastern Beaufort Sea (BLE LTER).

- **Key outcomes:** A Sea-Bird Scientific (SATLANTIC) SUNA sensor to measure nitrate, and a Sea-bird Scientific (WETLabs) Triplet sensor that measures chlorophyll, FDOM fluorescence, and red backscattering were acquired for build-out of M8 in time for the fall 2020 NOAA PMEL EcoFOCI mooring cruise. The mooring with these sensors was deployed in October 2020 and was successfully recovered in September 2022 after being deployed for two years. COVID-19 delayed scheduled annual mooring service in 2021.
- **Who used the information and for what purpose:** As with the CEO and GEO, baseline and temporally-indexed measurements are essential for understanding long period, time-dependent marine ecosystem and ocean- atmosphere interactions. Measurements from these 'connected' observatories (CEO in the northern Chukchi Sea, M8 in the northern Bering Sea and M2 in the southern Bering Sea) provide more robust data to scientists on year-round changes in ocean conditions, biological and chemical properties, and ecosystem change. Data from M8 observatory will be integrated into a transfer of information to AOOS (and IOOS) and shared with Alaska-regional managers and through indicator reports used for fisheries management.

*Subaward to University of Texas at Austin (UTA) - Beaufort Lagoon Ecosystems Long-Term Ecological Research (BLE LTER) mooring sensors.*

- **Purpose of the project:** The NSF BLE LTER Program deploys mooring arrays along the Beaufort Sea coast to determine how climate change impacts such as permafrost thaw, shifting precipitation regimes, and losses of sea ice alter the hydrographic and physio-chemical characteristics of the nearshore environment. This project provided additional equipment for the moored arrays to provide continuous, high-frequency records of pH and dissolved oxygen used to investigate trends in ocean acidification and ecosystem metabolism.
- **Key outcomes:** Three Sea-Bird Scientific SeaFETs (™) to measure pH and four miniDOTs (™) to measure dissolved oxygen were acquired for deployment at the BLE LTER long-term moorings in August 2022. The addition of these sensors to the BLE LTER array has since established a continuous, high-frequency record of pH and dissolved oxygen observations in the Alaskan Arctic nearshore environment. Data are providing insights to environmental regulators of ecosystem metabolism and ocean acidification. This support enhanced multi-instrument and multi-disciplinary moorings that record ecosystem conditions year-round in one off Alaska's LMEs, contributing to part of the pan-regional series of ecosystem moorings spanning the Northern Gulf of Alaska (GEO) to the eastern Beaufort Sea (BLE LTER).
- **Who used the information and for what purpose:** The addition of pH and dissolved oxygen sensors makes it possible for researchers to accurately assess rates of whole ecosystem metabolism throughout the year, especially during the iced-over period and break-up. The BLE LTER anticipates long-term data streams (10+ years) with significant

results generated by these instruments that will be used by the scientific community and government agencies.

*Subaward to PWSSC - Conductivity-Temperature and Acoustic moored arrays in Prince William Sound.*

- **Purpose of the project:** To maintain long-term observations of fish movements from the Ocean Tracking Network (OTN) acoustic monitoring array, and to establish long-term oceanographic observations for temperature and salinity in Prince William Sound, filling a critical data gap in the highly under sampled southeast Alaska region with respect to basic ocean temperature and salinity conditions. Observations from the hyperlocal Prince William Sound area in the northern Gulf of Alaska contribute to the pan-regional series of ecosystem observations spanning the Gulf of Alaska to the eastern Beaufort Sea.
- **Key outcomes:** The OTN array was maintained and upgraded to continue providing important information on the timing of migration into and out of Prince William Sound for Pacific herring, and movement patterns into and out of the Sound by chinook salmon (tagged by NOAA) and sleeper sharks (tagged by Wildlife Technology Frontiers). The conductivity-temperature (CTD) sensor was deployed in cooperation with NOAA CO-OPs at the NOAA NWLON water level station in Cordova, providing real-time temperature, conductivity and derived salinity (TS) information during the 5-year project. This is one of the only long-term coastal TS stations in a region with the highest freshwater inputs to the Northern Gulf of Alaska and the North Pacific.
- **Who used the information and for what purpose:** Researchers, ocean and atmospheric modelers, fishery managers, resource agencies, oil spill investigators, and tribes.

*Subaward to the Wildlife Conservation Society (WCS) - Acoustic moored array in Kotzebue Sound.*

- **Purpose of the project:** To document the use of the Kotzebue Sound by beluga whale and seals, as well as other key species such as harbor porpoise, killer whale, and any large cetaceans (e.g., gray, humpback, fin) using passive acoustic monitoring on moorings.
- **Key outcomes:** All equipment was purchased and received for deployment in April 2022.
- **Who used the information and for what purpose:** This work will inform several key policy areas for the Native Village of Kotzebue, including Tribal resource management plans, ESA deliberations, vessel traffic policy, and responding to resource development activities in Kotzebue Sound. WCS completed the purchasing activities above for the purpose of this award, the rest of this 3-year project will be in collaboration with the Native Village of Kotzebue (Alex Whiting), University of Washington (UW; Manolo Castellote), and California Ocean Alliance (Brandon Southall).

### **Autonomous Underwater Vehicles/Gliders for Ecosystem Assessment and Fisheries Management**

*Subawards to Woods Hole Oceanographic Institute (WHOI), UAF, and University of Washington (UW) - Marine mammal and oceanographic survey of the Chukchi Sea using a Slocum autonomous underwater glider.*

- **Purpose of the project:** To monitor vocal marine mammal occurrence in the Chukchi Sea utilizing the digital acoustic monitoring (DMON) instrument and the low-frequency detection and classification system (LFDACS) while mapping oceanographic conditions using an autonomous underwater Slocum ocean glider. These sustained long-term observations of ecosystem conditions made seasonally in one of Alaska's LMEs contribute to the pan-regional series of ecosystem observations spanning the Northern Gulf of Alaska to the eastern Beaufort Sea.
- **Key outcomes:** The Chukchi glider surveys started in 2013. Four additional years of simultaneous passive acoustic/marine mammal identification and oceanographic surveys of the Chukchi Sea were completed in this project period using a single Slocum autonomous underwater glider during summers of 2016-2018, and 2020. The glider surveyed south to north using an onshore-offshore zigzag track to cover different oceanographic environments in order to understand how oceanography influences marine mammal community composition and distribution. Due to technical issues, 2019 was the only year a glider deployment was not completed. Subarctic marine mammals, including humpback, fin, and gray whales, were detected on every transect, illustrating the extent to which non-endemic species now visit the Arctic. Killer whales, an emerging predator in the Arctic, were detected every year. Unsurprisingly, Arctic endemic species (walrus, bearded seals, and bowhead whales) were most often detected in the northeastern, and not the southern, Chukchi Sea.
- **Who used the information and for what purpose:** Information on the occurrence, distribution, and habitat of many Arctic marine mammals is important to scientific researchers and resource managers for assessing the health of Alaska marine ecosystems. The results from this project are particularly vital for informing communities that rely on marine mammals for subsistence, particularly during current accelerating climate change and industrial development.

*Subaward to UAF - Conduct glider surveys in the Gulf of Alaska and the Bering Sea in support of EAFM.*

- **Purpose of the project:** To support EAFM activities, including those conducted by the NPFMC, a world leader in the implementation of EAFM for maintaining sustainable fisheries. A successful implementation of EAFM is based on timely (near real-time) information that guides an informed approach to setting fisheries harvest levels in the context of environmental conditions.
- **Key outcomes:** Glider upgrades were completed to the existing UAF Teledyne Slocum G2 glider fleet and all three gliders have been utilized in numerous deployments in the Gulf of Alaska and in the Chukchi Seas for improved real-time monitoring of the marine environment. This project also supported glider pilot training and glider mission operations for multiple deployments in Prince William Sound and the Gulf of Alaska. This project worked closely with the NOAA IYS demonstration for operational readiness of AUV-based ecosystem monitoring, and applied autonomous underwater gliders to the task of developing real-time indices of key physical and biological parameters to inform the NPFMC EAFM decision-making process and other fisheries management related research activities. The real-time ecosystem indicator time series was submitted to the NPFMC for inclusion in their ecosystem status reports (ESRs). This project also

supported glider missions in key fishing areas in the northern Gulf of Alaska and Prince William Sound, one of Alaska's LMEs, and contributed to the pan-regional series of ecosystem observations spanning the Northern Gulf of Alaska to the eastern Beaufort Sea. In conjunction with the NOAA OAR Program funded IYS glider efforts, an Ecometrics Dashboard application was developed that allows near real-time evaluation of the ecosystem to assess if anomalous conditions are occurring. The near-real-time data delivery and visualization now better supports operations and allows analysts to add or redefine glider trajectories to supplement or change how samples are acquired and ensures that data are received if the vehicle is not recovered.

- **Who used the information and for what purpose:** Conditions observed by the EAFM gliders displayed through the Ecometrics Dashboard may impact food web dynamics and living marine/managed resources in the region and are critical components of the EAFM framework. Data are therefore used for the Ecosystem-Based Fishery Management (EBFM) Policy implementation and the EBFM model for maintaining sustainable fisheries. Data from the EAFM glider program is slowly starting to be integrated into the NPFMC ESRs. Other major data customers include researchers, fisheries managers, NOAA, and glider operators.

*Subaward to UAF and UW - Demonstrate operational readiness of AUV-based ecosystem monitoring through a field program supporting the IYS.*

- **Purpose of the project:** To support the NOAA's OAR Program efforts to expand the sampling capability of a Slocum autonomous underwater gliders that provide in-situ ecosystem monitoring, and demonstrate an advanced readiness level for operationalizing an AUV-based ecosystem monitoring system, with application to sustainable resource management. Efforts were closely integrated with ongoing AOOS supported EAFM glider project activities, and both projects benefited from cooperative collaborations between NOAA, UW, UAF, and Axiom. This project also supported glider missions in key fishing areas in the northern Gulf of Alaska, one of Alaska's LMEs, and contributed to the pan-regional series of ecosystem observations spanning the Northern Gulf of Alaska to the eastern Beaufort Sea.
- **Key outcomes:** Glider missions in the northern Gulf of Alaska were supported during this project. An echosounder and auxiliary processor were successfully integrated in an autonomous underwater glider to provide near-real-time biological and environmental data through a satellite line that was then visualized in near real-time on the AOOS Data Portal website during glider missions. The ability to independently monitor data in near real-time provided unprecedented access to in-mission data and simultaneously disseminated the data to a global audience. The combination of biological and environmental sensors now provides an ecological suite of data streams that can be used to characterize any ecosystem, and the combination of active acoustics and environmental sensors provides a generic ecosystem sampler that can be deployed for long periods, cover large spatial ranges, and is economical to operate compared to a personnel-staffed vessel. The addition of active acoustics to the traditional glider instrumentation package also expanded the glider capability to sample upper trophic levels throughout the water column. The project successfully demonstrated that an ecosystem monitoring underwater glider can supplement and/or replace many components of vessel-based surveys, be deployed when staffed vessel platforms may have limited availability (as was the case



during COVID-19), and can be used operationally for long-term monitoring of high latitude environments.

- **Who used the information and for what purpose:** Researchers, fisheries managers, the NPFMC, NOAA, and glider operators. Data are used for the EBFM Policy implementation and the EBFM model for maintaining sustainable fisheries. The near-real-time data delivery and visualization provides opportunities for analysts to add or redefine the glider trajectory to supplement or change how samples are acquired and ensures that data are received if the vehicle is not recovered. The project data contributed fisheries acoustic and other environmental data to the IYS field program and improved scientist and fisheries manager understanding of winter-season North Pacific ecosystem dynamics.

*AOOS one-time purchase for Institute for Seabird Research and Conservation (ISRC) Middleton Island Seabirds Project - Capelin fish acquisition.*

- **Purpose of the project:** To purchase 5000 lbs frozen capelin for 2022 field season. The Middleton seabird project is part of the pelagic ecosystem component of Gulf Watch Alaska, an EVOSTC ecosystem observing program that covers forage fish sampling on Middleton Island in Prince William Sound. This support was used for continuing research on seabird diets, which was not supported by the EVOSTC program.
- **Key outcomes:** The fish purchase by AOOS provided the ability to continue a vital study component that underpins much of the design and utility of seabird research and monitoring on the island.
- **Who used the information and for what purpose:** Researchers and resource managers working on ecosystem shifts in seabird populations dynamics and their responses to short and long-term changes in the environment related to events like an oil spill (short term response then longer-term recovery) all the way to climate change induced trends. Seabird responses at Middleton, including results from the long-term experiment and thorough sampling of seabird diets provide clear indicators of shifting ocean regimes.

### *Ecosystem Data Products and Services*

*Subaward to Axiom - Ecosystem glider monitoring dashboards.*

- **Purpose of the project:** To expand the sampling and data service capability of a Slocum autonomous underwater glider in support of the NOAA OAR AUV-based ecosystem monitoring field operations during the IYS. This project was to demonstrate operational-ready, automated near-real-time ocean-to-internet UxS system for ecosystem data collection, processing, monitoring, and reporting. Specifically, this project was to make real-time and post-processed glider data accessible through the AOOS Data Portal and to develop an Echometrics Dashboard that could expose past and current environmental conditions while the gliders were underway.
- **Key outcomes:** This project delivered environmental metrics from the Gulf of Alaska in near-real-time through a web-based Echometrics Dashboard available through the AOOS Data Portal. Initial version of the data dashboard was deployed in February 2022 for inspection and testing during the 2022 IYS glider deployments and cruises. Axiom used the Glider Utilities package to support transforming data and metadata in JSON format to NetCDF formats compliant with the DAC services. This effort required significant

troubleshooting and updates to the data and metadata formatting with the IOOS Glider DAC developers. Both package and metadata enhancements will be made with continued funding for this project to ensure smoother submission of those data in real-time to the DAC.

- **Who used the information and for what purpose:** This project supported NOAA Fisheries Climate Science Strategy and EBFM Policy. Outputs from this project are intended to be shared with members of the NPFMC for ready access to physical and biological parameters in the Gulf of Alaska.

*Subaward to Axiom - Enhance the utility of AFSC's ESRs and Integrated Ecosystem Assessment (IEA) Indicators.*

- **Purpose of the project:** To display National Marine Fisheries (NMFS) ecosystem integrated ecosystem assessment (IEA) indicators from Alaska ESRs as a report card/dashboard on AOOS portal as part of a State of Alaska's Coasts and Oceans synthesized report.
- **Key outcomes:** AOOS and Axiom developed requirements for the ESR dashboard tool. Data from the indicators were ingested, standardized, and a dashboard mock-up was created.
- **Who used the information and for what purpose:** The dashboard remains in prototype format. If desired by NMFS/AFSC, AOOS will continue to develop the dashboard.

