BOEM OCEAN SCIENCE

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BOEM's Physical Sciences Studies

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BOEM OCEAN SCIENCE is published by the Bureau of Ocean Energy Management to communicate recent ocean science, technological information, and issues of interest related to offshore energy recovery, marine minerals, and ocean stewardship.

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ON THE COVER

NASA's MODIS Terra image of ice circulation around Hanna Shoal and through Barrow Canyon in the northeast Chukchi Sea on July 13, 2016. University of Alaska Fairbanks Geographic Information Network of Alaska.

All photos courtesy of the Bureau of Ocean Energy Management unless otherwise noted.

Publication services provided by The C3 Group and Schatz Strategy Group.

Frequently Used Abbreviations

E	existing emissions exemption amount
EA	Environmental Assessment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
GOM	Gulf of Mexico
NAAQS	national ambient air quality standards
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
OCS	Outer Continental Shelf
OSRA	oil-spill risk analysis
R/V	Research Vessel
USACE	U.S. Army Corps of Engineers
WRF	Weather Research and Forecasting Model

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The Acting Director's Message

Physical sciences are central to BOEM's mission to manage development of U.S. Outer Continental Shelf energy and mineral resources in an environmentally and economically responsible way. For Fiscal Years 2012–2018, they comprised 25 percent, or $56.5 million, of BOEM's ocean science budget. This includes physical oceanography, atmospheric studies, oil spill risk analysis (OSRA), and marine acoustics.

Our research includes examining deep circulation in the Gulf of Mexico, impacts from wave action, meteorological studies of air quality and wind, chemical analysis of the oceans, and understanding the potential effects of anthropogenic (human-generated) sound on animal behavior. Inter-disciplinary linkages between the physical, biological, and social sciences are key to BOEM's environmental program and decisions governing BOEM's three program areas: oil and gas, renewable energy, and marine minerals.

During the course of the Environmental Studies Program's 45-year history, technological advances have enabled more rapid data acquisition and have revolutionized science. This is especially the case with more sophisticated software, greater computational power, and the development of tracers and gliders with satellite-linked communications.

This edition of *BOEM Ocean Science* extensively covers many applications for modeling, including 3D modeling. We examine ocean circulation models and how ocean dynamics may affect ecosystems, impact scenarios for oil spill risk analysis, or affect sediment transport. Modeling also helps us to predict the consequences of wave energy absorption from marine renewable energy facilities on nearshore ecosystems.

In the meteorology area, we look at air quality and emissions dispersion modeling for conventional energy, and from vessels used in marine minerals activities. We are developing and using new knowledge about the atmosphere, wind, and emissions to analyze impacts from wind energy development and operation on air quality related to the renewable energy program.

In addition, BOEM uses modeling to improve emission and pollutant dispersal estimates associated with vessel traffic or equipment used for beach nourishment and coastal restoration. BOEM's physical science program also delineates areas of enhanced sediment accumulation offshore, and monitors water quality and biogeochemical processes in sediment borrow areas.

Scientists about the R/V *Norseman II* release non-toxic Rhodamine-WT dye to study ocean circulation patterns in the Chukchi Sea. Photo by Peter Winsor, University of Alaska Fairbanks.

Please enjoy reading this edition of *BOEM Ocean Science* to learn more about our physical science research.

—Walter D. Cruickshank

What are the Physical Sciences?

Physical Sciences

Physical sciences are an important part of the Environmental Studies Program and provide information for National Environmental Policy Act (NEPA) Environmental Assessment (EA) and Environmental Impact Statement (EIS) documents. The physical sciences research supported by BOEM includes physical oceanography, atmospheric sciences, sand and gravel studies, and oil-spill risk analysis (OSRA).

Physical Oceanography

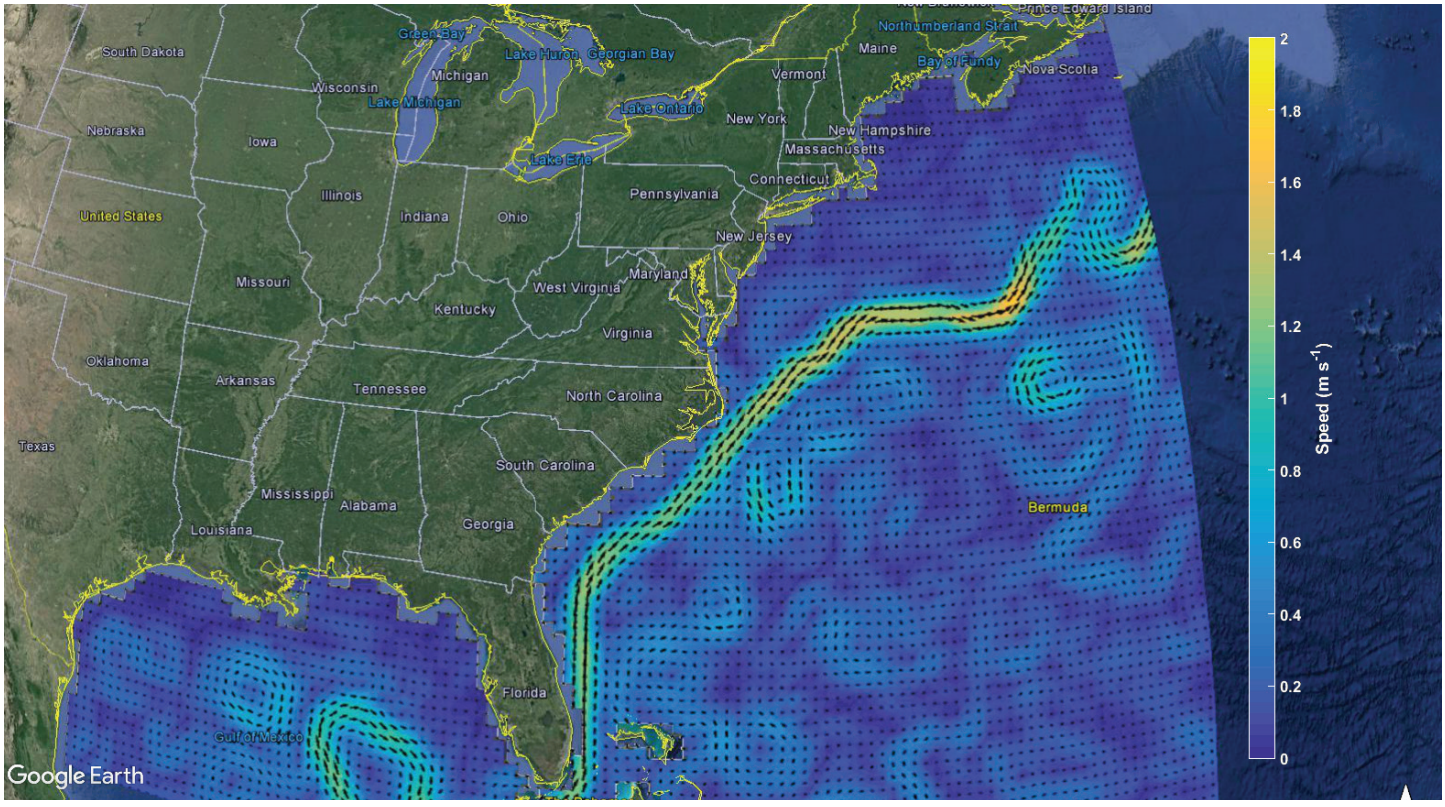
Physical oceanography is the study of the physical conditions within the marine environment. These physical conditions include water motion (currents, waves, tides) and the properties (temperature, salinity) of the water. Ocean circulation is forced by wind stress at the ocean surface and changes in temperature and salt content that modify ocean density. These processes can change the ocean circulation on many time scales, from hourly and daily to seasonal and inter-annual. The seasonal processes are particularly important in changes in upwelling and downwelling of water. Physical oceanographic studies focus on understanding and verifying physical processes and features on the Outer Continental Shelf (OCS). The mechanisms of these processes and features in the ocean and atmosphere control the transport of materials and cause the mixing and redistribution of materials. The methods used in these studies include field data collection, remote sensing, analysis, and modeling studies. The general strategy is to use field observation and model results to calculate the circulation for a given area. These calculations, in turn, provide the basis for OSRA and other assessments.

