Briefing Note

The Sea Is the Foundation: Why the Marine Environment Matters for Arctic Domain Awareness

Douglas Causey and Maria E. Hanson

Introduction—The Arctic Ocean

The Arctic Ocean is changing faster than the systems built to watch it. Since 1979 the Arctic has warmed nearly four times as fast as the planet as a whole (Rantenan et al. 2022). The twenty lowest summer sea-ice minimums in the satellite record are the twenty most recent ones, 2007 through 2026 (Riordon 2026). Winter ice peaked at 14.29 million square kilometers in March 2026, statistically tied with 2025 for the lowest maximum on record, and ice volume that month was reported as the lowest ever measured (Klein et al. 2026). Less ice means more of everything else. In 2025, 1,812 unique vessels operated inside the Arctic's Polar Code area, about 40 percent more than in 2013 (Humpert 2026).

Domain awareness is an official term for a plain idea: knowing what is happening in a region well enough to make good decisions about it. In the Arctic, that means knowing who and what is there, what they are doing, and what the environment will let them do (Causey et al. 2024). Most public discussion focuses on the first two, on sensors, and on ships, aircraft, and satellites. This briefing note argues that the third, the marine environment, is actually the foundation for increased Arctic domain awareness (Churchill 2015). Sea ice, ocean conditions, weather, and the shape of the seabed decide where ships can travel, where submarines can operate, how well sensors work, and how quickly a rescue can reach someone in trouble. Without a complete picture of the environment, activity is hard to interpret and harder to act on (Byers 2019, Causey & Greaves 2021). This briefing note explains why, identifies the main gaps, and recommends how investment in environmental observation can serve security, safety, and economic goals at once.

Douglas Causey, PhD is an Affiliate, Arctic Initiative, Belfer Center for Science and International Affairs, Harvard Kennedy School, Harvard University, Professor, Dept. Biological Sciences, University of Alaska Anchorage

Marie E. Hanson, MS is a Policy Analyst of the Ted Stevens Center for Arctic Security, PhD student, University of Alaska Fairbanks

What domain awareness means, and why the Arctic makes it hard

Domain awareness means having a timely, accurate understanding of what is happening in a region, including anything that could affect its safety, security, or economy (Berkman & Young 2009, Causey et al. 2022). Three features make that task unusually difficult.

Distance and emptiness

The Arctic has few people, almost no roads, and little commercial demand for large communications or surveillance networks, so the infrastructure that blankets other regions never got built. Analysts describe the result as sparse coverage and limited ability to move data cheaply and reliably (Fish 2024).

Poor coverage from space

Geostationary satellites sit above the equator, so at high latitudes they hang near or below the horizon. A Naval Postgraduate School study of Coast Guard needs concluded that dependence on such satellites will not support optimal Arctic operations (Forster & Lied 2021). Radio is not a simple fix: charged particles in the upper atmosphere frequently disrupt high-frequency signals at high latitudes, leaving mariners with static instead of a clear channel (Machi 2018). New low- and medium-orbit constellations and polar-orbit payloads are being fielded to close the gap, but coverage remains uneven (Fish 2024).

A hostile and shifting environment

Ice, fog, storms, and darkness degrade the sensors that do work and make ships harder to find and reach (Berkman et al. 2022). Ice also moves, so a chart that was correct last week may be wrong today.

These problems compound one another. Sparse sensors make each observation matter more, and weak data links mean fewer observations reach the people who need them. This raises the value of environmental knowledge (Causey & Filamontov 2023). If analysts know where ice is open, where weather will close in, and how sound travels through the water, they can predict where activity is possible, interpret what sensors show, and point scarce assets in the right direction (Palosaari & Tynkkynen 2015).

A sea in motion: ice loss and rising traffic

The ocean that governments are trying to watch is not the one they planned for a generation ago, and it is still changing.

The ice

The 20 lowest summer minimums on the satellite record are the 20 most recent years (Humpert 2026). Winter ice is following: the 2026 maximum of 14.29 million square kilometers tied 2025 for the lowest on record, and NASA and NSIDC scientists report that much of the remaining ice is thinner (Klein et al. 2026, Sangomia 2026). Thinner ice breaks up and moves more readily, which matters to anyone planning a voyage or a search. Even the headline ranking depends on the method. The 2026 summer minimum is the 11th lowest in one widely used dataset and the 14th lowest in another while NASA describes it as tying for 10th (West & Blockley 2026). The practical lesson is that ice is a measured, contested quantity, not a given, and that agreement on a common operating picture must be built (Aaboe et al. 2026, Barodo et al. 2023).

The traffic

In 2025, 1,812 unique vessels operated inside the Polar Code area tracked by the Arctic Council, about 40 percent more than in 2013. The activity is intensely seasonal. In September 2025 alone, 1,060 vessels entered the area, 58 percent of the year's total (Humpert 2026a). In other words, the ice minimum sets the rhythm of human activity, and *the busiest weeks are the ones in which conditions are changing fastest*.

The routes

The Northern Sea Route along Russia's coast recorded 103 transit voyages in 2025, a record at the time (Humpert 2026a). Transits in 2026 passed that record by the end of September.

