



DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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ACCOMPLISHMENTS

24. What were the major goals and objectives of this project?

Efforts of this project are grouped in seven themes: Climate Research and Impacts, Environmental Chemistry, Marine Ecosystems, Ocean and Coastal Observations, Protection and Restoration of Marine Resources, Seafloor Processes, and Tsunami Observations and Modeling. Major goals of research conducted under these themes include: collecting, and analyzing data to better understand physical, biological, and chemical processes of ocean and coastal areas; understanding climate variability and change; improving our understanding of ocean and atmospheric processes associated with climate change and determining adaptation strategies; studying how the ocean absorbs carbon dioxide and the resulting increase in acidity of ocean water; studying hydrothermal vents and volcanoes on the seafloor; studying effects of interactions between human communities and natural ecosystems; developing tools and technology to restore and protect marine habitats; and improving prediction and forecasting of tsunami impacts.

25. What was accomplished under these goals?

JISAO's accomplishments during the reporting period are summarized here in the form of highlights organized by theme. It should be noted that these activities feature data acquisition and analysis in support of NOAA's mission.

- Climate Research & Impacts – Analyzed satellite data and output from high-resolution coupled atmosphere-ocean-land model simulations with a focus on the Madden-Julian Oscillation (MJO); deployed new autonomous platforms for monitoring freeze-up in the marginal ice zones of Alaska, and contributed to the Sea Ice Prediction Network and assessment of climate model simulations for the Arctic
- Environmental Chemistry – Directly documented the flux of aerosols due to sea spray versus ecosystem sources; maintained pCO₂ instrumentation on a variety of platforms, fabricated new carbonate instrumentation, and shared new results on ocean acidification along the Pacific NW coast with local tribes; used ocean models to quantify the effects of temperature on ocean acidification in the Bering Sea; quantified freshwater exchanges between the North Atlantic and Arctic; measured nutrient concentrations in the northwest Indian Ocean; quantified anthropogenic changes in CO₂ and deep ocean ventilation through observations of oceanic trace constituents
- Marine Ecosystems – Used measurements from research cruises, moorings and UAVs to monitor the physical and chemical properties of Alaskan waters under the auspices of the EcoFOCI program, contributed to the Stock Assessment and Fishery Evaluations report to the North Pacific Fishery Management Council, and documented the recent warming in the Northern Bering Sea from an ecosystem perspective; summarized spatial patterns in fishery efforts and removals, and their impacts on lower-trophic levels, in the California Current System; calibrated the echosounder on the NOAA Pt. Adams enabling acoustic surveys of eucalalon (an ESA threatened species) in the lower Columbia River; developed new tools for statistical analysis of the results from Ecopath; synthesized projections for the eastern Bering Sea in terms of its future as a favorable habitat for walleye Pollock and Pacific cod; assessed dynamic response of zooplankton in the Salish Sea to hypoxia and ocean acidification through a combination of metagenomics and more traditional taxonomic techniques
- Ocean & Coastal Observations – Oversaw release of Surface Ocean CO₂ Atlas (SOCAT) version 2019, which is a core product of the Global Ocean Observing System (GOOS), and developed the Open Access to GTS project so that ocean data providers can distribute their data in near real-time to potential users; deployed buoys in the central Arctic for directly monitoring sea ice drift; deployed 90 profiling floats as a primary contributor to the Argo program
- Protection & Restoration of Marine Resources – Carried out comprehensive surveys of harbor seal populations in the Pribilof Islands; monitored Steller sea lion and northern fur seal populations in Alaskan waters using vessel and aerial surveys and land-based tagging to determine survival and reproductive rates; conducted aerial surveys of bowhead whales in the Alaskan Arctic and beluga whales in Cook Inlet, and deployed passive acoustic recorders on moorings in the Chukchi Sea focusing on bowhead whales; continued refinement and testing of a real-time modeling system providing seasonal ocean forecasts for the coastal waters of the Pacific NW; completed a genomic analysis of the Olympia oyster towards its restoration in the waters of Puget Sound
- Seafloor Processes – Explored the chemistry of methane seeps offshore of the Pacific Northwest coast in relation to underlying

Attach a separate document if more space is needed for #6-10, or #24-50.

