Research Performance Progress Report

Northern Gulf Institute

NA16OAR4320199

July 1, 2022 to June 30, 2023

NGI
NORTHERN GULF INSTITUTE
a NOAA cooperative institute

Gulf Coast Pier

Heidi Stiller, NOAA Coastal Management

GOMA Flickr

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DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
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RECIPIENT ORGANIZATION	
20. Recipient Name: MISSISSIPPI STATE UNIVERSITY	
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22. Recipient UEI: NTXJM52SHKS7	23. Recipient EIN: 646000819

ACCOMPLISHMENTS

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

NGI is a consortium of six universities geographically distributed across the U.S. Gulf of Mexico states bring broad expertise to the NOAA partnership.

NGI's research goals are: (1) to understand the structure, function, and services of ecosystems across land-sea, ocean-atmosphere, and coastal waters-deep sea interfaces; (2) to synthesize information across disciplines to reduce uncertainty and to forecast ecosystem responses; and (3) to develop applications that address regional management needs.

NGI's engagement goals are: (1) develop, facilitate, disseminate, and transition research, knowledge, and applications and (2) build internal and external connections for institutional sustainability.

25. What was accomplished under these goals?

FORECASTS, WARNINGS, AND RESPONSE (1) A UAS mission covered a river flooding event, a UAS cost & feasibility analysis was completed, continued integration/testing of detect & avoid technology for UAS, submitted concept for Beyond Visual Line of Sight (BVLOS) Operations (2) Surface wind data collected by hurricane hunter aircraft was improved by updating the Stepped Frequency Microwave Radiometer (SFMR) algorithm for rain rates from tail-Doppler radar (TDR) and developing a new flight module in collaboration with HRD radar experts to calibrate TDR data (3) AOML seasonal hurricane outlook was incorporated into NOAA/CPC operational model, and a tropical cyclone motion and tracking model was validated (4) Atlantic Niño was found to be an important SST predictor of seasonal hurricane activity (5) generalized beta-advection model for simulating tropical cyclone motion and track was validated against historical data and will help develop probabilistic forecasts of landfalling hurricanes.

FISHERIES CONSERVATION, MANAGEMENT (1) 5 sawfish and 3 hammerhead sharks were tagged and released to gauge population, reproduction, and habitat data (2) Analyzed eDNA and microbiome samples to reveal taxonomic composition of Bryde's whale and dolphin samples for health monitoring, applied a modified 12S MiFish protocol to obtain better fish eDNA data (3) Extensive library of annotated images was developed for models that detect and identify reef fish, with important Gulf species identified and counted accurately (4) Electronic monitoring (EM) hardware to collect fish species, size, and catch events was prototyped; EM software was evaluated; an eLog sensor system, chutebox with depth sensors, and stereo camera system were installed on vessels.

ECOSYSTEM MANAGEMENT (1) FY23 hypoxia monitoring cruise, data QA/QC, and hind cast models were completed (2) Hydrodynamic and salinity models were added to South FL water quality model, which is being calibrated (3) Bioinformatics infrastructure included development of protocols for high-throughput DNA extraction and PCR amplification of eDNA and used on ~2000 biological samples, published sequence analysis pipeline and Omics Data Management Guide on GitHub (4) Collected ~500 biological samples on GOMECC cruise then used high-throughput DNA extraction that was PCR-amplified, sequenced, and analyzed to understand ecosystem response to ocean acidification.

DATA SERVICES (1) Meteorological and oceanographic data from vessels were collected, monitored, archived, and disseminated through the Shipboard Automated Meteorological and Oceanographic System Data Assembly Center (SAMOS DAC) (2) Acquired a server for continued maintenance and delivery of geospatial modeling web applications (3) Data generated across all NGI efforts benefited from data management and product development that enhance data usability.

EDUCATION AND OUTREACH (1) Peer-reviewed publications and presentations reached scientific and management communities (2) Formal, informal learning activities engaged K-12 educators and students (3) Professional development trained project researchers, students, and staff (4) NGI website and social media disseminated research results to broader audiences.

ACCOMPLISHMENTS *(cont'd)*

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

Participation at scientific conferences, meetings, and workshops:
Gulf Estuarine Research Society Meeting

International Conference on Environmental Systems, International society for optics and photonics

Metabolomics Association of North America Microbiome Interest Group

NOAA Marine Ecosystem Task Force Meeting, NOAA Modular Ocean Model 6 Regional Meeting, NOAA 'Omics Seminar Series, NOAA Ocean Acidification Community Meeting

South Central Climate Adaptation Science Center Meeting, SPIE Ocean Sensing and Monitoring Session

World Aquatic Veterinary Medical Association

Specialized training during research projects:
Students gained experience in conducting fisheries surveys as part of their graduate theses or dissertations; participated in hypoxia data acquisition, compilation, and analysis; learned about use of remote sensing to understand effects of wind structure on tropical cyclones; heard from experts on applying machine and computer vision to develop innovative sampling technologies; experienced use of high-performance computing and cloud services; and helped develop journal articles and science presentations.

