

USING BIG DATA, SCENARIOS DEVELOPMENT, AND GAME THEORY TO MONITOR, UNDERSTAND AND ADAPT TO CLIMATE CHANGE IN THE CIRCUMPOLAR ARCTIC

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1. Introduction

Adaptation to climate change in the circumpolar Arctic requires strategic and innovative approaches. One of the major adaptation challenges in the circumpolar Arctic is engagement and making effective societal decisions to adapt to climate and other global changes at local and regional scales. Complexity and uncertainty around climate and other changes make existing analysis and governance approaches inadequate, particularly given the expanding and exponential nature of change and information, and increasing expectations of participation.

Several case studies are considered, and used as the basis for preliminary recommendations for the use of big data analytics, scenarios and games for monitoring, understanding and adapting to climate change in the circumpolar Arctic. However, there is first a discussion of the partnerships for this research.

2. Research Partners

Through research projects and research tools and networks, the Arctic Institute of North America and the Aarhus School of Business and Social Sciences are collaboratively exploring the use of big data analytics, scenarios development, and games theory to engage government, industry, indigenous peoples and local residents, and other stakeholders in monitoring, understanding and adapting to climate change in the circumpolar Arctic.

a. Arctic Institute of North America, Universities of Calgary and Alaska Fairbanks

The Arctic Institute of North America, based at the Universities of Calgary and Alaska Fairbanks, has research collation and dissemination tools such as the ARCTIC Journal which has over seven decades of publications, and the Arctic Science and Technology and Information Systems (ASTIS) open access data bases which hold over seventy six thousand records and reports. AINA research projects including Arctic adaptation governance, climate adaptation and mitigation for coastal and marine areas, and sustainable energy and resource development. These research projects utilize big data analytics, scenario development and games theory.

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This research described here is being jointly implemented with the Aarhus School of Business and Social Sciences and the Nordic Centre of Excellence for Strategic Adaptation Research. Other collaborating universities and programs for aspects of this research include the Masters of Science Energy Policy and Climate program at John Hopkins University, the Centre for Carbon-Free Development and the Mangone Centre for Marine Policy in the College of Earth, Ocean and Environment at the University of Delaware, and the Earth Institute at Columbia University.²

b. Aarhus School of Business and Social Sciences, Aarhus University

The Aarhus School of Business and Social Sciences is one of four faculties at Aarhus University, and is the largest university unit of business studies and social sciences in Denmark, with a wide academic scope and strong research communities. Multi-disciplinary research and research-based teaching includes law, economics, entrepreneurship, business engineering and management, political science and psychology.

The Nordic Centre of Excellence for Strategic Adaptation Research³ is a network involving nine founding partners in all five Nordic countries, with industry partners, which focuses on two overarching research questions of what constitutes a strategic approach for adapting sustainably to the inevitable impacts of climate change and the unintended consequences of climate policy; and secondly how dialogue and innovation can be used to advance adaptation strategies in the Nordic region. Innovative approaches such as games theory are being used in this research.

Introduction to Big Data, Scenario Development and Games Theory

a. Big Data Analytics

Monitoring for climate change and adaptation, including citizen participatory science, gives rise to significant volumes of data. As the amount of climate data and information increases, how that data is collected, used and supports decision making becomes increasingly important. Big data analytics, and the modeling and interpretation of that data can assist in monitoring and understanding climate impacts and inform adaptation responses.

² This research is described at the Arctic Institute of North America research page (arctic.ucalgary.ca/research), and specifically under the Sustainable Energy Development project (arctic.ucalgary.ca/research/sustainable_energy_development) and Adaptation Governance for Global and Climate Change in the Circumpolar Arctic (arctic.ucalgary.ca/research/adaptation-governance).