ACCOMPLISHMENTS (cont'd)

26. What opportunities for training and professional development has the project provided?

Individuals attended numerous meetings and conferences, including the Acoustical Society of America Conference, the Alaska Marine Science Symposium, the American Geophysical Union meeting, the ASLO Aquatic Sciences Meeting, the Bowhead Whale Abundance Survey Workshop, and the Camden Bay Workshop. Staff were also at the Carbonate System Measurement Intercomparison Working Group meeting, the Density Modeling of Cetaceans workshop, the Fisheries Acoustics Science and Technology meeting, and a major carbon cycle conference (RECCAP2). Staff attended the NOAA Environmental Data Management Workshop, the Polar 2018 Open Science Conference, the Southern CA Marine Mammal Workshop, the US GO-SHIP review on Carbon Group activities in service of GO-SHIP, and bi-weekly meetings of the USDA Forest Service. Staff held a weeklong Biogeochemical Profiling Float Workshop at UW that had over 80 people in attendance. The workshop showed how Argo floats work and how the various biogeochemical sensors and CTDs on floats operate. Most of the attendees plan to use floats on various projects in the future, but didn't truly understand the technical capabilities of the instruments prior to the workshop. One scientist participated in a workshop in London, UK to work on data collected during a cruise to the Mid Atlantic Ridge, and gave presentations at the University of Southampton and the University of Liverpool.

Training and professional development opportunities included both attending and serving as instructors on courses that include manuscript development, publishing, preparing for presentations; working with managers and decision makers at NOAA; hands-on training in the field, and data analysis in the lab. Staff offered and participated in training on both the theory and computational implementation of Bayesian inversion; the use of NASA land surface products; the Madden-Julian Oscillation, and Unmanned Aerial System payload development. Staff instructed students on the curation of museum specimens with emphasis on larval fishes, and collection techniques. Staff provided direct, hands-on training in areas such as instrument programming, data handling and processing, logistics, CTD operations, and mooring deployment and recovery operations. Individuals learned and used Python programming to help automate harbor seal data processing. Staff are studying and developing protocols to analyze images collected from an aircraft belly port camera, studying the bowhead whale photo ID catalogue, and figuring out how to incorporate ASAMM bowhead photos. Staff visited Scripps Institute of Technology to learn non-linear time-warping techniques for mode detection of low frequency calls. Individuals enrolled in an Ocean Acidification methodology training course, CTD training hosted by Seabird, and budget management training for PIs and took Kongsberg Maritime Oculus Glider Pilot and Scientist training. One of our scientists participated in computer-programming workshops at the eScience Institute at the UW focused on bash, python, R, and GitHub. She also completed a Pacific Science Center Science Communication Fellowship to develop a science communication activity/demonstration.

Outreach activities included the development of a series of webinars through SiPN2 platform to raise the awareness of importance and challenges of sea-ice cover forecasts. One scientist visited Tongji University, Shanghai, China, to interact with graduate students. This work furthered efforts to work towards the development of an iron sensor.

JISAO's internship program included a seminar series to illustrate important issues in environmental science, giving participants ~~direct experience in methods of scientific inquiry and communication. One undergraduate intern subsequently enrolled in graduate~~

27. How were the results disseminated to communities of interest?

We presented results via peer-reviewed journal publications and presentations at scientific conferences and workshops, as well as at universities, invited open public lectures, community outreach events, working groups, and laboratory tours. We served on advisory boards, and as members of steering committees. One of our scientists founded the Seattle chapter of the Society of Women in Marine Sciences, which meets monthly. She also taught a weeklong course in Colombia, South America designed to spread ocean acidification monitoring technology and methods to developing nations. We participated in career days at various elementary and high schools, including a demo introducing middle school girls to Coding Robotics and Data Science (CORDS), and presenting a demo with Women in Science and Engineering for high school students. We worked at the Seattle Aquarium during Discover Science Weekend, and gave talks at the Pacific Science Center, including an exhibit for Curiosity Days called, "How to detect animals on ice using infrared thermal cameras." It included several hands-on activities such as an infrared thermal camera demonstration, a matching game using thermal and color images of ice seals and polar bears, and an ice seal coloring station. This event helps underserved populations by donating free passes to Big Brothers Big Sisters of Puget Sound and Upward Bound, in addition to providing bus passes to public schools. We have partnerships with numerous coastal treaty tribes. Their role in the collaboration is providing information about the on-the-ground impacts of a rapidly changing ocean in tribal resources, valuable biological time-series data, and input on decision-support information they could use from ocean forecast models. We held operational safety briefings for Alaska stakeholders. We hosted a community outreach event for the Community of St. Paul Island that focused on harbor seals, current research happening on the Pribilof Islands, and an overview of drone technologies currently used for surveys. We published a pamphlet that included our results in the 2018 Alaska Ocean Acidification "State of the Science" report that was circulated to the Alaska fishing community. We shared data via the annual Ecosystem Considerations Chapter of the Stock Assessment and Fishery Evaluations report to the North Pacific Fishery Management Council. We shared data with the ICES Secretariat, and then published it as an open document. The entire ASAMM database, 1979 – 2018 is on our website for public access. We have numerous websites and blogs, and share findings through press enquiries. Innovative Technology for Arctic Exploration has a blog about the SAILdrone missions entitled "Follow the SAILdrone" to engage the public in this new science. We posted videos made by student interns online. We are active on social media. News items are posted via Twitter, Facebook, and the JISAO website. One of our scientists posted tens of thousands of tweets on Twitter that have been viewed 30 million times since January 2015. One of our PIs appeared in an episode of NOVA on PBS entitled "Decoding the Weather Machine", where the Argo project and its relevance to climate models and climate prediction was discussed in detail. Specimens from the AFSC were featured in several outreach events at the UW School of Aquatic and Fishery Sciences and the Burke Museum, including but not limited to Future Student Day, Behind the Scenes Night, College of the Environment Labs Unlocked, the SAFS 100 Year Centennial Open Labs event, and the SAFS Aquatic Open House. We engaged with autonomous surface craft vendors to discuss possibilities of designing a version for installation. We participated in the NOAA Open House event. We served on the organizing committee of SeaTalk, a group that meets quarterly with the broader ocean science community in Seattle to build a mutually respectful, inclusive, and equal opportunity community in fieldwork and sea-going careers.