Professional staff received training on fisheries surveys, statistical analysis, and use of AI/ML tools and software; refined skills in analysis and interpretation of ocean surface wind speed and rain rate data for hurricane forecasts; participated in tutorials on bioinformatics and data analysis using Python; refined skills in 'omics research and teaching; incorporated high-powered computing for research; received training in processing cetacean biological samples for environmental DNA analysis; gained experience in data collection on NOAA ships and sample processing in NOAA labs; learned how to incorporate stakeholder feedback in development of experimental seasonal hurricane outlooks for operational models; continued building relationships with project colleagues and stakeholders; and refined skills in scientific communications. Technicians onboard research vessels received advice from scientists to identify problems with meteorological and surface ocean sensors on vessels and learned best practices for sensor deployment and acquisition of sensor data and metadata.

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

Results of sponsored operations and research are disseminated through publication in peer reviewed journals, technical reports, presentations; at invited lectures, meetings, briefings, conferences, and workshops (see Question 29 Products). Research findings and technology advancements are incorporated into coursework, professional development and training, K-12 activities and resources, and public event activities and materials. Programmatic and scientific information is also disseminated through the NGI website, the Portal newsletter, listserv emails, and social media.

Additional research data were disseminated to stakeholders online:

The 2023 hypoxia forecast from the 2022 hypoxia monitoring cruise will soon be available at https://gulfhypoxia.net/research/shelfwide-cruise/?y=2022&p=hypoxia_fc. Online coverage of the 2022 monitoring effort included https://www.noaa.gov/news-release/noaa-forecasts-below-average-summer-dead-zone-in-gulf-of-mexico as well as an NGI-hosted press event.

Video and imagery data of fisheries surveys are available at https://github.com/SEFSC/SEAMAPD21, and a summary of a Frontiers in Marine Science paper on use of AI/ML to improve image processing is available at https://www.northerngulfinstitute.org/news/?d=1086.

The OAR 'Omics Data Management Plan and data and metadata standards are available at https://microbiomedata.org/. 'Omics and bioinformatics data analysis tutorials are available at https://github.com/aomlomics/tutorials. An updated Tourmaline amplicon DNA sequence analysis workflow is available at https://github.com/aomlomics/tourmaline.

Meteorological and oceanographic observation data from U.S. research vessels is available at https://samos.coaps.fsu.edu/html/data_availability.php, at ftp.coaps.fsu.edu, and at THREDDS https://www.coaps.fsu.edu/thredds-listing. A data management plan for the meteorological and oceanographic observation data is available at https://samos.coaps.fsu.edu/html/docs/SAMOS_DMP_for_NOAA_6Nov2019_v05.pdf.

ACCOMPLISHMENTS *(cont'd)*

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

Continue to improve forecasts, warning, and response to weather and climate impacts by (1) conducting 2 UAS missions for flood event assessments, analyzing data, and developing BVLOS safety case (2) developing a method to calibrate the historical TDR archive, computing new rain rates from historical data, and updating the SFMR algorithm (3) improving the seasonal hurricane outlook with robust measure of forecast uncertainty, refining statistical model with predictive ML/AI algorithms, and producing experimental probabilistic seasonal forecasts of hurricane US landfalls by Fall 2024.

Continue fisheries conservation and management by (1) conducting 4 sampling trips to tag and collect samples from smalltooth sawfish and hammerhead sharks and supporting a graduate student (2) producing and evaluating new iterations of training models that detect and identify reef fish using data from different years and locations 3) working with SEFSC to draft, submit a manuscript on cetacean eDNA analysis for health monitoring (4) using EM to collect fish data and developing acoustic detectors for fish and marine mammals to improve ecosystem monitoring, improving the chutbox system and installing more of them on vessels to gather data, and improving AI/ML algorithms for fish identification and size/volume estimates.

Continue ecosystem-based management by (1) monitoring and assessing the hypoxia zone and running hindcast models for NOAA resource managers (2) simulating management scenarios for south Florida water quality (3) analyzing 16s and 18s biological data for response to ocean acidification, including additional statistical models, and submitting manuscript for publication.

Continue data services by (1) collecting, processing, disseminating, and archiving meteorological and oceanographic data and working with OMAO to develop automated instrument metadata ingestion procedures presently being deployed to the NOAA fleet for more complete and accurate metadata for SAMOS data products (2) supporting all efforts (ecosystem management, fisheries conservation/management, and forecasts/warnings/response) by providing data management and development of data-derived products to enhance data usability.

