

NAVAL SCIENCE AND TECHNOLOGY FUTURE FORCE™

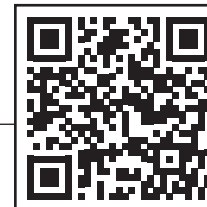
WINTER 2017

BUILDING THE
NEXT ICEBREAKER

HOW DO WE PREVENT THE
SPREAD OF AQUATIC NUISANCE
SPECIES IN THE ARCTIC?

SCIENCE IN ANTARCTICA HAS
ALWAYS BEEN ESSENTIAL

POLAR SCIENCE AND TECHNOLOGY



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Future Force is a professional magazine of the naval science and technology community. Published quarterly by the Office of Naval Research, its purpose is to inform readers about basic and applied research and advanced technology development efforts funded by the Department of the Navy. The mission of this publication is to enhance awareness of the decisive naval capabilities that are being discovered, developed, and demonstrated by scientists and engineers for the Navy, Marine Corps, and nation.

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In October 2016, the National Snow and Ice Data Center reported that the 2016 Arctic sea ice minimum tied 2007 as the second lowest on record. This data point highlights the concerning trend of sea ice decline in the Arctic since the late 1970s. Reduced sea ice coverage has effects on the physical behavior of both the ocean below and the weather above. An Arctic with reduced sea ice extent may experience more frequent and more intense storms, greater wave action, and new acoustic patterns, all of which can have direct implications on naval operations.

Leaders within the submarine community have expressed that this change in sea ice extent and composition has presented a much more dynamic navigational picture in the Arctic. Submarine captains, who participated in the most recent ice exercise (ICEX) in March 2016, have acknowledged this challenge to me first-hand, as they described the ice keel avoidance measures they used when encountering ice keels of 200 feet in depth.

The Navy recognizes the strategic importance of the Arctic region and the national security implications of an opening Arctic Ocean. Furthermore, extended access to Arctic sea routes is expected to encourage growth in human activity, including maritime trade, oil and gas development, fishing, and tourism. Shifting and reduced sea ice coverage in the Arctic Ocean continues to attract increasing interest from Arctic nations, including Russia, which continues to build capacity in the region, and non-Arctic nations, such as China, which has expressed economic and scientific interest in the region, in a perceived effort to expand its global reach.

The Navy is preparing to adapt to a changing Arctic to execute our global mission. In 2009, the Navy’s Task Force Climate Change charter was signed by the chief of naval operations. The charter designated the position of oceanographer of the Navy as the director of the Navy’s Task Force Climate Change, and as a result the first edition of the “U.S. Arctic Roadmap” was released in 2009. A subsequent update, the “U.S. Navy Arctic Roadmap, 2014-2030”, included accomplishments from the first roadmap and an implementation plan. The roadmap outlines the Navy’s strategic objectives in the Arctic:

- To ensure US Arctic sovereignty and provide homeland defense
- To provide ready naval forces to respond to crisis and contingencies
- To preserve freedom of the seas
- To promote partnerships within the US government and with international allies and partners.

The Arctic Roadmap implementation plan provides a path to gradually build capabilities to meet anticipated operational requirements. Science and technology is the underlying enabling foundation which makes this possible. Scientists seek to characterize the physical conditions of the Arctic to provide improved decision support to operations.

This issue of *Future Force* addresses some of the Arctic research that is leading the way to address these challenges. The Office of Naval Research’s Arctic and Global Prediction program has three focus areas:

- Improving understanding of the physical environment and key processes in the Arctic Ocean
- Investigating new technologies (e.g., sensors, platforms, navigation, and communications) that may enable a sustained observational capability in the challenging Arctic environment
- Developing integrated ocean-ice-wave-atmosphere models for improved Arctic prediction at a variety of time scales.

Photo by MC2 Tyler N. Thompson



ET2 Nate Madlem, with the Arctic Submarine Lab, stands safety watch during Ice Exercise 2016.

The need for improved forecast capability at multiple time scales was realized during the 2014 and 2016 ICEXs. The biannual exercise allows the Navy to assess operational readiness in the Arctic, increase experience in the region, advance understanding of the Arctic environment, and develop partnerships and collaborative efforts. Though both ICEXs benefited from National/Naval Ice Center satellite analysis and a 72-96 hour ice camp movement prediction, both camps had to end early because of the breakup of the ice surrounding the camps. The development of integrated ocean-ice-wave-atmosphere models that can predict surface conditions at multiple time scales, from the daily to the decadal, will assist with the preparation and planning efforts of future Arctic operations and exercises.

The Office of Naval Research’s Arctic program is working on several beneficial research initiatives to understand, describe, and predict the environment to enable increased presence and safe and effective operations in the Arctic:

- The “Marginal Ice Zone” departmental research initiative (FY12-16) employed a network of autonomous platforms to study the seasonal ice growth and retreat in the Beaufort Sea
- The “Sea State and Boundary Layer Physics of the Emerging Arctic Ocean” initiative (FY13-17) used a similar mix of autonomous platforms, moorings, and R/V Sikuliaq to study wave behavior in the presence of sea ice as well as ocean-atmosphere heat transfers
- The “Stratified Ocean Dynamics in the Arctic” (FY16-20) initiative will study the impacts to the upper ocean layer, which may experience increased turbulence, mixing, and vertical heat transport because of reduced sea ice
- The newest initiative, the “Arctic Mobile Observing System/Science” (FY17-21) will seek to develop new sensors and systems suited to the Arctic environment; this is expected to result in new sensors, platforms, and techniques that will enable the sustainment of a mobile observing capability that can enhance our scientific understanding of the physical Arctic Ocean environment and lead to improved predictions for this region.

The Arctic is a fascinating frontier and there is much to learn from it. As you review this issue, I challenge you to consider the long-term benefits of Arctic research to the Sailors and Marines of tomorrow.

Adm. Gallaudet is the oceanographer of the Navy and director, Task Force Climate Change.



ARCTIC INVASION: HOW DO WE PREVENT THE SPREAD OF AQUATIC NUISANCE SPECIES?

By Dr. Lisa A. Drake and Dr. Matthew R. First

THE FRAGILE ECOSYSTEM OF THE ARCTIC IS PARTICULARLY VULNERABLE TO THE INCREASING SPREAD OF INVASIVE SPECIES. TO NEUTRALIZE THE THREAT, MOST SHIPS IN THE GLOBAL SHIPPING INDUSTRY WILL INSTALL AND OPERATE BALLAST WATER MANAGEMENT SYSTEMS.

The extent of Arctic sea ice is decreasing rapidly in response to warming of the Arctic Ocean (e.g., Stroeve et al. 2007). As a result, additional high-latitude shipping routes have become available, and ship traffic has increased greatly to take advantage of the shorter shipping routes between oceans.

The Arctic ecosystem may be especially vulnerable to invasion by “aquatic nuisance species” (ANS) delivered by ships—whether by ballast water discharge or through biofouling (e.g., Miller and Ruiz 2014). In addition, the

possible short- and long-term effects of “seeding” the Arctic with ANS are not known and are difficult to predict. Further, the Arctic ecosystem is relatively pristine and generally has lower aquatic species diversity than waters in warmer latitudes, so invasive species may have outsized effects there.

The US Naval Research Laboratory (NRL)—in partnership with other federal agencies, particularly the US Coast Guard—has been working for over a decade to address the introduction of ANS in US waters.

Ballast Water

Throughout maritime history, ballast has been used to maintain a vessel’s stability, trim, and draft. Stones and other solid material were used historically as ballast, but now water is used, as it is much easier to pump aboard than it is to carry heavy material that must be disposed of at subsequent ports of call. The use of ballast water provides a route of entry for ANS because living organisms are pumped to onboard tanks in one location and then discharged at subsequent locations.

Organisms are sequestered in tanks and cargo holds that are nearly free of sunlight, though, so many organisms die in transport. Not all do. Some organisms that survive the journey and are discharged to a different location may thrive in their new, watery homes. They may out compete native organisms, as with the zebra mussel, which now carpets areas of the Great Lakes and other water bodies throughout North America. These thumbnail-sized mollusks were likely transported from Europe to the Great Lakes in ballast water and are one of the most striking examples of ANS. Other organisms transported in ballast water may be harmful to animals, plants, or humans, such as the microscopic algae that form so-called “red tides.”

In the 1990s, the international maritime transportation community and countries began to take action to reduce the transport and delivery of ANS. At the international level, the United Nations’ maritime agency, the International Maritime Organization (IMO), began to develop the Ballast Water Management Convention, which was subsequently adopted in 2004 (IMO 2004). In the United States, the Coast Guard and Environmental Protection Agency currently regulate ballast water discharged from commercial ships. Both the IMO and the United States have instituted a ballast water discharge standard that greatly restricts the number of living organisms that may be discharged.

To meet the stringent standard, most commercial ships will install a ballast water management system (BWMS), basically, a small-scale water-treatment plant. In fact, many of the systems on the market have borrowed technologies and processes from land-based water treatment plants: they typically filter water and then disinfect it, often using ultraviolet radiation or chlorination. The BWMS may employ a substantial amount of equipment and may require significant economic investment: a BWMS may fill one or more shipping containers and may cost \$1 million to \$1.5 million.

The BWMS must be tested to give shipowners and regulators confidence that the systems work as designed (before they are installed on ships as well as when ships

arrive in ports). Since 2003, NRL, with support from the Coast Guard, has been developing protocols for testing the efficacy, reliability, and robustness of BWMS. In this capacity, NRL has addressed a myriad of technical issues, including engineering- and biology-related aspects of testing. Among these issues are how a ballast water sample should be collected (e.g., Richard et al. 2008, Drake et al. 2014, Wier et al. 2015), how to ensure that sample collection and post-collection processes do not inadvertently kill organisms, and how to determine if nonmoving, microscopic organisms are living or dead (e.g., Steinberg et al. 2010, First et al. 2017).

The Environmental Protection Agency protocol for land-based verification testing of BWMS was finalized in 2010 with the input of stakeholders from industry, academia, state and federal regulatory agencies, and research from NRL and other organizations.

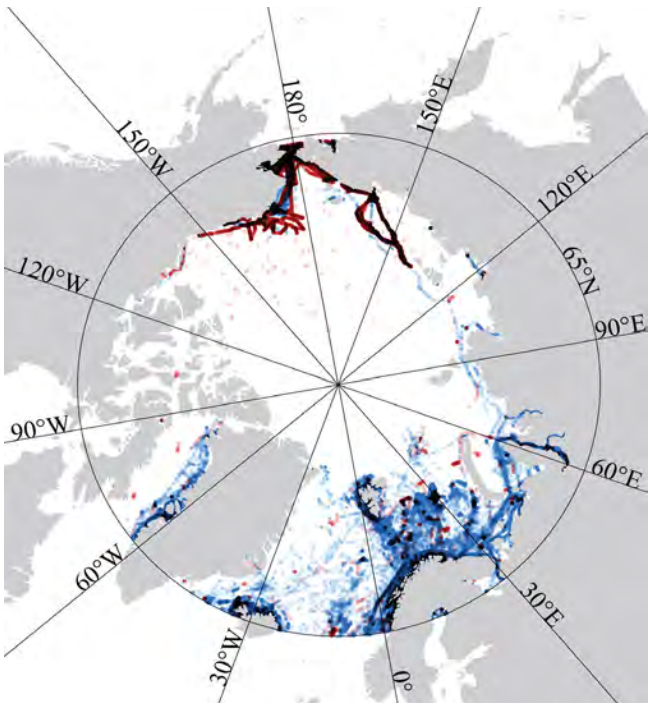
In parallel, IMO has developed guidelines for testing BWMS. Taking into account these guidelines, maritime administrations have type approved more than 60 BWMS to be installed and used on ships, and more than 3,000 systems have been sold worldwide.

The IMO Convention is poised to enter into force on 8 September 2017, and ships will have to comply with the discharge standard at an as-yet-undetermined time in the future. In the United States, ballast water management regulations are already in place and in force. Many ships have requested and have received extensions until US type approved BWMS are widely available. Eventually, the global commercial fleet of approximately 60,000 vessels will need to comply with the ballast water discharge standard, and the vast majority are expected to do so by using a BWMS.