ACCOMPLISHMENTS (cont'd)

28. What do you plan to do during the next reporting period to accomplish the goals and objectives?

JISAO will continue to work closely with its NOAA partners in the development, deployment and utilization of new measurement technology and analysis tool at the forefront of environmental science. A sample of our ongoing projects by them is included below.

- Climate Research & Impacts – Research on the physical mechanisms responsible for blocked versus propagating MJO events; continue analysis of output from CMIP6 models and serve the Arctic research community by organizing workshops and leading sessions at conferences
- Environmental Chemistry – Lead the development of new instrumentation to improve the biogeochemical measurements from Argo; use dynamical downscaling with a high-resolution ocean model with biogeochemistry to project future carbonate properties of Alaskan waters; continue participation in GO-SHIP towards quantifying changes in nutrient concentrations in the world's oceans; provide a toolbox for the oceanographic community to carry out tracer-based dating of ocean ventilation
- Marine Ecosystems – Maintain time series of physical and chemical properties in the Bering Sea and Chukchi Sea in collaboration with partners at the Alaska Fishery Science Center and use emerging technologies to better and more efficiently observe and model Alaskan waters; conduct workshops towards the publication of additional journal articles on the effects of fishery removals along the US west coast; continue the collection and analysis of samples from groundfish surveys, and the development of models and tools facilitating ecosystem based fisheries management; refine genomic methods to better describe the diversity of zooplankton and ichthyoplankton in the Salish Sea
- Ocean and Coastal Observations – Continue development in the support of NOAA's Unified Access Framework Project; maintain the KEO and Papa ocean climate stations and use their data to document air-sea exchanges of heat, freshwater and carbon; use sea ice drift data from buoys to identify and resolve coupled climate model shortcomings in the Arctic; continue as a primary contributor to the Argo project
- Protection & Restoration of Marine Resources – Complete analysis of sample data towards assessing the health and diets of seal populations in the Pribilof Islands; maintain pinniped monitoring efforts with a new component related to estimating human-caused mortality; continue monitoring cetaceans in Alaskan waters and develop innovative software for identifying whale vocalizations
- Seafloor Processes – Continue the development and testing of an in-situ spectrometer for methane and carbon isotope measurements; collect additional samples and refine eDNA assays to quantify community structures at hydrothermal vents and methane seeps
- Tsunami Observations & Modeling – Use new techniques for accounting for details in the source displacements that trigger tsunamis towards the improvement of forecasts

PRODUCTS

29. Publications, conference papers, and presentations

Detailed list of publications submitted to the NOAA repository. A summary is attached as an appendix.

PRODUCTS (cont'd)

30. Technologies or techniques

Below is a list from the various projects:

A high-resolution, cloud-resolving, fully coupled atmosphere-ocean-land model, satellite remote sensing measurements.

ASAMM: Line-transect aerial survey methodology, aircraft belly mounted camera system.

MML Acoustics group (ALTIMA): Passive acoustic monitoring and analysis techniques, including noise metrics.

Cook Inlet beluga (CIB) project: drones, aerial survey methodology, HD video cameras.

Regional modeling (Regional Ocean Modeling System), Matlab, Ferret, R, statistical analyses.

DNA sequencing

targeted multi-gene metabarcoding techniques, including amplification with primers targeting informative gene regions, high-throughput sequence (HTS) assays, calibration with synthetic DNA internal standards (IS) for quantification (i.e., estimating biomass of species in a sample based on number of sequence reads), and custom bioinformatic assays.

