ADVANCED RISK AND IMPACT MODELS FOR OFFSHORE SYSTEMS

BACKGROUND

Over the past several decades, ocean energy development and operations has pushed from shallow water to more challenging deep- and ultra-deep-water systems. This shift places offshore drilling and operational activities in more complex, and occasionally volatile, environments, which can result in extreme safety and environmental consequences. As offshore energy develops new technology and ventures into new territory, the need for improved system-wide knowledge and advanced computational tools to support offshore spill prevention, reduce geohazards, mitigate uncertainty, and support decisions, from local-to-regional scales, grows more urgent. To this end, NETL researchers are focused on providing actionable information from intelligent, data-driven, science-based solutions that promote the safety and sustainability of offshore energy operations, including oil, gas, and carbon storage, in remote, environmentally sensitive, and economically-challenging environments

NETL

NATIONAL ENERGY TECHNOLOGY LABORATORY

PROJECT GOAL AND OBJECTIVES

The goal of this project is to provide a comprehensive framework to support analytics, visualizations, modeling, and forecasting to better inform a range of offshore energy operations. The objectives focus on developing novel data, tools, models, and approaches that span the full engineered and natural offshore system to assess and provide actionable insights to predict hazards, reduce risks, enhance safety, save costs, and mitigate key knowledge and technology gaps. These efforts ultimately provide a “one-stop shop” for data, tools, and models that address many of the offshore energy industry’s most demanding and complex challenges.

ADVANCED RISK AND IMPACT MODELS
FOR OFFSHORE SYSTEMS

PROJECT DESCRIPTION

Building off DOE's core competency of simulating and predicting the behavior of engineered-natural systems, NETL researchers developed the Offshore Risk Modelling (ORM) suite, which comprises nine innovative science- and data-driven computational tools, models, and applications (Fig. 1).

FIGURE 1. The Offshore Risk Modeling (ORM) suite compiles data- and science-driven tools built and crosscuts multiple offshore environments, providing users with a clear picture of the full system for more informed decision-making.

Several ORM tools and models incorporate machine learning (ML) and artificial intelligence (AI), and the ORM suite is underpinned by innovative big-data computing infrastructure to support rapid predictions and analytics for offshore systems. The ORM suite of proven tools, models, and applications can be used individually or synergistically, offering capabilities to effectively utilize millions of data points from numerous sources to simulate a range of real-world and hypothetical scenarios. As a result, the ORM suite serves as a "one-stop shop" for data, tools, and models that can be used to predict complex hazards and to mitigate challenges throughout the fully engineered and natural offshore system, from the subsurface, through the water column, to the coast. Overall, these capabilities can be used to fill knowledge gaps, reduce resource uncertainty, predict geohazards and support decision-making needs for a range of industry, regulatory and research stakeholders to improve operational efficiency and safety.

The ORM suite's nine tools, models, and applications include:

- ***The Climatological and Instantaneous Isolation and Attraction Model*** (CIIAM) applies mathematical theory of dynamical systems and metocean data to determine where oil and other particles in the ocean (e.g. debris, hazardous waste, plastics, plankton, etc.) are likely to be attracted or repulsed. CIIAM offers a novel and efficient way to summarize big ocean current and wind data to determine the ultimate destination of ocean particles using large datasets from operational reanalysis and U.S. Navy Operational forecasts and nowcasts in real time to anticipate pathways and deformation (Duran & Serra 2021; Duran et al., 2020; Duran, Beron-Vera, and Olascoaga, 2018). A variety of international research groups have used CIIAM to understand the Brazil Current, the Red Sea, the Mediterranean and adjacent Atlantic, the Gulf of Mexico and the Bay of Bengal.
- ***The Blowout Spill Occurrence Model™*** (BLOSOM) is an open-source, comprehensive model that predicts the fate and transport of oil following offshore blowout and spill events. BLOSOM is the first open-source oil spill and blowout model in 4-D (latitude, longitude, depth and time), which has been compared to and validated against traditional and industry-applied spill models (Duran et al., 2018; Socolofsky et al., 2015). Built upon a flexible framework, BLOSOM consists of several modules to help visualize, characterize and simulate spills, including behaviors in high-pressure environments, gas and hydrate dynamics, as well as how oil particles move throughout the water column.

