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The Potential Contribution of Sustained, Integrated Observations to Arctic Maritime Domain Awareness and Common Operational Picture Development in a Hybrid Research-Operational Setting

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Abstract

Increased maritime activities and rapid environmental change pose significant hazards to Arctic maritime operators and coastal communities. Major categories of hazards discussed in this white paper include (1) technological hazards (amplified by natural hazards and challenging environmental conditions), including threats to life, vessels and infrastructure, (2) natural hazards that present a direct threat to maritime activities, including presence of sea ice, icing conditions, extreme weather and ocean state, (3) natural hazards that present a direct threat to coastal communities and infrastructure as well as human activities, including coastal storms, hazardous shorefast and drift ice conditions, coastal flooding and extreme weather events. We outline a framework for the development of a common operational picture (COP) in the context of maritime domain awarenees (MDA) relevant for Arctic coastal and offshore regions. A COP in these regions needs to consider threats not typically part of the classic MDA framework, including sea ice, threats emanating from slow-onset hazards and other factors. An environmental security and MDA testbed is proposed for the Barrow region of northern Alaska, building on research and community assets to develop a hybrid research-operational framework that addresses major challenges to MDA and effective emergency response in Arctic regions.

Introduction and Rationale

Recent increases in Arctic maritime activities and offshore resource development in conjunction with rapid climate change have increased the exposure of coastal communities and infrastructure to environmental and technological hazards (Brigham, 2014; Pizzolato et al., 2014; Eicken and Mahoney, 2015). Herein we recommend several measures to mitigate the risk of these hazards and exercise these risk-reduction measures in a testbed system. These measures include rapidly delivered *in-situ* and remotely sensed sensor data that are distributed on a common grid using open standards, active engagement with end users to determine needs and preferred methods of operation, and the use of existing tools to provide situational awareness, such as desktop GIS and web mapping systems like the National Oceanic and Atmospheric Administration's (NOAA) Arctic Environmental Response Management Application (Arctic ERMA; Merten, 2013; Merten et al., 2014).

The binding agreements on Search and Rescue and Oil Spill Response recently adopted by the Arctic Council (2011, 2013) highlight the need for an effective, cooperative emergency response framework. The Arctic Council's Emergency Prevention, Preparedness and Response Working Group (EPPR WG), and the newly established Arctic Coast Guard Forum, are key entities to enhance emergency response capacity by scaling up or coordinating national efforts at the pan-Arctic level. Efforts to date have focused on emergency preparedness and response in terms of trained personnel, assets, protocols and frameworks (EPPR, 1998; Arctic Council, 2013; EPPR, 2014). For the time period 2015-17 key goals or themes to be addressed by EPPR WG include, among others, an International Exercise under the auspices of the Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic, a project on Prevention, Preparedness and Response for Small Communities, and development of a Database of Arctic Response Assets. EPPR WG is also beginning to address activities focused on Search and Rescue which has come under the EPPR purview. Relevant for the Arctic Observing Summit 2016 (AOS), is EPPR's examination of the use of Unmanned Aerial Systems in Arctic Response Activities (Merten, EPPR Presentation in Anchorage, AK, 2015), as well as its designation of Arctic ERMA as an EPPR pilot project (Arctic Council, 2015).

Many parts of the Arctic that could be impacted by a maritime disaster are remote and lack local response assets and infrastructure. At the same time, the increase in maritime activities may outpace the deployment of assets dedicated to enhancing Arctic or maritime domain awareness (MDA). This includes instrumentation and hardware to monitor the physical and ecological environment and the type and extent of human activities related to hazards and vulnerabilities in the region. In light of such potential shortfalls, environmental data collected in the context of sustained observations of Arctic change can play an important role in providing environmental intelligence (Sullivan, 2015) that contributes to MDA. A recent study in the U.S. Arctic showed that such sustained observations in the marine environment are conducted by an array of different entities. U.S. federal agencies account for about one fifth of all observations, while the academic research community account for about one third, with the remainder being conducted by industry and foreign nations (Lee et al., 2015).

The impacts of rapid climate change have resulted in an array of major natural hazards, many of them associated with slow onset, such as permafrost thaw (Ravens et al., 2012; Barnhart et al., 2014), that threaten coastal communities and infrastructure. Rapid onset hazards are typically better tracked and prepared for than slow onset hazards, leaving a gap in the response and adaptation capacity and challenging the classic picture of MDA in the Arctic. This problem will be considered in more detail below.

The current and future requirements of MDA and the status of sustained Arctic environmental observations raise an important question that guides our white paper: In the event of an emergency or a disaster (such as an oil spill from a pipeline or vessel, a vessel accident requiring evacuation and rescue, an ice break-out or push event putting people and infrastructure at risk, or a coastal storm with threats emanating from flooding, wind or ice action), how can a response effort best draw on research resources, specifically observing assets and data streams that contribute to sustained observations of Arctic environmental change? Given the breadth and depth of this problem, we will focus our discussion on the coastal Arctic Ocean and marginal seas where the presence of ice represents a major hazard. Relevant operations that need to be considered in this context include shipping, subsistence activities by local communities, resource development, and tourism. We include a discussion of increased exposure to storms, coastal erosion and flooding as key environmental hazards, that in turn also enhance existing technological hazards. Drawing on a case study in the North American Arctic we identify promising approaches and next steps in bridging gaps between the research and EPPR communities, in particular in providing a common operational picture (COP) that informs MDA in the context of emergency response.

Maritime Domain Awareness and Common Operational Pictures in Arctic ice-covered seas

Traditional definitions couch MDA in terms of understanding and tracking any aspect of the maritime domain that could impact the security, safety, economy or the environment of a particular region or nation (Department of Homeland Security, 2005). In this context, the maritime domain encompasses the seas, coasts, and associated waterways and the activities therein. In most applications the focus of MDA is on vessels or anthropogenic threats or to a lesser extent ocean state and weather conditions (e.g., Department of Homeland Security, 2005; Bruno et al., 2010). At high latitudes, there are a number of major environmental hazards and threats associated with the presence of ice in the ocean, often in combination with hazardous weather or strong ocean currents (Eicken and Mahoney, 2015).

These environmental hazards have a disproportionate importance in the Arctic. First, they may amplify the risks associated with technological failure or human error in a remote environment, and therefore require advances in MDA research and technology specific to the Arctic maritime domain. Second, changes in sea-ice extent and seasonality are major drivers in enhancing coastal erosion and flooding and threatening the livelihood of Arctic coastal communities (Ravens et al., 2012; Barnhart et al., 2014). Third, such changes are also driving other slow-onset hazards such as permafrost thaw. While changes in sea ice, seasonality and permafrost are not part of the classic definition of MDA (Department of Homeland Security, 2005), we regard them of comparable importance to hazards of the first type because of their disproportionate importance in the Arctic. At the same time, emergency response frameworks may not be effective in addressing these latter two types of hazards in the Arctic (see discussion by Huggel et al., 2015 and Eicken and Mahoney, 2015), which may further increase exposure and vulnerability of communities over time.

Hence, for the framework and case study discussed below, we focus on the following types of hazards: (1) technological hazards (amplified by natural hazards and challenging environmental conditions), including threats to vessels and infrastructure with the potential for loss of life and property as well as oil spills from vessels and hydrocarbon exploration and production, (2) natural hazards that present a direct threat to maritime activities, including presence of sea ice, icing conditions, extreme weather and ocean state, (3) natural hazards that present a direct threat to coastal communities and infrastructure as well as human activities, including coastal storms, hazardous shorefast and drift ice conditions, coastal flooding and extreme weather events. We recognize a fourth type of hazard, i.e., slow-onset hazards that threaten coastal communities and infrastructure, such as through sustained reductions in summer ice extent, decreased stability and presence of shorefast ice or permafrost thaw. While detailed consideration of such hazards is outside of the scope of this white paper, we recognize that they may greatly amplify the impact of other hazards considered here and can drive short timescale catastrophic events (Cutter et al., 2008). Hence, we will provide recommendations relevant to consideration of slow-onset hazards in the context of MDA.

Necessary advances in Arctic MDA include development of robust approaches to vessel detection using standard remote sensing or acoustic techniques (Bruno et al., 2010), tracking systems such as the Automated Identification System (AIS), or inversion of high-frequency ocean radar data (Statscewich et al., 2014). At the same time, information about the state of the environment is needed to inform the development of a common operational picture (COP), identify hazards – including slow onset hazards threatening coastal communities and industry infrastructure, and support vessel detection and tracking. Here, we focus on development of interoperable data sources for use in COPs and briefly explore how to foster integration of relevant data obtained in the context of sustained Arctic observations. As a case study, we consider a subregion of the North Slope of Alaska, centered roughly on the town of Barrow, located at the boundary between Chukchi and Beaufort Seas (Fig. 1).

A case study at Barrow

The Barrow region and North Slope of Alaska are the setting for a range of activities in the maritime domain relevant in the context of this white paper. To the West and East are oil and gas leases, with the Beaufort Sea leases slated both for exploration and development. Maritime traffic typically hugs the coast at the Barrow peninsula, both to minimize distance and to avoid ice often lingering well into summer towards the North. Recent years have seen increased tourist traffic, both in terms of small-craft adventure tourism and larger cruise ships. By number, the greatest proportion of vessel traffic is associated with subsistence hunters from Barrow and neighboring communities who harvest marine mammals and fish in the region. At the same time, the community of Barrow and surrounding regions have experienced increasing threats to community infrastructure and well-being from coastal erosion, flooding and extreme weather events (Gearheard et al., 2006; Brunner and Lynch, 2010). This combination of high level of maritime activity and the range of environmental hazards and potential impacts on the community make this an ideal location to explore various aspects of MDA and COP development in a hybrid research-operational setting.

Barrow is also home to a large number of long-term terrestrial and marine research projects (Norton, 2001). This includes a strong presence by federal, state and local agencies and broad range of U.S. and international universities and research institutions. Significantly, there is also an increasing interest in research at Barrow among non-Arctic nations. The Iñupiat population in the region has a long, well established history of sharing insights from Traditional Environmental Knowledge (TEK) and providing essential support and collaboration on research projects. Indeed, this history includes a number of major research efforts that would not have succeeded without the involvement and assistance of local experts. The remoteness of the location – the nearest U.S. Coast Guard (USCG) base in Kodiak is some 1500 km distant – and challenging environmental conditions put significant emphasis on expertise and assets within the local community. Such assets could include sensor systems currently deployed for long-term studies of environmental change and related research but potentially relevant in the case of emergency response.

