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Perspective

The Arctic Highlights Our Failure to Act in a Rapidly Changing World

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Abstract: In this perspective on the future of the Arctic, we explore actions taken to mitigate warming and adapt to change since the Paris agreement on the temperature threshold that should not be exceeded in order to avoid dangerous interference with the climate system. Although 5 years may seem too short a time for implementation of major interventions, it actually is a considerable time span given the urgency at which we must act if we want to avoid crossing the 1.5 to <2 °C global warming threshold. Actions required include co-production of research exploring possible futures; supporting Indigenous rights holders' and stakeholders' discourse on desired futures; monitoring Arctic change; funding strategic, regional adaptation; and, deep decarbonization through transformation of the energy system coupled with negative carbon emissions. We are now in the decisive decade concerning the future we leave behind for the next generations. The Arctic's future depends on global action, and in turn, the Arctic plays a critical role in the global future.

Keywords: Arctic; COVID-19; Indigenous rights; climate change; co-production; desired futures; adaptation; mitigation; decarbonization; rapid change

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1. Introduction

Through feedback and coupled processes, the Arctic system amplifies global change signals including global warming. Arctic amplification increases temperature rise by a factor of between 2 and 4 at the pan-Arctic scale [1]. In 2016, a workshop called 'A 5C Arctic in a 2C World' was convened by the Columbia Climate Center to explore the implications of projected temperature increases in an Arctic context [2]. The report from the workshop identified a series of measures, couched in terms of recommendations to the First Arctic Science Ministerial (ASM) [3], to inform and advance effective responses to a rapidly changing Arctic. Five years later, where do we stand on some of these proposed actions? Has progress been made; has the rate of change outpaced responses? Is it time to rethink some of what was proposed?

As participants in the 2016 workshop, we briefly review the trajectory of the Arctic system in a warming world and revisit the recommendations of the 2016 workshop report, referred to in this contribution as the 5C Arctic report [2]. The contribution is not meant to be comprehensive, in particular with respect to research updates, many of which are reflected in recent Intergovernmental Panel on Climate Change (IPCC) reports [1,4] and the annual Arctic Report Cards [5,6]. Rather, we focus on the exploration of actions taken to mitigate warming and adapt to change over the past 5 years. Although 5 years may seem too short a time for the implementation of major interventions, it actually is a considerable time span given the urgency at which we must act if we want to avoid crossing the 1.5 to <2 °C global warming threshold set by the Paris Accord [7] and, more recently, the IPCC Special Report SR15 (the '1.5 degree report') [8]. According to model projections, in order to avoid crossing this threshold, we need to reach net zero carbon emissions by the middle of this century. This means that we have only a decade left to cut emissions by half, which requires cutting emissions by ca. 7 to 8 percent each year starting now, i.e., in 2022.

Discussion of the root causes underlying the failure to address climate change at the global or national scale is beyond the scope of this contribution. We acknowledge that the rapidity of change outpaces timescales over which most societies are able to develop consensus and commitment to action. Some of the discussions at COP 26 illustrate this circumstance through the lens of the underlying value systems including equity and climate justice. At the same time, there are indications that research, focused on understanding how societies—through social learning and effective decision making—can address major threats such as climate change, is starting to bear fruit. Below, we provide examples of such progress on scales relevant to Arctic issues.

2. Materials and Methods

In this perspective, we first consider continuing rapid change throughout the Arctic system including secular changes, abrupt changes, and shocks. We then explore the question: are we on the right response trajectory at the required pace? Issues reviewed include the co-production of research exploring possible futures, supporting rights holder and stakeholder discourses on desired futures, the need to monitor Arctic change, and funding strategic and regional adaptation—in contrast to the ad hoc adaptation and self-adaptation that has mostly been the case thus far. We then address the fact that the Arctic's future depends on global action, and, in the inverse, that the Arctic plays a critical role in the global future.

3. Results

3.1. Continuing Rapid Change throughout the Arctic System

3.1.1. Secular Changes

Since the 2016 workshop, we have seen continuing trends of the key pressure points on the Arctic system. Cryospheric changes have resulted in major, compounding impacts on ecosystems and environmental system services important to Arctic Indigenous Peoples and humanity as a whole [4]. Specifically, summer sea ice reduction, likely unprecedented over the past millennium, continues unabated [4]. Loss of sea ice is resulting in major shifts with implications for food webs and marine living resources [9]. Winter sea ice loss in the Bering Sea, tied to anthropogenic warming [5,10], has led to a northward shift of fish stocks, with disruption of subsistence and commercial fisheries, compounded by marine heatwaves [11].