Continue education and outreach through (1) publications and presentations (2) formal and informal activities with K-12 educators and students (3) professional development and training (3) relevant website content (4) social media promotion.

PRODUCTS

29. Publications, conference papers, and presentations

NGI generated 11 publications and 16 presentations during this reporting period. See attached MS Excel Document for details.

A complete list of publications has been submitted to IR.

PRODUCTS *(cont'd)*

30. Technologies or techniques

Advancements in electronic monitoring for automated detection of fish included implementation of an active learning AI/Semi-supervised learning-based framework to reduce annotation cost of fish species.
Advancements in using video and imagery data for fisheries assessments included development of adapted R statistical analysis scripts for evaluating model precision. Open-source models and large image library are available at https://github.com/VIAME/VIAME.

South Florida water quality assessment and management scenarios can be conducted with newly developed hydrodynamic and salinity models for use in water quality model simulations.

Advancements in bioinformatics infrastructure include development of 2 magnetic bead DNA extraction protocols that are run on the KingFisher Flex bead-handling robot and development of PCR preparation, PCR cleanup, DNA dilution, and extraction prep protocols that are run on the Opentrons liquid handling robot.

Acquisition of water column data improved hypoxia hindcast modeling.

Development of geospatial data applications for resource management include:
GeoCoast 3D Coastal Inundation GIS http://geoproject.hpc.msstate.edu/GeoCoast3D/
GeoInundation 3D Coastal Inundation Viewer https://geoproject.hpc.msstate.edu/geoinundation3d/
GeoPanorama VR Coastal Inundation Viewer https://geoproject.hpc.msstate.edu/geopanorama/

A newly developed tropical Atlantic-Pacific (interbasin) SST index skillfully predicts Atlantic hurricane activity and is now used as part of an operational statistical model in the NOAA/CPC Atlantic seasonal hurricane outlook.

31. Inventions, patent applications, and/or licenses

For electronic monitoring of fish species, size, and catch events, a patent will be applied for a class-aware loss function developed to eliminate the class-imbalance problem in the dataset. The proposed loss function is developed in Python. The proposed loss function was presented in this article https://doi.org/10.3390/s22218268

PRODUCTS *(cont'd)*

32. Other products

A new GitHub repository (https://github.com/SEFSC/SEAMAPD21) facilitates the sharing of video and image fisheries data by scientists and researchers to process large volumes of raw image-based data at a significantly faster rate compared to current manual methods.

A mid-season experimental AOML seasonal hurricane outlook was created and shared with NOAA/CPC for feedback and discussion ahead of their 2022 August hurricane outlook update. A similar update will be created this season and shared with NOAA/CPC for incorporation into the 2023 August Atlantic hurricane outlook update.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Robert Moorhead – Director NGI
Paul Mickle – Co-Director Director NGI
Jamese Sims – Deputy Director NGI
Whitley Alford – Program Administrator
Jamie Dyer – Associate Director NGI
Just Cebrian – Associate Director NGI
Jonathan Harris – Outreach Coordinator

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?

35. What other organizations have been involved as partners?

NGI closely aligns itself with NOAA and other partners' regional efforts, some having representation on the NGI Executive Board or who sponsor/participate in NGI research and outreach. Therefore, NGI's approach is science driven, regionally focused, and coordinated with other organizations that focus on Gulf of Mexico issues. The Director of the OAR Atlantic Oceanographic and Meteorological Laboratory (AOML) serves as the NOAA Technical Program Manager for NGI; thus, AOML is the NOAA laboratory that NGI works most closely. NGI and the NESDIS National Centers of Environmental Information (NCEI) share a building at the NASA Stennis Space Center, facilitating a close working relationship.

Long-standing NGI regional partners include:
Coastal Protection and Restoration Authority, Environmental Protection Agency Gulf of Mexico Program, Gulf Coast Ecosystem Restoration Council, Gulf of Mexico Alliance, Mississippi Alabama Sea Grant Consortium, Mississippi Department of Environmental Quality, Mississippi Department of Marine Resources, National Academies of Science Gulf Research Program, NOAA Regional Collaboration Network, NOAA Restore Science Program

During this reporting period, NGI projects involved the following partners:

NOAA
OAR Atlantic Oceanographic and Meteorological Laboratory, Earth Systems Laboratory, Great Lakes Environmental Research Laboratory, Ocean Acidification Program, Physical Oceanography Division, Physical Sciences Laboratory, Uncrewed Systems Research Transition Office (UxSRTO)

