Research Performance Progress Report

Northern Gulf Institute

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NGI
NORTHERN GULF INSTITUTE
a NOAA cooperative institute

Harbor, Pass Christian, MS

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DEPARTMENT OF COMMERCE
RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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RECIPIENT ORGANIZATION	
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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) Surface wind data for hurricane forecasts was improved (2) AOML seasonal hurricane outlook was incorporated into NOAA/CPC operational model, and a tropical cyclone motion and tracking model was validated (3) El Niño–Southern Oscillation (ENSO) variability and ENSO-driven atmospheric circulation were shown to influence US extreme hydroclimatic events (4) New planetary boundary layer (PBL) scheme improved rapid intensification prediction in NOAA's HAFS3 model (5) 2023 Atmospheric River Recon mission received support, sensitivity tools were updated, and a high-res Atmospheric River Analysis and Forecast System (AR-AFS) was evaluated (6) A gridded wind product was produced for NWS, and improved understanding of surface fluxes in hurricanes was made (7) Storm Surge and Tide Operational Forecast (STOFS-2D-Global) and Global STOFS models were upgraded with improved storm surge and wind products (8) Model hindcasts characterized historical patterns of carbonate system variables in Gulf and East Coasts (9) Initiated experiments to calibrate the ocean-biogeochemical model

FISHERIES CONSERVATION, MANAGEMENT (1) 5 sawfish and 3 hammerhead sharks were tagged and released to gauge population, reproduction, and habitat data (2) Extensive library of annotated images was developed for models that detect and identify reef fish, with important Gulf species identified and counted accurately (3) 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 (4) 5,000+ plankton samples were archived in storage bunkers

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 (3) eDNA samples were collected at sea for analysis of biodiversity and contributions to the Gulf carbon pump (4) DNA collection, preservation, extraction, and analysis of initial sediment trap collections revealed temporal diversity patterns (5) Data analysis of nekton abundance and diversity, blue crab growth, and stable isotope model development are underway (6) Comparisons made of species composition, abundances, and food web structure at created and natural marshes (7) a food web model to predict the impact of habitat restoration on marsh food webs was tested

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) Inventory, documentation, and archival services were provided for DSCRTP with quarterly updates to the Deep Sea Corals and Sponges database; a mapping and data portal was upgraded; custom analytical services were provided to partners (3) Product development, training, and outreach for CMECS, CEDAC, DIVER, and World Ocean Database continued (4) Updates made to OER data landing pages; to manuals and guides for Simple Ocean Data Assimilation, Sample Data Manager, Operations and Management Programmer, Benthic Animals, and Data Atlas (5) Omics Data Management Guide and framework for automated assignment of 16S and 18S ASV sequences to functional categories was completed; a cloud HPC system was setup; and taxonomic assignment

ACCOMPLISHMENTS *(cont'd)*

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

Participation at scientific conferences, meetings, and workshops:
American Geophysical Union Fall Meeting, American Meteorological Society Annual Meeting, ASLO Aquatic Sciences Meeting

Bays and Bayous, Benthic Ecology Meeting

Florida RESTORE Act Centers of Excellence Program

GEO Blue Planet Symposium, GEOMAR Ocean Circulation and Climate Dynamics Colloquium, Gulf Estuarine Research Society Meeting

Integrated Ocean and Coastal Mapping Seminar Series, International Atmospheric River Conference, International Conference on Environmental Systems, International Conference on Mesoscale Convective Systems, International Marine Debris Conference, International Symposium for Deep-Sea Corals, International Symposium on Microarchitecture, International Workshop on Tropical Cyclones

Joint Meeting of Ichthyologists and Herpetologists

Marine Atmosphere eXtreme Satellite Synergy workshop

National Tropical Weather Conference, NOAA AOML seminar, NOAA AOML/PhOD Seminar, NOAA AVAPS Users Group Meeting, NOAA Ocean Acidification Community Meeting & Mini Symposium

Scripps Machine Learners Group Seminar, Sharks International Conference

US-Africa Frontiers of Science, Engineering, and Medicine Symposium

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; heard lectures on data flow pipelines; and helped develop journal articles and science presentations.

