Security and Climate Risk in the Arctic

Temperatures & Tensions Rise

Investigating the threat Arctic climate change poses to international security

Woodwell Climate Research Center

The Converging Risks Lab

Council on Strategic Risks

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June 2021

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Cover page image attribution:
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An oil rig in the Russian Arctic.
By Vladimir Endovitskiy

Across the Arctic, temperatures are warming faster than any other location on Earth, rapidly shifting the operational environment of an already dangerous and inhospitable region. In the coming decades, the region is set to experience intense change along two main trendlines: first, the major environmental shifts that accompany our current warming trajectory, including sea ice loss and permafrost thaw; and second, an influx of new human activity, including resource extraction, the development and use of new shipping lanes, and commercial and military traffic.

These trends take place across a region witnessing increasing defense force activities by many Arctic nations. For the past decade, Russia has been expanding its military presence and upgrading infrastructure along its Northern Border, while improving the technology of its submarines, ice-breakers, and forces to enable greater control over sea-lanes.[1] Meanwhile, NATO allies have conducted increasingly larger joint training exercises in the region, with the United States refurbishing bases and considering the creation of an Arctic brigade.[2] China, classifying itself a "near-Arctic nation," has likewise exerted its growing interest in a region it deems critical to commercial futures, investing in polar-capable ships and icebreakers, outlining an Arctic strategy, and detailing ambitions to build a new "Polar Silk Road" in its 14th Five Year Plan.[3]

Seen together, these developments present worrying realities for ensuring security in the region, including from the point of view of U.S. interests and power projection. Critically, changes in the environment and human activity are not expected to happen gradually, but instead to cascade in unpredictable new extremes, increasing uncertainties in a manner that makes building resilience difficult. These developments increase the likelihood for accidents, misunderstandings, and disasters in a region that is already fragile and defined by growing great power tensions. Likewise, given that major Arctic players are nuclear powers and adversaries, and possess multiple facilities and nuclear armaments in the region itself, the risk of growing military tensions in the region, alongside destabilizing climate factors, should not be taken lightly. Security actors in the Arctic will need to navigate these icy seas with a full picture of the rapid changes underway in order to preserve cooperation, rather than conflict, in response to new challenges.

Changing Extremes

Climate change is not simply a macro-trend opening up the Arctic for more activity. It also encompasses a range of environmental changes that are destabilizing the region. Each of these changing variables, from amplified warming trends to accelerating sea ice loss, present new challenges for security actors.

Amplified Warming: For the past two decades, the change in Arctic temperatures has been nearly double that of the global average due to the phenomenon of Arctic amplification, with the strongest warming signals occurring in the Northern Hemisphere's autumn and winter months.[4] In fact, surface air temperatures in the Arctic during the most recent Arctic meteorological year (October 2019 - September 2020) were the second warmest on record, with the Siberian region seeing winter temperatures 3-5°C (5.4-9°F) above average (Figure 1).[5]

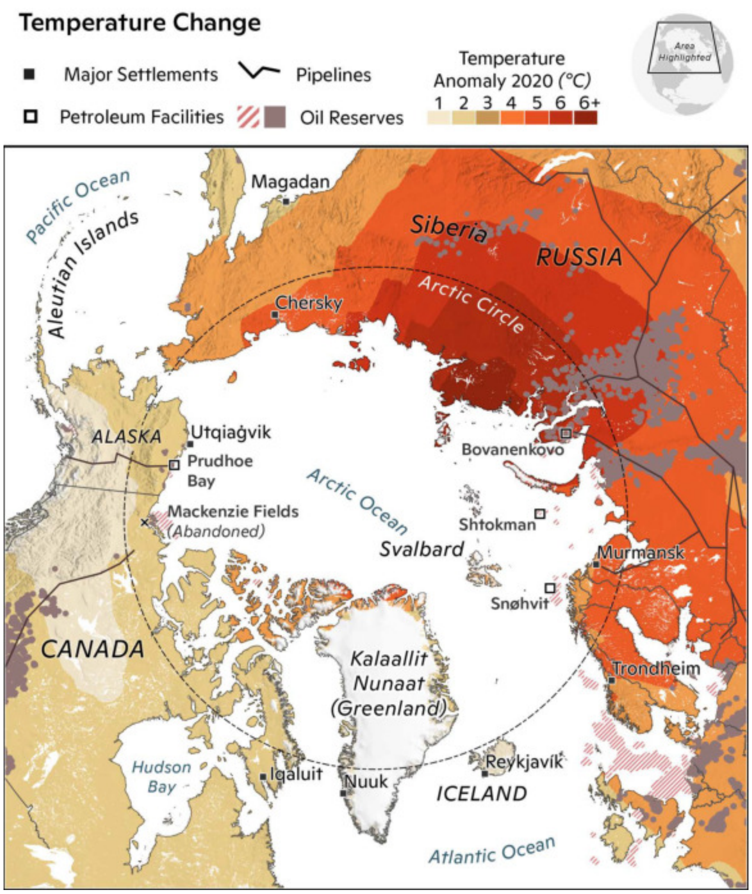

Figure 1: A map of the annual mean 2020 temperature anomaly (relative to 1951-1980 climatology) captures the Siberian heatwave, in which parts of Russia saw temperatures more than 6°C above average.

In the coming years, Arctic temperatures are projected to continue their dramatic rise (Figure 2), and will contribute to the enhanced risk of several hazards, including wildfires, intense precipitation events, and coastal erosion, all of which could have dangerous implications for Arctic communities and security actors in the region.[6] Recent research suggests that the Arctic may already be transitioning into a new climate regime as the region shifts away from its predominantly frozen state, with unprecedented changes in surface temperatures and sea-ice extent expected as soon as early- to mid-century.[7] Existing security actors will need to rapidly adjust their planning and presence accordingly. These high-latitude changes have implications that extend far beyond the Arctic, however, as sea ice decline and overall Arctic warming have been linked to changing weather patterns in mid-latitude regions like the Continental United States, increasing the likelihood of extreme weather events.[8]