NESDIS National Centers of Environmental Information

NMFS Office of Protected Resources, Southeast Fisheries Science Center

NWS Climate Prediction Center, Lower Mississippi River Forecast Center, National Hurricane Center, Southern Region Headquarters, West Gulf River Forecast Center

NOAA OMAO Aircraft Operations Center

Academia
Mote Marine Laboratory, University of North Florida

Industry

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS *(cont'd)*

36. Have other collaborators or contacts been involved?

NOAA
OAR AOML Gregory Foltz

NMFS Farron Wallace, Jack Prior, Ryan Caillouet, Matthew D. Campbell, Matt Grossi, John Carlson, Andrea Kroetz; Joan Browder

NCEIS NCEI Chris Paver, Steve Rutz, John Relph, Vidhya Gondle; International Comprehensive Ocean Atmosphere Data Set Project

NWS Climate Prediction Center Hui Wang, Matthew Rosencrans

OMAO Maryland Solomon Tadele, John Katebini, Philip Zublay, Kevin Cromer

Academia
University of Basel, Switzerland Vital Heim; University of Miami/CIMAS Dongmin Kim; University of North Florida Jim Gelsleichter; University of Washington Aotian Zheng, Jeng-Neng Hwang

Industry
Google Cloud Brett Alger

Government
EPA Steve Blackburn, Miami-Dade County FL Laura Eldredge; NSF-funded Rolling Deck to Repository project; South FL Water Management District Nicole Cortez; US Army Corps of Engineers James Riley, April Patterson; US Fish and Wildlife Bahram Charkhian

Non-Profits
Havenworth Coastal Conservation Tony Wiley, Miami Waterkeeper Rachel Silverstein

IMPACT

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

FORECASTS, WARNINGS, AND RESPONSE (1) NHC forecasters received improved data on surface wind speed to analyze and forecast tropical cyclones (2) A new statistical methodology for Atlantic seasonal hurricane outlook is now an operational statistical model in the NOAA/CPC outlook, which is widely used by stakeholders to manage the risks of tropical cyclones.

FISHERIES CONSERVATION, MANAGEMENT (1) New methods produced automated counts that match manual counts in fisheries video surveys and time series data can be adapted to other video-based surveys across NOAA and academia (2) EM provided efficient processing of fisheries digital media, reducing labor costs and giving faster data to inform decisions for closures and stock assessments (3) Fish datasets with images and videos were transitioned to a CLOUD-based platform, assisting data acquisition, processing, and archiving (4) Progress was made toward defining important habitats and estimating bycatch risk for endangered smalltooth sawfish; results from hammerhead shark work contributed to federal stock assessments.

ECOSYSTEM MANAGEMENT (1) Simulated water quality scenarios for Biscayne Bay and Coral Gables inform decisions by resource managers (2) Advancements in bioinformatics infrastructure are recognized across NOAA and the international science community as enhancing the use of omics and bioinformatics for marine system studies (3) Understanding ecosystem response to ocean acidification contributed to improved understanding of basic biodiversity responses at multiple trophic levels of organisms to changes in carbonate chemistry and pH (4) Data from hypoxia monitoring cruises is the key variable for models that inform nutrient loading goals of the Hypoxia Task Force.

DATA SERVICES (1) The GOMO mission is supported by SAMOS data for modeling circulation and ocean temperature structure; SAMOS observations are often collected in remote regions making them ideal for marine climate and ocean process studies and evaluating numerical models and satellite products (2) Data generated across all NGI efforts benefit from data management and product development that enhance data usability.

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

NGI research and operations contribute to a more holistic, interdisciplinary understanding of interconnections among Gulf of Mexico ecosystems, resources, and people and facilitate decision-making based on those interconnections. Examples include the following:

Methods developed to manage fisheries video and image data can be adapted to other applications using machine learning.

Incorporating data from other disciplines such as sea-level rise and climate change predictions into water quality modeling for south Florida is significant as current resource planning does not consider effects of global environmental change.

More accurate surface wind speed estimates in hurricanes contribute to improvements in other disciplines such satellite calibration at high winds; estimates of air-sea exchanges of momentum, energy, mass; preparation of coastal communities for land-falling storms; and safety at sea for the marine community.

Development of bioinformatics infrastructure is inter-disciplinary work and includes fields of microbiology, toxicology, fisheries biology, and marine genomics.

Analysis of eDNA for cetacean health monitoring is changing how prey contents of whales and diseases of dolphins are studied.

Ocean acidification research is inherently interdisciplinary and impacts the understanding of OA by other oceanography disciplines, such as chemical oceanography.