Physical oceanographic information is used to evaluate the biological and ecological conditions that are influenced by the water masses in which these ecosystems are embedded. Variability in physical oceanographic conditions, for example, could be a cause of variation in biological communities and could be useful in interpreting long-term monitoring and cumulative impact studies.

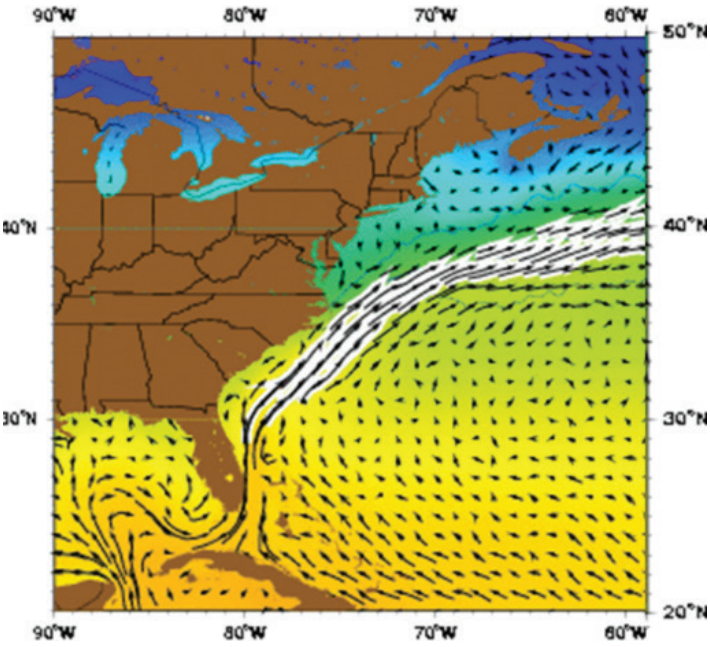
Physical oceanography studies are also used to predict the transport of drilling muds and water discharges containing petroleum compounds and other by-products of oil and gas exploration and production.

Atmospheric Sciences and Air Quality Modeling

Conventional energy exploration, development, and production activities add materials to the marine atmosphere and could affect air quality over coastal states and specific protected areas. These activities are primarily normal operations, such as the exhaust of machinery on the platform or structure, but might also include accidental releases of pollutants. BOEM uses atmospheric science studies to develop air quality impact analyses based on the emissions at the drilling rigs and/or



A visualization of the Ocean Surface Current Analyses Real-time processing system, or OSCAR. Image from Google Earth.



Ocean currents in the Gulf of Mexico and Atlantic Ocean as shown in the Mariano Global Surface Velocity Analysis. http://oceancurrents.rsmas.miami.edu/atlantic/gulf-stream.html.

platforms and from support vessels. Atmospheric sciences research focuses on development of emissions inventories; field data collection; and atmospheric, dispersion, and photochemical modeling.

Initially, field studies in the BOEM Pacific OCS Region were important in developing air quality models. Currently, these studies focus on Gulf of Mexico issues. This is due to the continued rapid growth of the oil and gas-related activities in the Gulf, as well as revised regulatory standards that the U.S. Environmental Protection Agency (EPA) is implementing.

Marine Minerals Program

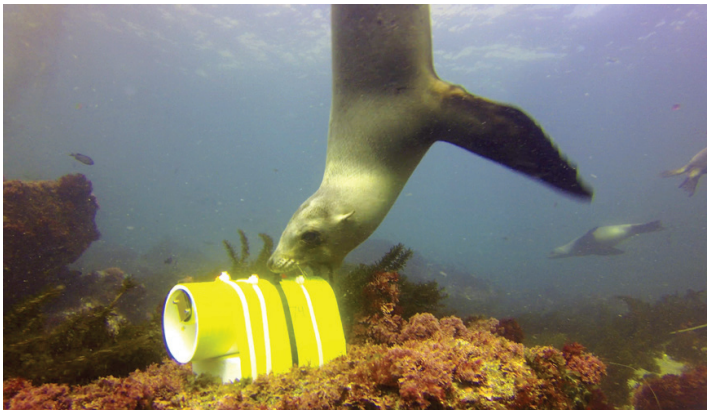
In addition to offshore conventional and renewable energy, BOEM has legal and jurisdictional authority over mineral resources on the OCS. These include sand and gravel deposits, many of which are suitable as beach nourishment or wetlands restoration material, or as a source of coarse material for construction aggregate. In recent years, there has been increasing interest in OCS marine mineral resources. BOEM has responsibilities with respect to the potential environmental impacts from using these resources and must fulfill its NEPA responsibilities by addressing biological and physical environmental questions concerning sand extraction from the OCS. The physics of sand transport is tightly linked to the forces of surface wave motions. A huge amount of sand can be removed from a beach in a matter of hours by a large storm, such as a hurricane. Sand transport also occurs on a seasonal basis, as summer may allow sand to accumulate, while winter causes it to erode. The sediment transport depends on the size of the waves and the angle as they approach the beach. The transport may also depend, to a lesser extent, on the sediment, sand, and mud properties.

Oil-Spill Risk Analysis (OSRA)

BOEM uses the OSRA model to estimate the probability of oil spills occurring in a specific lease area, to calculate hypothetical oil-spill trajectories from selected spill launch points (i.e., places that a spill is assumed to occur), and to determine the probability that an environmental resource or coastline segment might be affected by oil released from specific launch points. OSRA modeling results are used in different types of documents: (1) EA and EIS documents completed by BOEM for OCS lease sales, oil exploration, development, and production; (2) oil-spill response plans submitted by industry; (3) environmental reports submitted by industry; (4) biological opinions for endangered and threatened species; and (5) other federal and state agencies' special reports.

These four research components of physical sciences are closely related to each other. Each component provides useful information to the others to support decision-making. For instance, the physical oceanographic studies supply accurate ocean current data for OSRA modeling and sand and gravel studies, and the atmospheric sciences studies give more detailed wind data that are needed in determining the physical conditions in the environment.

—Dr. Walter Johnson, Chief
Branch of Physical and Chemical Sciences,
Division of Environmental Sciences



A sea lion investigates a wave sensor deployed at Santa Barbara Island, California. Screen capture of video by Susan Zaleski, BOEM.

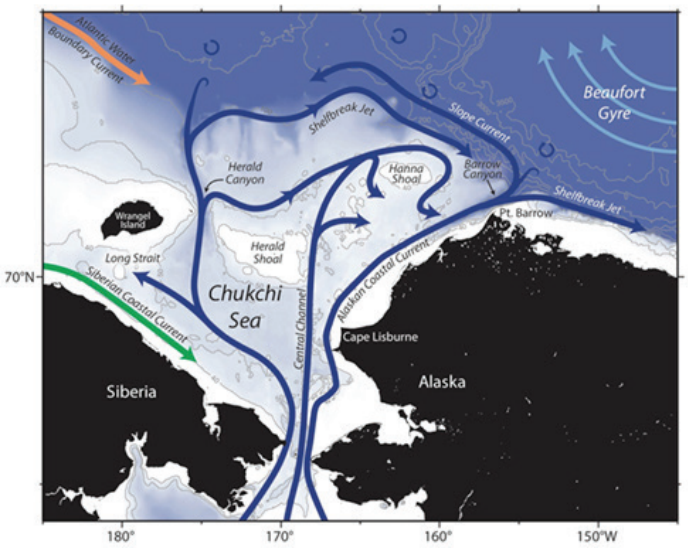
For More Information

BOEM's Ongoing Studies

https://www.boem.gov/Ongoing-Environmental-Studies-by-Region/

Understanding Ocean Circulation in Alaska's Arctic Waters

The Chukchi and Beaufort seas are the northernmost shelves bordering Alaska. The Chukchi shelf is atmospherically and oceanographically connected to the Pacific Ocean, which significantly influences wind and wave regimes, seasonal formation and distribution of sea ice and water masses, and the unique circulation characteristics.