Standard approaches to development of a COP (such as Shahir et al., 2014) typically employ an approach that draws on a variety of datasets to determine whether the potential for an *engagement*, *rendezvous* or *anomaly* exists. An *engagement* is the first stage of the evaluation process and occurs when a vessel is brought to within a specified distance of a hazard, which may be another vessel. If a potential engagement is identified, then a second stage of evaluation assesses the potential for an actual *rendezvous,* which conforms with a specific preidentified scenario. If such a scenario is deemed a risk to people, a vessel or infrastructure then it is classed as an *anomaly* and a third stage is initiated in which a decision-maker needs to be involved to take action. The problem in Arctic regions is that a lack of environmental intelligence can compromise MDA and prevent the establishment of an accurate COP, thereby curbing the effectiveness of prevention or response efforts. The ice entrainment and drift of a fuel barge in the eastern Beaufort Sea past Barrow and into Russian waters in the winter of 2014/15 serves as an example of this problem (CBC News, 2015). Moreover, the short-term, event sequence-based approach to COP establishment does not necessarily apply to slow-onset hazards and will require further research into whether and how the classic COP framework can be applied to slow-onset hazards. While this is somewhat beyond the scope of this paper, we recognize the importance of this issue and include it in the recommendations for the Arctic Observing Summit to consider.

In the context of this study, developing data sources and operator knowledge to inform a COP includes the following steps and prerequisites: (i) identification of available sensor system capabilities and relevance to response scenarios; (ii) integration of these data streams into a common reference framework; (iii) automated or supervised evaluation of the potential for engagement, rendezvous or anomaly with potentially hazardous outcomes. To illustrate the scope of step 1, Table 1 shows key capabilities and constraints of selected research sensor networks for the Barrow region. These include: remote sensing data downlinked and processed by the Geographic Information Network of

Alaska (GINA; gina.alaska.edu) at the University of Alaska Fairbanks (UAF), serving both researchers and the National Weather Service; Synthetic Aperture Radar data obtained through the Alaska Satellite Facility; an HF ocean radar (Statscewich et al., 2014); an ice radar (Eicken et al., 2011); unmanned aerial systems deployed by the Alaska Center for Unmanned Aerial Systems Integration (ACUASI); and Iñupiaq ice experts contributing to a seasonal ice zone observing network (Eicken et al., 2014). A capabilities assessment such as this can help identify potential gaps as well as guide the integration of different data streams.

Integration and automated evaluation require that the COP builds on rapid data processing, appropriate distribution methods and flexibility to accommodate a variety of data streams and use cases. Data processing should focus on transferring the raw data quickly from the acquisition point transforming it into an information product on a common grid. Distribution channels must make use of the right networks and transfer protocols while allowing data to be either pushed or pulled as necessary. At the same time, the underlying framework needs the flexibility to allow integration into a variety of systems and for use cases requiring limited bandwidth, alternative projections, scalability, symbol styling, and attribute querying. Stakeholder engagement confirmed that USCG District 17 (Alaska) gravitated towards two major categories of COP interfaces: Desktop GIS systems and Web Map systems. Building on GINA's resources, a demonstration system was developed to provide data sets and data feeds via open standards such as OGC Web Mapping Services (WMS), KML, GeoJSON, and standardized map tile interfaces as endpoints for distribution. Such interoperable feeds would be at the core of an operational system that could provide a relevant COP.

A range of system integration approaches have been identified or scoped out. These include the Alaska Ocean Observing System's (AOOS) Arctic Data Integration Portal (portal.aoos.org/arctic), and an integrated system of systems (ISOS) approach currently under development by the Arctic Domain Awareness Center (ADAC; adac.hsuniversityprograms.org/centers-of-excellence/adac) led by University of Alaska Anchorage. However, a fundamental challenge remains in bridging the research-to-operations gap. This problem is amplified if research infrastructure is to be relied upon for operations and emergency response. To circumvent this challenge, it will be critical to form partnerships between the research community and key entities charged with providing information for emergency response. Additionally, any approach must draw on technology and infrastructure that is well integrated into local, national or international response networks. Here, the State of Alaska Division of Homeland Security and Emergency Management (AKDHSEM) is of particular relevance, in particular in terms of its emergency response guide for small communities (AKDHSEM, 2014) which would need to integrate information about MDA and COP relevant to community-level first responders. For the maritime domain, the Marine Exchange of Alaska (MXAK) is an important potential partner, in particular in the context of the shorebased Automated Identification System (AIS) infrastructure the MXAK has built up in recent years and with respect to the information provided to mariners at the local level.

For the present case study in the North Slope region, but also potentially Arctic-wide, NOAA's Arctic ERMA (Merten et al., 2014) is of particularly relevance. As outlined in Fig. 1, Arctic ERMA is already capable of integrating many types of relevant baseline datasets as well as operationally relevant environmental information such as ice charts or radar data. It also capable of interfacing with local and traditional knowledge (Merten et al., 2014). At the same time, it is the tool of record to be used by USCG and other responders in the management of oil spill response and restoration. The application resides on federally accredited, secure infrastructure, but is also able to use cloud-based computing services to address higher demands and portability during major response efforts. Potential next steps in further advancing the utility of Arctic ERMA as an integrative framework would include further interaction with the research community (see also AOS 2016 white paper by Lovecraft et al., 2015) to help define priorities of variables to be observed and more effective integration of dynamic, near-realtime information relevant for MDA and decision support into the ERMA framework. The interface between Arctic ERMA and community-level response may also require further consideration, e.g., in the context of community response guides (AKDHSEM, 2014).

The availability of a common reference framework, computational infrastructure and a core set of data streams could open the door for a broader evaluation of other resources and datasets that would enter into and substantially enhance development of a COP. The North Slope of Alaska and in particular the Barrow region are an ideal location to further explore and test such approaches, given both the level of maritime activity and the wide array of data collected in the region for environmental change research. Indeed this process has already been started following an incident in which data products from a radar system operated by UAF at Barrow for coastal ice research (e.g., Druckenmiller et al., 2009; Mahoney et al., 2015) contributed to a successful search and rescue operation after the detachment of a section of landfast ice (Fig. 2). This radar system is now generating near-real time information on ice velocity near Barrow, which is shared with USCG District 17 and others through a web interface and datafeed maintained by GINA. There is also potential to expand this capability using data from an atmospheric radar system operated in Barrow by the U.S. Department of Energy's Atmospheric Radiation Measurement North Slope Site (DOE-ARM; www.arm.gov/sites/nsa/C1).While the DOE-ARM radar has been installed to obtain data on atmospheric precipitation and other climate variables, a first assessment indicates that the system may also be of potentially great value in providing information on ice movement and hazards (Fig. 3).

Towards an Environmental Security and MDA Testbed to evaluate the accuracy, relevance and impact of sustained observations and prediction systems on operations and response capacity

Effective integration of different sensor systems and translation of research activities and findings into improved operations will also have to draw on numerical models. For the scenario considered here, this will most likely be some type of coupled ice-ocean model (e.g., Zhang et al., 2012) with atmospheric forcing derived from reanalysis for hindcasts or weather prediction systems for forecasts. Such work would be conducted in partnership with NOAA's Arctic Testbed. The NOAA Arctic Testbed goals are to improve marine, weather, climate and sea ice forecasting decision support capability to meet expanding needs in the Arctic, in particular through evaluation and improvement of new modeling and data acquisition approaches, drawing on agency partners and the broader research community (Petrescu, 2015). We propose that significant advances in Arctic MDA could be achieved through the expansion of the testbed approach and implementation of a comparable effort. A North Slope Arctic MDA Testbed (NSAMDAT) would provide a proving ground for new sensor technology, automated observation systems, new modeling and process parameterization approaches as well as different data fusion and integration methods. The Barrow region is ideal for such a testbed because of the multitude of sustained observing activities and associated data sets, relative ease of access, variety of environmental and operational hazards encountered in the region, and the support and interest of the local community such efforts.

A further potential benefit of such a testbed would be the availability of datasets, infrastructure, data product reference frameworks and on-site support that would greatly increase the efficiency and potential impact of any individual sensor deployment, data acquisition or field experiment. Some of the work planned as part of the ADAC effort, such as validation of coupled ice-ocean models for tracking of oil spills or improvement of coastal erosion and flooding models (Ravens et al., 2012; Ravens and Allen, 2012) would help provide a framework to evaluate the impact of specific types of measurements or observations on the accuracy and utility of predictions feeding into a COP and MDA system. Hence, such a testbed would also play an important role in helping identify, calibrate and refine guidance from stakeholders and decisionmakers on the types of observation and modeling efforts needed to meet their most pressing demands.

A challenge in this context is to ensure that available information and data sets are both shared in near-realtime with all relevant agencies and entities from the local to the (inter)national level, and that they are furthermore archived so as to be available for retrospective analysis, an important part of the testbed approach.

Recommendations and Potential Action Items

We conclude that sustained observations and data sets obtained as part of research efforts tracking Arctic environmental change can play an important role in informing planning and bolstering capacity for emergency response in maritime settings. Specific next steps and recommendations for consideration in the context of the Arctic Observing Summit and Arctic Council Working Group process include the following:

(1) Implement a framework for an MDA Testbed on the North Slope of Alaska that serves federal and state agencies, the national and international academic research community, local stakeholders – in particular partners in CBONs (see AOS white paper by Alessa et al., 2016) – and others interested in building capacity and increasing effectiveness of emergency response. Such a framework would include concepts and designs to bound the effort, a web-based portal and data and information service, and

formal and informal agreements on contributions and collaboration between testbed partners and outside participants.

(2) Survey and interview potential operational users to establish operational requirements and preferences. Use the outcomes of these interactions to set priorities for data feed development and COP softwares to be supported.

(3) Conduct a survey of potentially relevant data sources, partners and contributors for such a testbed centered on the Barrow region. Explore to what extent platforms of opportunity provided by industry can be utilized in testbed implementation (see also Thematic Working Group #3 for Arctic Observing Summit 2016).

(4) Explore the utility of such a testbed concept in fostering international coordination and collaboration, e.g., by implementing a testbed in transnational or international waters, in particular Bering Strait, where increasing vessel traffic and other constraints (Huntington et al., 2015) lend further urgency to such an approach.

(5) Explore the potential value of Arctic ERMA in providing a framework for integration of datastreams, model output and other relevant information, both at the national and international level, tying into plans by the Arctic Council EPPR WG to draw on Arctic ERMA at a broader scale.

