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Artificial Intelligence and the Arctic

Maps of the Arctic are misleading. The vastness of the region is not fully captured in two dimensions: the Arctic Circle **spreads** across roughly 14.5 million square kilometers (km^2), a **greater** area than any country in the world save Russia. This fact is not only trivia; it has serious implications for the well-being of the communities who live there, the militaries who monitor it, and the scientists who seek to better predict the coming global impacts of climate change. To perform their functions well, each of these actors seeks tools to compensate for or overcome these vast distances, as well as the harsh environment that makes sustained presence in the Arctic so challenging. Increasingly, these communities—some of which have been in the Arctic for decades, and others for centuries—are coming to understand that artificial intelligence may be essential to monitor the region and predict changes within it.

In this edition of *Northern Connections,* the authors tackle the implications of this new tool for national security and climate research. Both pieces illustrate how governments, scientists, and Indigenous communities can use artificial intelligence/machine learning (AI/ML) to better understand key Arctic problem sets, particularly those that involve parsing either a massive amount of data or complex and shifting future scenarios. At the same time, both note that AI/ML, while holding immense potential, remains not entirely proven. In some cases, a lack of funding hinders a robust deployment of AI/ML; in others, it must compete with more established and orthodox methodologies.

In the first essay, **Lieutenant Commander Michael Bielby** of the Canadian Armed Forces lays out Canada's incipient efforts to use AI/ML for its domain awareness mission in the far north. He explains the unique physical challenges of the region and the insufficiency of using only crewed resources to monitor it, given the finiteness of those assets and the vast distances involved. Passive and active sensors are the means to compensate for this reality, but as Lt. Commander Bielby notes, this creates a new problem: a "deluge" of data where it is not always possible for human operators to distinguish quickly (enough) between what might be an adversary vessel and what might simply be natural debris. He argues that AI/ML may well be the answer to this riddle.

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The second contributor is **Dr. Lillian "Doc" Alessa,** an Arctic and intelligence expert and a member of the National Climate Assessment Team. Dr. Alessa interrogates the applicability of AI/ML for researching the thaw of Arctic permafrost, which underlies 25 percent of the Northern Hemisphere. The rate at which climate change causes this permafrost to melt has serious consequences for not only local Arctic communities, but the entire world. Dr. Alessa argues that, especially if paired with the knowledge of those local communities, AI-generated models will allow policymakers to better understand permafrost thaw as well as test different scenarios of melting against various tactics for intervention or adaptation.

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Military Implications: Artificial Intelligence in the Arctic

By Michael Bielby

A responsibility of every state is to exercise its sovereignty through the protection of its defined territory from intrusions by foreign states. For that to happen, the state must understand what is happening within those physical spaces. It must have domain awareness. For a number of reasons, this becomes extremely challenging in far northern regions. In recent years, Canada and other Arctic states are increasingly considering how to develop and deploy AI/ML tools to address this domain awareness challenge.

Approximately 40 percent of Canada's land mass, roughly 3.5 million km^2, lies north of 60° north latitude. As with most inhabited Arctic regions in North America, Europe, and Russia, it is scarcely populated—in Canada's case, fewer than 120,000 people, or less than one person per approximately 26 km^2. Understandably, it is very difficult to generate the requisite level of domain awareness necessary for the state to exercise sovereignty in this remote territory. The obvious solution is to start generating that awareness before state actors can breach territorial boundaries—in other words, to detect them at sea.

This introduces a whole new problem set, as Canada's exclusive economic zone north of 60° encompasses approximately 4 million km^2. The economic and logistical feasibility of monitoring such a vast area using crewed resources would be taxing enough, but the task of generating maritime domain awareness becomes financially and logistically untenable when considering the inhospitable climate of the Canadian north, a lack of suitable extant infrastructure, and the fact that infrastructure development projects are plagued by supply chain issues and a shortened building season. To further exacerbate the issue, the finite crewed resources suitable to conduct this mission are also required to deliver

similar strategic effects on overseas missions. As such, the only viable option, at this time, for Canada becomes the employment of space-based intelligence, surveillance, and reconnaissance (SB-ISR) capabilities.