³ Nordic Centre of Excellence for Strategic Adaptation Research, <http://www.nord-star.info/>.

b. Scenario Development

Scenarios are stories that describe a possible future. Building and using scenarios allows an exploration what the future may look like, and facilitates preparation for change. Scenario approaches that consider future climate are typical of climate impacts assessments involving the Arctic. This includes the Arctic Climate Impact Assessment Scientific Report of 2004 and Intergovernmental Panel for Climate Change Assessment Report of 2007. Scenarios can be equally useful in understanding key strategic thrusts and forces, possible futures, and in developing a shared societal vision for future adaptation action.

c. Games Theory

Games theory is the study of strategic decision making. Games provide an alternative means of sharing information and knowledge and participating in decision making, including interactive strategic games that test stakeholder responses to changing decisions and circumstances. Games approaches have already be used in the Arctic to address current knowledge and capacity and how best to respond to changes in the circum-Arctic region.

3. Case Studies Engaging Big Data, Scenario Development and Games Theory

a. Shell New Lens Scenarios

The Shell New Lens Scenarios are the international corporation's latest look at trends at the economy, politics and energy for the next half century.⁴ In their latest scenarios, Shell considers two possible scenarios of the future, considering global trends and issues and using them as lenses to view the world.

The first Shell scenario called Mountains sees a strong role for government and the introduction of policies and regulations that encourage more compact cities and transform the global transport network. The new policies assist in the development of natural gas resources, with it being the largest energy source by the 2030s, and accelerating carbon capture and storage technology, supporting a cleaner energy system.

⁴ Shell New Lens Scenarios, <http://www.shell.com/global/future-energy/scenarios/new-lens-scenarios.html>.

The second Shell scenario called Oceans describes a prosperous but more volatile world. Energy demand increases due to economic growth, but power is more widely distributed. Governments take longer to make important energy decisions to address climate change. Market forces shape the energy system more than government. Oil and coal remain but the share of renewable energy grows.

The Shell scenarios provide an analysis of current trends and how they may develop into the future, including implications for global and Arctic economic and energy developments. The scenarios also highlight policies and regulations likely to have the greatest influence for clean energy, energy efficiency and carbon reduction. It is interesting to consider the role of the circumpolar region under both scenarios as a source of natural gas and natural gas liquids, and as a region through which natural gas is shipped.

b. Case Study: Naval War College Fleet Arctic Operations Game

In September 2011, the United States Naval War College hosted the Fleet Arctic Operations Game.⁵ It was designed to boost understanding of possible challenges and co-operative approaches to sustained maritime operations in the Arctic.

Participants were selected based on their Arctic knowledge, or expertise in planning, operations, and cold-weather systems. People with different backgrounds took part to ensure that many perspectives and variables were considered during the game. Many participants came from military and civilian operational commands; they provided an understanding of how to sustain naval operations in a difficult environment. Another group from government, academia, and industry brought expertise on strategy and policy, and Arctic-related systems and climate issues.

One of the key findings of the US Naval War College report on the game was that the US Navy was not prepared enough for continued maritime operations in the Arctic. The report noted that this was because of poor reliability of current capabilities as well as the need to develop new partnerships, ice capable platforms, infrastructure, satellite communications and training.

Another conclusion was that as weather and climate conditions intensify (particularly ice, wind, and fog), and as time ticks by on an operation and the distance travelled creeps up, there is more risk of mission failure and loss of or harm to allies.

A third finding was that in order to reduce risk, the US Navy needed to rely on partnerships with the US Coast Guard, Alaskan people, industry, and international partners. Recommendations from the game included: establishing an Arctic working group or centre of excellence, building domestic and international relationships, and focusing on learning from other experiences.

