

SYMPOSIUM ON THE FUTURE OF A MELTING ARCTIC: CHALLENGES FOR INTERNATIONAL LAW

CLIMATE CHANGE AND THE RECONFIGURATION OF ARCTIC ACCESS

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Arctic Amplification

The Arctic is warming faster than any other region on Earth, with surface air temperatures increasing at a rate nearly four times the global average.¹ This amplification of global change has been reshaping the Arctic for decades, altering sea ice extent and thickness, snow regimes, permafrost stability, and hydrological systems. Against this backdrop, a persistent narrative has taken hold that the diminishing cryosphere² is setting the table for opportunity: opening the Arctic to navigation, development, and exploitation. But this thaw renders the Arctic neither benign nor uniformly accessible. The region remains frozen for most of the year, dark for months at a time, increasingly storm-prone, and profoundly remote. Rather than producing a uniform expansion of access, accelerating climate change is reconfiguring when, where, and for whom access is possible, creating patterns of simultaneous opening and closing that are seasonal, uneven, and uncertain.

Arctic amplification of climate change, currently occurring at a rate as high as 0.8°C (1.44°F) per decade, is among the most robust findings in climate science. This amplification is attributable to the loss of the cryosphere, changes in atmospheric stability, and seasonal heat storage in the ocean.³ The process acts to concentrate warming near the surface and outside the summer months. These mechanisms are well understood and consistently reproduced across observations, theory, and models. As a result, continued Arctic warming and widespread cryospheric diminution over the coming decades are not in doubt.

What is less well-appreciated is how Arctic climate change manifests. Operationally relevant information is characterized less by long-term averages than by extremes, seasonality, and importantly, thresholds. Small shifts around freezing—whether air temperature crosses 0°C, precipitation falls as snow or rain, ice thickens or fractures—often determine whether movement, construction, or subsistence activities are possible. These threshold effects mean that a modest average warming can produce outsized consequences.

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¹ Accelerated Arctic warming was first predicted in 1980, Syukuro Manabe & Ronald J. Stouffer, *Sensitivity of a Global Climate Model to an Increase of CO₂ in the Atmosphere*, 85 J. GEOPHYS. RESCH. 5529 (1980), and then emerged in observations, Mark C. Serreze et al., *The Emergence of Surface-Based Arctic Amplification*, 3 CRYOSPHERE 11 (2009). The magnitude of acceleration is posited by Mika Rantanen et al., *The Arctic Has Warmed Nearly Four Times Faster Than the Globe Since 1979*, 3 COMM. EARTH & ENV'T 168 (2022).

² The “cryosphere” comprises sea and river ice, glaciers, snow, and frozen soils or permafrost.

³ Paul C. Taylor et al., *Process Drivers, Inter-model Spread, and the Path Forward: A Review of Amplified Arctic Warming*, 9 FRONTIERS EARTH SCI. 758361 (2022).

Extreme and episodic events illustrate this dynamic. For example, when rain falls on snow during a midwinter warm spell, snowpacks rapidly transform, creating ice crusts that block access to large mammal forage and disrupting travel routes, without any large change in seasonal mean temperature.⁴ Late freeze-up and early break-up events can eliminate the narrow windows during which ice roads, river crossings, and nearshore sea ice are usable, even as average winter temperatures remain well below freezing.⁵ In marine settings, thinner and more mobile sea ice can increase hazards by compacting and ridging in narrow straits, creating localized chokepoints that persist despite declining overall ice extent.⁶ These events are not anomalies at the margins of change; they are central to how Arctic climate change is experienced and managed.

Uncertainty is also intrinsic to the near-term Arctic future, but it is important to distinguish its sources. On the timescales most relevant to infrastructure, navigation, and governance—the next two to three decades—uncertainty is dominated not by differences in global emissions pathways, but by fluctuations from year to year (interannual climate variability) and structural differences in climate models (model bias).⁷ Interannual variability contributes to the incidence of extreme events that can amplify or mask long-term trends. Model bias arises from differing hypotheses concerning the complex of physical processes that comprise the climate system. No model is “best” in every respect, but all perform with high precision.⁸ This does not undermine confidence in the direction of change, but it complicates assumptions about timing, location, and persistence.