Professional staff received training on fisheries surveys, statistical analysis, use of AI/ML tools and software, ArcGIS, data archiving

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.

The plankton sample archive is listed on the Gulf States Marine Fisheries Commission webpage https://www.gsmfc.org/.
Storm surge model results are disseminated through the interactive CERA website https://cera.coastalrisk.live
Research data on innovative sampling technologies were disseminated to stakeholders online https://github.com/SEFSC/SEAMAPD21.

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) developing a method to calibrate the historical TDR archive, computing new rain rates from historical data, and updating the SFMR algorithm; (2) 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; (3) investigating the role of mass fluxes in hurricane simulations to improve their parameterization in high-wind conditions, analyzing HAFS forecasts of boundary layer processes during intensification; (4) producing gridded wind products; and (5) analyzing Global Circulation Model data for improved reliability, significance of findings.

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) 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, 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) performing metabarcoding on DNA extracted from biological sea samples and analyzing their metagenomes to identify patterns of plankton diversity; (4) deploying/retrieving sediment traps and extracting/analyzing DNA samples for biodiversity and carbon pump contributions; and (5) validating MOM5-TOPAZ outputs for ocean acidification.

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) providing data inventory and archiving for DSCRTP, transitioning mapping/data portal to new portal, developing custom analytical products as requested; (3) producing quarterly reports for OER program; (4) expanding use of omics workflows by interns and new hires, running amplicon data through new Tourmaline V2 on Parallel Works cloud platform for a new database of analyzed eDNA data; and (5) 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, and (4) social media promotion.

PRODUCTS

29. Publications, conference papers, and presentations

NGI generated 32 publications and 72 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

A new PBL scheme tailored to hurricane boundary layers has been implemented into NOAA's hurricane forecast model HAFS.

The Coastal Emergency Risks Assessment (CERA) infrastructure is a real-time storm surge and inundation web-based visualization system showing the impact of impending and active tropical storms. CERA uses open-source web technologies, sophisticated program languages and modules, and uses NOAA services https://tidesandcurrents.noaa.gov or S3 cloud services for data retrieval.

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

DSCRTP support requires maintenance and development of data inventory pipelines in NOAA VLab Redmine to inventory and track incoming coral and sponge species occurrence data. Data stewardship, QA, and assembly of these datasets requires refining the codebase in both R and Python. Providing synthesis and custom analytical products involves novel approaches to raster and biodiversity analysis in deep-sea habitats.

Information Services Project Support for Coastal and Marine Ecological Classification Standard (CMECS) involves improvements to its standardized catalog of terms and definitions marine ecological data; for Coastal Ecosystem Data Assembly Center (CEDAC), a new landing platform for data must be assessed and packaged for onboarding within federal cloud based systems; and the Data Integration Visualization Exploration and Reporting (DIVER) Explorer need to be repositioned to allow development of future cloud based NOAA products.

Ocean and Ecosystem Project Support involves transforming data capabilities to improve decision support for habitat characterization, water quality, living marine resources, and coastal hazards and mitigation.

Ocean Exploration and Research Program Support includes producing a new metadata generating database that accepts input through a series of Google Forms, produces metadata records for data archival, and enhances video data discoverability and access through the OER Video Portal.

Support for Atmospheric River Recon includes upgrading Ensemble Sensitivity Tools for flight path planning for the East Coast and using additional variables. Upgraded data improves verification tools, forecast skills, verification domains, and model sounding profiles against observations.

eDNA monitoring of biological sea samples involves intercomparisons to test different methods of DNA sampling for ship flow-through sampling and peristaltic pump filtering through Sterivex filters.

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

High-resolution modeling of ocean acidification produced 2 new datasets:
(1) one that contains monthly-averaged surface and bottom fields of temperature, salinity, total alkalinity, and dissolved inorganic carbon for the Gulf of Mexico from 1980-01-01 to 2019-12-31 (NCEI Accession 0277155) NOAA National Centers for Environmental Information https://doi.org/10.25921/5hzy-5s58;
(2) A river chemistry dataset (RC4USCoast) for regional ocean model application in the U.S. East, Gulf of Mexico, and West Coasts from 1950-01-01 to 2020-12-31 (NCEI Accession 0260455). NOAA National Centers for Environmental Information https://doi.org/10.25921/9jfw-ph50.
Habitat modeling for nekton in turtle grass has a project webpage http://www.darnellseagrassecologylab.com/turtlegrass.