(6) Arrange for a field exercise that builds on table-top exercises and both draws on and evaluates key aspects of an environmental security and MDA testbed on the North Slope of Alaska. A key goal for such an exercise would be to improve data and information product availability for key partners from the local to the national level, including but not limited to North Slope Borough Search and Rescue and Barrow Rescue Base, AKDHSEM, MXAK, USCG, NOAA Office of Response and Restoration, Alaska Clean Seas and others tasked with emergency management and response.

(7) Promote broader exchange between the EPPR, local and national response and research communities on how to enhance emergency response efforts by drawing on research resources, datasets and dedicated information products.

(8) Develop a research plan that identifies effective ways of expanding classic MDA and COP concepts to address challenges posed by slow-onset hazards that are typically not well addressed in a rapid-onset hazard response framework.

(9) Data availability and integration contribute to but do not in of themselves constitute operator knowledge relevant to MDA and response situations. Hence, instruction, development of training modules and mentorship should be part of any MDA testbed and COP development from the outset.

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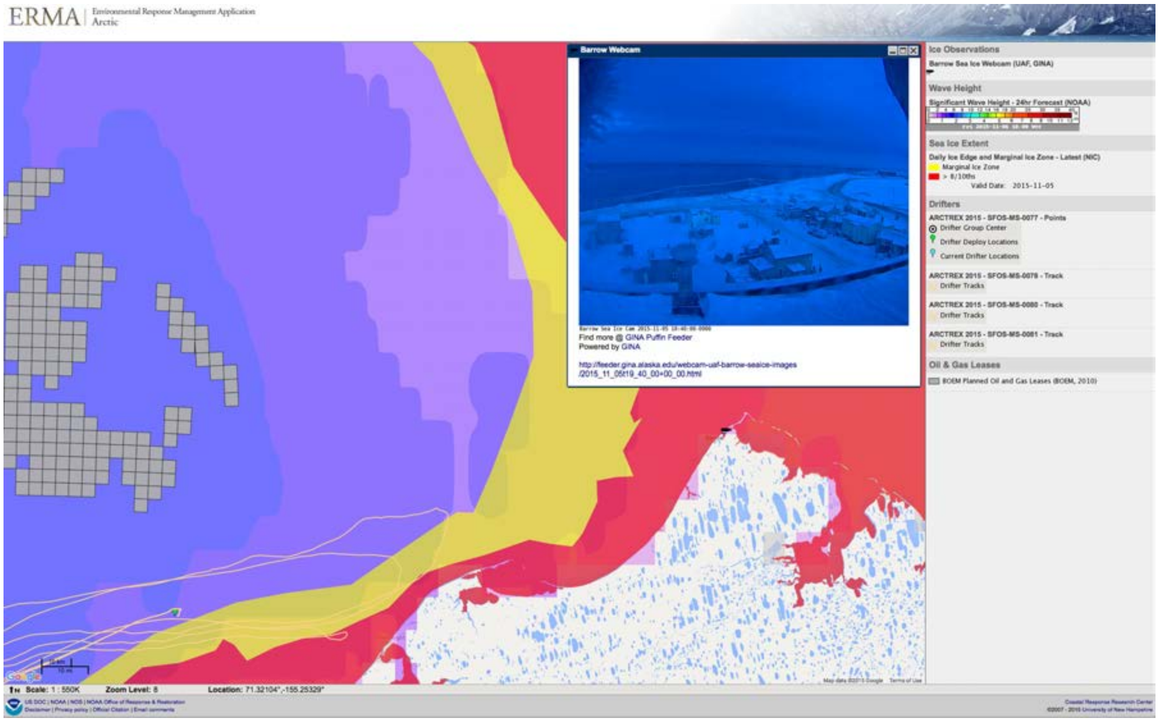

Fig. 1: Map of the Barrow region and part of the North Slope of Alaska, as seen in NOAA's Arctic ERMA interface. Out of a larger number of variables, key locations, such as oil and gas lease areas, ice conditions on 5 Nov 2015 based on NOAA National Ice Center ice charts, sea state (24-hour forecast of wave height), trajectories of surface drifters released in September 2015 and an image of the Barrow Sea Ice Webcam showing new ice forming nearshore with some open water and thicker young ice further offshore. The camera also captures atmospheric riming conditions.

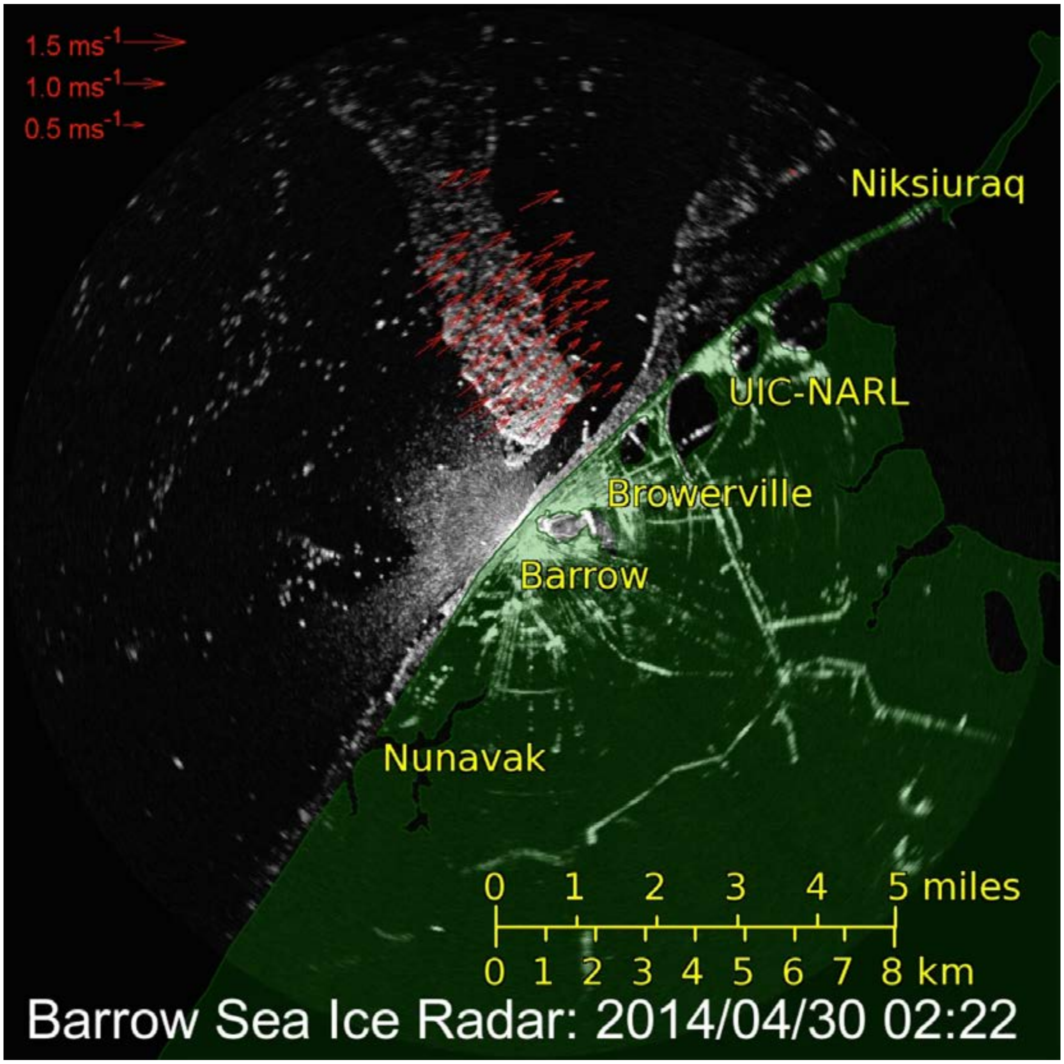

Fig. 2: Ice movement in association with shorefast ice break-out event tracked by UAF X-band sea ice radar at Barrow, Alaska. Velocity vectors are superposed on the backscatter image and have been derived in near-realtime based on analysis of sequential radar imagery (MV et al., 2013). Note the ice floe derived from the break-out event moving back towards shorefast ice between Browerville and Niksiuraq.

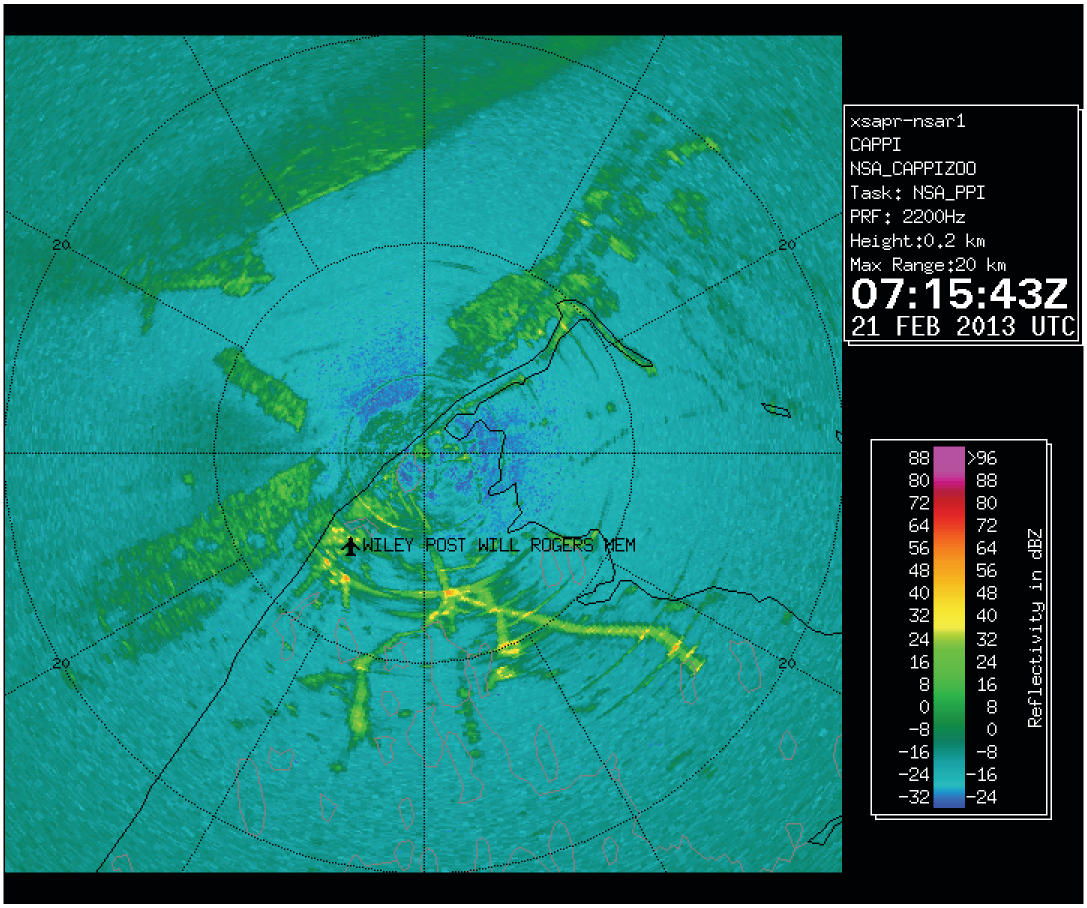

Fig. 3: Radar backscatter image from low-elevation horizon scan by DOE-ARM X-band precipitation radar system. The scene shows ice conditions comparable to Fig. 2, with a fragment derived from the break-out event visible between the shorefast ice in the South and the offshore pack ice in the North. Range of image is twice that of scene shown in Fig. 2, such that inner circle (radius c. 10km) corresponds to area covered by ice radar in Fig. 2.