Live Access Server, PyFerret, ERDDAP, NetCDF, Climate and Forecast Metadata Conventions, ISO 19115 metadata standards, GFDL Modular Ocean Model, GFDL Earth System Model 2G, satellite measurements of wind vectors, data from various in situ observing systems

Deep ocean moored buoy technology for sustained ocean observation

Advanced technologies included the Environmental Sample Processor (for real-time detection of HABS), a remote pCO₂ system, and a host of other autonomous, in-situ mooring instruments including a profiling system

ESP (Environmental Sample Processor) a robotic electromechanical fluidics system that uses cELISA to detect plankton species and toxins. We also use advanced underwater cabling (Falmat extreme-net cable) and an integration of several straightforward technologies (underwater pumps, valves, and power systems and cellular telemetry) to permit the long-term offshore deployment of the ESP with real-time communications and data.

eDNA processing, Solidworks mechanical design, C programming for Raspberry Pi

Echosounder EK60 data, custom-made mid-frequency horizontal-looking sonar system (2.6-10 kHz), matrix factorization, tensor factorization, echo statistics, Python programming, cloud computing

31. Inventions, patent applications, and/or licenses

Nothing to Report

PRODUCTS (cont'd)

32. Other products

Nothing to Report

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

CI Director: John Horne
CI Deputy Director: Nicholas Bond

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)

34. Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to Report

35. What other organizations have been involved as partners?

Not a consortia.

Subawardees: University of Connecticut

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)

36. Have other collaborators or contacts been involved?

Mike Alexander, Simone Alin, Aleksandr Araykin, Diego Arcase, Kerim Aydin, Dan Ayers, M.O. Baringer, Sonia Batten, Tamara Baumberger, S. Becker, Catherine Berchok, Bryan Black, Nicholas Bond, Peter Boveng, Charlotte Boyd, William Brazelton, J.L. Bullister, Randie Bundy, Eugene Burger, Michael Cameron, Antonietta Capotondi, C.A. Carlson, William Chadwick, Carolina Chambers, Guiwan Chen, Wei Cheng, Dezhang Chu, Kathryn Chumbley, Sarah Converse, Kelly Corbett, Jessica Crance, Jessica Cross, Shawn Dahle, Michael Dalton, Alison Deary, S.C. Doney, Stan Dosso, John Dunne, Marie Eble, Steven Emerson, Reagan Errera, Andrea Fassbender, Richard Feely, Megan Ferguson, Bridget Feris, R.A. Fine, E. Firing, Robert Foy, Nancy Friday, Thomas Gelatt, Christopher German, Georgina Gibson, Maxime Grand, N. Gruber, Jen Hagen, Melissa Haltuch, Owen Hamel, D.A. Hansell, Ed Harrison, Alan Haynie, Tom Helsler, Albert Hermann, Gaele, Hervieux, Kevin Hiers, Anne Hollowed, Kirstin Holsman, Makio Honda, Julie Huber, Jim Ianelli, M.O. Ishii, Catherine Jeandel, G.C. Johnson, Ken Johnson, Isaac Kaplan, Stephen Kasperski, K. Katsumata, Yoshimi Kawai, Kelly Kearney, Julie Keister, R.M. Key, Peter Kiffney, Laura Kong, M.O. Kramp, Jason Kriesel, Arun Kumar, Carol Ladd, Edward Laman, Susan Lang, C. Langdon, Sim Larkin, Marvin Lilley, Xiaopei Lin, Maeve Lohan, Josh London, Rick Lumpkin, John Lupton, A.M. MacDonald, Ansley Manke, Nathan Marshall, J.T. Mathis, Beth Matta, Liz McCullough, E.L. McDonagh, S. Mecking, Chris Meinig, Susan Merle, Richard Methot, F.J. Millero, Dong-Ha Min, Christopher Moore, Erin Moreland, Danielle Naiman, T. Nakano, Jan Newton, Jeff Nystuen, Eitarou Oka, James Orr, Christopher Paight, Surya Prakash, Andre Punt, Sulagna Ray, Heather Renner, Marie Robert, Nora Rojek, Kenneth Rubin, Greg Ruggerone, Steve Rutledge, C.L. Sabine, Peter Salameh, Beth Sanderson, Jorge Sarmiento, Ajda Savarin, Joe Schumacker, Roland Schweitzer, Sarah Seabrook, Peter Sedwick, Kim Shelden, Samantha Siedlecki, Bob Simons, B.M. Sloyan, W.M. Smethie, Matthew Snyder, Laura Spencer, Paul Spencer, Ingrid Spies, Phyllis Stabeno, Valentina Staneva, Timothy Stanton, Jeremy Sterling, William Stockhausen, Robert Stone, Adrienne Sutton, J.H. Swift, Cody Szuwalski, Alessandro Tagliabue, Lynne Talley, Dajun Tang, T. Tanhua, James Thorson, Eric Thorsos, Andrew Thurber, A.M. Thurnherr, Vasily Titov, Jason Toft, Verena Tunnicliffe, Henry Vanderploog, Morgan Varner, Paul Wade, Sharon Walker, Hu Wang, R.A. Wanninkhof, Eric Ward, Amanda Warlick, Mark Warner, Janet Watt, Wilbert Weijer, Tom Wilderbuer, Sarah Wise, Lixin Wu, Yan Xue, Jie Yang, Stephani Zador, Jeannette Zamon, Tonya Zeppelin, and J.-Z. Zhang.