Developing innovative sampling technologies contributes to a more holistic decision-making process that incorporates interdisciplinary understanding of the interconnections among Gulf of Mexico ecosystems, resources, and people. Electronic monitoring and incorporation of ML algorithms have other applications beyond fisheries such as military marine geospatial intelligence and marine resource management.

SAMOS observations contribute to other marine products such the International Comprehensive Ocean-Atmosphere Data Set and the Surface Underway Marine Database. SAMOS reports include components of the solar radiation spectrum and precipitation measurements, and some of its ships provide doppler speed logs which, along with high-quality vessel navigation parameters, can be used to estimate ocean surface currents.

The progress of Mississippi River watershed nutrient reduction practices in mitigating hypoxia is better informed by monitoring and modeling protocols that are effective and cost-efficient. Managers have improved capability for refining hypoxia mitigation strategies in an adaptive management context. Formal partnerships have been established to ensure a sustainable hypoxic zone monitoring

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

NGI research and operations provided training resulting in highly qualified candidates for NOAA's and other research organizations' workforce. NGI scientists gained experience leading to promotions and increased research expertise. Interdisciplinary work contributed to a more holistic understanding of complex issues. See Question 26 (training and professional development the project provided) for details.

IMPACT *(cont'd)*

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

NGI provided training and professional development to students and staff. PIs mentored and provided experience during project work, with students incorporating knowledge into theses/dissertations. Scientists incorporated research findings in tutorials, lectures, workshops, and coursework. See Question 26 (training and PD the project provided).

NGI's E&O program supported NOAA by developing an engaged and educated public who are better able to make science-based decisions and a workforce pipeline for science, technology, engineering, and math (STEM) careers. Activities engaged a variety of audiences (1) K-12 educators and students; (2) scientists, university students, staff, and administration; and (3) broader science-interested communities. The program collaborated with regional education initiatives of the Gulf of Mexico Alliance, NOAA Sea Grant programs, and National Academies Gulf Research Program and incorporated NGI research into activities and resources. Information is shared through a variety of avenues, including listserv emails, social media, the Portal newsletter, and website.

NGI E&O program activities:
•Develop marine and atmospheric science curriculum and fieldwork for supplemental classroom material and host lesson plans (500+) from previous projects at http://gk12.msstate.edu/lessonplans.html
•Support STEM/STEAM events with resources such as (1) Traveling Trunk Shows with art and science curriculum that support college and career readiness standards; (2) Scientists Get Involved program for STEM faculty guest lectures; (3) Interactive ROV, robotics, UAS/UAV demonstrations; and (4) Science and curriculum for homeschool education groups.
•Provide experiential learning for middle and high-school students onboard the R/V Jim Franks to collect marine samples and learn about Gulf Coast history, geography, geology, biology, ecology, and climate.
•Facilitate high school students/upcoming college freshmen interested in marine, earth, and atmospheric sciences to participate in summer data collection and fieldwork.
•Provide professional development and training on technologies such as uncrewed aerial and marine systems, geospatial techniques, and continuing education through MSU Geosciences and Interdisciplinary Studies programs.
•Participate in science teacher associations to strengthen connections with educators.
•Encourage diversity in science through the Girls Engaged in Math and Science (GEMS) Program.

NGI's E&O program has significant reach to a wide range of audiences, engaging nearly 10,000 people annually during local, regional, and national events and programs such as:
•A new diversity internship program at NGI affiliated institutions (15 college students)
•Teacher workshops in meteorology, computational thinking, visualization (18 teachers)
•Travelling Trunk and Visiting Scientists programs (180 students)
•Mississippi Aquarium Home School program (100 students)
•MSU Science Education at SEA program (300 students)
•Celebrate the Gulf Marine Science event (1,500 attendees)

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

The use of AI/ML to improve the efficiency and use of fisheries video assessments resulted in models, imagery, and metadata organized in NCEI database networks. Standard operating procedures have been developed for use of machine learning tools and associated data management.

Improvements in estimations of surface wind speed in tropical cyclones resulted in an updated TDR rain rate and SFMR comparison dataset that will be publicly available.

Advancements in bioinformatics infrastructure included renovations of the AOML Omics Lab and creation of code repositories and organizations on GitHub for hosting and version control of software produced by AOML.

Research on ecosystem responses to ocean acidification enabled equipment purchases that improved the throughput and capacity of the AOML 'Omics Lab.

Research that uses EM technologies for improving estimations of fish length and species recognition will result in publicly available fish datasets. Several hardware test structures were built, and several ML algorithms were developed that have a wide variety of applications. The development of advanced catch event detection hardware and software can be deployed on cruises around the ocean.

During SAMOS operations, PI and researcher feedback to vessel operators routinely resulted in improvements to sensors on vessels, with operators seeking recommendations on which sensors to deploy and in what locations. This improves the overall measurement infrastructure on recruited RVs.