The consequence is a climate future that is directionally clear but operationally complex. Arctic warming will continue, and the cryosphere will continue to diminish, sometimes catastrophically quickly and sometimes gradually. In practical terms, this means that opportunities for strategic posture, Indigenous and community development, or commercial expansion are not simply increasing or decreasing; they are being redistributed across space, season, and mode. Understanding this physical baseline is essential for evaluating claims about the future in a warming Arctic.

Access as a Compound Condition

Accessibility in the Arctic emerges through the interaction of environment, infrastructure, capacity, geopolitics, and macroeconomics. Climate change affects each of these elements, extending or compressing operating windows and reshaping risk tolerance. As a result, Arctic warming is better understood as reconfiguring access rather than simply producing opportunity.

Seasonality is the dominant organizing feature of this redistribution. Even with continued warming, for the next several decades the Arctic will remain ice and snow covered for a substantial portion of each year. Maritime access has been focused on the late summer and early autumn, when sea ice extent is at a minimum.⁹ Terrestrial

⁴ John R. Putkonen & Gregory Roe, *Rain-on-Snow Events Impact Soil Temperatures and Ecological Processes in the Arctic*, 37 GEOPHYS. RES. LETT. L07502 (2010); Emma T. D. Perkins, Amanda H. Lynch, Vera Solovyeva & David A. Bailey, *Predicting Snow Structures Relevant to Reindeer Husbandry*, 56 ARCTIC, ANTARCTIC & ALPINE RSCH. (2024).

⁵ Emma Haggerty et al., *The Road to Nowhere*, in THE MANY ARCTICS IN 2050 (Amanda H. Lynch, Laurence C. Smith & Lawson W. Brigham eds., forthcoming 2026).

⁶ M.L. Rocha, A.H. Lynch & K.J. Bergen, *Enhancing Sea Ice Concentration Resolution in a Northern Sea Route Strait Using a Generative Adversarial Network*, 2 J. GEOPHYS. RSCH.: MACHINE LEARNING & COMPUTATION e2024JH000281 (2025).

⁷ Ed Hawkins & Rowan Sutton, *The Potential to Narrow Uncertainty in Projections of Regional Precipitation Change*, 37 CLIMATIC CHANGE 407 (2009).

⁸ Intergovernmental Panel on Climate Change, *Climate Change 2021: The Physical Science Basis, Summary for Policymakers*, B.1–B.3 (2021).

⁹ Charles H. Norchi & Amanda H. Lynch, *Arctic Navigation and Climate Change: Projections from Science for the Law of the Sea*, 99 INT'L L. STUD. 491 (2022).

access, by contrast, has historically been optimal during sustained cold, making use of seasonally constructed ice roads and permafrost stabilized infrastructure.

Across the circumpolar Arctic, future declines in terrestrial accessibility are large, widespread, and robust across climate scenarios.¹⁰ Integrated modeling of year-round and seasonal terrestrial transport (road, rail, and barge) indicates an average loss of approximately seventy-four accessible days per year by mid-century; a 52 percent reduction relative to present conditions under a moderate warming trajectory, increasing to seventy-eight days (55 percent) under higher warming.¹¹ These losses are not marginal: 68 percent of Arctic settlements experience declining terrestrial accessibility, while only 16 percent show any increase, and those increases average just two additional days per year, compared with losses averaging more than one hundred days in declining regions.¹² Seasonal impacts are concentrated in winter with declines in 2050 of 70 percent on average, and up to 90 percent. In Alaska, approximately 80 percent of the state is projected to lose more than fifty accessible days per year, regardless of emissions pathway. These declines reflect degraded ice roads, and permafrost degradation of permanent roads and rail. For communities and industries dependent on terrestrial transportation corridors, warming replaces a predictable, if harsh, access regime with one that is shorter, more variable, and increasingly unreliable.