IMPACT

37. What was the impact on the development of the principal discipline(s) of the project?

Efforts by JISAO scientists have national and international impacts that increase knowledge, develop analytic techniques, enlarge the pool of potential NOAA employees, and provide educational and professional training.

Efforts within the Climate Research and Impacts theme have resulted in a better understanding and prediction of global weather, rainfall, sea ice freeze up, and climate.

Environmental Chemistry impacts included expanded knowledge on spatial and temporal variability in the carbon chemistry of the Bering Sea, estimates on interactions between ocean and atmosphere using transient tracer fields, and quantified decadal changes in ocean circulation and carbon uptake.

Impacts of efforts in the Marine Ecosystems theme have been extensive: measurements from the Bering Sea biophysical mooring array were used by the North Pacific Fishery Management Council to inform stock assessments of economically important fisheries; development of spatial indicators and survey techniques were used to understand trends in ecosystem changes over coastlines and to characterize Endangered Species Act threatened fish species; an ICES research symposium resulted in international dissemination of state of the art techniques and knowledge in Fisheries Acoustics; and development and use of autonomous underwater vehicles in Alaskan waters has been exported to scientists operating autonomous platforms in every ocean throughout the world; fisheries management is benefiting from new integrated modeling tools that investigate climate driven, ecosystem models to understand ecosystem changes and this approach is being adopted in Alaskan regional Fisheries management; improved life history understanding and assessment of commercially and ecologically important invertebrate (e.g. snow crab, Tanner crab), fish (e.g. walleye pollock, Pacific cod) and marine mammal (e.g. Beluga whale) species are being used to improve management and sustainability of Alaskan marine animal populations. Included in this research effort is the concurrent training in capacity constrained fields (e.g. quantitative sock assessment, fishery economics, ecological modeling) of undergraduate interns, graduate students, and postdoctoral research fellows as potential and actual STEM and NOAA employees.

Impacts from the Ocean and Coastal Observations theme included open ocean eddy observations that showed variable, subsurface production that is not detectable by satellites and occurs during non-bloom periods. This variability in production combined with observed variability in ocean albedo affects accuracy of high resolution, ocean heating models.

Research impacts from the Protection and Restoration of Marine Resources theme include census and fisheries bycatch surveys that contributed to population abundance estimates mandated in the Endangered Species Act, the Marine Mammal Protection Act, the National Environmental Policy Act, and the Alaska Mammal Stock Assessment report; passive acoustic monitoring is now used as indicators of ecological change and an index of potential impact on native communities who hunt marine mammals; regional oceanographic modeling was used to assess impacts of ocean acidification on crab recruitment; and results from oyster genomic studies are used to modify best practices in the aquaculture industry.

Impacts of the Seafloor Processes theme included: the characterization of vent and seep communities using alternate technologies (e.g. eDNA); correlation of hydrothermal output to volcanic activity using carbon dioxide and chloride data; and increased

IMPACT (cont'd)

38. What was the impact on other disciplines?

Impacts from studies conducted by JISAO scientists are not constrained within their primary disciplines. For example, knowledge gained from intra-seasonal tropical climate variability research is used by hydrological and weather managers in rainfall forecasts in monsoon regions. In Environmental Chemistry the identification of ocean acidification processes that impact marine processes such as larval fish and crab development are being transferred to recruitment of marine populations in resource management. Efforts to reduce constraints of the ocean component in earth system models are now being used to forecast climate. From the Marine Ecosystems theme, cooperation with BOEM and NPRB has extended the Bering Sea mooring program to the Chukchi Sea to monitor environmental changes in US Arctic waters and will increase knowledge of how atmosphere and ocean processes are assimilated and influence living marine resources. Knowledge from the development and use of autonomous platforms and the integration of sensing instruments continues to expand multidisciplinary capabilities that enable the sampling of remote and extreme environments. A unified modeling approach developed for ecological communities can be expanded to incorporate other disciplines for climate-influenced, ecosystem management. ; And social media is continuously used to increase social awareness of science advancements. JISAO-based research is used as a launch point for interdisciplinary and international research projects. Ongoing support for the mooring program resulted in the use of long term mooring sites as locations for multi-disciplinary, internationally-coordinated field sampling efforts. Research products from projects collecting marine mammal data are routinely used in the interpretation of sea ice, physical oceanography, and lower trophic research studies. Recent applications of genomic methods are being used to characterize and understand hydrothermal vent and seep communities. This understanding of the geochemistry of hydrothermal systems are then connected to plate tectonics and biogeography and used in biogeochemical models including marine microbial ecology. As an operational example tsunami impact knowledge is transferred to the American Society of Civil Engineers to be included in building codes and to scientists working on wave energy impacts on Antarctic ice shelves for ice melt and sea level rise predictions.

