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"Blue Technologies: Use of New Maritime Technologies to Improve Efficiency and Mission Performance"

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Thank you Chairman Hunter, Ranking Member Garamendi, and Ranking Member DeFazio for the opportunity to testify today on the potential for maritime technology innovation to support efficiency and performance within the United States Coast Guard. I am pleased to provide testimony today on the role university-based research can play in providing the Coast Guard with information and tools that will help realize effective and efficient operations.

I am a Professor at the College of Earth, Ocean, and Atmospheric Sciences at Oregon State University (OSU) and have been conducting research on the prediction and forecasting of ocean conditions for more than 20 years. As part of this effort, I have helped develop and test various wave and circulation prediction systems. I have also been involved with numerous large multi-agency observational campaigns to assess and improve the fidelity of ocean forecasts. These field campaigns have at times involved standard oceanographic instrumentation, and at other times have invoked innovative new technologies, including autonomous sensing. Finally, my work has explored ways in which forecast results can be presented and shared to make them most usable to stakeholders, including bar pilots, the fishing community, the National Weather Service, and the Coast Guard. Components of this work have involved basic research funding from various sources, including the National Science Foundation. Other more applied components have been funded by mission-oriented agencies, such as the Office of Naval Research, the Army Corps of Engineers, NOAA, and the Department of Energy. The presence of a multitude of funding agencies with interest in forecasting tools is encouraging, but it can also mean that close inter-agency coordination is imperative to holistically address challenges affecting coastal and at-sea operations.

Overview

This testimony summarizes current ocean state prediction and forecasting technologies and touches upon potential future enhancements that would increase the utility of the forecasts. The focus is on coastal regions and inlets where navigational planning and safety are of concern for the Coast Guard, along with recreational and commercial stakeholders. The discussion also covers recent efforts aimed at forecasting the potential for risk to the beachgoing public, including rip current and sneaker wave forecasts.

Ocean forecasting systems are enabled by a few key efforts. First, building forecasting models requires an understanding about the way in which the ocean works. Such an understanding can only be obtained through observations of the ocean-atmosphere system, and through careful analysis of the resulting data that enables us to hone in on the dominant natural relationships which can then be codified in the forecasting models. Such observations can be obtained as part of long-term ocean observing initiatives, but sometimes also require specialized innovative approaches to get at observations that are key pieces of the puzzle. Second, the accuracy of forecasting results can only be quantified if they are compared with observations of the conditions. Such data-model comparisons also guide further development and refinement of the forecasts. Finally, engaged educational activities involving the stakeholders and users of the forecasts point towards improvements in the forecasts while also training individuals to interpret forecast products as intended. This testimony will address all components of the system, including the forecast systems, the enabling observations, innovative data analysis, and the engaged educational programs required to enable the use of the forecasts for operational purposes.

Utilizing ocean wave and current forecasts for efficient navigational safety, safe passage, as well as search and rescue operations

Recent advances in predictive models now allow for detailed and high-resolution forecasts of ocean conditions. The forecasts include spatially well-resolved information about wave conditions and ocean currents in the open ocean, but also near navigational inlets where wave heights are strongly affected by tidal currents.

Although further development and testing is needed, wave forecasts in their current form can aid in several activities. For example, forecasts of ocean conditions in the open ocean can be used during search and rescue operations to narrow down the geographical area of interest. Forecasts near navigational inlets can be especially critical at challenging inlets where the transit through the river mouth can be treacherous. The Mouth of the Columbia River, bordering Oregon and Washington, often colloquially referred to as the "Graveyard of the Pacific," is one such example. The Coast Guard ships transit the bar during large wave events routinely. Further, the Coast Guard, collaboratively with other entities, makes decisions about bar closures that halt vessel traffic. Given that $24 billion of cargo moves on the Columbia River System annually, the cost of a bar closure to port operations and the local economy is significant.

One of the groups that play a role in bar closure decisions is the Columbia River Bar Pilots, a group of captains that are responsible for boarding every vessel that is crossing the bar and piloting it safely into or out of the inlet. The Bar Pilots make decisions about releasing vessels into river traffic from ports for transit across the bar. They require accurate forecast 10 hours in advance, because a tanker released from the upriver port of Portland requires hours to reach the river mouth. Once there, most of these tankers are too large to turn around, so the hazards of making the wrong decision are either a disaster on the bar or create the need to anchor a fully loaded ship in the river where there is a high likelihood that it will drag its anchor and go aground, given the strength of the waves (that routinely reach 30-35 ft) and strong currents (up to 4 knots).