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 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?

Nothing to Report

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
NESDIS NCEI

NMFS Office of Protected Resources, Southeast Fisheries Science Center

NOS

NWS Climate Prediction Center, Deep Sea Coral Research and Technology Program, Environmental Monitoring Center, National Centers for Environmental Prediction, National Hurricane Center

NOAA OAR AOML Hurricane Research Division, Omics Program, Physical Oceanography Division, ESL Physical Sciences Laboratory

NOAA OAR Global Ocean Monitoring and Observing Program, Office of Ocean Exploration Research
NOAA OMAO Aircraft Operations Center

CIRES, CISESS

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

36. Have other collaborators or contacts been involved?

NOAA
Central Library Institutional Repository; Restore Science program technical monitors

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

NESDIS STAR Paul Chang

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

NWS CPC Hui Wang, Matthew Rosencrans; NCEP Xingren Wu, Vijay Tallapragada

OAR AOML Gregory Foltz; HRD Paul Reasor, John Gamache, Bob Black; Omics Working Group; POD Renellys Perez; GFDL Charlie Stock, Andrew Ross

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

Academia
Center for Wester Weather and Water Extremes Marty Ralph, Gulf Coast Research Laboratory Jeremy Johnson; University of Basel, Switzerland Vital Heim; University of Miami/CIMAS Dongmin Kim; University of North Florida Jim Gelsleichter; USM Abiola Obafemi; University of Washington Aotian Zheng, Jeng-Neng Hwang

Industry
Google Cloud Brett Alger; Saltwater Inc.

Government
EPA Steve Blackburn, Miami-Dade County Laura Eldredge, Nancy Jackson; NSF-funded Rolling Deck to Repository Project; US Fish and Wildlife/South Florida Water Management Division Bahram Charkhian; USACE James Riley, April Patterson

Non-Profits
Havenworth Coastal Conservation Tonya Wiley, Miami Waterkeeper Rachel Silverstein; UCAR Zorana Jelenak, Murali M. Nageswararao

IMPACT

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

FORECASTS, WARNINGS, AND RESPONSE (1) NOAA's HAFS model incorporated a new PBL scheme that improved its forecasts of rapid intensification; (2) Visualizations provide real-time comparisons of observations and STOFS-3D-Atlantic storm surge model output for better guidance during storms, continued model assessment, and expedited R2O model upgrades; (3) Coupling currents with stress and winds should impact ENSO forecast models and improve understanding and forecasting of US extreme hydroclimate events; (4) NHC forecasters received improved data on surface wind speed to analyze and forecast tropical cyclones; (5) 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; and (6) Atmospheric River Recon missions have benefited from the AR-AFS enhanced data assimilation and prediction capabilities.

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; and (5) 40+ years of SEAMAP zooplankton samples and 125K+ NRDA larval fish and zooplankton samples have been archived.

ECOSYSTEM MANAGEMENT (1) Ship-based eDNA monitoring demonstrated to the marine science community possibilities for global-scale marine biodiversity monitoring efforts; (2) Understanding the Gulf's biological carbon pump advances understanding of seasonal and inter-annual trends in taxonomic composition of microbes exported to the deep ocean; (3) Scientists have shown interest in using the river chemistry dataset (from OA modeling for the US Gulf and East Coasts) as input for ocean-biogeochemical model off the US coast; (4) Results from biodiversity comparisons between created and natural marshes inform restoration approaches; (5) Simulated water quality scenarios for Biscayne Bay and Coral Gables inform decisions by resource managers; (6) 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; and (7) Data from hypoxia monitoring cruises is the key variable for models that inform nutrient loading goals of the Hypoxia Task Force.