Biofouling

To date, regulatory efforts to reduce the transfer of ANS by ships have focused primarily on the discharge of organisms in ballast water. In contrast, biofouling of ships as a vector for ANS has been a secondary concern (although hull husbandry—essentially hull cleaning practices—is undertaken to reduce drag and fuel costs).

“Biofouling” includes organisms attached to or associated with ship hulls as well as those in “niche” areas. These areas include appendages, cavities, and portions of the ship (e.g., sea chests, thruster tunnels, or rudderposts). Although these areas represent only about 10 percent of the available surfaces for colonization (Moser et al. 2017), they can host higher concentrations of organisms than the general flat hull surface.



Ships' locations from June 2014 (red circles) and June 2015 (blue circles). The locations show different shipping patterns as well as the relative abundance of ships between the two years. A marked increase in shipping traffic is seen in 2015. Data from US Coast Guard Navigation Center.

In some regions, biofouling is thought to pose a greater risk of delivering ANS than the risks posed by ballast water (e.g., Hewitt 2002). While the IMO has promulgated guidelines (rather than a convention) on biofouling, researchers are forming working groups to develop procedures to quantitatively assess the extent of biofouling and the effects that hull cleaning has on removing attached organisms (Drake et al. in preparation). Regardless, biofouling as a vector of ANS, particularly in the Arctic (e.g., Chan et al. 2016) remains understudied.

Aquatic Nuisance Species and the Arctic

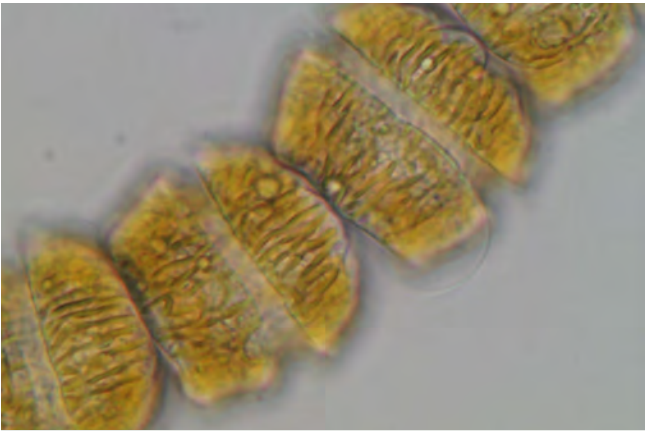
Ships traveling worldwide will be subject to the ballast water discharge standard, including those sailing in the Arctic Ocean. The rush of ships to trade in the cold waters of the Arctic will pose new challenges to BWMS. In general, BWMS are tested at locations that are temperate or tropical; even those facilities situated in northern climates conduct testing in the warmer seasons, when the organisms in the water are abundant. Commercially available BWMS have not been tested in or routinely subjected to the cold-water temperatures encountered in the Arctic.

Another concern in cold waters is the disassociation of the by-products from systems that use chemicals to disinfect the water. At low temperatures, chemical reactions proceed more slowly than at warmer temperatures. As a result, disinfection by-products that may degrade quickly in warmer waters may persist or not behave as expected in colder waters.

This paradigm is not just a theoretical one. Type approval was granted to a BWMS that used PERACLEAN® Ocean (IMO 2014), an oxidizing biocide with two active substances, peracetic acid and hydrogen peroxide. In general, this biocide is an environmentally friendly compound, but shortly after it was approved for the BWMS application in 2008 it was voluntarily withdrawn from the market by the manufacturer because of concerns about toxicity in cold freshwater (e.g., Lafontaine et al. 2008, Laursen 2010). The system has been redesigned with the potential to use a neutralization step, and it is now undergoing testing.

In the future, BWMS types approved in accordance with IMO guidelines will include an evaluation of their use at temperatures ranging from 0 to 40 degrees Celsius (32 to 104 degrees Fahrenheit) (IMO 2016), but it is unclear how that assessment will be made.

Efforts are under way to reduce the ship-mediated transport, delivery, and establishment of ANS. Standards are now mandated for the allowable concentrations of living organisms from ballast water, and most commercial ships will install a BWMS to meet the standard. How the



A chain of toxic algae cells (Gymnodinium catenatum). This species can form "red tides," which discolor the surface of the water. These and other microscopic cells can grow to such great densities that the algae blooms they form are visible from space (cells approximately 30 micrometers wide). Data from US Coast Guard Navigation Center. (Photo by Martina Doblin)



Naval Research Laboratory researchers collect a ballast water sample aboard M/V Indiana Harbor. They are using the shipboard filter skid to collect organisms by concentrating them in miniature plankton nets contained within the oblong silver housings (the housing visible in the photo is marked "A").

systems will work in cold Arctic waters is uncertain at this point. Likewise, the transport of organisms to the Arctic through ballast water and biofouling are likely to rise in concert with increased shipping traffic. Their potential effects are unknown.

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A DIFFERENT KIND OF THEATER: LEVERAGING SCIENCE FOR THE WORLD'S COLD SPOTS

By David Smalley

OPERATING IN THE POLAR REGIONS MEANS NEW CHALLENGES FOR NAVAL RESEARCH.

They are vast, frozen tracts of land and ocean. They are sparsely populated.

And they will be critical in the decade ahead, for US naval forces and the world.

They are the Polar Regions—the Arctic and the Antarctic. To the average person, they are remote, barren, snow-capped expanses of 24-hour darkness in the winter and round-the-clock sunshine in the summer. In fact, the two regions are vastly different, both in geological makeup and naval impact. The Arctic is an ocean, with territorial claims by multiple surrounding coastal nations. By contrast, the Antarctic is a continent, with no territorial claims per international agreement, surrounded by international waters.

But while they are different in so many ways, most especially geopolitically, naval scientific efforts in both regions are proving vital in gaining greater understanding of these extreme environments.

In recent years, the Arctic in particular has been increasingly a topic of discussion, from the Pentagon to the halls of Congress to the media. Shifting international considerations are part of the reason, but environmental factors—rapidly diminishing sea ice and significant changes in wind and wave patterns in the Arctic Ocean, for instance—bring new urgency to how we look at future operations.

Data from the region tell a story of dramatically changing conditions: Summer sea ice coverage in the Arctic Ocean has reached all-time lows. According to the National Snow and Ice Data Center, even winter ice levels are lower than ever before. That means new waterways are opening up, and regions once nearly impossible to reach are now accessible. Mineral- and resource-rich regions long inaccessible are now rife with potential. Tourism, fishing and shipping opportunities are growing. New oil fields beckon.

Military strategists from nations that in the past may have had less cause to ponder these regions realize that there are new opportunities for governments as well as commerce—all of which bring new challenges for naval forces. Time is money. Many analysts see an Arctic transit shaving precious days from today's sea routes moving goods from Asia to Europe. The Bering Strait could become a new choke point for seagoing commerce.

US naval leaders are well aware of the changing parameters. Chief of Naval Operations Adm. John

Richardson has said, for instance, that despite constrained budgets and urgent needs around the world, future surface ship design must incorporate the likelihood of increased Arctic operations. The replacements for current guided missile cruisers, destroyers, and littoral combat ships will need to be "modular and modernizable," and their designs will need to consider the unique Arctic environment for their hulls as well as energy and propulsion systems.

"The Arctic is going to be a different kind of theater in the future, and if we neglect the fact that we're going to be operating in the Arctic as we design this new class of ship, that's just narrow thinking on our part," Richardson told an audience at the Center for American Progress.

In short: With an increase in accessibility comes a demand for increased naval capability. And right now, the Navy doesn't know enough about Arctic variability to forecast safe conditions for deployments of its surface fleet.

Cmdr. Blake McBride, former science director for polar science and technology for the Office of Naval Research Global, and currently a military deputy in ONR's Ocean Battlespace Sensing Department, has been in regular contact with US partners in the Polar Regions.

"The United States is an Arctic nation, and the Arctic is an ocean," he said. "That means that we, as the naval security forces of the United States, have a duty to prepare and be able to operate effectively in our Arctic territory if and when called upon."



Cmdr. Blake McBride, science director for polar science and technology for the Office of Naval Research Global, visits Nuuk, Greenland, aboard the Royal Danish Navy frigate HDMS Triton (F358). (Royal Danish Navy photo)

Photo by Shutterstock

The Navy's 2009 Arctic Roadmap served as a wake-up call for many within the fleet and force. The current version—"U.S. Navy Arctic Roadmap, 2014-2030"—assigns tasks to various naval organizations to prepare the fleet for future Arctic operations. "The US Navy recognizes that the opening of the Arctic Ocean has important national security implications as well as significant impacts on the US Navy's required future capabilities," says the document's introduction.

These environmental changes and resultant geopolitical challenges are being discussed in the scientific and popular press as well. "America Needs to Get Serious about the Arctic," says a headline in the *National Interest*. *Foreign Affairs* has looked at "The Coming Arctic Boom" and the *National Interest* described "The Battle for the Arctic." These are just the tip of the iceberg.



Crew members aboard a Coast Guard C-130 launch expendable current probes while on a flight over the Arctic during an Office of Naval Research-sponsored expedition to study the seasonal ice zone. (Photo by John F. Williams)

The problem is more widely recognized, but solutions are costly and not quickly achieved. We have far fewer icebreakers than, for instance, Russia. According to published reports, Russia has 40 such seagoing vessels (four of which are nuclear powered). Seven more are planned or under construction. In addition, numerous other Russian vessels have at least some icebreaking capabilities.

The United States by contrast has a total of two icebreakers—both of which are operated by the Coast Guard. One, USCGC *Polar Star* (WAGB 10), is operating well past its planned lifecycle, mostly in the Antarctic. "The highways of the Arctic are icebreakers," said Alaska Sen. Dan Sullivan. "Right now the Russians have superhighways and we have dirt roads with potholes."

That's a problem when resources are constrained and the cost of even one new icebreaker costs approximately \$1 billion.

In the face of those kinds of numbers, effective science and technology will be key to furthering US interests in the decades ahead. Better fundamental understanding of changing dynamics is essential. Existing forecasting models need to incorporate changed conditions. How fast is the ice melting in the marginal ice zone? How does that affect wave patterns and currents, and hence sea states and shipping lanes? In regions that are already challenging because of harsh weather, vast distances, minimal infrastructure and unique sea conditions, America's global leadership responsibilities—ensuring open sea lanes; providing ready forces for current operations; and designing effective contingency plans for future requirements—underscore the need for accurate forecasts. That alone is anything but simple if we want to get it right.

To move forward (literally and figuratively), ONR, together with its international command, the Office of Naval Research Global (ONR Global), is spearheading multiple efforts to increase our understanding of the Polar Regions. In addition to material science efforts to minimize ice buildup on hulls, these include new programs to better understand sea and ice dynamics in the Arctic, new platforms and sensors to explore vast regions of the Antarctic, and increased international partnerships in both regions.

Polar TRACER

The ONR Global office in Santiago, Chile, is partnering with the US Army's Research, Development and Engineering Command; the Air Force Office of Scientific Research; and a prominent Chilean company on the Polar Traversing Robotics for Autonomous, Collaborative and Efficient Reconnaissance (Polar TRACER) project. The program focuses on developing novel machine learning algorithms to understand extremely low-feature environments such as those found in Antarctica.



Currently being tested on an autonomous land vehicle in Chile, the Polar TRACER algorithm is designed to help unmanned vehicles navigate in featureless environments such as Antarctica. (Photo by ONR Global)

Currently, many state-of-the-art autonomous rovers and vehicles in use around the world rely on complex, often extremely delicate sensors. But what works in most geographic settings often fails in the vast uninterrupted polar ice, which features white-outs, high winds, snow-covered hazards and slippery, deformable terrains, including sometimes massive undetected crevasses.

The TRACER program is developing special terra-mechanic sensors, using new algorithms, to be placed on a new land vehicle platform, to enhance short-range capability.

The ultimate goal? Getting more and better information to humans, while decreasing the likelihood of injury or loss of life in unexplored terrain. The small autonomous vehicle that will use the new algorithms will go ahead of large convoys over Antarctica, with sensors able to withstand the harsh conditions and assess ground conditions for safety.

The knowledge gained from the project will help scientists and naval forces in the Arctic as well.