Given the various factors that complicate maritime activity in northern waters—such as sea state (high sea states result in sea spray and accumulation of ice on the upper decks in sub-zero temperatures, which can affect ship stability and potentially result in a ship sinking or capsizing), icebergs, and the varying constructions of vessels plying those waters—no single SB-ISR sensor type is a panacea. An active sensor may detect the signal return off an object (e.g., metal reflect signals better than fiberglass) but cannot necessarily differentiate between a ship and a **bergy bit**, and passive sensors can be defeated simply by turning off an emitter. Therefore, a mix of active and passive sensors ensures a greater probability of detecting contacts. However, in solving one problem, another is created: multiple sensor feeds create massive amounts of positional data. The result is that Arctic operators drown in the deluge of data from SB-ISR sensors while starving for domain awareness.

If the deluge of data is framed as a **big data** issue, there are four variables to consider: volume, variety, velocity, and veracity. Maritime positional data from various sensor feeds for the approaches to North America and the Arctic exceeds tens of millions of reports daily (volume), is received in a variety of structured and unstructured reporting formats (variety), and arrives continuously (velocity). System operators are not able to keep up with the velocity of the data flow from SB-ISR sensors while performing the necessary quality-control functions (veracity) while also monitoring for anomalous behavior as bad actors attempt to exploit various interstitial gray areas.

The only way to correlate the volume and variety of data at the velocity in which it is received is through the adoption of AI/ML. This technology will not only solve the operators' problems but, at machine-to-machine speeds, will be able to cross-cue additional sensors based on the data received, thereby improving the probability of achieving positive identification and subsequent domain awareness.

The Canadian Armed Forces (CAF) is still somewhat of a newcomer to the adoption and implementation of AI/ML to support maritime domain awareness. However, the Royal Canadian Navy's Innovation Team recently trialed an advanced maritime domain awareness software that uses AI/ML to detect surface vessel traffic acting unusually. In addition, the Royal Canadian Air Force, as the CAF Functional Authority for space, has factored AI/ML requirements into many of the SB-ISR projects currently under way. Given the complexities of the approval process for CAF projects, the implementation of many of these solutions is still a few years off.

In the interim, the CAF's most effective AI/ML mitigating strategy has been the reinvigoration of multinational partnerships, such as the Five Eyes intelligence alliance, and the (re)establishment of information-sharing agreements among allied nations and partner departments within the Canadian government. Once the data is shared, recipients can process it and notify the broader operational community of any indications and warnings of anomalous behavior. Within national chains of command, or in accordance with extant multinational treaties, this then allows platforms such as aircraft, ships, and

uncrewed aerial vehicles (UAVs) to be tasked to conduct ISR missions against specific targets. This is a more efficient use of limited resources for *known* high-value targets and for missions of national importance. However, the weakness in this strategy is revealed in situations where the military is dealing with contacts that have not been positively identified and whose value is unknown. In such cases, the competition against other national interests and departmental priorities for the allocation of scarce resources makes it difficult to justify ISR missions. This is why this multinational approach, while useful, remains an interim solution at best.

The more that countries depend on SB-ISR in the vast and remote high north to aid in the exercising of sovereignty, the more likely Arctic operators are to drown in a deluge of big data. In the long term, investing in the development of robust AI/ML capabilities that can be employed in the region is the only way for Arctic states to turn big data into domain awareness and ensure their sovereignty is protected.

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The views expressed are those of the author and do not necessarily reflect those of, or imply endorsement by, the Canadian Armed Forces and its components.

GABRIEL BOUYS/AFP via Getty Images

Artificial Intelligence and Permafrost

By Lillian "Doc" Alessa

Even though the population of the Arctic is only around 4 million people, the region has global significance due to its strategic geography, exploitable natural resources, and rapid rate of climate and environmental change (CEC). It also contains permafrost, which is ground that remains below 0°C for two or more consecutive years, making it frozen and a largely stable foundation for the active layer, which supports above-ground flora, fauna, and built infrastructure.