*Subaward to Coastal Observation and Seabird Survey Team (COASST) for Bio OTT Coastal Biology - Integrate historical COASST beached bird monitoring data into the AOOS and MBON Data Portals using Darwin Core Standards.*

- **Purpose of the project:** To provide the historical records of sea-bird mortality data from 10 locations in the form of date, location and most specific taxon conforming to the Darwin Core Standards, with the ultimate goal to make the data publicly-available in the AOOS and Marine Biodiversity Observation Network (MBON) data portals for use by various stakeholder audiences.
- **Key outcomes:** COASST provided AOOS with a post-processing script needed to generate summaries of beached bird abundance, and specifically three flat-file data products that can be incorporated into the AOOS platform to enable exploration of beached bird data throughout Alaska. Period of data completed during this effort was 2006 to 2021. COASST staff worked closely with Axiom staff on metadata development for these data files and visualization requirements to make the data useful and discoverable without compromising data integrity.
- **Who used the information and for what purpose:** COASST volunteers have been collecting beached bird data in Alaska from 2006 to present, and since surveys were initiating in Alaska 189 beaches have been surveyed from Ketchikan in Southeast Alaska, east in the Aleutian Island chain, and north to Kotzebue in the Chukchi Sea. This unique data record from Alaska complements other efforts on archiving data from other west coast regions cataloging marine bird mortalities, including Central and Northern California Ocean Observing System (CeNCOOS); Effort-based surveys, Northern and Central California Beaches: Seabirds and Marine Mammals – Bird Carcasses).

*Subawards to Axiom for Bio OTT Coastal Biology - Enhance the North Pacific Seabird Data Portal tool, aligning data to Darwin Core Standards, and integrate historical COASST Beached Bird Monitoring Data into the AOOS and MBON Data Portals using Darwin Core Standards.*

- **Purpose of the project:** These projects were combined to provide the U.S. Fish and Wildlife Service (USFWS) and its stakeholders with an updated version of the [North Pacific Seabird Data Portal](#) for discovering and interacting with seabird information and to ingest 15 years of COASST beached seabird mortality observational data from Alaska coasts. Sea bird data were to be aligned to Darwin Core Standards for inclusion in the AOOS and MBON Data Portals.
- **Key outcomes:** This project successfully upgraded the North Pacific Seabird Data Portal and enhanced the web map tool to ease discovery, access, and visualization of seabird data layers. Fifteen years of seabird mortality data from the COASST program, an established citizen-science volunteer monitoring of beached seabird abundance in Alaska, were translated from native version to the Darwin Core Standard and visualized in the AOOS and MBON Data Portals.
- **Who used the information and for what purpose:** AOOS received funding from the IOOS Program to advance biological data stewardship activities in the AOOS region, working with regional data providers to align biological datasets to the Darwin Core Standard and make them available through ERDDAP servers and the North Pacific Seabird, AOOS, and MBON data portals. The Darwin Core Standard is useful as it allows for the integration of these diverse datasets most simply, consistently and efficiently so scientists, analysts and policymakers can use them in research and policy. The availability of these beached bird data through the data portals allows for integration with other ecosystem monitoring efforts to facilitate detection and communication of concurrent conditions associated with normal versus anomalous seabird mortality and understanding of North Pacific marine ecosystem change.

*Subaward to Oregon State University (OSU) - Increase the accessibility and application of the regional downscaled seascape product for the U.S. Arctic region.*

- **Purpose of the project:** To increase access to the downscaled seascape product for the U.S. Arctic.
- **Key outcomes:** High resolution seascapes for Chukchi and Beaufort Seas are [now available on the AOOS Data Portal](#).
- **Who used the information and for what purpose:** This data product provides more regionally-focused (Arctic) information to the scientific community and resource managers about the quality and extent of different oceanographic habitats or features and can be used to assess and predict the different planktonic and fisheries communities that reside within seascapes.

## **D. Water Quality**

### **Marine Debris**

*AOOS Sponsored Alaska Marine Debris Summit - Leveraging Resources to address Debris Disposal and Microplastics.*

- **Purpose of the project:** A collaboration amongst the Environmental Protection Agency, NOAA, the Alaska Department of Environmental Conservation, and AOOS hosted a workshop on marine debris issues in the state of Alaska.
- **Key outcomes:** A workshop was convened as a listening session during the Alaska Forum on the Environment Conference February 10-14, 2020. Topics included how to characterize marine debris issues onshore/nearshore, reporting, and points of contact for Alaska; congressional updates and the current status of legislation and congressional priorities; case studies demonstrating marine debris disposal needs, best practices, successes, lessons learned. The workshop hosted community panels of members from numerous Alaska coastal communities, and drafted the scope for a marine debris action plan for Alaska.
- **Who used the information and for what purpose:** This was the start of coordinated discussions on how to address marine debris issues in the state of Alaska.

### **Ocean Acidification**

*OAP Project awards to AOOS - Maintaining the Alaska Ocean Acidification Network (AOAN) and engaging Alaskans to advance ocean acidification science, public understanding and response.*

- **Purpose of the project:** To provide outreach and engagement activities and products for Alaskans to advance ocean acidification science, public understanding and response, foster coordination of regional monitoring and research efforts related to OA, engage with stakeholders to communicate state of the science and improve public understanding of OA processes and consequences.
- **Key outcomes:** This project provided salary support for the AOAN Coordinator position, and also provided financial support for the development of an AOAN website, researcher travel to outreach events, community sampler travel to attend water sample collection training workshops and ‘State of the Science’ workshops. It also supported the production of outreach materials and events related to OA tailored to specific audiences such as shellfish growers, including the production of a short video, the production of a central OA exhibit to be displayed at the Alaska SeaLife Center in Seward, and several community meetings and two AOAN State of the Science Workshops.
- **Who used the information and for what purpose:** Most of the work supported outreach to the public, fishing communities, coastal subsistence communities, and resource managers to provide ocean acidification information and products.

*Subawards to UAF- Sustaining time series monitoring of OA.*

- **Purpose of the project:** To continue a ten-year (2008-2017) regional water sampling time-series in the Gulf of Alaska along the Seward Line (through 2017), and support the operations and maintenance of moored OA sensors including the collection of water samples for calibration and validation of OA sensor-equipped NOAA PMEL moorings in the Gulf of Alaska (GAKOA) and the southeastern Bering Sea (M2). This project also supported the shared-purchase of a lab-based OA monitoring system, a BoL, for operations at the Kodiak NOAA AFSC, and ocean acidification sensors for deployment on the NOAA PMEL OA moorings.

- **Key outcomes:** This project supported biannual research cruises in the northern Gulf of Alaska to collect OA water samples during each cruise at repeat stations along the Seward Line and in the western Prince William Sound through 2017. Water samples were also collected throughout the project period during cruises to maintain calibrations of moored sensors and validate the surface OA data coming from the NOAA PMEL moored platforms at the GAKOA and M2 moorings. The finalized 10-year dataset of marine inorganic carbon chemistry parameters taken along the Seward Line between 2008 and 2017 was published following Ocean Carbon and Acidification Data System (OCADS) standard formatting to facilitate ingestion into the NCEI OCADS archive. Additional support was provided in 2018-2020 from the NOAA Ocean Acidification Program (OAP) to specifically maintain and operate the moored OA sensing infrastructure at these two moorings, as the initial infrastructure funding was insufficient for long-term operation. Equipment was serviced and maintained in order to continue to provide uninterrupted surface OA observations from the moorings. As of 2021, the GAKOA and M2 sites are officially recognized within the National Ocean Acidification Observing Network (NOA-ON).
- **Who used the information and for what purpose:** NOAA Fisheries and university researchers conducting species response studies, and eventually coastal communities when data products are complete. GAKOA mooring data are used as an oceanic reference point for the shoreside BoL ocean acidification monitoring station at the Alutiiq Pride Marine Institute. M2 biophysical mooring data provide a unique ability to combine innovative technologies to observe the holistic ecosystem changes in the southeastern Bering Sea. The M2 mooring data are also used as a reference point for NOAA PMEL's Innovative Technology for Arctic Exploration (ITAE) group. Both the moored and water sampling time series datasets are helping determine seasonal and interannual trends on the marine inorganic carbon system parameters in Alaska waters. Data are also used by the research community to better understand comprehensive spatial information on OA conditions across the shelf and throughout the water column in high latitude coastal seas.

*Subaward to UAF - Conduct a full-scale regional OA monitoring cruise in the Gulf of Alaska.*

- **Purpose of the project:** To continue tracking OA conditions in the Gulf of Alaska system by maintaining the regional time series initiated in 2008 and ending in 2017, and updating regional biogeochemical algorithms leading towards the development of an OA indicator.
- **Key outcomes:** This project was to be conducted in spring of 2020, four years after the last large-scale regional OA sampling in the Gulf of Alaska, but was delayed due to vessel capacity and later due to work/travel restrictions during the COVID-19 pandemic. A modified (reduced) scale survey was eventually completed August 8 – 30, 2022. 150 CTD casts were completed with preliminary analysis showing patterns across depths similar to the 2015 NOAA OAP GOA sampling cruise. Rutgers deployed a Glider during this cruise to augment the modified survey coverage (see following project).
- **Who used the information and for what purpose:** As with all OA data being observed from the Gulf of Alaska via shipboard efforts, moorings and shore-based observing, data are used by the research community to better understand comprehensive spatial information on OA conditions across the shelf and throughout the water column in

Alaska coastal seas. Anticipated users of the Gulf of Alaska OA data from 2020 include NOAA Fisheries Aquaculture Opportunity Area process, the NPFMC ESR, and the data will be used as input for Claudine Hauri's Gulf of Alaska Downwelling Index (GOADI), and will contribute to a synthesis product alongside other regional sampling efforts.

*Subaward to Rutgers University - Autonomous glider assessment of pH and Plankton in the Southeastern Gulf of Alaska in support of the simultaneous ocean acidification cruise.*

- **Purpose of the project:** To collect biogeochemistry data in the Gulf of Alaska using a Slocum glider to augment shipboard sampling efforts of the NOAA Gulf of Alaska ocean acidification cruise in 2022.
- **Key outcomes:** The glider was deployed out of Sitka, AK on July 14, 2022 and recovered on August 12, 2022. The glider covered 250 km and collected 286 vertical profiles of temperature, salinity, chlorophyll, pH, dissolved oxygen before encountering a leak and being recovered. Data were used to derive total alkalinity and aragonite saturation state. Near real-time glider data (raw, uncorrected) streamed to ERDDAP during the deployment. Processing of the full glider dataset and quality control procedures are complete, and the final processed delayed-mode dataset is openly available on both the glider DAC (<https://gliders.ioos.us/erddap/tabledap/ru26d-20220714T2322-delayed.html>) and the NCEI Ocean Carbon and Acidification Portal (OCADS; Accession # 0281161; <https://www.ncei.noaa.gov/data/oceans/ncei/ocads/metadata/0281161.html>). Project PIs also conducted outreach on behalf of this project to the communities around Sitka.
- **Who used the information and for what purpose:** As with the OA data from the Gulf of Alaska shipboard efforts and moorings and shoreline observing, data are used by the research community to better understand comprehensive spatial information on OA conditions across the shelf and throughout the water column in Alaska coastal seas.

*Subaward to UAF - Co-locate chemical monitoring and forecasts with current fishery and ecosystem monitoring activities for inclusion in NOAA's IEA Program ESR.*

- **Purpose of the project:** To improve understanding of the links OA and fisheries population dynamics, and to improve the forecasting of OA to benefit fishery biologists in NOAA's IEA Program and fisheries managers through the ESR. This project co-located in situ monitoring of OA parameters at sampling sites visited during NOAA fisheries research cruises in the Bering Sea to help develop an OA forecast through a newly developed carbonate chemistry package for the Bering10K model. This model is already used by the Bering Sea IEA Program. The efforts will ultimately enable the development of an OA index for the Bering Sea ESR.
- **Key outcomes:** Efforts to collect and analyze co-located chemical oceanographic water samples as part of the Bering Arctic Subarctic Integrated Survey (BASIS) survey cruises were delayed due to COVID-19 restrictions that canceled the BASIS cruise scheduled for 2020. The next scheduled BASIS Research Cruise was completed during August-September 2022, and sample analysis was completed in time for inclusion in the annual ESR report due each October. OA was included in the "Emerging Stressors" section of the ESR. This rapid turnaround in sample collection to reporting had not been done before. Data archiving was completed in March 2024.

- **Who used the information and for what purpose:** Key improvements in the forecasting of OA will benefit fishery biologists in NOAA's IEA Program and fisheries managers through the ESR. The primary audience for the ESR is the NPFMC. The actual audience is quite large as NOAA does well at getting these reports out to a wide range of stakeholders including researchers, fishers, coastal communities, policy makers and state, federal, and Tribal governments.

*Subaward to the UAF - Execute a comprehensive carbonate chemistry assessment of U.S. Distributed Biological Observatory (DBO) stations.*

- **Purpose of the project:** To integrate a carbon chemistry assessment into the DBO program by collecting discrete water samples and processing and publicly archiving the data. This project supported a comprehensive carbonate chemistry assessment during U.S. DBO activities during the 2018, 2019, and 2020 field seasons.
- **Key outcomes:** This project funded the laboratory analysis of discrete water samples collected during three ship-based oceanographic cruises between 2019-2020, and supported the collection and evaluation of temperature/salinity and the ASVCO<sub>2</sub> (carbonate chemistry sensing equipment) data collected from two autonomous surface-mapping glider Saildrone missions in 2018 and 2019. The combination of Saildrone and traditional shipboard sampling provided high resolution measurements. Comparisons of water sample and Saildrone data validated the performance of the ASVCO<sub>2</sub> sensors deployed on the Saildrone.
- **Who used the information and for what purpose:** Pacific Arctic Region ecosystems are vulnerable to OA and experiencing sustained exposure to corrosive waters every year and require data to characterize OA in this under sampled region. Researchers are using the OA parameters observed on the DBO 'Change Detection Array' to identify important ecosystem vulnerabilities and uncover areas of unexpected resilience.

*Subawards to Alutiiq Pride Shellfish Hatchery (APSH) - Maintain continuous ocean acidification monitoring and community sampling using a permanently installed BoL.*

- **Purpose of the project:** To expand understanding of ocean carbon system conditions and impacts through continuous BoL monitoring of coastal waters in Seward, AK, supporting regional community sampling efforts, laboratory-based OA exposure studies, and deployment and testing of a new low-cost CO<sub>2</sub> analyzer known as an Autonomous Coastal Drifting CO<sub>2</sub> (ACDC) system. One-time support also upgraded a new water heater and associated plumbing infrastructure to the lab.
- **Key outcomes:** APSH produced continuous carbon system data from the BoL and expanded their regional discrete community sampling program to include seven additional Tribal communities. The APSH provides the longest nearshore OA observation site in Alaska of continuous OA monitoring (>8 years as of 2020). APSH developed a lab to conduct organism exposure studies and the capacity to prepare liquid standards used for calibrating/validating the BoL. APSH now has a fully developed discrete monitoring program with 15 partners, and has added a species exposure module and a pore sampling program. APSH completed filming a community sampler video working with the Ocean Foundation and Dr. Burke Hales to develop a portable sensor for use in shellfish hatcheries to dose with buffers for OA mitigation. The de-ionizing water

system at Seward Marine Center and used by APSH became inoperative, so a new water system and heater, along with upgraded plumbing, was installed and is now operating at APSH.