DATA SERVICES (1) DSCRPT data support enhances the ability of government agencies and academia to understand and manage deep-sea coral and sponge habitats and assess impacts of human activities on these systems; (2) Data support for information services, ocean, and ecosystem products involved transitioning to automated, cloud-based products for archival, making them available for future use in research, education, and outreach efforts; (3) HPC support contributed to expanded use of omics and bioinformatics to study marine systems; (4) The COMO mission is supported by SAMOS data for modeling circulation and ocean

IMPACT *(cont'd)*

38. What was the impact on other disciplines?

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

Forecasts of ocean coupling processes, storm surge, precipitation, and others can benefit from the new PBL scheme that improves the surface wind accuracy in models.

NOAA Navigation Managers and OCS Navigation Response Teams benefit with upgraded visualization tools (i.e., CERA) to track where a storm may hit for better planning for post-storm response (e.g., surveying storm-impacted areas).

Understanding the smaller end of mesoscale air-sea coupling will impact oceanography and meteorology, including applications related to biology, biogeochemistry, pollution transport (in the air and sea), and eventually weather and climate forecasts. The surface fluxes under hurricanes will, hopefully, inspire other researchers and improve modeling and forecasts of tropical cyclones.

Hydroclimate events such as droughts and floods are closely linked to water resources, agriculture, and food supply. Improved understanding of the influences on hydroclimate events could help response to a socio-economic issues or situations.

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.

Incorporating eDNA monitoring to the GO-SHIP efforts has expanded its core mission to include biological observations in addition to physical and chemical aspects of oceanography.

Because carbon export research is inherently interdisciplinary, research on the biodiversity of carbon export (sedimentation) will impact ocean chemistry and biogeochemistry research.

NOAA data products support a wide range of scientific disciplines and outreach efforts.

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.

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 PD the project provided).

Additional project-specific impacts include:

Staff supporting the DSCRTP have enhanced their ability to manage and assess biological occurrence data focused on deep sea communities and their ability to code in R and Python in the realms of data stewardship and scientific synthesis.

Staff supporting the OER program were invited to participate onboard the Okeanos Explorer for training as a Sample Data Manager. Other training opportunities included training in meeting facilitation and python programming.

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)*

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 (e.g., the Dynamics 2 class at Texas A&M University-Corpus Christi included LES simulations and mixing length formulations; the Boundary Layer Meteorology course at University of Huntsville included PBL parameterizations in high-wind conditions). 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)

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

Data, images, videos, and other analytical products stewarded and published through support provided to the DSCRTP provides a ready institutional information resource that enhances the information infrastructure of the government and academia.

The OER program produces rapidly increasing volumes of data, which challenges servers' ability to accommodate it all and internet services to provide access to it.

Data-derived products generated through support to NOAA's Information Services, Ocean, and Ecosystem efforts may be transitioned to automated cloud-based resources.

Improved visualization tools can display real-time storm surge water level forecasts; this capability benefits NOS operational storm surge modeling continuity of operations (COOP) which enables NOS storm surge model developers to continually assess model skill and target areas for model improvement.

eDNA sampling kits that were developed for use on GO-SHIP cruises that can be deployed on research cruises around the world.

Educational resources created on GitHub https://github.com/aomlomics are expanding access to bioinformatics tools.

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.

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.

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.

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 new PBL scheme has been implemented into NOAA's HAFS, and code is shared to the entire community via the GitHub repository of HAFS.

US COOPS and IOC water level stations for STOFS-2D-Global were implemented for operational use to directly compare observations with model results. A complete set of new scripts and workflow techniques have been developed to introduce the new STOFS-3D-Atlantic model.

Transferring the technology for coupled ocean/atmosphere modeling to groups interested in ocean and atmosphere modeling is in process in collaboration with NOAA researchers (and others) to improve the capability to measure surface hurricane surface fluxes.

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.

Data management and synthesis products resulting from support provided to DSCRTP provides common information resources and techniques that can be used for direct management of deep-sea coral and sponge habitats within stakeholder communities.

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.

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

The new PBL scheme can improve model forecasts of hurricanes and facilitate decision-making during landfalling hurricane events, benefiting coastal communities who face risks from hurricanes.

Improvements to the storm surge model helped provide more informative flood risk maps, which will again allow NOS/OCS/NSD to prepare for and respond to daily water conditions in a more cost-effective manner.

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.

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.

