

Research Performance Progress Report Northern Gulf Institute

NA16OAR4320199

July 1, 2021 to June 30, 2022

**Flower Garden Banks
National Marine Sanctuary**



NGI
NORTHERN GULF INSTITUTE
a NOAA cooperative institute



DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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Signature of Submitting Official: Whitley Alford	
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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 and 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?

NGI research strives for new/improved knowledge and technology and their transition to ecosystem-based management. NGI accomplishments are documented in peer-reviewed publications, an established metric for their quality, rigor, and significance. Alignment to other agencies' outcomes points to leveraging resources, extending impact, and strengthening stakeholder ties. NGI accomplished the following:

IMPROVED FORECASTS, WARNINGS, AND RESPONSE UAS missions documented river flooding following Hurricane Ida; advancements in UAS use included mapping plane coordinates, DAA tracking technology, concept for Beyond Visual Line of Sight Operations, and a cost benefits analysis for uncrewed versus crewed missions. Surface wind data collected by hurricane hunter aircraft was improved by addressing interference and under-sampling issues. Wind and flux forecasts were improved by assimilating satellite and in situ ocean data. Differences in the influence of SST anomalies in the Atlantic and Pacific on hurricane activity were identified. Data to improve tornado detection and forecasts were collected and analyzed.

FISHERIES CONSERVATION AND MANAGEMENT To gauge population, reproduction, and habitats, fishery-independent longlines were set resulting in the capture, tagging, and release of 14 smalltooth sawfish and six scalloped hammerhead sharks. Processing/analysis of eDNA and skin microbiome samples for whales, dolphins, and porpoises provide health monitoring. Simulations of ocean biogeochemical patterns help evaluate their impact on fishery resources. Impacts of regional ocean dynamics on fishery productivity are quantified with modeling and satellite products.

ECOSYSTEM MANAGEMENT The hypoxia monitoring cruise was conducted, gathering data on oxygen and nutrients in the hypoxic zone. Water quality assessments for Biscayne Bay were facilitated by the calibration of salinity and water elevation used in the Soil and Water Assessment Tool. The current state of EBM practice by resource managers was analyzed, resulting in a white paper presented to RESTORE Science Program leadership.

INFRASTRUCTURE AND CAPACITY SUPPORT FOR RESEARCH The High Performance Computing (HPC) system Orion served 195 users working on 58 projects that consumed 120 million+ wallclock-hours of CPU time this year. HPC capacity on AOML servers and cloud platforms advanced the application of 'omics and bioinformatics tools for high-throughput DNA extraction and PCR amplification of eDNA. Improvements to GOES-R Convective Initiation products included algorithm updates and assimilating the cloud-top cooling rate field into the High Resolution Rapid Refresh model. Safe and efficient hydrographic data collection were supported by repairs and tests to an ASV, a mapping drone, and a tide gauge VDatum package. Training for operating underwater gliders was improved with new curriculum for an Operator's Certificate program.

DATA MANAGEMENT & ENHANCEMENT Seafloor video were improved by Python scripts that extract data and yield GIS digital maps. Digital fisheries media were organized; and electronic monitoring hardware, software (including calibration of VIAME

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

ACCOMPLISHMENTS (cont'd)

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

NGI provided research updates to stakeholders and incorporated knowledge and technology advancements in presentations, professional development, coursework, and education and outreach events and resources.

Researchers, students, and staff attended a variety of science events this year (for a complete listing, see Question #29 products), including:

American Geophysical Union Conference
American Association of Geographers Meeting
American Meteorological Society Meeting
Association of Environmental & Engineering Geologists Conference
Canadian Hydrographic Conference
Gulf of Mexico Conference
Joint Satellite Conference
Mississippi Geospatial Conference
NOAA RESTORE Science Program Review
NOAA Leveraging AI in Environmental Sciences Workshop
Ocean Acidification Week
Ocean Sciences Meeting
World Fisheries Congress

This year, NGI research provided specialized training to those associated with projects:

Students were trained to gather and manage meteorological data; gather atmospheric data; apply geospatial analysis to ROV data; calculate surface flux from in situ data; analyze physics observations; link ocean surface processes; and to couple currents, stress, and wind in models. Students were trained to operate underwater gliders, use remote sensing to track tropical cyclones, operate global navigation satellite systems, conduct fisheries surveys, conduct human subjects research, use evaluation protocols, and develop journal articles.

Professional staff received training on meteorological and surface ocean sensors and data acquisition, geospatial technologies, computer coding, the operation of large HPC systems, advocating for potential research activities using HPC systems, Video Image Analytics for the Marine Environment (VIAME), fishery stock assessment models, bioinformatics analysis, high-throughput DNA extraction and sequencing, eDNA sampling, and the development of grant proposals. One staff member was certified as an Amazon Web Services Developer Associate and Google Cloud Platform Engineer Associate. Stakeholders helped researchers refine the development of seasonal hurricane forecasts to meet their needs and provided support for robust modeling tools for living marine

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

Results of sponsored operations and research are disseminated through multiple channels including publication in peer reviewed journals and proceedings and technical reports and in presentations at meetings, briefings, conferences, and workshops (see Question #29 Products). Knowledge and findings are incorporated into professional development and training sessions, K-12 activities and resources, and activities and materials at science-related public events. Programmatic and scientific information are also disseminated through the NGI website, the Portal newsletter, listserv emails, and social media.