- **Who used the information and for what purpose:** BoL data are submitted to the IPACOA and AOOS data portals for use by the research community, and are published as a finalized data product by Hakai for modeling and data synthesis applications. Community sampling data are helping coastal communities build an understanding of current local conditions in areas that are important for subsistence species. The low-cost ADC technology transfer to the shellfish aquaculture community was an important activity in that the ACDC system is less expensive to operate and represented a less hands-on and simpler approach to tracking marine CO<sub>2</sub> conditions compared to using a BoL. Evaluation of the ACDC is now complete.

*Subawards to the Sitka Tribe of Alaska/Southeast Alaska Tribal Ocean Research Network (SEATOR) - BoL Sitka and IOOS Partners Across Coasts Ocean Acidification Data Portal (IPACOA) Headlights Projects supporting Indigenous-led baseline OA data collection and monitoring efforts.*

- **Purpose of the project:** To support indigenous-led, baseline OA monitoring efforts by sustaining operations of the Sitka BoL and community sampling program, providing supplies and contract assistance for SEATOR community observing partners in southeast AK, and helping test new, lower-cost ocean acidification sensing technologies (Autonomous Coastal Drifting ACDC CO<sub>2</sub> system) in efforts to expand regional observing capacity.
- **Key outcomes:** The Sitka BoL provided continuous sampling at the SEATOR facility and data were submitted to the IPACOA portal and the AOOS Data Portal. Sampling kits were purchased that increased the monitoring capacity of the community observing program. Community samples were also processed using the SEATOR BoL (in lab mode). SEATOR participated in testing a new, low-cost ACDC system with partners at Hakai Institute.
- **Who used the information and for what purpose:** Continuous BoL data are largely used by the research community and are published as a finalized data product by Hakai Institute for modeling and data synthesis applications. Community sampling data are helping coastal communities build an understanding of current local conditions in areas that are important for subsistence species.

*Subawards to the Tula Foundation (Hakai Institute) - Upgrade the APSH BoL equipment in Seward, continue testing prototype ACDC equipment in BoL sites in Seward, Ketchikan, and Sitka, and test additional OA sensors used for ACDC validation in Ketchikan and Sitka.*

- **Purpose of the project:** To provide ongoing support to Alaska BoL operations, help maintain the BoL in Seward at the APSH via upgrades, and support continued testing of the prototyped alternative and lower cost ACDC CO<sub>2</sub> system alongside the APSH, Sitka and Ketchikan BoLs. Additional OA sensors were to be purchased and tested in Ketchikan and Sitka as an alternative validation method for the ACDC prototyped systems being trialed at those locations.



- **Key outcomes:** The APSH BoL was maintained, upgraded and remained operational during the project period. ACDC prototype testing at three BoL sites was supported. Partial costs were covered for the purchase of two sensors being tested and evaluated for validating the ACDC prototype. The SAMI-Alk sensor in Ketchikan was successful and produced useful validation results, but the iSAMI sensor deployed in Sitka had an issue providing data to the prototype ACDC during deployment. The ACDC is no longer being evaluated, but the plan is to utilize these new sensors in ocean acidification observing efforts in southeast Alaska.
- **Who used the information and for what purpose:** Continuous BoL data are largely used by the research community and are published as a finalized data product by Hakai Institute for modeling and data synthesis applications. The community sampling data whose samples are analyzed using the BoLs, are helping coastal communities build an understanding of current local conditions in areas that are important for subsistence species. The aim of testing new sensors at the BoL locations was to validate an alternative and lower cost in situ prototype OA observing system, the ACDC, and test an alkalinity-salinity relationship using the results. The low-cost ADC technology transfer to the shellfish aquaculture community is an important activity in that the ACDC system is less expensive to operate and represents a less hands-on and simpler approach to tracking marine CO<sub>2</sub> conditions compared to using a BoL. Evaluation of the ACDC is now complete.

*Subawards to Tula Foundation (Hakai Institute) and UW - Complete installation, operate and maintain the ocean acidification instrumentation onboard the Alaska Marine Highway ferry Columbia.*

- **Purpose of the project:** To provide support with the installation and ongoing operations and maintenance of an autonomous carbon dioxide MAP\_CO<sub>2</sub> measuring system aboard the Alaska Marine Highway System (AMHS) ferry M/V *Columbia* for tracking ocean acidification variability along the nearshore region of the Pacific Coast spanning southeast Alaska, Canada, and Washington State.
- **Key outcomes:** The General Oceanics pCO<sub>2</sub> monitoring system (MAP\_CO<sub>2</sub>) installation on the M/V *Columbia* was completed in April 2017, and was routinely serviced up to 15 times each year when the ferry was dockside in Washington State. The ferry transit was a ~1600 nm “transect” occurring weekly along a repeated (round-trip) track between Bellingham, WA and Skagway, AK throughout the summer months (April-October). Two years of data from these transits were acquired during this project period from 2017-2019. Data are publicly accessible for CO<sub>2</sub> synthesis and data product development through NCEI, Surface Ocean CO<sub>2</sub> Atlas (SOCAT), and AOOS.
- **Who used the information and for what purpose:** The combination of the ferry measurements with an alkalinity-salinity relationship built from data collected largely using AOOS funding on previous work will allow tracking of the surface water saturation states of aragonite and calcite, as well as pH and the other CO<sub>2</sub> system parameters along the ferry’s transit path. The data are being used to provide baseline information and identify local processes and drivers in an area identified as a global OA hotspot. Results have been shared in multiple outreach presentations to researchers, fishermen, and the aquaculture community.

### Harmful Algal Blooms (HABs)

*AOOS Supported Alaska Harmful Algal Bloom (AHAB) Intern Position through the Alaska Sea Grant Program.*

- **Purpose of the project:** To support for one year a Schommer Alaska Sea Grant Fellowship position in the AOOS office to help organize and coordinate a newly forming Alaska Harmful Algal Bloom (AHAB) Network.
- **Key outcomes:** Coordination of multiple meetings to bring those working on HABs issues in the state together to share knowledge and work out standard operating protocols to ensure quality data outcomes. This intern also worked on developing outreach materials related to HABs. The fellow participated at a full-time level within the host office and worked on site under the supervision of the AOAN Coordinator. The internship ran from September 2018 through September 2019.
- **Who used the information and for what purpose:** The Alaska Sea Grant State Fellowship Program aims to build and strengthen the workforce dedicated to healthy fisheries and coastal environment by encouraging students to launch their careers in Alaska and offering work opportunities with organizations in the state.

*IOOS Support for the National Harmful Algal Bloom Observing Network - AOOS AHAB.*

- **Purpose of the project:** To support the formalization of the nascent AHAB to improve HAB monitoring and event response across Alaska, especially in the U.S. Arctic, which is emerging as a high-risk area for HAB-related events.
- **Key Outcomes:** Funds supported the hiring of a qualified, full-time HAB coordinator within the AOOS office, who brought together disparate projects, provided integrated data management support and increased access to information products. Field kits for detecting domoic acid, microscopes and development of qPCR molecular testing capability were purchased for multiple regions in the state who are collecting data for existing HAB species in Alaska. AHAB, now a formalized network with a steering committee, has formed a strong alliance in Alaska, has an up-to-date functional website for information exchange, and an operating data portal.
- **Who used the information and for what purpose:** The project has increased awareness of HABs in Alaska, has improved communications with all the various groups working on HAB issues in the state, and have brought together groups to ensure that appropriate methodologies are being followed using best practices. Data products and activities will address climate impacts, subsistence needs/impacts, public health, and safety.

*2018 NOAA Alaska Regional Collaboration Team Transfer to IOOS - Integrated Services & Response related to HAB events in the Bering Sea Region.*

- **Purpose of the project:** The NOAA Alaska Regional Collaboration Team transferred \$8,850.00 to support the rapid-response collection, analysis, and communication of results of water samples and other data acquired to assess HAB conditions in the Bering Strait region.
- **Key Outcomes:** Funding was used towards sample analysis of water samples collected for HABs during research cruises operating in the Bering Strait region. The sampling efforts were not well funded and not well coordinated due to lack of sufficient planning

and oversight, and did not produce conclusive results. However, this effort informed on what was needed to improve sampling approaches in future collaborative HABs sampling projects in this region.

- **Who used the information and for what purpose:** The information was of interest to residents and experts who are concerned the extraordinarily warm and sea ice free waters of the Bering Sea Region will promote a HAB event with human health consequences. Unfortunately, the results were insufficient to produce useful information related to HAB risks in the region.

*Subaward to University of Alaska, Alaska Sea Grant - Provide HABS response support for Bering Sea Communities.*

- **Purpose of the project:** To expand community awareness and engagement around HABS in the Bering Strait region.
- **Key outcomes:** A 2-day HABS workshop was held in Nome with HABS experts, public health experts, Tribal representatives and local community members. An outreach flier was produced and disseminated on saxitoxin research results in the area. Funding was also used for STX/DA kits to test marine mammals for toxins.
- **Who used the information and for what purpose:** The focus of this information was residents of Bering Sea communities who harvest and consume marine organisms and mammals for subsistence, and the health professionals in the region that might support a possible case of poisoning. It also initiated collaboration between interdisciplinary groups based in and out of the region working together on this issue.

*Subaward to the Native Village of Kotzebue - Collect and analyze water samples from the nearshore waters near Kotzebue to establish baseline data on microcystins.*

- **Purpose of the project:** To assist with building local capacity to sample suspected cyanobacteria blooms, monitor water samples for various toxins related to blooms, and assess water samples for toxins to support public health.
- **Key outcomes:** Sampling sights were identified, equipment was purchased, and 24 samples were collected July through September in 2018 and sent to a lab to contribute to the ongoing effort of understanding and documenting the emerging issue of cyanobacteria occurrence in coastal waters in northwest Alaska. The project increased local sampling capacity, both experience and equipment, and added another year of baseline data to the emerging observing program.
- **Who used the information and for what purpose:** The Native Village of Kotzebue used the information to continue to document and understand the nature and timing of cyanobacteria blooms in the region. It also is using the increased understanding and capacity to partner with interested parties in developing research proposals to continue monitoring activities and research on this phenomenon.

### **Water Quality Data Products and Services**

*Subaward to Axiom - Provide data management support to the AHAB network.*

- **Purpose of the project:** To provide data management services to the AHAB.

- **Key outcomes:** Axiom created an internal Research Workspace for storing and sharing data; worked with the AHAB to facilitate data submission through a data entry system and standards-compliant metadata generation; visualized data and data products in an interactive map interface for public access and discovery; and made final data and data products publicly accessible through the AHAB and the AOOS Data Portals. Final data submission to NCEI was not initiated during this project period because quality control and review of HAB datasets were not completed.
- **Who used the information and for what purpose:** This project improved the coordination of state-wide HAB data collection and sharing efforts across state, federal, local, Tribal agencies, researchers, and communities. The AHAB Network continues to develop the data portal and observing information and assets beyond this project period.

#### IV. Data Management & Communications Subsystem

##### AOOS Core Data Management & Cyberinfrastructure (DMAC)

*Subaward to Axiom - Core Data Management.*

- **Purpose of the project:** To provide AOOS Core DMAC serving as a regional DAC to facilitate access to regional federal, state, local, tribal & private data, and to develop regional data products in response to stakeholder needs. Efforts focused on maintaining the AOOS data system cyberinfrastructure, managing and ingesting new AOOS and regional data assets, extending the capabilities of existing data management tools, and developing new functionality for the AOOS web-based data portals, primarily the Ocean Data Explorer.
- **Key outcomes:** Provided technical support for the AOOS cyber infrastructure, implemented Quality Assurance / Quality Control of Real-Time Oceanographic Data (QARTOD) checks for real-time and delayed mode data feeds (as required for NOAA's Regional Coastal Ocean System [RCOS] Certification), and provided overall DMAC project management. Participated in regional, state and international DMAC activities and implemented recommended and standard data management procedures for AOOS data assets. Worked with AOOS staff on development of special data products while supporting existing data products, and ingested new data/metadata prioritized by AOOS. The AOOS Ocean Data Explorer framework was directly leveraged by IOOS and other IOOS RAs, and now data systems, capabilities and lessons learned from ongoing DMAC activities that support AOOS, the Southeast Coastal Ocean Observing System (SECOORA), CeNCOOS, and IOOS can be shared in order to develop cross-regional and U.S.-wide data products and capabilities.
- **Who used the information and for what purpose:** The AOOS Data Portal was designed to meet science-based needs of its stakeholder community by providing high-quality ocean data and information products. Developed data products are aimed to improve maritime safety, enhance the economy, and protect our environment. Stakeholders include scientists and students studying Alaska's ocean ecosystems; commercial and recreational mariners and fishermen; spill responders; resource managers at community, municipal, state, and federal levels.

### **AOOS Regional Ocean Data Partnership (ROP)**

*Subaward to Axiom - Develop data products in the Alaska region to support the national Regional Ocean Data Sharing Initiative (RODSI).*

- **Purpose of the project:** To support data management activities related to AOOS' Regional Ocean Data Sharing Initiative (RODSI).
- **Key outcomes:** A dedicated data discovery portal for the project (<https://bering-sea.portal.aos.org/>) was developed. Additional data products developed with this funding included the [AMBON Arctic Seascapes](#), [Bering Strait Incident Response Tool](#), [Chukchi Trawl data rescue](#), [Sea Ice for Walrus Outlook forecasts](#), and the [Marine Weather Dashboards](#).
- **Who used the information and for what purpose:** These data products are used by the scientific community, incident response agencies and organizations for use as a common operating picture during maritime incidents, and Alaska Native subsistence hunters, fishermen and recreational boaters for safety at sea.

*Subaward to UAF) IARC - Provide outreach materials and community engagement activities for ROP.*

- **Purpose of the project:** To create outreach materials that deliver synthesized information on federal, state, university and community-based science findings in the Bering Sea region to rural residents and those working in the region.
- **Key outcomes:** Four “Bering Science” publications were created with information shared by dozens of partners and distributed to thousands of residents across western Alaska.
- **Who used the information and for what purpose:** Community members used the products to learn about changes happening in other regions of the Bering Sea outside of their home community. Several local science teachers in the region planned to use Bering Science as a tool in their classrooms. Scientists told us that Bering Science helped them understand the breadth of research happening in the region and explore ways to collaborate with other related projects.

*Subaward to UAF - Develop distance learning modules for the ACCAP.*

- **Purpose of the project:** To develop user-focused Arctic-specific, remote access training modules for NOAA personnel and NOAA internal and external partners including emergency managers and Native Alaskan communities and tribes with responsibility for vulnerable coastal communities.
- **Key outcomes:** The development of a distance training module, specially designed for use by NWS Alaska region staff, for use in responding to Arctic marine transportation decision support, including 508 compliance documents and a training quiz.
- **Who used the information and for what purpose:** The training module is designed to be used by NWS staff. The NWS Climate Services Branch intends to incorporate this training module into their Professional Development Series training.