Circulation of the Chukchi Sea and western Beaufort Sea from Brugler et al. (2014).

In 2008, the Chukchi Sea Lease Sale No. 193 attracted considerable interest from the oil and gas industry, especially south of Hanna Shoal and southwest of Barrow Canyon, two biologically productive areas where marine mammals feed and where subsistence hunts occur. Oceanographic conditions in the northeast Chukchi Shelf are complex and difficult to reproduce in models without observations, due to persistent sea ice, complex ocean current circulation around Hanna Shoal, and the convergence of currents and the intermingling of different water masses south of the shoal that flow into Barrow Canyon and exit the Chukchi Shelf. In addition, the risk of a potential oil spill was a major concern to many, especially the subsistence hunters. As a result, BOEM needed to increase ocean observations to support our ocean modeling and improve capabilities to track a potential oil spill.

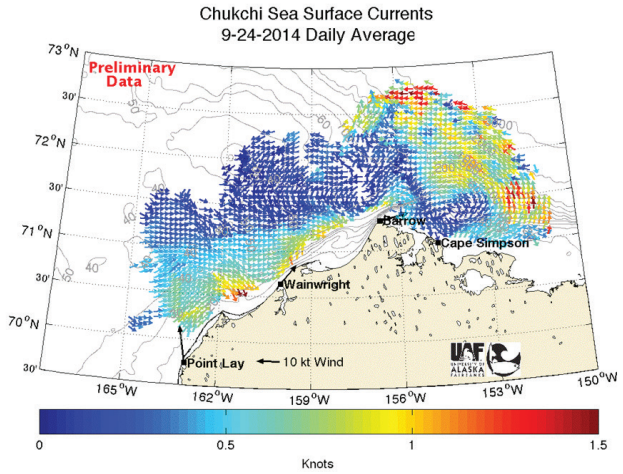
The Alaska OCS Region procured two studies "Characterization of the Circulation on the Continental Shelf Areas of the Northeast Chukchi and Western Beaufort Shelf" and "Arctic Tracer Release Experiment (ARCTREX) Applications for Mapping Spilled Oil in Arctic Waters." The first study produced a comprehensive understanding of the ocean circulation for the northeast Chukchi shelf and slope, whereas the ARCTREX study applied knowledge gained from the first study—an enhanced understanding of the ocean currents, water masses, and fronts, and performance testing of new ocean observing technologies in Arctic conditions—to the development of new oil spill tracking capabilities.

The first study focused on the northeast Chukchi Sea shelf and slope region between the Central Channel and the western Beaufort Sea shelf and slope. Moored oceanographic instruments; satellite-tracked drifters; towed Conductivity, Temperature, and Depth (or CTD) instruments (acrobat); autonomous underwater vehicles (gliders); shipboard measurements; high-frequency radars (HFR); and meteorological buoys were utilized to develop a comprehensive understanding of the physical oceanography.

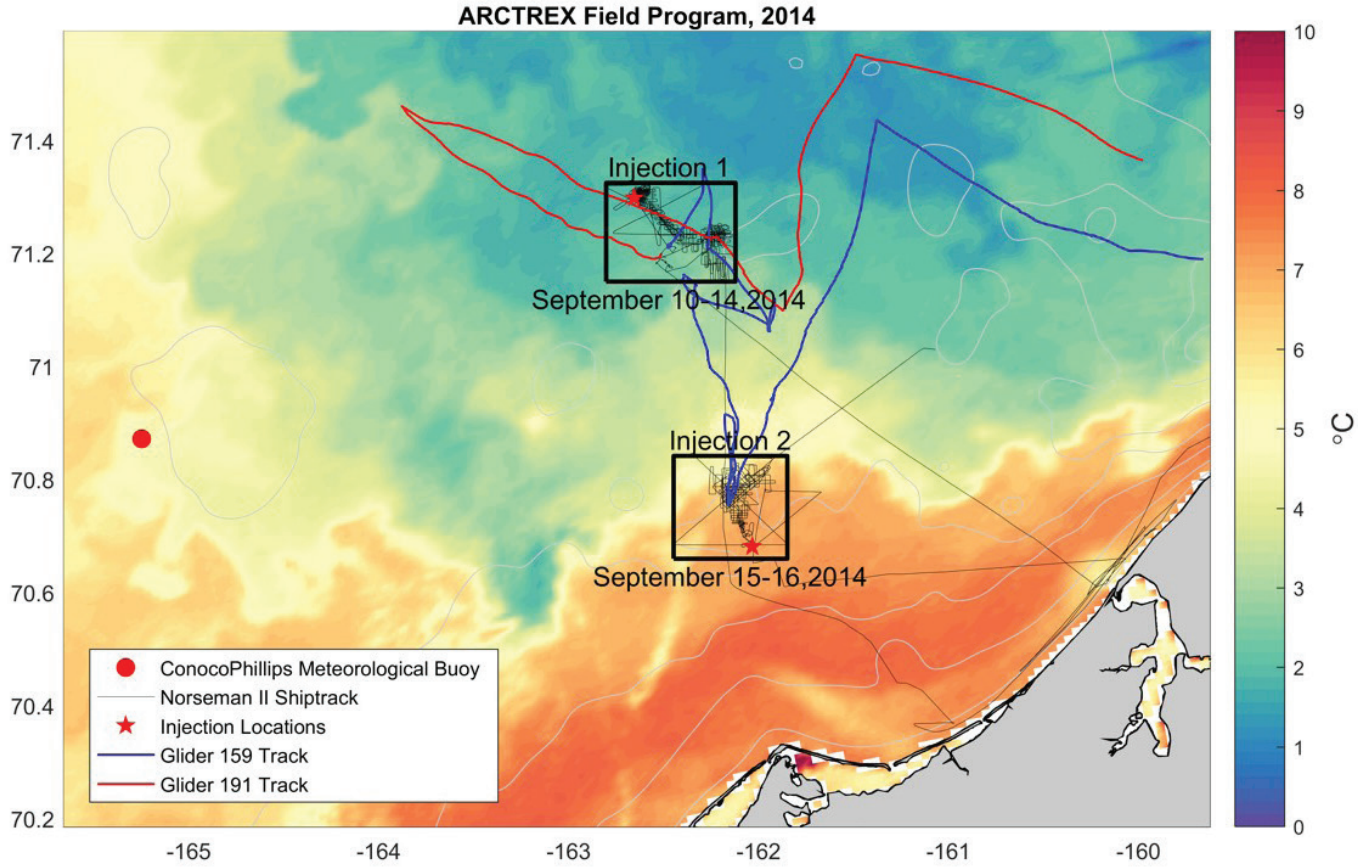
Oceanographic moorings were deployed on the seabed and collected data over multiple years. These moorings collected ocean current measurements of the water column beneath the sea ice and other physical variables such as sea ice thickness, ice velocity, and hydrographic properties of the bottom waters. These moorings improved our understanding of the year-round ocean circulation within the lease area, around Hanna Shoal within Barrow Canyon, and along the Chukchi slope.

This was also the first study in the Arctic to deploy extended long range HFR along the northeast Chukchi Sea coast to map offshore surface currents on an hourly interval in near-real time. The University of Alaska Fairbanks transmitted the surface current data to the public via the project web site. These systems operated during the open water season from July through October between 2012 and 2014.