Robots under Ice

Through the ONR Arctic and Global Prediction program, ONR-sponsored scientists have had great success using unmanned underwater vehicles and other autonomous technologies to better understand what's happening on and beneath the ice. ONR-sponsored scientists have over the past few years pioneered a new generation of lightweight, autonomous sensing packages. No longer are wooden huts and oil generators needed for persistent environmental observations.

Better knowledge of the Arctic environment will assist in the development of better forecasts for weather, sea conditions and ice movement—all important considerations for future naval and maritime activities.

"The Arctic has been poorly understood and poorly measured such that it causes us to have less accurate weather forecasts overall," notes McBride. "Being able to operate effectively in the region will enable us to have

capabilities that are resilient to punishment from the extremes of the environment. Having that, in turn, will enable us to negotiate and operate from a position of strength in the region.”

The core ONR programs are the Seasonal Ice Zone Recon Surveys (SIZRS), and Department Research Initiatives, or DRIs. SIZRS is a program of repeated ocean, ice and atmospheric measurements across the Beaufort Sea seasonal ice zone. It is a partnership with the US Coast Guard, which has, through search and rescue and drug interdiction missions, considerable operational experience in the Arctic—as well as planes and ships that have proved to be an invaluable resource for naval research.

ONR programs include the development and placement of advanced underwater platforms or wave buoys, which are transmitting data once unimaginable (due to being unobtainable) to civilian and Navy scientists. In just one example, a team of top scientists from the University of Washington, sponsored by ONR, boarded a Coast Guard C-130 and, above remote areas, put advanced, sensor-laden dropsondes into the northern waters. It has had an enormous return on investment in advancing fundamental scientific understanding of what’s actually taking place in the Arctic, and where specifically.

Last summer, ONR researchers placed deep- and shallow-water sonar arrays in the Canadian Basin to study acoustic propagation—basically, how sound travels in the water. Both sets of arrays will be collected this summer after one year of deployment. This begins a drive to develop greater persistence in scientific observations. Taken together with the DRIs listed below, findings will be incorporated into existing models to better predict conditions for Navy ships.

The DRIs:

- Marginal Ice Zone: This program looks at how fast the marginal ice zone—the transition zone between sea ice and open ocean—is changing.
- Arctic Sea State: This study analyses how waves are increasing as a natural consequence of the sea ice decline.
- Stratified Ocean Dynamics in the Arctic: This study examines the Arctic Ocean conditions and behaviors in the wake of increased wave action.
- Arctic Mobile Observing System: This program is

intended to integrate unmanned vehicle technology developed largely by ONR to better measure the Arctic without risk to human life, as well as reduce cost of studying the region. It allows us to measure parts of the Arctic at times when no human could do so for long—i.e., during the winter months.

Antarctic Partnerships

One of the ways ONR can gain enormous knowledge at low cost (compared to sponsoring multiple new research programs, for example), is to leverage the expertise of partner nations on sea ice/wave interaction in the southern ocean near Antarctica. In addition to gaining insights into the Antarctic, it informs our understanding of the Arctic, improving our ability to more accurately forecast sea states in various ice conditions.

A number of ONR Global grants focus on collecting and using improved wave/sea ice data. ONR works with oceanographers based in New Zealand and Australia who have vast experience in the waters “down under.” New Zealand’s National Institute for Water and Atmospheric Research, for instance, is leading efforts to improve wave/sea ice data collection, and is working with ONR Global on a new disposable sea ice wave buoy. ONR Global also is working with researchers at Nanyang Technical University in Singapore to study sea ice and waves in totally new ways, validating the Navy’s acclaimed Watch 3 wave model run by Dr. Erick Rogers at of the Naval Research Laboratory’s Stennis Space Center in Mississippi.

In an interconnected world, such collaboration is essential. Just as we understand that global weather patterns in one part of the world can impact conditions halfway around the planet, so too can research efforts in one part of the globe be analyzed and applied thousands of miles away.

Other current research grants include testing and validation of scalable sea ice material, and modeling and comparison with scaled-up simulations and real ice covers.

As part of the mutually beneficial collaborations, McBride has participated in multiple journeys with experienced polar partner navies, including New Zealand, Denmark, and Iceland. The lessons learned and reports back will be essential to informing the “Navy/Marine Corps after Next.”

“Through my travels and interactions with military and scientific experts, I have learned about the challenges,

opportunities, and needs they experience in the coldest and most extreme environments on Earth,” he said. “That enables me to translate the observations into relevance for US naval interests and for our country as a whole—while simultaneously exploring collaboration possibilities with our friends and allies.”

ICE-PPR

With those principles of engagement and partnership front and center, ONR Global has also been a key player in the establishment of the International Cooperative Engagement Program for Polar Research (ICE-PPR). This proposed framework between the United States, Canada, Denmark, Finland, Iceland, New Zealand, Norway, and Sweden, is part of ONR’s answer to the challenge of the Arctic Roadmap, which directs the Navy to “expand cooperative partnerships with Arctic nations and Arctic states, and international, interagency, and private sector stakeholders that enhance Arctic security.”

A multilateral framework between all of these partner nations is being finalized in a new memorandum of understanding for research, development, test, and evaluation cooperation in military-to-military polar research. The memorandum will formalize research collaboration between the partner nations and the US Navy, Air Force, Army, and Coast Guard.

Four research areas will be front and center in this new partnership as it begins: situational awareness, human performance, platforms, and the environment. While the US Navy has much to bring to the table, including its own existing research programs cited, as well as extensive submarine experience beneath the Arctic Ocean, it also has much to learn from the cold weather operational experience and capabilities of other nations.

“ICE-PPR is science diplomacy in action,” said Dr. Chris Bassler, director of the Naval S&T Cooperation program at ONR Global. “This will be an invaluable tool for all of the partner nations to increase understanding of, and capabilities in, these unique theaters, ensuring a safe, stable and secure Arctic region.”

The cooperative research projects will also be essential to leverage investments, avoid duplication of research, and build partnerships.

“It also will be an enormous assist as we work toward future interoperability in areas like search and rescue, or



The aurora borealis is observed from USCGC Healy (WAGB 20) while conducting science operations for the National Science Foundation in the southern Arctic Ocean. One of only two US icebreakers, Healy has seen significant service since being commissioned in 2000. (Coast Guard photo by PO2 Cory J. Mendenhall)

humanitarian assistance and disaster relief,” said Bassler. “This will support CNO directives and could potentially be a game-changer for all concerned.”

As the program evolves, officials see the memorandum enabling the development of projects in many mutual areas of interest, including: polar environmental modeling, prediction, and information-sharing; polar sensors and remote sensing techniques; polar communications and situational awareness; platform design and performance for polar environments; navigation in ice conditions; energy efficiency in polar environments; human performance in polar environments; and much more.

The first ICE-PPR meeting was held in Helsinki in February 2016, and included the US Navy’s chief of naval research, as well as counterparts from each of the seven nations currently planning to join the ICE-PPR memorandum of understanding. It is expected to be officially signed later this year.

Conclusion

As the Arctic opens for more human activity, there will be greater requirements for the US Navy to be operating in the region. Vast distances, punishing weather conditions and a lack of supporting infrastructure makes this a challenging proposition. The Navy is actively preparing for potential future polar mandates. Better understanding and forecasting capabilities of this demanding region, and better protections for surface ships, will be critical to that end. Naval S&T is leading the way. ✈

About the author:

David Smalley is the associate editor of Future Force.



PROTECTED COMMUNICATIONS GO POLAR

By Katherine Connor

COMMUNICATIONS IN THE ARCTIC RECEIVE A BOOST WITH A CONNECTION TO SATELLITE SYSTEMS—THE ENHANCED POLAR SYSTEM—THAT ACTS AS A 3,000 MILE “EXTENSION CORD.”

As warmer temperatures lead to a reduction of sea ice in the Arctic Ocean, the amount of open water is growing at a rapid rate. The Navy expects that trend to continue, with a correlating increase in ship traffic in the region. Space and Naval Warfare Systems Center (SSC) Pacific is working to facilitate communications for the submarines already able to traverse the icy waters, and for other Navy communities and military services which may soon find themselves operating regularly in this region.

A team of 45 from SSC Pacific recently completed a major milestone in the Enhanced Polar System (EPS) Gateway project, which will provide continuous extremely high-frequency (EHF), protected satellite communications to forces operating in the North Polar Region, above 65 degrees north latitude. The team completed both the installation and installation qualification test of the gateway, which is one of four components of the overall EPS system.

The Air Force Space and Missile Systems Center in El Segundo is the sponsor of the EPS program, which will replace an existing and aging communication system.

Peter Shchupak, SSC Pacific engineer and project lead for the EPS gateway, said SSC Pacific essentially created a 3,000-mile extension cord between the satellite communication terminals at Clear Air Force Station in Alaska, and the teleport at Camp Roberts, California, where there is existing access into the defense networking infrastructure.

“The gateway is part of the EPS ground system, and serves as the interface between polar and mid-latitude users of the system,” Shchupak said. “We have three terminals along with a suite of networking equipment at Clear Air Force Station, Alaska, and a small footprint of networking equipment at Camp Roberts, and these work together to pass communications traffic between the satellite and the teleport infrastructure.”

Shchupak said this will allow submarines to communicate with other polar users and others ashore, using services such as voice, email, instant messaging, and video as if they were connected to terrestrial infrastructure. In the future as more naval communities and services such as the Coast Guard are tasked with Arctic missions, they will be able to hook into the EPS system and the terminals at Clear Air Force Station as well, providing their platforms with protected EHF satellite communications.

The gateway segment was largely an integration effort, meaning no new hardware or software was developed, but existing commercial and government-off-the-shelf components had to be connected and configured in a manner that supported the mission.

“The bulk of the challenge was selecting the right design, the right equipment, and making sure it all talks together correctly,” Shchupak said. “Installation was very challenging as well because of the geographic location—you have a very short build season there, so we had to execute all installation-related activities between May and September.”

The completed EPS system is expected to be delivered in 2018, increasing the capacity, data rate, and connectivity available for Arctic communications. ✈

About the author:

Katherine Connor is a staff writer with Space and Naval Warfare Systems Center Pacific’s public affairs.



BREAKING ICE:

THE NEXT ICEBREAKER WILL BE A NAVY-COAST GUARD PARTNERSHIP

By Dustin Q. Diaz

WITH ONLY TWO WELL-USED ICEBREAKERS—THE COAST GUARD’S USCGC HEALY (WAGB 20) IS SHOWN HERE, WITH THE CANADIAN ICEBREAKER CCGS LOUIS S. ST-LAURENT—THE UNITED STATES IS POISED TO DESIGN AND BUILD A NEW GENERATION OF POLAR-CAPABLE SHIPS.

As global climate change occurs, the Arctic is changing with it, causing unprecedented retreat of sea ice in one of the world’s last great frontiers, opening new sea lanes and, with them, new opportunities for exploration, research, and trade.

The Naval Research and Development Establishment will play a necessary role in this expansion, and employees at Naval Surface Warfare Center Carderock Division (NSWCCD) are taking part in that effort, according to Dr. Tim Arcano, Carderock technical director.

“To maintain presence and to defend our national interests in these important emerging areas, and to enforce treaties and other international laws, the US Navy will need to design and build polar capabilities into its ships,” Arcano said. “Capabilities such as advanced ship-design modeling tools, hydrodynamics, ship systems and ice modeling must be given priority now to ensure that the US maintains relevance and presence in this critical arena.”

The Navy currently does not have any polar-capable

surface ships, nor does it have the ability to independently design and test them. What it does have is a roadmap of activities to pursue, as well as capable partners to work with and learn from to achieve those goals. The Navy Arctic Roadmap was created by Task Force Climate Change and most recently revised in 2014 to prepare the Navy to respond effectively to future contingencies, delineate the Navy’s Arctic region leadership role within the Defense Department, and articulate the Navy’s support to the National Strategy for the Arctic region.

“In the near-term, the focus is on training and understanding what the inherent capabilities of our existing platforms and systems are when operating in that region,” said Stephen Minnich, naval architect at Carderock’s West Bethesda, Maryland, headquarters. “Given what we learn about our existing platforms, we will investigate how we can enhance the capabilities of those platforms in the midterm. Far term, we are looking at the needed capabilities and platforms to support sustained presence in high latitudes. The Arctic Roadmap is guiding the research work that we’re doing here at Carderock.”