For the last 5 years, the Columba River Bar Pilots have been utilizing OSU's wave forecasts over the area of the navigational inlet to inform their decision-making on navigational planning. The forecasts are specifically used for the computation of under-keel clearance values for vessels with a large draft, as well as for recommendations regarding the closure of the bar along with, perhaps more crucially, the timing for the opening of the bar. The forecasts have been developed at OSU and were funded by a variety of federal and local funding sources, including NOAA, the Office of Naval Research, and the Department of

Energy. We have worked extensively and iteratively with the Bar Pilots to create an interface for data retrieval that meets their needs and maximizes their ability to use the results. Efforts such as these are promising avenues to the translation of scientific discoveries to operational settings to increase safety and security.

Although much progress has been made recently to advance ocean forecasting technologies, there are several shortcomings that still need to be remedied to increase their fidelity and reliability. For example, advancements are needed to further our understanding of wave and ocean currents under challenging conditions, for example during storm conditions with large wave heights or for the prediction of rogue waves or sneaker waves. Accuracy is limited by our ability to codify natural processes related to wave processes (wave growth, swell dissipation, wave breaking processes, among others), circulation processes (presence and effect of gyres, data assimilative efforts, salinity temperature variability and ocean mixing), as well as wave-circulation interaction processes. Forecasts of conditions at tidal inlets can be especially challenging because waves are strongly affected by the tidal velocities that, at times, can cause localized wave amplification at the inlet mouth and can lead to navigational hazards. Forecast models need to accurately account for these interactions.

Further, following the weather forecast community, probabilistic forecasts are required for the most effective use of these forecasts. These are not currently commonplace and are not yet operational for ocean forecasting, but the trajectory of this work is promising. Improved understanding for real-time application would enable new technology-based tools to promote safe navigation, as well as safe and efficient search and rescue operations.

Sustained observations of the ocean

As mentioned above, the development of ocean forecasting models requires a fundamental understanding on how the ocean-atmosphere system works so that discovered relationships (for instance, between wind speed and wave growth) can be codified in the forecasting models. Such understanding requires the use and analysis of targeted observations to develop and test hypothesized relationships. Observations are also needed to validate produced forecasts and quantify the confidence in the produced forecasts extending into the future. Finally, real-time observations give us a sense of the actual current conditions and enable decision-making about near-term activities.

Ocean observations efforts benefit from recent improvements in innovative technologies and autonomous platforms (such as gliders, Unmanned Underwater Vehicles, and Autonomous Unmanned Vehicles) that are providing a look into the ocean that was not possible with previous technologies. While there is significant attention on the service support that UUVs or AUVs can provide, these autonomous platforms also allow us to sample continuously, at locations that would not be safe for sampling by humans. This is of particular value when working near unstable glaciers or during large wave conditions when ships cannot safely sample conditions. Advancements in the technology platforms to support ocean observations, and the application of observational data to inform real-time understanding and expectations of ocean conditions, are critical tools for improving safety and efficiency of ocean operations.

Innovative ways of employing new technologies to patrol the Arctic or other far parts of the EEZ.

Recent advances in unmanned vehicles have enabled excursions to areas that were previously not safely accessible. Of particular importance to the Coast Guard's Arctic mission objectives, OSU researchers are obtaining observations near glaciers that have been made possible by unmanned vehicles that can come close enough to the glaciers to obtain previously unobservable information. Such information should prove crucial in the continued exploration of the Arctic that is becoming increasingly navigable but is associated with many unknowns.

Similarly, advancements in autonomous platforms are enabling new forecasting capabilities of wave heights. This has important potential applications for navigation, as well as protecting infrastructure and other critical assets. Obtaining wave height information during very large wave events is very challenging, and new rugged autonomous observing platforms are enabling such information and providing insight into conditions that remain challenging for forecast models, yet are important for operations.

As an example, wave height accuracy for nowcasts usually is around 10-15%, but new observations unearthed that model accuracies for very large waves (wave heights greater than 6 m) are sometimes well-predicted and at other times severely under-predicted, such as forecasting 5 m waves when the waves, in reality, reach 10 m, a potentially fatal mistake. Targeted new observations from autonomous platforms strategically deployed during large wave events have enabled us to pinpoint the environmental conditions during which the under-prediction occurred. This discovery enabled us to codify corrections to the forecast results (in this case, using machine learning technologies) to increase the forecast accuracy during large wave events.