Table 1: Capabilities of UAF research program components for the Barrow/North Slope of Alaska region relevant for COP applications.

UAF Arctic Sensors Capabilities Matrix									
		Satellite				Radar		UAS	HUMAN
		Optical			SAR	HF	Ice Radar	ACUASI	Local obs
Category	Factor	High Res	Med Res	Low Res		5 MHz	10 GHz	Med Weight	Local
Environmental	Day	√	√	√	√	√	√	√	√
	Night	X	X	!	√	!	√	√	√
	Clouds	X	X	!	√	√	√	!	√
	Water vapor	√	√	√	!	√	√	√	√
	Precipitation	√	√	√	√	√	!	√	√
	Winds	√	√	√	√	√	√	√	√
	Configurable sensor	√	√	√	√	X	X	!	n/a
	Oper'g Temperatures	all year	all year	all year	all year	Jul - Nov	all year	all year	√
	Ice/snow/water differentiation	√	√	√	√	X	!	√	√
Range	Current range from coast	n/a	n/a	n/a	n/a	50-200 km	10 km	100 Miles	n/a
	Maximum range from coast	n/a	n/a	n/a	n/a	200 km	50-70 km	?	n/a
EM Interference	Proximity	√	√	√	!	!	X	!	n/a
	Radiation/Induction	?	?	?	?	!	√	!	n/a
Comm's Link	Minimum bandwidth	?	?	?	?	Iridium	wifi	900MHz	n/a
	Optimal bandwidth	?	?	?	?	Fiber optic	Fiber optic	Iridium	n/a
Processing Times	Quick look avail.	<20min	<20min	<20min	<20min	√	5 - 30 min	√	√
	Full Product in <12 h	√	√	√	X	√	√	√	n/a
	Full Product in >12 h	√	√	√	√	√	√	√	n/a
Infrastructure	Electric power source	Onboard	Onboard	Onboard	Onboard	RPM	power grid	Onboard	n/a
	Duration of power	Years	Years	Years	Years	all season	constant	20+ hrs	
	Maintenance free	√	√	√	√	X	n/a	X	X
Data Costs	Acquisition costs	High	High	High	High	Low	Low	Low	n/a
	Distribution/Licensing	?	?	?	?	?	?	n/a	n/a
	No Cost	?	?	?	?	publ dom	publ dom	?	n/a
Detection	Vessel	√	√	√	√	√	√	√	√
	Landfast Ice Edge	√	√	√	√	X	√	?	√
	Surface Current - Water	X	X	X	X	√	X	X	?
	Surface Current - Drift Ice	X	X	X	!	X	!	X	√
	Ice Breakout Event	X	X	X	X	X	√	X	√
	Ice Cover					X	√	√	√
	Ice Surface Topography					X	√	!	√
	Ice Thickness					MSB	X	X	√
	Water Pooling on Ice					X	X	√	√
Ice Coverage	100% coverage	√	√	√	√	X	√	√	√
	50% mixed	√	√	√	√	X	√	√	√
	0% coverage (open water)	√	√	√	√	√	√	√	√

Legend
√ = Capable
! = Varying capability
X = No capability
n/a = Not applicable
? = Need further info

Adaptation Actions for a Changing Arctic (AACA):
The Transition from Science Assessments To a Science-Decision Making Process Founded Upon Sustained Observations and Sound Science

Armstrong, Thomas [1, 2]; Corell, Robert; Reiersen, Lars-Otto; and Fuglestad, Jon

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The Goal
The goal of the AACA is to *"inform Adaptation Actions in a Changing Arctic"*. The goal of this paper is to place the AACA Regional and pan-Arctic science assessments into the overall context of the AACA science-decision making enterprise so that AACA may indeed effectively inform actions and decisions.

Introduction
For years, AMAP, the Arctic Council, and many different national and international efforts have relied largely on the development of discreet scientific synthesis and assessment products in order to evaluate past, present and most importantly, potential future states of one or more aspects of the Earth system. These linear studies- broadly classified as assessments- have been valuable in helping different scientific communities develop broad frameworks for describing specific scientific questions, related gaps in our scientific understanding of the issues the questions were addressing, and ultimately, some level of prediction of the future state with an identified level of uncertainty. These assessments grew from a scientific tradition of "literature reviews" where a small team of experts summarized what was known about a particular topic to form a foundation for subsequent scientific research. Over time, these studies, initially intended for the scientific community, have evolved to include derivative summaries (Summaries for Policy Makers, or SPMs) aimed at communities that may utilize the science in order to inform decisions. These decisions typically include policies and management actions affiliated with the impacts and effects (past, present and future) on specific or general aspects of the physical, chemical, biological, social, economic and even behavioral systems. And while these SPMs have been a significant achievement in moving science-based information into a greater role of direct societal relevance, their immediate value in providing specific decision-support has been limited. This has primarily been a result of the assessments and the derivative SPMs being developed at levels too technical and scales too coarse for most types and specific examples of actual decision-making; a dilemma typically faced by the science community since the forces driving Arctic changes are global in origin, yet the resulting impacts and effects and related policy and decision-making span scales from local to global.

Adding to this dilemma, in many instances the assessment studies were conducted without significant up-front (i.e. pre-assessment) end-user (i.e. decision maker) collaborative consultations. This resulted in conclusions or recommendations that were meaningful to the scientists who developed the reports but not necessarily directly applicable to decision-makers. In fact, this collaborative-consultative process is a prerequisite for ensuring that the science community is actually aware of the specific issues directly relevant to decision-makers and that the decision-makers, in turn, effectively understand what information can be provided by the science community in order to effectively support the decision-making community's needs.

The Science-Decision Making Process

Over the past several years, through many significant collaborative studies, the science and decision-making communities have begun to work together in a more collaborative manner, albeit in limited cases. And in doing so, have begun to develop methods for effective and iterative consultation and decision support product development and the much-needed evolution of the assessment products themselves. Now, scientists and decision-makers of all types are taking additional and significant steps in forming collaborative consultations that are leading to the establishment of issue-based frameworks that identify the science needs of future assessment reports subsequent derivative products, including SPMs and specific decision support and communication/outreach tools and services. In those examples where such consultations have happened, the outcomes have been positive with a clear understanding of what is needed, what is known and where the uncertainties lie.

It is important to understand that the evolution of the science assessment process goes much further than just shaping the way that we conduct the assessments themselves. The evolution of the process is a metamorphosis of the entire engagement process between scientists and decision-makers, and includes changes in the timing and methods to which both parties engage and interact in identifying the issues relevant to decision-makers, the structure and content of the scientific assessments, the science needed to develop the assessments (including prioritization of areas of continued scientific uncertainty) and the nature and types of decision support and outreach tools and services that are provided (Figure 1). Furthermore, the overall framework of the collaborative-consultative process for engagement must be sustainable so that effective decision-making, with products co-designed to address, inform and support decisions around key issues and questions can occur. It must be highly responsive to complex decision-making issues. Thus, it must include an adaptive management loop; a mechanism that allows for iterative engagement between scientists and decision makers that focuses on evaluating the performance of decisions already made and subsequent recommendations by decision makers that helps scientists prioritize areas of continued scientific uncertainty that will require additional research investments (Figure 1).

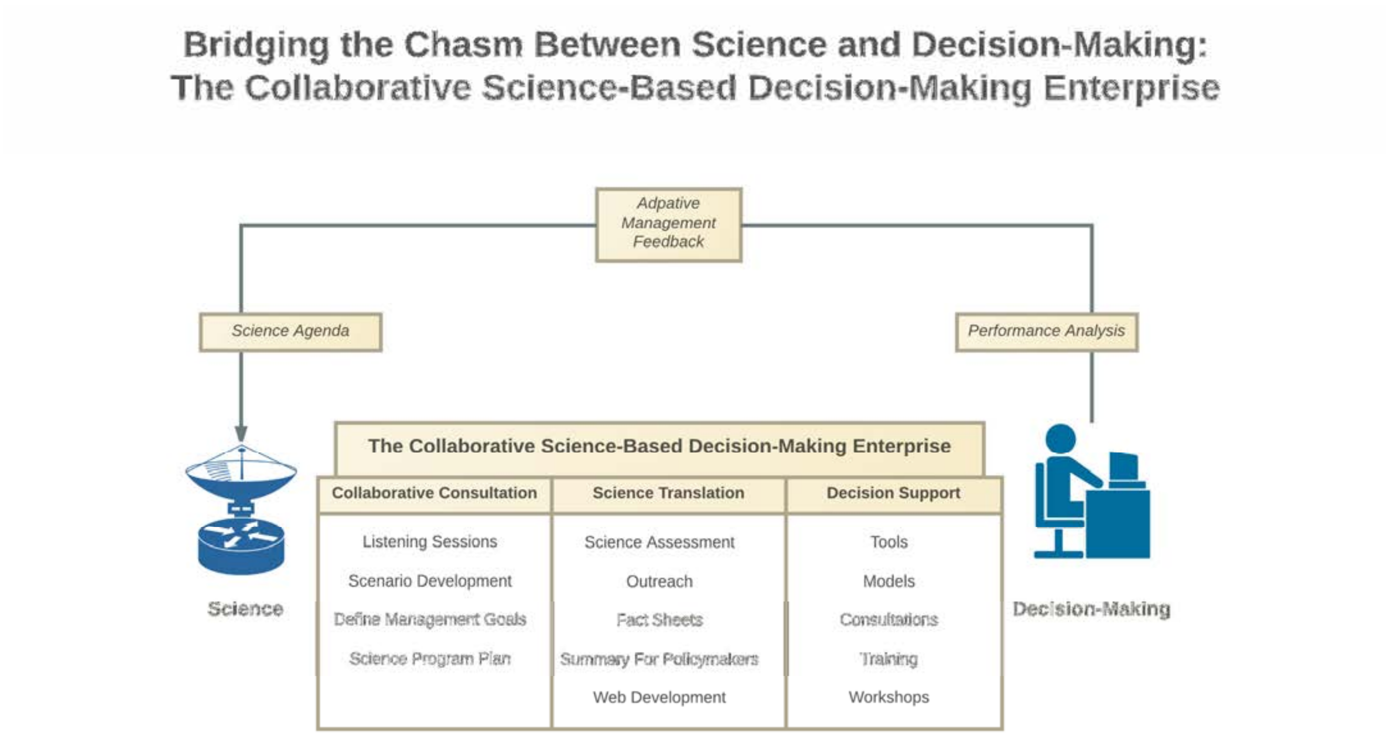

Figure 1. Science-Decision-making Schematic

Sustained Observations: A Foundational Element for the Science–Decisionmaking Process

And at the center of this feedback exists the need for a co-designed ***Sustained Observations Network-*** An integrated enterprise consisting of all relevant observing networks across the Arctic that have the potential to provide observational information that serves a dual role:

1. Providing key observational information that supports continued scientific research, and;

2. Supporting the decision performance of all stakeholders (ie decision-makers) by providing critical observational information on how science-informed decisions are performing, verifying system responses to adaptation actions, and ultimately, providing direction and guidance for adaptive management feedback to the science community in order to improve the next phase of scientific investigation and thus subsequent decision performance.