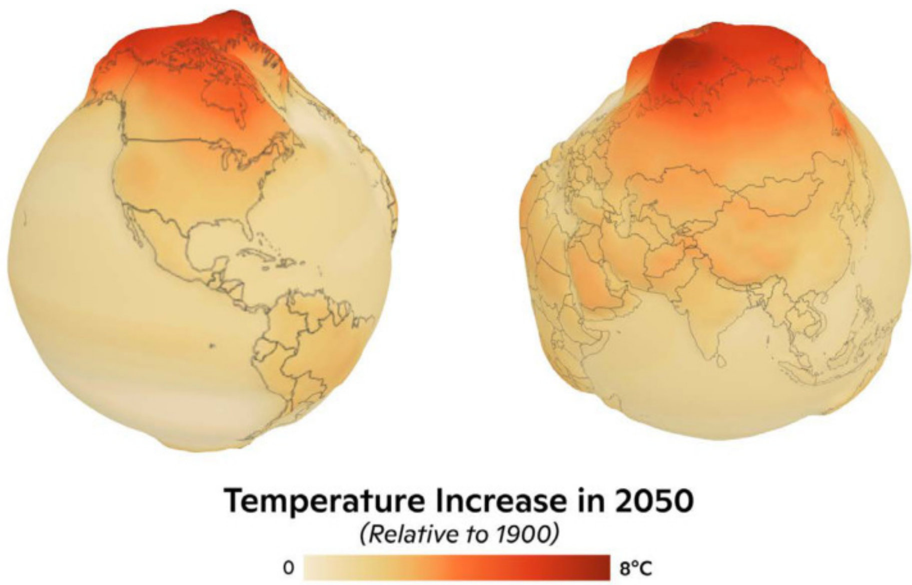

Figure 2:

Warming shown as elevation demonstrates the disproportionate effect of climate change on the Arctic. Values represent the difference between projected 2050 (2040–2060 average) and historical 1900 (1880–1920 average) temperatures. The RCP 8.5 scenario is used because of its close agreement with both historical and projected "business as usual" near-term emissions.[9]

Sea Ice Change: Since the 1980s, Arctic sea ice extent decreased by 3.5%-4.1% per decade on average.[10] In 2020, sea ice hit the second lowest recorded extent.[11] Arctic sea ice has also seen rapid reductions in average thickness, volume, and age.[12] Older sea ice is thicker and reflects more sunlight than young sea ice, and much more sunlight than the ocean surface, so as old ice disappears, more solar energy is absorbed, leading to increased warming. Furthermore, the loss of sea ice is threatening ecosystems and the isolated Arctic communities that rely on it and will have serious implications for commercial and security actors present in the region as ice melt makes routes increasingly unpredictable, unstable and prone to precipitating accidents.

Looking forward, the Arctic region could be ice-free during the Northern Hemisphere's summer as soon as ten to fifteen years from now.[13] Sea ice loss has been accelerating, meaning that even these rapid rates of change could be underestimated.[14] Climate projections indicate that in the 2021-2050 period, sea ice will reach a minimum extent of less than 20,000 km^2, compared to a 1981-2010 minimum extent of over 7 million km^2 (Figure 3)[15]—a reduction of over 99%.

The security implications of this have been long known. In 2011, the National Research Council issued a seminal study on the impacts such rapid climate changes in the Arctic would have on security forces and operations, highlighting sea ice loss as a potential destabilizing threat.[16] Together, diminishing sea ice and rising temperatures are opening up the region for increased commercial and military activities, presenting potential issues for navigation, communication, and submarine and anti-submarine warfare operations.[17] The United States Navy has publicly said that melting ice will make Arctic submarine forces more important, while Russian ice-breakers are already equipped with cruise missiles.[18] The Russian nuclear-powered cruise missile test accident that caused an explosion and multiple deaths in Nyonoksa in 2019 is just one example of how increasing activity in this melting region could lead to greater propensity of accidents or confrontation among militaries alongside tests and training activities.[19]

Projected climate and environmental trends will characterize a rapidly changing Arctic region across the coming decades and will presage new security risks. Investments made today in infrastructure, technology, and military capabilities for the Arctic region must take these changing variables into account, building resilience to the unprecedented temperatures and rapid ice melt that will increasingly define the coming decades.

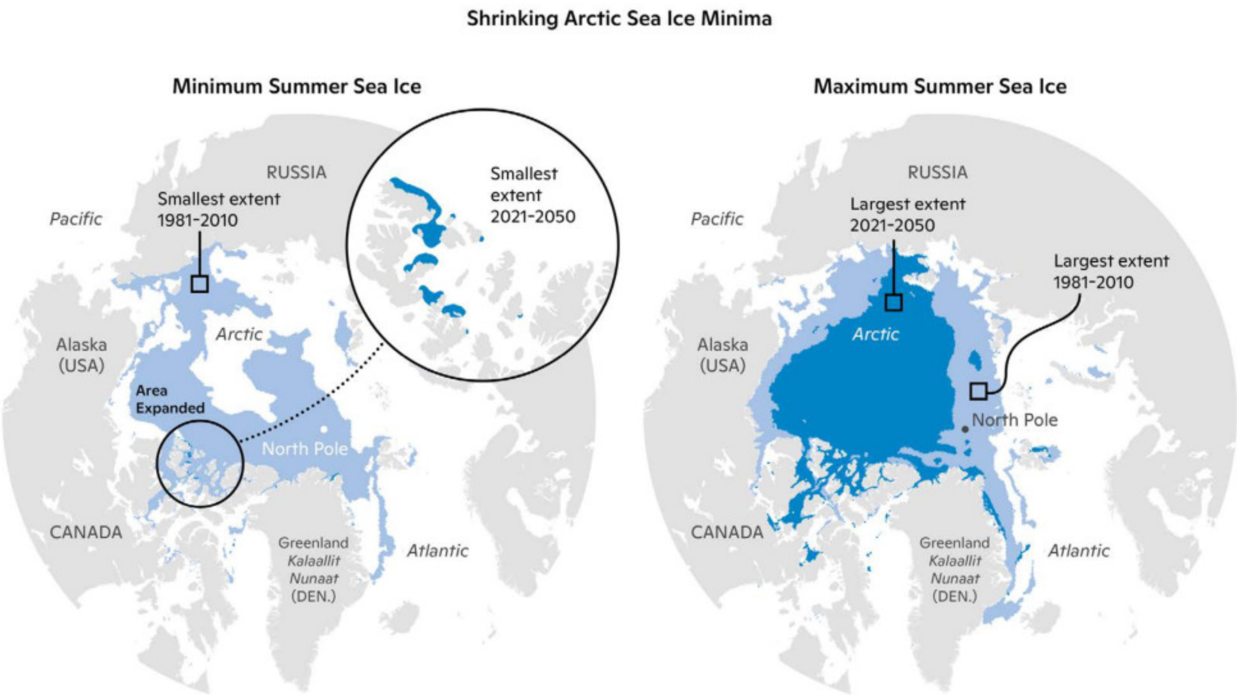

Figure 3: Sea ice loss is accelerating, and nearly ice-free summers open new regions for exploitation. The smallest minimum sea ice extent (left) and the largest minimum sea ice extent (right) are shown for two time periods, 1981-2010 (light blue + dark blue), and 2021-2050 (dark blue). On the left, the minimum sea ice extent in the future is reduced to less than 20,000 km^2 along the coast of the Canadian Arctic Archipelago (shown in inset)—a reduction of more than 99% from the historical minimum.

