



DEPARTMENT OF COMMERCE RESEARCH PERFORMANCE PROGRESS REPORT (RPPR)

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AWARD INFORMATION	
1. Federal Agency: Department of Commerce / NOAA	2. Federal Award Number: NA21OAR4320190
3. Project Title: Northern Gulf Institute	
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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 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.

Specific accomplishments include:

IMPROVED FORECASTS, WARNINGS, AND RESPONSE A new modeling framework integrated in-situ observations and large-eddy simulations, resulting in modifications to planetary boundary layer parameterizations and improvements to forecasts of rapid hurricane intensification. Reanalysis products applied to Community Earth System Model simulations linked drought conditions to large-scale climate variations. A new Atmospheric River Analysis and Forecast System supported the 2022 joint mission of NOAA, Scripps Institute of Oceanography, UC San Diego, and Air Force, and an impact study of AR Recon data was conducted. Surface wind data collected by hurricane hunter aircraft was improved by addressing interference, under-sampling, and rain data issues. Wind and flux forecasts were improved by assimilating satellite and in situ ocean data.

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.

ECOSYSTEM MANAGEMENT Assessment of river diversion impacts on the ecological trajectory and functionality of salt marshes quantified marsh geomorphology, function, and the composition and abundance of marsh-dependent taxa. Environmental DNA samples were collected on the 2022 GO-SHIP cruise for analysis of the relationship between biogeochemical fluxes in the ocean and microbial diversity. Four sediment traps were deployed at the euphotic zone in the Gulf of Mexico to collect particulate fluxes for analysis of biodiversity and contributions to the ocean's biological carbon pump. 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.

DATA MANAGEMENT & ENHANCEMENT Subject matter expertise helped develop, enhance, maintain, and make publicly available OER oceanographic data and video collections, including OER Digital Atlas, video portal, ROV/Cruise landing pages, benthic animal guide, GIS services, cruise information management system, video information system, and sampling operations database application. Data management supported the Deep-Sea Coral Research and Technology Program to identify, inventory, and provide stewardship of program data. The NOAA National Database for Deep Sea Corals and Sponges was transitioned to a new GIS-based platform; assistance was provided to NMFS for data acquisition, processing, and archiving for spatial analyses of Vulnerable Marine Ecosystems (VMEs); and multi-taxon VME analysis in the West Coast Economic Exclusive Zone was completed. Digital fisheries media were organized; and electronic monitoring hardware, software (including calibration of VIAME algorithms), and AI were applied

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 Meteorological Society Meeting
Collaborative Virtual Reality and Visualization Workshop
Earth Science Information Partners Meeting
Esri Ocean, Weather, and Climate GIS Forum
Federal Inter-Agency Working Group
Gulf of Mexico Conference
Hurricanes and Tropical Meteorology Conference
International Ocean Data Conference
International Ocean Vector Winds Science Team Meeting
National Academies of Sciences Annual Meeting
NOAA Environmental Data Management Workshop
Ocean Carbon and Biogeochemistry Workshop
Ocean Sciences Meeting
Tropical Cyclone Operations and Research Forum
World Oceans Week

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

Students were trained to quantify effects of river diversions on salt marshes; develop hurricane wind formulations use scripting languages, artificial intelligence, statistical software, and graphical packages; gather and manage meteorological data; conduct sampling and deploy sediment traps during research cruises; calculate surface flux from in situ data; analyze physics observations; link ocean surface processes; couple currents, stress, and wind in models; conduct fisheries surveys; and conduct remote sensing of wind structure in tropical cyclones.

Professional staff received training on meteorological and surface ocean sensors and data acquisition, analysis of sediment trap samples, and eDNA sampling. One staff member was certified as an Amazon Web Services Developer Associate and Google Cloud Platform Engineer Associate.

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>.

Meteorological and oceanographic observation data from U.S. research vessels are available via the web (https://samoss.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) assessing the performance of the modified PBL scheme in the 2021 hurricane season and preparing for a research-to-operations transition by integrating the revised scheme into NOAA's HAFS model during the 2022 or 2023 hurricane season; (2) incorporating knowledge gained from preliminary results to run climate model simulations and link drought conditions to large-scale climate variations; (3) providing support to AR reconnaissance missions in 2023 and assessing AR-related climatology from GEFSSv12 forecasts and reforecasts; (4) developing a method to calibrate historical data collected by tail Doppler radar and computing new rain rates to update the Stepped-Frequency Microwave Radiometer algorithm for more accurate surface wind data estimates; and (5) producing gridded wind products from satellite and in situ ocean data for storm forecasts.