Title: Many Strong Voices' Portraits of Resilience: bringing personal stories to the attention of the general public and to decision-makers

Authors: John Crump, Bjorn Alftan, Tiina Kurvits, Trista Patterson (GRID-Arendal, Norway)

This contribution by GRID-Arendal and over 25 partner organizations describes the Many Strong Voices Program (MSV), focusing on the role of innovation in communication and media to engage stakeholders, actors, and policymakers in identifying solutions and resilience in and for arctic communities. The presentation focuses specifically on MSV activities that highlight innovative outreach and engagement approaches, in the context of rapidly changing technologies, attention spans, bandwidths and consequent digital divides, and new/social/mobile media expectations & strategies.

One key example, is the role of digital storytelling. The Portraits of Resilience Project illustrates in a direct and personal way the ethical dimension of climate change. The project trains children in regions most affected by climate change in the use of photography and other digital media, helping to bring personal stories and faces to the attention of the general public and to decision-makers at international climate change negotiations (http://www.manystrongvoices.org/portraits/).

Many Strong Voices (http://www.manystrongvoices.org) was born at the climate change negotiations in Montreal, December 2005, out of a need for joint efforts to raise awareness about the effects of climate change in the Arctic and Small Island Developing States (SIDS), two of the world's most vulnerable regions. Since then, Many Strong Voices has worked to bring together over 20 organisations from these two regions to take collaborative and strategic actions on climate change mitigation and adaptation at the local, regional and international level. Many Strong Voices' activities are developing along a number of parallel tracks, including research, assessment, networking facilitation, support to regions and communities, communication and outreach, and action on climate change mitigation.

Activities of the Portraits of Resilience Project align with three core objectives of MSV, which are to:
1) Build a stronger voice in international negotiations, increase collaboration and build capacity in the Arctic and Small Island Developing States. Aims are for people in these vulnerable regions have a stronger voice in negotiating international and national measures to reduce greenhouse gas emissions, as well as developing and implementing adaptation strategies at the local, national regional and international levels.

2) Raise awareness about the effects of climate change on vulnerable regions in general, and on the Arctic and Small Island Developing States in particular, including Increase in understanding of the needs, solutions, and practical measures for adaptation

3) MSV is working to develop community-driven comparative and integrated research on the socio-economic and natural conditions that shape vulnerability and capacity to adapt to climate change. It is also undertaking practical, on-the-ground projects on adaptation in coastal communities in the Arctic and Small Island Developing States.

Developing Indicators of Social-Ecological Resilience

Marcus Carson[1] and Martin Sommerkorn[2]

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Monitoring and observing Arctic change

In order to monitor and better understand developments in the Arctic, scientists have deployed a wide array of scientific tools, including sensors, satellite monitoring, and painstaking on-site data collection to measure and track changes in physical (AMAP), ecological (PAME, CAFF), and social parameters (ASI, AHDI2). While some important data can be collected by sensors (primarily biophysical parameters) in what amounts to real time, research on Arctic communities and the ecosystems upon which people depend tend to involve data collection methods that are comparatively slow to carry out, and which for a variety of reasons including methodologies and scarcity of data availability, provide an incomplete picture.

In addition, research on Arctic communities is often case study based, with the consequence that the tracking and analysis of social developments lags far behind the developments themselves. Moreover, research tends investigate changes in biophysical and social systems as separate entities, even though these coupled social-ecological systems co-evolve (Gual and Costanza ref) - i.e. they evolve in concert with one another. In a period of rapid change, knowledge of changing social conditions and the ecosystems communities are tightly linked to often develops too slowly to identify critical thresholds while there is still time to respond. This presents serious challenges for community leaders and other policymakers who seek to base policy decisions on the best and most up-to-date knowledge available.

We see an important opportunity to tackle this lack of data and at the same time strengthen understanding of the links and interactions between social and ecological systems. Residents of the Arctic have traditionally been keen observers of variations in the physical and social environment. Our contention is that the communities across the Arctic monitor and are cognizant of small changes in the social and physical environment around them as they occur—often before they can be properly measured and interpreted by more conventional scientific means. By engaging in assessing key properties of the social-ecological system in a process of co-production, it will be possible to strengthen monitoring and the capacity to respond to change. Developing an indicator framework based on a social-ecological resilience approach can help support the assessment and monitoring of the complex interactions of social-ecological systems.

What do we mean by resilience?

In the context of operationalising resilience as a tool to develop knowledge tools for responding to and shaping change, the working definition of resilience employed here is:

> *the capacity to learn, share and use knowledge of systems functions and feedbacks, empowering communities to consciously and effectively engage in shaping adaptive or transformative social-ecological change – whether in response to disturbances, to strengthen a desired set of functions, to stave off unwanted changes, or in pursuit of a more desirable set of arrangements."*

This definition takes the subject social-ecological system as its starting point and makes agency fundamental. Agency is exercised by the communities (at whatever scale) that define the social-ecological system, making use of social and ecological systems-related learning & knowledge as an explicit element of "adaptive and/or transformative capacity".

What "ingredients" contribute to resilience?

Key capacities that facilitate effective adaptation to disturbances – or support transformational change where needed – have been identified based on a large body of empirical research. Among these, we have identified five key practical dimensions of resilience that are particularly important. The first two of these are cross-cutting, meaning that they enhance resilience as a component part of other "ingredients". The latter three characteristics provide the basis for useful indicators of social-ecological resilience.

Cross-cutting ingredients:

Assuming change has the benefit of accepting uncertainty and surprise as part of reality and leaves a community better prepared to steer itself through changing conditions. Crisis and change may be approached as an opportunity for pursuing developmental goals. Most importantly, expecting change leads to different kinds of choices than does an expectation that constancy will be the norm.

Diversity is important because it broadens the range of effective response paths. Diversity can be seen as a form of insurance - when disturbance or changing conditions lead to the failure of one kind of response, other mechanisms are available to carry out a given function or set of essential functions. Beyond that diversity provides the foundations for creative problem solving by maintaining a stock of elements that can be combined in novel ways in response to change– this function applies to both social and ecosystem aspects of the system. Biodiversity also enhances the resilience of ecosystem states to secure the production of desired sets of ecosystem services and for social-ecological adaptation and transformation.

Indicator categories for social-ecological resilience:

Livelihoods that provide for material and spiritual well-being emphasize human needs, capacity for goal oriented action, and also introduce broader issues of values, human rights and competing interests (Tanner, 2014). The material well-being aspect of livelihoods, which entails food, shelter, other material needs is essential to resilience, and poverty undermines basic capacity to respond to disturbance and to changing conditions. The concept of "livelihoods" also includes non-material benefits derived from livelihoods activities such as social contact, ability to pursue meaningful goals and contact with nature. Mixed livelihoods (combined market and non-market means of securing material and non-material needs) are a common and important feature of life in many Arctic communities. Livelihoods provides a framework for wider value sets linked to well-being that inform desired/desirable future states /trajectories of social-ecological systems.

Knowledge and capacity to learn to add to and modify existing knowledge is the key means by which community choices can be directed to enable effective responses to disturbances and challenges. Knowledge of cause and effect relationships between communities and ecosystems make it possible to consciously choose between competing priorities and at least some of the trade-offs embedded in those choices. The important precursor for knowledge is the capacity to learn, modify, or replace knowledge – this is an inherently social, even political process.

Capacity for self-organization is essential for the effective exercise of agency. It encompasses the multiple factors that contribute to a community's capacity for collective action, define the nature and cause(s) of challenges, and come to some measure of agreement on suitable responses. This capacity is also influenced by factors outside the community, including legal rights or norms that affect how collective efforts may be organized, or define ownership or authority over certain resources or activities.

Toward indicators of social-ecological resilience

In order to operationalize the above dimensions of resilience we are engaging in a scoping effort to identify first how they can be assessed, and second, how strengthening particular ingredients of resilience can support adaptation to change - and to as yet undetermined and/or unknown disturbances. Drawing on analyses of a large body of empirical research we have identified three key ingredients for which indicators could be identified: livelihoods, knowledge and self-organization (see above). Within each of these ingredients, or categories of ingredients, the two cross-cutting dimensions are applied: assuming change and fostering diversity.

Significant work has been done in an effort to develop sustainability indicators, including, for example, indicators of human well-being in the Arctic (i.e. Arctic Human Development Report II and Arctic Social Indicators II). Nevertheless, the development of indicators of social-ecological resilience, which remains in its early stages, is especially important in the context of planning adaptation actions for a future that is expected to carry with it major and sometimes disruptive change.

Two important issues arise in a process of developing the three sets of social-ecological resilience indicators described above. The first is that while the way in which they are defined and assessed is likely to vary somewhat dependent on local context, the indicators should be translatable into more general, comparable measures. The second is that due to the nature of these indicators, co-production through a participatory process can be expected to produce not only a more informed, nuanced, and well-grounded assessment, but also contribute to the community-based capacity for effective engagement in an on-going process of assessment.