IMPACT *(cont'd)*

42. What was the impact on technology transfer?

The use of AI/ML to improve the efficiency and usability of fisheries video assessments is a step towards implementation of machine learning tools into operations for NOAA fishery surveys.

Technology transition plans are being developed for bioinformatics workflows to ensure they are shared widely to benefit the marine bioinformatics community.

Electronic monitoring for fisheries generated several ML algorithms (semi-supervised learning, active learning) to detect and classify fish, helping reduce the data annotation cost and speed up the process of detection. These advanced technologies can be utilized for tracking and counting fish species and can be integrated into the system for real-time monitoring.

A new statistical methodology improved predictions over the 2001-2022 hurricane season than what was previously used by NOAA/CPC for Atlantic seasonal hurricane outlook. This methodology is now an operational statistical model in the NOAA/CPC Atlanta hurricane outlook, which is widely used by stakeholders to manage the risk of tropical cyclone impacts during hurricane season.

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

Artificial Intelligence and machine learning is an exploding subject in world markets, news, and social media. These tools are extremely powerful and can be used in many applications beyond fisheries management.

Improving surface wind speed estimates in tropical cyclones will improve forecasts and impact guidance for the public, helping coastal societies prepare for landfalling storms. More accurate ocean surface wind speed estimates are also critical for providing increased safety at sea for maritime operations.

Ocean acidification may have drastic effects on the ocean and everything that depends on it; research to understand ecosystem response to ocean acidification is critical to understand its broad effects and how to predict and model them.

Developing innovative sampling technologies enhanced public understanding of the interconnections among Gulf of Mexico ecosystems, resources, and people. Accurate fish species identification plays a crucial role in sustainable fishing practices and resource conservation.

Members of the public and educators were informed of the importance of maintaining biodiversity and protecting habitats needed by endangered fish species.

The SAMOS project provides foundational high-quality meteorological and near-surface oceanographic data to support an expanding research and operational user community, which in turn is addressing many questions of primary interest to GOMO and NOAA. Archiving all quality-evaluated SAMOS data at NCEI ensures that data collected at taxpayer expense are complete, accurate, and accessible for future generations of scientists, policy makers, and the public.

Understanding and monitoring the Gulf of Mexico Hypoxia Zone enhances public trust in NOAA.

The predictability of hurricanes and extreme weather has an enormous impact on human mortality, infrastructure, and socio-economic development for the US Gulf and Atlantic coasts. Resilience to extreme weather will benefit from improved understanding of the seasonality and frequency of hurricanes and US landfall events.

IMPACT *(cont'd)*

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

0 ,

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

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

CHANGES/PROBLEMS *(cont'd)*

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

47. Changes that had a significant impact on expenditures

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

CHANGES/PROBLEMS *(cont'd)*

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

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

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

PROJECT OUTCOMES

50. What were the outcomes of the award?

NGI outcomes include 27 presentations and publications advancing science in (1) climate change and climate variability effects on regional ecosystems; (2) coastal hazards; (3) ecosystem management; and (4) effective and efficient data management systems supporting a data-driven economy.

These advancements increased capability and capacity to 1) understand the structure, function, and services of ecosystems across land-sea, ocean-atmosphere, and coastal waters-deep sea interfaces; (2) synthesize information across disciplines to reduce uncertainty and to forecast ecosystem responses; (3) develop applications that address regional management needs; (4) develop, facilitate, disseminate, and transition research, knowledge, and applications; and (5) build internal and external connections for institutional sustainability.

Details are available in Question 25 (accomplishments), Question 29, 30, 32 (products), and Question 37, 38, 41, 42, 43 (impacts).

Outcomes summary:

Improved forecasts, warnings, and response resulted from (1) more accurate atmospheric and oceanic data used in storm and hazard forecasts (2) improved statistical methodology used by NOAA/CPC operational model for seasonal Atlantic hurricane outlooks (3) from fast, safe acquisition of flood events data and imagery using uncrewed technologies.

Improved fisheries conservation and management resulted from (1) recommendations based on field surveys of endangered smalltooth sawfish to reduce bycatch mortality (2) fisheries management decisions informed by timely analysis from efficient processing of video surveys with machine learning algorithms (3) stocks assessment decisions informed by timely estimates of fish total haul, catch, and by-catch from electronic monitoring supported by high-performance computing and cloud platforms (4) advancements in cetacean health monitoring using eDNA analysis generated with bioinformatics technologies and infrastructure.

