Challenges and Opportunities for Greenland and Maine in a Changing Climate

June 29, 2019

Submitted on behalf of the sixteen participants in the 2019 South Greenland Workshop by:

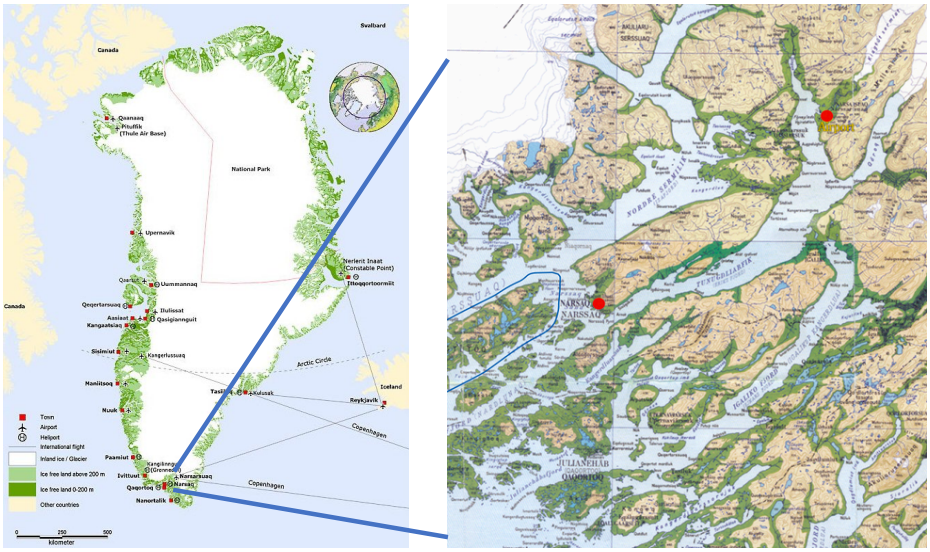
Paul Andrew Mayewski and Charles H. Norchi

Introduction

With the current abrupt warming of the Arctic the likelihood of a Northern Hemisphere "business as usual" future has ended and the linkages between these regions have been dramatically enhanced.

The University of Maine, University of Maine Law School and the University of Southern Maine have a legacy of Arctic, North Atlantic and Maine research. Through common problem solving in a common Arctic setting (Southern Greenland) the multi-disciplinary strength represented by these institutions has been combined to forge perspective, preparedness, and potential opportunities to address challenges in business/commerce and quality of life throughout the Arctic, North Atlantic and Maine.

Through support provided by the University of Maine System Research Reinvestment Fund, the University of Maine Vice President for Research Office, the University of Southern Maine MEIF, and Maine Center Ventures, sixteen researchers from the institutions noted above were able to spend the period 21-29 June together in a common Arctic setting, Southern Greenland (see map below). The researchers represented a broad array of disciplines with one common goal – to experience first-hand the land- and sea-scape, the people and the ecosystem of this region and in so doing learn about the issues facing all of the aforementioned due to climate, environmental and socio-economic change for the purpose of helping to address these issues and as appropriate relate them to Maine issues.



Based upon the knowledge and contacts gained from our multi and inter-disciplinary experience in South Greenland our objective is now to focus on the present and future potential of the Kujataa World Heritage Site, located directly in our workshop region, in an age of climate change. We believe that Maine and Southern Greenland, particularly Kujalleq Municipality, have much to offer each other. Both are high-latitude, natural resource based economies, with relatively small rural populations. Both are challenged in a fast-changing world by out-migration and unprecedented environmental changes.

We believe that there are both challenges and opportunities facing Greenlanders and Mainers. Collaboration and the development of multi- and inter-disciplinary projects can benefit us all. Joint efforts will center on developing and disseminating new research and educational products as well as discovering and sharing historic information pertaining to the Kujataa World Heritage Site. Kujatta (map on the right side of figure above) and the community within its boundaries also provide a case study for cooperative efforts addressing adaptation and resilience in the Arctic and North Atlantic in a changing local and global environment.

Challenges

C1. Coupling economic development with long-term stability in the environment, culture, and community

C2. Developing a partnership addressing global and local changes in climate, economy, environment and society

C3. Supporting Kujataa as a model of international/World Heritage best practices for socio-eco-development

Opportunities

O1. Assist with World Heritage Treaty compliance, and with recommendations regarding international assistance and capacity building

O2. Collaborate using multi- and inter-disciplinary approaches to:

A. Support the development of social, economic and environmental baselines in order to monitor the impacts of future climate, marine and landscape changes
B. Collaborate on and technical support for assessment of spatial (local to global) and temporal (past, present and future) impacts upon the World Heritage Site and Greenland's people and resources
C. Collaborate in consolidating socio-demographic and natural science data resources relevant to the Kujataa World Heritage Site
D. Collaborate to inform the public and other stakeholders
E. Collaborate on multi-institutional, international course projects based on Arctic futures through use of distance technologies (*e.g.* Zoom, Skype) to enhance education and share information and ideas between Greenland and Maine

Acknowledgements. The South Greenland Workshop attendees thank Ramon Larramendi and his colleagues at Tasermiut (tasermiutgreenland.com) for their remarkable logistics support. The Arctic Futures Institute (https://www.arcticfuturesinstitute.org/) initiated the plan and agenda for this workshop.

South Greenland Workshop 2019 Proposed Project Abstracts

For more detail concerning each of the proposed projects refer to Appendix A by attendee name.

Matthew Bampton (Geography-Anthropology, University of Southern Maine):

- A course designed to bring Greenlanders, and Mainers into the field with members of the Greenland Workshop to explore past and present physical and human components of the Greenland Bridge.
- An essay exploring the ideas behind the notion of the Greenland Bridge, as described here.
- A grant proposal to further investigate methods of linking Greenlanders and Mainers in mutually beneficial partnerships to exploit new ideas emerging from these discussions.

Yong Chen (School of Marine Sciences, University of Maine):

- Evaluate how climate-induced changes in fish stocks may influence spatio-temporal dynamics of fisheries (i.e., fish stocks and fishing fleets), what will be associated social and economic impacts on Greenland, and how we can develop management strategy to make fisheries and society more resilient to such climate-induced changes.
- Assess recreational/substance fisheries in the southern Greenland to improve our understanding of use of fisheries resources and identify new opportunity in this region and develop a self-reporting system for the recreational/commercial/subsistence fisheries to improve monitoring program for the Greenlandic fisheries assessment and management.
- Assess the carrying capacity in the southern Greenland ecosystem for possible aquaculture program.