## National IOOS Program and Other Federal Data Management Activities

*Subaward to Axiom - Maintain and Enhance Data Access Service Software: ERDDAP and Environmental Sensor Map (ESM) and Global Data Integration.*

- **Purpose of the project:** To support the ongoing stewardship of several open-source software packages that are crucial to the IOOS DMAC enterprise, including integration of the results of the brokering/scalability tool (Sensor Map) with the IOOS Catalog. IOOS is prioritizing ERDDAP as the DMAC basis for serving in-situ environmental data and developing a consistent dataset structure across RA ERDDAP servers. A main goal was to improve documentation/planning/testing/ease-of-use to further mature both the ERDDAP and ESM projects and maximize the likelihood of external contributions and use by the community.
- **Key outcomes:** Axiom created a document entitled “*IOOS Environmental Sensor Map: FY19 ERDDAP RoadMap*” that outlines the release approach and timelines maintained throughout the project. User documentation was updated for IOOS Metadata Profile version 1.2, QARTOD guidelines using the CF ancillary variables approach, and 'Gold standard' ERDDAP configuration documentation, with datasets compliant with IOOS Metadata Profile 1.2. Twelve versions of the ESM were released to incorporate new features, stabilize the codebase, respond to user feedback, and resolve bug fixes. Data from the ESM were previously obtained through various SOS access points; however, this project has implemented changes needed to switch to ERDDAP and improve data and metadata ingestion into national products.
- **Who used the information and for what purpose:** The primary users include Federal, State, and local marine scientists, coastal resource managers, and the general public. The primary users of information from the ERDDAP project are IOOS RA DMAC managers, IOOS Program Office staff, and NDBC staff, who rely on guidelines, documentation, and data to develop standardized data products at regional and national levels. A primary motivation for a new release of the ERDDAP service and v1.2 IOOS Metadata Profile is to ensure consistent dataset structure across RA ERDDAP servers, so that national partners can harvest data via a single process.

*Subaward to Axiom Data Science - Develop the MBON Data Portal.*

- **Purpose of the project:** To increase access to marine biodiversity information for researchers and managers to help understand species population trends and ecosystem change.
- **Key outcomes:** Development of the [MBON Data Portal](#), which integrates key marine biodiversity and environmental data submitted by IOOS RAs, researchers, resource managers, and other partners.
- **Who used the information and for what purpose:** The data available on the MBON Data Portal has been used by the scientific community, federal agencies and resource managers to describe the relationships between biodiversity, organismal, and ecosystem productivity and determine patterns and trends for ecosystem-based management.

*Subaward to Axiom - Finalize HFR Range Series File Archiving through the Research Workspace.*

- **Purpose of the project:** To improve tools for preserving HFR output and allowing for reprocessing HFR data by using the Research Workspace for capturing, documenting, and preserving HFR Range Series files. This project supported the HFR Network (HFRNet) being developed to manage and distribute in near-real-time ocean surface currents measured by a distributed network of shore-based HFR systems.
- **Key outcomes:** Technical scoping meetings with the IOOS Program Office isolated technical requirements. Project tasks included providing space in the Research Workspace for storing all range series files for all HFR operators within the IOOS HFRNet, processing and archiving HFR data, evaluating and developing new tools for improved decision making, exposing HFR data inventory to end users, improving documentation on IOOS HFR website, and providing an offsite data back-up recovery. A pilot IOOS HFR website was developed to include information about HFR data archive, an inventory of available data, and data formatting guidelines. A data inventory tool was created that allows users to easily view and search the archive by location, IOOS region, and temporal availability, streamlining HFR data access to end users. Offsite back-up for stored HFR data files was maintained to guard against disaster and provide data recovery. This project will be ongoing.
- **Who used the information and for what purpose:** This project supported the IOOS office and other NOAA offices by cultivating software packages and national DMAC networks. It also supported ongoing stewardship of several open-source software packages that are crucial to the IOOS DMAC enterprise and integration of the results of the brokering/scalability tool (Sensor Map) with the IOOS Catalog.

*Subawards to Axiom for Saildrone - Develop novel streamlined data from platform to application through cloud hosted data acceptance and quality control*

- **Purpose of the project:** To explore the use of cloud services for data ingress and analysis using autonomous ocean observing data acquired from the Saildrone. In close collaboration with the NOAA PMEL, Axiom examined the following two services: (1) the use of IoT technologies to land data at the lab and automatically add the data to an ERDDAP server, and (2) the use of serverless functions to automatically QA/QC data coming into the lab.
- **Key outcomes:** Axiom worked with NOAA PMEL to scope potential cloud-based, serverless capabilities for Saildrone data hosting. Two core capabilities (AWS and Azure) were evaluated and the optimal cloud provider solution was identified. Technical scoping was completed to configure listeners and apply the modified PMEL RUDICS implementation to accept payloads from the Iridium satellite provider. Technical steps required to modify the PMEL RUDICS software for Cloud platform hosting were conducted. At the end of the project, Axiom provided PMEL with configuration files used to provision components of the pipeline, the relevant docker images created for the pipeline, and documentation and deployment information: <https://github.com/NOAA-PMEL/iot-data-landing>

- **Who used the information and for what purpose:** NOAA, IOOS, and anybody working with autonomous moving platforms (gliders, drones, AUVs). In partnering with Axiom, NOAA PMEL was looking to benefit from Axiom's experience in managing data pipelines. Specifically, PMEL sought assistance on design components to use for each part of the pipeline (e.g., what type of message/queue system is appropriate) and how to set up the data flow, and also on testing/implementation.

*Subawards to Axiom - Develop an AIS analytical and data storage system and an interactive marine traffic information web tool.*

- **Purpose of the project:** To develop a scalable methodology for storing and querying the national AIS data set assembled by the NOAA OCS (~20 Billion records), and to produce standard and customizable outputs and data products. The AIS data products were to be made accessible using an interactive web-based tool allowing a user to output subsets based on time/distance, vessel type calculate density per cell based on total number of vessels, total number of unique vessels (based on MMSI/IMO), and total number of unique vessels with user-defined cap.
- **Key outcomes:** This project built upon a prototype AIS analysis platform that was developed in the summer of 2015 utilizing 300 Million AIS records. Axiom provided 8 high performance compute nodes (96 cores, 576 GBs of Ram, 48 TBs of storage) for long-term support of the AIS data storage and analysis platform. The team benchmarked and tested several horizontally scaling data sharing approaches (Postgres-XL, Hadoop, Mongo DB, Elastic Search) to determine an optimal approach and technology for storage and analysis of the data set. Axiom processed over 159 billion raw AIS vessel data from MXAK and NOAA into an Apache Geo-Spark cluster for horizontally scalable, parallel processing stack transformation and analysis; developed vessel traffic summaries using a series of data cleanup and analysis stages on the computing cluster; applied a GeoTrellis open-source library to generate vessel density heatmaps. The final outputs include a variety of heatmap raster grids representing various spatial and temporal vessel traffic trends and density footprints. Axiom also worked with project partners to develop and refine a web-page tool for public access to [AIS Vessel Traffic Data Products](#) that allows visualization of data by vessel type, number of unique vessels, total number of vessels, etc. Funding for these efforts was provided by AOOS, NOAA NOS, and NOAA OCS.
- **Who used the information and for what purpose:** NOAA OCS used the standard outputs created during this project to provide one of the many variable inputs in their Hydrographic Health Model, which is used to prioritize where NOAA conducts modern hydrographic (bathymetric) surveys. Other users include the USCG for evaluating new shipping routes (for example, in some uncharted portions of the U.S. Arctic); researchers interested in vessel traffic patterns over time in areas important to environmental resources (e.g., subsistence users of marine mammal resources); resource managers and policy makers interested to see how vessel traffic patterns are changing in specific regions; those responsible for decision-making about vessel traffic and safety in U.S. waters.



*Subaward to Axiom - NESDES BEDI Create and curate vessel heatmaps from AIS ship location data.*

- **Purpose of the project:** To acquire raw AIS data held by a variety of federal entities, clean and aggregate the data to produce spatio-temporal vessel heatmaps as GeoTIFF and netCDF files, and serve data products via publicly-accessible AOOS/IOOS resources.
- **Key outcomes:** The workflow developed for AIS data may also prove useful for other large sets of environmental point data such as locations of tagged fish or marine mammals. The workflow from this project has been documented and made publicly-available for use by the broader community. The AIS data acquired during this effort have been fully curated in preservation-ready data packages and are available at: <http://ais.axds.co/> and the AOOS Data Portal.
- **Who used the information and for what purpose:** The technical approach has been prototyped in a project with NOAA's OCS. For that project, the 2015 terrestrial AIS dataset was processed to vessel traffic heatmaps for use in OCS's Hydrographic Health Model. These heatmaps were in GeoTIFF format with 500 meter resolution. The input dataset was 74 billion raw AIS messages, which were transformed into 20 million total voyages that were used to generate the heatmap files. This project will build upon and complement the earlier project by greatly expanding the sources of data and concentrating on Alaska and Arctic data.

*Subaward to Axiom - Provide OCS Coastal Survey Dev Lab a High Fidelity Prediction System for coastal storm hazards.*

- **Purpose of the project:** To improve storm surge models using a fast response 3D model engine. This project was cooperative with the NOAA-NOPP proposal: High Fidelity Prediction System for Coastal Storm Hazards in Support of Disaster Prevention and Safe Navigation, a multi-agency (NOAA, USGS, and Office of Naval Research [ONR]) project in collaboration with academia and industry.
- **Key outcomes:** Axiom implemented capability to seamlessly run the modeling system on conventional High Performance Cluster (HPC) and cloud environment, and implemented a cloud-based environment for post-processing and dissemination of modeling system products.
- **Who used the information and for what purpose:** This work is a part of NOAA efforts to develop disaster risk assessment tools and practical technical applications to reduce and mitigate coastal vulnerability to natural disasters. New products will improve communication and collaboration with other international agencies by informing charting, bathymetry, water level, currents, and other products that NOAA produces, and will also support products and services that are vital for safe maritime navigation, world class geodetic infrastructure, and sustainable use of ocean resources for economic health and growth.

*Subaward to Axiom - Marine mammal stranding data visualization in IOOS Portals.*

- **Purpose of the project:** To support the Marine Mammal Health Monitoring and Analysis Platform (HealthMAP) project by implementing a national system where the

marine mammal stranding information can be accessed and visualized through IOOS RA nodes (regional data portals).

- **Key outcomes:** A functional prototype HealthMAP for the Gulf of Mexico region was developed to support data flow and visualization envisioned for the program's database. It incorporates 12 unique datasets with 41 corresponding layers and metadata containing marine mammal strandings, entanglement, and health assessment information together with habitat and other physical environmental data layers. Three Gulf of Mexico marine mammal health datasets were assimilated and integrated into select IOOS RA portals for public data access and visualization.
- **Who used the information and for what purpose:** The successful delivery of this prototype served as a proof-of-concept of an architectural system that has the potential to be scaled to support all data sources of the HealthMAP nationally and be shared on portals of the Regional International Ocean Observing System Associations. The NMFS Office of Protected Resources, Marine Mammal Health and Stranding Response Program (MMHSRP) coordinates a national network of 100+ external partners that collect information on stranded marine mammals. Basic information on these stranding events ("Level A data") is collected in a national centralized database ("Level A Database") maintained by NMFS; however, though these data are considered public information, they are only available upon request to NMFS and are generated through manual searches of the database and distributed via Excel files. This project helped to facilitate access to up-to-date information across the national network.

*Subaward to Axiom - Animal Telemetry Network (ATN) Data Acquisition Center (DAC).*

- **Purpose of the project:** To establish the operational capacity of the U.S. Animal Telemetry Network Data Assembly Center (ATN DAC) by transitioning the technology, capabilities and functions of the prior ATN DAC from its developmental level of functionality in a research laboratory at the Stanford University Hopkins Marine Station to Axiom.
- **Key outcomes:** Axiom served in an operational capacity as the data assembly center and national aggregator of marine animal telemetry data research underway throughout the United States. Axiom developed the capability for the ATN-DAC to ingest ocean profile data from animal-borne sensor tags, perform real-time quality control on the data, reformat the data into the table-driven coded message format required by the World Meteorological Organization (WMO), and insert the messages onto the GTS. During the performance period 54 new projects encompassing 2,316 deployments were added to the ATN-DAC Data Portal, which now provides access to 146 projects, 5,263 tag deployments from over 81 different species. 15 animal telemetry datasets have been archived with DataONE using the automated pathway from the Research Workspace DataONE Member Node. Throughout the project, the transitioned enterprise-level supporting cyberinfrastructure established in June 2018 was optimized to support and enhance the ATN data management vision and improve the ability of the PIs to share, aggregate, and access data as defined in the ATN Implementation Plan.
- **Who used the information and for what purpose:** ATN development efforts have enhanced the national ATN and led to increased coordination of biologging research activities and improved standardization and efficiency in handling and integrating marine

animal telemetry data together with physical oceanographic information. This project is making animal telemetry data and data management capabilities accessible to the broader ocean science community to manage, share, and use telemetry datasets, which will result in enhanced biological and ecosystem-based management decisions that are informed by the data synthesis, integration, and tool development activities of this project.

*Subaward to Axiom - IEAs NOAA Regional Collaboration.*

- **Purpose of the project:** To develop data products in the Alaska region to support NOAA's Regional Collaboration Team, specifically, to make the AFSC's ESRs available electronically via the AOOS data management system; directly link the observational data behind the ecosystem indicators to the status report products; and pursue the addition of other indicators.
- **Key outcomes:** NMFS ecosystem IEA indicators from current Alaska ESRs were presented as a report card/dashboard on the AOOS portal as part of a State of Alaska's Coasts and Oceans synthesized report. Axiom isolated requirements for further development of the ESR dashboard tool, and data from the indicators were ingested, standardized, and exposed for interaction by end-users in an early version of the dashboard. It is unclear if any of these products were completed beyond Beta-stage test products.
- **Who used the information and for what purpose:** These Beta products were developed primarily for use by the North Pacific Fishery Management Council, but could be made available for use by a broader user audience through visualizations, expanded indicators (HABs), and other products using the AOOS Data System. Methods will enhance the utility of the AFSC's ESRs and IEA indicators.

*Subaward to Axiom - Maintenance and software developments to the existing Coastal and Marine Geology Program (CMGP) photography and video portal and the CMGP oceanographic model and data portal.*

- **Purpose of the project:** To provide technical services to the U.S. Geological Survey (USGS) Coastal and Marine Geology Program (CMGP) for the development of web portals for geospatial data. Two of the portals CMGP had already developed are a photography and video portal (<http://cmgvideo.usgsportals.net/>) and a oceanographic model and data portal (<http://cmgdata.usgsportals.net/>) , both of which leverage advances made possible by the IOOS framework.
- **Key outcomes:** Tasks included maintenance and software developments to the existing CMGP photography and video portal and the CMGP oceanographic model and data portal. Axiom provided high performance data hosting support and implementation of time series comparisons tools. USGS photo and video portal was upgraded to Next Gen Framework.
- **Who used the information and for what purpose:** CMGP portals as well as specific enhancements to the CMGP portals added functionality and value for users, leveraging U.S. IOOS expertise and capabilities to perform the work.