Traffic in the Arctic region is small when placed beside the world's major trade routes, but growing, and all growth is concentrated in a just few months of the year. Russian resource projects and Russia-China trade are the catalyst for much of the traffic increase, which in turn, affects who is present and who is watching (Willis & Dupledge 2015). Past patterns are a poor guide: baselines from even a decade ago understate how far north ships can reach, and when. Activity that is not tied to a current picture of the sea *will* mislead.

Why the marine environment shapes what can be seen

Environmental conditions affect domain awareness in two ways: they determine what activity is possible, and they decide how well anyone can observe it.

Ice decides where ships can go

Ice extent, thickness, and movement determine which routes are open, which hulls can use them, and when. Government ice centers exist for this reason. The U.S. National Ice Center, for example, analyzes sea-ice extent at 1-kilometer resolution using a system built jointly with NSIDC (Doris 2026). These products are used to plan voyages and to track seasonal change, so they are part of the operating picture, not a separate scientific exercise.

Weather and darkness limit sensors

Months of winter darkness and frequent cloud limit optical imaging, which is why radar satellites matter so much, when storms and icing slow or ground the ships and aircraft that would otherwise fill the gaps.

Sound is the main sensor underwater

Light and radar do not travel far below the surface, but sound does, and how it travels depends on the temperature and salinity of the water. In the Beaufort Sea, a layer of warmer water beneath a colder one forms a channel that guides sound. Researchers reported in 2017 that sounds there could be detected about 400 kilometers away, where a decade earlier they faded after about 100 km (Nowogrodski 2017). More recent work finds that the changing structure of the water is stabilizing that channel and focusing sound energy more tightly (Niklasson & Rowe 2024). The U.S. Navy depends on underwater sound for submarine communication, and the reporting noted that the channel's extent is probably shifting every year. What can be heard, from how far, and by whom, is set by the ocean itself, and the ocean is changing (Chen 2025).

Environmental knowledge makes scarce sensors go further

Satellite surveys can scan large areas for anomalies and then cue higher resolution views at the ones that matter (Berkman et al. 2022, Fish 2024). Deciding which anomalies matter requires knowing what is normal for that place and season. A ship following a gap in the ice is expected. A ship in an area that should still be ice-locked is a signal. *Environmental data turns a track on a screen into information that can be utilized and interpreted.*

Where the gaps are

The Arctic seabed is largely unmapped

After a 2025 update to the international bathymetric chart, about 25 percent of the Arctic Ocean floor has direct depth measurements, up from roughly 15 percent. Depth data is still missing for almost 75 percent. Thick ice and extreme weather make surveying hard, and powerful icebreakers are essential. A seabed that is not mapped is harder to navigate over, harder to model acoustically, and harder to guard (Jakobsson et al. 2024).

Seabed infrastructure is exposed

In 2026, Reuters reported that British, Norwegian, and U.S. forces disrupted a Russian exercise near Svalbard involving equipment designed to disable undersea cables without leaving evidence (Baes 2026, McFarlane & Slattery 2026). The two fiber-optic cables linking Svalbard to mainland Norway, each about 1,400 kilometers long, carry data from a major satellite ground station. Russia did not comment, and the Kremlin has repeatedly denied sabotage plans (Baes 2026).

The hardest question is dual use. Almost all environmental data helps both a scientist and a submariner. Some information should be shared, some protected, and the boundary will keep moving. The answer is neither to lock everything away nor to publish everything. It is to decide deliberately which categories of data serve everyone's safety and can be shared, and to protect the rest.

Recommendations

The most direct path to strengthen Arctic Domain Awareness is by strengthening what it rests on.

1. **Fund environmental observation as core infrastructure.** Sea-ice, ocean, and weather observation should have multi-year, protected funding, treated like radar or satellites rather than as discretionary science. At minimum, the ice and snow data products that shippers, forecasters, and defense planners rely on should not be allowed to degrade.
2. **Build one shared picture and name who owns it.** Vessel tracking, ice analyses, ocean and weather forecasts, and seabed data should be combined in a common product, with one lead agency accountable for delivering it to Coast Guard, Navy, and civilian users. Fusing these layers is what allows a sensor cue to be interpreted.
3. **Close the seabed and acoustic data gap.** Expand Arctic surveying with allies, using icebreakers and uncrewed vessels where ice allows, and maintain long-term oceanographic and acoustic monitoring in places where conditions are shifting, such as the Beaufort Sea.
4. **Make communications a first-order requirement.** Continue fielding low- and medium-orbit and polar-orbit systems, with priority to links for search and rescue and for moving

environmental data to the people who need it.

5. **Protect cooperation where it works and set clear rules for data.** Keep search and rescue, monitoring, and marine-protection work going through the Arctic Council's working groups. Decide in advance which categories of environmental data will be shared openly and which will be protected.

Progress should be measurable. Useful indicators include the share of the Arctic seabed with direct depth measurements, the number of persistent ocean and ice observing stations, and the time it takes to get an ice or weather product from analyst to ship.

Conclusion

The sea sets the terms for everything else in the Arctic. It determines where ships and submarines can go, how well sensors perform, how quickly help can arrive, and which infrastructure is at risk. A common objection is that scarce defense dollars should buy sensors and platforms first, with ocean observation a lower priority. But a sensor without environmental knowledge records what it sees but can't explain it. Environmental observation also serves rescue, shipping, science, and defense together, which makes it one of the few Arctic investments with support across all four. The sea ice is thinning and sea traffic is rising now. The foundation must be built to hold strong before the structure resting on it is tested.

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