Continuous (deep) and discontinuous (shallow) permafrost comprises a **full 25 percent** of the Northern Hemisphere, and current estimates suggest that between 30 and 85 percent of current subsurface permafrost will **thaw within a century**, depending on global temperature increases. While permafrost thaw is often thought of as a future phenomenon, it has been changing rapidly for roughly the past 40 years. The effects can be readily seen in natural terrain and built infrastructure, where degradation is ultimately placing at risk roughly **$15.5 billion** in civil infrastructure in the United States alone, much of which supports the defense enterprise. Furthermore, given that permafrost

covers approximately **65 percent** of the Russian Arctic, it is necessary to understand, with exquisite precision, where and when changes to Russia's infrastructure will result in opportunities to gain strategic advantage by improving the Department of Defense's own resilience to a highly variable operating environment. Understanding the complex dynamics of permafrost thaw and its effects on strategic activities such as defense and security requires leveraging all available tools, particularly AI/ML.

This idea bucks a deep-seated tradition in Arctic research, where field research is synonymous with the golden era of exploration. However, field research places significant burdens on local communities and funding agencies, which incur high costs for increasingly low returns on investments. Especially when combined with the deep pools of local and place-based knowledge of Indigenous peoples, new tools such as AI/ML are a better means to improve U.S. and allied resilience to climate change.

However, the concept of resilience in Arctic defense is poorly articulated. It is a term often overused and thrown around in strategic intents and policies, holding different meanings for different interest groups. Here it is defined as the ability of three types of integrated systems—(1) social (people, including their cultures and perceptions); (2) ecological (the natural environments in which they live); and (3) technological (the tools and structures used by human organizations)—to maintain desired functions despite climate change. To be achieved, Arctic resilience in this context must include the social elements of cultures and human behavior. Given the many variables and their complicated interactions, it is more critical than ever that social and societal systems be incorporated into permafrost science.

AI/ML promises to yield the needed insights in time to be proactive and adapt successfully to the unprecedented rate of CEC. A holy grail for permafrost researchers, geopolitical strategists, and military planners alike is the development of data-driven scenarios within which it is possible to forecast potential early warnings of threats and opportunities to guide proactive interventions. AI/ML permits the user to take known interactions of variables (i.e., rule sets) within academic disciplines and apply them to a range of scenarios at landscape and regional scales as an integrated system. Working within these scenarios, AI/ML can process data to visualize the consequences and trade-offs of different CEC conditions and types of interventions at the local scale. Extending this to permafrost and defense, AI/ML creates knowledge of where and when a strategic advantage may be gained and by whom as CEC affects different types of infrastructure and ecological processes. For example, permafrost underlies the majority of Russia's Arctic coastline and infrastructure in the region. Using AI/ML to model these effects accelerates the ability to accurately gauge, for example, which military bases will be at risk and what the consequences are to the United States and its partners and allies, which can lead to better precision in defense planning and diplomacy.

AI/ML can be used in this context only because extensive funding over the past 30 years has yielded rule sets for permafrost physics, soil biology, and behavior of built environments that are highly precise. This means AI/ML worlds can be used to scale down to individual structures, which can rapidly improve the way infrastructure, logistics, and operations are designed. However, knowledge of how humans will react to such changes is lacking, such as how communities **could be held at risk** by and respond to the loss of freshwater resources. AI/ML offers a readily available laboratory to run scenarios and

understand trade-offs far more quickly, cost effectively, and safely than could ever be accomplished in the past. Its value is increased when it is used as a tool that enhances engagements with diverse human communities. Since it allows multiple variables to run simultaneously, and since these series can be adjusted and amended in real time by human stakeholders and **rights-holders**, it also helps eliminate much of the uncertainty that policymakers and decisionmakers dislike. For example, it can be used to better identify key water sources and the systems that need to be in place to either protect them or mitigate their loss, in order to ensure their resilience for future use. In short, knowing the likely effects of permafrost on key resources allows affected communities to articulate consequences, trade-offs, and their approaches to dealing with them.