39. What was the impact on the development of human resources?

We continue efforts to encourage the hiring of minority science students and minority early career scientists. A previous student intern will present her research at a Society for Advancement of Chicanos/Hispanics and Native Americans in Science conference this fall. Two other projects supported professional development for minority, first-generation college graduates in STEM, allowing them to work with government scientists at agencies where they may work in the future.

While the number of female PhD students and postdoc researchers in the sciences has increased in recent years, retention of female scientists beyond their postdoc remains a challenge. We are helping support female research scientists, allowing one to obtain both theoretical development and hands-on experience in applying modern inference techniques to fisheries acoustics problems, and another to become familiar with the MJO, an important mode of variability in the Tropics. We trained another on grant-writing skills, project management, budget development, expense tracking, experimental design and sampling, and presentation and outreach skills. We taught two female graduate students techniques to help them understand processes that impact ocean chemistry and productivity.

Our outreach efforts include programs that reach out to students of all ages and levels, including talks on Career Day at various elementary schools, and contributing support to three high school summer interns in collaboration with the Pacific Science Center, where the students trained in stomach sample analysis and data exploration – providing exposure to STEM careers.

Undergraduate students, graduate students, postdocs, and early career scientist are all active participants in our programs. They are able to query the community for help with their research, are encouraged by established researchers in the community, and can increase networking among peer and senior researchers around the globe. We funded tuition and salary for an MS student, as well as continued education for a full-time staff member working towards a Ph.D. We supervised a visiting graduate student from Tsinghua University, China. We trained two graduate students from Western Washington University in CFC/SF6/N2O analyses. Two recent and two current undergraduate students have formed a field team, learning data collection protocols under the guidance of scientists and carrying out data collection and field logistics as paid hourly employees. About 20 additional undergraduate students have gained field data collection experience as interns assisting with debris surveys and special events that engage volunteers. Two graduate students participated in WOAC research cruises, and learned zooplankton and carbonate chemistry sampling and zooplankton taxonomy. We mentored a postdoc on new techniques (ddRADSeq), and he will interface with another postdoc from NRC in the lab.

We continually present research results to the public on various projects to diverse groups. One project's results were presented at a public event held at the University of Alaska Anchorage campus bookstore. That audience consisted of a mix of current and former UAA faculty and students, and members of the public. All PIs and associates involved in the GO-SHIP Repeat Hydrography Program presented scientific research in several forums including universities, invited open public lectures, lab tours, and on advisory boards

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT (cont'd)

40. What was the impact on teaching and educational experiences?

What follows is a list of impacts on teaching and educational experiences:

- GO-SHIP CLIVAR hydrographic program – Collaborating PIs have sponsored undergraduate and graduate students and postdoctoral fellows.
- AFSC Interns – The students that participated in this project carried out research on specific topic(s). This type of experience is both valuable and complementary to their academic studies.
- Eulachon – Training in the calibration of a scientific echosounder and data analysis was completed.
- WG Fast Meeting – The community is educated on current research results and developing techniques. Industry representatives present the latest hardware and software advances, which are then vetted and reported on by the community in subsequent meetings.
- Fish Interactions – Lab staff oversees training of summer interns for sample analysis, modelers train interns on data exploration and poster/talk preparation.
- ITAE program – The construct of the ITAE program has been used widely across NOAA as an educational activity on the development of technologies, and the inter-working of collaborative research.
- ACLIM – ACLIM supports one PhD and two postdoc researchers. ACLIM models were used in guest lectures at SAFS.
- FATE AK – One project provided training in single- and multi-species stock assessment methods to the graduate student.
- Groundfish 15 – Funding was provided for a graduate student.
- NWFSC/AFSC/SAFS Partnership - Trevor Branch teaches three courses, all required for the education of students pursuing stock assessment as a career.
- Ocean Climate Stations – OCS will have an intern this summer to work on the Papa dataset.
- Observer Bias – The field team has been mentored by senior COASST staff.
- ARGO – The results and data from Argo were used in courses taught by the PI. These included Oceanography 215 [Methods of Oceanographic Data Analysis, UW undergraduate course taught Autumn 2018] and Oceanography 510 [Physics of Ocean Circulation, UW graduate course taught Autumn 2018]. In both of these courses Argo data was used extensively in teaching about ocean processes and used as examples to manipulate and analyze data. In total, about 50 students participated in the two courses.
- ASAMM – We contributed to blog posts to the NOAA Fisheries blog, documenting ASAMM findings during the 2018 field season.
- Forecasts of OA Variability – Our impacts came mostly through our outreach activities.
- G3 Fish – We had one undergraduate intern who worked with the PMEL Genetics and Genomics Group (G3) lab, who gained experience in experimental design and lab methods. Another will work in the G3 lab this summer, gaining experience on the July 2019 WOAC cruise and in the lab.
- G3 Vents – One research scientist presented a talk on eDNA at the Seattle Aquarium Science Nights in November 2018.
- CAEP Program –The MML acoustics group has contributed data to the UW Marine Mammal Laboratory course. The CIB project provides an education segment during NOAA Science Camp.
- Venues/Earth Ocean Interactions – In previous years, we have brought teachers to sea to experience oceanographic research, and involved teachers and classroom observations via live video links. In 2019, we met with a group of 6th grade Earth science teachers for