An Arctic training exercise in Bardufoss, Norway. By Cpl. Careaf L. Henson for the US Marine Corps

Unstable Ground

Permafrost—defined as ground that has been frozen for at least two consecutive years—covers the majority of non-glaciated land in the Arctic. As the Arctic warms, permafrost degradation (i.e. thaw) not only threatens local security and civilian infrastructure, but also presents novel security risks to human health and the global climate system.

Woodwell scientist standing in front of thawing permafrost at Duvanny Yar, northern Yakutia Russia.

Infrastructure Risks: U.S. security technology in the Arctic region is already known to be out-of-date, with military bases, radar stations, and national guard posts in Alaska and Greenland in need of modernization.[20] Permafrost degradation presents serious threats to this aging infrastructure, particularly in Alaska, where roughly half the state is underlain by permafrost, and where foundations of military and civilian infrastructure alike are already cracking, and will become increasingly destabilized as soon as the coming decades.[21]

This threat varies geographically across the Arctic and depends on a number of factors (Figure 4).[22] For example, regions of ice-rich permafrost thaw are particularly susceptible to ground subsidence, which has dangerous and costly consequences.[23] Urban destruction and accidents involving hazardous materials threatening human and environmental health have already occurred with the collapse of residential, industrial, and oil and gas infrastructure built on thawing permafrost, raising concerns about nuclear installations built on unstable, degrading permafrost as well.[24] Projects to refreeze permafrost under buildings and oil and gas pipelines, or re-engineer vital transportation infrastructure like roads and ports, are already underway. Overall, permafrost degradation in the Arctic region could cause trillions of dollars in damage globally across the next centuries, on current trajectories.[25]

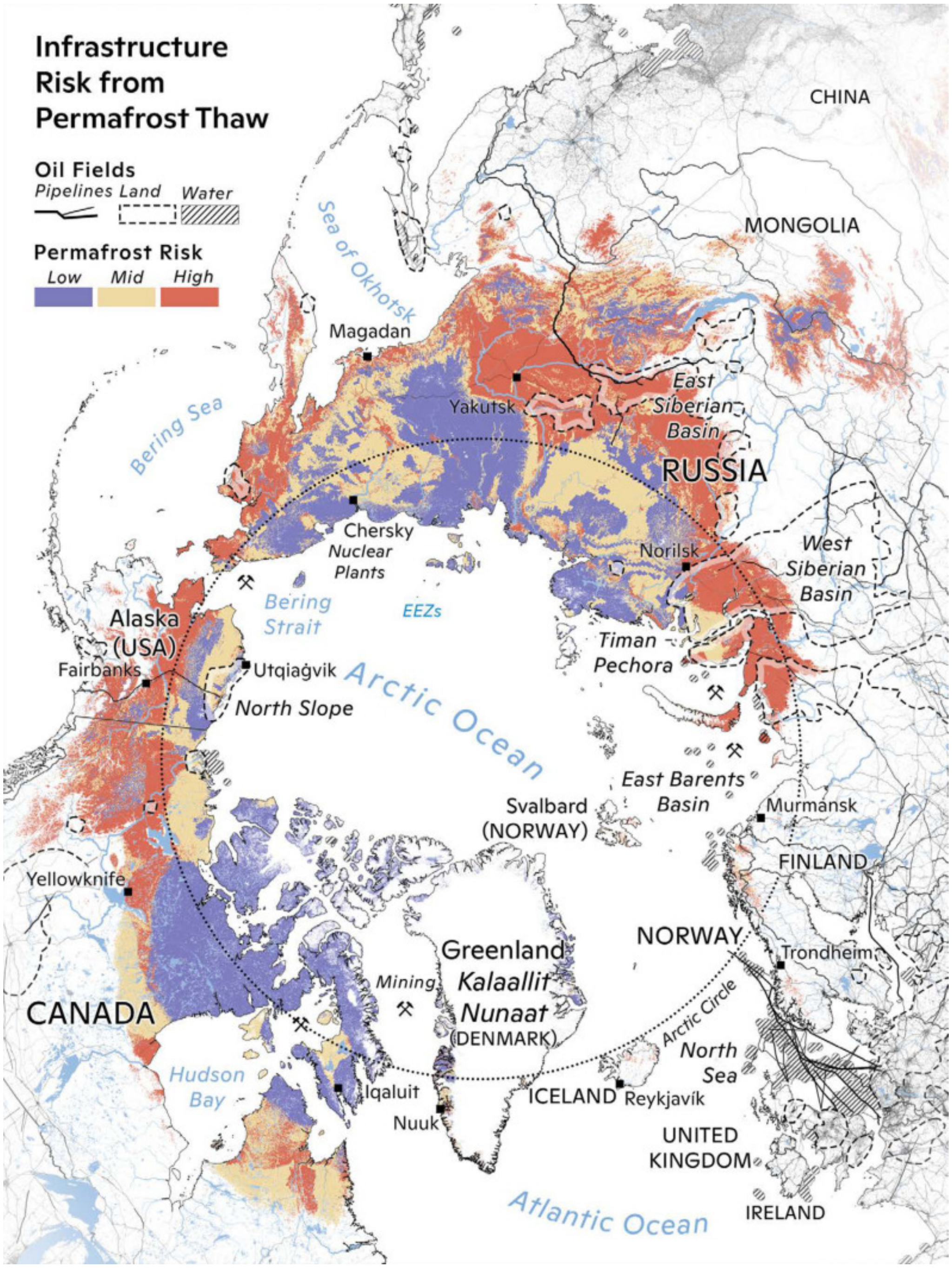

Figure 4:

Thawing permafrost threatens to destabilize Arctic infrastructure in the coming decades. Index represents risk for 2040-2060 using RCP 8.5.[26]

Novel Pathogen Exposure: While permafrost thaw disrupts the built environment, it can also unleash new threats of infectious disease from centuries ago. New research is capturing the likelihood of permafrost degradation unearthing frozen pathogens; for example, recent outbreaks of anthrax and release of amoeba-infecting viruses in Siberia are believed to be the result of thawing permafrost.[27] The release of viable microorganisms preserved in Arctic human and animal remains, including pathogens that have been eradicated or are novel to modern times, could present serious worldwide health security consequences. When viewed together with increased mobility and commercial activity in the region, as well as the destabilization risks to local sanitation infrastructure, these high-impact but low-probability health risks become more likely, and more risky.