The Navy has the ability today to surface through ice with its submarines, with limitations. Safe-operating guidance for doing this was developed at Carderock in the 1980s and 1990s by members of the structures and composites division. While the Navy accumulates more knowledge and develops technology to operate in marginal ice zones with its own ships, the need to explore arctic regions and resupply American interests at both poles is currently met by the Coast Guard’s polar icebreakers: the heavy icebreaker USCGC *Polar Star* (WAGB 10) and medium icebreaker USCGC *Healy* (WAGB 20). These massive ships have fulfilled regular commitments for decades under very arduous conditions, and the effort now under way to create a new class of icebreakers will be a historic one, according to Neil Meister, technical director of the polar icebreaker replacement project within the Coast Guard.

“You don’t build a heavy icebreaker except once in a generation,” Meister said. “These are considered national strategic assets. What we’re making is essentially a steel fist that has to last for decades and be able to float, run into things, and operate at 40 below zero. These ships do a lot of crazy things that most ships don’t do. The capabilities we are building into the replacement reflect that.”

The Coast Guard recently began the acquisition process for a new polar icebreaker and formed an integrated program office with the Navy’s Program Executive Office Ships and Naval Sea Systems Command’s Naval Systems

Engineering Office to maintain this capability by building the next generation of these unique vessels. With *Polar Star* reaching 40 years of age in 2016, the program intends to begin production activities for the next heavy icebreakers in the very near future. Carderock, in multiple ways, will play a key role in this acquisition.

“The Navy and Carderock are now in a position to support the Coast Guard in terms of the research and development efforts that are associated with acquiring a platform with icebreaking capability,” Minnich said. “This collaboration with the Coast Guard is strategically important. It helps us to identify and quantify the challenges that we face, which will help to inform requirements. This shared knowledge and expertise will help us continue to execute the Arctic Roadmap.”

The Coast Guard has its own Arctic Strategy, released in 2013, that has a lot of overlap with its Navy counterpart, according to Meister. Both services have an interest in preserving freedom of the seas, projecting Arctic sovereignty, and supporting scientific research. With the Navy’s Arctic reach limited to submarines for now, these icebreakers give the United States the reach it needs at the poles with the incredibly limited shore infrastructure and hazardous conditions faced when operating in these environments. Minnich said that navigation, for example, is difficult enough in open-water conditions, but even more so at extreme latitudes where the functionality of some systems aboard surface ships may be degraded.

“Some of the environmental challenges faced by vessels operating in high latitudes include topside icing, extreme cold, heavy seas and limited visibility. You get spray that ices the deckhouse so you get a lot of weight up high, which has a negative impact on ship’s stability,” Minnich said. “Navigation in close proximity to the poles is challenging. Our understanding of the bathymetry in that area is poor, relatively speaking. Operational awareness, understanding where the ice is and how it’s changing so that we can plan our operations, is a challenge.”

Currently, *Healy* is tasked with regular science research missions to the Arctic while *Polar Star* conducts the annual Operation Deep Freeze deployment to resupply McMurdo Station in Antarctica. Meister said both are chartered by the National Science Foundation: *Healy*, to conduct arctic research, with a full research vessel-level science capability aboard; and *Polar Star*, to provide logistical support capability for Antarctic research. These icebreakers are uniquely qualified for the missions they perform with much of the global icebreaking fleet dedicated to commercial purposes.



Adm. Paul Zukunft, commandant of the US Coast Guard, delivers remarks during the Sixth Symposium on the Impacts of an Ice-Diminishing Arctic on Naval and Maritime Operations at the Naval Heritage Center in Washington, DC. (Photo by John F. Williams)

“You want reach, because there is nothing up there. It’s very difficult for people who have never been to the Arctic or Antarctic to understand what ‘nothing’ is, because they’ve never been exposed to it,” Meister said. “Up there, it is effectively a moonshot. There is very little infrastructure. Communications are very difficult up there. You are on your own and you need to be able to take care of yourself. Coast Guard ships are traditionally designed for independent operations.”

Nathan Hagan, a naval architect and Carderock’s technical point of contact for ice-structure loading assessment for naval vessels operating in the Arctic, said Carderock’s involvement in the upcoming icebreaker class motivated the unification of the division’s efforts in hydrodynamics and ship structures into a team that will look at all the disciplines involved in building this ship.

“Previously, both from a hydrodynamics and a structural perspective, subject-matter experts at Carderock continued research to develop polar ship design knowledge within the Navy, but it didn’t quite have a clear goal, other than technical diligence,” Hagan said. “And now we have an objective that really helps us identify priorities more appropriately when allocating resources.”

One area that Carderock Division can’t directly support at its own facilities is ice model testing. Hagan said one of Carderock’s partners in this area has been the Army Corps

of Engineers Cold Regions Research and Engineering Laboratory (CRREL) in Hanover, New Hampshire, which maintains the nation’s primary ice-tank facilities, and is currently collaborating with Carderock’s structural team by looking at discrete element modeling to simulate a notional Navy ship moving through an ice field to understand how ice breaks and moves in chunks as the hull moves through it.

“Material science associated with Arctic conditions is traditionally in the swim lane of our domestic partner CRREL. Their facility has ice tanks and ice labs already, so we have a very strong working relationship with them to use their facilities when we need to do certain model tests and share simulation and modeling expertise,” Hagan said. “We’ve provided all the structural assessment capability for the submarine platforms—which look to bend ice to break it for surfacing, unlike the icebreakers, which crush ice to go through it—as well for arctic operations.”

Dr. Paul E. Hess III, of the Office of Naval Research (ONR), is sponsoring this structural work between Carderock and CRREL. This is not the first work Hess has done with ice model testing, or even the first time working with Carderock and CRREL, as he worked with Carderock’s Ed Devine, who is now retired, on ice impact testing using a polar icebreaker model and a conceptual Navy frigate model on a study in the early 1990s.

“Based on my past association with ice-loading experimentation, and the uptick in interest in potential Navy operations in the Arctic regions, in 2009 I started working with Ed Devine to find a way to resurrect past Navy knowledge and figure out how to move forward in development of new tools and knowledge with regard to ice loading on hulls,” Hess said. “That work led to increased and renewed engagement with CRREL and coordination with the U.S. Coast Guard Surface Forces Logistics Center and Defence Research and Development Canada [DRDC], both sharing interests with the Navy in knowing how capable non-ice-strengthened ships are in ice covered waters.

“The Coast Guard and DRDC funded American Bureau of Shipping [ABS] and Memorial University of Newfoundland, Canada [MUN], to provide a spreadsheet tool for predicting ice capability of non-ice-strengthened ship hulls to assist in operator guidance in areas with floating sea ice. To leverage the Coast Guard and DRDC investments and interest, I began funding NSWCCD,

ABS, MUN and CRREL to collaborate on the evaluation of existing toolsets and data to determine effectiveness for naval non-ice-strengthened hulls. ABS and MUN are taking their in-house tools, developed for ice-class ships under the [International Maritime Organization] Polar Code, and exploring their use on a notional Navy combatant ship design provided by NSWCCD.”



USS Staten Island (AGB 5), a Wind-class icebreaker, off the Antarctic Peninsula in April 1963. Built during World War II and scrapped during the 1970s and 1980s, the Wind class had a colorful and long career, with the ships serving variously in the US Navy, US Coast Guard, and the Soviet (under the Lend-Lease program) and Canadian navies. The last US Navy icebreakers were transferred to the Coast Guard in 1966.

Hagan said the heterogeneous nature of ice presents unique challenges not only for ships to operate in, but also during scaled model testing. Ice, he said, adds many more variables than open water.

“There are many dependencies that determine what the strength of ice will be. It forms naturally in many different ways resulting in many different ice types. These factors play into our ability to predict the structural load that a

ship will experience if it impacts ice. It makes operating more unpredictable,” Hagan said.

Hess said reporting on this initial work should be complete in 2017 and will increase knowledge of the capability of current tools to support operations of existing Navy ships in areas such as the marginal ice zone in high-latitude regions.

“With increased understanding of current hull ice-resistance capacity, we can both operate our existing ships more safely and understand the value added by increased plate thickness, or other strengthening approaches, in future design,” Hess said.

This need for increased naval operability is becoming more critical as Arctic ice melts and new sea lanes open, according to Arcano. He said cargo shipping volume through the Northern Sea Route has increased with the retreat of ice.

“As the Arctic opens up, commercial vessels will begin to use these northern routes for shipping, trade, exploration, and more between Europe and Asia, reducing travel times between the Atlantic and Pacific oceans,” Arcano said. “The US’s interest includes not only shipping, but also scientific research and exploration, critical natural resources, and strategic location, which could be especially beneficial to our nation.”

Carderock’s next step to help the new icebreakers come to fruition will be to join the Coast Guard and the Department of Homeland Security as they use a standing Cooperative Activity Arrangement with the Canadian government to share knowledge and begin ice-model testing of a Coast Guard-developed indicative design, with open-water testing expected to begin at Carderock in summer 2017, according to Meister. Hess said that he hopes the work he and others have done so far can contribute to “Naval Ship Maneuverability in Ice,” a NATO Science and Technology Organization collaboration with Canada, Germany, the Netherlands, and New Zealand, which starts in fall 2017 and for which he is the lead. Carderock also provides delegates to the specialist team on polar ship design and safety under the NATO Ship Design and Capability Group. ✈

About the author:

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COUPLING ATMOSPHERE, ICE, AND OCEAN MODELS IMPROVES PREDICTION

By Dr. Neil Barton, Richard Allard, Pamela Posey,
E. Joseph Metzger, Dr. James Hansen, and Dr. Ruth Preller

INCORPORATING AN ATMOSPHERIC MODEL WITH THE NAVY'S SEA ICE-OCEAN
PREDICTIVE SYSTEM WILL LEAD TO MORE REALISTIC POLAR SIMULATIONS.

Photo courtesy of NASA/Goddard/MODIS Rapid Response Team

The Arctic is a challenging environment to simulate and predict. The dynamic sea ice surface is strongly connected to the overlying atmosphere and its underlying ocean. The link between these three Earth systems is strongest at the surface, which is where naval forces typically operate. The US Navy has benefited from world-leading Arctic sea ice and ocean predictions systems developed at the Naval Research Laboratory (NRL), such as the Polar Ice Prediction System, the Arctic Cap Nowcast/Forecast System, and, more recently, the Global Ocean Forecasting System (GOFS) 3.1, which provides global coverage of ice prediction. These sea ice prediction systems are driven by atmospheric forecasts, but no information is exchanged from the sea ice-ocean system to the atmosphere. NRL is now adding a dynamic atmosphere to these world-leading sea ice prediction systems, resulting in a more realistic representation of the earth system and new prediction capabilities.

The importance of adding a dynamic atmosphere to the sea ice and ocean prediction systems is shown by an Arctic storm that occurred in August 2012. This storm brought warm and windy conditions to regions of the Arctic that aided in accelerating sea ice melting. Over the course of three days, about 77,200 square miles of sea ice (equivalent to the size of Nebraska) melted each day. Many factors affect sea ice loss, such as temperature, winds, and sea ice thickness, and each storm may not have such a pronounced effect as the 2012 storm. To understand and predict future storms, a modeling system that is able to simulate the dynamic interactions of sea ice, atmosphere, and ocean is needed.

Current operational atmospheric-only and sea ice-ocean predictions extend out to only seven days. Adding an atmospheric model component to the sea ice and ocean prediction systems enables a capability of long-range predictions for the first time. As highlighted in the Navy's Arctic Roadmap of 2014, naval operations are expected to increase in the Arctic, and sea ice forecasts longer than seven days are required to provide commanding officers with ample time to plan how to safely traverse the Arctic. A forecast model that simulates sea ice, atmosphere, and ocean in one modeling system is essential for these long-range forecasts.