Title: The Economics of Ecosystems and Biodiversity (TEEB) for the Arctic Scoping Study

***Authors**: Miriam Geitz[1], Tom Barry[2], Joan Eamer[3], Salman Hussain[4], Thierry Lucas[5], Trista Patterson[6], and Martin Sommerkorn[1]*

1 WWF Global Arctic Programme; 2 Conservation of Arctic Flora and Fauna (CAFF); SLR Consulting (Canada) Ltd.; 3 UNEP TEEB office; 4 UNEP Regional Office for Europe; 5 GRID Arendal

The concept of ecosystem services (ES) as the benefits that nature provides was given prominence in the policy arena and with the public through the findings of the Millennium Ecosystem Assessment (MEA) in 2005. Building on the groundwork of the MEA, The Economics of Ecosystems and Biodiversity (TEEB) approach was developed.

TEEB is a global initiative coordinated by the United Nations Environment Programme (UNEP). TEEB draws attention to the benefits that people gain from nature (ecosystem services), including food from fishing and hunting, maintenance of culture, water, enjoyment of wilderness, nature and wildlife, and provision of raw materials. Equally important but less obvious benefits include climate regulation and flood control. TEEB also brings attention to the costs to society when ecosystems are damaged and when plant and animal populations are lost. TEEB provides an analytical approach as well as tools and guidance that aim to recognize, demonstrate and capture the value of nature. Hence, the approach can help make the range of nature's benefits more visible when politicians, businesses, communities and others make decisions that affect or are affected by the state of ecosystems.

The Arctic Council has also recognized the significance of assessing and understanding the multiple services and values that ecosystems provide. This is evident in several initiatives such as Arctic Council work on ecosystem-based management, the Adaptation Actions for a Changing Arctic, the Arctic Resilience Report, and in particular the Arctic Biodiversity Assessment (ABA) recommendations that were approved at the Arctic Council Ministerial in Kiruna in 2013. ABA recommendation 12 refers to ecosystems services and recommends that the Arctic states "evaluate the range of services provided by Arctic biodiversity in order to determine the costs associated with biodiversity loss and the value of effective conservation in order to assess change and support improved decision making".

In response to this recommendation, a partnership – comprising the World Wide Fund for Nature (WWF), the Conservation of Arctic Flora and Fauna (CAFF) Working Group of the Arctic Council, UNEP Regional Office for Europe, UNEP TEEB, and GRID-Arendal – initiated an effort to better understand ways that the Arctic Council can address this important topic. The TEEB Arctic scoping study carried out by the partnership is an important first step (www.arcticteeb.net).

The TEEB Scoping Study for the Arctic encompasses a number of different elements (workshop, survey, literature review, political process analysis and case studies) that feed into the main product (the technical report) and together comprise the overall scoping study. The findings as presented in the technical report are predominantly based on the TEEB scoping study approach and methodology as developed by the global TEEB program. The scoping study differs from this model in two ways:

1) it includes information and discussion related more generally to improving understanding of the full range of Arctic ecosystem services, as well as information and discussion on aspects of governance and of valuing ecosystem services in the context of the circumpolar Arctic and Arctic Council; and
2) it does not conclude with a defined set of specific policies for assessment in a full TEEB study, but rather provides guidance and examples on policy focus areas that could be further refined and assessed using TEEB methodology.

These differences are related to the multi-jurisdictional nature of Arctic governance, the diversity of value systems around the Arctic, and to meeting the needs identified by the Arctic Council, both through the ABA and through recommendations on implementation of ecosystem-based management in the Arctic.

By choosing this approach, reaching out widely and actively working through the Arctic Council working group and associated consensus building process, the project developed a wide understanding of the utility of incorporating ecosystem services into decision-making in the Arctic. The partnership with the Arctic Council provided credibility for the scoping study as well as access to key expertise and stakeholders on this topic.

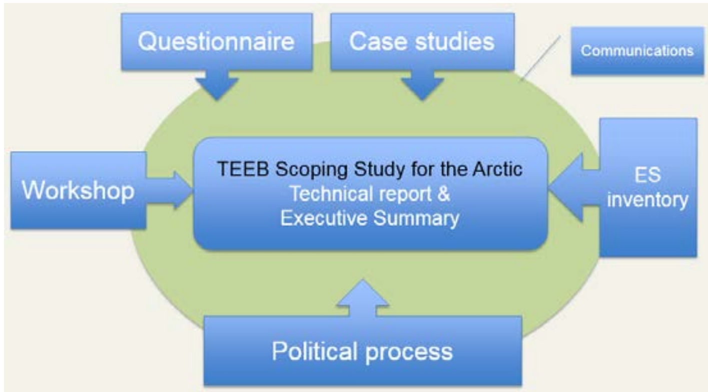

Figure 1. Components of the TEEB for the Arctic Scoping Study

The technical report consolidates all elements of the scoping study on ecosystem services and outlines the potential application of a TEEB approach and methodology in the Arctic (Figure 1). It addresses context and issues, describes the type of Arctic ecosystem services that can be found, looks at how they are governed and valued, explores the most relevant policy areas that would benefit from an ecosystem service focus, identifies stakeholders and suggests as set of options for the way forward.

The technical report is supplemented with two extended case studies (one marine and one terrestrial), which were instrumental in developing the recommended broad policy fields for a full TEEB study. The technical report and an executive summary are available at www.arcticteeb.net .

One objective of the project partnership was to reach out widely to Arctic stakeholders, knowledge holders and rights holders in order to collect information and develop a wider consensus on the understanding and utility of the ecosystem services concept and a TEEB approach in an Arctic context. The lively discussion and feedback that the study generated and the thoughtful comments received from a diverse range of experts confirm that this process and consensus building has been beneficial to this project and any future follow up. The scoping study report has been reviewed by CAFF participants and approved by the Senior Arctic Officials of the Arctic Council.

To reach out widely to the Arctic community and interested stakeholders, the project team designed an online questionnaire which was available from April to July 2014 and gathered 60 in-depth responses. A special version of the questionnaire was designed to better capture traditional knowledge, and the main version was also translated into Russian. Questionnaire input is included throughout the scoping study report, both in synthesis form and as direct quotes.

Two workshops were held as part of the project to hear and discuss views on project development and implementation and to agree on the policy areas to be explored in the scoping study.

A literature review on Arctic ecosystem services was conducted and a preliminary inventory of available knowledge compiled. The technical report includes rationale and options for further development of this inventory.

The scoping study concludes by proposing two main follow-up options that are not mutually exclusive. One is a full TEEB study with suggested priority policy areas. The second is a suite of activities that would improve capacity at all scales to better understand Arctic ecosystem services and their values, and to apply this knowledge to policy, by synthesizing and analyzing available information, developing guidance, tools, information and methods. These activities would improve the extent, quality and access by decision makers to knowledge on Arctic ecosystem services.

Such follow-up work would embrace participatory and interdisciplinary approaches to recognize and where appropriate evaluate ecosystem services in the context of specific policies and value perspectives. It would also provide a basis for monitoring the diversity of ecosystem-service-associated values that people hold and the natural capital that is the origin of these services. With the understanding that ecosystem services are co-produced by nature and people, the monitoring of ecosystem services could become an important way to track social-ecological change. Realizing the social-ecological interconnectedness that ecosystem services represent as clusters rather than single- category benefits, could help prioritize and design observing efforts more effectively.

Data to Decisions

The Potential Impact of Data Analysis to Alaskans

Adam Krynicki

CONTENTS

The Value of Data Analytics

Without data you're just another person with an opinion.

- *W. Edwards Deming* *(1900-1993)*

The ability to use software and sensors provides a gigantic opportunity for Alaskans. In addition to solving local problems, information has economic value worldwide. It reduces uncertainty; less uncertainty improves decisions; and better decisions result in more effective actions. Effective actions can improve profit. [1]

For example, Climate Corp. integrates weather data and climate data to determine where crops may need water or fertilizer, and sells that data to farmers and stock market traders.[2] The Company was acquired by Monsanto to the tune of approximately a billion dollars,[3] which is a bargain considering that Monsanto estimates that data science could be "$20 Billion opportunity beyond its core business of seeds and chemicals."[4]

Financial institutions, such as Citigroup, use data to predict loan defaults, and many use algorithms to control stock trading. The automobile insurance company, Allstate, saves millions by predicting bodily injury liability solely based on the characteristics of an insured vehicle. Hewlett Packard uses predictive models to generate a "flight risk" score for each of its almost 350,000 employees so managers may intervene in advance to retain employees, and plan accordingly for employee turnover. Target uses data to make recommendations to customers which has increased revenue between 15 and 30 percent. Universities are using data to identify students at risk of dropping out to take action in the hope of retaining them.[5]

- Google uses data and software to calculate the ROI on advertising campaigns.
- Ford uses data and software to improve the design of its vehicles.
- Twitter uses data and software to monitor user experience.
- The US National Weather Service uses data and software to predict severe flooding.
- The Rockefeller Institute of Government uses data and software to develop models for simulating the finances of public pension funds.

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[1] *Hubbard, Douglas. How to Measure Anything.*
[2] *http://techcrunch.com/2013/10/02/monsanto-acquires-weather-big-data-company-climate-corporation-for-930m/*
[3] *Climate Corp. monitors vegetation growth to determine where the crops may need water or fertilizer, and sells that data to farmers and stock market traders.*[3]
[4] *http://www.forbes.com/sites/bruceupbin/2013/10/02/monsanto-buys-climate-corp-for-930-million/*
[5] *Predictive Analytics. John Wiley & Sons.*

- The Human Rights Data Analysis Group uses data and software to quantify the impact of war.
- New York Times uses data and software to create infographics and interactive data journalism applications.[6]

A satellite firm takes pictures of Wal-Mart parking lots and sells them to an analysis firm, which scrutinizes the images and sells the aggregated data to hedge funds and Wall Street analysts. Shell uses data to manage exploration portfolios.[7] Numerous other companies are using data to calculate the monetary benefit of decisions, real options, stock market prices, insurance, reinsurance, commodities - you name it.[8]

In 2013, the worldwide business analytics software market grew 8.2% to reach $37.7 billion.[9] The Predictive Analytics Market is estimated to grow to $5.24 billion in 2018 at a compound annual growth rate of 25.2%.[10] A recent IDC forecast shows that the Big Data technology and services market will grow at a 26.4% compound annual growth rate to $41.5 billion through 2018.[11]

Further, new business models based on emerging disciplines, such as additive manufacturing (3D printing), rapid prototyping, predictive maintenance, driverless cars, geographic information systems (GIS) and the Internet of Things (IoT) are also highly dependent on big data analytics and low-cost storage capabilities.