Results from ENSO forecasts are wide reaching, impacting agriculture in several parts of the US, hurricane activity forecasts and fisheries. Search and rescue could be improved if recommendations on coupled modeling are implemented.

Carbon dioxide and its export to the deep ocean have potential implications for all life on earth. It is critical that we understand the biological carbon pump to understand climate change.

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.

Developing innovative sampling technologies that provide for efficient and accurate identification of fish species can provide valuable information for 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.

By conducting eDNA sampling on GO-SHIP cruises, the public is inspired to think about connections between humans and the ocean and how understanding biodiversity may help to preserve it.

The OER Data Management team seeks to excite, entertain, and entice the public's interest in the deep ocean. The team responded

IMPACT *(cont'd)*

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

0 , null

CHANGES/PROBLEMS

45. Changes in approach and reasons for change

For OER program support, NCEI's plans to move to cloud computing will likely cause delays and re-engineering of some applications; for example, the Simple Ocean Data Assimilation (SODA) is maintained in Microsoft Access and will need to be migrated to a cloud-based solution; the OER Video Portal uses the NOAA Comprehensive Large Array Storage System (CLASS) and will likely need to migrate to the cloud. There will no doubt be other impacts.
For providing NWS with gridded wind products, the project lacks sufficient funding to update the code for gridding winds; therefore, the machines on which the old code runs will cease to work within a few years.
For high-resolution modeling of ocean acidification, the MOM5-TOPAZ hindcast was able to reproduce main open-ocean patterns in temperature, salinity, and biogeochemistry, including carbonate system variables such as DIC and alkalinity. However, significant biases were detected in the US East Coast, especially in the Mid Atlantic Bight and Gulf of Maine, associated with biases in the trajectory and strength of the Gulf Stream and Labrador Current. To improve the representation of regional circulation and leverage existing NOAA modeling efforts, the project is transitioning to the MOM6-COBALT-NWA model (1/12 degree resolution), which was recently developed by NOAA-GFDL.

CHANGES/PROBLEMS *(cont'd)*

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

Nothing to Report

47. Changes that had a significant impact on expenditures

Nothing to Report

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

Nothing to Report

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

Nothing to Report

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 104 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).

Outcome 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) successful Atmospheric River Recon missions supported by flight planning with updated sensitivity tools and enhanced regional AR-AFS model; (4) improved NOAA hurricane forecasts with calculations based on a new PBL scheme; (5) new STOFS-3D-Atlantic storm surge model with real-time comparisons of observations and model output for continued model assessment; (6) improved forecasting of US extreme hydroclimate events from ENSO models that couple currents with stress and winds; and (7) monthly outputs on ocean acidification from MOM-TOPAZ and ROMS-GoMBio models.

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; and (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.

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) expanded marine biodiversity monitoring with ship-based eDNA sampling; (4) improved understanding of temporal trends in biological export of carbon dioxide to the deep ocean; (5) more informed restoration efforts from ecological structure comparisons between created and natural marshes; and (6) improved resource management based on nekton habitat modeling.

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; and (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; and (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 25, 26, 30, 35, 37, 38, 40, and 43.

NA21 OAR 4320190 July 1, 2022 to June 30, 2023

25. WHAT WAS ACCOMPLISHED UNDER THESE GOALS?

FORECASTS, WARNINGS, AND RESPONSE (1) Surface wind data for hurricane forecasts was improved (2) AOML seasonal hurricane outlook was incorporated into NOAA/CPC operational model, and a tropical cyclone motion and tracking model was validated (3) El Niño–Southern Oscillation (ENSO) variability and ENSO-driven atmospheric circulation were shown to influence US extreme hydroclimatic events (4) New planetary boundary layer (PBL) scheme improved rapid intensification prediction in NOAA's HAFS3 model (5) 2023 Atmospheric River Recon mission received support, sensitivity tools were updated, and a high-res Atmospheric River Analysis and Forecast System (AR-AFS) was evaluated (6) A gridded wind product was produced for NWS, and improved understanding of surface fluxes in hurricanes was made (7) Storm Surge and Tide Operational Forecast (STOFS-2D-Global) and Global STOFS models were upgraded with improved storm surge and wind products (8) Model hindcasts characterized historical patterns of carbonate system variables in Gulf and East Coasts (9) Initiated experiments to calibrate the ocean-biogeochemical model