Improved ecosystem-based management resulted from (1) hypoxia mitigation strategies based on forecasts and hindcasts from annual hypoxia monitoring analysis (2) improved watershed management from enhanced water quality modeling capabilities (3) advancements in bioinformatics infrastructure, workflows, and protocols for processing, analyzing, and interpreting biological samples (4) development of automated eDNA collection for efficient harmful algal blooms assessment (5) improved knowledge of metagenomes and metabolomes of global Earth microbial communities.

Enhanced data accessibility and usability resulted from (1) data management, services, and product development curated by data specialists and subject matter experts and disseminated online to stakeholders (2) use of high-performance computing and cloud platforms (3) advancements in efficiently collecting, processing, and analyzing digital media (4) dissemination of QA/QC meteorological and oceanographic data collected on NOAA vessels.

Effective engagement with target audiences resulted from (1) publications and presentations for science and management communities (2) education resources for K-12 teachers and students (3) professional development for students/staff on research projects (4) relevant website content and social media use to reach broader science-interested audiences.

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

Gender:

- ◯ Male
- ◯ Female
- ◯ Do not wish to provide

Ethnicity:

- ◯ Hispanic or Latina/o Not
- ◯ Hispanic or Latina/o Do not
- ◯ wish to provide

Race:

- ◯ American Indian or Alaska Native Asian
- ◯ Black or African American
- ◯ Native Hawaiian or other Pacific Islander
- ◯ White
- ◯ Do not wish to provide

Disability Status:

- ◯ Yes
  - [ ] Deaf or serious difficulty hearing
  - [ ] Blind or serious difficulty seeing even when wearing glasses
  - [ ] Serious difficulty walking or climbing stairs
  - [ ] Other serious disability related to a physical, mental, or emotional condition
- ◯ No
- ◯ Do not wish to provide

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

The following provides complete text for answers to questions 35, 38, and 40.

NA16 OAR 420199 July 1, 2022 to June 30, 2023

#35 WHAT OTHER ORGANIZATIONS HAVE BEEN INVOLVED AS PARTNERS?

NGI closely aligns itself with NOAA and other partners' regional efforts, some having representation on the NGI Executive Board or who sponsor/participate in NGI research and outreach. Therefore, NGI's approach is science driven, regionally focused, and coordinated with other organizations that focus on Gulf of Mexico issues. The Director of the OAR Atlantic Oceanographic and Meteorological Laboratory (AOML) serves as the NOAA Technical Program Manager for NGI; thus, AOML is the NOAA laboratory that NGI works most closely. NGI and the NESDIS National Centers of Environmental Information (NCEI) share a building at the NASA Stennis Space Center, facilitating a close working relationship.

Long-standing NGI regional partners include:
Coastal Protection and Restoration Authority, Environmental Protection Agency Gulf of Mexico Program, Gulf Coast Ecosystem Restoration Council, Gulf of Mexico Alliance, Mississippi Alabama Sea Grant Consortium, Mississippi Department of Environmental Quality, Mississippi Department of Marine Resources, National Academies of Science Gulf Research Program, NOAA Regional Collaboration Network, NOAA Restore Science Program

During this reporting period, NGI projects involved the following partners:

NOAA
OAR Atlantic Oceanographic and Meteorological Laboratory, Earth Systems Laboratory, Great Lakes Environmental Research Laboratory, Ocean Acidification Program, Physical Oceanography Division, Physical Sciences Laboratory, Uncrewed Systems Research Transition Office (UxSRTO)

NESDIS National Centers of Environmental Information

NMFS Office of Protected Resources, Southeast Fisheries Science Center

NWS Climate Prediction Center, Lower Mississippi River Forecast Center, National Hurricane Center, Southern Region Headquarters, West Gulf River Forecast Center

NOAA OMAO Aircraft Operations Center

Academia
Mote Marine Laboratory, University of North Florida

Industry
CVisionAI, Kitware, ProSensing Inc, Saltwater Inc

Government
EPA, Hypoxia Task Force, Miami Waterkeeper, Miami-Dade County FL, South Florida Water Management District, US Army Corps of Engineers, US Fish and Wildlife Service

Non-Profits
Havenworth Coastal Conservation, Monterey Bay Aquarium Research Institute

#38 WHAT WAS THE IMPACT ON OTHER DISCIPLINES?

NGI research and operations contribute to a more holistic, interdisciplinary understanding of interconnections among Gulf of Mexico ecosystems, resources, and people and facilitate decision-making based on those interconnections. Examples include the following:

Methods developed to manage fisheries video and image data can be adapted to other applications using machine learning.

Incorporating data from other disciplines such as sea-level rise and climate change predictions into water quality modeling for south Florida is significant as current resource planning does not consider effects of global environmental change.

More accurate surface wind speed estimates in hurricanes contribute to improvements in other disciplines such satellite calibration at high winds; estimates of air-sea exchanges of momentum, energy, mass; preparation of coastal communities for land-falling storms; and safety at sea for the marine community.