Lee Karp-Boss (School of Marine Sciences, University of Maine)

- Develop collaborations and seek funding opportunities for a pilot study to assess the effects of retreating tidewater glaciers on fjord ecosystems in South Greenland.
- Collaborate and assist in an assessment of the potential for successful aquaculture and recreational fishing developments in South Greenland.

Alice R. Kelley (Climate Change Institute and School of Earth and Climate Sciences, University of Maine)

- Cultural Heritage – Working with stakeholders to monitor the impacts of changing climate (weather variability, sea level change, etc.) and increased tourism to provide data for informed cultural resource management.
- Water – Collaborative evaluation of the surface and groundwater availability and quality that is critical to the success of small farms in southern Greenland. Droughts and increased tourism are likely to increase water demands during the summer months
- Education – Create opportunities for shared educational experiences through undergraduate/graduate student exchanges and electronic/distance collaboration and courses.

Paul Andrew Mayewski (Climate Change Institute and Schools of Earth and Climate Sciences, Marine Sciences, Policy and International Affairs, the Business School, the Center for Oceans and Coastal Law (Law School), University of Maine):

- Continue to develop past climate and environmental change perspective.
- Continue to develop present climate change perspective.
- Continue to develop future climate perspective.
- Assess changes in water quality as a consequence of glacier melt.

Peter Neill (World Ocean Observatory, Climate Change Institute, University of Maine): The following proposals relate most specifically to C3 — 01 and 02(D).

- Assist Museum with smartphone application for Kujataa interpretation.
- Provide Museum with educational curricula relating to Arctic, Greenland, and Kujataa
- Assist Museum with public awareness of Kujataa as cultural tourism destination
- Provide services in advance of 2020 visitor season

Charles H. Norchi (University of Maine Law School)

- This coming academic year, law students in Maine and Greenland would adopt the Kujataa World Heritage Site (KWHS) as a case study through joint course modules using Zoom technology.
- I will seek support to send students (one or two) with Arctic law interest and background to Greenland to interact with Maine student scientists and Greenlanders during summer 2020 on (i) expeditionary law, (ii) Arctic science agreements & research guidelines, (iii) World Heritage Treaty, (iv) indigenous peoples law, (v) environmental law/climate change.
- I will continue research on pan-Arctic World Heritage Treaty obligations incorporating the case of Kujataa Greenland.

Rob Northington (Climate Change Institute, University of Maine and Husson University)

- Sources and fates of groundwater resources around the Kujataa World Heritage site.

Firooza Pavri (Geography-Anthropology, Muskie School of Public Service
University of Southern Maine)**:**

- Employ satellite data to map shifts in landscape and vegetation changes across South Greenland over a 40-year time period.
- Work toward a collaborative, short travel course to Greenland in 2020 focused on exploring the Kujataa World Heritage site and examining the impacts of CC on the ground.
- Explore educational exchange opportunities with Greenlandic institution

Neal Pettigrew (School of Marine Sciences, University of Maine)**:**

- Real-time MetOcean data buoy to monitor variations of the transport of meltwaters on the Southwest Greenland shelf.
- Monitor the winds within and surrounding the potential mine region to estimate mine dust advection and diffusion.
- Development and testing of fjord MetOCean buoy platforms and inexpensive temperature and salinity sensors.
- South Greenland Boat CTS surveys of key ocean climate change fjords.

Jan Piribeck (Department of Art, University of Southern Maine)**:**

- An animation series that brings to life features of the Kujataa World Heritage site making them accessible to a wide audience. The animations will be designed for distribution via website portals and displays in art galleries, museums and community centers.

Erin Roche (Cooperative Extension, University of Maine)**:**

Understanding and Communicating the Impacts of Climate Change on Agriculture:

- Disseminate information gained about agricultural production in Southwest Greenland, agricultural opportunities and risks associated with climate change, and the World Heritage Site (WHS) as a case study to four agricultural groups in Maine.
- Establish a relationship with the Upernaviarsuk Experimental Station and representatives from the Agricultural Consultancy Service.
- Develop relevant resources for Greenlandic farmers about potential response actions for dealing with climate change. Incorporate input from UMaine Extension and other Maine-based agricultural groups in effort to broaden exposure and input to the challenges and opportunities of the region.
- Assist in the facilitation of a student course. Utilize the relationships formed with the Experimental Station and the Agricultural Consultancy Service to identify project topics for student involvement.

Jasmine Saros (Climate Change Institute and School of Biology and Ecology, University of Maine)

- Deciphering past environmental conditions using lake sediment cores, and exploring present lake water quality through monitoring with sensors

Kristin Schild (Climate Change Institute and School of Earth and Climate Sciences, University of Maine)

- Modeling of particle transport through the atmosphere from point locations.
- Testing of new monitoring equipment including arctic buoys (in collaboration with Neal Pettigrew (SMS) and others) and thermal cameras on drones, both with the intention of capturing meltwater runoff.
- Quantify the resilience and adaptation of both glacial and biological systems during transitional phases in glacial fjords (in collaboration with Lee Karp-Boss and Emmanuel Boss (SMS)).

Jeff Thaler (University of Maine Law School)

- Use of UMS Inter-disciplinary cross-campus expertise to implement Maine-Greenland course and program offerings, and for support of efforts to develop environmentally sustainable work force development initiatives both in Greenland and Maine

Vinton Valentine (Geography, Anthropology, University of Southern Maine)**:**

- Discover and compile a list of geodata resources relevant to the Maine and Greenlandic colleagues and professionals with whom we met.
- Establish and nurture a partnership to share Maine Library of Geographic Information (GeoLibrary) experiences and learn about use cases of the geospatial data platform, new NunaGIS, which is being used and customized by Greenland National Museum and Archives, Asiaq, and Government of Greenland.
- Analyze the Kujataa World Heritage Site component boundaries, buffers, and zones by incorporating more data and factors of influence (farming, tourism, mining impacts, airport operations) and present options to stakeholders and the public to assist with effective management.
- Associate shoreline data from recent topographic and bathymetric mapping projects with tide levels and perform basic coastal erosion and inundation studies for site impacts and for above buffer analysis.