⁵ Fleet Arctic Operations Game: Game Report, http://www.usnwc.edu/getattachment/Research---Gaming/War-Gaming/Documents/Publications/Game-Reports/FAOG_Game-Report_09-2011.pdf

The Fleet Arctic Operations Game is interesting as diverse people and groups came together in a simulation to understand how to respond and react to a complex and changing situation in the Arctic seas. As international and political interest, shipping, tourism, and resource activity increases in the Arctic seas and adjacent lands, it will be very important to use these types of complex approaches involving scenarios and gaming to develop shared approaches to governance, marine shipping, and emergency response that engage local and international participants, and all co-operative approaches.

c. Case Study: Adaptation Governance for Arctic Circumpolar Change

One of the major challenges for global and climate change in the circumpolar Arctic is adaptation governance, and making the effective societal decisions to enable adaptation to changes at local and regional scales. Climate, economic, environmental and societal stresses will be magnified without appropriate decision making processes for people, communities, businesses and governments for the circumpolar Arctic. Vulnerabilities, impacts and adaptations will differ across the circum-Arctic given such factors as geographical location, heritage and ethnicity, socio-economic status, occupation and business, and prosperity.

Local, national and regional decision-making and leadership is required to adapt to change. Complexity and uncertainty around climate and other changes make existing governance approaches and structures inadequate. Hierarchical and regulatory models of decision making will not be successful, given the expanding and exponential nature of change and increasing citizen expectations of participation and informed decision making. Without decentralization and greater access to decision making, local and traditional knowledge will not be incorporated into decisions for the peoples and communities most affected by change.

Effective adaptation governance requires scientific and societal understanding of vulnerabilities, impacts and adaptation, supported by scaled-down scenario building and forecasts. Foresight and shared learning are key aspects of integrating scientific and social scenarios and successful decision processes, and can engage people in thinking and learning about the future together, so robust responses and commitments can be developed. Extensive communication and continuous interactive dialogue is necessary among people and societies to equitably and ethically allocate the benefits, burdens and risk of adaptation, and to make societal choices on adaptation that will be accepted and implemented.

Communication and dialogue can incorporate web based platforms and social media to provide wide-spread real time access to monitoring, information and analysis; and to support communications and interactive dialogue among governments and stakeholders. Internet-based platforms, facilitated by satellite and space technology, are already prevalent in much of the circumpolar region.

There are extensive existing governance structures and processes in the circumpolar Arctic at the local, national and international level including the Arctic Council, European Union and United Nations, or on a sector basis such as energy, mining, fisheries, wildlife harvesting, sport fishing and hunting, and tourism that support adaptation to change. The region has many companies, non-governmental organizations and indigenous organizations which span multiple jurisdictions and can assist in the development and transfer of adaptation best practices and lessons learned.

There are unique structures and co-management regimes in North America, Greenland and the Nordic region which may already be able to consider adaptation to climate and other global changes within their mandates, processes and structures. This is in contrast to a more traditional approach elsewhere where directives, legislation and policies need to be formally modified to adapt to climate and other global changes.⁶

d. Case study: Circum-Arctic Resource Development, Navigation and Shipping

Big data and games are useful to examine extractive resource development in the Arctic, and the marine activities required to support these activities. Arctic resource development, and related marine shipping and navigation, are key opportunities and challenges that are being explored by member states of the Arctic Council, and other countries interested in being active in the Arctic resource development and marine transport. Research has initially focused on the Canadian Arctic with some of that research briefly summarized below.⁷

Mining, energy and infrastructure are subject to challenges and opportunities in the northern Canada. This region has significant natural resources with energy, mining and infrastructure development being the largest private sector contributors to northern economies. For development to occur, discussion on impacts, adaptation and mitigation needs to occur with businesses, governments, northern communities, and non-government organizations to assess and respond climate impacts and vulnerabilities.

Games theory and strategic games can facilitate this discussion, while big data analytics can inform the discussion. This discussion will be essential for risk assessment, adaptation and

⁶ An initial presentation on adaptation governance and this research project took place at the International Polar Year 2012 From Knowledge to Action conference in Montreal, Canada on April 26, 2012: Adaptation to Climate Change for Coasts and Marine Areas in the Circumpolar Arctic. See Adaptation Governance for Global and Climate Change in the Circumpolar Arctic for further information, <http://arctic.ucalgary.ca/research/adaptation-governance>.