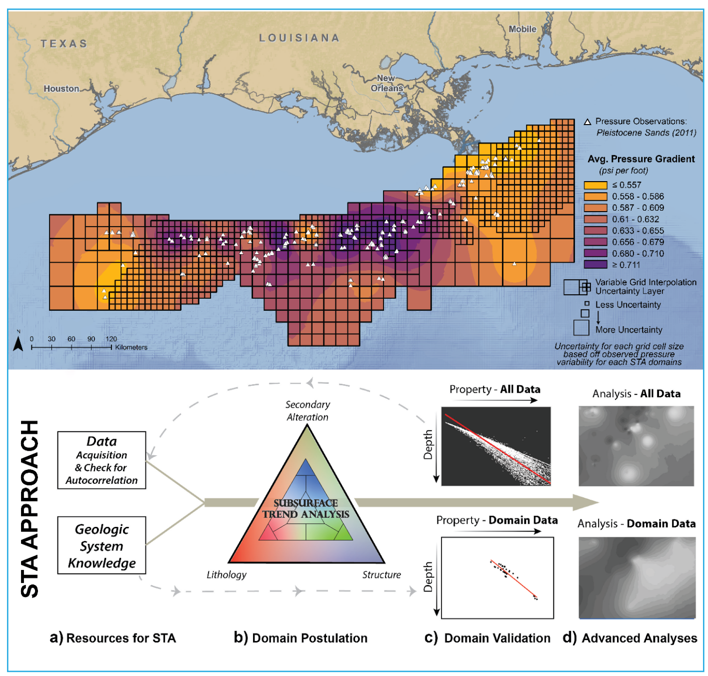

FIGURE 2. Application of the ORM Suite's Subsurface Trend Analysis (STA) and Variable Grid Method (VGM) tools to improve prediction of subsurface properties, subsurface pressure in this case, even in areas with little or no existing subsurface data. Overlaying a VGM uncertainty layer, to communicate confidence in the predicted pressure gradient offers critical information to reduce subsurface economic and drilling risks for offshore energy operations.

- ***Cumulative Spatial Impact Layers™*** (CSIL) is a spatial tool that rapidly identifies and quantifies potential socio-economic and environmental risk. The CSIL tool is capable of handling multiple disparate datasets, measuring data density and producing multivariable layers that identify vulnerabilities within a given area (Romeo et al., 2019). The CSIL tool has been adapted to integrate BLOSOM simulation outputs and summarize the potential risks or response availability associated with hydrocarbon events over time.
- ***Spatially Weighted Impact Model™*** (SWIM) explores relationships among oil spill simulations, response availability, and potential risk to inform decision-making. SWIM enables users to apply weights to rank and compare different scenarios and come up with varying plans of action in the event of a spill under different conditions.
- ***Subsurface Trend Analysis™*** (STA) is a multi-resolution method that predicts and characterizes subsurface properties leveraging geologic expertise and advanced spatio-temporal statistical methods. Built over five years of research, the STA has been applied for reserves calculations, exploration and resource identification, geohazard prediction, drilling safety and improved well design (Rose, Bauer, and Mark-Moser, 2020).
- ***Ocean & Geohazard Analysis*** (OGA), the most recent addition to the ORM Suite, is an advanced AI/ML analytical tool in development that collects, processes, and analyzes metocean and bathymetry data to predict offshore hazards and hazardous conditions. This smart tool advances current predictive abilities using layered geospatial analysis and probabilistic and statistical assessments. The OGA utilizes multidimensional, multiscale spatial data that includes conditions conducive to a landslide event in addition to predicting landslide trigger mechanism events. Metocean conditions such as extreme waves, wind, and currents are also assessed by the smart tool to estimate the spatially explicit risks associated with these factors. The final product of this technology will offer insights to improve infrastructure longevity, support the identification of shallow hazards, and inform offshore operations.
- ***Variable Grid Method©*** (VGM) communicates the uncertainty in data and modeled results, which is critical to efficiently communicate results in an intuitive manner. The VGM tool provides the flexibility to use different data types and uncertainty qualifications, preserves overall trends and patterns observed within the data and enables users to customize the analysis and final product to meet their needs (Bauer and Rose, 2015; Wanjau et al., 2019).
- ***Energy Data eXchange®*** (EDX) is the DOE Office of Fossil Energy's (FE) virtual data library and laboratory. As an online data computing platform, EDX curates products from fossil energy research, including data, tools, and models, and supports the execution of gigabyte- and petabyte-scale simulations, including those performed by the ORM suite. EDX has been expanded to serve additional FE programs and end-users for a range of needs and continues to host and support the ORM on its collaborative and private virtual framework (Rose et al., 2020).
- ***GeoCube*** is a custom web-mapping application hosted via EDX that allows users to quickly view and visualize spatial data, download resources, identify overall trends and patterns in the data, and share these discoveries with others (Barkhurst et al., 2018).