Additional specific research data were disseminated to stakeholders online:

The 2022 hypoxia forecast from the 2021 hypoxia monitoring cruise is available at https://gulfhypoxia.net/research/shelfwide-cruise/?y=2022&p=hypoxia_fc. Online coverage of the 2021 monitoring effort included <https://www.noaa.gov/news-release/larger-than-average-gulf-of-mexico-dead-zone-measured> as well as an NGI-hosted press event <https://www.noaa.gov/media-advisory/noaa-partners-to-report-on-annual-gulf-of-mexico-dead-zone-monitoring-cruise>.

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 are available via the web (https://samos.coaps.fsu.edu/html/data_availability.php), ftp (<ftp://ftp.coaps.fsu.edu>), and THREDDs (<https://www.coaps.fsu.edu/thredds-listing>).

ACCOMPLISHMENTS (cont'd)

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

NGI will continue to provide high-quality research and research support and to disseminate its findings. Planned activities include the following:

Continue efforts to improve forecasts, warning, and response to hazards and climate impacts by (1) producing a hurricane landfalling outlook for the US Gulf and Atlantic coasts, (2) demonstrating the new method for collecting improved surface wind data during the 2022 hurricane season, (3) conducting flood assessment missions with uncrewed aircraft systems, and (4) producing gridded wind products from satellite and in situ ocean data for storm forecasts.

Continue support for fisheries conservation and management by (1) obtaining improved eDNA data for cetacean health assessments and (2) conducting sampling trips to tag and collect life history data of smalltooth sawfish and scalloped hammerhead sharks.

Continue support for ecosystem-based management in the Gulf of Mexico region by (1) monitoring and assessing the hypoxia zone and regional watersheds and (2) developing EBM training and education resources for regional resource managers.

Continue providing infrastructure and capacity support for research by (1) providing HPC services, (2) improving 'omics and bioinformatics tools and training, (3) enhancing satellite products, (4) testing hydrographic and oceanographic data collection technologies, and (5) updating curriculum that trains underwater glider operators.

Continue support for data management and enhancement by (1) improving the use of automated fish detection products; (2) collecting, processing, disseminating, and archiving meteorological and oceanographic data; and (4) developing geospatial training and providing GIS services to partners.

Continue engagement with target audiences through (1) publications and presentations, (2) education and outreach to 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 89 publications, papers, and presentations (26 publications and 63 presentations) during this reporting period. See the attached MS Excel Document for details.

PRODUCTS (cont'd)

30. Technologies or techniques

NGI research resulted in the following developments in technology or techniques:

A Subsurface Automated Sampler for eDNA (SASe) was developed for marine biological monitoring and research (published in HardwareX <https://doi.org/10.1016/j.ohx.2021.e00239>).

Two different magnetic bead DNA extraction protocols were developed and run on the KingFisher Flex bead-handling robot. PCR preparation, PCR cleanup, DNA dilution, and extraction prep protocols were developed and run on the Opentrons liquid handling robot.

DAA technology (detect and avoid) was integrated into the TigerShark UAV, allowing the UAV to avoid collisions with other aircraft, buildings, power lines, birds, and other obstacles.

Advancements in the use of electronic monitoring for automated detection of fish incorporated several machine learning and deep learning-based algorithms for object detection, estimation of length and size of fish species, and classification of fish species.

The GOES-R Convective Initiation algorithm's 5-minute cloud-top cooling rate fields were improved for use with GOES-16/-17 data. Improvements occurred in the area of enhanced cloud tracking and convective cloud development quantification.

The generation of Python scripts created viewshed maps from video data collected by the NOAA ROV Deep Discoverer.

The development of a tropical Atlantic-Pacific (interbasin) SST index was shown to skillfully predict Atlantic hurricane activity (published in Geophysical Research Letters <https://doi.org/10.1029/2021GL096712>).

MATLAB code was developed to improve the modeling of impact from fishing on length at age distributions using historical fishery-dependent data on length and age. Collaborations with SEFSC scientist Nikolai Klibansky resulted in the development of a Generalized Additive Model (GAM) to evaluate the connection between King Mackerel length at age time series and satellite-derived sea surface temperature and Chlorophyll at different temporal and spatial scales.

31. Inventions, patent applications, and/or licenses

Nothing to Report

PRODUCTS (cont'd)

32. Other products

NGI launched a new website in March 2022 to provide up-to-date information and resources for its target audiences (<https://www.northerngulfinstitute.org/index.html>).

The NGI Education & Outreach program produces The Portal, a quarterly newsletter of current events, notices, and relevant research based upon requested researcher submissions; the newsletter is disbursed via an email listserv and is available on the NGI website (https://www.northerngulfinstitute.org/news_events.html).

A dataset for surface patterns of temperature, salinity, total alkalinity, and dissolved inorganic carbon across the Gulf of Mexico was derived from the GoMBio model experiments from 1981 to 2014 (NCEI Accession 0242495) <https://doi.org/10.25921/c34h-gb83>.