41. What was the impact on physical, institutional, and information resources that form infrastructure?

- Marine Carbon Program – A new mooring and an underway pCO₂ system were added to an existing network of 37 moorings, 4+ vessels, 6+ autonomous surface vehicles, and numerous decadal-repeated hydrographic cruises. This project sustains and develops this equipment, the researchers that operate this equipment, and institution that supports the researchers. A significant investment was also made developing the software, hardware, and expertise needed for efficient data quality control and assimilation into data products.
- Fish Interactions – Contribution to the largest Trophic Interactions (food habits) database worldwide, and advancement of EBFM documents and products at institutional and national level.
- Alaska's Climate Change Integrated Modeling Program – ACLIM PIs are involved in discussions of modeling infrastructure needs at NOAA to support short- to long-term projections of climate change impacts on marine social-ecological systems. ACLIM is presently being considered for operational support through NMFS-OAR collaborations and is central to the Bering Sea Fisheries Ecosystem Plan. Climate-enhanced models developed through ACLIM have been included in Bering Sea stock assessments and are planned to be expanded to other species. Reconstructed changes in distributions based on ACLIM hindcasts informed, and are informing stock assessments of key species like Pacific cod.
- Ocean Climate Stations – OCS maintains the KEO and Papa buoy lab, with the capability to deploy and maintain deep ocean moored buoys in challenging environments.
- ARGO – An engineer employed on this project directed the UW Underwater AUV Team and helped to mentor over 20 undergraduates (some from underrepresented groups) on the construction and use of robotic vehicles. He did this on weekends and evenings on his own time, using UW float lab facilities, at no additional cost to the project.
- Techno Fish – The open-source software we are developing (echotype) will allow interoperability between sonar data collected from different physical systems. It will also provide a solution to scale up sonar data analysis at a lower cost than what is currently possible based on commercial software.
- G3 Fish – We've increased analysis capacity and sequencing infrastructure by providing essential reference sequences, meta-barcoding laboratory procedures, and analysis techniques.

Attach a separate document if more space is needed for #6-10, or #24-50.

IMPACT (cont'd)

42. What was the impact on technology transfer?

What follows is a list of impacts on technology transfer:

- Marine Carbon Program – Many of the products developed through this effort are freely shared online as git repositories and open access supplementary materials to publications. In addition, one of the researchers on this project led a tutorial this year for NOAA and Cooperative Institute scientists on github and version control.
- Spatial Indicators – Our code and R packages are being made available to other researchers via our public Github repositories.
- WG Fast Meeting – Developments in hardware, data acquisition, and analytic techniques are presented, discussed, and developed into best practices by this international community. These results set the world standard for active acoustic data collection and analysis.
- ITAE Program – ITAE regularly contributes to technology transfer through the continued development of its technologies.
- ACLIM – EOF methods
- Ocean Climate Stations – OCS has been working with NOAA NDBC to improve real time data transfer of the subsurface current measurements from the Tropical Atmosphere Ocean (TAO) Array.
- Design and Construction of Two Real-Time, Shallow-Water Bottom Moorings for the Environmental Sample Processor – This project allowed APL-UW to further refine and improve upon a previous design to allow the remote-deployment of the ESP. This proven design provides a solution for other ESP users (now global) to deploy the ESP in remote environments to identify HABs, toxins and the associated risk to human health in near real-time.
- ARGO – The floats built at UW were used to improve commercial models built at Teledyne/Webb and SeaBird. The BGC Profiling Float Workshop held at UW in July 2018 was attended by commercial entities from around the world, and things learned at the workshop will undoubtedly affect their products.
- G3 Fish – We are developing eDNA, metabarcoding, and bioinformatic approaches for technology transfer to other research laboratories and monitoring efforts.
- Vents/Earth Ocean Interactions – The Hydrothermal Fluid and Particle Sampler has been used as a model instrument for other scientists (e.g. Dr. Susan Lang's Hydrothermal Organic Geochemistry sampler). We are developing new technology for deep-sea in-situ chemical sensors (e.g. methane and iron) that may be adopted by other researchers or technology developers.