Appendix A – More detailed descriptions of proposed projects

Matthew Bampton (Geography-Anthropology, University of Southern Maine)

The Greenland Bridge: Meeting at the Apex of the North Atlantic - Greenland is the meeting place between Europe and North America. Separated by the shortest open ocean crossing between the two continents, Greenland supported the first and most enduring contact between European and North American Peoples. The Fram Strait serves as a key choke point for the movement of Arctic sea ice into lower latitudes, and the ice sheet serves as a major driver of climate processes. Greenland is at the apex of North Atlantic atmospheric and oceanic circulations; it is the only autonomous Indigenous North American nation; its people maintain a distinctive, rich, and varied culture; their language pervades every aspect of daily life; they coexist within both European and Native North American lifeways, and; their environment is experiencing a profound response to global climate change. Greenland and Greenlanders are uniquely positioned to inform our understanding of how humans adapt to and prosper in changing physical and social environments over long periods. The region provides an ongoing long-term experiment reporting on human adaptation and resilience to climate-driven environmental change in a marginal environment over more than 1200 years.

By mapping the physical and cultural parameters of the long-term balance Greenlanders have maintained between hunting, agriculture, and most recently industrialism the relationship between global changes and local impacts and can be explored. The South Greenland region offers a landscape analogous to other high-latitude marginal environments, such as the Scottish Highlands and Islands, Arctic Scandinavia, Northern New England, and the Canadian Maritimes. In each of these cases rich marine ecosystems supplement marginal agriculture. Small changes in external circumstances propagate rapidly through human ecosystems and can easily precipitate failure. Alone among these environments Greenland is unique in having preserved a nearly continuous occupancy switching between hunters, farmers and hybrids of the two. With many challenges remaining Greenland offers a case study in adaptation, exploitation of diverse wild and cultivated resources, and survival into the modern industrial age. Although currently facing several existential threats Greenlandic society and landscapes have historically proven resilient in the face of catastrophic changes. The lessons of adaptability and ecological and economic diversification that can be drawn from this example may be scalable and transferable to other similar marginal high-latitude landscapes.

I propose to generate three products from these ideas:

1. A course designed to bring Greenlanders, and Mainers into the field with members of the Greenland Workshop to explore past and present physical and human components of the Greenland Bridge.
2. An essay exploring the ideas behind the notion of the Greenland Bridge, as described here.
3. A grant proposal to further investigate methods of linking Greenlanders and Mainers in mutually beneficial partnerships to exploit new ideas emerging from these discussions.

Yong Chen (School of Marine Sciences, University of Maine)

Improving fisheries assessment and management in changing environments in Greenland and Maine - Fisheries play a critical role in Greenlandic economy and society accounting for almost one quarter of total employment and providing over 90% of Greenlandic exports. The major target fish species in the Greenlandic fisheries include northern shrimp, Greenland halibut, scallop, snow crab, redfish, Atlantic cod, mackerel, Atlantic herring, and several other species. Many of these species also support important fisheries in the Gulf of Maine (and state of Maine). Northern shrimp fishery is largest and most valuable in Greenland, consisting of 60% of total export revenues. Northern shrimp used to support an important winter fishery in the state of Maine, providing Maine fishermen valuable opportunities in winter when lobstering is not available inshore. The Maine northern shrimp fishery, however, has been on moratorium since 2015 because of low stock abundance, and rising sea temperature is considered one of main drivers leading to the collapse of the fishery. Like many fish species in the Gulf of Maine, the spatio-temporal distribution and abundance of northern shrimp and many other fish species in Greenland have also been influenced by the changes in their environments, providing an opportunity to learn from each other regarding how to manage fisheries resources in a changing environment.

This trip to Greenland has been very informative and productive. The schedule is intensive and well planned, including self-study, group discussions, field trips, lectures, and formal/informal interactions with locals. Through these activities, I would like to propose the following questions for both Greenlandic and Maine fisheries: *how the distribution of key fish stocks change as a result climate change; how such climate-induced changes in fish stocks may influence spatio-temporal dynamics of fisheries (i.e., fish stocks and fishing fleets) and what will be associated social and economic impacts on Greenland, and how we can develop management strategy to make fisheries and society more resilient to such climate-induced changes?*

To address these questions, using stock assessment framework we have developed at the University of Maine, I propose the following potential activities/research projects: (1) compile existing/available fisheries data for Greenland including biological, environmental/oceanographic, economic and social data, which will allow us to identify potential data gaps for fisheries assessment and management and develop new or optimize existing monitoring programs (we have done this work in Maine); (2) evaluate the role of science in fisheries management, including fisheries monitoring programs, stock assessment framework, harvest control rules, and determination of fish stock status and annual catch levels; and (3) partner with relevant Greenland fisheries agency or scientists (to be identified) to conduct a comprehensive stock assessment for northern shrimp and other key fish species. Specifically, I would like to focus on the northern shrimp because it is the most important fisheries in Greenland. It used to support an important fisheries in Maine, and I have developed an extensive research program for this species in the Gulf of Maine. I plan to (a) quantify and evaluate spatio-temporal variability in suitable habitat in Greenlandic and Maine waters and project possible changes in the spatial distribution of suitable habitat under plausible climate change scenarios; (b) evaluate and quantify spatio-temporal distribution of northern shrimp and project possible changes under different climate change scenarios; (c) evaluate and quantify possible differences between Maine and Greenlandic shrimps in their response to changes in environments (e.g., climate changes and changes in predator fields) to have a better understanding of how northern shrimp in their distributional ranges respond to environmental changes, which can lead to improved predictive power; (d) conduct an comparative study of life history of

northern shrimp between Greenland and Maine to have a better understanding of possible spatial variability in key life history processes and their impacts on population dynamics; (e) modify a cutting-edge length-structured northern shrimp stock assessment model which is develop in my lab at UMaine and has been used by Atlantic States Marine Fisheries Commission to assess the Gulf of Maine shrimp and apply the model to assess Greenlandic northern shrimp fishery; and (f) identify management strategies that can make the two fisheries more resilient to the changing environments in Greenland and Maine.

Similar approaches can also be applied to other fish species (e.g., Atlantic cod, scallop, Atlantic herring, and mackerel).

I am also interested in conducting an assessment of the recreational/substance fishery in the southern Greenland in which commercial fishery plays limited roles. With possible climate changes-induced changes in fish distributions, more species and fishing opportunity may be available, which can enhance the tourism activities. An assessment of recreational/substance fishery in the southern Greenland can improve our understanding of use of fisheries resources and identify new opportunity in this region. Developing a self-reporting system for the recreational/substance fisheries may also be important to an improved monitoring program for the Greenlandic fisheries assessment and management.

I am also interested in studying the carry capacity of southern Greenland for possible aquaculture program. Such a project will collect environmental data through various approaches (e.g., remote sensing, water sampling, physical and chemical oceanographic data) and develop ecosystem models to ensure the sustainable use of the ecosystem service.