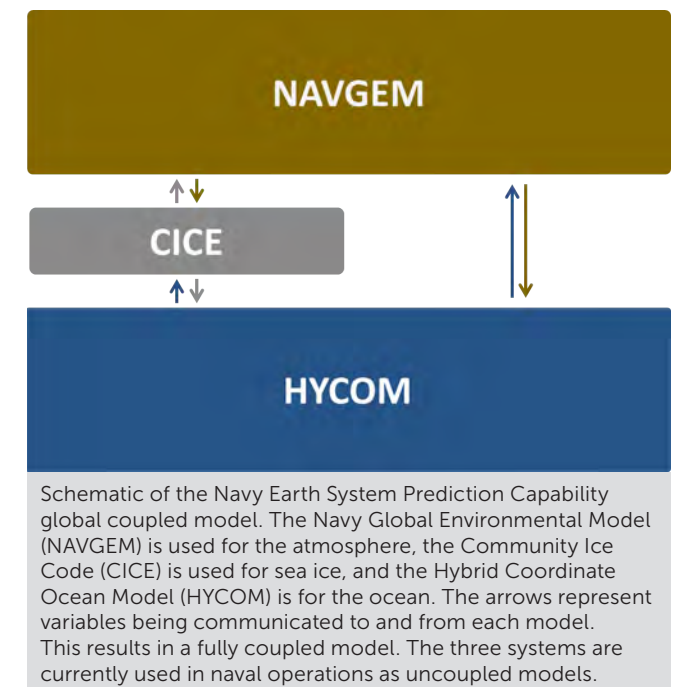
Development Based on Current Systems

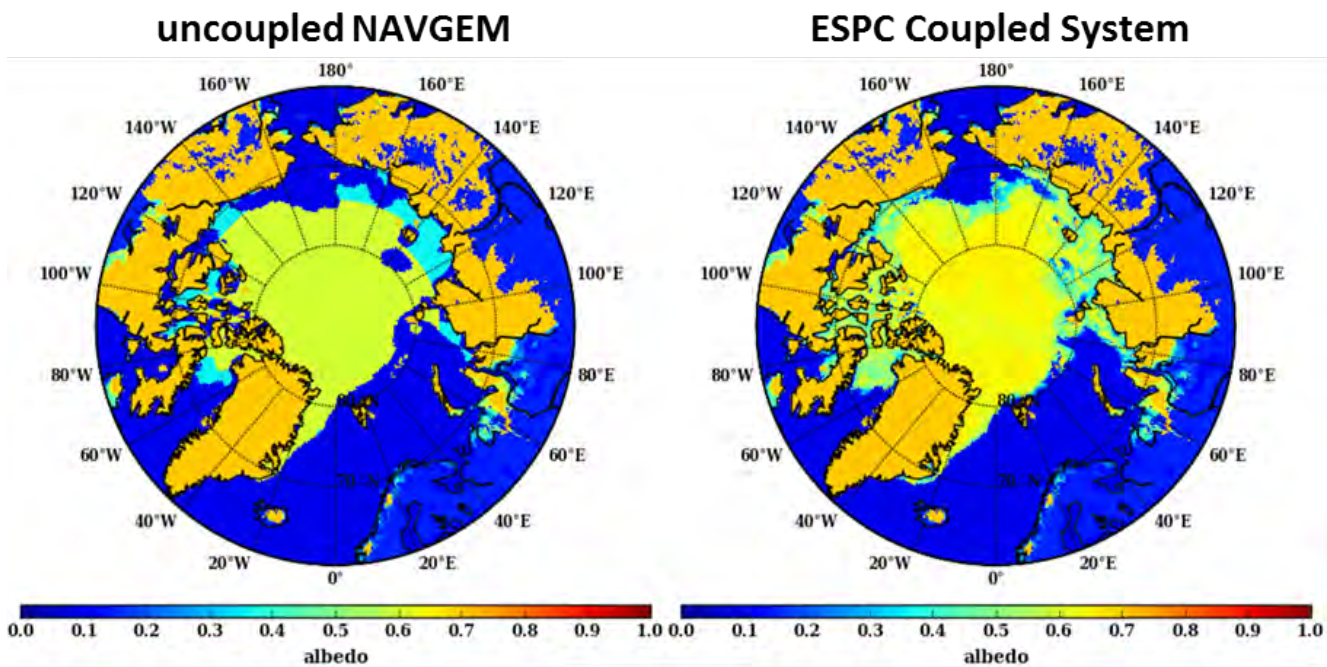
Scientists from NRL's marine meteorology and the oceanography divisions are developing a new modeling

system to predict Arctic sea ice, atmosphere, and ocean conditions within one system, as part of the Navy Earth System Prediction Capability (ESPC) program sponsored by the Office of Naval Research. Historically, NRL's oceanography division developed the ocean and sea ice prediction systems (which did not include an active atmosphere), and the marine meteorology division developed the atmosphere prediction systems (which did not include active sea ice and ocean models).

Though the ESPC system is a new paradigm for Navy predictions, this model framework largely uses existing operational or preoperational systems. The ESPC model components include: the Los Alamos National Laboratory Community Ice Code (CICE) for sea ice prediction, the Navy Global Environmental Model (NAVGEN) for atmospheric prediction, and the Hybrid Coordinate Ocean Model (HYCOM) for ocean prediction. All of these component models are currently used in naval operations, but not together as one system.

Initial developments in the ESPC system focused on how the Navy's mature models communicate with each other in one system framework. Running the models in a manner where they communicate with one another is called coupled modeling. New code development for coupling between mature models is the major part of a national ESPC effort, and NRL uses tools similar to those of other national agencies (such as





The currently uncoupled NAVGEM uses simple static sea ice properties with the surface albedo being constant (left figure). In the coupled model system, sea ice properties are from the sea ice model, CICE, which are much more sophisticated and result in more realistic sea ice properties (right figure).

the Department of Energy, the Air Force, and others) to allow communications between models. In particular, NRL is using the National Unified Operational Prediction Capability (NUOPC) code, which is based on tools developed for the Earth System Modeling Framework.

For communication between models, the NUOPC tools are added to the mature models, and minimum updates are needed to the mature models. The inclusion of these tools does not affect how the mature models run in a noncoupled mode, but it allows for models to exchange variables when they are coupled. For example, in the Navy ESPC system, the sea ice is predicted in CICE and then passed to NAVGEM and HYCOM.

Coupled Modeling Benefits Predictions

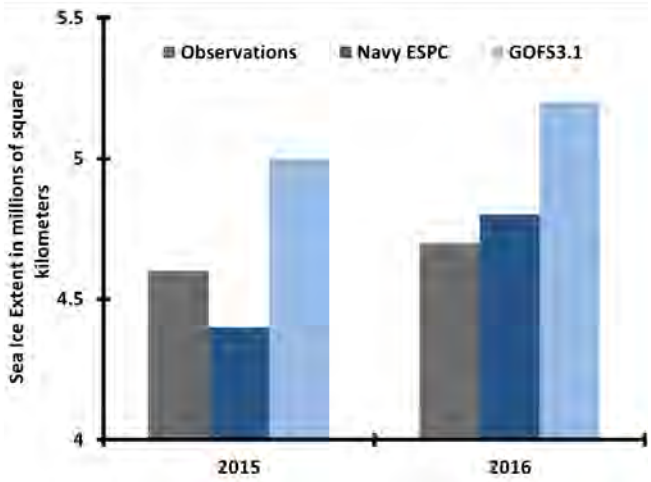
A benefit of coupled models is that the atmosphere model uses a more realistic representation of sea ice and ocean, while a more realistic atmosphere is used by the sea ice and ocean models. For example, in NAVGEM, sea ice concentrations stay constant throughout the seven-day forecast. In the Navy ESPC system, the atmosphere sees the changing sea ice concentrations predicted by CICE. Of course, more properties than sea ice concentration are passed to NAVGEM when run within the Navy ESPC

system. For example, the albedo of sea ice is an important driver of the surface energy budget. The albedo of sea ice with fresh fallen snow is very high (0.87), reflecting much of the incoming solar radiation, while melt ponds over the sea ice have a lower albedo, allowing solar radiation to be absorbed within the melt pond and promote additional melt. Within the Navy ESPC system, CICE calculates surface albedo using a much more sophisticated method compared to NAVGEM on its own. This leads to more realistic values of surface albedo in NAVGEM and aids in better predictions across systems.

In a coupled modeling system, the interaction between each model is better represented compared to uncoupled models. As one might expect, the movement of sea ice is very much connected to near-surface winds. In the current Navy operational sea ice and ocean models, atmospheric near-surface winds are not altered when there are changes in the sea ice or ocean. In the Navy ESPC system, atmosphere near-surface winds from NAVGEM take into account multiple factors, including variables from the sea ice and ocean simulations, resulting in a better representation of movement of ice from near-surface winds. A need for a better representation between near-surface winds and ice movement has been noted in the Navy’s 2016 Arctic Ice Exercise debrief, which

stated that “models need more information for ... ice ... movement resulting from wind stress.”

A significant benefit from the Navy ESPC modeling system is the ability to forecast sea ice at time scales greater than current operational forecasts. Presently, NAVGEM and GOFS 3.1 forecasts occur out to seven days. Within this time frame, realistic forecasts are obtained without coupling variables between the systems. When performing longer forecasts, the sea ice, atmosphere, and ocean need to change at the same time consistently with each other. For example, realistic Arctic atmosphere predictions can be obtained when keeping sea ice constant for seven days. If a month’s forecast is required, however, keeping sea ice characteristics constant would generate a fair amount of error as sea ice can change substantially over a 30-day period.



Predictions of the September Arctic sea ice extent for 2015 and 2016 from the initial Navy ESPC coupled model and GOFS 3.1 for the Sea Ice Prediction Network international model inter-comparison program. The new Navy ESPC system predicted September Arctic sea ice extent two months in advance with slightly better accuracy than the current system for these two years.

Long-range sea ice predictions have been produced using the Navy’s ESPC coupled system in 2015 and 2016 through an international effort called the Sea Ice Prediction Network (<https://www.arcus.org/sipn>) to forecast the September minimum Arctic sea ice extent months in advance. The Navy ESPC model performed well and was comparable with the more mature Navy GOFS 3.1 and other international models. The September sea ice extent in 2015 was 4.6 million square kilometers (1.77 million square miles), and from runs starting in June, the Navy ESPC system predicted 4.4 million square kilometers and the GOFS 3.1 system predicted 5 million

square kilometers. In 2016, the September sea ice extent was 4.7 million square kilometers, and the Navy ESPC system and GOFS 3.1 system predicted 4.8 and 5.2 million, respectively.

Next Steps

The Navy ESPC model is not expected to be fully operational until the 2020s, with initial operational capability expected at the end of 2018. Research and development is currently being performed to increase the fidelity of the modeling system. NRL researchers are developing the model for long-range predictions and wisely using data near the surface to initialize the atmosphere, sea ice, and ocean models together. Different physical processes may control the accuracy for coupled longer-range forecasts compared to the current short-range forecasts, and the current methods in which the stand-alone models simulate physics need to be tested and possibly updated for these long-range forecasts. Ensembles, or parallel execution of multiple similar forecasts, are essential when examining predictions greater than seven days. These ensembles aid in characterizing the forecast errors or “uncertainties” and can be used to quantify risk assessment, and new techniques to best characterize forecast uncertainty are currently being examined. NAVGEM and GOFS 3.1 have separate methods for how observations are used to initialize model simulations. Techniques to communicate model initialization across the atmosphere, sea ice, and ocean are currently being developed.

The Navy’s ESPC modeling system will supply Arctic predictions across multiple time scales (from days to months) and Earth systems (sea ice, atmosphere, and ocean). For the first time in Navy operations, Arctic predictions for atmosphere, sea ice, and ocean will be produced within one modeling system enabling the Navy to prepare for Arctic operations from days to months ahead.

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“OPERATIONALLY BLENDED”

SATELLITE DATA CAN IMPROVE SEA ICE FORECASTS

By Drs. L. Li, P. Gaiser, P. Posey, R. Allard, D. Hebert, W. Meier

Photo by Alek Petty/NASA's Goddard Space Flight Center

WITH LESS AND LESS ICE EVERY SUMMER IN THE ARCTIC, THE NAVAL RESEARCH LABORATORY AND NASA ARE COLLABORATING ON A SYSTEM THAT COMBINES DATA FROM DIFFERENT SATELLITE SYSTEMS TO HELP IMPROVE ICE FORECASTING.