At the same time, a consensus has emerged that sea ice loss is reversible with decreasing atmospheric greenhouse gas concentrations [12]. Permafrost thaw and degradation, on the other hand, are irreversible on decadal to centennial timescales and have reached record levels, threatening the release of greenhouse gases from large reservoirs [13]. The increased surface melt of the Greenland Ice Sheet has contributed significantly to accelerated global sea level rise, with Greenland expected to continue as the single largest contributor to global sea level rise in the coming decades [14]. Ice sheet loss mechanisms suggest a greater vulnerability to ocean heat increases and surface melt than previously envisioned, emphasizing the potential for greater uncertainty and underestimation of Greenland's contribution to sea level rise [1,4].

Terrestrial Arctic ecosystems are undergoing substantial changes, ranging from "greening" of the land cover to the increasing importance of wildfires in landscape disturbance and carbon loss [15,16]. These changes are stressing Arctic communities and societal dynamics, including challenges related to transportation, infrastructure, and food security.

For example, residents are facing the ongoing loss of biodiversity and decline in health and populations of critical subsistence species both in marine and terrestrial environments.

These latter threats are tied to health and well-being, in particular through food security. The Utqiaġvik Declaration expressed this in the following way, "Inuit food security is multi-faceted and reflective of interconnecting elements, such as language, child development, mental and physical health, high cost of transportation, economic development, and management. The Arctic's living resources and the ability of our hunters to harvest and process these resources are fundamental to food security and core to Inuit identity, making the health and availability of Arctic wildlife of utmost concern" [17]. This is fundamentally true for all Arctic Indigenous Peoples—hunters, herders or otherwise.

Reflecting on the 6th Assessment Report of the IPCC [1], Inuit Circumpolar Council (ICC) Chair Dalee Sambo Dorough stated, "Inuit have moved beyond 'if' climate change is real to action to protect Inuit Nunaat—our Inuit homeland—including the Arctic land, sea ice and the Inuit way of life. Inuit have been calling for immediate action to contain temperature rise to 1.5 °C, as even this increase will see the reduction in Arctic sea ice, snow cover, and permafrost loss continue. Both the Policy Summary and the Technical Summary note with high confidence that the rate change continues, with sea ice becoming younger, thinner, and more dynamic (very high confidence). Such change has severe consequences for our food security and multiple other aspects of our day to day lives" [18].

The current work indicates major changes in ecosystems, including the appearance of novel contaminants [19] and invasive species [20]. Expanded shipping and fishing in Arctic waters along with wind and ocean currents bringing and accumulating microplastics result in Arctic communities having to deal with increased levels of debris, fishing gear, and microplastics [21].

Concomitant with these changes, adaptation is occurring at both local and regional scales. An example of a new adaptive strategy is vegetable farming [22], such as off-grid containerized agriculture [23]. However, many such approaches and innovations are fragmented, disconnected, and/or still in development stages and hence lose adaptive significance and do not increase overall resilience (e.g., [24]). The lack of strategic adaptation naturally leads to ad hoc self-adaptation of the Arctic system that has the potential to add additional challenges to our capacity to respond to the multi-dimensional and highly interconnected set of changes seen in the Arctic system.

3.1.2. Abrupt Changes and Shocks

Studying past changes manifested in paleo archives, such as ocean sediments or ice cores, reveals that changes in complex systems—and, the Earth system is the ultimate complex system—can occur relatively smoothly. However, they also demonstrate that typically these complex systems also show rapid (abrupt) changes. During 2020 and 2021 we have been reminded by the rapid emergence of COVID-19 how quickly changes can occur—in essence, as shocks to the system [25].

The COVID-19 pandemic created another unsettling stress on Arctic Indigenous communities compounding the already significant challenges presented by the multiple pressures they have experienced in recent decades [26]. Most communities responded with great concern and established recommended social distancing protocols between households, with preliminary research suggesting that such measures were effective relative to regions at lower latitudes [27]. Travel was restricted and involved extended quarantines. As for so many people, this caused separation and a sense of isolation. However, Arctic Indigenous people greatly depend on large, extended families for their social, cultural, nutritional, and emotional well-being. Indigenous food security in small village communities that rely on communal harvests and sharing practices were altered because of social distancing. Significant community gatherings for celebrating, honoring, and healing were interrupted for over a year, which has caused unresolved public health concerns.