Curriculum materials were developed for courses taught in the Operator's Certificate (Tier 2) focused on underwater gliders: MAR 435 Operating Instrumentation in Marine Environments (3 credit hours); MAR 436 UMS Vehicle Planning (3 credit hours); MAR 438 UMS Vehicle Management (3 credit hours); MAR 440 Field Project (3 credit hours) <https://www.usm.edu/ocean-science-engineering/uncrewed-maritime-systems-ums-certification.php>

Web applications were created for the GeoCoast 3D Coastal Inundation GIS <http://geoproject.hpc.msstate.edu/GeoCoast3D/>, for the GeolInundation 3D Coastal Inundation Viewer <https://geoproject.hpc.msstate.edu/geoinundation3d/>, and for the MS Lidar Viewer <https://arcg.is/0nuevC>.

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Robert Moorhead – Director NGI
Paul Mickle – Co-Director 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?

Associate Director Anna Linhoss left MSU July 31, 2021. Jamie Dyer was hired as an Associate Director to increase the experience in hydrometeorology and weather within the cooperative institute.

35. What other organizations have been involved as partners?

NGI closely aligns its research and outreach activities with NOAA and other organizations' 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 provides OAR with high performance computing capacity and contributes to OAR programs in 'Omics, UAS, Ocean Acidification, Climate, and Weather.

NGI and the NESDIS National Centers of Environmental Information (NCEI) share a building at the NASA Stennis Space Center, facilitating a close working relationship. NGI and NCEI provide enhanced data, products, and services for the Coastal Ecosystem Data Assembly Center; the Ocean Exploration and Research Program; the Deep-Sea Corals Research and Technology Program; the Data Integration, Visualization, Exploration, and Reporting Tool; and satellite weather products.

NGI provides the NOS Office of Coastal Management with geospatial education and outreach and with the Office of Coast Survey for hydrographic research and is the NOAA CI for Gulf of Mexico Hypoxia, providing monitoring data to inform the NOAA Hypoxia Task Force and the National Centers for Coastal Ocean Science Hypoxia Program.

NGI works with the National Weather Service (NWS) to develop more accurate estimates of ocean surface wind speed and air-sea interactions for hurricane forecasts, to detect and forecast tornadoes, and to provide Atmospheric River Reconnaissance missions support for weather, water, and climate predictions.

NGI works with the National Marine Fisheries Service (NMFS) to monitor several marine species, including sea turtles, smalltooth sawfish, and scalloped hammerhead sharks and provides secure storage of plankton specimens at the Stennis Space Center. NGI works with the Southeast Fisheries Science Center to support cetacean conservation and automate fish detection and identification from video.

Other regional NGI 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, NOAA Restore Science Program

Additionally, NGI research projects involved the following partners: CVisionAI, Havenworth Coastal Conservation, Monterey Bay Aquarium Research Institute, Mote Marine Lab, National Center for Atmospheric Research, Naval Meteorology and Oceanography

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

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS (cont'd)

36. Have other collaborators or contacts been involved?

NGI research projects involved the following collaborators:
CIMAS/UM: Dongmin Kim
Coastal Conservation and Restoration Program
Havenworth Coastal Conservation: Tonya Wiley
Marine Fisheries Ecology Program at the Mississippi State Coastal Research and Extension Center
National Center for Atmospheric Research: Holger Voemel
NOAA AOML/HRD: Sim Aberson, Kathryn Sellwood, James Franklin, Paul Reasor
NOAA AOML/PhOD: Renellys Perez
NOAA AOML: Gregory Foltz
NOAA ESRL: James Wilczak
NOAA Fisheries: John Carlson, Andrea Kroetz
NOAA NCEI Maryland: Chris Paver, Steve Rutz, John Relph, and Vidhya Gondle
NOAA NMFS Google Cloud: Brett Alger
NOAA OMAO Silver Spring: Solomon Tadele, John Katebini, Philip Zublay, and Kevin Cromer
Pacific Northwest National Laboratory: Karthik Balaguru
Prosensing, Inc: Ivan PopStefanija
University of Basel, Switzerland: Vital Heim
University of North Florida: Jim Gelsleichter

IMPACT

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

Forecasts, warnings, and response
Rapid flood data provided inundation maps and improved warnings and emergency response. Wind surface data informed forecasts of tropical cyclone track, intensity, and wind radii. Gridded wind and flux products informed ENSO forecasts, and the Navy plan to use new knowledge generated from coupling currents, stress, and winds in their ocean modeling. The Atlantic-Pacific SST index contributed to new understanding about when ENSO affects hurricanes and was used in an experimental 2022 Atlantic hurricane outlook that was shared with NOAA. Analysis of non-classical tornado formation showed the influence of surface roughness on vertical shear, characteristics of stratocumulus clouds in advance of cold fronts, and implications on boundary layer properties.

Fisheries conservation and management
Habitat and bycatch risk data on smalltooth sawfish led to recommendations of seasonal region closures to shrimp trawling. Data from scalloped and great hammerheads contributed to federal stock assessments. The application of 'omics methods for eDNA analysis of deep-sea fish and dolphin microbiome samples supported SEFSC conservation efforts. The improved ocean biogeochemical model provided insights into underlying processes determining biogeochemistry variability and its impact on fishery resources. Use of the MATLAB growth code to model the impact of fishing may improve accuracy of fisheries management benchmarks. The Trip Interview Program's secondary production estimates can be used to study the link between lower trophic level productivity and the productivity/recruitment of other species.