Many further discoveries can be enabled by autonomous sensing, and there have been many advancements in autonomous vehicle technology. Gliders are now routinely being used to assess the state of the ocean. Some challenges still exist, especially near navigational inlets where salinity variations cause difficulties in sensing and in buoyancy regulation. As these challenges are being overcome, autonomous vehicles will enable further exploration and aid in patrolling functions.

Exploration through the Arctic or any other parts of the EEZ that is removed from civilization will also necessitate considerations of power requirements. This is where energy extraction from renewable sources may become important. Candidate sources are energy extraction from waves, or tidal currents, and technology development is currently underway. The last 20 years have seen surges in interest in wave energy extraction and development. The industry is still very young, and the considered technologies are varied and diverse. OSU is currently preparing to construct an off-shore grid-connected wave energy test facility with the Department of Energy that will allow technology developers to test and further develop their wave energy converter devices and is, therefore, poised to accelerate the development of wave energy technologies. Wave energy has promise for offering a viable source of energy in the future with potential importance to the Coast Guard's mission in the high seas and remote areas, such as the Arctic.

Promising emerging technologies geared towards identifying illegal activities at sea

Illegal, Unreported and Unregulated (IUU) activities at sea, their location and timing are challenging to assess and predict, yet such activities are of concern to the Coast Guard. Maritime IUU activities include illegal fishing and the trafficking of people, arms and narcotics. The key challenge is that vessels committing IUU activities turn off their GPS transponders and therefore "go dark." In fact, there are estimates that project that an an entire fleet of such vessels (a "dark fleet") is currently at work in the oceans. And although these vessels cannot be directly tracked, there is nonetheless a need to pinpoint their locations, or even provide short-term forecasts of their potential future positions.

New solutions for predicting IUU activity are currently emerging from academic research. They involve the field of mathematical geometry and information theory. These methods were originally developed to predict the behavior of complex systems such as the financial markets, but the principles apply in the context of IUU activities. More specifically, because the vessel traffic responds to the presence or absence of other vessels in the area (whether they are visible or “dark”), observing the behavior of the visible fleet and any anomalous behavior within that system carries clues about movement of the dark fleet. Much like observations of visible celestial bodies can pinpoint the location of black holes, analysis of the movement of the visible fleet (with emerging mathematical methods) is showing promise in identifying the locations and movements of the dark fleet. These methods take advantage of the emerging science of “big data” and involve the melding and merging of disparate kinds of data sets to infer information of interest for national security. Further developments in this line of research could aid in developing more efficient and effective patrol strategies.

Engaged educational programs that train Coast Guard personnel

Close working relationships between the scientists who are developing products and the user base are crucial in assuring that the forecast products are tailored to the needs of the specific user. Our experience with wave forecasting products shows that the needs of the Bar Pilots are quite different from those of the tuna fishing industry. Hence, close engagement is needed during the development phase of the products. Further, translating scientific and technological advances to application by the Coast Guard will require specialized training of Coast Guard personnel. Both of these needs can be met with engaged educational activities that are designed to provide input and testing for forecast product interfaces while also helping personnel attain an intuitive understanding of the forecasts, their accuracy, and any potential shortfall. Note also, that these programs will benefit from close inter-disciplinary linkages between the Ocean Sciences and Engineering.

Such educational partnerships within graduate programs are already in place. For example, OSU houses a cross-disciplinary program in Nearshore Oceanography and Coastal Engineering and is engaging with Coast Guard students at the graduate education level. Further enhancing such programs with innovative hands-on curriculum that includes extensive experiential learning and focusses and tailors the education to the needs of the Coast Guard can enable them to engage fully with the latest blue technologies available to aid in the mission of the Coast Guard.

Summary

University researchers, myself included, are keen on seeing their discoveries translated to application and used to increase our safety and personal, national, and resource security. The scientific advances have been made possible through investments in science by various agencies. To that end, continued encouragement of inter-governmental collaboration in research and development among federal agencies invested in ocean sciences and operations is imperative to further advance knowledge for innovation in blue technologies. However, while the presence of multiple agencies with interest and investment in the research is encouraging, it also results in situations where the translation of the science to application can be difficult to fund. This is of particular concern with the constrained budget of the US Coast Guard mission, particularly for research and development. Nearshore ocean science is rapidly reaching a point of maturity so that numerous forecast technology products can be produced. With strategic investment in the Coast Guard for applied research and development and operations of direct importance to the Service capabilities, there is real potential to promote significant advancements in safety, efficiency and effectiveness of critical mission objectives.

In closing, I thank the Subcommittee for your efforts to consider the role of technology innovation and applications for efficiently and effectively advancing critical Coast Guard capabilities needed for the current and future mission objectives. I would be pleased to answer any questions.