COVID-19 alerted us to how vulnerable our highly interconnected Earth system is and how shocks to one part of it will ripple through the entire system, including all environmental and societal components [25]. However, it also showed that society has the capacity to react quickly and offer responses such as testing to diagnose the extent of the impact and vaccination to control the pandemic. Additionally, we learned that measures that are available to minimize adverse effects of particular pressure on our planet or one of its subsystems are frequently not taken up by parts of local, regional, and global communities. And, we learnedthat even when uptake is desired, solutions may not be readily implemented due to wealth, infrastructure, and other disparities. In the end, it also highlights that the deciding factor for how we master challenges to the Earth system is not the availability of (technological) solutions, but our willingness to act. Additionally, in many cases, we are too slow in our response, thereby increasing the challenges for the present and future generations to thrive on a healthy planet.

3.2. Are We on the Right Response Trajectory at the Required Pace?

As highlighted in the 2019 IPCC Special Report on the Oceans and the Cryosphere [4], governance systems at the pan-Arctic and global scales are challenged by the rapidity and interconnectedness of changes, pushing existing response mechanisms to the brink and straining the limited capacity at the level of Arctic communities and regions. However, there has also been progress on several fronts. While since 2016 we saw several major changes in the political and governance systems with slow or no tendency to action related to the threats faced by global society around the world, we are noting a recent reversal of some of these trends, initiatives, and legislation. Especially when it comes to climate solutions, there is a significant set of actions that are under consideration or have been moved forward.

3.2.1. Co-Production of Research Exploring Possible Futures

The 5C Arctic report recommended: "Enhance and support research in projecting which future states of the Arctic are possible in principle, under which conditions they can be reached, and which impact they would have" [2]. Some progress has been made in recent years recognizing the role of different approaches and knowledge systems—in particular Indigenous knowledge (IK) [28,29]—in describing the plausible range of future states of the Arctic system and the impacts of changes of the present state, from the local to the global scale. However, holistic approaches and mechanisms for bringing relevant knowledge to bear on Arctic issues remain peripheral and under-resourced (see also Table 1).

Earth system models, as well as multi-sector dynamics or integrated assessment models, hold significant promise but are currently not able to capture the full range of plausible futures and associated outcomes in a rapidly changing Arctic. Key processes, such as implications of permafrost degradation, are not yet fully captured, nor are societal and geopolitical drivers of change. In the near term, this shortfall presents challenges in meeting global and Arctic carbon policy and management goals, for example with respect to the impact of underestimated permafrost carbon feedbacks [30]. In this context, participatory scenarios may serve as a useful complement to models and have gained prominence in identifying impacts and vulnerabilities in the Arctic [31,32]. Scenarios draw on both quantitative and qualitative information and expertise, and hold great promise as vehicles for mutual social learning and the formation of communities of practice. A major hurdle that needs to be overcome is how to facilitate participation by Arctic rights holders and a broader range of stakeholders.

Indigenous involvement in research and policy development must include greater equity with the scientific and research sector. Funding should provide IK scholars with an equitable level of participation and should provide support for IK as a system of knowledge and learning. Some examples are Sea Ice and Walrus Outlook (SIWO) (https://www.arcus.org/siwo, accessed 2 September 2021), which is a collaboration of sea ice observations related to walrus migration in spring, and the U.S. National Science Foundation's Navigating the New Arctic initiative and their efforts to recognize the value of proper co-production of knowledge. In Canada, several compelling examples of Indigenous-led monitoring, co-production and co-management have recently been compiled to illustrate the breadth and efficacy of different approaches [33]. Another example is Sea-Ice Monitoring and Real-Time Information for Coastal Environments (SmartICE). This is a partnership among communities, academia, and governments that draws upon Inuit traditional knowledge and state-of-the-art technology to support ice-information needs (https://smartice.org, accessed 5 January 2022). Since its inception as a co-produced research project, SmartICE has developed into a social enterprise with a business model grounded in Inuit values including intergenerational teaching, community building, and meaningful employment for Inuit youth. A final example of funding IK expertise and participation in climate change research is Ikaaġvik Sikukun (https://www.ikaagviksikukun.org, accessed 7 January 2022) in Kotzebue, Alaska. The stated goals include to "...address key questions concerning the mechanisms and impacts of rapid changes taking place in the Arctic while ensuring that our answers incorporate traditional ways of knowing and are relevant to local needs". In the words of ICC Chair Dalee Sambo Dorough, "There is a pressing need for large-scale institutions to be responsive and adaptive to understand and address diverse issues across scales. Such adaptation requires the involvement and use of Indigenous Knowledge to inform research, observation and monitoring programs, as well as governance" [34].