Ecosystem-based management
Monitoring the Gulf of Mexico hypoxic zone advanced the science that underpins its management and measures progress on the Hypoxia Task Force's nutrient management goals set out in the Gulf Action Plan. The data are used in biogeochemical and hydrodynamic models that generate forecasts and hindcasts. The addition of salinity and water elevation to the Soil and Water Assessment Tool improved its use for Coral Gables Canal and Biscayne Bay and was shared with an advisory panel. Insights from case studies on the use of EBM by resource managers was shared with researchers, funders, scientists, and decision-makers along with suggestions to support the increased use of EBM in practice. Scientists expressed interest in using outputs from the improved ocean biogeochemical model for studies on ocean chemistry and ecosystem applications.

Infrastructure and capacity support
HPC capability and capacity allowed NOAA research activities to continue and expand, with nearly 700 million hours of computational time was consumed by NOAA researchers. Advancements in 'omics and bioinformatics is recognized across NOAA and the international science community for contributions to marine systems studies. Improvements to GOES-R CI satellite and cloud-top cooling products will be used in the new HRRR model. Testing of uncrewed surface and aerial vessels for marine surveys improved procedures on their use. Tying water levels from pressure sensors on the seafloor to the ellipsoid improved data in vertical datum separation models. Bathymetry from optical remote sensing provided a new tool for use in shallow waters that are dangerous to navigate and survey resources are lacking. Curriculum for training operators in underwater glider technologies contributed to

IMPACT (cont'd)

38. What was the impact on other disciplines?

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

Accurate surface wind speed estimates in hurricanes improve satellite calibration at high winds; provide better estimates of air-sea exchanges of momentum, energy, and mass; and provide information to the maritime community for safety at sea and to coastal communities to prepare for land-falling storms.

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 experimental outlooks on seasonal hurricanes and landfalling provide forecasters with additional resources to inform stakeholders on the predicted severity and impacts of the upcoming hurricane season.

Meteorological and oceanographic observations include collections from remote areas, making them ideal for marine climate and ocean process studies and evaluating numerical models and satellite products.

'Omics research is interdisciplinary, covering fields in microbiology, toxicology, fisheries biology, marine genomics, and bioinformatics.

Comprehensive digital mapping of seafloor environmental parameters (including ecological observations) can inform a variety of disciplines as well as natural resource managers.

Incorporation of electronic monitoring for sampling provided electrical and computer engineers a better understanding of fisheries issues.

Insights into EBM as practiced by resource managers provides other disciplines with information on how change within institutions or organizations involved with policy-making affects decision-making.

A trained workforce to operate underwater glider technology benefits scientists, marine resource managers, military marine geospatial intelligence workers, and others that can utilize data from buoyancy gliders.

GIS data, resources, and tools facilitate interactions with researchers from other disciplines (coastal ecosystems, hazards,

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

NGI research and operations provide training for highly-qualified candidates for NOAA's and other research organizations' future workforce. For more details, please see information provided in Question #26 (training and professional development the project provided).

IMPACT (cont'd)

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

NGI research and operations provided training and professional development to university students and others associated with projects that result in highly-qualified candidates for NOAA's and other research organizations' current and future workforce. Many PIs mentor students while working on research projects, with graduate students incorporating research into their theses/dissertations. Scientists who teach update their coursework based on research findings and operations; for example, LES simulations and mixing length formulations were incorporated into the Dynamics 2 class at Texas A&M University-Corpus Christi. More details are provided in Question 26 (training and professional development the project provided). The NGI E&O program supports the missions of NOAA and partner organizations in the region to develop an engaged and educated public who are better able to make scientifically informed decisions. This includes the development of a workforce pipeline for science, technology, engineering, and math (STEM) careers that engages a variety of audiences, including (1) K-12 educators and students; (2) scientists, university students, staff, and administration within its member academic institutions; (3) partners (NOAA and regional science-based organizations); (4) the larger scientific community; and (5) the science-interested public. The program incorporates NGI research into professional development and workshops, K-12 activities and resources, and activities and materials at science-related public events. Some activities incorporate the arts into STEM subjects (STEAM) to encourage innovative and creative thinking in scientific approaches to real-world problems. Information is shared through a variety of avenues, including listserv emails, social media, the Portal newsletter, and its website. Specific activities include:

Development of coastal, marine, and atmospheric science curriculum and fieldwork for educators to use as supplemental material for their classrooms, and hosting lesson plans (500+) from previous projects at <http://gk12.msstate.edu/lessonplans.html>. Participation at community science events such as (1) NASA Infinity Center Homeschool Mondays (2) Stennis "Take your kids to work day," (3) Lynn Meadows Discovery Center Earth Day and Career Day Celebrations and (4) Celebrate the Gulf Festival. Provide education resources such as (1) the Traveling Trunk Shows which include art and science curriculum designed to support the national college and career readiness standards; (2) the Scientists Get Involved program for science, engineering, and mathematics faculty from NGI partner institutions to give guest lectures in classrooms, children's museums, and science festivals; and (3) the traveling ROV program that provides the basic principles of ROVs and their marine science applications. Facilitate the involvement of high school students in data collection and fieldwork during summer and interactions between scientists and educators at annual meetings of science teacher associations. Provide professional development and training on technologies, such as uncrewed aerial and marine systems and geospatial techniques, and continuing education for science faculty through the MSU Geosciences Program. Two innovative programs created by the NGI E&O program are (1) an award-winning traveling theatrical production that helps students understand environmental and socio-economics threats posed by climate change and disasters and provides scientifically accurate talking points for them to use with others in conversational dialogue; and (2) an experiential learning opportunity for middle and high-school students onboard the R/V Jim Franks or one of the Biloxi Schooners (operated by the Maritime and Seafood Museum) to take part in scientific sampling and learn about Gulf Coast history, geography, geology, biology, ecology, and climate topics. More details are available at https://www.northerngulfinstitute.org/education_outreach.html

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

HPC capability and capacity allowed NOAA research activities to continue and expand, with nearly 700 million hours of computational time was consumed by NOAA researchers. The HPC system Orion is the largest system ever housed at Mississippi State University and, as such, required significant modifications to electrical and mechanical facilities to support its use.