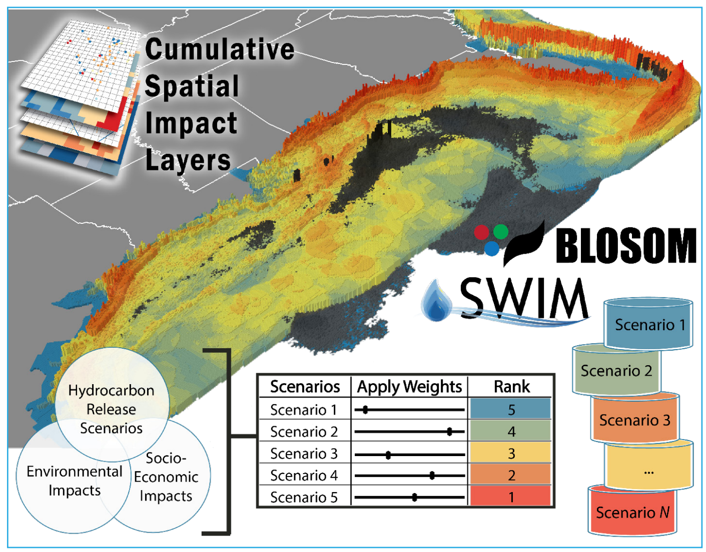

FIGURE 3. Application of the ORM Suite's BLOSOM, CSIL, and SWIM tools to simulate worst case hydrocarbon release scenarios, model environmental and socio-economic impacts, and rank resulting simulations based on user-applied weights to aid in decision making for offshore spill prevention and preparedness planning.

ADVANCED RISK AND IMPACT MODELS
FOR OFFSHORE SYSTEMS

RECENT ACCOMPLISHMENTS

The ORM suite, a 2019 R&D 100 Award winning technology, has been utilized to assess geohazard and subsurface resources, support worst-case oil spill planning, predict a spill's socio-economic impact and characterize offshore infrastructure lifespan. To date, ORM components have been used by numerous domestic and international stakeholders, including government agencies, academia, and industry. Applications include the analysis and prediction of subsurface geologic properties such as pressure, temperature, porosity and permeability in offshore regions with low data density and resolution; predicting the fate and transport of offshore oil spills and blowouts from a range of natural and anthropogenic sources, including seeps, pipelines, wellbores, and tanker spills; spatially summarize big, metocean data to understand hazards to offshore infrastructure. ORM tools, data and models are further being applied to understanding the complex factors affecting the integrity of offshore platforms, enabling improved decision-making for platform operation and extended utility.

In addition, since the start of this project, petabytes of authoritative data and model simulations have been collected and published on EDX and GeoCube. Several of the tools, including BLOSOM, CIIAM, and CSIL, have been released for public use via EDX and VGM has been developed as part of a commercial application with an industry partner. The remaining tools and models are under final testing and will undergo external review before they are released. Furthermore, functionality from ORM tools and GeoCube are being integrated into an online portal, NETL's Common Operating Platform (COP), that will support near real-time offshore data analysis and visualization utilizing NETL's computing resources and EDX.