43. What was the impact on society beyond science and technology?

Overall impacts of research during the reporting period has resulted in increased knowledge and forecasting of climate and the impacts of climate change; better management of harvestable resources that will increase national and international sustainable fisheries management and food security; guidelines for prescribed forest burning to reduce impacts of wildfires and smoke; transfer of science activity an knowledge including an eDNA activity game to educate youth on genomic applications; and tsunami forecasts that are used by coastal communities to increase hazard resilience and emergency preparedness.

IMPACT (cont'd)

44. What percentage of the award's budget was spent in foreign country(ies)?

1 , An exact figure is difficult to obtain, as it's hard to track all of foreign travel \$ spent in a foreign country and purchases from foreign vendors, but looking at the data we do we have, we estimate it's about 1% to 1.5%. We will be initiating a subaward to a foreign entity later this year.

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

Nothing to Report

CHANGES/PROBLEMS (cont'd)

46. Actual or anticipated problems or delays and actions or plans to resolve them

This is attached as appendix 4

47. Changes that had a significant impact on expenditures

Nothing to Report

CHANGES/PROBLEMS (cont'd)

48. Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Nothing to Report

49. Change of primary performance site location from that originally proposed

Nothing to Report

PROJECT OUTCOMES

50. What were the outcomes of the award?

We are pleased with JISAO's contributions on a wide variety of important scientific problems. A partial list follows.

- Improved understanding of the MJO's response to the terrain of Indonesia towards better sub-seasonal weather forecasts for the US
- Documentation of the importance of sub-surface heat contents to the timing of freeze-up in the Arctic waters of Alaska
- Better account of how sea spray aerosols impact clouds and the scattering of shortwave radiation
- Development of ocean models for investigating the probable changes in the chemical properties of Alaskan waters in future decades
- New insights on the causes of rapid loss of sea ice in the northern Bering Sea and its implications for the food web including threatened marine mammals
- Demonstration that even low-intensity fishery removals have substantial ecosystem impacts in the California Current system
- New capabilities to track key environmental indicators for the Aleutian Islands and Gulf of Alaska
- Stronger relationships with Alaskan coastal communities in terms of sharing new information on changes in the physical and biological oceanographic conditions
- Evidence that management practices can mitigate the probable negative impacts of climate change on Pollock and cod populations in the Bering Sea
- Increasingly valuable time series on marine mammal distributions and population trends in Alaskan waters
- Progress in the development of procedures in the use of environmental DNA to map marine species distributions and their relationships to physical and chemical ocean properties
- Collaborations between UW and NOAA researchers, state agency resource managers and tribes in the use of forecast model output to assess conditions related to Dungeness crab along the coast of the Pacific Northwest
- Direct observations indicating the lack of a hiatus in the long-term warming of the central Arctic
- Evidence of open ocean deep convection in the Weddell Sea polynya with important implications for the ocean circulation near the Antarctic Peninsula
- New data on eruptions at mid-ocean ridges showing that the heat fluxes during these intervals are 6 times greater than previously estimated
- Novel information on how well eDNA from water samples can be used to characterize biological communities near seafloor vents
- Dissemination of the tsunami rapid assessment tool (TsuCAT), for use in staging tsunami warning exercises

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

<p>Gender:</p> <p><input type="radio"/> Male</p> <p><input type="radio"/> Female</p> <p><input type="radio"/> Do not wish to provide</p>	<p>Ethnicity:</p> <p><input type="radio"/> Hispanic or Latina/o Not</p> <p><input type="radio"/> Hispanic or Latina/o Do not wish to provide</p> <p><input type="radio"/> wish to provide</p>
<p>Race:</p> <p><input type="radio"/> American Indian or Alaska Native Asian</p> <p><input type="radio"/> Black or African American</p> <p><input type="radio"/> Native Hawaiian or other Pacific Islander</p> <p><input type="radio"/> White</p> <p><input type="radio"/> Do not wish to provide</p>	<p>Disability Status:</p> <p><input type="radio"/> Yes</p> <p style="padding-left: 20px;"><input type="checkbox"/> Deaf or serious difficulty hearing</p> <p style="padding-left: 20px;"><input type="checkbox"/> Blind or serious difficulty seeing even when wearing glasses</p> <p style="padding-left: 20px;"><input type="checkbox"/> Serious difficulty walking or climbing stairs</p> <p style="padding-left: 20px;"><input type="checkbox"/> Other serious disability related to a physical, mental, or emotional condition</p> <p><input type="radio"/> No</p> <p><input type="radio"/> Do not wish to provide</p>

Attach a separate document if more space is needed for #6-10, or #24-50.