⁷ Arctic Resource Development and Climate Impacts, Adaptation and Mitigation, http://www.arctic.ucalgary.ca/arctic_resource_development_climate. See also the internal summary, Climate Impacts and Adaptation for Energy, Mining and Infrastructure in Canada's North.

mitigation, and the development of best practices and resiliency among all these sectors. For all sectors, there is the need to proactively manage risk, where those risks are compounded by economic and environmental change, including climate change.

The changing climate affects hydroelectric developments on rivers, and impoundments in northern Canada. Projected increases in winter runoff from rainfall and enhanced winter snowmelt will lead to declines in the water stored in snow. Changes in the magnitude and seasonality of flows will stress existing impoundments, particularly inflow flood design. Changes in river ice regimes may increase threats of downstream ice jamming. Risk assessment for this sector requires hydrological modeling in regions that often lack flow gauges.

The hydrocarbon industry engages in exploration, production and transportation, with exploration most affected by climate change. For example, projected decreases in sea ice cover may result in increased exploration activity in the Canadian Arctic Archipelago. Permafrost thaw and snow cover shifts require lower impact vehicles and changes in the exploration scheduling, with unpredictable winter seasons and ice roads requiring more flexible schedules.

The greatest impact may be the use of in-ground sumps for drilling wastes, as this disposal relies on permafrost to prevent subsurface release of drilling wastes into the environment. Increased ground temperatures could result in increased contaminant transport for hydrocarbon and mining wastes. Offshore exploratory drilling will also be affected by decreasing sea-ice cover and shifting weather, could require change to drilling platforms due to increased wave action and storm surges.

Hydrocarbon processing facilities need to consider changing permafrost and ground stability. For facilities located on river channels or coasts, such as in the Mackenzie Delta region, river ice break-up and ice jam flooding, coastal erosion and sea level rise must be considered. The ground thermal regime, drainage and terrain stability, all of which may change due to a warming climate over the lifetime of pipelines project, must be considered. In turn, there is the need to closely monitor the performance of the pipeline and right-of-way to maintain pipeline integrity and minimize environmental impacts.

The development of integrated land and marine transportation as a result of sea ice decline will support and encourage both energy and mining exploration and development. Considering mining, re-supply is currently limited to winter periods and by the availability of ice roads, while exploration is restricted to air access in the summer. Climate change will affect the engineering design, operations, closure and abandonment of mines. Reduced ice roads may require the development of all season roads and water transport. Another concern is the impact of climate change on permafrost and ground stability. Similarly to the hydrocarbon sector, the stability of waste rock piles, tailings piles and tailings containment for mining depends on permafrost to ensure that contaminants and acid rock drainage are not released.

Permafrost challenges the design, construction and operation of infrastructure in northern Canada and throughout the circumpolar region. Thawing of ground can lead to loss of strength, settlement and stability. The removal of insulating vegetation and other ground disturbances can lead to warming and thawing of permafrost. Additional warming may occur due to heat generated by the mine for buildings and water, sewage and hydrocarbon pipelines. For runways, roads and pipelines, settlement and slope instability may occur.

Warmer temperatures presents future challenge for northern resource development and infrastructure design. In the short term, the impacts associated with ground disturbance and construction may be greater. Climate becomes significant over longer time scales. Failure to properly design infrastructure can have serious consequences. Current engineering practices already minimize ground disturbance and the impacts on structures, as locations are chosen to avoid thaw, and modern infrastructure is designed to preserve permafrost.

Reductions in the duration and extent of sea-ice cover could present new opportunities for marine transport in the Canadian North, thus encouraging energy and mining development. A longer shipping season supports the construction of deep water ports along Canada's northern coastline connected by an all weather road with the inland sites. For earlier structures, change can require increased maintenance costs and remedial work for structural integrity.