These new industries will generate more than $100 billion in new revenue in 2016 alone.[12] They will also greatly accelerate the creation of new and even larger data sets – which means that big data will be getting even bigger.

Make no mistake: Big data is not a trend or fad. Prominent investors in big data technologies include Microsoft, GE, IBM, Intel, Goldman Sachs, Greylock Partners, Sequoia Capital and Accel Partners. Clearly, they believe the revolution is still in its early stages, and they're betting that big data will become synonymous with big profits."[13]

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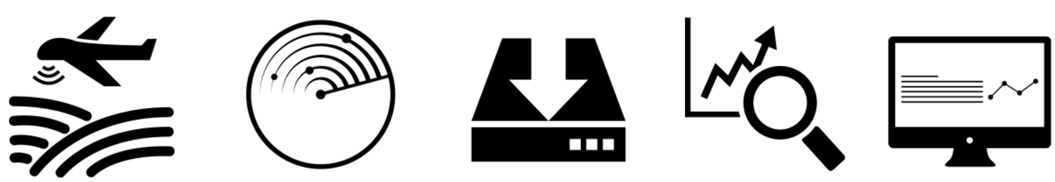
[6] http://techcrunch.com/2015/05/07/the-business-economics-and-opportunity-of-open-source-data-science/
[7] *Savage, Sam. The Flaw of Averages. 2009. John Wiley & Sons. Pg 223.*
[8] *See generally the IEEE conference on Big Data and Cloud Computing.*
[9] *http://www.sas.com/content/dam/SAS/en_us/doc/analystreport/idc-ba-apa-vendor-shares-excerpt-103115.pdf*
[10] *http://www.istockanalyst.com/business/news/6552364/predictive-analytics-market-worth-5-24-billion-by-2018*
[11] *https://www.idc.com/prodserv/4Pillars/bigdata and http://www.idc.com/getdoc.jsp?containerId=prUS25329114*
[12] *http://techcrunch.com/2015/05/07/the-business-economics-and-opportunity-of-open-source-data-science/*
[13] *http://techcrunch.com/2015/05/07/the-business-economics-and-opportunity-of-open-source-data-science/*

An Overview of Data Analytics Solutions

Companies around the world recognize that information has economic value. It reduces uncertainty; less uncertainty improves decisions; and better decisions result in more effective actions. Effective actions can improve profit.[14]

Data Capture	Sensor Integration	Data Collection and Storage	Data Analysis	Data Delivery
We build or provide vehicles and systems for remote data collection.	We build and integrate new devices that can collect remote data.	We collect and store data.	We generate substantive and financial value from data.	We get information into the hands of users.
Aircraft, Unmanned Aircraft Watercraft Autonomous Underwater Vehicles Satellites Microsats Light Rockets Remote data collection systems	Electronics integration Embedded Systems design and manufacture Medical Assays and Kits	Signal processing High Performance Computing Large dataset storage	Large dataset storage Statistical analysis, Machine Learning Change Detection Complex systems modeling	Data streaming Data Portals Visualization



[14] *Hubbard, Douglas. How to Measure Anything.*

THE OPPORTUNITY

Companies are continually proving that big data is big money around the world, and in Alaska, there is a great opportunity. Alaskans routinely invent technologies that turn data into actionable intelligence, and from this work, they can help companies turn this information into cost savings and profit.

What distinguishes our innovators is that, unlike numerous other digital innovators in cities around the globe, our innovators are leaders in **remote** data capture, processing, software, and analysis. In other words, Alaskans have built numerous technologies that can withstand working in a remote area, under extreme cold, or in extreme isolation.

Where Silicon Valley companies focus on Silicon Valley problems, Alaskans are making the most of our remote solutions laboratory to build technology at a distance for the distant.

ALASKA IS A REMOTE SOLUTIONS LABORATORY. OUR INNOVATORS BUILD TECHNOLOGY AT A DISTANCE FOR THE DISTANT.

IS ALASKA RIPE FOR BUILDING THE NEXT BILLION DOLLAR DATA ANALYTICS COMPANY?

GIVEN OUR EXPERTISE, ALASKANS HAVE A MAJOR OPPORTUNITY TO TURN DATA INTO DOLLARS, AND DOLLARS INTO SUSTAINABLE BUSINESSES AND JOBS. FURTHER, DATA CAN HELP OUR PUBLIC SECTOR ENTITIES LOWER COSTS AND MITIGATE RISKS.

Alaskans Produce a Variety of New Technologies to Analyze Data

Data Capture	Sensor Integration	Data Collection and Storage	Data Analysis	Data Delivery
We build or provide vehicles and systems for remote data collection.	We build and integrate new devices that can collect remote data.	We collect and store data.	We generate substantive and financial value from data.	We get information into the hands of users.
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A. VEHICLES AND SYSTEMS TO EXPLORE THE WORLD

ALASKANS HAVE A WIDE VARIETY OF EXPERTISE IN BUILDING AND OPERATING SYSTEMS TO CAPTURE DATA UNDER HARSH CONDITIONS.

1. MANNED AND UNMANNED AIRCRAFT

Numerous researchers at in Alaska are professional pilots as well as experts at collecting remote data. Further, Alaska is home to one of the six **Federal Aviation Administration (FAA) test ranges** for unmanned aircraft. [15] The Pan- Pacific unmanned aircraft systems (UAS) Test Range Complex includes principal partners in Oregon and Hawaii as well as 56 non-state partners located all over the U.S. and internationally. Alaskan inventors across the university have demonstrated that unmanned vehicles can automate expensive activities that require manual inspection, such as pipeline surveillance, [16] road inspection[17] or property tax assessment. [18] Further, UAS are being used to explore for natural gas and mineral resources.[19]

UAF UNDERGRADUATE COREY UPTON DESIGNS A COLD RESISTANT PAYLOAD FOR UAVS WHILE STEVE KIBLER, A PH.D. CANDIDATE, FLIES AN UNMANNED AIRCRAFT AROUND THEIR FAIRBANKS LAB. UAF PHOTO BY TODD PARIS

2. AUTONOMOUS UNDERWATER VEHICLES

UAF operates several Autonomous Underwater Vehicle (AUV) gliders. The gliders are non-propelled, autonomous, quiet, and can perform up to 3-month missions using lithium batteries. The devices have been tested for the use of tracking tagged fish.

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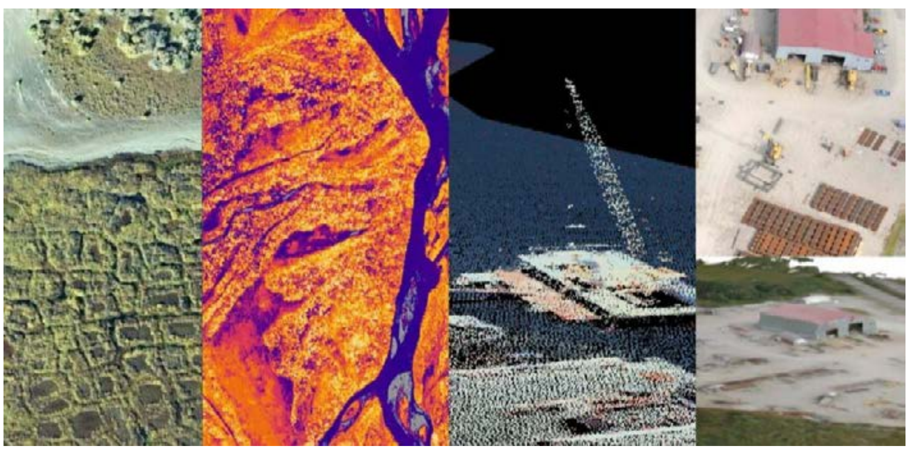
[15] *http://www.faa.gov/news/updates/?newsId=75399*
[16] *http://uafcornerstone.net/uaf-researcher-initiates-pipeline-research-using-unmanned-aircraft/*
[17] *US Patent Application 61/589,247*
[18] *LIDAR PATENT*
[19] *Grimes, Marmian. Geologic Methane Seeping from Thawing Cryosphere. May 21, 2012.*

3. RESEARCH VESSELS

One of the most advanced **research vessels** ever built, the 271 foot long National Science Foundation funded **Sikuliaq** has extensive scientific facilities. In addition to 2,250 square feet (209 m2) of built-in laboratories, The Sikuliaq allows up to 26 scientists and students to conduct multi-disciplinary studies in high latitude open seas, near-shore regions and single-year sea ice.

4. SATELLITES AND GROUND STATIONS

The Alaska Satellite Facility (ASF) is part of the Geophysical Institute of the University of Alaska Fairbanks. ASF downlinks, processes, archives, and distributes remote-sensing data to users around the world. ASF is part of the National Aeronautical and Space Administration (NASA)'s Near Earth Network system of ground stations around the world known as Distributed Active Archive Centers (DAAC), and provides data and associated specialty support services to researchers in support of NASA's Earth Science Data and Information System project.



AERIAL IMAGERY. LEFT: EPSCOR ACE NORTHERN TEST CASE AERIAL IMAGERY BY QUANTUM – THERMAL IMAGERY FROM ALASKA ENERGY AUTHORITY'S SUSITNA WATANA HYDROELECTRIC PROJECT – LIDAR IMAGERY FROM THE ALASKA DOT ROADS TO RESOURCES PROJECT (VALLENAR BAY)

5. MICROSATELLITES

The CubeSat program, along with the Alaska Space Grant Program, is testing a novel low-power attitude control and determination system, and a communication system capable of high bandwidth data transfer. Further, they are testing CubeSats. A CubeSat is a miniaturized satellite for space research that usually has a volume of exactly one liter (10 cm cube), has a mass of no more than 1.33 kilograms and typically uses commercial off-the-shelf components for its electronics.

6. ROCKETS

The Poker Flat Research Range (PFRR) is the largest land-based rocket research range in the world, the only high-latitude rocket range in the United States, and the only one operated and maintained by a U.S. university. Poker Flat launches scientific sounding rockets, performs satellite tracking and is home to a growing fleet of unmanned aircraft. From its location in interior Alaska, rockets can launch and fly over the sparsely populated tundra hundreds of miles north of the range with special permission from federal, state and tribal landowners. UAF has designed a reusable, $25,000 Carbon Fiber Rocket that can test sensors repeatedly.