Advancements in 'omics and bioinformatics is recognized across NOAA and the international science community for contributions to marine systems studies. The 'omics lab space at AOML has continued to be upgraded, including renovation of two rooms and the addition of a gel documentation system and a microplate reader. Code repositories and organizations were created on GitHub for hosting and version control of software produced by AOML.

Improvements to GOES-R CI satellite and cloud-top cooling products will be used in the new High-Resolution Rapid Refresh (HRRR) model, a real-time 3-km resolution, hourly updated, cloud-resolving, convection-allowing atmospheric model.

Research that uses UAS missions to collect data and imagery on flooding events has resulted in greater capacity and capability in its flight laboratory. Research on tornado formation included funding to maintain one mobile X-band radar and a fixed-site C-band radar (ARMOR and MAX), three wind profiling systems (MIPS, MoDLS, and RaDAPS), and balloon sounding systems.

Research that uses electronic monitoring technology for fisheries surveys built several hardware test structures and developed several machine learning and deep learning-based algorithms that have a wide variety of applications.

Testing of uncrewed surface and aerial vessels for marine surveys included an upgraded Wingtra to newer body, new LM3GNSS+INS systems for research and teaching, and seafloor mooring with CTD and a high precision and accuracy pressure sensor. A Seaglider was procured for use in the 12-credit hour certificate program that trains operators of underwater glider technologies.

IMPACT (cont'd)

42. What was the impact on technology transfer?

The newly-developed Subsurface Automated Sampler for eDNA (SASe) is being deployed in Biscayne Bay as part of a new project funded by the 'omics program.

Personnel in the UxS RTO gained a better understanding of the trade-off in flying uncrewed and crewed aircraft for surveys.

The GOES-R Convective Initiation algorithm will be transferred to NOAA operations when the cloud-top cooling rates are used routinely in the new HRRR forecast model.

Initial efforts were started related to the transfer of technology for modeled coupling of currents with stress and winds to groups interested in ocean and atmosphere modeling, with one being the Navy.

Applications developed such as GeoCoast and the MS LiDAR viewer provide a means of geospatial data/technology transfer to scientist, resource managers, decision makers, and the public. MDEQ is currently developing and updated system to improve project-developed spatial data availability and dissemination.

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

NGI research and operations increase public understanding of the interconnections among Gulf of Mexico ecosystems, resources, and people and facilitates decision-making based on these interconnections. The collection, processing, and archiving of a wide-range of scientific and environmental data in NOAA repositories ensures that data collected at taxpayer expense are complete, accurate, and accessible for future generations of scientists, policy makers, and the public.

More accurate storm, hazard, and extreme weather forecasts provide better warnings, preparation, and response that can have a significant impact on human life, infrastructure, and socio-economic development. Use of uncrewed technologies to acquire data during storms and hazards and in remote locations reduces danger to humans and fossil fuel consumption.

Professional development and training provide for a more effective workforce now and in the future, setting the foundation for continued advancements in science and technology that informs decision-making for healthy and resilient Gulf of Mexico ecosystems, resources, and people.

Education and outreach to the public on marine and coastal conservation and management help inform them of the importance of healthy and resilient ecosystems and garners their continued support for the research that provides the foundation for these efforts.

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

Nothing to Report

CHANGES/PROBLEMS (cont'd)

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

CoVid-19 restrictions and impacts have played a key role in limiting operations and interactions of NGI personnel. Please see the attached list of all projects that were extended beyond their originally scheduled project end date, address reasons for the delays and plans to resolve them.

47. Changes that had a significant impact on expenditures

Nothing to Report

CHANGES/PROBLEMS (cont'd)

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

Nothing to Report

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

Nothing to Report

PROJECT OUTCOMES

50. What were the outcomes of the award?

Significant outcomes of NGI research and operations during this reporting period include: 89 presentations and publications which advanced science in areas of (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 science advancements increased our 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 on outcomes are available in responses to Question #25 (accomplishments), Question #29 (publications, papers, presentations), Question #30 (technology/technique products), Question #32 (other products), Question #37 (impacts on principal disciplines), Question #38 (impacts on other disciplines), Question #41 (impact on physical, institutional, and information resources), Question #42 (impact on technology transfer), and Question #43 (impacts on society).

Summaries of outcomes in these areas include:

Improved forecasts, warnings, and response resulted from improved atmospheric and oceanic data that function as parameters in storm and hazard forecasts and from the fast and safe acquisition of data and imagery using uncrewed technologies.