*Subaward to Axiom - Provide Statistically-generated Probabilistic Sea Ice Guidance for three week to seasonal time scale (S2S Sea Ice Guidance).*

- **Purpose of the project:** To provide probabilistic information on a weekly basis for forward looking 3- to 6-week time periods, as well as monthly guidance for up to 9-months, derived from available seasonal sea ice and atmospheric dynamic models, and to provide decision-makers with calibrated information to aid in the planning of marine-related activities.
- **Key outcomes:** Axiom in collaboration with the NWS Alaska region developed a prototype system that used advanced machine learning models to produce probabilistic sea ice guidance for 300+ points of interest in the waters of the Bering Sea and Arctic Ocean surrounding Alaska. All data, models, and outputs are available on GitHub.
- **Who used the information and for what purpose:** The sea ice concentration guidance information is intended to help quantify the uncertainty in the S2S forecasts and aid in the planning of marine-related activities. By improving forecast uncertainty for sea ice concentration through machine learning, this work provided important tools for NWS and the scientific community to improve guidance information. The analysis, based on the historical output from the operational National Centers for Environmental Protection (NCEP) Climate Forecast System Version 2 (CFSv2) coupled with an experimental sea ice model (CPC), was also an effort to provide communities and commercial stakeholders in Alaska with improved guidance on seasonal sea ice concentrations.

*Subaward to Axiom - BIO-ML Optimizing Machine Learning Pipelines for Novel Biological Data Streams.*

- **Purpose of the project:** To apply innovative machine learning techniques on streamed data using a cloud environment, with the goal to increase the efficiency and accuracy of producing data outputs. The goal was to overcome the inability to reliably and efficiently handle integration of environmental observations of novel data types (e.g., such as data generated by Imaging FlowCytobots (IFCB - sensors that capture in-situ images of particles typically triggered via fluorescence to capture images of phytoplankton).
- **Key outcomes:** A streaming system to ingest and process IFCB datasets from multiple instruments was implemented to replace the existing classifier. A modular and flexible streaming pipeline was developed to support ingestion and analysis of any data type and make access to data available to internal consumers or through API endpoints. Source code and documentation for data ingestion pipelines and processing is publicly available on GitHub at the hydraulics repository. A portable and scalable biodiversity processing framework was also developed, applicable to other novel biological data types (e.g., acoustic and eDNA).
- **Who used the information and for what purpose:** NOAA needs integrated data products and curated data sets interoperable and publicly accessible for adoption into NOAA applications for broader access by management and scientific audiences. Automating the real-time detection of harmful phytoplankton species provides the ability for resource managers and enables communities and individuals to be quickly informed. The project improved biodiversity outputs through machine learning and can be adapted to other technologies.

*Subaward to UAF - Develop NOAA State of the Arctic Report for NOAA Climate Program Office.*

- **Purpose of the project:** To support the development of the “Arctic Report Card,” a timely and peer-reviewed source for clear, reliable, and concise environmental information on the current state of different components of the Arctic environmental system relative to historical records.
- **Key outcomes:** The Arctic Report Card was published from 2017-2020 with support from this subaward (and has continued past the AOOS support).
- **Who used the information and for what purpose:** The annual press release of the Arctic Report Card has become one of the most highly anticipated media events of the Fall American Geophysical Union (AGU) meeting and generates one of the most widely viewed events on NOAA’s Climate.gov website. It provides information to a wide audience interested in the Arctic environment and science, including scientists, teachers, students, decision-makers, policymakers, and the general public.

*Subaward to University of Notre Dame - Support enhancement of OceanMesh2D capabilities and implement an operational Global ESTOFS 3.0 model.*

- **Purpose of the project:** To enhance the automated mesh generator OceanMesh2D1,2 capabilities and refine meshes for the U.S. East and Gulf coasts to improve accuracy. Tasks focused on developing more accurate and efficient meshes of the global and coastal ocean that extend far inland, including river and adjacent floodplain systems for both longwave and non-phase resolving wind-wave computational modeling.
- **Key outcomes:** This multi-year effort accomplished several modeling improvements including: an improved shoreline that melds NOAA’s Continuously Updated Shoreline Project (CUSP) database with the National Hydrography Dataset (NHD) shoreline database with the NOAA U.S. Medium Shoreline (USMSL) database along shorelines where neither CUSP nor NHD were available; a refined ability of OceanMesh2D to generate global meshes; an improved ability of ADCIRC to simulate high latitude regions and solve one comprehensive mesh of the entire Earth; an improved meshing of deep channels that occur within shallower estuarine and shelf environments; strategies to optimize upriver river meshing so that the meshes can be readily couple to the National Water Model; targeted bathymetric improvements into the 30 m and 120m meshes and validation with hurricanes; activating river inputs for simulations. Additional development and implementation of an updated integrated and now operational Global ESTOFS 3.0 model was completed.
- **Who used the information and for what purpose:** Mostly NOAA coastal hazards modeling projects, working with personnel at NOAA Coastal Survey Development Laboratory (CSDL) to bring in the latest bathy/topo data as this comes online in order to better represent tides, storm surges, and riverine flows at all NOAA water level gauges and USGS gauges in the model domains.

**SECTION 2**

**Table 4. Summary of IOOS, NOAA, and Other Agency Funding By Year**

<b>IOOS, NOAA, Other Agency Funding</b>		
<b>FY16</b>		
<b>Funding amount spent</b>	<b>Funding Area /Recipient</b>	<b>Task</b>
Provided \$156,000. Spent \$156,000. Remaining \$0.	Regional HFR	High frequency (HF) radar operations and maintenance.  Status: Completed
Provided \$192,000. Spent \$192,000. Remaining \$0.	Axiom	National DMAC Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0.	Axiom	To develop a preservation pathway and visualizations for animal telemetry data  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0.	Axiom	MSI OTT Special Project  Status: Completed
Provided \$10,000 Spent \$10,000 Remaining \$0	AOOS	AK Geo Spatial Coordinator  Status: Completed
Provided \$17,000 Spent \$17,000 Remaining \$0	Ocean Acidification	FY17 OAP Support to RA  Status: Completed
Provided \$50,000 Spent \$50,000 Remaining \$0	Axiom	National Marine Mammal Stranding Data Support  Status: Completed
Provided \$42,000 Spent \$42,000 Remaining \$0	Axiom	NESDIS BEDI Proposal  Status: Completed
Provided \$68,000 Spent \$68,000 Remaining \$0	NOS Stimulus Fund Proposal OCS/AIS Project	NOS Stimulus Fund Proposal OCS/AIS Project  Status: Completed
Provided \$25,000 Spent \$25,000 Remaining \$0	AOOS	AK Geo Spatial Coordinator  Status: Completed
Provided \$55,000 Spent \$55,000 Remaining \$0	Axiom	Provide maintenance and software developments to USGS's Coastal and Marine Geology Program's photography and video web portal and its oceanographic model and data web portal.  Status: Completed

<b>FY17</b>		
<b>Funding amount spent</b>	<b>Funding Area /Recipient</b>	<b>Task</b>
Provided \$156,000. Spent \$156,000. Remaining \$0.	Regional HFR	HFR operations and maintenance. While you may allocate these funds to support any HFRs within the region, the allocation should not be one that negatively affects the performance of priority HFRS for the benefit of nonpriority HFRs. HFR performance is measured by a metric that was developed with input from the IOOS National HFR Technical Steering Team and the IOOS HFR community. To ensure that IOOS HFR expertise is engaged to the largest extent possible, any HFR quality control or quality assurance development funded by IOOS is required to include no fewer than three IOOS regions.  Status: Completed
Provided \$142,000. Spent \$142,000. Remaining \$0.	Axiom	To continue enhancements to the Environmental Sensor Map including improved sensor performance monitoring, collection of use metrics, and streamlining adding new sensors to the map Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0.	Axiom	To develop a preservation pathway and visualizations for animal telemetry data  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0.	Axiom	Axiom will work with NMFS PRD to integrate currently collected marine mammal stranding data ("Level A data") into the regional IOOS portals for visualization  Status: Completed
Provided \$30,000 Spent \$30,000 Remaining \$0	OTT	For the Ocean Technology Transition Customer Service Application Project  Status: Completed
Provided \$20,000 Spent \$20,000 Remaining \$0	UAF	For the Arctic Freeze-up Buoy  Status: Completed
Provided \$50,000 Spent \$50,000 Remaining \$0	Axiom	To facilitate and accelerate the process of refining functionality of the existing MBON Portal, increasing the availability of data in the portal, and determining the most efficient process and data formats for future submissions of data to the Portal  Status: Completed
Provided \$35,000 Spent \$35,000 Remaining \$0	AOOS	To support an AK Geospatial Coordinator  Status: Completed
Provided \$17,000 Spent \$17,000 Remaining \$0	Ocean Acidification	For regional CAN Investment ACAN  Status: Completed

Provided \$42,000 Spent \$42,000 Remaining \$0	Axiom	To execute the NOAA funded Big Earth Data Initiative project "Creation and curation of vessel heatmaps from AIS ship location data"  Status: Completed
Provided \$68,000 Spent \$68,000 Remaining \$0	Axiom	For the for the Office of Coast Survey Marine Traffic Information Interactive Web Tool  Status: Completed
Provided \$55,000 Spent \$55,000 Remaining \$0	Axiom	To support the USGS model data portal  Status: Completed
Provided \$25,000 Spent \$25,000 Remaining \$0	Axiom	To support efforts to improve data servers and data access, especially via the use of ERDDAP and THREDDS servers  Status: Completed
<b>FY18</b>		
<b>Funding amount spent</b>	<b>Funding Area /Recipient</b>	<b>Task</b>
Provided \$156,000. Spent \$156,000. Remaining \$0.	UAF	Regional HFR  Status: Completed
Provided \$350,000. Spent \$350,000. Remaining \$0.	Axiom	Regional DMAC (ATN)  Status: Completed
Provided \$95,000. Spent \$95,000. Remaining \$0.	Coastal Mapping Position	To support the Alaska Coastal Mapping Position  Status: Completed
Provided \$20,000. Spent \$20,000. Remaining \$0.	ACAN, PI- Dugan	AOOS Alaska Ocean Acidification Network (ACAN, PI-Dugan)  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0	Axiom	MBON Portal  Status: Completed
Provided \$900,000. Spent \$900,000. Remaining \$0	Fill the Gaps - HFR	To fill gaps toward a complete and operational the National High Frequency Radar System. Prepare scope in coordination with the IOOS office on site planning, schedule, and communications about length of operations and maintenance costs expected for new sites.  Status: Completed
Provided \$75,000. Spent \$75,000. Remaining \$0	Fill the Gaps -Obs Access	To better integrate and disseminate information with the goal of reducing duplication of effort and to provide users with streamlined access to observational information (Streamlined Access to Obs)  Status: Completed
Provided \$90,000. Spent \$90,000. Remaining \$0	Axiom	For Environmental Sensor Map and global data integration  Status: Completed
Provided \$35,000.	Axiom	To maintain and enhance data access service software - ERDDAP



Spent \$35,000. Remaining \$0		Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Axiom	To finalize HFR range series file archiving through research workspace  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0	UAF	Develop distance learning modules on climate decision support in the Arctic  Status: Completed
Provided \$15,000. Spent \$15,000. Remaining \$0	OTT Biology Pilot Projects	In honor of Matt Howard: \$15,000, to each RA, to advance IOOS Biology through biological data stewardship activities in the region, in coordination with the Program Office. This includes working with Gabrielle Canonico on an IOOS synthesis report articulating regional needs for and prioritization of biological observations and data. IOOS Ras should also work with regional data providers to align biological datasets to the Darwin Core standard and make them available through ERDDAP servers and the MBON Portal. The Program Office will work with each RA to provide guidance toward completing this activity.  Status: Completed
Provided \$25,000. Spent \$25,000. Remaining \$0	IOOS Advisory Committee	To support U.S. IOOS Advisory Committee meeting in Juneau, AK August 28-29, 2018  Status: Completed
Provided \$276,668. Spent \$276,668. Remaining \$0	Alaska Earthquake Center	To fund Alaska seismic stations as part of the Alaska Earthquake Center, to provide information about seismic events that could assist in assessing earthquakes with tsunami potential. This project supports NOAA's Weather- Ready Nation initiative by providing capacity that would otherwise not exist in Alaska.  Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Ocean Acidification	Technical support for OA observing at nearshore shellfish hatcheries/growing sites  Status: Completed
Provided \$161,488. Spent \$161,488. Remaining \$0	Autonomous Observations of Ocean Acidification in Alaska Coastal Seas	Support for ongoing monitoring through the GAKOA surface buoy, a time series site in the central Gulf of Alaska, and the M2 surface buoy (Peggy), a time series site in the southeastern Bering Sea. It also provides support for ongoing subsurface monitoring at the M2 and M8 time series sites in the southeastern Bering Sea.  Status: Completed
Provided \$89,103. Spent \$89,103. Remaining \$0	Acidification in the Distributed Biological Observatory	Support for Natalie Monacci to assist with data processing and DBO collaboration, including 1 in-state (Alaska) and 1 out-of-state (outside Alaska) trip. The in-state trip should include an outreach effort, while the out-of-state trip will cover a national conference or US DBO data workshop.