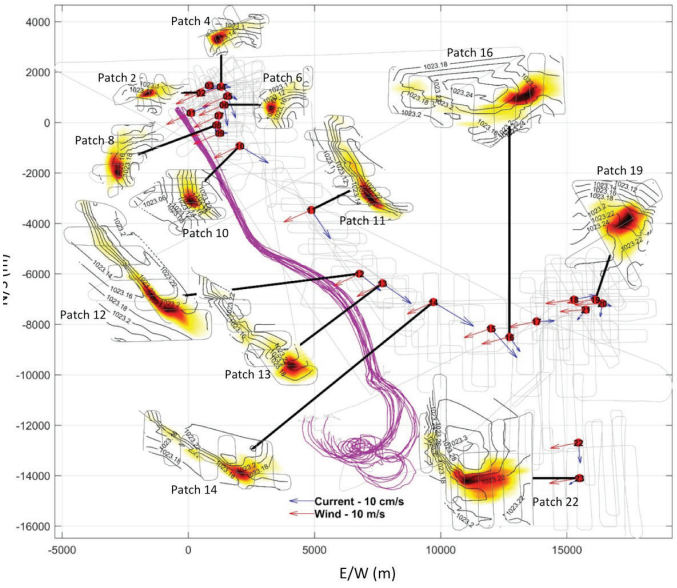
The HFR measurements in the Chukchi Sea confirmed the mean predominate current flow but also revealed, when combined with other ocean measurements, that there was significant ocean current variability across the shelf and slope. This variability was the result of changes in sea ice extent, winds, Pacific water influx, and changes in water column structure.



Chukchi and Western Beaufort Sea Surface Currents, showing the variability in current speed and direction in a given day.



ARCTREX Study Area, Northeastern Chukchi Sea. Location of two dye injection sites in 2014 (black boxes). Red stars depict dye injections #1 and #2. Daily average Sea Surface Temperature (SST) from MODIS satellite imagery for September 15, 2014.



Mapped patches of dye for the first 75 hours after dye injection #1, in 2014. The centers of mass of dye patches are shown by red dots. Shaded contours of dye concentration, contours of density, and the gray ship tracks of the sampling transects are shown along with the patch numbers. Tracks of drifters for same time period are shown in purple.

The ARCTREX study tracked a non-toxic dye release in real time on the surface and within the subsurface utilizing a complex array of instruments. During the ice-free season of 2014, two releases of Rhodamine-WT dye were performed, a second set was released in 2015. The R/V *Norseman II* transmitted the locations of the dye concentrations to NOAA's Environmental Response Management Application, improving communication and coordination among responders and environmental stakeholders. Although this was a significant improvement in tracking technologies for the Arctic, more work needs to be done in the development of positively-buoyant, non-toxic dyes with oil-like properties and coupling detailed observations and three-dimensional ocean modeling.

—Warren Horowitz, Alaska OCS Region

For More Information

Characterization of the Circulation on the Continental Shelf Areas of the Northeast Chukchi and Western Beaufort Seas

https://marinecadastre.gov/espis/#/search/study/26869

Arctic Tracer Release Experiment (ARCTREX)

https://marinecadastre.gov/espis/#/search/study/26872

Physical Science Studies in the Atlantic Region: Anticipate, Estimate, and Integrate

BOEM's Atlantic region is bustling with renewable energy planning and leasing, coastal restoration with marine minerals from federal waters, and potential conventional energy development. BOEM's Environmental Studies Program plays an important role in acquiring physical science information to inform decisions on these program areas. This includes gathering and analyzing meteorological; ocean wave, circulation, and current; and sediment transport data along the Atlantic OCS.

Offshore Wind

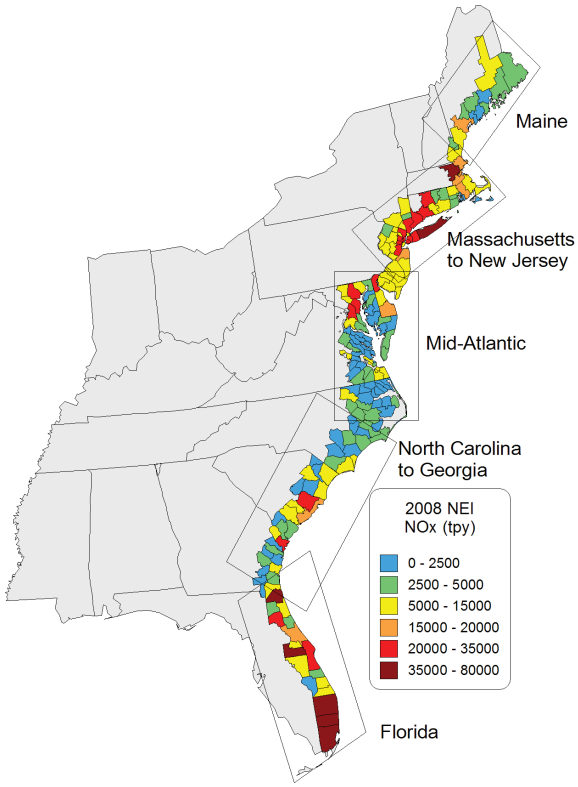
Before establishing Atlantic offshore wind energy areas, BOEM and its partners must consider any potential impacts on air quality in nearby coastal areas. This requires an understanding of the relationships between meteorology, emissions, and air quality within each area of interest. BOEM, other federal and state agencies, the private sector, and academia have collected a range of data on these topics for offshore and nearby onshore areas. We are developing and using new atmospheric knowledge to better assess wind energy and air quality impacts.

Synthesis, Analysis and Integration of Air Quality and Meteorological Data for the Atlantic Coast Region

This study created the first baseline assessment of the entire U.S. Atlantic coast region by assembling and synthesizing meteorological, emissions, and air quality data. The U.S. Environmental Protection Agency (EPA), the National Weather Service, the National Buoy Data Center, and others collected the data. The resulting database contains millions of regional data points collected from 2000 through 2012, and emissions inventories for Atlantic coastal regions for 2008.

The Atlantic Region Air Quality Database (ARAQDB) consists of two primary components: an Oracle database containing air quality, meteorological, and emissions data for onshore and offshore areas, and a custom interactive database tool designed to provide users with easy-to-use query capabilities to retrieve specific data subsets based on a variety of criteria such as date range, location, and parameter type. Researchers conducted a variety of data analyses in order to mine the integrated ARAQDB and ensure the integrity and usability of the dataset. The report provides an overview of the meteorological, air quality, and emission data and highlights key features and components of the integrated dataset.

The study found that wind speeds aloft are lowest during the summer and there is greater stability during the winter throughout the study area. The combined analysis of visibility and wind data indicates that reduced visibility occurs under a range of wind speeds and wind directions, and that recirculation leads to poorer visibility along the middle and southern portions of the Atlantic coast. Not surprisingly, the analysis found that the observed air quality along the Atlantic coast is influenced by anthropogenic and biogenic sources emitting pollutants, with the highest density of anthropogenic emissions occurring in the highly populated urban areas or at the major ports. Forests, wetlands, crops, and other vegetation are the highest contributors to biogenic emissions.



Area of inclusion along the Atlantic coast for the air quality and meteorological data synthesis study. Figure by ICF International.

Studying Currents in the Atlantic Ocean

Accurate information on Atlantic Ocean currents is critical to BOEM's Oil Spill Risk Analysis (OSRA). Present-day OSRA modeling is a state-of-the-art approach that provides BOEM's environmental analysts with reliable, long-term estimates of spill risks associated with potential conventional energy activities in all federal offshore waters.