Support for fisheries conservation and management resulted from field surveys on endangered marine species, application of 'omics and bioinformatics to cetacean health monitoring, simulations of ocean biogeochemical patterns that affect marine organisms, and quantification of impacts from regional ocean dynamics on productivity.

Support for ecosystem-based management resulted from annual monitoring of and forecasts for the Gulf of Mexico hypoxic zone, water quality assessments in regional watersheds, understanding large-scale ocean processes such as biogeochemical patterns and their implications on ecosystem functions; and understanding the state of EBM as practiced by regional resource managers.

Research support resulted from the provision of infrastructure and capacity in areas of high-performance computing, cloud platforms, automated laboratory protocols for and development of 'omics and bioinformatics tools, satellite products, and hydrographic and oceanographic survey technologies.

Improvements to data accessibility and usability resulted from the application of subject matter expertise to data management and enhancement

DEMOGRAPHIC INFORMATION FOR SIGNIFICANT CONTRIBUTORS (VOLUNTARY)

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

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

The following provides complete text for answers to questions 25, 26, 35, 37, 38, and 50 as information in the pdf of the submitted form was cut off.

NA16 OAR 420199

#25 (ACCOMPLISHMENTS)

What was accomplished under these goals?

NGI research strives for new/improved knowledge and technology and their transition to ecosystem-based management. NGI accomplishments are documented in peer-reviewed publications, an established metric for their quality, rigor, and significance. Alignment to other agencies' outcomes points to leveraging resources, extending impact, and strengthening stakeholder ties. NGI accomplished the following:

IMPROVED FORECASTS, WARNINGS, AND RESPONSE UAS missions documented river flooding following Hurricane Ida; advancements in UAS use included mapping plane coordinates, DAA tracking technology, concept for Beyond Visual Line of Sight Operations, and a cost benefits analysis for uncrewed versus crewed missions. Surface wind data collected by hurricane hunter aircraft was improved by addressing interference and under-sampling issues. Wind and flux forecasts were improved by assimilating satellite and in situ ocean data. Differences in the influence of SST anomalies in the Atlantic and Pacific on hurricane activity were identified. Data to improve tornado detection and forecasts were collected and analyzed.

FISHERIES CONSERVATION AND MANAGEMENT To gauge population, reproduction, and habitats, fishery-independent longlines were set resulting in the capture, tagging, and release of 14 smalltooth sawfish and six scalloped hammerhead sharks. Processing/analysis of eDNA and skin microbiome samples for whales, dolphins, and porpoises provide health monitoring. Simulations of ocean biogeochemical patterns help evaluate their impact on fishery resources. Impacts of regional ocean dynamics on fishery productivity are quantified with modeling and satellite products.

ECOSYSTEM MANAGEMENT The hypoxia monitoring cruise was conducted, gathering data on oxygen and nutrients in the hypoxic zone. Water quality assessments for Biscayne Bay were facilitated by the calibration of salinity and water elevation used in the Soil and Water Assessment Tool. The current state of EBM practice by resource managers was analyzed, resulting in a white paper presented to RESTORE Science Program leadership.

INFRASTRUCTURE AND CAPACITY SUPPORT FOR RESEARCH The High Performance Computing (HPC) system *Orion* served 195 users working on 58 projects that consumed 120 million+ wallclock-hours of CPU time this year. HPC capacity on AOML servers and cloud platforms advanced the application of 'omics and bioinformatics tools for high-throughput DNA extraction and PCR amplification of eDNA. Improvements to GOES-R Convective Initiation products included algorithm updates and assimilating the cloud-top cooling rate field into the High Resolution Rapid Refresh model. Safe and efficient hydrographic data collection were supported by repairs and tests to an ASV, a mapping drone, and a tide gauge VDatum package. Training for operating underwater gliders was improved with new curriculum for an Operator's Certificate program.

DATA MANAGEMENT & ENHANCEMENT Seafloor video were improved by Python scripts that extract data and yield GIS digital maps. Digital fisheries media were organized; and electronic monitoring hardware, software (including calibration of VIAME algorithms), and AI were applied to automate detection of fish length, size, and species Meteorological and oceanographic data from NOAA vessels were collected, monitored for quality control, archived, and disseminated. Geospatial databases were developed, and GIS training and technical support were provided at 19 workshops to 133 participants from local, state, and federal government agencies.

ENGAGEMENT WITH TARGET AUDIENCES Peer-reviewed publications and presentations targeted science partners and resource managers. Formal and informal outreach targeted K-12 educators and students. Professional development targeted researchers, university students, and staff associated with projects. The website and social media targeted broader science communities and the science-interested public.

26. (ACCOMPLISHMENTS)

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

NGI provided research updates to stakeholders and incorporated knowledge and technology advancements in presentations, professional development, coursework, and education and outreach events and resources.

Researchers, students, and staff attended a variety of science events this year (for a complete listing, see Question #29 products), including:

- American Geophysical Union Conference
- American Association of Geographers Meeting
- American Meteorological Society Meeting
- Association of Environmental & Engineering Geologists Conference
- Canadian Hydrographic Conference
- Gulf of Mexico Conference
- Joint Satellite Conference
- Mississippi Geospatial Conference
- NOAA RESTORE Science Program Review
- NOAA Leveraging AI in Environmental Sciences Workshop
- Ocean Acidification Week
- Ocean Sciences Meeting
- World Fisheries Congress

This year, NGI research provided specialized training to those associated with projects:

Students were trained to gather and manage meteorological data; gather atmospheric data; apply geospatial analysis to ROV data; calculate surface flux from in situ data; analyze physics observations; link ocean surface processes; and to couple currents, stress, and wind in models. Students were trained to operate underwater gliders, use remote sensing to track tropical cyclones, operate global navigation satellite systems, conduct fisheries surveys, conduct human subjects research, use evaluation protocols, and develop journal articles.