		Status: Completed
Provided \$8,850. Spent \$8,850. Remaining \$0	NOAA AK Regional Team Support	NOAA AK Regional Team support for the collection, analysis, and communication of results of water samples and other data acquired to assess harmful algal bloom conditions in the Bering Strait region.  Status: Completed
FY19		
IOOS, NOAA, Other Agency Funding		
Funding amount spent	Funding Area /Recipient	Task
Provided \$156,000. Spent \$156,000. Remaining \$0.	Regional HFR	For HFR system operations and maintenance. While you may allocate these funds to support any HFRs within the region, the allocation should not be one that negatively affects the performance of priority HFRs for the benefit of non-priority HFRs. HFR performance is measured by a metric that was developed with input from the IOOS National HFR Technical Steering Team and the IOOS HFR community. To ensure that IOOS HFR expertise is engaged to the largest extent possible, any HFR quality control or quality assurance development funded by IOOS is required to include no fewer than three IOOS regions.  Status: Completed
Provided \$350,000. Spent \$350,000. Remaining \$0.	Axiom	Axiom work on Animal Telemetry Network Data Assembly Center  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0.	Alaska Coastal Strategist	AK Coastal Management Strategist (Marta Kumle)  Status: Completed
Provided \$15,000. Spent \$15,000. Remaining \$0.	Ocean Acidification	AOOS Alaska Ocean Acidification Network (ACAN, PI-Dugan)  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0	Axiom	MBON Portal  Status: Completed
Provided \$80,000. Spent \$80,000. Remaining \$0	Axiom	Axiom maintain and enhance Data Access Service Software - ERDDAP  Status: Completed
Provided \$60,000. Spent \$60,000. Remaining \$0	Axiom	For Environmental Sensor Map and global data integration  Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Axiom	Axiom work to finalize HFR Range Series file archiving through Research Workspace  Status: Completed
Provided \$15,000. Spent \$15,000. Remaining \$0	OTT Biology Pilot Projects	Biology pilot projects in honor of Matt Howard to advance IOOS biology through biological data stewardship activities in the region, in coordination with the Program Office. IOOS RAs should work with regional data providers and stakeholders to align biological datasets to

		<p>the Darwin Core standard and make them available through ERDDAP servers and the MBON Portal.</p> <p>Status: Completed</p>
<p>Provided \$287,000. Spent \$287,000. Remaining \$0</p>	<p>AK Earthquake Center</p>	<p>NWS Office of Observations funds for AK Earthquake Center - improve the robustness of NOAA tsunami warnings for earthquakes in Alaska. This project supports NOAA's Weather-Ready Nation initiative by providing capacity that would otherwise not exist in the Alaska.</p> <p>Status: Completed</p>
<p>Provided \$452,505. Spent \$452,505. Remaining \$0</p>	<p>Ocean Acidification</p>	<p>Funds are intended for the preparation, collection, processing, and analysis of Alaskan carbon data by the Ocean Acidification Research Center at the University of Alaska, Fairbanks. This includes time-series missions from the GAK 1 and M2 mooring sites in the Gulf of Alaska and Bering Sea as well as the Distributed Biological Observatory in the Chukchi Sea. It additionally includes funding to support the collaboration of the Ocean Acidification Research Center in an upcoming NOAA carbonate chemistry mission to the Gulf Alaska.</p> <p>Status: Completed</p>
<p>Provided \$195,000. Spent \$195,000. Remaining \$0</p>	<p>Fill the Gaps - Adjustment to Base</p>	<p>Glider Operations / deployments</p> <p>Status: Completed</p>
<p>Provided \$120,000. Spent \$120,000. Remaining \$0</p>	<p>Fill the Gaps - Adjustment to Base</p>	<p>Surface Currents - O&amp;M for HFRs purchased with FY18 funds, plus additional radar and remote power module for Bering Strait region</p> <p>Status: Completed</p>
<p>Provided \$100,000. Spent \$100,000. Remaining \$0</p>	<p>Fill the Gaps - Adjustment to Base</p>	<p>Glider procurement (batteries and sensors)</p> <p>Status: Completed</p>
<p>Provided \$80,000. Spent \$80,000. Remaining \$0</p>	<p>Fill the Gaps - Adjustment to Base</p>	<p>Water Level Observing Pilot Projects</p> <p>Status: Completed</p>
<p>Provided \$166,262. Spent \$166,262. Remaining \$0</p>	<p>Regional Ocean Partnership</p>	<p>Regional Ocean Data Sharing Initiative</p> <p>Status: Completed</p>
<p>Provided \$100,000. Spent \$100,000. Remaining \$0</p>	<p>Notre Dame</p>	<p>Notre Dame University project to enhance grid generation software to better represent river-coastal grid interface.</p> <p>Status: Completed</p>
<p>Provided \$50,000. Spent \$50,000. Remaining \$0</p>	<p>NOAA AK Regional Team Support</p>	<p>Make Alaska Fisheries Science Center Ecosystem status reports available electronically via the AOOS data management system and feed status report products by linking the observational data behind the ecosystem indicators. Methods will support similar activities in other regions.</p> <p>Status: Completed</p>

Provided \$50,000. Spent \$50,000. Remaining \$0	Fill the Gaps - Adjustment to Base	Joint funds from IOOS/CO-OPS for AOOS water levels (\$25,000 IOOS, \$25,000 CO-OPS)  Status: Completed
Provided \$45,033. Spent \$45,033. Remaining \$0	Axiom	From PMEL for Axiom work on Saildrone data QC funded by NOAA HPC Program  Status: Completed
Provided \$41,000. Spent \$41,000. Remaining \$0	Axiom	Axiom to implement the project 'Optimizing Machine Learning Pipelines for Novel Biological Data Streams' as proposed to the NOAA HPCC program  Status: Completed
Provided \$35,750. Spent \$35,750. Remaining \$0	State of the Arctic Report	State of the Arctic Report  Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0	Ocean Acidification	"Turning the headlights on 'high': Improving an ocean acidification observation system in support of Pacific coast shellfish growers"  Status: Completed
Provided \$8,826. Spent \$8,826. Remaining \$0	Ocean Acidification	AOOS Thresholds in a changing ocean environment: bioeconomic implications to inform adaptation decisions for Alaska's salmon fisheries (Dugan, AOOS).  Status: Completed
<b>FY20</b>		
<b>IOOS, NOAA, Other Agency Funding</b>		
<b>Funding amount spent</b>	<b>Funding Area /Recipient</b>	<b>Task</b>
Provided \$156,000. Spent \$156,000. Remaining \$0.	Regional HFR	For HFR system operations and maintenance. While you may allocate these funds to support any HFRs within the region, the allocation should not be one that negatively affects the performance of priority HFRs for the benefit of non-priority HFRs. HFR performance is measured by a metric that was developed with input from the IOOS National HFR Technical Steering Team and the IOOS HFR community. To ensure that IOOS HFR expertise is engaged to the largest extent possible, any HFR quality control or quality assurance development funded by IOOS is required to include no fewer than three IOOS regions.  Status: Completed
Provided \$20,000. Spent \$20,000. Remaining \$0.	Ocean Acidification	AOOS Alaska Ocean Acidification Network (ACAN, Dugan)  Status: Completed
Provided \$74,503. Spent \$74,503. Remaining \$0.	Axiom	MBON Data Portal  Status: Completed
Provided \$90,000. Spent \$90,000.	Axiom	Axiom maintain and enhance Data Access Service Software - ERDDAP

Remaining \$0.		Status: Completed
Provided \$50,000. Spent \$50,000. Remaining \$0	Axiom	Axiom work on Environmental Sensor Map and Global Data Integration.  Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Axiom	Axiom work to finalize HFR Range Series file archiving through Research Workspace  Status: Completed
Provided \$16,500. Spent \$16,500. Remaining \$0	OTT Biology Pilot Projects	Biology pilot projects in honor of Matt Howard to advance IOOS biology through biological data stewardship activities in the region, in coordination with the Program Office. IOOS RAs should work with regional data providers and stakeholders to align biological datasets to the Darwin Core standard and make them available through ERDDAP servers and the MBON Portal.  Status: Completed
Provided \$287,000. Spent \$287,000. Remaining \$0	K Earthquake Center	NWS Office of Observations funds for AK Earthquake Center - improve the robustness of NOAA tsunami warnings for earthquakes in Alaska. This project supports NOAA's Weather-Ready Nation initiative by providing capacity that would otherwise not exist in the Alaska  Status: Completed
Provided \$108,000. Spent \$108,000. Remaining \$0	Ocean Acidification	From PMEL for existing: DBO Project  Status: Completed
Provided \$110,604. Spent \$110,604. Remaining \$0	UAF	From PMEL for existing: 2) Glider project  Status: Completed
Provided \$120,000. Spent \$120,000. Remaining \$0	Fill the Gaps - Adjustment to Base	HFR O&M - Support HFR in the Bering Sea.  Status: Completed
Provided \$60,000. Spent \$60,000. Remaining \$0	Fill the Gaps - Adjustment to Base	Glider procurement - Glider sensors: acoustics, AZPs, optical sensors.  Status: Completed
Provided \$166,666. Spent \$166,666. Remaining \$0	Regional Ocean Partnership	Regional Ocean Data Sharing Initiative  Status: Completed
Provided \$125,000. Spent \$125,000. Remaining \$0	Notre Dame	Notre Dame University project will provide advice and guidance for ADCIRC install in the cloud sandbox and enhancement and OCS mesh dissemination project: transition to operations  Status: Completed
Provided \$85,396. Spent \$85,396. Remaining \$0	UAF	From PMEL for existing: 3) The new Bering Sea ESR Project  Status: Completed

Provided \$41,148. Spent \$41,148. Remaining \$0	Axiom	Axiom to implement the project 'Optimizing Machine Learning Pipelines for Novel Biological Data Streams' as proposed to the NOAA HPCC program  Status: Completed
Provided \$40,900. Spent \$40,900. Remaining \$0	State of the Arctic Report	State of the Arctic Report  Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Ocean Acidification	"Turning the headlights on 'high': Improving an ocean acidification observation system in support of Pacific coast shellfish growers."  Status: Completed
Provided \$4,973. Spent \$4,973. Remaining \$0	Ocean Acidification	AOOS Thresholds in a changing ocean environment: bioeconomic implications to inform adaptation decisions for Alaska's salmon fisheries (Dugan, AOOS).  Status: Completed
Provided \$180,000. Spent \$180,000. Remaining \$0	Fill the Gaps - Adjustment to Base	Glider O&M - Operate 180 glider days in GOA & Bering  Status: Completed
Provided \$151,000. Spent \$151,000. Remaining \$0	Fill the Gaps -Obs Access	Streamline Observations Procurement - Sensors for ecosystem moorings in Bering (new Buildout); Chukchi & GOA (existing) -- e.g., N2,&O2 optical sensors for each Ecosystem mooring.  Status: Completed
Provided \$75,000. Spent \$75,000. Remaining \$0	Fill the Gaps -Obs Access	Streamline Observations O&M - Utqiagvik and other water level station.  Status: Completed
Provided \$44,000. Spent \$44,000. Remaining \$0	Axiom	National Weather Service Project on S2S Sea Ice Guidance  Status: Completed
Provided \$30,000. Spent \$30,000. Remaining \$0	Axiom	OCS/Coastal Survey Development Laboratory - Cloud implementation support for modeling and post-processing.  Status: Completed
Provided \$3,000. Spent \$3,000. Remaining \$0	Axiom	Axiom Administrative - Trello subscription  Status: Completed
Provided \$41,703. Spent \$41,703. Remaining \$0	UAF	From PMEL for existing: 4) Existing mooring project  Status: Completed
Provided \$200,000. Spent \$200,000. Remaining \$0	HABS	To further harmful algal bloom (HABS) understanding and prediction  Status: Completed
Provided \$189,559. Spent \$189,559. Remaining \$0	International Year of the Salmon	Demonstrating operational readiness of AUV-based ecosystem monitoring through a field program supporting the International Year of the Salmon  Status: Completed

Provided \$25,000. Spent \$25,000. Remaining \$0	AOOS	Purchase, install, and maintain Hydroball  Status: Completed
Provided \$16,281. Spent \$16,281. Remaining \$0	Alaska Regional Coordinator	As requested by Alaska Regional Coordinator, a pilot project with OCS and the Alaska Department of Natural Resources for nearshore bathymetry technology demonstration and NOS crowdsourcing data processing  Status: Completed
Provided \$100,000. Spent \$100,000. Remaining \$0	UAF	HFR One time - Refurbish 2 radars for navigation purposes, Mouth of Prince William Sound or Cook Inlet  Status: Completed
Provided \$35,000. Spent \$35,000. Remaining \$0	Ocean Acidification	Alaska Enterprise: Observations of ocean acidification in Alaska Coastal Seas - Coastal Cruise (Saba, AOOS).  Status: Completed

## I. **PROJECT CHALLENGES/MODIFICATIONS**

- The COVID-19 pandemic resulted in delays in AOOS fieldwork and engagement and outreach activities from March, 2021 until spring 2023 including:
  - nearly all fieldwork and outreach (including planned workshops) were cancelled or postponed due to travel restrictions and rural community lock-downs.
  - equipment and sensor purchases, upgrades and refurbishments for ecosystem moorings and gliders were delayed due to manufacturing and construction backlogs.
  - Research cruises planned for 2021 and 2022 and representing three AOOS projects were cancelled due to travel restrictions and rescheduled for 2023 and 2024.
  - Travel to remote HFR sites was delayed due to community lock-downs.

## II. **PUBLICATIONS**

Bakker, D. C. E., et al.\*, 2022. Surface Ocean CO2 Atlas Database Version 2022 (SOCATv2022) (NCEI Accession 0253659). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/1h9f-nb73>. \* is >100 authors including Monacci, N. M.

Bakker, D. C. E., et al.\*, 2021. Surface Ocean CO2 Atlas Database Version 2021 (SOCATv2021) (NCEI Accession 0235360). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/yg69-jd96>. \* is >100 authors including Monacci, N. M.

Bakker, D. C. E., et al.\*, 2020. Surface Ocean CO2 Atlas Database Version 2020 (SOCATv2020) (NCEI Accession 0210711). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/4xkx-ss49>. \* is >100 authors including Monacci, N. M.

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- Danielson, S., and coauthors. 2022. GAK1 and Seward Line Physical Hydrography, Preview of Ecological and Economic Conditions (PEEC) Workshop, NOAA Integrated Ecosystem Assessment Program.
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Wright-Fairbanks, E.K., Miles, T.N., Cai, W.-J., Chen, B., Saba, G.K. 2020. Autonomous Observation of Seasonal Carbonate Chemistry Dynamics in the Mid-Atlantic Bight. *Journal of Geophysical Research: Oceans* 125 (11): e2020JC016505, <https://doi.org/10.1029/2020JC016505>.

### **III. EDUCATION, MEDIA ENGAGEMENT, AND OUTREACH MATERIALS:**

#### **Articles**

- 2021 *Breakwater Newsletter*
  - Bishop, M.A. Shackleton's Search for herring. *Breakwater* March 2021 (about the AUV)
- *Delta Sound Connections*
  - Bishop, M.A. 2021. O herring, where are thou?
  - Bishop, M.A. and J.W. Bernard. 2021. Acoustic-tagged herring - modeling the unknown
  - Bishop, M.A. 2018. How to tag a herring
  - Bishop, M.A. 2018. A year in the life of a cod
  - Bishop, M.A. 2017. Pacific herring: Once done spawning – Where to next?
  - Gray, B. 2019. Ping! Tracking fish using passive acoustic technology

#### **Presentations**

- ACCAP webinars (October 2020, March 2017)
- AGU Fall Meeting (December 2020, December 2018)
- AAAS Annual Meeting (February 2018)
- Alaska Forum on the Environment (February 2017)
- Western Alaska Interdisciplinary Science Conference, WAISC (April 2021)
- Bishop, M.A. and B. Gray. How to tag a herring and where do they go afterwards? PWSSC Tuesday night community science lecture series. January 2019. Cordova.
- September 2021, Preparing for the fall storm season: flood & erosion hazards on Alaska's west coast, National Weather Service Webinar.
- September 2021, Preparing for the fall storm season: flood & erosion observations, Local Environmental Observer (LEO) Network Webinar.
- August 2018, Coordination of integrated and inter-agency water level observations for Alaska, NOAA Hydrographic Services Review Panel Meeting. Juneau, AK.
- February 2018, Public-private solution for collecting datum referenced storm surge water level data in coastal communities, Alaska Surveying and Mapping Conference. Anchorage, AK.
- October 2017, Documenting coastal flooding & erosion in western Alaska, Local Environmental Observer (LEO) Network Webinar.
- September 2017, Storm impacts in western Alaska: documenting shoreline change and flooding through remote sensing and community-based monitoring, OCEANS 2017, Anchorage, AK.
- October 2019 – Rachel Potter, UAF, gave a presentation at the UAF Northwest Campus in Nome, Alaska, as part of their Strait Science seminar series titled 'Bering Strait

Surface Current Project’. The seminar was recorded and turned into a story by KNOM(<https://www.knom.org/wp/blog/2019/11/04/uaf-radar-systems-offer-a-variety-of-uses-for-bering-strait-region/>).