The OSRA model considers probability of oil spill occurrence, oil spill trajectories (contact), and combined oil spill probability and contact. With its ability to factor in large areas (thousands of kilometers) and long periods of time (years to

Dredge Ship Liberty Island transports dredged sand closer to shore for the pump-out at Long Beach Island, NJ. Photo by Marjorie Weisskohl, BOEM.

decades) of ocean current and wind input data, the model provides answers to two important questions: (1) What is the probability of a large oil spill (greater than or equal to 1,000 barrels) occurring? and (2) What is the probability that oil spilled at Point A (platforms, pipelines, tankers, etc.) reaches Point B (coastlines and environmental resources)?

BOEM is expanding its OSRA capability in the Atlantic and improving its ability to estimate oil spill trajectories by using the HYbrid Coordinate Ocean Model (HYCOM). HYCOM will use Atlantic data from 1993 through 2013 to create trajectories in BOEM's OSRA model. HYCOM is also relevant to other industrial activities, problem-solving, or in addressing other information needs on the OCS.

Emission Estimates for Impact Analysis of Beach Nourishment and Coastal Restoration Projects

To assess the potential air quality impact from dredge equipment, support vessels, and construction equipment for beach nourishment and coastal restoration projects, BOEM developed a conceptual approach and tool to estimate emissions and determine appropriate mitigation. BOEM sponsored development of the Dredge Project Emissions Calculator (DPEC) to calculate project emissions based on project design parameters, such as the amount of material to be placed on shore, location of the project borrow area(s) and pump-out location(s) relative to the beach construction zone, and specifications of the dredge vessel and other equipment to be used on the project.

BOEM sponsored an initial demonstration using DPEC for a typical beach nourishment project in Brevard County, FL. Results showed that the dredge vessel is the major source of emissions, and the impact on air quality is greater as the vessel operates close to shore for significant periods of time, and when wind blows toward the shore.

Collaborating with the U.S. Army Corps of Engineers (USACE), BOEM also applied the DPEC in the planning process for the Long Beach Island Storm Damage Reduction Project in New Jersey, which experienced severe erosion and storm damage from Hurricane Sandy. The USACE, BOEM, EPA, and the New Jersey Department of Environmental Protection evaluated several options to offset emissions impacts.

The DPEC was instrumental in estimating the air quality impact and evaluating options to mitigate the risk of adverse emission standards.

Summary

BOEM applies state-of-the-art advances in modeling to better understand oceanographic, meteorological, and other physical science fields in order to predict impacts on resources, and improve mitigation.

—Angel McCoy, Jeffrey Ji, Douglas Piatkowski, and Marjorie Weisskohl, BOEM Headquarters

For More Information

Synthesis, Analysis and Integration of Air Quality and Meteorological Data for the Atlantic Coast Region
https://www.boem.gov/ESPIS/5/5368.pdf

HYCOM Model – Chassignet et al. 2007
https://hycom.org/attachments/191_Chassignet_et_al_07.pdf

Emission Estimates for Impact Analysis of Beach Nourishment and Coastal Restoration Projects
https://marinecadastre.gov/espis/#/search/study/23165

From the Seafloor to the Sky: Physical Science in the Gulf of Mexico Region

BOEM has recently completed and continues to fund a number of studies in the Gulf of Mexico (GOM) Region to research the evolving impacts of conventional energy activities on water and air quality as well as ecosystems.

A Lagrangian Study in the GOM Region

BOEM funded a four-year study to examine ocean circulation throughout the deep GOM using subsurface neutrally-buoyant floats. The objectives were to: (1) increase knowledge and understanding of the deep circulations in the Gulf; (2) use a Lagrangian approach (focuses on simulations and modeling fluid particle movement) that could produce observations through the deep Gulf, without regard to national boundaries; (3) develop Lagrangian statistics on dispersion and deep currents; and (4) investigate the connections between upper- and lower-layer circulation processes.

To achieve these objectives, 152 floats were deployed at depths of 1,500 and 2,500 m (4,920 and 8,200 ft.), along with six profiling floats. The floats drift with deep currents and listen for acoustic "pongs" emitted at designated times from multiple moored sound sources. By analyzing the time required for each pong to reach a float, researchers can pinpoint its position by triangulation. The floats are able to detect the pongs at ranges of hundreds of kilometers.

Sampling began in July 2011 and ended June 2015, producing 158 trajectories and 597 profiles of temperature and salinity. The most important results were: there was little evidence of deep mass exchange from the eastern to the western basin giving rise to two distinct basins; an anticlockwise current following the escarpment from south of the Mississippi delta, along the Mexican slope, and around the Bay of Campeche to the northeastern point of the Campeche-Yucatan shelf; and finally, observations of a large anticlockwise gyre over the deepest part of the western basin. The connectivity results will inform biological studies of dispersion and our understanding of pollutant dispersion, and should facilitate a better understanding of the distribution of deep benthic communities.

Monitoring Sediment Borrow Areas

BOEM and Louisiana State University (LSU) jointly funded a study to assess potential affects to water quality, sediment biogeochemical processes, and physical oceanographic process due to alterations to seafloor topography from dredging OCS sediment resources. Of particular interest is off the coast of Louisiana where river discharge plays a major role in governing water quality and sediment biogeochemistry.

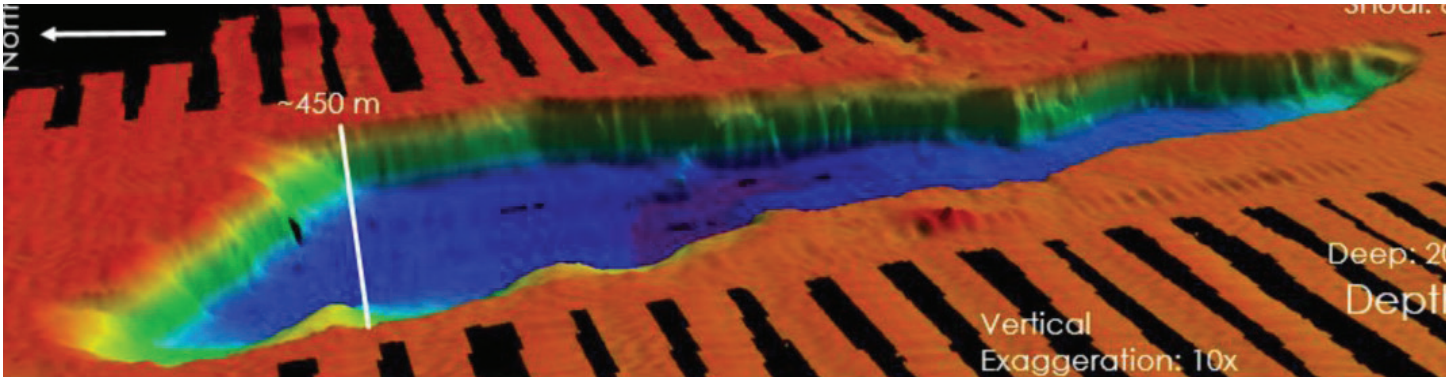
Researchers acknowledge the benefits of introducing new sand to coastal systems from OCS borrow areas in protecting barrier island, estuarine, and wetland habitats, as well as reducing risk to infrastructure and communities due to storm risk. The focus now turns to the potential effects of this excavation on water quality, biogeochemical processes, and habitat function.

The researchers have hypothesized affects in the areas of oxygen dynamics, biological and biogeochemical processes, and pit water dispersal and dredging depth tests.

Results of this two-year study will increase BOEM's decision-making ability regarding safety and protecting environmental and cultural resources, and develop a monitoring protocol for various borrow area scenarios to inform management of OCS mineral resources and associated habitats.