Table 1. ICC Priorities in Guiding Research in Inuit Nunaat as laid out in the Utqiaġvik Declaration 2018 (reprinted with permission from Dalee Sambo-Dorough, ICC Chair, [35]).

The following actions are required to protect Inuit Nunaat and guide academic institutions, governments, and researchers in the conduct of the Inuit Nunaat research:
• Enhance ICC's work with Arctic research efforts, such as the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) Working Group, Sustained Arctic Observing Network (SAON), International Arctic Science Committee (IASC), the European Union (EU), and during high-level ministerial processes to ensure our views and concerns are addressed on how research in the Arctic should be conducted and to highlight how ethical approaches for research in the Arctic advance Inuit self- determination in research;
• Urge ICC to promote the interconnectedness of drivers of change and the interrelated impacts and implications on our health, economy and environment in high level political discussions and decision-making at fora such as the Arctic Council, the EU and UN agencies among other relevant international fora;
• Mandate ICC to participate actively in the operationalization of the United Nations "Local Communities and Indigenous Peoples Platform" to create a space to share best practices, relevant climate change programs and policies, and build capacity for Indigenous Peoples to engage in the UNFCCC process

Just as Science, Technology, Engineering, and Mathematics (STEM) funding aims to grow the next generation of scientists, engineers, and researchers for universities, government agencies, and research institutions, IK should have equivalent initiatives to ensure there is the next generation of IK experts and practitioners in all communities and regions. This is critical for Indigenous communities' full and proper partnership in the co-production of knowledge projects in the Arctic into the future. The scientific/academic/governmental knowledge production industry is firmly established and well-funded to perpetuate itself, but even it must create large funding initiatives to support additional STEM education, post-graduate internships, and postdoctoral opportunities to develop the next generation of scholars, scientists, and researchers to continue their work.

Co-production approaches and adaptation strategies for Arctic Indigenous communities require a balanced approach with resources committed to support the continuity and growth of IK, the Indigenous Peoples' way of knowing and understanding (Table 1). In broad terms, Indigenous education is comprehensive and involves extensive experiential learning, language instruction, and study of cultural practices, beliefs, and spirituality. The learning experience of IK sharing is a necessity for the well-being of Indigenous people, families, and communities and is necessary to ensure that IK remains a critical partner and contributor to humankind's understanding of the Arctic.

3.2.2. Rights Holder and Stakeholder Discourse on Desired Futures

The 5C Arctic report recommended: "Design, initiate, and support a platform for a broad stakeholder dialogue on which future state of the Arctic we should strive for, drawing on existing local and regional platforms. The outcomes of the continuing dialogue have to inform decision-making processes in the context of the evolving Arctic trajectory" [2]. It is important to differentiate Indigenous communities and "local" communities, even though the experiences and knowledge of both contexts have important roles in understanding and responding to the challenges of the Arctic. Specifically, the UN Declaration on the Rights of Indigenous Peoples recognizes "the urgent need to respect and promote the inherent rights of indigenous peoples which derive from their political, economic and social structures and from their cultures, spiritual traditions, histories and philosophies, especially their rights to their lands, territories and resources" [35]. This presents a distinctively different status than "local communities", which is the term generally used to describe the inhabitants of a geographic area. This necessity of ensuring the sovereignty of Indigenous communities to maintain connection to their land and waters and to conserve its resources, which have sustained Arctic Indigenous Peoples for millennia, must be recognized. Therefore, Arctic Indigenous People should be designated as "rights holders" instead of stakeholders. Stakeholders for Arctic discussions include many different interest groups, industries, and organizations.

The viewpoint from an Indigenous coauthor of this perspective (V.M.) ties in with the acknowledgment by participants in the 2016 workshop that "There is no 'one Arctic'"—a point echoed by Young in 2021 [36] from a governance perspective. The need for a platform, in the broadest sense, to support discourse on different desirable and achievable future Arctic states is greater than ever. However, this question has already been answered by the Arctic's Indigenous Peoples. Any discourse about Arctic futures raises fundamental ethical questions that remain as vexing as ever in light of competing interests and post-colonial tensions [34]. Some might point to the Arctic Council as a consultative body or the U.N. Framework Convention on Climate Change and its various instruments to effect climate justice as entities that could support discourse.