Lee Karp-Boss (School of Marine Sciences, University of Maine)

My research aims at better understanding the responses of planktonic food-webs in Arctic and sub-Arctic marine ecosystems to changes in environmental forcing. I just learned this week that Southwest Greenland provides an excellent natural laboratory with many advantages that could lead to a competitive NSF proposal (or other agency): strong environmental gradients and accelerated environmental changes, opportunities to address novel questions, relatively easy (by Arctic standards), year-round accessibility, and an existing infrastructure that will make logistics easier and costs smaller (compared to research done in other regions of the Arctic). I propose to begin with a pilot study to collect data for a proposal on the effects of tidewater glaciers on marine ecosystems in the fjord system of Southwest Greenland (see separate document for proposed activities).

Ideas for future activities in Southwest Greenland

I hope to be back next summer to conduct a pilot study (in collaboration with Kristin Schild and Emmanuel Boss) on the effects of tidewater glaciers on fjord ecosystems. Tidewater glaciers at the sites we visited are at different stages of retreat making this area a great natural laboratory for studying responses of the marine ecosystems to climate change.

- The proposed pilot study will include hydrographic surveys at fjords with tidewater glaciers that are at different stages of retreat. Measured properties will include temperature, salinity and

optical properties to determine concentrations of dissolved and suspended material. Water samples will be collected for the analyses of concentrations of nutrients, and suspended inorganic (sediments) and organic (phytoplankton) particles. Seawater sampling for the determination of the concentrations of other compounds will be possible in coordination with other proposed activities (e.g., fresh water, snow and ice cemistry sampling).

- Remote sensing data will be compiled for initial assessment of spatial and temporal variability in seawater and ice properties in the study area (in collaboration with Kristin Schild and Firooza Pavri) and this activity will help in the design of the pilot study.
- The proposed pilot study will also contribute to assessments of the carrying capacity of the system (proposed by Yong Chen) in order to evaluate potential developments of aquaculture and recreational activities in the area. It became clear during the visit that hydrographic surveys of the fjord system have been done to a limited degree, if any.
- I will contact colleagues involved in the Greenland Ecosystem Monitoring program to assess how the proposed pilot study could contribute to ongoing monitoring effort in northern fjords and discuss a potential future collaboration

In addition to addressing research questions I am happy to provide my expertise in oceanography to proposed summer school programs in Southwest Greenland.

I teach SMS354- "The Arctic Ocean in a changing climate". This workshop provided me with new ideas and opportunities to strengthen and broaden the course content by bringing additional expertise to the classroom. This will already apply to the coming Fall semester where I will begin a collaboration with Charles Norchi (USM, Law), bringing his expertise in Arctic Law to my classroom and my expertise in Oceanography to his classroom.

Alice R. Kelley (Climate Change Institute and School of Earth and Climate Sciences, University of Maine)

The Kujatta World Heritage Site (KWHS) was established to preserve the unique South Greenland mixture of indigenous and Northern European cultures. This lifeway and its cultural and physical manifestations will experience pressure as the result of climate change and development pressures related to growing international interest in the World Heritage site. The recent Greenland trip brought together Greenlanders and Maine researchers to discuss challenges facing the residents of this isolated region and to provide a sense of regional landscape and social setting. Below are three potential areas of collaboration:

Monitoring Impacts at Cultural Heritage Sites: Monitoring the impacts of changing climate (weather variability, sea level change, etc.) and increased tourism will provide data for sound cultural resource management. Changes in regional weather patterns have the potential for impacting archaeological sites within the KWHS. Warming in South Greenland has already resulted in the decay of organic material in archaeological midden deposits throughout the region and shifting of ruin foundations as permafrost melts. Drought has impacted the area for two consecutive summers. Coastal deposits are experiencing erosion during storms, and this is anticipated to continue. Other impacts may include:

- Increased freeze thaw – disruption of archaeological building foundations and structural integrity.
- Drought – affect archaeological building foundations and protective vegetation.
- Increased rain – erosion along existing paths and those created by increased visitation.

- Coastal erosion – damage/remove archaeological structures, indigenous occupation sites, and midden deposits
- Increased foot traffic – existing paths are widened and deepened, development of "social trails" that can damage protective vegetation and increase gullying during rain events.
- Climbing/Walking on sensitive areas – dislodging ruins, trampling buried archaeological material.
- Collecting – removal of material damages site and reduces the archaeological record.
- Expanding economic activities – disturbance of previously unidentified sites or alteration of ground conditions at sites.

Opportunities: Working with the local stakeholders, the Greenland and Danish Museums and the University of Greenland to develop a monitoring program to track climate change, tourism, and economic development impacts at KWHS cultural heritage locations. This program could include;

- Annual detailed drone imaging to produce 3-D digital models of structures and landscapes is an established and efficient way to track archaeological and landscale changes. (Kelley, Pavri, Bampton, Valentine)
- Regular ground-based monitoring, including collecting observations and photographic images to document processes and change. If set up as a citizen science initiative, this effort could involve local residents to provide year-round data gathering. (Kelley, Pavri, Bampton, Valentine)

Both Kelley and Pavri have worked with citizen science groups. Kelley is currently monitoring coastal erosion of archaeological sites using drone imaging. Bampton and Vinton can address the GIS needs of the effort

Water availability and quality is critical to the success of small farms in southern Greenland. Additionally, increased tourism may increase water demands during the summer months, the most critical time for agricultural water use. Current droughts suggest that weather patterns may be changing, and will challenge already marginal conditions. Stakeholders, working with Maine researchers and students can collaborate to evaluate water resources at each farm, and explore the possibility of surface or groundwater irrigation to increase the yield of existing groups and diversify farm production.

This effort dovetails with Climate Change Institute work on the variability of South Greenland precipitation, and could be carried out as an REU or graduate research project. (Kelley, Northington, Roche, and UM ground and surface water hydrologists).

Education– Create opportunities for shared educational experiences through student exchanges and electronic/distance collaboration and courses. This can include study-abroad opportunities in a variety of discipline areas that can address the issues of climate change, environmental quality, indigenous culture, and economic development.

Paul Andrew Mayewski (Climate Change Institute and Schools of Earth and Climate Sciences, Marine Sciences, Policy and International Affairs, Business School and the Center for Ocean and Coastal Law (Law School), University of Maine)

- Continue to develop past climate and environmental change perspective.

Continue to develop high resolution (annual and finer scale) reconstructions of Arctic climate change following on the 110,000 year-long annually resolved GISP2 ice core record in order to investigate the causes and precursors for abrupt climate change, and to provide perspective

concerning natural vs anthropogenic era climate variability and changes in the chemistry of the atmosphere. Plans are currently evolving to recover and analyze an ice core from the GISP2 Summit Greenland site to add significant detail and resolution to the time period covering the end of the last ice age to modern climate.