Waste containment facilities present a particular challenge, as they were not designed for the warmer conditions likely in the future. Failure of tailings ponds and piles could result in contaminants being released with impacts on ecosystems and human health. Remedial action may be required at these older sites, and new containment structures in the southern part of the continuous permafrost zone in the Canadian Arctic may need to utilize techniques presently used in the more southern discontinuous permafrost zone.

An important element of understanding climate impacts is monitoring, emphasize the value of big data analytics. Although lake and river ice have historically served as natural transportation routes with sophisticated methods of winter ice road construction, there is restricted analysis on the effects of climate on these systems. Ice roads and ice bridges that are constructed and maintained each winter provide a relatively inexpensive way to supply northern communities and industry, particularly the rapidly expanding mining sector that relies on ice roads to move heavy equipment, materials and fuel for the remainder of the year.

Adaptation requires response to climate impacts, and often occurs in tandem with the impacts. Some of these adaptive measures are already occurring in northern Canada and further measures are anticipated. Major changes are expected across all sectors, and particularly hydroelectric generation, hydrocarbons, and mining.

Hydroelectric facilities and operations will need to be adapted to changing flow regimes associated with an altered timing and magnitude of snowmelt runoff. There will be the need to consider how best to construct and operate future impoundments particularly on the Mackenzie River as the needs for renewable energy increase. Where older infrastructure in the Arctic overlies thaw sensitive permafrost, some form of structural or operational adaptation may be needed to deal with permafrost thawing.

Demand for energy, and particularly electricity, is rising due to increasing population and industries such as the diamond mines in the Northwest and Nunavut Territories. Alternative renewable energy sources, such as solar, wind, wood and even geothermal power, could meet increasing electricity demand.⁸ These types of sustainable energy approaches could also assist in mitigating climate and substitute for expensive and polluting diesel-based electricity generation.

As already mentioned, an important issue for the hydrocarbon and mining industry is the containment of wastes. Historically, permafrost has been used for long-term storage, but future thaw could eliminate this storage and require remediation of older sites. For both sectors, the changing climate could positively affect exploration, production and delivery. Reductions in sea ice could lead to more exploration and development in the energy and mining sectors, and further economic development throughout the circumpolar Arctic.

Reductions in the thickness and seasonal extent of river, lake and sea ice in northern Canada will require adaptation for marine and freshwater transportation. These will vary from changes in the types of vessels use, and the routes to a shift to more barge- and land-based traffic as ice roads and crossings decrease. Expansion of marine and land-based transportation supports further resource exploration, as previously remote resources would become more accessible and economically viable. Changes in the magnitude and seasonality of river flows require a focus on the safety of existing impoundments, and the most severe inflow flood for which an impoundment is designed. Fuller assessment of the risks to hydroelectric facilities requires hydrological models to predict flow and either ground or remote monitoring approaches.

4. Recommendations

It is important to compare and contrast big data analytics, scenarios, and game strategy to determine the best uses of these innovative approaches across the circumpolar Arctic. One key aspect is to evaluate how it can successfully engage complex actors and stakeholders in monitoring, understanding and adapting to climate change in the circum-Arctic and Nordic region. Based on the research and case studies, preliminary recommendations can be made for uses of big data, scenarios and games theory, with all these tools being endorse for adapting to climate and other changes in the Arctic.

Big data analytics will be important in understandings impacts, and discerning patterns and trends in these changes. As international interests, resource, shipping and tourism activities increase in Arctic seas and northern lands, it will be important to use t complex approaches involving scenarios and gaming to develop shared approaches that can engage local and international participants.

⁸The importance and role of sustainable energy development is a key focus of the research, being implemented with many partners, and described under the Sustainable Energy Development project, http://www.arctic.ucalgary.ca/research/sustainable_energy_development.