It is important to note that AI/ML does not provide answers or solutions, it merely enables the humans tackling these challenges to ask better questions, refine understandings, and then ask the harder questions together. This cycle has traditionally taken months or years but can be done within hours via AI/ML-assisted research. Indeed, the key to addressing the many unknowns of a rapidly changing Arctic and the roadmap to resilience in defense and security is asking the right questions. Using AI/ML offers the freedom to think and do things differently by envisioning scenarios of plausible futures where a diverse range of adaptation interventions can be examined—in collaboration with the people, especially local actors, who will have to carry them out.

This latter point underlines yet another benefit of leveraging AI/ML: this process of refining questions simultaneously enhances partnerships. In fact, one of the most critical factors in using AI/ML effectively is close collaboration with rights-holders and stakeholders—ideally at the same time—whether they be local communities or military planners. Models that are not aligned with the perceptions and knowledge that exist at local scales induce higher uncertainties in outcomes. In other words, using AI/ML to understand the consequences of changes in permafrost and develop the interventions to build resilience relies as much on human behaviors as it does on engineering. AI/ML is a key tool to bring the end users, operators, and stakeholders directly into the data-driven scenarios where human perceptions, decisionmaking, and reactions can be incorporated in real time, something that cannot be achieved outside of AI/ML-built worlds.

Despite the overwhelming evidence that human behaviors and social dynamics are powerful determinants of resilience outcomes, disciplinary approaches in engineering, human factors (i.e., human-machine teaming), and ecology heavily dominate Arctic permafrost research. Alone, these will not deliver the level of adaptation needed to address CEC in the Arctic because **adaptation is itself a human endeavor**, which requires the integration of the social sciences.

This adaptation can be accomplished by leveraging the analytic power of AI/ML to integrate the authoritative data available in hand, in order to identify critical gaps in knowledge, training, and preparedness and gain a more precise understanding of resilience. Approaching permafrost in the Arctic as an engineering problem will not lead to resilience if social dynamics are not central to analyses. AI/ML has often been criticized as something that removes humans from the loop, but it is only through **engagement** with partners—those who must deal with the consequences of changing permafrost, especially the loss of freshwater systems—that it is possible to develop

accurate scenarios where decisions can be made and the effects of those decisions can be seen more quickly. Approaching permafrost thaw in the Arctic through AI/ML-assisted scenarios built and amended by stakeholders will result in more effective policies and the acquisition of technologies that are tailored to specific adaptations. For example, instead of trying to move water over long distances, something that requires an enormous amount of fuel, water storage systems can be engineered specific to the locale in which permafrost is changing. Innovation is often met with **resistance** even at the highest levels, but a growing number of practitioners—including colleagues across academia, Arctic communities, the U.S. government, and partners from the Five Eyes and NATO alliances—recognize the need to shift the approach to science and encourage the use of AI-related tools such as **agent-based modeling**.

AI/ML is clearly a **useful tool** for permafrost research in the Arctic, and other nations are beating the United States to it. Leveraging it may even lead to ideas for novel applications relevant for questions of Arctic geopolitics, such as Russia's militarization of the region. Without AI/ML, the United States may not gain insights at the speed of need, and research will remain slow and expensive, yielding models that are less useful to the U.S. defense enterprise and the stakeholders and partners in the Arctic on whom the United States relies. Leveraging AI/ML allows the mess of reality, in all its glorious diversity, to be incorporated into a structured set of analyses and scenarios that are only possible with advanced computational tools. It is the means by which the inputs from diverse stakeholders, whether the defense enterprise or an Indigenous corporation, can be fully included in establishing and maintaining adaptation actions that collectively ensure resilience in a rapidly changing Arctic.

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The views expressed are those of the author and do not necessarily reflect those of, or imply endorsement by, the University of Idaho or the Department of Defense and its components.

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