Emissions and Wildfire Threats: Permafrost degradation has implications that extend well beyond the Arctic. Permafrost stores vast amounts of carbon, nearly twice as much as in the atmosphere.[28] As warming continues, thawing permafrost will become an increasing source of greenhouse gases, further exacerbating climate change.[29] Thawing permafrost releases not only carbon dioxide into the atmosphere, but also methane—a potent greenhouse gas that has reached record concentrations, well above those that would allow the world to stay within the Paris Agreement's 1.5 °C warming target.[30] Additionally, in fire-susceptible areas in the Arctic, the frequency and severity of wildfires have increased in recent decades at alarming rates. Wildfires exacerbate warming on a global scale by burning carbon-rich biomass and also furthering permafrost thaw by burning the insulating layer above the frozen ground.[31] Increased prevalence of holdover "zombie" fires in carbon-dense peatlands, which smolder throughout the winter only to reignite later, are adding to global carbon emissions and threatening regional security infrastructure.[32] Military installations and training grounds, such as the Northern Warfare Training Center at Fort Wainwright, AK, should be particularly cautious of these fire risks in nearby peatlands.[33]

These changes will bring direct threats to U.S. security infrastructure and operations, most notably in Alaska where key American military installations and training areas are built on, or next to, increasingly unstable permafrost (Figure 5). Alaska has been seen as a strategic "hinge" for American security forces at the middle of growing security tensions in the Pacific and Arctic seas.[34] Installations like Fort Wainwright, however, must increasingly focus not only on threats from foreign actors but also on the changing conditions of its own local environment. The Department of Defense has already requested upwards of $1 billion to cover retrofitting and repair of three Alaskan bases over the last five years and is using a nearby site to conduct important permafrost research along with the Army Corps of Engineers and Cold Regions Research and Engineering Laboratory.[35]

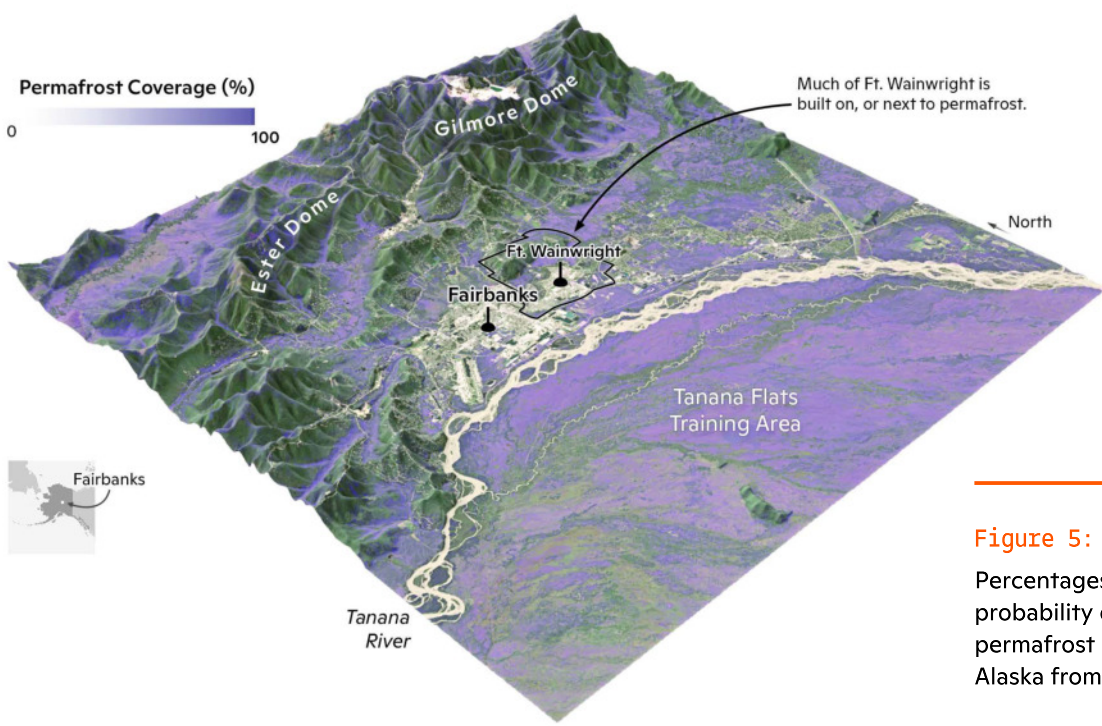

Figure 5:

Percentages reflect the probability of near-surface permafrost near Fairbanks, Alaska from 2000 to 2009.[36]

Potential Sparks

As a warming Arctic becomes more navigable, and commercial interests rush in to take advantage of historically inaccessible routes and resources, the security dilemma in the region intensifies alongside the changing climate. With Russian-NATO relations deteriorating, all sides of this historic rivalry are becoming increasingly hostile and mistrusting of the others' activities in the Arctic region. This creates a new landscape of competing claims: with Russia and Canada exerting dominance along the Northern Sea Route and Northwest Passage, respectively; China investing rapidly in infrastructure build-out, including on Norwegian-controlled Svalbard; and the United States refusing to ratify the UN Convention on the Law of the Sea, limiting its influence in resolving competing claims.[37]

Much of this growing competition among nation-states is currently playing out in the new rush of civilian and commercial activity in the polar region. These activities are already risky in the inhospitable Arctic environment, with the likelihood of accidents increasing alongside human presence, and could become more so as the military build-out in the region intensifies. States have already shown their readiness to use commercial and civilian interests as mediums for strategic posturing, data collection, and legal claim assertion in the Arctic, and these interests could quickly become gray zone competition vehicles, whereby military operations accompany non-military assets and lead to their escalation in use.[38]

Booming Shipping Activity: Commercial activity in the Arctic region has increased rapidly in recent years, with mineral, gas, and oil exploration, shipping routes, research activities, fishing and tourism all migrating further north (Figure 6). Shipping activities alone increased by 25% between 2013-2019, and projections for the future with decreasing sea ice show rapid increases over those numbers.[39]

A Danish helicopter takes off from a US Coast Guard vessel during joint Arctic training exercises. From the US Coast Guard News