Delineating Areas of Enhanced Sediment Accumulation

Another study in collaboration with LSU examined the transport of sediments, nutrients, and pollutants between the continental shelf and deep basin regions of coastal Louisiana. It focused on the organic matter cycling related to pelagic/benthic habitat and oil fate. Another focus area is the availability of offshore versus nearshore sediment resources for



Multibeam bathymetric image of a sediment borrow area off the coast of Louisiana. Image by Louisiana State University.

coastal restoration by identifying areas of enhanced sediment buildup in the region.

The researchers investigated the average length of time particulate matter remains suspended in the water column, particle mixing rates, and sedimentation rates; and the transport of these particles from shallower to deeper regions. This research will assist in developing mitigation plans for reducing the GOM hypoxic zone where excess nutrients and stratification of the water column cause dissolved oxygen to decrease to a level of hypoxia where it cannot support living organisms. Additionally, the research is providing evidence of distribution and accumulation rates of polycyclic aromatic hydrocarbons (PAHs) originating from Mississippi River discharge, coastal erosion, atmospheric deposition, natural oil seeps, and during the 2010 *Deepwater Horizon* (DWH) oil spill (in high concentrations). Results show the total PAH concentrations have been decreasing around the DWH spill site due to various geochemical process and therefore suggests they are unlikely to cause adverse effects on benthic communities.

Forecasted Ecosystem Conditions in Gulf of Mexico OCS Habitats

BOEM is currently funding the Naval Research Laboratory (NRL) at the Stennis Space Center to perform the study "Forecast Ecosystem Conditions in Gulf of Mexico OCS Habitats Using Coupled Modeling and Climate Scenarios." This research will improve our understanding of cumulative impacts from multiple stressors on OCS ecosystems, including from various natural and anthropogenic forcing factors, such as disturbances in the atmosphere.

The ocean's response to atmospheric perturbation varies geographically and according to the individual characteristics of regional air, land, and water masses. Therefore, the oceanic response to climate change projections has to be rigorously evaluated in a geographically specific context of air-sea heat energy exchange, bio-physical interactions, and relevant processes of regional-scale variability.

Coupled biological-physical ocean modeling is now 4-dimensional in space and time and is interdisciplinary, incorporating aspects of physical forcing (e.g., ocean currents, winds, and solar radiation), chemical concentrations (e.g., carbon, nitrogen, and phosphorus), and biological components (e.g., bacteria, phytoplankton, and zooplankton). Coupled ocean modeling can help answer a variety of questions about the functioning of the marine ecosystem and habitat variability.

NRL is conducting two climate-scale GOM ocean model simulations for 2000–2050. These simulations will be informed by Community Earth System Model atmospheric conditions obtained from the National Center for Atmospheric Research. The overarching goal of this 4-year study is to simulate future GOM ecosystem conditions, using the most appropriate regional physical circulation and biological ecosystem model that is informed by prescribed atmospheric scenarios, to inform cumulative impact analyses.

Year 2014 Gulfwide Emissions Inventory

BOEM recently completed the Year 2014 Gulfwide Emissions Inventory Study, an ongoing calculation of air emissions from offshore oil and gas operations. These inventories are used in photochemical modeling to assess air quality impacts which guide informed policy decisions on regulations and National Environmental Policy Act documents.

This annual survey included all production platforms and non-platform sources in federal waters of the GOM—adjacent to Texas, Mississippi, Louisiana, and Alabama. Emissions covered in the inventory are the criteria pollutants and precursors ammonia and volatile organic compounds, and three major greenhouse gases.

BOEM developed software to assist offshore operators in recording information from emissions-related offshore activities and required operators to collect all activities for calendar year 2014. The study included methodologies for calculating the platform production equipment emissions based on the collected activity data, then compiled the inventory into databases consistent with the Environmental Protection Agency's Emissions Inventory System format. Emissions from platform sources included gas and diesel engines and turbines; boilers, heaters, and burners; pneumatic pumps; and other equipment.

Non-platform sources included oil and gas production sources consisting of survey vessels, drilling rigs, pipelaying operations, and support vessels and helicopters. Non-production sources included commercial marine vessels, the Louisiana Offshore Oil Port, vessel lightering, commercial and recreational fishing, and biogenic and geogenic sources. Emission estimates for most marine vessels were developed based on automatic identification system (AIS) data along with classification society vessel characteristics, which provides more accurate estimates of the vessels operating in the GOM, their power ratings, and propulsion engine load estimates.

The emission estimates for all oil and natural gas production-related sources showed a substantial decrease in all emissions between the 2011 and 2014 inventories – most notably an 84% decrease in sulfur dioxide. A comparison of the 2011 and 2014 emission estimates for non-platform sources also indicates a significant decrease in emission estimates for OCS oil and gas production-related vessels. This is due in part to the use of AIS data. Emission estimates for some sources not associated with oil and gas production increased, particularly commercial marine vessels. This was attributed to a more complete assessment of the vessels transiting the GOM, specifically the inclusion of cruise ships and dredging vessels.

A detailed trends analysis for BOEM inventories for calendar years 2000 through 2014 was included in the study. Overall, the findings indicate emissions are largely affected by: (1) activity and production levels, (2) changes in inventory methodologies, and (3) improvements in the factors used to estimate emissions.

Enhancing the Capability of a New Meteorological Model for Air Quality

BOEM recently funded a study for wind-wave measurements to be used for improving the Weather Research and Forecasting (WRF) Model for air quality and other applications, including oil spill analyses, conventional energy platform design, alternative energy, and hurricane forecasting. The WRF is a tool to assess the environmental impact on the onshore air quality.

Objectives of this research were to:

- Improve the accuracy of an advanced meteorological model and the model physics to produce better meteorological fields for use in air quality modeling;
- Incorporate observational and remote sensing data into the meteorological model; and
- Modify the WRF by including the air-sea interaction and the atmospheric boundary layer processes over the ocean and near the sea-land transition zone

The development of an improved WRF model and model simulations, including satellite data assimilation, is complete and a final report will be published soon.

SCOAPE (Satellite Continental and Oceanic Atmospheric Pollution Experiment)

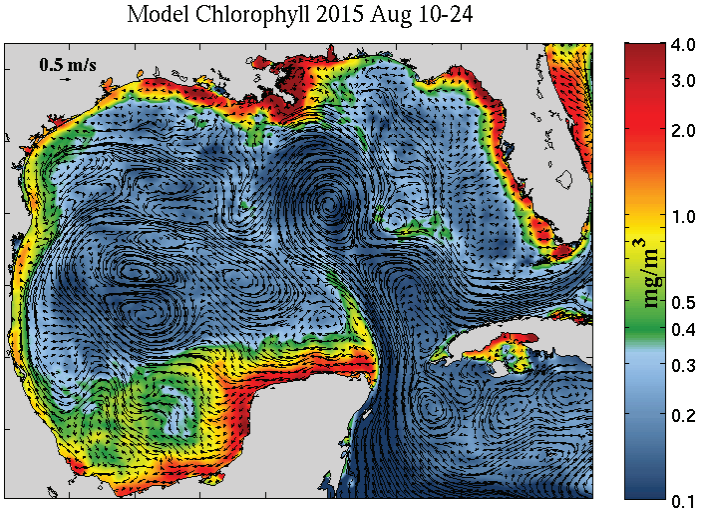
BOEM and NASA are working together to evaluate the potential for using satellite data to monitor offshore air quality, with an emphasis on the GOM region. NASA scientists will document the current satellite data products, including oil slicks, lights at night, flare detection, nitrogen dioxide, sulfur dioxide, aerosols, and formaldehyde. These findings will be compared to surface monitoring networks. An upcoming field campaign over coastal and open water will assess pollutant measures from a ship-based remote sensor to the satellite remote sensors, thereby identifying improvements needed in satellite data measures to prepare for new and improved earth-observing missions in the future.