At the same time, the importance of rights holder perspectives and place-based solutions has already been reflected on above with respect to community-driven adaptation and change management. This calls for a multitude of conversations in a polycentric approach to foster synergy and cross-Arctic communication and mutual support that is nevertheless tied to a particular place.

As an Indigenous Peoples non-governmental organization, the ICC-International has United Nations Consultative Status and is active in its role, including within the United Nations Permanent Forum on Indigenous Issues (UNPFII), which is the central United Nations coordinating body for Indigenous Peoples. ICC-International is also a Permanent Participant at the Arctic Council, one of six Indigenous Permanent Participants (the others being the Arctic Athabaskan Council, the Aleut International Association, the Gwich'in Council International, the Russian Association of Indigenous Peoples of the North, and the Saami Council). The ICC considers the UN and Arctic Council activities as fundamental to its work as an international organization. Each provides a degree of involvement in areas important to Inuit Nunaat, such as human rights and health, environment and climate issues, and food security.

"There is a strong connection between our culture, environment, and our homeland, which transcends national and political boundaries and connects us as one people. We affirm our right to self-determination and through a unified voice and approach are committed to advocate for, and protect the collective interests of, our membership at the international level" [37] (p. 6).

The priority areas presented in the Utqiaġvik Declaration [17] identify what is important to Inuit in the Arctic of the future. Together they represent the understanding that "We continue to rely on the land and ocean for nutrition, social, cultural, and spiritual well-being as well as traditional healing across Inuit Nunaat" [37]. In the words of co-author Vera

Metcalf, "We are only as healthy as our world is—our homeland and waters, air, and all those living with us".

3.2.3. Monitoring Arctic Change

The 5C Arctic report recommended "Complete and sustain the emerging Arctic Observing System, augmented by early warning components and enhanced Arctic system models to closely track key components of the changing Arctic" [2]. The importance of networks of sustained observations of Arctic change has increased further since 2016, driven by a combination of factors. The extent, pace, and effects of Arctic system change are key drivers of response action to mitigate risks stemming from feedback processes and adverse impacts from the local to the global scale. With accelerated and potentially underestimated changes, in particular in the Arctic cryosphere (see above), anticipating major transitions through observations and observation-informed models is increasingly relevant. As articulated in the National Academy of Sciences "The Arctic in the Anthropocene" report, monitoring is a critical alert system for "unknown unknowns" [38]. At the same time, increasing human activities and potentially competing interests in the Arctic have created an urgent need for observations that meet a range of societal information needs. A series of recent reports have examined in more detail the societal (including economic) benefits of Arctic observing activities in response to priorities defined by the Arctic Observing Summits (AOS) and the ASM process [39,40]. Finally, observations will be central to assessing the efficacy of any global scale action meant to stabilize and reduce atmospheric greenhouse gas concentrations.

The SAON initiative has recently made significant progress towards the implementation of more concerted observing efforts. In this context, the focus on widely shared benefits as a driver of the collaborative or coordinated deployment of observing assets has gained traction and is embedded in SAON's Roadmap for Arctic Observing and Data Systems (ROADS) [41].

A remaining challenge is the lack of effective, internationally coordinated funding support mechanisms for such work. One of three themes of the Second ASM was "Strengthening, Integrating and Sustaining Arctic Observations, Facilitating Access to Arctic Data, and Sharing Arctic Research Infrastructure", which has led to the creation of an Arctic Funders Forum [42]. Yet, major bureaucratic hurdles continue to impede effective transnational funding capabilities and capacities—despite the positive outcomes achieved by the Belmont Forum in accelerated international co-sponsorship of environmental research. Individual countries are also challenged to coordinate internally so as to effectively contribute to an internationally supported effort [43]. At the same time, we need to acknowledge that the co-design and co-management of sustained observations and observing networks in partnership with Arctic Indigenous Peoples has some ways to go. There remain significant challenges in bridging knowledge systems and providing opportunities and resources, although the needle is starting to move. In addition to community-driven observing initiatives and individual collaborations at the local scale [44,45], there is encouragement in SAON ROADS calling for Indigenous-led Expert Panels to help identify and prioritize observations with societal benefits in mind [41]. As another example, Canada and the United Kingdom recently agreed to cooperatively fund the Canada–Inuit Nunangat–United Kingdom Arctic Research Program, which is guided by the National Inuit Strategy on Research [46] and requires full Inuit engagement in leadership, design, development and execution. In the words of ICC Chair Dalee Sambo Dorough: "Our desire is that our perception of the Arctic is well understood, that Indigenous knowledge is acknowledged and utilized, that we seize opportunities for co-production of knowledge, and that we create a shift of what observing priorities are—all these steps create opportunities for action. Each of these points could trigger a change of how science is conducted in the Arctic by the simple act of reaching out to our communities, the willingness to co-produce knowledge, while respecting the value of Indigenous knowledge and the ethics related to utilizing it. There are many opportunities throughout observation processes for real action" [47].