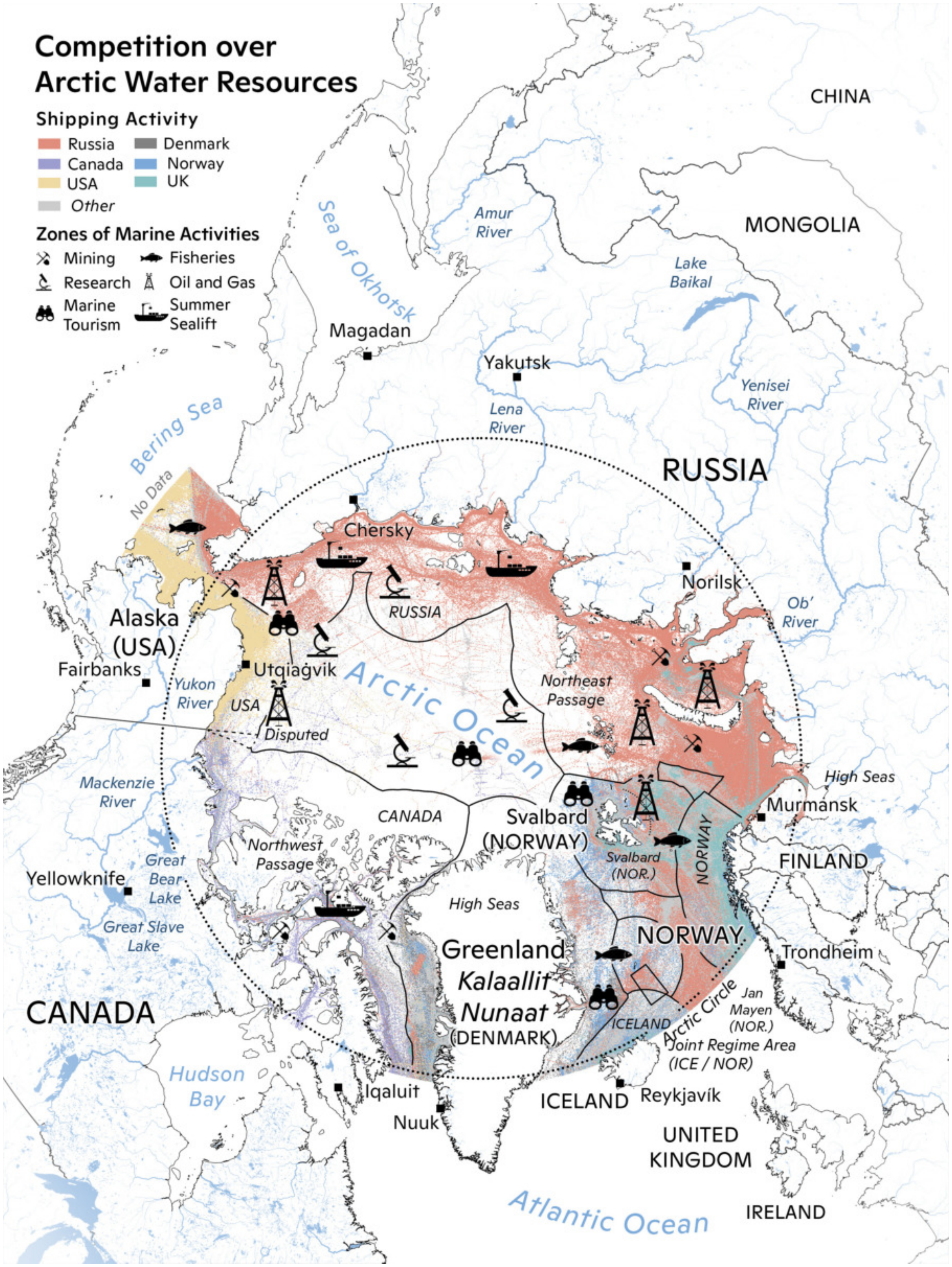

Figure 6:

Shipping activity is increasing in the Arctic as shrinking sea ice makes way for more navigable waterways. Colored ship tracks shown are from 2009 to 2016.[40]

A transport plane prepares for takeoff from Elmendorf Air Force Base, Alaska. From the US Air Force

Russia, in particular, is promoting the Northern Sea Route as an increasingly viable lane for shipping traffic between Asia and Europe, with state-sponsored ice breakers and incentives for cargo.[41] The country possesses over forty ice-breakers (in comparison with the United States' two), for the purpose of clearing shipping lanes. The Arktika-class of Russian icebreakers operating in the region are nuclear-powered, adding another layer of risks to accidents or confrontation. Increasing activity in the region will pose increasing demand on security actors for secure escorts, search-and-rescue, and ice-breaking operations, and could lead to a more rapid militarization of multiple states' naval forces.[42]

Increasing Oil and Gas Extraction: A prominent driver of increased navigation across the Arctic is the development of hydrocarbons across the Beaufort Sea, Norwegian and Chukchi Seas, and their transportation. The region possesses an estimated 30% of the world's undiscovered recoverable gas reserves, and 13% of its undiscovered oil reserves.[43] The Russian economy is particularly dependent on the continued development of these reserves, and the Kremlin has shown its willingness in recent years to use nuclear-equipped submarines in the transport of these resources.[44] Increasingly, Asian companies and Chinese state investors are developing oil and gas extraction infrastructure, and building out military technologies to operate in the region.[45] Arctic resource extraction poses its own security risks, particularly in the growing likelihood of accidents like spills or collisions between actors. Scenario-based modelling of potential incidents by the Council on Strategic Risks, the Polar Institute, and Sandia National Laboratories including collisions of Arctic gas and nuclear equipment, shows the high level of severity and limited ability for security response of such accidents.[46]

Growing Military Tensions: While most of the growing activity in the Arctic region has been civilian in nature, militaries and state security actors have also been building out their operations and this trend is likely to continue. Russia's military has invested large sums to upgrade Soviet-era installations, expand coastal defenses, buy new aircraft and naval equipment, train forces, and test weapons systems in the Arctic.[47] The Russian government has also shown its willingness to act aggressively, including by precipitating incidents with Alaskan fisherman, bomber patrols of the Alaskan coast, and planting its flag on the seafloor of the North Pole.[48] These actions have led NATO to increasingly look north, building a comprehensive Arctic strategy, while increasing training and patrol operations.[49] Any of the previously discussed climate impacts or growing activity could provide a spark for these escalating military tensions, and growing concerns of gray zone interaction around shipping routes, resource extraction, and commercial activity point to a more complex picture of conflict in the region.