- November 2019 – Rachel Potter, UAF, gave a presentation on Alaska HFR on the Alaska Marine Policy Forum phone call
- January 2020 – Rachel Potter, UAF, gave a poster presentation at the Alaska Marine Science Symposium titled ‘Bering Strait Surface Current Project’.
- Summer 2020 – Rachel Potter, UAF, wrote an AOOS e-newsletter story
- November 2020 – Alice Bailey, at UAF then but now at AOOS, wrote an article on HFR in Alaska (<https://www.uaf.edu/news/archives/news-archives-2010-2021/real-time-maps-show-ocean-currents-in-the-arctic.php>) that was picked up by many sources, including the Fairbanks Daily News-Miner, The Arctic Sounder, the US Arctic Research Commission Arctic Update, and KTUU.
- January 2021- Seth Danielson, UAF, gave a virtual presentation for the UAF Northwest Campus in Nome, Alaska, as part of their Strait Science seminar series titled ‘Bering Strait Oceanography Local Partnership’. The seminar was recorded and turned into a story by KNOM (<https://knom.org/2021/01/21/high-frequency-radar-sites-in-wales-and-shishmaref-could-help-track-debris-and-save-lives/>).
- Thompson, Gerald, et. al., “Tidal Measurements Using GNSS-R in a Location with Receding Tides”, Presentation, 2018 AGU Session on “Integration of GNSS into Water Level Observation Networks: Priorities, Technologies, and Benefits”
- Wardwell, Nathan, E. Stromberg, C. Jansen, “GNSS Reflectometry – The Future of Coastal Observing in Alaska”, Presentation, 2019 Alaska Surveying & Mapping Conference
- Thompson, Gerald, et. al, “Ionospheric Characterization using the RIO GPS Space Weather Monitor from Remote, Autonomous Platforms”, Poster, 2019 Pacific Operational Science & Tech Conference
- A report of the HAB 2019 Workshop as well as copies of the Alaska Sea Grant books “Guide to Seaweeds of Alaska” and “Guide to Marine Mammals of Alaska” were printed and provided to each of the twenty tribal offices of the Bering Strait.
- The Nome Nugget News produced a full page story (July 25, 2019) entitled “Biologists Advise to Use Caution in Shellfish Consumption” that covered the 2019 HAB Workshop in Nome. The Nome Nugget readership is approximately 24,000 people weekly.
- KNOM Radio produced a radio/online story (July 18, 2019) entitled “Low Levels of Algal Toxins in Northern Bering Sea of Interest to Scientists and Resident”. The KNOM broadcast range regular coverage of approximately 100,000 square miles (260,000 km<sup>2</sup>), including into Chukotka, Russia <https://www.knom.org/wp/blog/2019/07/18/low-levels-of-algal-toxins-in-northern-bering-sea-of-interest-to-scientists-and-residents/>
- Additionally, KNOM Radio worked with Sheffield and produced a radio/online story that included Sheffield (Dec 20, 2019) entitled “Little Known about Algal Toxin Effects on Subsistence in Arctic Waters”. The KNOM broadcast range regular coverage of approximately 100,000 square miles (260,000 km<sup>2</sup>), including into Chukotka, Russia. <https://www.knom.org/wp/blog/2019/12/20/little-known-about-algal-toxins-effects-on-subsistence-in-arctic-waters/>
- During 2020, Sheffield was invited to work collaboratively with the regional healthcare provider, regional tribal consortium, and NOAA with an informational flyer that was

entitled “Harmful Algal Blooms in the Bering Strait Region” that was subsequently distributed to all 20 tribal offices in the Bering Strait region for public posting.

- Information on harmful algal blooms in the Bering Sea was provided to AOOS and utilized in their report that was distributed to regional Bering Strait USPS box holders and others entitled “Bering Science: Spring 2020 Bering Region Ocean Update – Learn What’s Changing” <https://legacyaaos2.wpengine.com/wp-content/uploads/2020/06/Bering-Science-FOR-WEB-15June2020.pdf>
- Sheffield authored an Alaska Sea Grant Outreach community flyer in collaboration with Wood Hole Oceanographic Institution, North Slope Borough, NOAA, and AOOS regarding the results of the 2018/2019 HAB research efforts and findings in the Bering and Chukchi seas re. Alexandrium, Saxitoxin, and Clams. This was distributed to all regional tribal offices and is available via the UAF Alaska Sea Grant Bookstore: <https://doi.org/10.4027/aascbscs.2019>
- Sheffield continues to serve the Alaska Harmful Algal Bloom Network (AHAB), as the Arctic representative and on the Steering Committee. She participated in AHAB listening sessions, provided updates on HAB monitoring efforts in the Bering Strait region, has engaged community members to help identify HAB-related needs regionally, as well as provided information about AHAB.
- During February 2019, Sheffield attended the Alaska Forum on the Environment conference and presented “An Arctic Update” that included Bering Strait regional results of harmful algal biotoxins and an update on the July 2019 HAB Workshop. The AFE conference had over 1,000 attendees total.
- AOOS created Nome 2019 HAB Workshop page to their website [<https://legacy.aaos.org/alaska-hab-network/nome-habs-workshop/>] of their site to the Nome that included links to the 2019 HAB Workshop Report and the Alaska Sea Grant Workshop flyer [<https://legacyaaos2.wpengine.com/wp-content/uploads/2019/07/2019-Bering-Strait-HAB-flyer-PDF.pdf>]
- The New York Times published an Op-Ed during September 2019 that highlighted the 2019 HAB Workshop and the emerging issue of HABs in western Alaska (below). The New York Times readership is approximately 15 million people weekly.
- Trainer, V., R. Thoman, and G. Sheffield. “Where the Sea Ice Recedes, So Does an Alaska Way of Life”. *New York Times*, 25 Sep. 2019, Op-ed. <https://www.nytimes.com/2019/09/25/opinion/climate-change-ocean-Arctic.html>
- A freeze-up project news story was featured in each of the two quarterly AOOS Updates for Summer 2015 and Winter 2016;
- A freeze-up project update in the AOOS Summer 2016 semiannual update: Water Level and Ice Observations Pilot Projects Underway in 2016.
- Freeze-up project featured as an oral presentation and accompanied by a published conference proceedings paper (The Alaska Ocean Observing System’s Past and Future Presence in the Arctic) for OCEANS 16’, presented at the MTS/IEEE sponsored conference in Monterey, CA Sept 20-22, 2016.
- A freeze-up project summary included in article prepared for Ocean News and Technology: AOOS Water Level and Ice Observation Pilot Projects (ONT, Vol 22, Issue 9, September 2016, p. 33).



- A freeze-up project webpage that described the program and provided technical details was also used to graphically display real time data. The webpage was developed in September 2015, completed in October 2015, made public on the AOOS website and remains available to the public on the AOOS website at <https://aoos.org/project/ice-detection-buoy/>
- Real-time data were reported on the website and were made available on the AOOS Ocean Data Explorer Real-Time Sensor layer. The data are now found at the following links:
  - 2015 data: <https://portal.aos.org/#metadata/105557/station/data>
  - 2017 data: <https://portal.aos.org/#metadata/105558/station/data>
- Danielson, S. 2023. Autonomous in situ marine ecosystem monitoring over the Alaskan continental shelves. Oral presentation. Global Autonomous Systems Conference, August 2023, Anchorage, AK
- Danielson, S., and coauthors. 2022. Technology and tools for monitoring physical, chemical and biological ocean conditions and their relation to fish distributions and productivity, Basin-scale Events to Coastal Impacts (BECI) Workshop III, invited presentation.
- Danielson, S., and coauthors. 2022. GAK1 and Seward Line Physical Hydrography, Preview of Ecological and Economic Conditions (PEEC) Workshop, NOAA Integrated Ecosystem Assessment Program.
- Danielson, S., and coauthors. 2022. UAF-AOOS Ocean Observing Update. Presentation to the Alaska Ocean Observing System (AOOS) Board of Directors.
- Farley, E., S. Danielson, J. Horne, and M. McCammon. 2022. Demonstrating operational readiness of AUV-based ecosystem monitoring through a field program supporting the International Year of the Salmon. NOAA UxS Operations Center Project Briefing. Virtual.
- Horne, J., F. Chavez, E. Lindstrom, M. Saunders, F. Whoriskey, S. Danielson. 2022. Uncrewed monitoring of salmon and ecosystems: on the cusp. Invited lecture. International Year of the Salmon Symposium. Vancouver, Canada.
- Horne, J.K., S. Danielson, H. Statscewich, R. Cermak, E. Farley, B. Stone, and K. Wilcox. 2022. Characterizing pelagic salmon, their potential prey field, and environmental conditions in near-real-time from an underwater glider. International Year of the Salmon Symposium. Vancouver, Canada.
- Horne, J.K. Alternate approaches to aquatic distribution and census monitoring. 2022. Basin-scale Events to Coastal Impacts (BECI) Workshop III, invited presentation. Virtual.
- Janzen, C., S. Danielson, H. Statscewich, E. Farley, J. Horne, R. Bochenek, B. Stone, and M. McCammon. 2022. Autonomous glider applications to inform timely marine resource management decisions in Alaska. Association of the Sciences of Limnology and Oceanography, Ocean Sciences Meeting. Virtual.
- Silverman, A., J. R. Cermak, S.L. Danielson, and J.K. Horne. 2022. Pseudograms: adding spatial context to EchoMetrics by embedding Sv values in output from underwater gliders. ICES Fisheries Acoustics Science and Technology Working Group Annual Meeting. Dakar, Senegal. Virtual.

- Statscewich, H., S. Danielson, T. Hennon, C. Janzen, J. Horne, E. Farley, K. Stafford, and M. Baumgartner. 2022. A brief introduction to the University of Alaska Fairbanks Glider Center. Underwater Glider User Group Meeting. Virtual.
- Statscewich, H., Horne, J., Danielson, S., Cermak, R., Wilcox, K., Farley, E.. 2023. Adding an echosounder and an acoustic brain to an underwater glider to characterize water column biomass distributions. Poster. Alaska Marine Science Symposium.
- Taylor, J.C., J.K. Horne, K. Boswell, C. Lembke, A. Silverman, E. Hughes, K. Abernathy, and E. Berkenpas. 2021. Intelligent autonomous acoustic and optic characterization of mesopelagics in the Gulf of Mexico. ICES Fisheries Acoustics Science and Technology Working Group Annual Meeting. Virtual.

#### IV. PRODUCT DELIVERY

- Lauvset, S. K., et al. An updated version of the global interior ocean biogeochemical data product, GLODAPv2.2021, Earth Syst. Sci. Data Discuss., 2021, 1-32. [doi:10.5194/essd2021234](https://doi.org/10.5194/essd2021234). 2021.
- Dorothee Bakker, et al., 2021. SOCAT version 2021 for quantification of ocean CO<sub>2</sub> uptake. <https://doi.org/10.25921/4xkx-ss49>. (\*denotes >100 coauthors)
- Bakker, D. C. E., et al.\*, 2022. Surface Ocean CO<sub>2</sub> Atlas Database Version 2022 (SOCATv2022) (NCEI Accession 0253659). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/1h9f-nb73>. \* is >100 authors including **Monacci, N. M.**
- Bakker, D. C. E., et al.\*, 2021. Surface Ocean CO<sub>2</sub> Atlas Database Version 2021 (SOCATv2021) (NCEI Accession 0235360). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/yg69-jd96>. \* is >100 authors including **Monacci, N. M.**
- Bakker, D. C. E., et al.\*, 2020. Surface Ocean CO<sub>2</sub> Atlas Database Version 2020 (SOCATv2020) (NCEI Accession 0210711). NOAA National Centers for Environmental Information. Dataset. <https://doi.org/10.25921/4xkx-ss49>. \* is >100 authors including **Monacci, N. M.**
- Data were used by Jacquelyn Overbeck (AKDNR DGGS) for a report on a storm surge event in Unalakleet, Alaska during the winter months for 2019. Kristen Larson processed and provided Jacqui data from St. Michaels for this report, as this was before AOOS had secured an operational data solution.
- Data from the JOA Survey data feed from St. Michael were used for model validation and model comparison assessments during the [Western Alaska Storm Models](#) project funded by the IOOS OTT Program (Integrated Ocean Observing System, Ocean Technology Transition Project Grant NOAA # NA18NOS0120164) (PI J. Westerink).
- Monacci, Natalie M.; Andrews, Alex G.; Bell, Shaun W.; Cross, Jessica N.; Kennedy, Esther G.; Mordy, Calvin; Pilcher, Darren J.; Stabeno, Phyllis J.; Teevan-Kamhawi, Fiona (2024). Dissolved inorganic carbon (DIC) and total alkalinity (TA) and other hydrographic and chemical data collected from discrete sample and profile observations during the NOAA Ship Oscar Dyson Cruise DY2208 (EXPOCODE 330A20220818) in the Bering Sea during the Bering Arctic and Subarctic Survey (BASIS) from 2022-08-18 to 2022-09-09 (NCEI Accession 0289932). [indicate subset used]. NOAA National

Centers for Environmental Information. Dataset.

<https://www.ncei.noaa.gov/archive/accession/0289932>. Accessed [date].

- Siddon, E. 2022. Ecosystem Status Report 2022: Eastern Bering Sea, Stock Assessment and Fishery Evaluation [Report](#), North Pacific Fishery Management Council, 1007 West 3rd Ave., Suite 400, Anchorage, Alaska 99501.
- Natalie Monacci, Jessica Cross, Darren Pilcher, Grace Saba. Ocean Acidification Research Center: Monitoring for Alaska. Alaska Marine Science Symposium, Anchorage, AK, 2023
- Monacci et al., Observing Ocean Acidification for Alaska's Fisheries. North Pacific Marine Science Organization (PICES) Meeting, Seattle, WA, 2023.