The Arctic climate system is experiencing dramatic changes. One particularly important and very visible change is the reduction in the summertime sea ice cover. The Intergovernmental Panel on Climate Change models predict a further decrease in sea ice cover with a potentially ice-free summertime Arctic before 2100. The projections vary widely, however, with some models predicting an ice-free Arctic as early as 2040. Given the observed and forecast reduction in sea ice cover, Arctic shipping and commercial activities are expected to increase in the future. Warfighters must adapt to the fast changing Arctic, and it is vital for them to have access to accurate and timely information on sea ice conditions and forecasts at relatively small scales. This demands higher accuracy in sea ice observations and forecasts than is available today.

The Navy's current operational Arctic sea ice forecasting system is the Arctic Cap Nowcast/Forecast System (ACNFS), which has a grid resolution of approximately 3.5 kilometers (2.2 miles) at the North Pole. The ice concentration fields from ACNFS are updated daily with satellite-derived ice concentrations from the Defense Meteorological Satellite Program (DMSP) Special Sensor Microwave Imager and Sounder (SSMIS) at a resolution of approximately 25 kilometers (15.5 miles), and the Advanced Microwave Scanning Radiometer (AMSR2) at a resolution of approximately 10 kilometers (6 miles). Higher-resolution sea ice information from satellites is therefore critically needed to complement the ACNFS model resolution.

In response to this need for accurate ice forecasts by the Navy for its operations, the Naval Research Laboratory (NRL) and NASA's Goddard Space Flight Center developed a joint operational satellite data system to generate blended near-real-time, high-resolution sea ice products from microwave and visible/infrared satellite sensor platforms. The system's data products are currently being tested using the Navy's ACNFS for improved operational sea ice forecasts and safe navigation in the Arctic, especially in the marginal ice zone, the transitional point between the open sea and pack ice. Making such a satellite data system available to the Naval Oceanographic Office will provide the Navy with an in-house capability

for producing near real time sea ice observations, ending the practice of using satellite ice concentration products from non-Navy sources. This work responds directly to the Navy Arctic Roadmap's call to "support efforts to research, develop, resource, and sustain an Arctic environmental observation system to support U.S. operations" and to improve "the Navy's ability to understand and predict the Arctic physical environment." In addition, the sea ice concentration data products provided by this project support development of a fully coupled air-sea-wave-ice interaction model.

Technical Approach

Sea ice concentration is a key parameter for the Arctic battlespace environment. Satellite passive microwave (PMW) and visible/infrared data provide complementary observations of sea ice, and are performance drivers of sea ice forecast models. Passive microwave data (such as SSMIS and AMSR2) have complete daily coverage in all sky conditions, but also have low spatial resolution and cannot detect low sea ice concentration.

On the other hand, visible/infrared data (such as NASA's Moderate-resolution Imaging Spectroradiometer [MODIS] and Visible Infrared Imager Radiometer Suite [VIIRS]) provide higher spatial resolution and the ability to detect thin or melting ice. However, clouds limit both visible and infrared imagery throughout the year. Working with the complementary nature of PMW and visible/infrared data, a blended algorithm can combine data from various satellites where users automatically receive the best and most consistent sea ice concentration data at the highest resolution available.

Implementation and Result

Working toward a blended data product, we first selected AMSR2 as the source for the passive microwave products because of its wide availability. In addition, the Naval Oceanographic Office also established a data link to receive AMSR2 raw data in near real time. AMSR2 PMW imagery provides complete daily coverage of sea ice concentration in all sky conditions. Sea ice concentration is derived from the satellite obtained brightness

temperature data using empirically derived algorithms. The current SSMIS sea ice concentration product is available at 25-kilometer (15-mile) resolution, while AMSR2 provides standard products on a 10-kilometer (6-mile) grid, which is a considerable improvement.

MODIS and its follow-on mission VIIRS were selected as the source for the visible/infrared products because

of their wide-availability, long history of use, and well-calibrated measurements. Their visible and near-infrared data have very distinct spectral signatures against the ocean background and cloud cover. Based on these signatures, we developed new sea ice algorithms for both VIIRS and MODIS instruments. The sea ice classification algorithm was based on the spectral analysis of the high-resolution data, 500 meters (1,640 feet) for MODIS

and 750 meters (2,460 feet) for VIIRS. The algorithm uses combinations of visible and near-infrared bands to separate different surface types. For the purpose of calculating sea ice concentration, we grouped surface types into five classes: sea ice, snow on sea ice, cloud, water, and land. The land surface type is determined by the 250-meter resolution MODIS land mask data. The water surface is identified by its very low albedo in the visible spectrum. Ice/snow/cloud pixels are characterized and separated by their strong visible reflectance and strong short-wave infrared absorbing characteristics, represented by the Normalized Difference Snow Index. And additional screening of high and thin clouds is performed using the 1.38-micrometer channel. Using this 500-meter resolution sea ice classification data, sea ice concentrations were calculated at a degraded 4-kilometer resolution and projected onto a 4-kilometer grid to facilitate merging with the AMSR2 data.

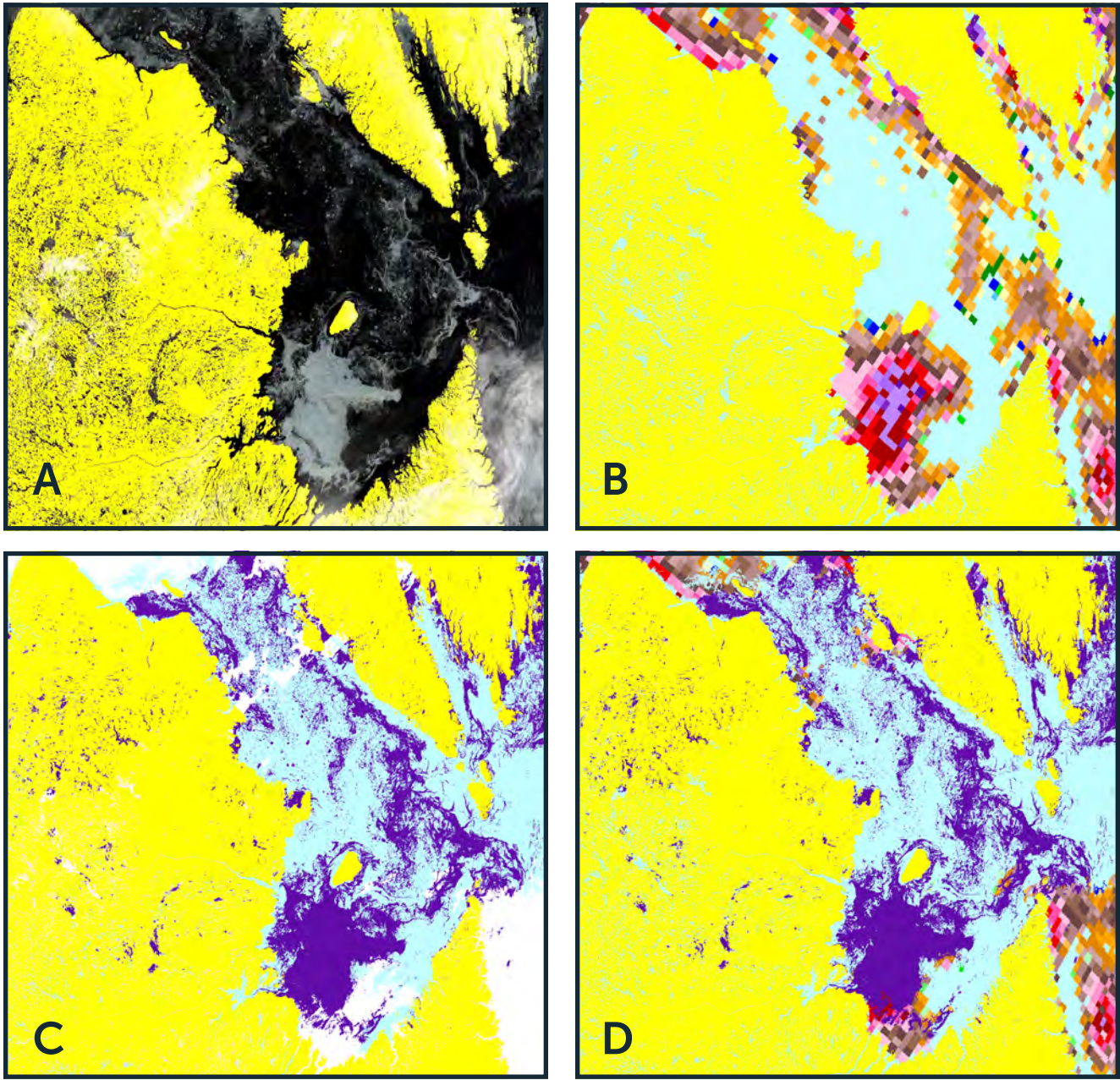
After the 4-kilometer VIIRS and MODIS ice concentration data products are produced, we combine them with the AMSR2 10-kilometer ice concentration data, subsampled to the 4-kilometer common grid, to create the blended 4-kilometer AMSR2/VIIRS/MODIS dataset that integrates the spatial coverage with visible/infrared resolution. The optimal combination is achieved based on error statistics of standalone VIIRS/MODIS and AMSR2 ice concentration data. For example, in the marginal ice zone, the PMW data from AMSR2 data is underweighted because of larger errors in the microwave data in this region. As a result, errors in the blended data are smaller in the marginal ice zone than when using only the AMSR2 data.

Figure 1 shows an example result of blended VIIRS/AMSR2 sea ice concentration data in the Davis Strait region (located on the western side of Greenland) on 20 June 2014. The yellow background is the land mask. In general, the AMSR2 and VIIRS standalone data are clearly very consistent, except that some areas are masked out by cloud cover (white color) in the VIIRS data. The greater detail provided by VIIRS compared to AMSR2 in the clear sky regions is apparent. Also, the VIIRS concentrations are generally higher than AMSR2, which correct the well-known low bias in passive microwave concentrations during summer melt when water pools on the ice surface. Finally, the VIIRS ice edge extends farther than AMSR2, which is in agreement with visual inspection of the VIIRS reflectance image and is not surprising because passive microwave algorithms may not detect thin, melting ice near the edge. There is discontinuity between the VIIRS

region (Figure 1c) and the AMSR2 region (Figure 1b) at the boundary of the VIIRS swath edge (Figure 1d). This could potentially be resolved or at least reduced by adjusting AMSR2 concentration or algorithm coefficients so that the passive microwave estimates are consistent with VIIRS. Nonetheless, the current product does provide improved fields in clear-sky regions.

Benefit to the Navy

The benefit of the blended visible/infrared/PMW sea ice concentration data can be tested in ACNFS to determine the improvement in the model forecast fields. Currently, the ACNFS assimilates near real-time sea ice concentration derived from SSMIS and AMSR2 by updating the initial ice concentration analysis fields along the ice edge. In the past year, NRL tested the 4-kilometer blended AMSR2/VIIRS ice concentration dataset as the initial condition to the ACNFS model run. Daily analysis of the ice edge location indicated the ACNFS initialized with the merged AMSR2/VIIRS dataset has substantially lower ice edge error (on average 30 km vs 50 km) than the ACNFS initialized using the coarser SSMIS data for a month-long study in 2008. The software for processing the blended sea ice products is currently undergoing system testing at the Naval Oceanographic Office at the Stennis Space Center as an operational satellite sea ice processing system. A successful transition of this new capability will result in an immediate leap in sea ice forecasting skills by the Navy, as well as a data system that integrates existing and future multisensor sea ice data in a physically consistent way.



An example of combined concentration product in the Davis Strait region on 20 June 2014, with a), Visible Infrared Imager Radiometer Suite (VIIRS) true color image, b), Advanced Microwave Scanning Radiometer (AMSR2) sea ice concentration, c), VIIRS sea ice concentration (clouds are in white), and d), combined VIIRS/AMSR2 sea ice field.

About the authors:

Drs. Li and Gaiser are researchers in the Naval Research Laboratory's remote sensing division.

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IT'S A SHIP, IT'S AN ICEBERG, IT'S A... POLAR BEAR?

By Katherine Connor

US Coast Guard photo by PO1 George Degener

IDENTIFYING THE DIFFERENCE FROM AFAR INVOLVES SOME ASSISTANCE FROM MACHINE LEARNING SOFTWARE.

The Arctic is a massive region touching eight countries and an ocean spanning 5.4 million square miles at the top of the globe. With relatively few people and little or no infrastructure in most parts of the expanse, getting information on current conditions and maritime travel is no easy task.