A regional view of lights at night highlights large scale activities in the Gulf of Mexico. This is a Suomi National Polar-orbiting Partnership (NPP) VIIRS product made through a NASA-NOAA partnership.

Summary

BOEM-funded research in the GOM region has resulted in new discoveries and is improving detection and monitoring of environmental impacts from OCS activities. New technologies are improving the data and helping to inform policy decisions for future development.

— Gulf of Mexico OCS Region and
HQ Division of Environmental Sciences staff



Example of modeled chlorophyll concentration in the GOM. U.S. Naval Research Laboratory.

For More Information

Lagrangian Study of the Deep Circulation in the Gulf of Mexico
https://www.boem.gov/ESPIS/5/5583.pdf

Development of a Monitoring Program for Water Quality of Louisiana Sediment Borrow Areas
https://marinecadastre.gov/espis/#/search/study/100227

Delineating Areas of Enhanced Sediment Accumulation in the Northern Gulf of Mexico
https://marinecadastre.gov/espis/#/search/study/100050

Forecasted Ecosystem Conditions in the Gulf of Mexico OCS Habitats Using Coupled Modeling and Climate Scenarios
https://marinecadastre.gov/espis/#/search/study/100162

Year 2014 Gulfwide Emissions Inventory Study
https://marinecadastre.gov/espis/#/search/study/100209

Enhancing the Capability of a New Meteorological Model for Air Quality and Other BOEM Applications in the Gulf of Mexico
https://marinecadastre.gov/espis/#/search/study/100044

Modeling Studies Inform Conventional and Renewable Energy Activities in the Pacific Region

Oil Spill Modeling

BOEM assesses oil spill risks associated with offshore energy activities by calculating spill trajectories and contact probabilities using modeling. Paths of hypothetical oil spills are based on the history (hindcast) of winds and ocean currents. The General NOAA Operational Modeling Environment (GNOME) has been used to conduct oil spill risk analyses but this model does not allow for reaching a wider geographic area to study the impacts of potential spill trajectories. BOEM recently funded two studies using improved modeling.

Expansion of West Coast Oceanographic Modeling Capability

Oil spills and the resulting effects on human and marine environments continue to be a major environmental concern with offshore conventional energy activities. A study to expand West Coast oceanographic modeling capability was recently completed. The objective was to update the modeling effort in the Southern California Bight and extend north of Point Conception, including Morro Bay. The study applied data from the Weather Research and Forecasting (WRF) model, the Regional Ocean Modeling System (ROMS), and the Simulating WAves Nearshore (SWAN) model to provide new hindcasts of 10-m winds (10 meters above sea surface), precipitation, cloud cover, water temperature, currents, salinity, tides, and waves.

These models were successful in meeting the study objective. The WRF simulation reproduced the nearshore wind features and the observed precipitation. The ROMS simulation captured primary characteristics of the tides, sea surface height, water temperature, salinity, and currents. The SWAN simulation captured the spatial pattern of the wave height and direction, as well as the reflection and diffraction of waves.

Assessing the Impact of Oil Spills Using Three-Dimensional (3D) Modeling

Assessing the impact of oil spills on pelagic and benthic biota in the subsurface (both in the water column and sediment) requires three-dimensional modeling, as opposed to a 3D model for surface biota and habitats located in the intertidal zone and on the beach. The 3D model is based on the ROMS and uses particle tracking to simulate fate and transport. The Pacific Region is pilot testing the 3D model in one location within the Southern California Planning Area.

Wave Energy Absorption

A study to predict the consequences of wave energy absorption from marine renewable energy facilities on nearshore systems was initiated to predict which siting alternatives of proposed wave energy facilities may be more favorable for reducing disturbance to biological habitats, most notably kelp forests.

The objective of the study is to build a statistical model from existing data that describes how wave energy affects nearshore communities and thereby predict the ecological consequences of marine renewable energy facility placement. To meet this objective, the study will (1) determine the distribution of wave period and amplitude using historical buoy data and oceanographic wave models; (2) determine how wave model predictions relate to empirical observations along a depth gradient by deploying real-time wave energy sensors to field sites with known variations in wave exposure to determine the relationship between buoy projections, depth, and wave forces; and (3) determine how marine communities respond to variation in wave exposure by using data from the first two tasks. The next step is to hindcast wave data and compare them with long-term kelp forest monitoring data. The study was conducted in partnership with the U.S. Geological Survey, Western Ecological Research Center, and the Channel Islands National Park.

Summary

Improved modeling continues to provide beneficial data for monitoring impacts of conventional and renewable energy activities and BOEM is at the forefront of research to continually assess environmental changes and make recommendations for limiting disruption to ecosystems.

— Susan Zaleski and Donna Schroeder,
Pacific OCS Region

Donna Schroeder retrieving wave sensor in kelp forest at Santa Barbara Island. Screen capture of video by Susan Zaleski, BOEM.

Spotlight on a Scientist: Holli Ensz

What is your job?

I work as a physical scientist at BOEM Headquarters in the Division of Environmental Sciences (DES) specializing in air quality. BOEM has an obligation under the Outer Continental Shelf Lands Act (OCSLA) to regulate conventional and renewable energy activities in federal waters to protect the air quality of any state. BOEM has air quality jurisdiction on federal waters in the Gulf of Mexico (GOM) adjacent to Texas, Louisiana, Mississippi, and Alabama and on federal waters in the North Slope Borough of the State of Alaska.

At BOEM, we have a robust research program investigating multiple topics, including air quality, in the Gulf of Mexico, the Atlantic, the Pacific, and the Arctic Regions. My main responsibility is to lead BOEM's air quality studies program conducting research on potential air quality impacts from OCS conventional energy sources, as required per regulations. In order to conduct these air quality impacts assessments, BOEM needs research on oil and gas emissions, offshore meteorology, background data, and photochemical and dispersion modeling. The results of this research will lead to sound policy decisions included in BOEM's Environmental Impact Statements (EISs) and regulatory updates.

Why did you decide to work for BOEM?

BOEM's Environmental Studies Program appealed to me because it involves researching and problem solving, two of my favorite things. BOEM then uses sound science from my research to make informed policy decisions on offshore conventional energy exploration, development, and production. I like being part of the solution.

What role do you play in BOEM's Environmental Programs?

I am a Contracting Officer's Representative (COR) for multiple air quality studies. Every three years, BOEM conducts an emissions inventory study to calculate the calendar year air pollutant inventory for conventional energy sources on the OCS. These calculated emissions are used in photochemical modeling to assess potential impacts, so it is imperative that these emissions are accurate. I'm also the COR for the Air Quality Modeling in the Gulf of Mexico Region study, which will be the first update of air quality impacts from conventional energy sources on the Gulf of Mexico (GOM) OCS since 1995. BOEM is using the data acquired from the year 2014 OCS emissions inventory in this photochemical modeling. All of my research is used to make conventional energy development determinations in our EISs and regulatory updates.

How has your educational background and experience prepared you for the work you do?

My educational background includes a Master of Science in Environmental Studies with a Bachelor of Science in Mathematics and Environmental Studies from Baylor University. Fortunately, I had a professor who recognized these two fields can be combined through computer modeling of environmental issues, and my career was started (and yes, people still use their degrees!).

Holli Ensz. Photo by Marjorie Weisskohl, BOEM.

Before BOEM, I worked at the Arkansas Department of Environmental Quality (ADEQ) as an air quality inspector ensuring facilities complied with their state air permits. This allowed me to observe and understand industrial equipment, processes, monitoring equipment, and emissions. I then transitioned to performing dispersion modeling for facility permit applications. Through this responsibility, I learned about the Environmental Protection Agency's (EPA) Clean Air Act (CAA) programs and practices, such as the National Ambient Air Quality Standards (NAAQS), calculations of emissions, modeling guidelines (Appendix W), control strategies, and monitoring programs. Because BOEM works closely with EPA to protect air quality, having this EPA knowledge ensures consistency between programs. For example, BOEM uses EPA emissions calculations and modeling guidelines in their program. However, BOEM's air program authority is the OCSLA and not CAA, so there are some differences.