Development of bioinformatics infrastructure is inter-disciplinary work and includes fields of microbiology, toxicology, fisheries biology, and marine genomics.

Analysis of eDNA for cetacean health monitoring is changing how prey contents of whales and diseases of dolphins are studied.

Ocean acidification research is inherently interdisciplinary and impacts the understanding of OA by other oceanography disciplines, such as chemical oceanography.

Developing innovative sampling technologies contributes to a more holistic decision-making process that incorporates interdisciplinary understanding of the interconnections among Gulf of Mexico ecosystems, resources, and people. Electronic monitoring and incorporation of ML algorithms have other applications beyond fisheries such as military marine geospatial intelligence and marine resource management.

SAMOS observations contribute to other marine products such the International Comprehensive Ocean-Atmosphere Data Set and the Surface Underway Marine Database. SAMOS reports include components of the solar radiation spectrum and precipitation measurements, and some of its ships provide doppler speed logs which, along with high-quality vessel navigation parameters, can be used to estimate ocean surface currents.

The progress of Mississippi River watershed nutrient reduction practices in mitigating hypoxia is better informed by monitoring and modeling protocols that are effective and cost-efficient. Managers have improved capability for refining hypoxia mitigation strategies in an adaptive management context. Formal partnerships have been established to ensure a sustainable hypoxic zone monitoring program.

#40 WHAT WAS THE IMPACT ON TEACHING AND EDUCATIONAL EXPERIENCES?

NGI provided training and professional development to students and staff. PIs mentored and provided experience during project work, with students incorporating knowledge into theses/dissertations. Scientists incorporated research findings in tutorials, lectures, workshops, and coursework. See **Question 26** (training and PD the project provided).

NGI's E&O program supported NOAA by developing an engaged and educated public who are better able to make science-based decisions and a workforce pipeline for science, technology, engineering, and math (STEM) careers. Activities engaged a variety of audiences (1) K-12 educators and students; (2) scientists, university students, staff, and administration; and (3) broader science-interested communities. The program collaborated with regional education initiatives of the Gulf of Mexico Alliance, NOAA Sea Grant programs, and National Academies Gulf Research Program and incorporated NGI research into activities and resources. Information is shared through a variety of avenues, including listserv emails, social media, the *Portal* newsletter, and website.

NGI E&O program activities:

- Develop marine and atmospheric science curriculum and fieldwork for supplemental classroom material and host lesson plans (500+) from previous projects at http://gk12.msstate.edu/lessonplans.html
- Support STEM/STEAM events with resources such as (1) Traveling Trunk Shows with art and science curriculum that support college and career readiness standards; (2) Scientists Get Involved program for STEM faculty guest lectures; (3) Interactive ROV, robotics, UAS/UAV demonstrations; and (4) Science and curriculum for homeschool education groups.
- Provide experiential learning for middle and high-school students onboard the R/V Jim Franks to collect marine samples and learn about Gulf Coast history, geography, geology, biology, ecology, and climate.
- Facilitate high school students/upcoming college freshmen interested in marine, earth, and atmospheric sciences to participate in summer data collection and fieldwork.
- Provide professional development and training on technologies such as uncrewed aerial and marine systems, geospatial techniques, and continuing education through MSU Geosciences and Interdisciplinary Studies programs.
- Participate in science teacher associations to strengthen connections with educators.
- Encourage diversity in science through the Girls Engaged in Math and Science (GEMS) Program.

NGI's E&O program has significant reach to a wide range of audiences, engaging nearly 10,000 people annually during local, regional, and national events and programs such as:

- A new diversity internship program at NGI affiliated institutions (15 college students)
- Teacher workshops in meteorology, computational thinking, visualization (18 teachers)
- Travelling Trunk and Visiting Scientists programs (180 students)
- Mississippi Aquarium Home School program (100 students)
- MSU Science Education at SEA program (300 students)
- Celebrate the Gulf Marine Science event (1,500 attendees)
- MSU ORED and Graduate Symposiums and CMLL Languages in STEM (1,000 students)
- NASA Stennis Space Center's Infinity Science Center (1,200 students)
- Mississippi Science Teachers Association Conference (500 attendees)
- Gulf Estuarine Research Society (200 attendees)

- Bays and Bayous (400 attendees)
- Gulf of Mexico Alliance All-Hands (450 attendees)
- Gulf of Mexico Conference (900 attendees)
- Oceans Conference and Exhibition (2,000 attendees)
- HUIC International STEM/STEAM Education Conferenced (1,000 teachers)

More details are available at https://www.northerngulfinstitute.org/education_outreach.html.