Today, the US Coast Guard's International Ice Patrol (IIP) flies a plane over 30,000 square miles of the North Atlantic Ocean five times a week to locate and map icebergs. They frequently get false alarms for shapes in Arctic satellite images that appear to be ships but are actually just icebergs.

At the National Ice Center, image analysts manually create weekly sea ice charts to determine how far ice extends past land. Annotating the sea ice over such a huge area is a tedious, often subjective process that can be prone to error.

Elan Sharghi, an engineer at the Space and Naval Warfare Systems Center (SSC) Pacific, has a solution to all of these challenges: the Ice Tracking, Recognition, and Age Characterization System (Ice TRACS), which analyzes synthetic aperture radar satellite imagery to automatically annotate sea ice objects and characteristics of interest to users operating in the polar regions.

"I believe the Navy has a high level of interest in the Arctic region because we anticipate there being a significant increase in ship traffic there in the next few decades," said Sharghi, an electrical engineer who also helped develop the Center's Rapid Image Exploitation Resource (RAPIER®) software, which is being used commercially for satellite imagery-based detection of wildfires in remote areas.

Here's how Ice TRACS works: Sharghi and a team of six engineers at SSC Pacific incorporate machine learning components into the software allowing it to learn how to detect certain objects and create sea ice charts. Using satellite images from Canada's RADARSAT-2 and the European Space Agency's Sentinel-1 satellite, the Ice TRACS software locates ships, icebergs, or other items of interest more accurately than other current methods.

One of the applications of the tool, developed at the request of the Coast Guard, more accurately detects ships in high-latitude regions while rejecting false alarms caused by icebergs. Julian Raheema, a new professional at SSC Pacific, used an approach based on machine

learning for the software to detect interest points in the satellite images, signaling the presence of a ship. This application has been successful at locating ships and differentiating them from icebergs during testing, hitting accuracy marks in the high 90-percent range. Sharghi said more trials are still necessary.

On the flip side, the team is also developing an application of the tool for the IIP component of the Coast Guard that can pick out icebergs from these satellite images of 30,000 square miles in the Arctic. The IIP flies over the area five times a week during iceberg season—February to August—to locate and map out iceberg locations. This information is used by the North American Ice Service to produce its iceberg chart, which informs the plans and movements of commercial and military vessels.

Detecting the extent of sea ice—how far it continues off land—is another use for the software. Sharghi said the National Ice Center's image analysts currently create vector-based files manually, which is tedious and time consuming. Using a texture-based, gray-level co-occurrence matrix approach, the software would be able to automatically extract features from the satellite images, determining how far the ice extends and greatly reducing the time and workload required for the process.

Measuring the thickness of sea ice to determine its age and study how it has changed over time is a future application of the tool, and Sharghi and her team are already in the early stages of developing a product to accomplish that goal.

She said using this method not only creates a safer maritime environment, but also reduces monitoring costs and the workload of the Coast Guard and National Ice Center personnel.

"It's important to have a robust ship detector if there is going to be more maritime traffic in the polar regions," Sharghi said. "And the other applications we're developing will assist various commands and organizations—anything that makes their jobs easier is of high importance to us."

About the author:

Katherine Connor is a staff writer with Space and Naval Warfare Systems Center Pacific's public affairs.



“THE SCIENCE IN **ANTARCTICA** HAS ALWAYS BEEN ESSENTIAL”

By Diane Owens

SPACE AND NAVAL WARFARE
SYSTEMS CENTER ATLANTIC HAS
BEEN PROVIDING SUPPORT TO AIR
OPERATIONS AND OTHER VITAL NEEDS
FOR SCIENTISTS AND SCIENCE ON THE
FROZEN CONTINENT FOR 20 YEARS.

For the past two decades, Space and Naval Warfare Systems Center (SSC) Atlantic employees have provided meteorology services, air traffic control, systems engineering and maintenance, ground electronics maintenance, information technology/security and operational logistics support in Antarctica. Their work enables scientists funded by the National Science Foundation (NSF) to conduct ground-breaking research.

“We are very proud to be teammates in the critical science mission at the boundary of human existence on the planet,” said SSC Atlantic commanding officer Capt. Scott Heller. “In a world challenged by global warming, understanding what is happening at our world’s poles is more important than ever. The science in Antarctica has always been essential . . . today it is even more urgent. Our employees contribute to the safety of members of the scientific community and keep them productive,” he added.

Challenges

Supporting researchers in polar regions involves unique challenges.

Power availability is limited. Every device requiring power must be run by a generator, alternative energy (e.g., solar, wind), or batteries. This is exceptionally challenging for siting airport equipment and designing systems for the deep field. Medical facilities also are limited, so employees who deploy must meet stringent medical and dental requirements. This affects staffing plans, contracting schedules, and general deployment readiness.

Antarctica is the coldest, driest, windiest, highest, and harshest continent in the world. Weather is extremely volatile, and many operations depend on an accurate weather forecast. Obtaining and retaining experienced talent is essential to forecasting the unpredictable weather phenomena.

Access to the continent is generally dependent on sunshine availability. During austral summer (October-February), the sun shines 24 hours a day, and when it sets for the year, darkness sets in 24/7 for more than 100 days straight

Photo by US Air Force photo by Tech. Sgt. Shane A. Cuomo

during austral winter (March-September). This funnels most activity into a narrow window of opportunity for engineers and technicians to plan, deploy, and execute projects and it influences all parts of the acquisition lifecycle.

Antarctica has very limited network bandwidth via satellite. The shared bandwidth for up to 1,000 people during peak season at McMurdo Station is about the equivalent of that in a typical American home. As a result, employees must closely manage their network while designs for operational systems and procedures for using them must minimize data transfer on and off the continent, where practical. There also is no cell phone connectivity. Mobile communications are limited to legacy communications systems such as high-frequency radio and mobile satellite devices such as Iridium. Engineers designing systems must limit communications within those systems to one of the few available technologies.

Airports are built on continuously moving ice. This requires much more frequent resets and realignment of runway lights and navigational systems. For example, skiways for Williams Field at McMurdo Station move about a foot a day as the ice

flows toward McMurdo Sound. Any significant cargo must come by sea, and supply ships arrive once a year after an ice breaker clears passage to the ice pier at McMurdo Station. Project planning for larger systems that are transported by surface vessel must have very robust acquisition schedules that can absorb long transportation requirements.

Workers who “winter over” in Antarctica are isolated for months at a time. Recently, a limited number of planned flights have been scheduled and accomplished during the winter months. These flights are enabling new opportunities for scheduling and executing projects normally confined to austral summer.

The extreme cold has detrimental effects on systems. Some critical components, such as battery cells, lubricants, etc., freeze at extreme temperatures. While most equipment specifications for military use are either -40 or -55 Celsius (-40 to -67 Fahrenheit), many applications in Antarctica necessitate much lower operating temperature capabilities and require skilled engineers and technical personnel who understand this need.

SSC Atlantic Executive Director Chris Miller flew to Antarctica in 2012 to see first-hand the work done there and to meet the staff. “Antarctica is extremely hard to describe in words and must be seen to be appreciated,” he said. “It’s an incredibly remote, stark, and desolate continent where you can see and experience nature at its most dramatic. It also remains almost exactly as it was long before human beings ever arrived. The environment enables unique and critical scientific research.”

SSC Atlantic Polar Programs

NSF funds and manages the United States Antarctic Program. Scientific disciplines in Antarctica include astronomy, atmospheric sciences, biology, earth science, environmental science, geology, glaciology, marine biology, oceanography, and geophysics.

NSF has a dedicated group of employees who plan and direct the program’s operations while drawing resources and logistical support from many federal civilian and Defense Department agencies, as directed under Presidential Memorandum 6646 signed by President Ronald Reagan in 1982.

Currently, the Secretary of the Air Force is the executive agent for defense efforts supporting NSF in the polar regions. SSC Atlantic’s focus support is on aviation command and control systems and services, along with core engineering and technical services in areas such as communications and information security. NSF levies other agencies’ capabilities under reimbursable agreements which, when combined, enable the world-class science that continuously originates from the continent.

In 1985, SSC Atlantic (then Naval Electronic Systems Command) employees and contractors began supporting Antarctic Program when called on by Naval Support Forces Antarctica to engineer and install an air traffic control radar at McMurdo Station. Immediately after, additional engineering support for various communications system upgrades, meteorology system updates, and installations occurred.

In October 1997, SSC Atlantic assumed all air traffic control and operational meteorology responsibilities from Naval Support Forces Antarctica and continued to be the engineering services provider for aviation, meteorology, and communications systems. SSC Atlantic employees and contractors have provided these services for 20 consecutive years.

McMurdo Station

McMurdo, the primary US Antarctic logistics center, is located on the southern tip of Ross Island, approximately 850 miles north of the South Pole. While SSC Atlantic employees provide some technical and operational support for South Pole Station on the interior of the continent and Palmer Station on the Antarctic Peninsula, deployed personnel primarily reside at McMurdo Station.

Approximately 45 SSC Atlantic government personnel and contract employees spend the austral summer season “on the ice” at McMurdo providing required services, with a minimum staff of four or five contractors remaining on-site during the austral winter. These numbers included engineering project personnel who may not spend extended time there but deploy based on individual project requirements. SSC Atlantic also has sought minimizing the number of personnel who need to deploy to the continent each season, accomplishing this through application of technology and use of carefully crafted operational processes and procedures.

SSC Atlantic’s remote operations facility in Charleston, South Carolina, provides operational forecast services to support all US assets in Antarctica. In addition, the facility provides air traffic control services and general support for Antarctic flights. Individual pilot briefings are provided using video conferencing tools from Charleston to Christchurch, New Zealand, before any southbound mission.

The SSC Atlantic team augments deployed personnel, increases capability, and improves work-life balance for program participants who would normally deploy each season. SSC Atlantic will continue to explore new ways to use technology and seek operational solutions to further reduce deployed personnel. This aligns with NSF strategic planning to conduct a major modernization of McMurdo Station in the near future with a goal of greater efficiencies, capabilities, and support to research scientists.

Meteorology

Antarctica, which wasn’t discovered until the 19th century, contains vast mountains layered in a mile or more of ice and an active volcano, and has an ever-changing land mass as ice melts and reforms. The terrain and rapidly changing extreme weather present unique challenges to researchers and support personnel alike.



The SSC Atlantic meteorology and air traffic control team works 24/7 during the active season for the US Antarctic Program at the remote operations facility in Charleston, South Carolina. The team monitors all weather forecasting and tracks all flights in and out of Antarctica. On this particular day, in December 2016, they were monitoring the medical evacuation flight of former astronaut Buzz Aldrin. Photo by Joe Bullinger

SSC Atlantic meteorologists must consider a myriad of factors when predicting weather for pilots, ship officers, and station or camp support personnel on the continent of Antarctica. Frigid temperatures, strong winds, crystalline snow (smaller than a grain of sand), glaciers, mountainous terrain, snow storms, white-outs, icebergs, fog, and blizzards all present unique challenges and hazards. Meteorologists also must factor in extreme elevation changes; flights departing from McMurdo Station’s sea-level air fields may land at stations or camps at altitudes of 10,000 feet or more.

Intercontinental flights generally originate in Christchurch, New Zealand, which is more than 2,400 miles north across the Southern Ocean. Adding to the complications of normal forecasting is the length of time it takes to complete a flight from New Zealand and the ever-increasing chance that unpredictable weather can affect aircraft. Forecasters calculate the point of safe return for each flight as the last location that a pilot can return to the point of origin with sufficient fuel, in the event of sudden weather changes. Pilots occasionally do turn around and return to the departure site, but these “boomerangs” cost taxpayers for used fuel, wear and tear on the aircraft, and labor for everyone from aircrews and passengers to logistics ground personnel on each end. Accurate weather predictions by SSC Atlantic forecasters are essential to avoid the high cost of aborted missions, delayed flights, and personnel safety—and to enable cargo and supplies delivery, as well as routine operations. Meteorologists study near real-time satellite images, numerical models, time-lapsed weather information, and input from human observers to generate forecasts.