After working at ADEQ, I moved to New Orleans, Louisiana, to work for BOEM's GOM regional office. This experience gave me the operational knowledge that today I use at BOEM Headquarters. Having that operational knowledge helps me apply practical policies that will work. Looking back, my educational background and experience have prepared me well for the work I do today.

Spotlight on a Study: Air Quality Modeling in the GOMR

According to the Clean Air Act Amendments (CAAA) of 1990, BOEM has air quality jurisdiction in the Gulf of Mexico (GOM) over the Outer Continental Shelf (OCS) adjacent to Texas, Louisiana, Mississippi, and Alabama. Air pollutant emission inventories and air quality modeling is needed on the GOM OCS to predict current and future air quality impacts from conventional energy sources. Knowledge of these air quality impacts helps BOEM make informed policy decisions on air quality regulations and address these impacts in National Environmental Policy Act (NEPA) documents.

BOEM's "Air Quality Modeling in the Gulf of Mexico Region" study will be the first update of the air quality impacts assessment from conventional energy-related sources on the GOM OCS since 1995. The study has two main tasks: (1) conduct photochemical modeling to assess cumulative OCS conventional energy sources of air quality impacts, and (2) conduct additional dispersion modeling to assess the existing emissions exemption amounts (or E) to determine if they are consistent with the annual and short term national ambient air quality standards (NAAQS). The U.S. Environmental Protection Agency (EPA) sets the NAAQS.

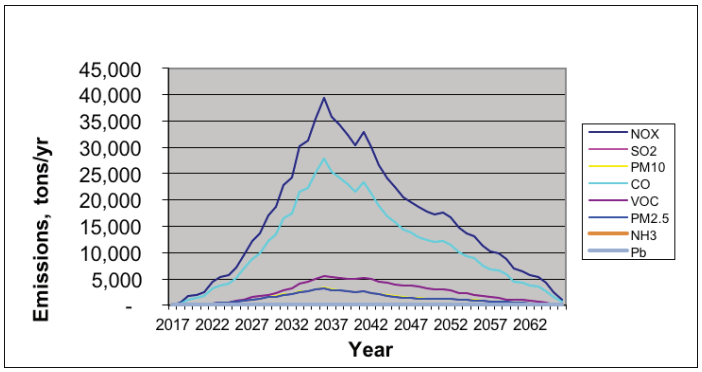
Photochemical Modeling

Photochemical modeling is necessary for assessing cumulative air quality impacts. Inputs to photochemical modeling include meteorological data, emissions inventories, and background concentration data. Ambient monitoring data are used to assess model performance. The Weather Research and Forecasting (WRF) model was used to compile a five-year meteorological dataset for years 2010–2014; the year 2012 dataset was used for the photochemical modeling.

The emissions inventory includes: carbon monoxide (CO), lead (Pb), nitrogen oxides (NO_x), sulfur dioxide (SO_2), particulate matter-10 (PM_{10}), particulate matter-2.5 ($PM_{2.5}$), ammonia (NH_3), and volatile organic compounds (VOCs).

BOEM assessed potential future year air quality impacts from the 2017–2022 OCS Oil and Gas Leasing Program using data from BOEM's 2014 Gulfwide emissions inventory and projections from the USEPA's 2011 modeling platform. The year 2036 was estimated to have the highest future emissions for all activities in all planning areas, therefore it was selected as the emissions year to use for the 2017–2022 OCS Oil and Gas Leasing Program as a reasonably foreseeable future emissions scenario.

Using the WRF meteorological data, photochemical grid modeling was performed and over-predicted ozone and sea salt (and thus $PM_{2.5}$) mostly at coastal sites. Due to these over-predictions, BOEM is revising the modeling, therefore the results discussed here are preliminary.



Air pollutants used to estimate potential future air emissions from oil and gas-related activities. Eastern Research Group, Inc.

Dispersion Modeling

BOEM must conduct dispersion modeling to determine if the E amounts used will need to be revised based on newer and lowered NAAQS. The oil and gas industry submits plans to BOEM detailing their proposed activities along with air quality spreadsheets estimating project emissions. BOEM compares the plan emissions estimates with E thresholds to determine potential air quality impacts to any state or if emissions would be insignificant, and therefore exempt from further air quality review. More air quality analysis and modeling are needed if the plan's emissions are above E. Dispersion modeling assesses if E thresholds are consistent with all NAAQS. If not, additional modeling is used to develop new E levels. The photochemical modeling is necessary to assess the individual plan emissions exemption amounts for ozone and secondary $PM_{2.5}$.

All platform sources were modeled as point sources, or a single point characterized by emission release point parameters. Vessels were modeled as volume sources, or emissions released from the surface of a 3D space adjacent to the platform. Nearly 40,000 modeling runs—comprising each location, emissions scenario, and pollutant used in the E evaluation—were performed throughout the GOM. The results of these air quality impact assessments will inform policy decisions on air quality regulations and be addressed in BOEM's NEPA documents.

—Holli Ensz, HQ Division of Environmental Sciences

For More Information

Air Quality Modeling in the Gulf of Mexico Region
https://marinecadastre.gov/espis/#/search/study/100048

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New Waves

Late-Breaking News & Information

BOEM and Partners Resume Atlantic Ocean Research in August

Scientists travel to the U.S. mid- and south Atlantic coast in August to resume the DEEP SEARCH project sponsored by BOEM, USGS, and NOAA. Aboard the research vessel *Atlantis*, they will explore deep-sea coral, canyon, and gas seep ecosystems. Fieldwork began last September under the National Oceanographic Partnership Program (NOPP).

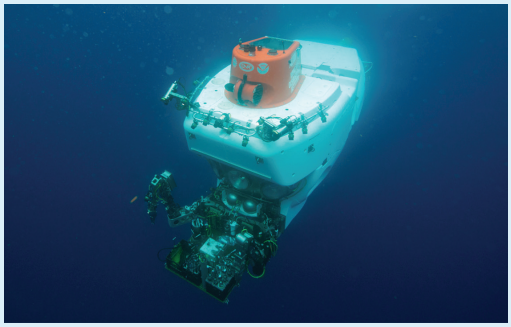

Photo by Chris Linder, ©Woods Hole Oceanographic Institution.

Seven academic institutions, including Temple University, plus the USGS, and TDI Brooks International are collaborating on the project, which will shed light on little-known natural resources of the deep ocean off the United States' southeast coast from Virginia to Georgia.

Deploying the manned deep-ocean research submersible *Alvin*, owned by the U.S. Navy and operated by the Woods Hole Oceanographic Institution, scientists will collect water, sediment, and benthic faunal samples, and imagery of benthic habitats. The research will increase our knowledge of U.S. continental margin geology, the types of communities found on the seafloor, and the mid-water communities that interact with those seafloor communities.

Last September's excursion included seafloor mapping and used the autonomous underwater vehicle *Sentry* offshore North Carolina, confirming the presence of chemosynthetic organisms at suspected seeps for the first time. The researchers noted large numbers of fish clustered around rocks within the same area. Upcoming research will examine fish distribution to determine how different species respond to localized features.

BOEM, NOAA, and the USGS began planning the study in 2015. Coincidentally, it overlaps with BOEM's proposed 2019–2024 National Oil and Gas Leasing Program, which may or may not result in Atlantic leasing. No decisions have been made, yet new information from this study could be useful in pre-leasing or post-leasing decisions, such as those affecting sensitive habitats that are the focus of this study.

For More Information

BOEM Press Release
https://www.boem.gov/press09122017/

Study Profile
https://www.boem.gov/AT-17-06/