Maritime accessibility illustrates this asymmetry. Declining summer sea ice can lengthen the period during which vessels are able to navigate Arctic waters. Observations and projections show that sea ice evacuates preferentially from the eastern Arctic, especially along the Russian maritime margin including the Northern Sea Route (NSR). Meanwhile, refuges for ice-dependent species are expected to endure longer in the Canadian Arctic Archipelago, where archipelagic geometry and ice dynamics sustain hazardous conditions even as Arctic ice declines.¹³ This spatial differentiation matters because it produces fundamentally different accessibility regimes among routes across the western and eastern Arctic that are often discussed as if they were interchangeable. The resulting pattern is not a linear opening but a reordering of navigability that interacts with zones of jurisdiction, vessel class, and risk tolerance in ways that have international legal and regulatory ramifications.¹⁴ In this context, Russia adopted a series of domestic regulations based on UN Convention on the Law of the Sea Article 234 to purportedly protect the marine environment, enhance safety of navigation, and manage traffic.¹⁵ In parallel, amendments to Russia's Federal Law of Shipping on the Water Area of the Northern Sea Route refer to the NSR as "a historically developed national transport communication of the Russian Federation."¹⁶ In this interpretation, navigation through the NSR is to be carried out in accordance with the *Federal Act on the Internal Maritime Waters, Territorial Sea and Contiguous Zone of the Russian Federation*, other federal laws, and the international treaties to which the Russian Federation is a

¹⁰ Andreas Gädeke et al., *Climate Change Reduces Winter Overland Travel Across the Pan-Arctic Even Under Low-End Global Warming Scenarios*, 16 ENVTL. RSCH. LETTERS 024049 (2021).

¹¹ Haggerty et al., *supra* note 5.

¹² *Id.*

¹³ Amanda H. Lynch et al., *The Interaction of Ice and Law in Arctic Marine Accessibility*, 119 PROC. NAT'L ACAD. SCI. e2202720119 (2022).

¹⁴ Norchi & Lynch, *supra* note 9.

¹⁵ The three principal Russian domestic regulations applicable to navigation in the NSR are the (1) Regulations for Navigation on the Seaways of the Northern Sea Route; (2) Regulations for Icebreaker-Assisted Pilotage of Vessels on the Northern Sea Route; and (3) Requirements for Design, Equipment and Supply of Vessels Navigating the Northern Sea Route.

¹⁶ *Federal Law of July 28, 2012, No. 132-FZ*, On Amendments to Certain Legislative Acts of the Russian Federation Concerning State Regulation of Merchant Shipping on the Water Area of the Northern Sea Route, Art. 14, adopted by the State Duma on July 3, 2012, approved by the Federation Council on July 18, 2012.

party.¹⁷ As retreating sea ice in this sector enables accessibility, these navigational servitudes have rendered the NSR a maritime toll road.

Transit shipping, which considers the Arctic primarily as a shorter (than the Suez route) corridor between distant markets, can exploit transient ice-free windows. At present this is feasible only along the NSR; Northwest Passage transits remain experimental. Shipping feasibility depends on ice conditions, vessel capability, insurance, and tolerance for strategic risk.¹⁸ Vessel usage requires compliance with the Polar Code,¹⁹ the Safety of Life at Sea Convention (SOLAS), and the International Convention for the Prevention of Pollution from Ships (MARPOL).²⁰ In the near term, access is conditioned strongly by the current sanctions regime: in 2025, transit cargo tonnage saw modest growth but remained around 8.6 percent of the total, as sanctions constrained vessel availability, financing, insurance, and access to critical technology. These cumulative vulnerabilities, including the loss of Western technical and operational support, means that true Arctic international transit remains marginal²¹ even as an early ice retreat extended the 2025 season.²² By mid-century, however, open-water (Category C) vessels are projected to have approximately one hundred days of viable access per year across several Arctic routes, concentrated in late summer and early autumn. Polar Class 6 vessels may achieve up to three hundred accessible days per year, including extended shoulder seasons.²³