SSC Atlantic engineers have designed or modified systems to provide critical information to weather personnel including commercial off-the-shelf portable weather stations mounted on skis, remotely controllable with fixed camera, and kits for deep field usage. They leveraged Iridium satellite communications to transport sensor output for real-time forecaster analysis.

NSF offers limited webcam views to the public from McMurdo that update every 30 seconds at <https://www.usap.gov/videoclipsandmaps/mcmwebcam.cfm>.

Air Traffic Control

Three airfields near McMurdo Station are built on snow and ice to support heavy-lift wheeled aircraft (C-17

Globemasters) and skied aircraft (LC-130F Hercules). Williams Field (NZWD) is a snow airfield specifically for skied aircraft. Pegasus Field (NZPG) and the new Phoenix Field (NZFX) have hard ice surfaces and can support wheeled operations. Each location has unique operational requirements and challenges and serves a specific purpose.

SSC Atlantic air traffic controllers are responsible for the safe flow of air traffic in and out of these airfields. NZWD has a small air traffic control tower built atop skis and equipped with all necessary communications and meteorology systems for controlling aircraft approaching or departing the airfield. In addition, air traffic controllers also manage the McMurdo Sector of the Auckland Flight Information Region from McMurdo Air Traffic Control Center—augmented by Charleston remote operations facility personnel.

Employees work around the clock and track thousands of aviation operations in Antarctica each year, including inter- and intracontinental fixed-wing flights and all McMurdo-area helicopter operations. There is no longer an air traffic control radar at McMurdo and all control is provided under nonradar control rules. However, by using technology and leveraging products across other government agencies, such as automated flight following from the National Forest Service, controllers’ situational awareness is greatly improved. Further enhancements will continue as aircraft and infrastructure continue to reach the 2020 compliance requirements for operating in national airspace.

Program Personnel

Matt Rushing, polar program integrated product team lead, is responsible for all SSC Atlantic polar programs systems engineering and operational support provided to NSF, including necessary systems and services for aviation, meteorology, communications, and numerous supporting functions. He attributes much of the program’s success to employees’ dedication, experience, and collective length of time on the job. He noted that the team is planning for the future and trying to bring in new professionals to learn from experienced colleagues so they can take the reins someday.

“A lot of work is done with very few people ‘on the ice’ since many tasks are done remotely, and this encourages innovation by SSC Atlantic personnel in technology, the use and application of technology, and in providing routine support.” He noted that polar program participants are



SSC Atlantic Executive Director Chris Miller appreciated the opportunity to visit Antarctica project sites and observe deployed employees in action in the challenging polar environment. (Photo by SSC Atlantic)

some of the most well rounded at the center because they gain so many different skill sets. Many people continue their careers supporting warfighters in central leadership roles. Extreme cold weather engineering expertise and other knowledge gained in the program benefits the Navy as a whole.

“It’s a dangerous and unique environment to work in, and it’s not for everyone,” Rushing said. At times, polar support can be highly stressful, but through it all, SSC Atlantic’s safety record is excellent. “There have been no accidents attributed to the Air Traffic Control services, Meteorology services, or systems performance since assuming the responsibility in 1997,” said Rushing.

Rushing also noted that personnel deployed to Antarctica develop symbiotic relationships with polar scientists, and are able to apply current scientific findings to their work, while scientists benefit from employees’ technical expertise and experience.

Meteorology administrator Art Cayette, who provides government oversight to polar contractors, was stationed in Antarctica during his active-duty Navy days, and 30 years later he continues to be passionate about keeping

personnel safe. “It’s the most humbling occupation ever,” he said.

Coy Johnson, who managed the first Antarctic radar installation in the 1980s, retired from SSC Atlantic and continues to work in the air traffic control sub-portfolio as a contractor. He recalls that McMurdo Station was quite “rustic” in the early days, and that it took eight hours to travel by Navy Hercules LC-130 ski-plane from Christchurch, New Zealand, to McMurdo.

Retired Navy commander Dave Kelch, senior operations advisor to the polar programs integrated product team lead and the competency lead for aviation command and control operations, said that “people in the polar programs are dedicated, and they’re very good at what they do. They love what they do and they’re pros.” Before joining the SSC Atlantic team as a Navy civilian, Kelch was the Navy’s head of airspace and air traffic control in Washington, DC.

Rhona North, SSC polar programs information system security manager, has spent time in Antarctica, and recalls that, after donning cumbersome outdoor gear and goggles to protect her eyes, she once transported updated IT equipment from one building to another on a sled. That’s an experience few IT professionals encounter.

Summary

SSC Atlantic’s first 20 years partnering with NSF in Antarctica have been an unqualified success; its employees look forward to continuing their support, enabling scientific research and keeping operational systems up and running during the next 20 years “on the ice.”

As commanding officer, Heller said, “At one level, polar support is one effort among 850 other concurrent efforts at SSC Atlantic that make our world safer, but on another level, the science at the poles has the potential to address the most important questions of our time.”

About the author:

Diane Owens is a senior writer, manager of the Daily News blog and editor of the Chronicle Lite employee newsletter at Space and Naval Warfare Systems Center Atlantic.

A LOOK AHEAD

BASIC RESEARCH

►► Dr. Walter F Jones

Most of the Office of Naval Research (ONR) programs that you hear and read about are large, high-payoff demonstrations such as the electromagnetic railgun and solid-state laser. We should never forget, however, that these technologies would never have been possible without a long-term investment in basic and applied research, which will be the focus of the next issue of *Future Force*. Almost half of ONR's \$2.2-billion science and technology program is spent on our discovery and invention program, performed primarily by scientists and engineers in universities and government laboratories, including our own Naval Research Laboratory (NRL). This program includes basic research and some applied research, but focuses on research that is not tied directly to any naval system. Our ONR program officers believe these efforts will be relevant to the Navy and Marine Corps either now or in the future. Good basic research has broad applications—some applications we can't even dream of right now! The basic research work that is planned and managed by program officers at ONR is focused on developing a fundamental understanding of oceanography, electronics, materials, aerodynamics, and other areas that are critical to the current and future Navy and Marine Corps. Our basic research work is performed by world-class professors and graduate students at major universities and by equally outstanding scientists and engineers in government laboratories. Many of our principal investigators have been recognized by their respective professional technical societies, and several have won Nobel Prizes.

The advantage of having all of ONR's program officers in the same building is that the fundamental knowledge from our basic research program can be easily transitioned to more advanced development programs by simply walking down the hall and interacting with other ONR scientists and engineers. Many program officers manage programs that include elements of basic research, applied research, and advanced technology development. They are overseeing programs right now that will define the Navy and Marine Corps of the future.

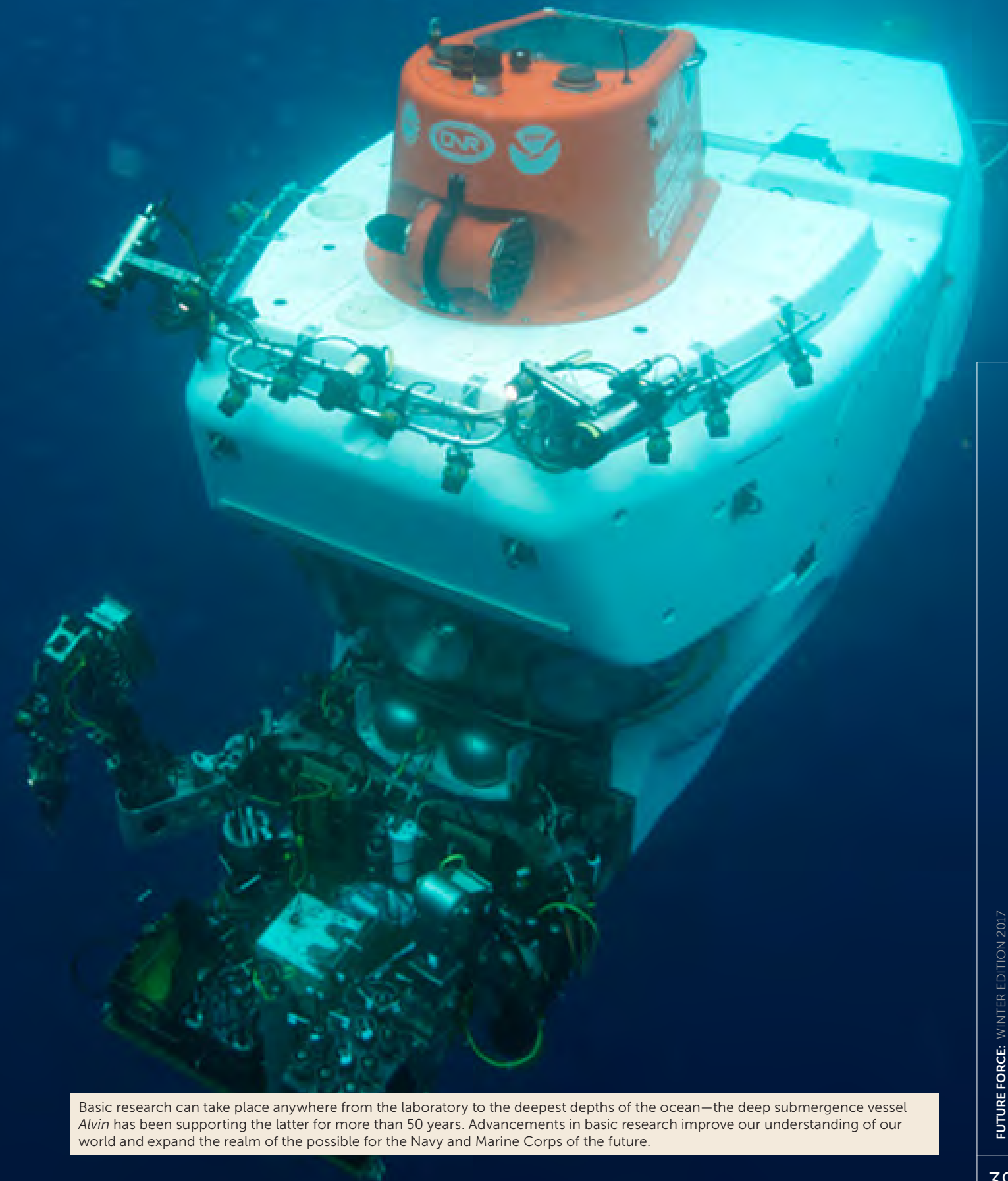
The products of our basic research program include two important elements—critical knowledge that will have broad application and the people who work on these research programs. Many graduate students in the United States perform their research work with ONR sponsorship to study topics we believe are critical to the Navy and Marine Corps of the future. Some actually go to work at NRL or in one of our warfare centers, others will teach in universities that perform much of our basic research, and still others will go to work in industry that will produce most of our future naval warfare systems. In any case, we will benefit from their graduate research experience as they become part of the Naval Research Enterprise in one form or another.

It is important to note that ONR is not the only investor in basic and applied research. Other services and defense agencies, other government offices, and many other nations invest substantial funding in research and development. For decades, the United States dominated worldwide investment in basic research, and the Department of Defense dominated research investment within the United States. Neither of these statements is true today. Commercial investment in research and development has outpaced defense investment in the United States, and the growth of research investment in many other nations far outpaces investment trends in the United States. We must continue to work through ONR Global to leverage the research investments of international partners to help ensure we can keep our military forces, along with those of our allies, at the forefront of technology. Our investments in basic research will keep us in the lead in this critical worldwide effort.

Our discovery and invention basic research program provides fundamental knowledge and outstanding technical professionals. The knowledge base from our long-term basic research will provide the ability to quickly move in any required direction to support the current and future Navy and Marine Corps. Today, lasers and railguns; tomorrow, who knows?

Dr. Jones is the executive director of the Office of Naval Research.

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Basic research can take place anywhere from the laboratory to the deepest depths of the ocean—the deep submergence vessel *Alvin* has been supporting the latter for more than 50 years. Advancements in basic research improve our understanding of our world and expand the realm of the possible for the Navy and Marine Corps of the future.



US Marines with Marine Rotational Force Europe (MRF-E) conduct live-fire training in preparation for exercise Joint Viking, in Porsangmoen, Norway, on 1 March 2017. The Marines of MRF-E attended a three-week cold weather training package led by the British Royal Marine Mountain warfare unit to improve their ability to perform in cold-weather environments. (Photo by Sgt Patricia A. Morris)

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