- Continue to develop present climate change perspective.

The Climate Change Institute utilizes in-house software, *Climate Reaanlyzer™*, to examine modern climate data. Our research has already focused on variability in South Greenland precipitation. We will focus even more specifically on understanding changes in the strength and position of the Iceland Low and other precipitation bearing atmospheric circulation patterns as they affect frequency of drought in Southwestern Greenland since drought is a key element in the success of sheep farming and agriculture in this region.

- Continue to develop future climate perspective.

The Climate Change Institute has already developed plausible scenarios for future climate change in the North Atlantic. We will now start to focus on refining these plausible climate scenarios for the Kujataa World Heritage Site.

- Assess changes in water quality as a consequence of glacier melt.

Glaciers are storehouses of all of the natural and anthropogenic source chemistry transported in the atmosphere. With warming this chemical storehouse is being released with potential impacts on humans and ecosystems. We plan to assess the impact of melting ice on water quality through chemical sampling of a spatial network of ice, snow and water.

Peter Neill (World Ocean Observatory, Climate Change Institute, University of Maine)

1) Beta version of web-based introduction to the overall site interpretation and five area descriptions, incorporating Museum approved text, images, and diagrams, in three languages, to be structured for access on smart phones through mobile services or localized wireless (as envisioned by the museum).
2) Kujataa specific promotion plan to engage public interest as a World Ocean Travel destination and to publicize eco-development goals and objectives as envisioned by the Museum.
3) Aggregation from W2O catalogue of educational curricula and programs relating Arctic/Greenland/Kujataa as a cultural focus for teaching and learning in Greenland and beyond.
4) Proposal to collaborate with the Museum to develop an on-line digital exhibition to relate Museum artifacts and related cultural material with Kujataa as focus for global public accessibility to an expanded presentation of Greenland cultural history.
5) If approved by the Museum, these programs are envisioned to be in place by the 2020 summer tourist season. All associated expenses would be funded through W2O.

Charles H. Norchi (University of Maine Law School)

Maine-Greenland Teaching Collaboration

This coming academic year, law students in Maine and Greenland would adopt the Kujataa World Heritage Site (KWHS) as a case study through joint course modules using Zoom technology. They would consider the public international law aspects, the Arctic conservation potential and WH designation

value for Greenland. A goal is that the WH Greenland case study would become an ongoing project of the law school's Center for Oceans and Coastal Law.
II. Student Mobility for Course Credit
I will seek support to send students (one or two) with Arctic law interest and background to Greenland to interact with Maine student scientists and Greenlanders during summer 2020. The law students would earn two credits and work on one or more of the following areas depending upon applicability at the time:

1. Expeditionary Law (permits, compliance, insurance)
2. The Arctic Science Agreement
3. Artic Research Guidelines (NSF)
4. The World Heritage Treaty
5. Indigenous Human Rights Law
6. Environmental Law

Law Students would closely observe the science tasks being formed. They would brief the scientists on legal issues that may arise as a consequence of field research, the relevant legal instruments and procedures. They would write a paper under my supervision to satisfy course credit.

Research - I intend to continue work on World Heritage Treaty obligations within the context of the legal order of the Arctic incorporating the case of Greenland. Arctic actors now operate in a social process that is shaped by abrupt climatic change. Ice is melting, there is more open water and greater access to a previously limited geographic area. Against those conditions, what role might UNESCO Arctic heritage designation perform in Greenland and the environing regional and international legal systems? It is in the dynamic nature of international law, including in the Arctic, that prescriptions do not remain constant. Conflicting demands, expectations and a stream of outcomes spawned by pressures and incidents can cause norms to be terminated. We have seen glimpses of this related to human activity impact upon Kujataa site components during our June 2019 mission.

Robert Northington (Climate Change Institute, University of Maine and Husson University)

Over the last week, I have learned a great deal from our visit to South Greenland. In spite of my prior experience in Kangerlussuaq, this area of South Greenland is distinct in several key ways. First, there is a large agricultural presence currently and historically, which I have learned more about from our visits to ruins and with the farmers in the area. Secondly, the hydrology is this area is very different than Kangerlussuaq. South Greenland has a great deal of lakes and running water (e.g. streams), suggesting the presence of significant groundwater resources. These freshwater resources are likely a contributor to the agricultural presence that is the foundation of the World Heritage Site designation. Finally, South Greenland represents an interesting mix of stakeholders (e.g. tour groups, mining interests, farmers), each with unique views on the future of this region. Being able to meet some of these stakeholders and discuss their views was another important outcome of this trip.

Future Work:

I see South Greenland as an opportunity for both undergraduate research and citizen science under the unified theme of groundwater resources. Groundwater is the currency through which precipitation is

stored and used for a variety of human uses. Further, this stored water can tell a story related to land use and future issues related to both farming and mining practices. Relative to my work on Western Greenland hydrology, South Greenland is unique in that there are obvious surface and groundwater connections that can be utilized for future research.

As I envision it, undergraduate research would be focused on sampling and monitoring groundwater, stream, and lake resources in the area. Very basic wells could be installed on the landscape for periodic sampling of the groundwater and water table; these samples would be later analyzed for a variety of nutrient and geochemical markers to gather a baseline for further comparisons. Surface water (streams and lakes) could also be sampled for invertebrate indicators of water quality. Any undergraduate that would be involved with this research would have prior experience in all of these, and thus the methods would be easily translated to South Greenland.

As for the citizen science component, these wells would necessarily be located in the vicinity (if not physically within) agricultural lands, so involving farmers in the process would be key. Additionally, there could be involvement with the small schools in the area where they are taught how to collect water and invertebrates for our analysis. This would not only help in the collection of baseline data, but truly involve local communities.

Firooza Pavri (Geography-Anthropology, Muskie School of Public Service, University of Southern Maine)

The Arctic Futures Institute (AFI) research trip to Greenland was well designed and executed. The mix of opportunities provided were particularly valuable. These included daily field excursions to become familiar with the Greenlandic landscape, talks and discussions with local government officials, private citizens and community members to understand relevant issues, and presentations and deliberations with AFI team members to augment our understanding of climate change impacts influencing the region.

On a personal level, it was a tremendous opportunity to interact and learn from colleagues with a variety of expertise and to help forge new collaborations moving forward. The dramatic South Greenland backdrop of mountains, glaciers, fjords and isolated human settlements having adapted to live on the edges, provided an ideal location to study this bellwether landscape coping with varied climate oscillations. As such, South Greenland will have lessons for Maine and beyond.