Currently, few institutions exist across the Arctic region to effectively manage the onset of new security risks of commercial, civilian and military activity. The Arctic Council specifically forbids the discussion of security matters in its proceedings; the Arctic Shipping Forum and Arctic Frontiers Conference do not touch on military issues; and important forums like the Arctic Security Forces Roundtable have excluded Russia following its 2014 occupation of Ukraine.[50] This lack of dialogue among Arctic militaries has led Russian and European governments to call for the creation of new Arctic dialogues among defense ministers.[51] Arctic nations have shown encouraging signs at regulating Arctic commercial activities, however, with countries agreeing to a 16-year ban on commercial fishing in the region in 2019 and some regulation on oil and gas transport through the International Maritime Organization.[52]

Navigating Change

All together, these rapidly changing realities in the Arctic represent a maelstrom of new conditions which security actors in the region must quickly, and likely continuously, adapt to. Many climate phenomena will have their own direct, harmful impacts on security maintenance in the region, particularly rapidly rising temperatures, increasing wildfires, melting sea ice, and thawing permafrost. The impacts of climate change will also introduce new opportunities to the region that actors will seek to exploit, including increasing access, navigability, and activity.

To move forward and navigate these rapid changes, decision-makers must first better integrate climate data and future projections into their consideration of regional geopolitics. No analysis of the region is sufficient without specific and up-to-date incorporation of the many climate phenomena discussed above. Furthermore, security actors must actively consider the potential compound impacts of these phenomena interacting with each other and other security threats, with focus on the potential escalation of tensions and novel risks. It's clear that even the near future of Arctic security will look very different than the recent past, so strategic planning must be appropriately adjusted to cover the changing dynamics that lay ahead.

With military presence in the Arctic growing each passing year, and overlapping claims on territories and resources already acute, security actors must pay close attention to the variables of change shifting the ice, ground, weather, and mobility of the region.

Endnotes

[1] Boulègue, M. "Russia's Military Posture in the Arctic." Chatham House - International Affairs Think Tank, June 28, 2019. https://www.chathamhouse.org/2019/06/russias-military-posture-arctic.

[2] Mayfield, M. "Army Looking to Base More Operational Forces in Arctic Region." National Defense Magazine. (2021). https://www.nationaldefensemagazine.org/articles/2021/1/19/army-looking-to-base-more-operational-forces-in-arctic; Department of Defense. "Report to Congress: Department of Defense Arctic Strategy." Office of the Undersecretary of Defense for Policy, 2019. https://media.defense.gov/2019/Jun/06/2002141657/-1/-1/1/2019-DOD-ARCTIC-STRATEGY.PDF.

[3] Lino, M. "Understanding China's Arctic activities." International Institute for Strategic Studies. (2020). https://www.iiss.org/blogs/analysis/2020/02/china-arctic; Lanteigne, M. "The Polar Policies in China's New Five-Year Plan." The Diplomat. (2021). https://thediplomat.com/2021/03/the-polar-policies-in-chinas-new-five-year-plan/.

[4] Scott, M. "2020 Arctic air temperatures continue a long-term warming streak." Climate.gov. National Oceanic and Atmospheric Administration. (2020). https://www.climate.gov/news-features/featured-images/2020-arctic-air-temperatures-continue-long-term-warming-streak; Screen, James., and Ian Simmonds. "The central role of diminishing sea ice in recent Arctic temperature amplification." Nature 464.7293 (2010): 1334-1337. https://doi.org/10.1038/nature09051.

[5] Ballinger, T.J., Overland, J.W., Wang, M., Bhatt, U.S., Hanna, E., Hanssen-Bauer, I., Kim, S.-J., Thoman, R.L., Walsh, J.E. (2020). Surface air temperature. Arctic Report Card: Update for 2020. https://arctic.noaa.gov/Report-Card/Report-Card-2020/ArtMID/7975/Article...

[6] Larsen, J.N., et al. "Polar regions." Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (2014). [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1567-1612. https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap28_FINAL.pdf; Meredith, M., et al. "Polar regions." IPCC Special Report on the Ocean and Cryosphere in a Changing Climate. (2019). [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)] https://www.ipcc.ch/site/assets/uploads/sites/3/2019/11/07_SROCC_Ch03_FINAL.pdf.

[7] Landrum, L. and Holland, M. "Extremes become routine in an emerging new Arctic." Nature Climate Change, 10, 1108-1115. (2020). https://www.nature.com/articles/s41558-020-0892-z.

[8] Francis, J., and Skific, N. "Evidence Linking Rapid Arctic Warming to Mid-Latitude Weather Patterns." Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 373, no. 2045 (2015): 20140170. https://doi.org/10.1098/rsta.2014.0170; Screen, James., Deser, C., Smith, D. M., Zhang, X., Blackport, R., Kushner, P. J., Oudar, T., McCusker, K. E., & Sun, L. "Consistency and discrepancy in the atmospheric response to Arctic sea-ice loss across climate models." Nature Geoscience 11, no. 3 (2018): 155-163. https://doi.org/10.1038/s41561-018-0059-y.

[9] Schwalm, C. R., Glendon, S., & Duffy, P. B. RCP8. 5 tracks cumulative CO2 emissions. Proceedings of the National Academy of Sciences.117, no. 33 (2020): 19656-19657. https://doi.org/10.1073/pnas.2007117117.

[10] Markon, C., Gray, S., Berman, M., Eerkes-Medrano, L., Hennessy, T., Huntington, H. P., Littell, J., McCammon, M., Thoman, R., & Trainor, S. F. "Chapter 26: Alaska. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II." U.S. Global Change Research Program. (2018). https://doi.org/10.7930/NCA4.2018.CH26.

[11] Ramsayer, K. "2020 Arctic Sea Ice Minimum at Second Lowest on Record." NASA. Global Climate Change: Vital Signs of the Planet, December 10, 2020. https://climate.nasa.gov/news/3023/2020-arctic-sea-ice-minimum-at-second-lowest-on-record.

[12] Taylor, P. C., W. Maslowski, J. Perlwitz, D.J. Wuebbles, D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock. "Ch. 11: Arctic Changes and Their Effects on Alaska and the Rest of the United States. Climate Science Special Report: Fourth National Climate Assessment, Volume I." U.S. Global Change Research Program, 2017. https://doi.org/10.7930/J00863GK.

[13] Peng et. al. "What Do Global Climate Models Tell Us about Future Arctic Sea Ice Coverage Changes?" Climate, 8(1), 15. (2020). https://www.mdpi.com/2225-1154/8/1/15.

[14] Ibid.

Endnotes

[15] Sea ice extent maps are based on sea ice thickness data from the CMIP6 model HadGEM3-GC31-HM bias corrected using historical data from the Pan-Arctic Ice Ocean Modeling and Assimilation System. This model provides daily data at a horizontal resolution of approximately 50 km from 1951-2050. The future period is forced by SSP585. Daily sea ice extent is calculated by summing the area of all pixels where sea ice thickness is above a certain threshold. These sea ice maps illustrate possible realizations of past and future minimum Arctic sea ice extent.