## V. **CERTIFICATION UPDATES**

*Please provide updates regarding Regional Coastal Observing System certification: Employee updates (new or departing staff), revised bylaws, or certification web site updates. Please provide as a list of bullets below.*

- 2016
  - New AOOS Board members approved: Theresa Peterson of NPFMC, Mike Mille of Indigenous Peoples Council on Marine Mammals (IPCoMM), and Bill Brit of Hilcorp Alaska.
  - RCOS certification application submitted October 2016.
- 2017
  - Official RCOS certification signed September 2017.
- 2018
  - AOOS funding a 1-year Alaska Sea Grant fellow to assist with AHAB activities.
- 2019
  - New AOOS Board member designated by Alaska Department of Fish & Game: Katherine Howard
- 2020
  - RCOS certification audit conducted and approved.
  - New AOOS Board members approved: Kenny Down of NPFMC, Lynn Palensky of North Pacific Research Board.
  - Jill Prewitt was hired as Regional Ocean Data Coordinator in April 2020.
  - Nic Kinsman performed a 3-month detail from Office of Geodetic Survey.
  - Thomas Farrugia was hired as AHAB Coordinator November 2020.
  - New AOOS Executive Director, Sheyna Wisdom, was approved by the Executive Committee to be hired on January 1, 2021.
- 2021
  - RCOS certification audit conducted and approved.
  - Marta Kumle contract for employment ended August 2021.
  - Sheyna Wisdom started as new Executive Director January 2021; Molly McCammon transitioned to Senior Advisor.
  - New AOOS Board members approved: Steve White of MXAK and Megan Kohler from Alaska Department of Environmental Conservation.
- 2022
  - New AOOS Board members approved: John Crowther of ADNR.
  - Re-certification application submitted.

## VI. EQUIPMENT

**Table 5. Equipment Purchased during Period of Performance**

<b>Equipment</b>	<b>Serial Number</b>	<b>Use Description</b>	<b>Cost</b>
Sea-Bird Scientific SBE 37SM Microcat	37-22733	Long term deployments to measure real time temperature, conductivity (for computing salinity) at NWLON station	\$6750.75 (or \$5756.89)
Dakunalytics Burke-o-lator (BoL)	UAF property tag # is 219156	AOOS Share purchased (20%) BOL and associated sensors (SBE flow through thermo salinograph -TSG) with State of Alaska for monitoring ocean acidification parameters in Kodiak, AK at the NOAA Alaska Fisheries Science Center	\$15,000 (of ~\$75,000)
Sea-Bird Scientific SEAFET pH sensor	Not available	AOOS Share purchased sensors measuring ocean acidification parameters on ocean deployed moorings	\$10,375 (partial funded)
Sea-Bird Scientific SeapHOx	Not available	AOOS Share purchased sensors measuring ocean acidification parameters on ocean deployed moorings	\$23,987 (partial funded)
Sea-Bird Scientific SEAFET V2	SBE-2330	used to measure ocean acidification parameters (pH) and marine chemistry observations on the Beaufort Lagoon Ecosystem Long Term Ecological Research moored array	\$14,410
Sea-Bird Scientific SEAFET V2	SBE-2331	used to measure ocean acidification parameters (pH) and marine chemistry observations on the Beaufort Lagoon Ecosystem Long Term Ecological Research moored array	\$14,410
Sea-Bird Scientific/Satlantic Suna	SUNA 1471	used to measure nutrients (nitrate)	\$29,210.25
Sea-Bird Scientific/WETlabs Triplet	BBFL2W B-6482	used to measure patterns of chlorophyll, FDOM fluorescence and red backscattering	\$14,849.50
Ocean Instruments ST500	5274	Passive Acoustic Monitoring instruments for deployment on Bering Strait Mooring A3 (Woodgate) or CEO to make year-round ambient ocean noise observations in the Arctic	\$5,500
Ocean Instruments ST500	5275	Passive Acoustic Monitoring instruments for deployment on Bering Strait Mooring A3 (Woodgate) or CEO to make year-round ambient ocean noise observations in the Arctic	\$5,500
Ocean Instruments ST500	6019	Passive Acoustic Monitoring instruments for deployment on Bering Strait Mooring A3 (Woodgate) or CEO to make year-round ambient ocean noise observations in the Arctic	\$5,500
Ocean Instruments ST500	6103	Passive Acoustic Monitoring instruments for deployment on Bering Strait Mooring A3 (Woodgate) or CEO to make year-round ambient ocean noise observations in the Arctic	\$5,500
Lithium Battery for Chukchi Glider	NA	Expendable batteries for long term glider deployments	\$17,200
Lithium Battery for Chukchi Glider	NA	Expendable batteries for long term glider deployments	\$17,200

Sound Traps (Ocean Instruments) and F-Pod (Chelonics)	Sound Traps: 6960 and 6961; F-Pods: 6807, 6808, 6809, 6810	Passive acoustic monitoring instruments for deployment in Kotzebue Sound to detect marine mammals.	\$18,435
Acoustic release (Edge Tech)	ETN61120	To be used in conjunction with passive acoustic monitoring instruments for deployment in Kotzebue Sound to detect marine mammals.	\$7,445
Refurbished SeaSonde Combined Tx/Rx Antenna with cable	480	HFR antenna for mapping surface currents	\$23,530
Refurbished SeaSonde Combined Tx/Rx Antenna with cable	481	HFR antenna for mapping surface currents	\$23,530
Battery Power Pack for IYS Glider	NA	Expendable batteries for glider deployments	\$17,000
Power system & enclosure (TYPE E6: PBO-style, Alaska Hut, dc)	NA	Housing for power supply and battery bank, secure enclosure that is animal proof and can withstand harsh weather of remote Alaska - still deployed	\$10,000
Septentrio GNSS satellite receiver w/ extended warranty	Unknown	Satellite receiver for remote Alaska installation to make water level observations - still installed	\$5,500
Oxygen probe	SBE43-0452	Full cost	\$5,329
ACS spectrometer	ACS-0347	AOOS share 25%	\$40,026
Fastcat CTD	SBE49-0590	AOOS share 25%	\$13,060
Nitrate Sensor V2	NTR-1551	AOOS share 25%	\$25,665
Oxygen probe	SBE43-4139	AOOS share 25%	\$5,329
Valeport Flow meter	76138	AOOS share 25%	\$7,072
Wetlabs Ecotriplet	FL#-5759	AOOS share 25%	\$10,400
SIMRAD Acoustics	267853, 267852	AOOS share 25%	\$36,000
ISIIS-DPI	ISIIS-DPI3-UAF2021	AOOS share 25%	\$443,483

SeaSonde Combined Tx/Rx Antenna with cable	480	HFR antenna for mapping surface currents	\$23,530
SeaSonde Combined Tx/Rx Antenna with cable	481	HFR antenna for mapping surface currents	\$23,530
JOA Survey - Inhouse Built Tide Gage Systems (Qty 2)	NA - built using components	2 water level sensor systems (downward looking radar and bubbler orifice) w/ integrated data loggers, modems, antennas to make NWLON-Lite water level station	\$14,722
Green Eyes Aquamonitor moored whole water 'bag sampler'	NA	Lost at sea, but replaced with insurance	\$43,665
Sexton Benthic Time Series Camera	XTN002 - 9302047	Benthic camera deployed at the CEO, Operational order	\$24,575 (or \$24,975)
RBR Duet T.ODO sensor	4041/206740 (204569?)	Temperature/oxygen datalogger, Lost at sea, but replaced via insurance	\$7,080
RBR Duet T.ODO sensor	231317	Replacement Temperature/oxygen datalogger	Insurance
Pro-Oceanus TDGP DataLogger	41-830-33 (40-733-33?)	Total Dissolved Gas Pressure datalogger - lost at sea	\$6,210
Pro-Oceanus TDGP DataLogger	43-190-33	Replacement Dissolved Gas Pressure datalogger	insurance
Bottom Tripod (fabrication costs)	SN001	Cost shared fabrication costs of platform for CEO benthic camera, AZFP and ADCP	\$13,882
Sequoia Scientific LISST mooring optics datalogger	1157	LISST Optical sensors - flooded and not operational	\$39,770
Kongsberg (CONTROS Hydro-C pCO2 dataloggers (qty 2)	BAT-7S12P-0416-001; BAT-7S12P-0117-01	Ocean acidification carbonate chemistry sensors- operational order	\$68,820
Sea-Bird Scientific SBE 37 CTD datalogger	22256	Moored CTD (Conductivity, Temperature, Pressure, Salinity) - operational order	\$6,987
Sea-Bird Scientific SeapHOx	3-1578	Moored CTD with pH and Oxygen sensors - operational order	\$22,262

Sea-Bird Scientific/WETLabs EcoPAR	6338	Moored optical PAR sensor - operational order	\$4,917
EdgeOne Acoustic Releases (qty 6)	58975, 59876, 59877, 59878, 59879, 59880	To remotely release bottom mounted moorings - operational order	\$70,783
Sexton - underwater benthic camera	XTN001	Underwater year-round imagery - operational order	\$20,646
Hydro-Bios Sediment Trap - (North America vendor Nigel Newing via Envrio-Analytical Systems)	1140315	ulti-Sediment Trap for moored applications	\$31,050
McLane Ice Tethered Profiler	ML 14696-02	Profiler capable for ice mounted or in-water mooring platforms (lost at sea)	\$60,414
Multi-Electronique - AURAL-M2 Passive acoustic recorder	296	Passive Acoustic Monitoring (PAM) Underwater Sound Recorder	\$12,668
ASL AZP active acoustics -Cost-shared (\$65K ea)	38-55063	Active acoustics transducer-acoustic zooplankton profiler	\$11,597
Sea Sciences tow cable	NA	Acrobat undulation CTD Tow Cable	\$7,779
Mooring Systems Inc - Flotation	NA	Mooring Flotation	\$30,948
Slocum glider lithium batteries	NA - Expendable	Power supply for Rutgers glider survey in southeast Alaska	\$16,799.85

## VII. **BUDGET SUMMARY:**

AOOS requested and received a 12-month No Cost Extension (NCE) in February 2021. The reason for this request was delays in AOOS fieldwork and engagement and outreach activities due to COVID-19. This extended the award through May 31, 2022.

AOOS requested and received a 24-month NCE in March 2022. This request was to accommodate the extension of three AOOS subawards: 1) Gulf of Alaska OAP Cruise, 2) Bering Sea ESR Cruise, and 3) Bering Strait HFRs. This extended the award through May 31, 2024.

Overall, invoicing went well through the course of the award. However, in April 2022, our accounting department notified the NOAA Grants Management Division (GMD) office of several significant changes to several of our accounts on the FY16-FY20 cooperative agreement, including closure of some drawlines and decrease/increase in other drawlines. After over three

months of trying to work with the Finance Office, it was finally determined that these drawlines were erroneously closed by an outgoing/retiring employee. During this three-month period, we were unable to pay subaward invoices and were unable to get any assistance from the NOAA helpline. We had to raise this issue to IOOS Program Office leadership to finally receive assistance. Once the cause of the problem had been identified, it took another month of AOOS staff time to reclassify and correct these drawlines. This resulted in significant work on the AOOS accounting staff time, delays in payment to our subawards, delays in administration of other facets of AOOS, and frustration from everyone.

The final financial report was submitted in May 2024. There are no other changes to the financial reporting for this award.

**VIII. SUCCESS STORIES**

**Table 6. Project Success Stories**

Project	Success Story	Contact
Acoustic arrays in Prince William Sound	By working closely with NOAA, this project demonstrated it is possible to add real time reporting oceanographic sensors to existing NOAA CO-OPS NWLON tide stations. The success of this project is leading to additional investments with NOAA CO-OPS NWLON to co-locate CTDs at other stations across the highly under sampled region of southeast Alaska. In 2022, a long-term CTD was installed at the NOAA CO-OPS Valdez NWLON station through a partnership with AOOS, Prince William Sound Regional Citizen Advisory Council and NOAA. Additional co-located installations are being proposed for up to seven NWLON stations in southeast Alaska.	Carol Janzen
Acoustic arrays in Prince William Sound	While no modifications were made to the goals and objectives, project PIs worked with other investigators in the Alaska Ocean Observing System to test the ability to detect tagged fish using an autonomous underwater vehicle through a collaborative effort with the University of Alaska Fairbanks (Dr. Seth Danielson and Hank Statsewich). In 2021, these efforts demonstrated how autonomous underwater vehicles (AUVs) are a useful supplement to mooring-based receivers for detecting acoustic-tagged herring. The AUV was an effective tool to determine tag mortality, as the AUV found shed tags that never would have been detected otherwise.	Carol Janzen
Freeze-up Detection	The 2015 IOOS OTT project: A Real-Time Sensor System for Detecting Freeze-up on Arctic Shelves produced a dataset that caught the attention of the NWS ice forecasters, which motivated NWS funding support to build and deploy a second ice detection buoy (IDB) in 2017. Water column data from the 2017 IDB deployment were shared through the GTS and utilized by ASIP analysts working real time on daily ice analysis and 5-day sea ice forecast products to gain a better understanding of how the upper levels of the water column	Carol Janzen



	<p>were behaving. This information was then kept in mind while analyzing current satellite imagery in the vicinity of the buoy to get a better full picture view of the coupled atmosphere/ice/ocean system. The analysts also utilized the buoy data when working on producing the monthly issued 3-month sea ice outlook product, examining trends in the water profiles and using this as supplemental information when forecasting timing of freeze-up in locations near the buoy. The data captured by the buoy also indirectly supported the ASIP by enhancing models. The success motivated a third IDB investment by IOOS, AOOS and the NWS in 2018, for which IDB real-time data was streamed through the GTS and made available to sea ice modelers so they could evaluate how useful the data were for their ongoing modeling activities.</p>	
<p>Water Level Observations in Northern and Western Alaska</p>	<p>ADNR successfully coordinated and led the newly formed Alaska Water Level Watch (AWLW) with support from AOOS, to establish a consortium of regional partners focused on increasing public access to water level data and products through innovative technologies and collaborative partnerships and expanding the coastal water level observation capacity across Alaska’s coastline. The AWLW has an official website and a dedicated data portal that allows regional partners to share data observations through a streamlined data submission process. Currently, there are 12 members on the AWLW Steering Committee representing state, federal, private industry, academic and non-profit organizations interested in improving coastal hazards information for Alaska. Since its inception, the AWLW has increased water level observational capacity in Alaska by over 65% and continues to coordinate and build-out water level and datum observing capabilities across the state. The AWLW Data Portal makes all water level data and information products for Alaska publicly accessible, including water level observing data not available through the NOAA CO-OPS Tides and Currents System.</p>	<p>Carol Janzen</p>
<p>New Equipment for Mooring M8</p>	<p>Recovery of this northern Bering Sea mooring at M8 and any data associated with it were at risk and not anticipated to be recoverable until Fall of 2022. This was a direct result of unforeseen circumstances with the 2021 EcoFOCI Fall Mooring/NOAA Arctic Cruise, directly impacted by positive cases of COVID-19. Unfortunately, other ships of opportunity operating in the area at the time were not able to recover this mooring either, though recovery of an older 2019 mooring at this site was achieved. An extended ice-year in 2022 deferred recovery efforts until the fall 2022 EcoFOCI Fall Mooring cruise. By this time, the mooring had been in the water for two years, and there was a strong possibility that it would not be recovered due to equipment failure and/or loss at sea. However, as reported to AOOS, this mooring was successfully recovered</p>	<p>Carol Janzen</p>

	in September 2022 after spending two years in the ice laden waters of the Bering Sea.	
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