3.2.4. Supporting Adaptation to the Changing Arctic

The 5C Arctic report recommendations included "Expedite research on adaptation of the Arctic to ongoing and expected environmental changes and provide resources for implementation of science-based adaptation strategies" and "Ramp up technical and financial support for Arctic societies needing strategic adaptation solutions—including relocation and soft infrastructure support (building codes, zoning, and others)" [2].

Since the release of the 5C Arctic report, a series of key publications by the Arctic Council's Arctic Monitoring and Assessment Programme (AMAP) has provided a kind of roadmap for broad-based adaptation action—with one important caveat. With three regional foci—Bering/Chukchi/Beaufort Region, Barents Region, and Baffin Bay-Davis Strait Region—the Adaptation Actions for a Changing Arctic (AACA) effort examined a broader range of options and approaches for adaptation measures [32]. Significantly, the Bering/Chukchi/Beaufort Report recognized the importance of developing a shared vision for desired Arctic futures by Arctic rights holders and stakeholders ([32]; see also the previous section), pointing to participatory scenario frameworks as a means to approach such visions. However, despite all their strengths, the AACA activities and reports are positioned mostly within an academic/government agency framework with disproportionate space given to a review of the magnitude and impacts of change, and little involvement of Indigenous expertise in the drafting of the reports. This circumstance is reflected in the Arctic Adaptation Exchange that emerged under the U.S. Climate Resilience Toolkit (https://toolkit.climate.gov/tool/arctic-adaptation-exchange, accessed 1 October 2021) as a follow-on to AACA, which is well positioned but underutilized in an adaptation context.

A number of other actions taken at the national and international level may qualify as adaptation measures or point in the direction of response. For example, the implementation of legally binding frameworks for search and rescue and spill response by the Arctic Council—established as a consultative rather than an executive body—is noteworthy [48,49]. Ratification of the Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean (CAOFA) [50] in 2021 with all Arctic coastal states, China, Japan, the Republic of Korea, and the European Union as signatories has sent an even stronger message. Specifically, the CAOFA calls for and has set in motion international scientific collaboration and monitoring to establish the state of marine living resources in the central Arctic Ocean, with the potential to develop a joint, ecosystem-based management regime [51]. In a similar vein, the ASM has demonstrated potential as a forum to advance internationally coordinated research responses to pressing Arctic issues. The Third ASM, co-hosted by Iceland and Japan in 2021, drew science ministers and officials from 27 countries, identifying priorities for international collaboration and helping build momentum for the support of concerted action by both Arctic and non-Arctic states. The guiding principles were transparency, inclusivity, and implementing a bottom-up approach to science. ASM3 expanded the ASM process by "attempting to create a more formal consultation process with the wider research community", complemented by "updates and new projects from participating countries, Indigenous Peoples' organizations, and international organizations engaged in Arctic science and education" [52]. Efforts such as the Sustaining Arctic Observing Networks (SAON) initiative, which is supported by both Arctic Council member states and non-Arctic states through membership of SAON co-sponsor International Arctic Science Committee (IASC), have shown promise as vehicles for follow-through on ASM recommendations. However, challenges remain, such as developing instruments for joint, transnational funding of internationally coordinated response action.

The designation of protected areas in light of rapid change can be a mechanism to develop effective response strategies at the local and regional level. Canada's recent designation of the Last Sea Ice—Tuvaijuittuq Marine Protected Area in the High Arctic—or the Northern Bering Sea Climate Resilience Area in the U.S. are examples of such action. Although, many questions remain as to how to best steward and manage such reserves. Different assessments have demonstrated that Indigenous, community-based management and support activities, such as community-driven monitoring, are most effective in ensuring adaptive and sustainable resource management in rapidly changing environments [45,53]. In the Arctic, increasing devolution of regulatory powers to the local, typically Indigenous-managed scale is evident. Examples include regulatory and management authority granted to the Nunatsiavut Government over terrestrial and marine resources in Labrador, Canada, or the Piniakkanik Sumiiffinni Nalunaarsuineq (Pisuna) locally based monitoring system that informs adaptive management approaches in Greenland [44].