Professional staff received training on meteorological and surface ocean sensors and data acquisition, geospatial technologies, computer coding, the operation of large HPC systems, advocating for potential research activities using HPC systems, Video Image Analytics for the Marine Environment (VIAME), fishery stock assessment models, bioinformatics analysis, high-throughput DNA extraction and sequencing, eDNA sampling, and the development of grant proposals. One staff member was certified as an Amazon Web Services Developer Associate and Google Cloud Platform Engineer Associate. Stakeholders helped researchers refine the development of seasonal hurricane forecasts to meet their needs and provided support for robust modeling tools for living marine resources applications.

#35 (PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS)

What other organizations have been involved as partners?

NGI closely aligns its research and outreach activities with NOAA and other organizations' 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 provides OAR with high performance computing capacity and contributes to OAR programs in 'Omics, UAS, Ocean Acidification, Climate, and Weather.

NGI and the NESDIS National Centers of Environmental Information (NCEI) share a building at the NASA Stennis Space Center, facilitating a close working relationship. NGI and NCEI provide enhanced data, products, and services for the Coastal Ecosystem Data Assembly Center; the Ocean Exploration and Research Program; the Deep-Sea Corals Research and Technology Program; the Data Integration, Visualization, Exploration, and Reporting Tool; and satellite weather products.

NGI provides the NOS Office of Coastal Management with geospatial education and outreach and with the Office of Coast Survey for hydrographic research and is the NOAA CI for Gulf of Mexico Hypoxia, providing monitoring data to inform the NOAA Hypoxia Task Force and the National Centers for Coastal Ocean Science Hypoxia Program.

NGI works with the National Weather Service (NWS) to develop more accurate estimates of ocean surface wind speed and air-sea interactions for hurricane forecasts, to detect and forecast tornadoes, and to provide Atmospheric River Reconnaissance missions support for weather, water, and climate predictions.

NGI works with the National Marine Fisheries Service (NMFS) to monitor several marine species, including sea turtles, smalltooth sawfish, and scalloped hammerhead sharks and provides secure storage of plankton specimens at the Stennis Space Center. NGI works with the Southeast Fisheries Science Center to support cetacean conservation and automate fish detection and identification from video.

Other regional NGI 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, NOAA Restore Science Program

Additionally, NGI research projects involved the following partners: CVisionAI, Havenworth Coastal Conservation, Monterey Bay Aquarium Research Institute, Mote Marine Lab, National Center for Atmospheric Research , Naval Meteorology and Oceanography Command , Naval Undersea Warfare Center , NOAA Aircraft Operations Center , NOAA Alaska Fisheries Science Center, NOAA Cooperative Institute for Marine and Atmospheric Studies at University of Miami , NOAA Cooperative Institute for Research in the Atmosphere , NOAA Earth Systems Research Laboratory Physical Science Division, NOAA Global Systems Laboratory, NOAA Great Lakes Environmental Research Laboratory , NOAA Hurricane Research Division, NOAA Integrated Ocean Observing System , NOAA International Comprehensive Ocean-Atmosphere Data Set , NOAA Lower Mississippi River Forecast Center, NOAA National Hurricane Center, NOAA NWS Southern Region, NOAA Northwest Fisheries Science Center, NOAA Office of Protected Resources , NOAA Pacific Marine Environmental Laboratory , NOAA Physical Oceanography Division, NOAA Uncrewed Systems Research Transition Office, NOAA West Gulf River Forecast Center, NSF Rolling Deck to Repository Project, Perspecta, Inc., ProSensing Inc., Saltwater Inc., University of North Florida

#37 (IMPACT)

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

Forecasts, warnings, and response

Rapid flood data provided inundation maps and improved warnings and emergency response. Wind surface data informed forecasts of tropical cyclone track, intensity, and wind radii. Gridded wind and flux products informed ENSO forecasts, and the Navy plan to use new knowledge generated from coupling currents, stress, and winds in their ocean modeling. The Atlantic-Pacific SST index contributed to new understanding about when ENSO affects hurricanes and was used in an experimental 2022 Atlantic hurricane outlook that was shared with NOAA. Analysis of non-classical tornado formation showed the influence of surface roughness on vertical shear, characteristics of stratocumulus clouds in advance of cold fronts, and implications on boundary layer properties.

Fisheries conservation and management

Habitat and bycatch risk data on smalltooth sawfish led to recommendations of seasonal region closures to shrimp trawling. Data from scalloped and great hammerheads contributed to federal stock assessments. The application of 'omics methods for eDNA analysis of deep-sea fish and dolphin microbiome samples supported SEFSC conservation efforts. The improved ocean biogeochemical model provided insights into underlying processes determining biogeochemistry variability and its impact on fishery resources. Use of the MATLAB growth code to model the impact of fishing may improve accuracy of fisheries management benchmarks. The Trip Interview Program's secondary production estimates can be used to study the link between lower trophic level productivity and the productivity/recruitment of other species.