By contrast, destination and cabotage shipping within the Arctic remains tightly coupled to coastal state jurisdiction, port infrastructure, and search-and-rescue capacity. Sanctions also have an impact: in 2025, total NSR cargo volumes, dominated by Russian LNG and oil, declined 2.3 percent. Ports function as the structural hinge. As terrestrial infrastructure, ports rely on stable ground, intact shorelines, and functioning road, rail, storage, and fuel systems. Many Arctic ports are built on permafrost or low-lying coasts and are directly exposed to thaw subsidence, coastal erosion, and sea-level rise.²⁴ Even modest degradation can negate longer navigation seasons by constraining loading, storage, and onward transport. In this sense, warming can increase the number of days when ships can reach Arctic waters while simultaneously undermining the land-based nodes required to capitalize on that access. Marine accessibility is thus intertwined with terrestrial accessibility—"the land dominates the sea."²⁵

River systems occupy an intermediate position and introduce additional asymmetry. River transport is a major accessibility mode, particularly in Eurasia. The Lena River alone exhibits cumulative traffic densities an order of magnitude higher than most North American rivers.²⁶ Fourteen of fifty-five rivers show statistically significant increases in barge traffic since 2012; none show declines.²⁷ Seasonality remains decisive here too. River traffic is concentrated between June and September, while winter ice transport becomes increasingly

¹⁷ [Federal Act on the Internal Maritime Waters, Territorial Sea and Contiguous Zone of the Russian Federation](#), Art. 14, adopted by the State Duma on July 16, 1998, approved by the Federation Council on July 17, 1998 (emphasis added). The 1998 law was amended by the 2012 Federal Law No. 132-FZ.

¹⁸ Scott R. Stephenson et al., *Accelerating Maritime Access*, in *THE MANY ARCTICS IN 2050*, *supra* note 5.

¹⁹ [International Code for Ships Operating in Polar Waters](#) (Polar Code), IMO Doc. MEPC 68/21/Add.1 Annex 10; [MSC 94/21/Add.1 Annex 6](#) (2015).

²⁰ Stephenson et al., *supra* note 18.

²¹ Björn Gunnarsson, *On the Vulnerabilities of the Northern Sea Route's Maritime Transportation System*, 15 *ARCTIC REV. L. & POL.* 94 (2024).

²² W.N. Meier et al., *Sea Ice*, *ARCTIC REPORT CARD* 2025.

²³ Stephenson et al., *supra* note 18.

²⁴ Jan Hjort et al., *Impacts of Permafrost Degradation on Infrastructure*, 3 *NATURE REV. EARTH & ENV'T* 24 (2022).

²⁵ *North Sea Continental Shelf* (Ger./Neth.), *Judgment*, 1969 ICJ Rep. 3, 51 (Feb. 20).

²⁶ Audrey N. Thellman et al., *Navigating Between Freeze and Flow*, in *THE MANY ARCTICS IN 2050*, *supra* note 5.

²⁷ *Id.*

unreliable.²⁸ Longer ice-free river seasons may partially offset losses in winter road access for some inland communities, particularly where barge transport can substitute for overland freight. Rivers thus mitigate some accessibility losses while amplifying spatial inequality between regions with navigable waterways and those without.

Taken together, these findings undermine any notion of a uniformly accessible Arctic under climate change, particularly in the coming decades. Maritime access increases by weeks to months per year for certain vessels and routes, while terrestrial access declines by months for most regions. Rivers provide partial and uneven offsets. The dominant signal is not expansion, but reconfiguration of access across modes, seasons, and geographies, with uneven consequences.