However, finding an effective and equitable balance between local and broader interests and perspectives remains a challenge. For example, there may be many different levels of government involved in observing and monitoring various aspects of the Arctic environment but little or no communication among those entities (federal, regional, local, etc.) to ensure consistency in approach, to eliminate redundancies and fill critical gaps, and to leverage resources including human capacity and Indigenous expertise. This disconnect can hinder efforts to adapt to change, such as leading to a mismatch between regulatory frameworks that may control access to critical resources—e.g., country food and observational information—which indicates a need for regulatory flexibility in a rapidly changing environment. The problem is equally applicable from the local to international scales.

The activities of hunting, fishing, herding, gathering, and sharing, then preserving, preparing, carving, sewing, and more must all be kept and supported as times of learning IK to ensure our next generation of IK bearers is prepared to provide the unique way-of-knowing to Arctic research and governance. This is where the Utqiaġvik Declaration priorities of Food Security, Education and Language, Indigenous Knowledge, Sustainable Wildlife Management, and Environment are most directly aimed and where progress toward Indigenous-led resource management will be critically important to the future of the Arctic. The following from the Declaration illuminates this: "Food security is central to Inuit identity and way of life; is characterized by a healthy environment and encompasses access, availability, economics, physical and mental health, Inuit culture, decision-making power and management, and education. Therefore, it will be promoted and endorsed in all aspects of ICC's work" ([17], preamble).

3.3. The Arctic's Future Depends on Global Action

Arctic warming is mainly driven by actions taken outside the Arctic. One prime example is the atmospheric concentration of carbon dioxide which is responsible for ca. two-thirds of the greenhouse gas effect. It is emitted primarily in mid and low latitudes but affects the globe as a whole due to the rapid mixing of the atmosphere on hemispheric (less than one year) and global scales (several years). Since 2016, CO_2 concentrations in the atmosphere have increased steadily at a rapid pace from about 402 ppm (parts per million) (2016 January) to about 418 ppm (2022 January), thereby driving further global and regional warming. These changes imposed onto the Arctic by drivers located in lower latitudes amplify warming in the Arctic—now assumed to exceed 3–6 °C for a 1.5 °C rise in global temperature. An analysis by Carbon Brief following COP26 estimates that current policies concerning carbon emissions will lead to global warming between 2.6–2.7 °C by 2100 (with an uncertainty range of 2 to 3.6 °C) [54]. On the other hand, if countries meet their long-term carbon emission goals, the warming would be kept at about 1.9 °C. There are feedback loops through which the amplified warming of the Arctic affects the lower latitudes, for example through weather patterns influenced by the strength and geographical pattern of the Arctic Vortex [1,55].

The 5C Arctic report recommended: "Deploy measures for deep decarbonization of the global energy system and accelerate the upscaling and deployment of technologies for negative carbon emissions. Unify the efforts for allocating resources to master this historic challenge". Decarbonization of the energy system and a reduction in carbon emissions require an accelerated buildup of renewable energy production. According to the IEA, it is possible to reach net zero carbon emission by 2050 if the right actions are taken now and are sustained [56]. Most of the substitution for fossil fuels will come from solar and wind energy. The report emphasizes that the pathway toward net zero carbon emissions is narrow and requires the "massive deployment of all available clean energy technologies—such as renewables, EVs, and energy efficient building retrofits—between now and 2030. For solar power, it is equivalent to installing the world's current largest solar park roughly every day". The number of ambitious goals by governments and the private sector is growing steadily (e.g., Europe's goal to cut emissions by 55 percent by 2030 to stay on course for carbon neutrality in 2050 [57], China's announcement to stop financing coal-fired power plants abroad [58], Microsoft's plan to be carbon negative by 2030 [59]), but in many cases the pace of implementation still lags behind the stated goals.