FISHERIES CONSERVATION, MANAGEMENT (1) 5 sawfish and 3 hammerhead sharks were tagged and released to gauge population, reproduction, and habitat data (2) Extensive library of annotated images was developed for models that detect and identify reef fish, with important Gulf species identified and counted accurately (3) 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 (4) 5,000+ plankton samples were archived in storage bunkers

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 (3) eDNA samples were collected at sea for analysis of biodiversity and contributions to the Gulf carbon pump (4) DNA collection, preservation, extraction, and analysis of initial sediment trap collections revealed temporal diversity patterns (5) Data analysis of nekton abundance and diversity, blue crab growth, and stable isotope model development are underway (6) Comparisons made of species composition, abundances, and food web structure at created and natural marshes (7) a food web model to predict the impact of habitat restoration on marsh food webs was tested

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) Inventory, documentation, and archival services were provided for DSCRTP with quarterly updates to the Deep Sea Corals and Sponges database; a mapping and data portal was upgraded; custom analytical services were provided to partners (3) Product development, training, and outreach for CMECS, CEDAC, DIVER, and World Ocean Database continued (4) Updates made to OER data landing pages; to manuals and guides for Simple Ocean Data Assimilation, Sample Data Manager, Operations and Management Programmer, Benthic Animals, and Data Atlas (5) Omics Data Management Guide and framework for automated assignment of 16S and 18S ASV sequences to functional categories was completed; a cloud HPC system was setup; and taxonomic assignment methods and databases for fish eDNA were compared

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.

26. WHAT OPPORTUNITIES FOR TRAINING AND PROFESSIONAL DEVELOPMENT HAS THE PROJECT PROVIDED?

Participation at scientific conferences, meetings, and workshops:
American Geophysical Union Fall Meeting, American Meteorological Society Annual Meeting, ASLO Aquatic Sciences Meeting

Bays and Bayous, Benthic Ecology Meeting

Florida RESTORE Act Centers of Excellence Program

GEO Blue Planet Symposium, GEOMAR Ocean Circulation and Climate Dynamics Colloquium, Gulf Estuarine Research Society Meeting

Integrated Ocean and Coastal Mapping Seminar Series, International Atmospheric River Conference, International Conference on Environmental Systems, International Conference on Mesoscale Convective Systems, International Marine Debris Conference, International Symposium for Deep-Sea Corals, International Symposium on Microarchitecture, International Workshop on Tropical Cyclones

Joint Meeting of Ichthyologists and Herpetologists

Marine Atmosphere eXtreme Satellite Synergy workshop

National Tropical Weather Conference, NOAA AOML seminar, NOAA AOML/PhOD Seminar, NOAA AVAPS Users Group Meeting, NOAA Ocean Acidification Community Meeting & Mini Symposium

Scripps Machine Learners Group Seminar, Sharks International Conference

US-Africa Frontiers of Science, Engineering, and Medicine Symposium

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; heard lectures on data flow pipelines; and helped develop journal articles and science presentations.

Professional staff received training on fisheries surveys, statistical analysis, use of AI/ML tools and software, ArcGIS, data archiving and ingest procedures; refined skills in analysis and interpretation of ocean surface wind speed and rain rate data for hurricane forecasts; gained experience in using ocean and atmospheric observations and numerical models to assess large-scale climate influences on drought events; participated in tutorials on bioinformatics and data analysis using Python; refined skills in ‘omics

research and teaching; incorporated high-powered computing for research; gained experience in data collection on NOAA ships and sample processing in NOAA labs; attended NOAA facilitator training; 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.

30. Technologies and Techniques

A new PBL scheme tailored to hurricane boundary layers has been implemented into NOAA's hurricane forecast model HAFS.

The Coastal Emergency Risks Assessment (CERA) infrastructure is a real-time storm surge and inundation web-based visualization system showing the impact of impending and active tropical storms. CERA uses open-source web technologies, sophisticated program languages and modules, and uses NOAA services https://tidesandcurrents.noaa.gov or S3 cloud services for data retrieval.