[16] National Research Council. National Security Implications of Climate Change for U.S. Naval Forces. Washington, DC: The National Academies Press. (2011). https://doi.org/10.17226/12914.

[17] Ibid.

[18] Doyle, J. "As Arctic Sea Ice Melts, Deputy CNO Says U.S. Subs Will Become More Important." Seapower Magazine. (2020). https://seapowermagazine.org/as-arctic-sea-ice-melts-deputy-cno-says-u-s-subs-will-become-more-important/.

[19] Sanger, D. and Kramer, A. "U.S. Officials Suspect New Nuclear Missile in Explosion That Killed 7 Russians." New York Times. (2019). https://www.nytimes.com/2019/08/12/world/europe/russia-nuclear-accident-putin.html.

[20] Marlatt, R. "The Intersection of U.S. Military Infrastructure & Alaskan Permafrost Through the 21st Century." The Arctic Institute, Center for Circumpolar Security Studies. (2020). https://www.thearcticinstitute.org/intersection-military-infrastructure-alaskan-permafrost-21st-century/.

[21] Markon, Gray, Berman, Eerkes-Medrano, Hennessy, Huntington, Littell, McCammon, Thoman, & Trainor. "Chapter 26: Alaska. Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II."; Hjort, Jan, Olli Karjalainen, Juha Aalto, Sebastian Westermann, Vladimir E. Romanovsky, Frederick E. Nelson, Bernd Etzelmüller, and Miska Luoto. "Degrading Permafrost Puts Arctic Infrastructure at Risk by Mid-Century." Nature Communications 9, no. 1 (2018): 5147. https://doi.org/10.1038/s41467-018-07557-4.

[22] A hazard index that classifies the risk of permafrost degradation to infrastructure hazard for the years 2040-2060 using the RCP8.5 scenario is shown in Figure 4. This is a hierarchical analytical index that accounts for the following factors: ground temperature and thaw of near-surface permafrost, ground-ice content, relative increase of active-layer thickness, fine-grained sediment content, and ground slope gradient. Data is from Karjalainen et al. 2018 and the hazard index is described in Hjort et al. 2018.

[23] Nelson, F. E., Anisimov, O. A. & Shiklomanov, N. I. Subsidence risk from thawing permafrost. Nature 410, 889-890 (2001). https://pubmed.ncbi.nlm.nih.gov/11309605/.

[24] BBC. "Arctic Circle oil spill: Russian prosecutors order checks at permafrost sites." June 5, 2020. https://www.bbc.com/news/world-europe-52941845; BBC. "The fragile future of roads and buildings built on permafrost." March 4, 2021. https://www.bbc.com/future/article/20210303-the-unsure-future-of-roads-and-buildings-on-melting-ground.

[25] Yumashev, Dmitry, Hope, C., Schaefer, K., Campe-Riemann, K., Iglesias-Suarez, F., Jafarov, E., Burke, E., Young, P., Elshorbany, Y., Whiteman, G. "Climate policy implications of nonlinear decline of Arctic land permafrost and other cryosphere elements." Nature Communications, 10, 1900. (2019). https://www.nature.com/articles/s41467-019-09863-x.

[26] Karjalainen, Olli, Aalto J., Luoto, M., Westermann, S. , Romanovsky, E., Nelson, F. , Etzelmüller, B., and Hjort, J.. "Circumpolar Permafrost Maps and Geohazard Indices for Near-Future Infrastructure Risk Assessments." Scientific Data 6, no. 1 (2019): 190037. https://doi.org/10.1038/sdata.2019.37; Hjort, Jan, Karjalainen, O., Aalto, J. ,Westermann, S., Romanovsky, V., Nelson, F., Etzelmüller, B., and Luoto, M. "Degrading Permafrost Puts Arctic Infrastructure at Risk by Mid-Century." Nature Communications 9, no. 1 (2018): 5147. https://doi.org/10.1038/s41467-018-07557-4.

[27] Doucleff, M. "Anthrax Outbreak In Russia Thought To Be Result Of Thawing Permafrost." NPR, August 3, 2016. https://www.npr.org/sections/goatsandsoda/2016/08/03/488400947/anthrax-outbreak-in-russia-thought-to-be-result-of-thawing-permafrost; Legandre et al. "In-depth study of Mollivirus sibericum, a new 30,000-y-old giant virus infecting Acanthamoeba. Proceedings of the National Academy of Sciences. (2015). www.pnas.org/cgi/doi/10.1073/pnas.1510795112; Stella, E. et al. "Permafrost dynamics and the risk of anthrax transmission: a modelling study." Scientific Reports, 10, 16460. (2020). https://www.nature.com/articles/s41598-020-72440-6.

Endnotes

[28] Schuur, E. a. G., McGuire, A. D., Schädel, C., Grosse, G., Harden, J. W., Hayes, D. J., Hugelius, G., Koven, C. D., Kuhry, P., Lawrence, D. M., Natali, S. M., Olefeldt, D., Romanovsky, V. E., Schaefer, K., Turetsky, M. R., Treat, C. C., & Vonk, J. E. "Climate change and the permafrost carbon feedback." Nature 520, no. 7546 (2015): 171-179. https://doi.org/10.1038/nature14338.

[29] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., Huang, Y., Ekici, A., & Obersteiner, M. "Path-dependent reductions in CO 2 emission budgets caused by permafrost carbon release." Nature Geoscience 11, no. 11 (2018): 830-835. https://doi.org/10.1038/s41561-018-0227-0.

[30] UN Environment Programme (UNEP) and Climate & Clean Air Coalition (CCAC). Global Methane Assessment: Benefits and Costs of Mitigating Methane Emissions. (2021). https://www.unep.org/resources/report/global-methane-assessment-benefits-and-costs-mitigating-methane-emissions.

[31] Taylor, Maslowski, Perlwitz, Wuebbles, Fahey, Hibbard, Dokken, Stewart, and Maycock. "Ch. 11: Arctic Changes and Their Effects on Alaska and the Rest of the United States. Climate Science Special Report: Fourth National Climate Assessment, Volume I."; York, A., Bhatt, U., Gargulinski, E., Jain, P., Soja, A., Thoman, R., & Ziel, R. "Wildland Fire in High Northern Latitudes." 2020 Arctic Report Card, 2020. https://doi.org/10.25923/2gef-3964.

[32] Witze, A. "The Arctic is burning like never before—And that's bad news for climate change." Nature 585, no. 7825 (2020): 336-337. https://doi.org/10.1038/d41586-020-02568-y/; McCarty, J., Smith, T., and Turetsky, M. "Arctic fires re-emerging." Nature Geoscience, 13, 658-660. (2020). https://www.nature.com/articles/s41561-020-00645-5; Scholten, R. C., Jandt, R., Miller, E.A., Rogers, B., and Veraverbeke, S. "Overwintering Fires in Boreal Forests." Nature 593, no. 7859 (2021): 399-404. https://doi.org/10.1038/s41586-021-03437-y.