Accessibility and International Law

The Arctic is in the grip of the irrepressible presence of power, an indispensable feature of law. But when state power is increasingly applied untethered from expectations of authority, in the unbridled pursuit of national interests, international law is breached and the international system is confronted with the alternatives of an orderly Arctic, the primacy of a single state, or a contest among hegemons.²⁹ States, Indigenous Peoples, and corporations operate within climatic and geopolitical systems, both marked by threshold and extreme events. While nation-state behavior is driven by survival and power, in the recent past that behavior was constrained by the perception of common interests, wherein national interests are furthered through formal agreements and institutions—essential modalities of international law.

Hegemons are gate keepers, making access contingent and elevating commercial risk. When states interact on the basis of common interests an orderly system results, and access becomes predictable—a fundamental condition for communities and commerce to thrive. In this sense, shipping, extraction, and investment do not respond to climate trends alone. They respond to the interaction of price, risk, and reliability, mediated by governance capacity and, increasingly, by Arctic communities and Indigenous Peoples asserting claims alongside powerful actors.³⁰ Longer navigational seasons matter only insofar as they reduce uncertainty, stabilize supply chains, and align with social license to operate. Where access is episodic, infrastructure fragile, or freight performance volatile, perceived opportunity can rapidly translate into financial exposure rather than advantage. Access carries a price.³¹

Toward an Ordered Arctic

The Arctic's future will be defined not solely by how much ice remains, but by whether access is governed in ways that stabilize expectations and distribute risk. Climate change is reconfiguring the physical baseline of opportunity. Law and power will determine whether that reconfiguration produces durable corridors of cooperation. Access is both expanding and contracting. Without order, the price of access will be high.

The shadow of state primacy—whether exercised by an Arctic great power or a self-described “near-Arctic” power—introduces the prospect of abrupt and destabilizing policy shifts.³² In a region where access is already being reconfigured by climate, volatility imposed by the exercise of power compounds uncertainty. Managing the

²⁸ Xiaogang Yang et al., *The Past and Future of Global River Ice*, 577 NATURE 69 (2020).

²⁹ Charles H. Norchi, *Order or Primacy in the Arctic*, in THE MANY ARCTICS IN 2050, *supra* note 5.

³⁰ Amanda H. Lynch et al., *Indigenous Navigations*, in THE MANY ARCTICS IN 2050, *supra* note 5.

³¹ Michael A. Goldstein and Dmitry A. Streletskiy, *The Price of Access*, in THE MANY ARCTICS IN 2050, *supra* note 5.

³² See UNDER DESTRUCTION: MUNICH SECURITY REPORT (2026).

uneven consequences of Arctic warming requires acceptance of scientific evidence, durable institutional arrangements, adherence to minimum standards of international law, and order that extends beyond narrow assertions of control. Grotian notions of order³³ may not guarantee justice; but they temper Hobbesian disorder and reduce the risk that access becomes a tool of coercion.

Arctic climate change is accelerating, and its direction is clear. Ice on land and at sea will diminish. The Arctic Ocean will reach seasonally ice-free conditions within the coming decade.³⁴ The Greenland Ice Sheet is committed to major mass loss; while full collapse would take centuries, the point of no return is much nearer. Yet clarity about the end state should not be mistaken for clarity about the path. The transition toward that future is unfolding through a contingent sequence of seasonal instabilities, threshold crossings, and uneven regional responses that reconfigure access rather than uniformly expand it. Communications gaps will persist; search and rescue capacity will remain limited; satellite coverage will remain imperfect; weather and darkness will continue to impose hard constraints. These realities mean that the Arctic's future is not being determined by climate alone.

³³ See HUGO GROTIUS, *DE JURE BELLI AC PACIS* (Carnegie Endowment trans. 1925).

³⁴ Alexandra Jahn et al., *Projections of an Ice-Free Arctic Ocean*, 5 NATURE REV. EARTH & ENV'T 164 (2024).