Over the next year, I will explore further work in *three* inter-related areas focused on landscape change/remote sensing research, student learning experiences, and developing collaborations with colleagues at universities and other research institutes in Greenland and possibly Denmark.

First, the so-called greening of the Arctic has captivated researchers and the public alike. However, as the literature suggests, we need scientific tools and techniques to systematically understand changes across the Arctic and anticipate what a future Arctic will look like. Advances in remote sensing have revolutionized how we can study isolated and hard to access regions. Working with AFI colleagues, I will use satellite and ancillary data to monitor landscape shifts over a 40-year period for South Greenland. Assessments of vegetation establishment and succession after melting and glacier retreat will significantly enhance our understanding of how these systems respond to climate change. Universities in Denmark have established long-term monitoring stations in Greenland under the auspices of the Greenland Ecosystem Monitoring Strategy. I will explore research opportunities that complement and augment work already accomplished.

Second, I firmly believe in the transformative power of engaging students in fieldwork and short travel experiences to augment their classroom understanding of relevant issues. I will contribute to efforts to develop a cross-campus short-term travel course and other fieldwork opportunities for students focused on exploring the Kujataa World Heritage site and examining the impacts of climate change on the landscape and people. USM requires summer 2020 travel course proposals by Friday, September 13, 2019. I will work with partners from across AFI to develop a course for 2020-21.

Third, I will explore educational exchange opportunities with Greenlandic institutions. The Muskie School has successfully hosted faculty, researchers and students from Iceland and elsewhere under the framework of the Maine-North Atlantic Institute. We also have faculty teach blended-format, semester-long courses at Reykjavik University. I would like to use our existing model in collaborative education to find similar opportunities with Greenlandic institutions. Particularly, I could see the Muskie School's expertise in the areas of geospatial technologies including GIS & RS, tourism development, and public health as significant contributors in this area.

Neal R Pettigrew (School of Marine Sciences, University of Maine)

METOCEAN real-time observation in Southwest Greenland

1) Continued melting of the Greenland ice cap will increase the transport of meltwater in the cyclonic circulation system that connects the East Greenland current, the West Greenland Current, and the Labrador Current to the Scotian Shelf and Slope. The Scotian Shelf/Slope water masses feed the Gulf of Maine and the continental shelf and slope as far south as Cape Hatteras.
    a. The low level of pack ice in Southwest Greenland shelf/slope make it a key location for deploying a METOCEAN observing buoy for monitoring coastal transport. University of Maine observing buoys may be able to survive sea ice and iceberg conditions in this region, but designing ice buoy platforms for the far north will begin.
    b. Summer glider surveys out to 200 km from the shore would provide spatial gradients of the spring/summer freshet transport.

2) Wind Monitoring surrounding the mines region to determine the atmospheric transport of mine dusts.
    a. Buoy MET systems can be deployed to measure wind speed and direction at several (2m and 5m?) altitudes
    b. Wind data will include gusts to estimate turbulence.
    c. Data will be averaged every 10 minutes including barometric pressure and air temperature.
3) Development and testing of fjord buoy platforms and inexpensive temperature/salinity sensors to monitor mouths of fjord with glaciers at the head. If the platform is successful ADCPs will be added to estimate the exchange of water masses between the sea and fjords.
4) Monitoring of annual spatial changes in key South Greenland fjords will be achieved by CTD/ADCP (Conductivity Temperature Depth / Acoustic Doppler Current Profiler) boat surveys.

Items 2 through 4 would be in collaboration with other members of the Maine-Greenland group

Jan Piribeck (Department of Art, University of Southern Maine)

The 2019 AFI Expedition provided an introduction to the physiognomy of South Greenland and an orientation to the challenges and opportunities facing the region. This was accomplished using a workshop format that alternated lecture/discussion sessions with excursions into the physical environment. The activities complemented one another and were very well organized. Guest speakers were extremely generous, and took time away from work and family to share perspectives on farming, mining and other issues related to the Kujataa World Heritage Site and *cultural property.*

During the summer of 2017 I visited the Ilulissat Icefjord to do research for a creative project called *The Qajaq Journey* and in 2018 attended the AFI Summer Institute held in Portland. However, I had very little knowledge about South Greenland prior to the 2019 AFI workshop. The week-long intensive in the Kujataa region built upon my prior knowledge, and taught me a great deal about Inuit and Norse settlements, generational sheep farming and the burgeoning tourism industry. My understanding and appreciation of South Greenland landscapes, shorelines and fjords expanded by interacting with colleagues from fields such as agriculture, fishing, geology and oceanography. We were also introduced to the pros and cons of rare earth mining near the town of Narsaq, and I became more sensitized to the complexity of these issues. This raised the question of how to stimulate economic prosperity while also preserving local culture and the environment.

Creative thinking is essential to addressing complex questions such as this, and I am planning to create an animation series that brings to life features of the Kujataa World Heritage Site making them accessible to a wide audience. This will be my contribution to the AFI South Greenland workshop. The animations will be designed for distribution via website portals and displays in art galleries, museums and community centers. I have several preliminary ideas regarding subject matter, and will consult with researchers and scholars from our group about these.

Series I – Rotating iceberg animations based upon 3D Digital Elevation Models (DEMs)

Series II – Animations based upon Greenlandic and Norse artifacts and allegories

Series III – Animations showing geological change

Series IV – Oceanic animations based upon fish and plankton imagery

The U Maine VEMI lab is a potential resource for the project, as is the Greenland National Museum and Archives and the Peary-MacMillan Arctic Museum at Bowdoin College, ME.

I am also available to do a one hour lecture on art and culture in South Greenland for the online course.

Another idea is to initiate cultural exchanges between Maine and South Greenlandic artists to explore the role that the arts and humanities can play in building cultural capital and fostering environmental awareness and economic prosperity.