Continue support for fisheries conservation and management by conducting sampling trips to tag and collect life history data of smalltooth sawfish and scalloped hammerhead sharks.

Continue support for ecosystem management in the Gulf of Mexico region by (1) extracting eDNA from samples collected on the GO-SHIP cruise and performing metabarcoding on the extracted DNA for analysis to identify patterns of and metrics for plankton diversity; (2) deploying and retrieving sediment traps on a six-month cycle, extracting DNA samples, and analyzing them for the communities they contain and their contributions to the ocean's biological carbon pump; (3) finalizing data analyses and manuscript submission on assessment of effects of freshwater additions on marshes; and (4) monitoring and assessing the hypoxia zone and regional watersheds.

Continue support for data management and enhancement by (1) installing prototype hardware (cameras, computers) on a NOAA survey vessel then collecting and annotating data and advancing fish species detection algorithms; and (2) collecting, processing, disseminating, and archiving meteorological and oceanographic data; and

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

This section (questions 29-32) should summarize information about main publications, technologies, or other products created under your award during the current reporting period. As a reminder, scholarly publications developed under the CI Cooperative Agreement must be submitted to the NOAA Institutional Repository. For more information, refer to the Special Award Condition, "Handling of Environmental Data or Peer-Reviewed Publications."

PRODUCTS

29. Publications, conference papers, and presentations

NGI generated 80 publications, papers, and presentations (25 publications and 55 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:

Development of a new modeling framework tailored to hurricane boundary layers provides modified EDMF-TKE and MYNN PBL schemes from NOAA models that make for more accurate hurricane conditions and forecasts. The framework is available to the research community in the model CM1 (testcase=10, param 21 section, <https://www2.mmm.ucar.edu/people/bryan/cm1/README.namelist>).

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.

An upgraded Ensemble Sensitivity Tool for Atmospheric River Reconnaissance (AR Recon) flight path planning was developed by adding Canadian Meteorological Center Ensemble Prediction System (CMC) data and replacing NCAR Command Language (NCL) script with Python script.

Advancements were made in the DNA sampling method for ship flow-through sampling and peristaltic pump filtering through Sterivex filters.

A new method was developed to extract DNA from formalin-preserved sediment samples.

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).

PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

33. What individuals have worked on this project?

Robert Moorhead – Director NGI
Paul Mickle – Co-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: Center for Western Weather and Water Extremes; Coastal Wetlands Planning, Protection, and Restoration Act; CVisionAI, Havenworth Coastal Conservation, International Comprehensive

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:
Center for Western Weather and Water Extremes: Marty Ralph
Havenorth Coastal Conservation: Tonya Wiley
NOAA AOML/HRD: Paul Reasor, John Gamache
NOAA AOML/PhOD: Renellys Perez
NOAA AOML: Ghassan Alaka
NOAA EMC: Chunxi Zang
NOAA Fisheries: John Carlson, Andrea Kroetz
NOAA NCEI Maryland: Chris Paver, Steve Rutz, John Relph, and Vidhya Gondle
NOAA NCEP: Xingren Wu, Vijay Tallapragada
NOAA NMFS Google Cloud: Brett Alger
NOAA OMAO Silver Spring: Solomon Tadele, John Katebini, Philip Zublay, and Kevin Cromer
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?

IMPROVED FORECASTS, WARNINGS, AND RESPONSE The new modeling framework with modified PBL parameterizations was incorporated into the Cloud Model 1, which is available to the forecasting community, and into the NOAA HAFS for more accurate predictions of rapid storm intensification. Reanalysis products applied to Community Earth System Model simulations that link drought conditions to large-scale climate variations advanced understanding about decadal variation of Southeastern U.S. drought modulators. Preliminary analysis found that the impact of the Atlantic Multi-Decadal Oscillation-El Niño Southern Oscillation (ENSO) relationship on Southeast U.S. drought frequency is modulated by the phase of the Interdecadal Pacific Oscillation. Improved techniques enhanced data assimilation and the predictive capability of the Atmospheric River Analysis and Forecast System, contributing to a successful 2022 joint mission of NOAA, Scripps Institute of Oceanography, the UC San Diego, and the Air Force and informed EMC predictions. Improved retrieval of ocean surface wind data from instruments on hurricane hunter aircraft informed tropical cyclone forecasts. Gridded wind and flux products informed ENSO forecasts, and the Navy plans to use new knowledge generated from coupling currents, stress, and winds in their ocean modeling.