Ecosystem-based management

Monitoring the Gulf of Mexico hypoxic zone advanced the science that underpins its management and measures progress on the Hypoxia Task Force's nutrient management goals set out in the Gulf Action Plan. The data are used in biogeochemical and hydrodynamic models that generate forecasts and

hindcasts. The addition of salinity and water elevation to the Soil and Water Assessment Tool improved its use for Coral Gables Canal and Biscayne Bay and was shared with an advisory panel. Insights from case studies on the use of EBM by resource managers was shared with researchers, funders, scientists, and decision-makers along with suggestions to support the increased use of EBM in practice. Scientists expressed interest in using outputs from the improved ocean biogeochemical model for studies on ocean chemistry and ecosystem applications.

Infrastructure and capacity support

HPC capability and capacity allowed NOAA research activities to continue and expand, with nearly 700 million hours of computational time was consumed by NOAA researchers. Advancements in 'omics and bioinformatics is recognized across NOAA and the international science community for contributions to marine systems studies. Improvements to GOES-R CI satellite and cloud-top cooling products will be used in the new HRRR model. Testing of uncrewed surface and aerial vessels for marine surveys improved procedures on their use. Tying water levels from pressure sensors on the seafloor to the ellipsoid improved data in vertical datum separation models. Bathymetry from optical remote sensing provided a new tool for use in shallow waters that are dangerous to navigate and survey resources are lacking. Curriculum for training operators in underwater glider technologies contributed to workforce development.

Data Management & Enhancement

ROV video data improved capacity to map deep sea observations. Electronic monitoring improved efficient processing of digital fisheries media. Meteorological and oceanographic observations contributed to the ICOADS <https://icoads.noaa.gov/> and the SUMD portal <https://www.ncei.noaa.gov/access/surface-underway-marine-database/>. Improved GIS visualization and dissemination allow for the application of these technologies for decision support. GIS trainings contribute to workforce and professional development.

#38 (IMPACT)

What was the impact on other disciplines?

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

Accurate surface wind speed estimates in hurricanes improve satellite calibration at high winds; provide better estimates of air-sea exchanges of momentum, energy, and mass; and provide information to the maritime community for safety at sea and to coastal communities to prepare for land-falling storms.

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 experimental outlooks on seasonal hurricanes and landfalling provide forecasters with additional resources to inform stakeholders on the predicted severity and impacts of the upcoming hurricane season.

Meteorological and oceanographic observations include collections from remote areas, making them ideal for marine climate and ocean process studies and evaluating numerical models and satellite products.

'Omics research is interdisciplinary, covering fields in microbiology, toxicology, fisheries biology, marine genomics, and bioinformatics.

Comprehensive digital mapping of seafloor environmental parameters (including ecological observations) can inform a variety of disciplines as well as natural resource managers.

Incorporation of electronic monitoring for sampling provided electrical and computer engineers a better understanding of fisheries issues.

Insights into EBM as practiced by resource managers provides other disciplines with information on how change within institutions or organizations involved with policy-making affects decision-making.

A trained workforce to operate underwater glider technology benefits scientists, marine resource managers, military marine geospatial intelligence workers, and others that can utilize data from buoyancy gliders.

GIS data, resources, and tools facilitate interactions with researchers from other disciplines (coastal ecosystems, hazards, economies) for improved modeling of coastal science.

Fishery biologists have shown interest in secondary production estimates as it demonstrates an important step past using satellite-measured chlorophyll to investigate variability in ecosystem productivity and impacts on fishery productivity. Demonstrating the impact of secondary production on growth rates of King Mackerel highlights the importance of an ecosystem-based management approach.

Testing of uncrewed surface vessels complements a project using the C-Worker 5 USV for baseline environmental surveys for offshore aquaculture siting. Hydrography provides the marine geospatial framework for all marine science, marine resource management, and marine recreation, so the impacts of this work cover a broad swath of societal concerns.

#50 (PROJECT OUTCOMES)

What were the outcomes of the award?

Significant outcomes of NGI research and operations during this reporting period include: 89 presentations and publications which advanced science in areas of (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 science advancements increased our 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 on outcomes are available in responses to Question #25 (accomplishments), Question #29 (publications, papers, presentations), Question #30 (technology/technique products), Question #32 (other products), Question #37 (impacts on principal disciplines), Question #38 (impacts on other disciplines), Question #41 (impact on physical, institutional, and information resources), Question #42 (impact on technology transfer), and Question #43 (impacts on society).

Summaries of outcomes in these areas include:

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Research support resulted from the provision of infrastructure and capacity in areas of high-performance computing, cloud platforms, automated laboratory protocols for and development of 'omics and bioinformatics tools, satellite products, and hydrographic and oceanographic survey technologies.

Improvements to data accessibility and usability resulted from the application of subject matter expertise to data management and enhancement, such as increasing the efficiency of collecting and processing digital media, from which informative products can be created; from the continued collection, processing, and dissemination of meteorological and oceanographic data; and providing GIS products, training, and technical support.

Effective engagement with target audiences resulted from publications and presentations targeted to science partners and resource managers; education resources for K-12 teachers and students; professional development for university and profession staff associated with research projects; and current, relevant website content and targeted social media use to reach broader science-interested audiences.