Erin Roche (Cooperating Extension, University of Maine)

My first goal in participating in the Arctic Futures Workshop was to develop an understanding of the impacts of climate change (i.e. longer growing seasons, higher average annual temperatures, milder winters, and periods of drought) on the existing and future potential for agriculture in the Arctic. As a result of the meetings held on this trip I have come away with concrete examples of how these changes are realized on farms. For example, extended periods of dry weather during the spring has made seeding of spring forage crops a challenge for sheep farmers. This issue, which was noted by sheep farmer Elna Jenson and echoed by others, means that farmers will have to purchase off-farm imported feed, which is costly and unreliable in terms of type and quality. While this is just one example, I have come away with the understanding that in comparison to Maine, farming in Southwest Greenland is even more vulnerable to weather variability due to a lack of transportation infrastructure, arable land, and isolation from resources on both a local and global scale. As well, not unlike Maine, farmers in Southwest Greenland are highly vulnerable to outside influences such as fuel costs, labor shortages and the environmental quality issues that come with new enterprises, such as mining. These issues and others can make adaptations for dealing with a changing climate, a secondary issue, and yet it remains a primary threat to agricultural productivity. Based on this experience, I will disseminate the information I gained about agricultural production in Southwest Greenland, the agricultural opportunities and risks associated with climate change, and the World Heritage Site (WHS) as a case study for Maine (C3) to the following groups:

- Certified Crop Advisors (~50), January 2020, Portsmouth, NH;
- UMaine Cooperative Extension agricultural staff (~30), February 2020;
- UMaine Climate and Agriculture Network (MECAN) (~12), Spring 2020;
- Downeast Maine UNESCO WHS Planning committee (~5), Spring 2020.

In my discussion with these groups I will also solicit their input on ideas for strengthening and/or diversification of agricultural production in Southwestern Greenland. My second goal in participating in this trip was to develop a method for sharing the agricultural research, resources, and approaches between Maine and Greenland. This trip provided me with a greater understanding of the ways in which information is shared between farmers and their Agricultural Consultancy Service. I now have a good foundation for developing further relationships and resources for farmers about potential response actions for dealing with climate change. For example, one resource that could be developed is a “Farm Response to Changing Weather” bulletin for Southwestern Greenland, similar to the document created by MECAN. Due to its agricultural heritage and the economic impact of farming in the region today, future student courses should include an undergraduate from the Sustainable Agriculture Program. To assist in a course, I will work to make connections with the Upernaviarsuk Experimental Station and representatives from the Agricultural Consultancy Service to identify relevant project topics for students that would benefit local farmers.

Jasmine Saros (Climate Change Institute and School of Biology and Ecology, University of Maine)

My goals in participating in this workshop were: 1) to learn more about the environmental interests and concerns of Greenlandic people; 2) to scope out the possibility of developing an interdisciplinary research program in this location and determine what I can contribute.

In terms of the first goal, we met and talked with people from several sectors, and had great opportunities to hear more about their concerns and interests. Charles did an amazing job of arranging these meetings with diverse stakeholders. We covered quite a bit on this front in just a few short days, and I certainly learned much in this area. This was a key first step towards achieving what I think are many of the goals of the group.

For the second goal, we have an evolving theme of fostering sustainable economic development. I think I can contribute various things in this area:

1) Given the use of lakes for irrigation, I could provide some monitoring tools and expertise around water quality and water temperature, the latter of which was a concern directly expressed by one of the farmers. I may also be able to help with ideas on altering lake water temperatures to expand options for water use.
2) Given that environmental conservation is a foundation of sustainable development, I am interested in possibly deploying monitoring equipment in lakes of the area. In addition to applied uses of these data, there are several basic research questions that my group addresses (e.g., changing lake thermal structure, changing freshwater biodiversity, etc) to which these data could contribute. My initial thoughts are to deploy temperature and oxygen sensors, possibly a profiling fluorometer to assess algal profiles, and sediment traps in lakes. My group can also conduct lake sediment core studies to assess the extent and magnitude of cultural eutrophication across the landscape. These cores may also be of interest to the geography/archaeology researchers- we've had some discussions about this.
3) I can also help to bring a systems approach to any interdisciplinary projects or student training that develops here, similar to the various proposals and programs I've put together & run in recent years. I think a systems approach will be useful for integration across disciplines.

Kristin Schild (Climate Change Institute and School of Earth and Climate Sciences, University of Maine)

- Modeling of particle transport through the atmosphere from point locations. This project could be done as a student research project in my fall ERS 230 course (Geomatics) using a particle tracking model with Southern Greenland DEM (data: Arctic DEM or constructed DEM from WorldView imagery) and Automated Weather Stations (AWS) in the area.
- Several new technologies are emerging in ice-ocean monitoring. Interactions between the ice and ocean play a dominant role in tidewater glacier health, but quantifying this system is inherently dangerous. For the potential course, I propose testing of new monitoring equipment including arctic buoys, in collaboration with Neal Pettigrew (SMS) and others, and thermal cameras on drones, both with the intention of capturing meltwater runoff.
- With the changing Greenland environment, more of Greenland will begin to experience the current climate of Southern Greenland, including decreased sea ice and warmer ocean and air temperatures. Currently, the glaciers in Southern Greenland are in a transition from tidewater to land-terminating, and therefore the drivers of glacier and ecosystem behavior are also changing.

In collaboration with Lee Karp-Boss and Emmanuel Boss (SMS), we are proposing to submit a RAPID/EAGER proposal this fall to quantify the resilience and adaptation of both systems during different phases of these transitions.

Jeff Thaler (Maine Law School and University of Maine)

Despite having been involved with the development and implementation of the Arctic Futures week-long course in June 2018, I knew very little about Greenland other than what has increasingly been in the public press: The ice sheet is melting, and sea level rise from Greenland's melt could pose devastating changes and risks to much of the coastal world. Once I was accepted to go to Greenland, I spent time doing online reading of reports and articles concerning a range of Greenlandic issues. However, as with most classroom-only pedagogy, just reading about complex issues is not enough to fully grasp and attempt to develop solutions to the challenges posed by topics such as climate change, renewable energy and environmentally sustainable economic development.

Thus, the 10 days just spent traveling from Maine to Greenland and Iceland with 15 other UMS faculty were tremendously invaluable in multiple ways; my hope is that the fruits of the effort will not fade with time, but rather be the genesis of more efforts for the mutual benefit of Greenlanders, Mainers, and others. Here are some reasons why:

1. Prior to departure, I knew about half of the participants. Our many hours spent together on buses, boats and planes, and in conference rooms and farmhouses, provided great opportunities to learn from many disciplinary perspectives, and to brainstorm ways of future collaborations—the epitome of some of the goals of Maine Center Ventures, the Alfond Foundation and other funders, and UMS. We came from multiple campuses, programs, and professional and personal experiential backgrounds
2. By combining both time for team presentations to and discussions with each other…and time in the field with Greenlanders…. the program was a great demonstration of the value of experiential educating. In other words, many of us had certain pre-trip assumptions about Greenland and its issues, which were then revised from on-the-ground realities that would not have been possible in a classroom-only setting. Indeed, one of the valuable lessons is that Maine and Greenland have much more in common than most realize; we both are relatively isolated, rural, natural resource-based economies that are facing challenges from rapidly changing economic and environmental forces, and with people who often feel powerless in the face of such forces. Without overstating the situation, Greenland and Maine can be seen as epicenters or case studies of a rapidly changing natural and economic world, whose locations also are key geopolitically to the North Atlantic and Arctic.