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

DSCRTP support requires maintenance and development of data inventory pipelines in NOAA VLab Redmine to inventory and track incoming coral and sponge species occurrence data. Data stewardship, QA, and assembly of these datasets requires refining the codebase in both R and Python. Providing synthesis and custom analytical products involves novel approaches to raster and biodiversity analysis in deep-sea habitats.

Information Services Project Support for Coastal and Marine Ecological Classification Standard (CMECS) involves improvements to its standardized catalog of terms and definitions marine ecological data; for Coastal Ecosystem Data Assembly Center (CEDAC), a new landing platform for data must be assessed and packaged for onboarding within federal cloud based systems; and the Data Integration Visualization Exploration and Reporting (DIVER) Explorer need to be repositioned to allow development of future cloud based NOAA products.

Ocean and Ecosystem Project Support involves transforming data capabilities to improve decision support for habitat characterization, water quality, living marine resources, and coastal hazards and mitigation.

Ocean Exploration and Research Program Support includes producing a new metadata generating database that accepts input through a series of Google Forms, produces metadata records for data archival, and enhances video data discoverability and access through the OER Video Portal.

Support for Atmospheric River Recon includes upgrading Ensemble Sensitivity Tools for flight path planning for the East Coast and using additional variables. Upgraded data improves verification tools, forecast skills, verification domains, and model sounding profiles against observations.

eDNA monitoring of biological sea samples involves intercomparisons to test different methods of DNA sampling for ship flow-through sampling and peristaltic pump filtering through Sterivex filters.

Characterizing the Gulf of Mexico's biological carbon pump involves development of a new method for extracting DNA from formalin-preserved sediment samples.

Unlocking the potential of omics data involves making products such as the Tourmaline version 2 (https://github.com/aomlomics/tourmaline) and the NOAA Omics Data Management Guide (https://github.com/aomlomics/omics-data-management) accessible through HPC.

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.

Acquisition of water column data improved hypoxia hindcast modeling.

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

NESDIS NCEI

NMFS Office of Protected Resources, Southeast Fisheries Science Center

NOS

NWS Climate Prediction Center, Deep Sea Coral Research and Technology Program, Environmental Monitoring Center, National Centers for Environmental Prediction, National Hurricane Center

NOAA OAR AOML Hurricane Research Division, Omics Program, Physical Oceanography Division, ESL Physical Sciences Laboratory

NOAA OAR Global Ocean Monitoring and Observing Program, Office of Ocean Exploration Research
NOAA OMAO Aircraft Operations Center

CIRES, CISESS

Academia
Dauphin Island Sea Lab, Louisiana State University, Louisiana Universities Marine Consortium, Mote Marine Lab, Oregon State University, UC Center for Western Weather and Water Extremes, University of California at Irvine, University of Florida, University of North Florida, University of Notre Dame, University of South Alabama, University of South Carolina, USM Invertebrate Plankton Archiving Center, University of Wisconsin Milwaukee, Virginia Institute of Marine Science, Waynesburg University

Industry
CVisionAI, ESRI, General Dynamics Information Technology, Kitware, ProSensing Inc, Saltwater Inc, Science and Technology Corporation

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

Non-Profits
Gulf States Marine Fisheries Commission, Havenworth Coastal Conservation, Miami Waterkeeper

37. WHAT WAS THE IMPACT ON THE DEVELOPMENT OF THE PRINCIPAL DISCIPLINE(S) OF THE PROJECT?

FORECASTS, WARNINGS, AND RESPONSE (1) NOAA's HAFS model incorporated a new PBL scheme that improved its forecasts of rapid intensification; (2) Visualizations provide real-time comparisons of observations and STOFS-3D-Atlantic storm surge model output for better guidance during storms, continued model assessment, and expedited R2O model upgrades; (3) Coupling currents with stress and winds should impact ENSO forecast models and improve understanding and forecasting of US extreme hydroclimate events; (4) NHC forecasters received improved data on surface wind speed to analyze and forecast tropical cyclones; (5) 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; and (6) Atmospheric River Recon missions have benefited from the AR-AFS enhanced data assimilation and prediction capabilities.

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; and (5) 40+ years of SEAMAP zooplankton samples and 125K+ NRDA larval fish and zooplankton samples have been archived.