[33] Innes, R. "Fire regimes of Alaskan wet and mesic herbaceous systems." Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory. (2015). www.fs.fed.us/database/feis/fire_regimes/AK_wet_herbaceous/all.html.

[34] Ferdinando, L. "Carter Highlights Alaska's Strategic Importance During Fort Wainwright Visit." DoD News. Department of Defense. (2015). https://www.defense.gov/Explore/News/Article/Article/626826/carter-highlights-alaskas-strategic-importance-during-fort-wainwright-visit/.

[35] Karlovitch, S. et al. "As the world warms, costs rise for Alaska military bases." Anchorage Daily News. (2020). https://www.adn.com/alaska-news/military/2020/08/01/as-the-world-warms-costs-rise-for-alaska-military-bases/; Nelson, D. "Providing safety to the installation, the residents and the climate." U.S. Army. (2019). https://www.army.mil/article/227496/providing_safety_to_the_installation_the_residents_and_the_climate.

[36] Pastick, N.J., Jorgenson, M.T., Wylie, B.K., Nield, S.J., Johnson, K.D., and Finley, A.O. "Probabilistic estimates of the distribution of near-surface (within 1m) permafrost in Alaska" U.S. Geological Survey data release (2015). http://dx.doi.org/10.5066/F7C53HX6.

[37] Nevitt, M. "Climate change, Arctic security and why the U.S. should join the U.N. Convention on the Law of the Sea." The Rule of Law Post. Center for Ethics and the Rule of Law, University of Pennsylvania Law School. (2020). https://www.law.upenn.edu/live/news/10524-climate-change-arctic-security-and-why-the-us/news/cerl-news.

[38] Goodman, S., Maddox, M., Guy, K., Hansen, V.V., Sending, O.J., Winther, I. "Climate Change and Security in the Arctic." The Center for Climate and Security (CCS), an institute of the Council on Strategic Risks (CSR), and The Norwegian Institute of International Affairs (NUPI). Edited by Femia, F. and Sikorsky, E. (2021). https://climateandsecurity.org/wp-content/uploads/2021/01/Climate-Change-and-Security-in-the-Arctic_CCS_NUPI_January-2021-1.pdf.

[39] Protection of the Arctic Marine Environment (PAME). "The Increase in Arctic Shipping, 2013-2019: Arctic Shipping Status Report (ASSR) #1."(2020). https://pame.is/projects/arctic-marine-shipping/arctic-shipping-status-reports/723-arctic-shipping-report-1-the-increase-in-arctic-shipping-2013-2019-pdf-version/file.

Endnotes

[40] Berkman, Paul Arthur, Fiske, G., Røyset, J., Brigham, L., and Lorenzini, D. "Next-Generation Arctic Marine Shipping Assessments." In Governing Arctic Seas: Regional Lessons from the Bering Strait and Barents Sea: Volume 1, 241–68. Informed Decisionmaking for Sustainability. Cham: Springer International Publishing (2020). https://doi.org/10.1007/978-3-030-25674-6_11.

[41] Shankman, S. "Russia is Turning Ever Given's Plight into a Marketing Tool for Arctic Shipping. But It May Be a Hard Sell." Inside Climate News. (2021). https://insideclimatenews.org/news/31032021/russia-is-turning-ever-givens-plight-into-a-marketing-tool-for-arctic-shipping-but-it-may-be-a-hard-sell/.

[42] Goodman, Maddox, Guy, Hansen, Sending, Winther. "Climate Change and Security in the Arctic."

[43] Gautier et al. "Assessment of Undiscovered Oil and Gas in the Arctic." Science, 324:5931, 1175-1179. (2009). https://science.sciencemag.org/content/324/5931/1175.abstract.

[44] Nilsen. T. "Russian subs honing stealth skills in major North Atlantic drill, says Norwegian intel." The Barents Observer. (2019). https://thebarentsobserver.com/en/security/2019/10/russian-northern-fleet-massive-submarine-show.

[45] Koh, S.L.C. "China's strategic interest in the Arctic goes beyond economics." Defense News. (2020). https://www.defensenews.com/opinion/commentary/2020/05/11/chinas-strategic-interest-in-the-arctic-goes-beyond-economics/.

[46] Goodman, S., Davies, P., Townsend, J., and Maddox, M. "Inclusive Planning for Changing Arctic Futures: Demonstrating a Scenario-Based Discussion." Council on Strategic Risks, with Sandia National Laboratories and the Polar Institute, Wilson Center. (2019). https://councilonstrategicrisks.org/wp-content/uploads/2019/09/2050-Arctic-Tabletop-Report.pdf.

[47] Boulègue, "Russia's Military Posture in the Arctic."; Baev, P. "Threat Assessments and Strategic Objectives in Russia's Arctic Policy." Journal of Slavic Military Studies, 32:1. (2019). https://doi.org/10.1080/13518046.2019.1552662; Walsh, P. N. "Satellite images show huge Russian military buildup in the Arctic." CNN News. (2021). https://www.cnn.com/2021/04/05/europe/russia-arctic-nato-military-intl-cmd/index.html.

[48] Baker, M. "'Are We Getting Invaded?' U.S. Boats Faced Russian Aggression Near Alaska." The New York Times. (2020). https://www.nytimes.com/2020/11/12/us/russia-military-alaska-arctic-fishing.html; Parfitt, T. "Russia plants flag on North Pole seabed 2007." The Guardian. (2007). https://www.theguardian.com/world/2007/aug/02/russia.arctic.

[49] Deja, C. NATO'S Future Role in the Arctic. Air Command and Staff College, Air University. (2020). https://apps.dtic.mil/dtic/tr/fulltext/u2/1037210.pdf.

[50] Tingstad, A. "Today's Arctic Diplomacy Can't Handle Tomorrow's Problems." Defense One. (2020). https://www.defenseone.com/ideas/2020/01/todays-arctic-diplomacy-cant-handle-tomorrows-problems/162719/.

[51] High North News. "Russia Should Be Invited Back to Arctic Security Forums, New Report Suggests." (2021). https://www.highnorthnews.com/en/russia-should-be-invited-back-arctic-security-forums-new-report-suggests.

[52] Hoag, H. "Nations agree to ban fishing in Arctic Ocean for at least 16 years." Science Magazine. (2017). https://www.sciencemag.org/news/2017/12/nations-agree-ban-fishing-arctic-ocean-least-16-years.