I am not a scientist or engineer, but as an environmental and energy attorney I have worked for decades—and continue, as University Counsel for UMaine's floating offshore wind program, to work—in a very interactive team-based manner to develop and implement solutions to large-scale development concepts and proposals. Indeed, both in the U.S. and Greenland, such development projects must undergo environmental impact assessment processes that include the physical environment (flora, fauna, soil, geology, water, air, climate, cultural heritage, energy, resources), health (illness, accident, etc.), population (planning, settlement, education, employment, crime, etc.), as well as socioeconomic

(regional and natural economics) impacts. A key goal is to avoid or mitigate the negative impacts and to enhance the positive impacts as much as possible—whether what is being evaluated is an increase in cruise ship tourism on small towns, mega-development projects, or new energy initiatives such as hydropower, tidal power, wind or solar energy. The old battles and tensions of "jobs vs environment" in Maine continue to this day—and are coming not just to Greenland, but also to other places like Iceland. How best to develop impact benefit agreements that provide as much win-win as possible, and to provide both mitigation of negative impacts as well as adaptation to those impacts that are unavoidable.

I also, however, have also worked for decades as an educator, from nursery school to graduate and law school levels. I have created, implemented and written about several different experiential education programs for college and graduate level students. I created and taught some of the first multi-campus, multi-disciplinary courses in the UMaine System, and thus am intimately familiar with both the challenges and opportunities of such pedagogical methods. But ultimately, I am a strong proponent of and advocate for the necessity in the 21st century on how best to prepare students to find jobs and work in an increasingly multi-disciplinary, interconnected world—through the transformative power of engaging students in a combination of course and fieldwork in conjunction with educators and professionals from a wide range of backgrounds.

Thus, my overall thoughts on how I can best support and contribute to future efforts revolve around the following theme: How to best use our UMS Inter-disciplinary cross-campus expertise to implement Maine-Greenland course and program offerings, and for support of efforts to develop environmentally sustainable work force development initiatives both in Greenland and Maine. Technological advances, such as Zoom, Adobe Acrobat and Skype, now allow us to also much more smoothly and inexpensively engage, from Maine, in dialogue with people and peers around the world.

PROPOSALS: Challenges and Opportunities for natural resource, rural economies in rapidly changing world to yield workforce development that is environmentally and economically sustainable, be it renewable energy projects, tourism, or other work.

A) Develop a pilot course for 2020-2021 and a Symposium (Muskie School, Maine Law's Ocean and Coastal Program and Journal, CCI, University of Greenland, and other Maine and Greenland entities)—use zoom, multiple sites and speakers; experiential education, not just having classroom/books but using, applying…discussing, reflecting, writing, engage—impacts and policy futures.

B) As Applied: If Greenlandic collaborators can be identified and are willing, work with them to facilitate consensus-building around well-researched, developed and implemented environmental, economic and socio-economic impact assessments, as well as generate ideas for provision of better energy supplies (electricity, heating, transportation) for the far-flung Greenland population. Outside of the capital Nuuk, Greenland is primarily reliant on expensive and polluting fossil fuels, and most farms and rural businesses struggle with energy efficiency and costs. Mainers have a great deal of experience in addressing similar struggles here, and can help develop solutions there—creating both workforce opportunities here and in Greenland, as well as other benefits to all.

In sum, I truly hope that our efforts June 21-30 are able to lead to ongoing collaborative programming and projects across the UMaine System, Maine and beyond, and am willing to be an active part of them.

Vinton Valentine (Geography-Anthropology, University of Southern Maine)

This exploratory trip to Greenland was revelatory and stimulating. As a geographer and geospatial professional, I saw concrete examples of the power of information and the responsibility to inform. Given the requests for visitors to keep conversations active beyond initial contacts, our interdisciplinary group could be some of the first researchers to realize this appeal from the local population and the government.

In regards to my goals in participating, I obtained a variety of materials, ideas, and direct contacts to enhance and implement upcoming courses in coastal and marine geography and Arctic and North Atlantic regions. Of more substantial benefit was the opportunity to learn, share, and interact with a variety of top-notch researchers and professionals from Maine and Greenland within the area of interest. Being onsite in this extraordinary region to stimulate our thinking and exchange of ideas with each other and the local population, including real-time rework and refinement of potential collaborative lines of investigation, was invaluable to focus and formulate my thinking for the courses and for future projects.

Planned Potential Projects

In terms of future work, I see four particular opportunities relevant to information infrastructure and applied research. First, based on preliminary searches for this meeting, there are a number of government organizations operating in Greenland that have or are creating geodata. Discovering and compiling a list of geodata resources relevant to the Maine and Greenlandic colleagues and professionals with whom I meet during this excursion will be useful and impactful.

Second, the geodata used during World Heritage submission process is not readily accessible but can be made available. The National Museum plans are to utilize the new version of Greenland's geographic information platform, New NunaGIS, as an open data portal for discovery and dissemination of Kujataa WHS data. According to the National Strategy for Geodata 2018-2012, this new version operated by Asiaq, the Greenland Survey, will support many government geospatial programs. Given my involvement within the Maine Library of Geographic Information (GeoLibrary) and our use of the same data portal platform, creating and nurturing a partnership to share experiences and learn about use cases with National Museum staff and Asiaq can benefit both Greenland and Maine.

Third, in the discussions we had with Greenlanders during the trip, questions about the adequacy of the World Heritage Site component boundaries and various buffers arose. From archaeological, tourism, and farming perspectives, it seemed a re-analysis and refinement of the defined zones could improve their effectiveness. Assuming the change in conditions and context since inscription could allow for revised boundaries and buffers, analyzing the component zones by incorporating more data and factors of influence (farming, tourism, mining impacts, airport operations) and presenting different options to stakeholders and the public can assist with effective management of Kujataa and the adjacent areas.

Fourth, the Kujataa submission documents note coastal erosion and sea level rise as particular challenges. To address these challenges to the site and to the region, there is a need to collate and reconcile the sources for recent topographic and bathymetric mapping projects with the limited available tide data. Associating any mapped shorelines from these project data with tide levels can then provide the basis for performing basic coastal erosion and inundation studies for site impacts and offer another element to the above buffer analysis. This project would provide opportunities for student field work next summer to map shorelines and field-verify tidal data.