ECOSYSTEM MANAGEMENT (1) Ship-based eDNA monitoring demonstrated to the marine science community possibilities for global-scale marine biodiversity monitoring efforts; (2) Understanding the Gulf's biological carbon pump advances understanding of seasonal and inter-annual trends in taxonomic composition of microbes exported to the deep ocean; (3) Scientists have shown interest in using the river chemistry dataset (from OA modeling for the US Gulf and East Coasts) as input for ocean-biogeochemical model off the US coast; (4) Results from biodiversity comparisons between created and natural marshes inform restoration approaches; (5) Simulated water quality scenarios for Biscayne Bay and Coral Gables inform decisions by resource managers; (6) 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; and (7) Data from hypoxia monitoring cruises is the key variable for models that inform nutrient loading goals of the Hypoxia Task Force.

DATA SERVICES (1) DSCRPT data support enhances the ability of government agencies and academia to understand and manage deep-sea coral and sponge habitats and assess impacts of human activities on these systems; (2) Data support for information services, ocean, and ecosystem products involved transitioning to automated, cloud-based products for archival, making them available for future use in research, education, and outreach efforts; (3) HPC support contributed to expanded use of omics and bioinformatics to study marine systems; (4) 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; and (5) Data generated across all NGI efforts benefit from data management and product development that enhance data usability.

38. WHAT WAS THE IMPACT ON OTHER DISCIPLINES?

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

Forecasts of ocean coupling processes, storm surge, precipitation, and others can benefit from the new PBL scheme that improves the surface wind accuracy in models.

NOAA Navigation Managers and OCS Navigation Response Teams benefit with upgraded visualization tools (i.e., CERA) to track where a storm may hit for better planning for post-storm response (e.g., surveying storm-impacted areas).

Understanding the smaller end of mesoscale air-sea coupling will impact oceanography and meteorology, including applications related to biology, biogeochemistry, pollution transport (in the air

and sea), and eventually weather and climate forecasts. The surface fluxes under hurricanes will, hopefully, inspire other researchers and improve modeling and forecasts of tropical cyclones.

Hydroclimate events such as droughts and floods are closely linked to water resources, agriculture, and food supply. Improved understanding of the influences on hydroclimate events could help response to a socio-economic issues or situations.

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.

Incorporating eDNA monitoring to the GO-SHIP efforts has expanded its core mission to include biological observations in addition to physical and chemical aspects of oceanography.

Because carbon export research is inherently interdisciplinary, research on the biodiversity of carbon export (sedimentation) will impact ocean chemistry and biogeochemistry research.

NOAA data products support a wide range of scientific disciplines and outreach efforts.

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.

Developing innovative sampling technologies such as EM contributes to a more holistic decision-making, and its use 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.

43. WHAT WAS THE IMPACT ON SOCIETY BEYOND SCIENCE AND TECHNOLOGY?

The new PBL scheme can improve model forecasts of hurricanes and facilitate decision-making during landfalling hurricane events, benefiting coastal communities who face risks from hurricanes.

Improvements to the storm surge model helped provide more informative flood risk maps, which will again allow NOS/OCS/NSD to prepare for and respond to daily water conditions in a more cost-effective manner.

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.

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.

Results from ENSO forecasts are wide reaching, impacting agriculture in several parts of the US, hurricane activity forecasts and fisheries. Search and rescue could be improved if recommendations on coupled modeling are implemented.

Carbon dioxide and its export to the deep ocean have potential implications for all life on earth. It is critical that we understand the biological carbon pump to understand climate change.

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.

Developing innovative sampling technologies that provide for efficient and accurate identification of fish species can provide valuable information for 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.

By conducting eDNA sampling on GO-SHIP cruises, the public is inspired to think about connections between humans and the ocean and how understanding biodiversity may help to preserve it.

The OER Data Management team seeks to excite, entertain, and entice the public's interest in the deep ocean. The team responded to several external data requests that ranged from video data of specific species for research, personal interests specific to habitat types, and requests that deep-sea footage of underwater volcanos to be included in an upcoming documentary.

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.

Results from habitat-specific modeling for nekton in turtlegrass can be used to inform natural resource management.