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.

ECOSYSTEM MANAGEMENT An empirical assessment quantified the effects of river diversion on the ecological trajectory and functionality of salt marshes and can be integrated into restoration and monitoring plans. Efforts involved with the collection of eDNA samples on the 2022 GO-SHIP cruise show the marine science community what is possible with global scale marine biodiversity monitoring efforts. The first deployment of sediment traps was retrieved, with data contributing to a 5-year time-series for use by the research community; and a new method for extracting DNA from sediment trap samples was tested and validated. 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.

DATA MANAGEMENT & ENHANCEMENT OER data and video collections were enhanced, maintained, and made publicly available; this effort included the OER Digital Atlas, video portal, ROV/Cruise landing pages, benthic animal guide, GIS services, cruise information management system, video information system, and sampling operations database application. Data generated by the Deep-Sea Coral Research and Technology Program were transitioned to a new GIS-based data platform; NMFS was assisted with data acquisition, processing, and archiving for VMEs. 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://sumd.noaa.gov/>

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

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:

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.

Accurate ocean 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.

More accurate PBL schemes could improve the accuracy of surface wind parameters, which would improve the model forecasts of ocean coupling processes, storm surge, precipitation, and other weather-related conditions. The developed evaluation framework pioneers the way to evaluate the PBL schemes in hurricane conditions, and the LES data produced by this framework together with the special model setup can be easily applied to evaluate different PBL schemes from different models, which would greatly increase the efficiency for model evaluation among the hurricane community.

The impact of AMO-ENSO relationship modulated by IPO phase can modulate weather conditions other than drought, such as heat waves over the Southeastern U.S., which would be important to agricultural and recreational/tourism industries.

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.

Empirical quantification of the effects of river diversions on marshes will inform current and future management planning and communication decisions and restoration efforts, not just in Plaquemines Parish, Louisiana, but also other Gulf of Mexico coastal areas and ecosystems.

The Bio-GO-SHIP research effort is expanding the core mission of GO-SHIP, which is focused on the physical and chemical aspects of oceanography, by integrating biological observations.

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

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' current and 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 staff associated with projects that result in highly-qualified candidates for NOAA's and other research organizations' current and future workforce. Pls 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 the NGI 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?

Research that improves estimations of ocean surface wind speed from instrumentation flown on hurricane hunter aircraft will provide publicly-available updated datasets on tail Doppler Radar rain rates and comparison datasets from the Stepped-Frequency Microwave Radiometer.

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.

The development of eDNA sampling kits can be deployed on cruises around the ocean.

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.

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.

IMPACT (cont'd)

42. What was the impact on technology transfer?

The improved EDMF-TKE PBL scheme tailored to hurricane boundary layers is demonstrated to improve hurricane intensity and structure forecasts in NOAA's hurricane models. Implementation of the PBL scheme into the hurricane forecast model HAFS can have a substantial impact on the real-time forecasts.

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.

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. For example, carbon dioxide and its export to the deep ocean have potential implications for all life on earth, underscoring the importance of investigating the biological carbon pump to understand climate change.

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. For example, the Bio-GO-SHIP research is inspiring the public to think about the connections between humans and the ocean and how understanding biodiversity may help to preserve it.

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: 80 publications and presentations 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 modeling frameworks, sensitivity tools, and more accurate atmospheric and oceanic data that function as parameters in predictions; 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.

Support for ecosystem-based management resulted from annual monitoring of and forecasts for the Gulf of Mexico hypoxic zone; ecological assessments of hazards response, such as river diversions; application of 'omics to analyze eDNA to understand large-scale ocean processes such as the biological carbon pump and biogeochemical fluxes and their implications on ecosystem function; and water quality assessments in regional watersheds.

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 and providing end-to-end stewardship services, from which informative products can be created and quality data is available for future research; and from the continued collection, processing, and dissemination of meteorological and oceanographic data.

Effective engagement with target audiences resulted from publications and presentations targeted to science partners and resource managers.

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="margin-left: 20px;"><input type="checkbox"/> Deaf or serious difficulty hearing</p> <p style="margin-left: 20px;"><input type="checkbox"/> Blind or serious difficulty seeing even when wearing glasses</p> <p style="margin-left: 20px;"><input type="checkbox"/> Serious difficulty walking or climbing stairs</p> <p style="margin-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.