In addition to the buildup of renewable energy sources, reaching net zero carbon emissions by 2050 requires a substantial capacity for negative emissions. Negative emissions are one of the major concerns laid out in the 2016 report. There are increasing efforts to upscale negative emissions through nature-based and technological solutions. Examples of nature-based solutions include reforestation (e.g., the American Forests Trillion Trees Movement), the restoration and expansion of wetlands and peatlands, regenerative agriculture, and marine ecosystem augmentation or restoration practices. Technological solutions include mechanisms that extract carbon dioxide from the atmosphere, including those developed by the construction of CO_2 extraction units by at least four startups (Climeworks, Carbon Engineering, Carbon Collect, and Global Thermostat.). Although those startups are still in the process of scaling their technology to the next level of tons to hundreds of tons per day, they principally can be scaled to the Gigaton level needed by mid-century to reach the goals of the Paris agreement.

Overall, there is more global action towards the recommendations related to the transformation of the energy system towards carbon neutrality by 2050 listed in the 2016 report. However, it is also clear that the pace towards implementation of the measures outlined in this report has to be accelerated.

3.4. The Arctic Plays a Critical Role in the Global Future

In the past, the Arctic was frequently seen as a part of the Earth system that is largely decoupled, being located 'at the end of the world,' but also playing a minor role in global budgets such as heat and water transport. The Arctic system was thought to be mainly driven by global processes without major feedback on lower latitudes. It is now clear that there are powerful feedback loops from the Arctic to lower latitudes including impacts on weather systems, freshwater budgets in critical areas of the world ocean, and impacts on the global albedo and radiation balance. This recognition has led to improved integration of the Arctic into Earth system models, and it is now also widely accepted that Arctic communities and their knowledge systems have to be included in decision-making processes within the Arctic and beyond its geographical borders.

This changing situation is well captured by Lisa Koperqualuk, ICC Canada Vice-President (International), who stated "Inuit recognized early that safeguarding the Arctic would protect the planet—however, these calls remain unheard. As an observer to the IPCC, ICC advocated for the co-production of knowledge to guide the AR6, which would include Indigenous Knowledge as an important knowledge source" [18].

4. Conclusions and Outlook

We see increasing activity in most of the areas addressed in the 2016 report 'A 5C Arctic in a 2C World' [2]. It is also clear that the present pace of response to the challenges facing the Arctic and its communities remains too slow. However, there is still hope that humankind can turn the corner and implement the necessary steps to reach solutions to the challenges caused by the ever-expanding human footprint on our planet. These are solutions that include the Arctic with its amplified response to global drivers.

A key challenge is the fact that the rate and magnitude of change experienced by Indigenous Peoples of the Arctic and other Arctic residents outpace changes at lower latitudes. Yet, policy in many Arctic nations is made in locales and by policymakers far removed from where the greatest impacts are felt. This reality, combined with a history of colonization and focus on extractive resource development, complicates the translation of lessons learned in the Arctic into national or global policy frameworks. This is also reflected in the discourse around climate justice at COP 26 where a rift has expanded between industrialized nations on the one hand, and developing countries and Indigenous Peoples on the other. Part of the work in bridging this rift and supporting climate action involves framing and communication of the issues highlighted in this perspective from an Arctic into a global setting.

Strong Arctic voices can bring the major issues facing the Arctic to the attention of those involved in the decision-making processes that will decide the trajectory of the Arctic and indeed the planet. Although finding these voices is a challenge in itself, and clearly there are many positions concerning which Arctic future is the most desirable, a consensus has to be found concerning the future for which we should aim. For example, the voices of the people of the low-lying island nations had a major impact on the definition of the temperature targets during COP 21 that led to the Paris Agreement [7].

Unfortunately, at this critical time when it is so necessary for the voices of Arctic Indigenous Peoples to be heard, the COVID-19 pandemic's impact on engagement with government managers on policy, and with science on research, has limited Indigenous participation even more. Since most boards, commissions, and workgroups, which are primarily made up of individuals from different communities, postponed travel for face-to-face meetings, engagement, full involvement, and collaboration did not happen. Virtual meetings did not provide the same opportunity for effective participation, especially since Internet-based communication remains too expensive, very slow, and unavailable to most community members—a good illustration of Indigenous People's ongoing disparity in their ability to respond to crises or participate in solution development due to insufficient infrastructure.

We are now in the decisive decade concerning the future we leave behind for the next generations. Every year we fail to meet the milestones towards the targets that would reroute our planet and the Arctic onto a sustainable track into the future will require stronger, more concentrated, and more focused efforts in the years ahead. Additionally, if we hedge the milestones for too many more years, the envisioned targets will be unreachable. The coming few years will give us a clear indication if we are moving towards a future of hope or if we have missed the chance to preserve the 'safe operating space for humanity' in the decades and centuries to come [60].

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