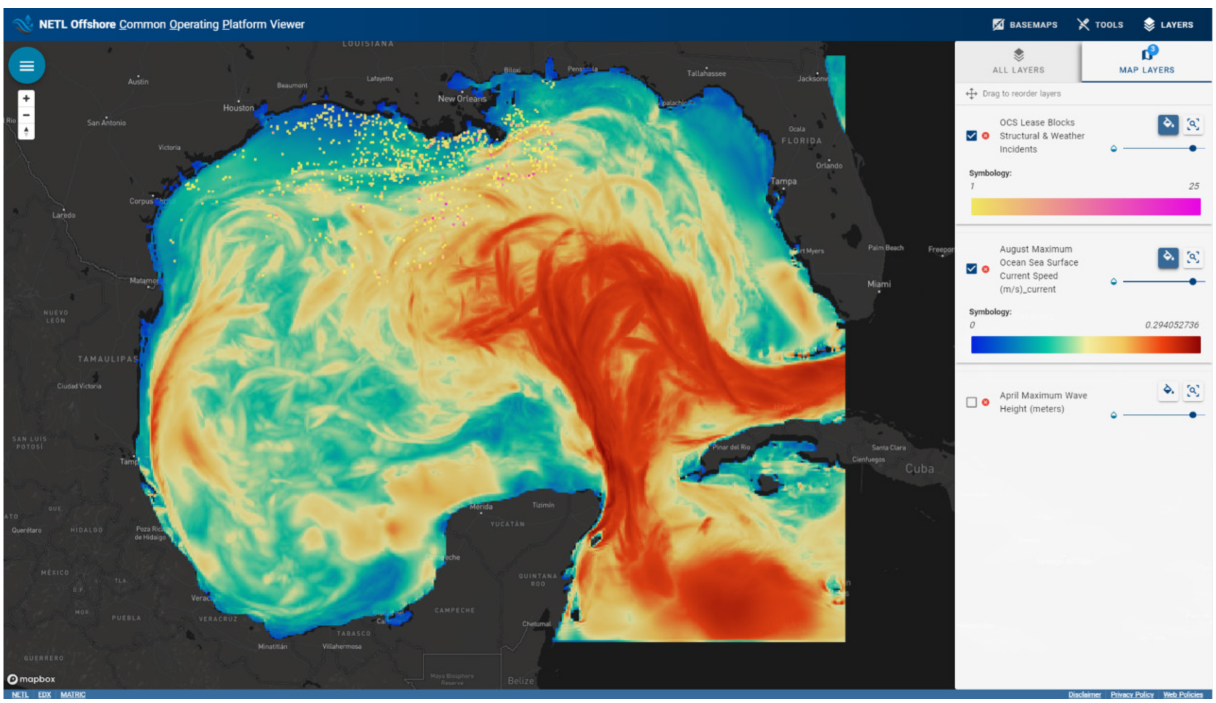

FIGURE 4. The ORM Suite's tools and models are being developed into a custom online portal, provided as NETL's Common Operating Platform (COP). This COP will enable near-real time analytics and execution of ORM capabilities, driven by EDX for data and computing capabilities and GeoCube for visualization, to provide remote access and rapid simulation and analytics to inform and aid with offshore operational planning and response planning alike for a variety of offshore energy interests.

Working together with our partners, the U.S. Department of Energy is committed to using the most current technology to implement safeguards and practices that address the offshore energy industry's most demanding and complex challenges, resulting in a safer workplace, improved environmental stewardship performance, and greater domestic energy security

Contacts

Kelly Rose
Principal Investigator
Research Physical Scientist
Geo-Analysis & Monitoring Team
kelly.rose@netl.doe.gov

Jennifer Bauer
Geospatial Researcher
Geo-Analysis & Monitoring Team
jennifer.bauer@netl.doe.gov

Brian Dressel
Supervisor, Geo-Analysis & Monitoring Team
Geological & Environmental Systems Directorate
brian.dressel@netl.doe.gov