7. REMOTE MONITORING STATIONS

UAF has built and tested an autonomous power system (wind, solar, and biodiesel) System. The units are made to withstand arctic conditions and Eight radar-RPM systems can cover the Beaufort Sea and the north-east Chukchi Sea (40,000 n.mi.2).[20]

THE REMOTE POWER MODULE CONTAINS COMMUNICATION EQUIPMENT AND USES OPEN SOURCE SOFTWARE TO BALANCE ENERGY LOADS AND MAINTAIN EFFICIENCY. THE MODULE IS RESISTANT TO COLD TEMPERATURES AND HARSH ARCTIC CONDITIONS.

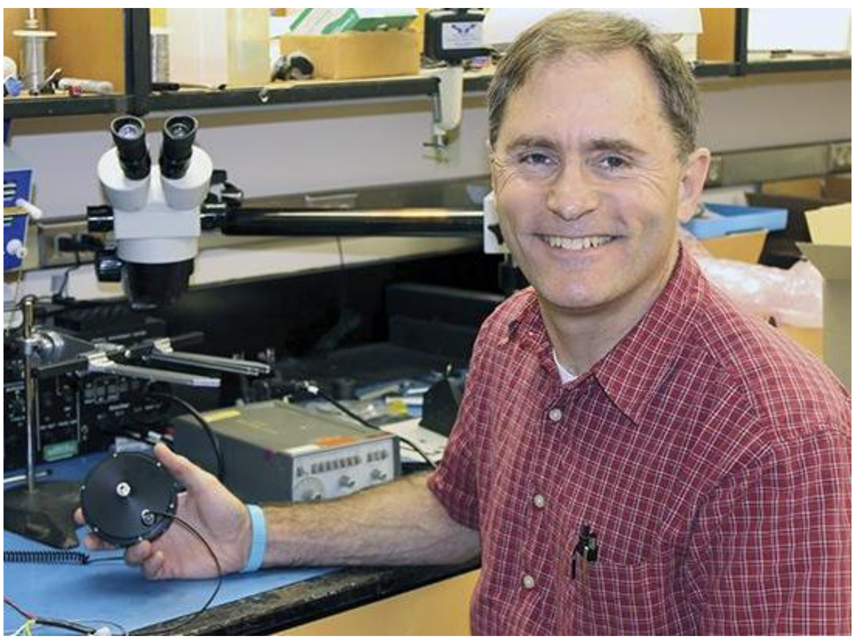
[20] *Remote Power Stations. University of Alaska in collaboration with Remote Power Incorporated. 2011.*

B. IMPROVED SENSORS AND DEVICES TO COLLECT DATA

RESEARCHERS IN ALASKA BUILD SENSORS, DEVICES, AND SYSTEMS THAT IMPROVE UPON SCIENTIFIC, TECHNICAL, COMMUNICATION, AND SURVEILLANCE INSTRUMENTS.

1. ELECTRONICS INTEGRATION

The UAF Geophysical Institute Electronics Shop designs, constructs, calibrates, tests and repairs a wide range of scientific and technical instruments. A team of shop personnel maintains and repairs computers, computer terminals, data acquisition systems, and radio frequency (RF) communications equipment. Technicians are available for installation, operation and repair of a wide variety of electronic field equipment as required by scientific projects. Shop employees are experienced in installing and operating remote telemetered systems.



JEFF ROTHMAN SHOWCASES HIS HOCKEY PUCK SIZED SENSOR THAT WAS DEVELOPED AT THE ELECTRONICS SHOP.

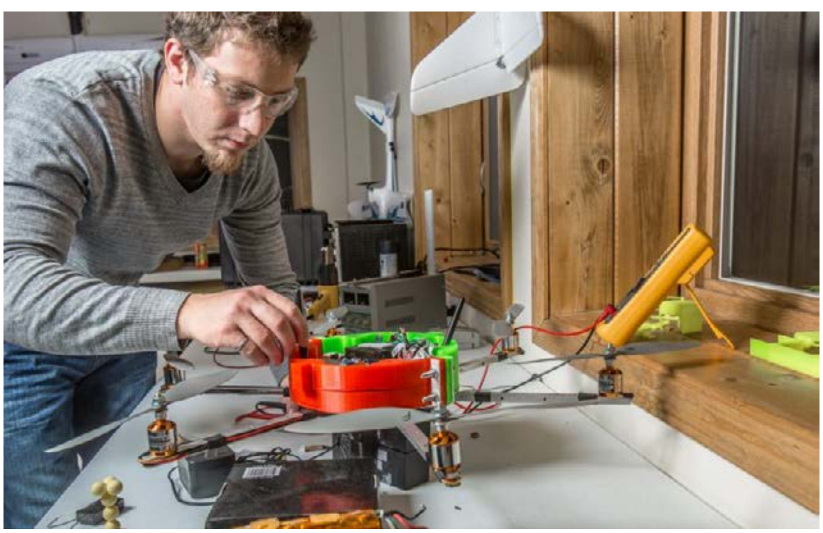
2. Sensor Design and Fabrication

The Geophysical Institute Machine Shop is the most extensive research and development machine shop facility in the state of Alaska. It provides complete research and design services from concept development to fabrication of the finished product by combining innovative engineering and design with precision craftsmanship in machining and fabrication. The shop is well-equipped with precision machine tools which have been fitted with high resolution digital read-out systems, highly sophisticated computer driven three and four access milling machines provide the ability to quickly and accurately design and fabricate complex machine parts. Other capabilities include: MIG, TIG, and stick welding, silver soldering, brazing, heat treating, aluminum anodizing tumble finishing, and 3D printing.

3. EMBEDDED SYSTEMS AND SENSORS

Northern Embedded Solutions (NES) is an engineering design firm dedicated to advancing the commercial and scientific scope of work accomplished by Unmanned Aerial Systems (UAS) by developing new payloads, control systems, communication systems, and user interfaces to the burgeoning UAS market. NES' focus has been payload development, working with UAF to develop unique payloads with unique sensors for science missions that have never before been done with UAS systems. NES works with UAF to help develop new UAS vehicles that may be used for carrying these payloads while on campaign.

SAM VANDERWAAL, A UAF GRADUATE STUDENT AND ENTREPRENEUR, CALIBRATES SENSORS ON A UNMANNED AIRCRAFT. THE DEVICE IS LARGELY FABRICATED FROM PLASTIC FROM A 3D PRINTER IN THE FAIRBANKS LAB.



C. SYSTEMS TO STORE DATA AND PROCESS DATA

RESEARCHERS HAVE A WIDE VARIETY OF SIGNAL PROCESSING, COMMUNICATIONS, AND DATA PROCESSING EXPERTISE.

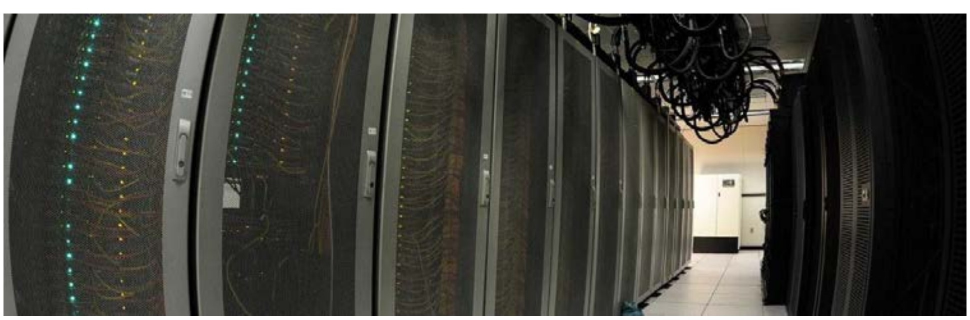
1. REMOTE SENSING

UAF's research in remote sensing, geographic information systems (GIS) and global positioning system (GPS) involves mapping and monitoring geological features and processes. We cover all aspects of geospatial research including acquisition of ground based, airborne, and satellite data; development of software tools and data processing techniques; and use of data and tools for a variety of applications. These applications include, but are not limited to, mapping and modeling in support of exploration, volcanology, planetary science, ecology, and cryospheric studies.

FUNNY RIVER FIRE FROM LANDSAT-8 DATA – THIS DATA WAS USED BY EMERGENCY CREWS TO RECOMMEND WAYS TO EXTINGUISH THE FIRE & MITIGATE PROPERTY DAMAGE.

2. HIGH PERFORMANCE SUPERCOMPUTING

The high-performance computing (HPC) unit of UAF provides a broad range of research computing services to the University of Alaska community, supercomputer access, and programming expertise.



THE HIGH PERFORMANCE COMPUTING FACILITY AT UAF – JE MCGILL

3. SIGNAL PROCESSING

The Space Physics and Aeronomy research group studies the Earth's geospace environment. The group's main observatory at PFRR hosts a wide variety of instruments at the Davis Science Center, the LIDAR Research Laboratory, an imaging riometer, and the Advanced Modular Incoherent Scatter Radar Poker Face. PFRR also supports rocket launches and operates remote observatories in Ft Yukon and Barter Island. A large instrument suite and remote observatories that include the Super Dual Auroral Radar Network, magnetometers, and cameras, spectrometers, infrasound sensors and photometers is deployed across the State of Alaska.

Featured Technology: Signal Processing Software and Patents

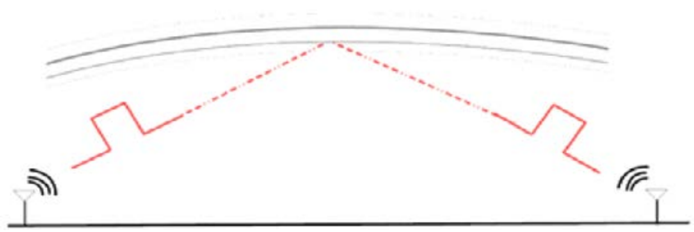
UAF Patent # 8,554,816 describes a filter which cleans digital signals and resolves the cocktail party effect. This technology focuses a listener's attention on a single sound among a mixture of background noises, while ignoring other conversations.

Tracking a moving signal by passive methods has been difficult due to the Doppler shift that is introduced into the observations of each sensor. The system and method described in patent #7,710,827 overcomes the complications of Doppler shifting in signal source tracking.

Using a passive sensor array to determine the position of a signal source has proven difficult, and many techniques are only designed for application with sensor arrays of specific, symmetrical geometries. Patent #7,746,225 protects a fast method of determining the location of a signal source

Featured Technology: Improved Radar Resolution Software

UAF Inventors have developed a new method to improve the resolution of radar systems by a factor of 10 and have filed a patent on the technology. The invention independently corrects for the environmental effects on the signals received at each radar antenna. The method approximates the signals that would exist under ideal conditions and updates them over time to track the random fluctuations observed. Through experiments with SuperDARN, the team observed a reduction of the uncertainty in determining the direction of a target by as much as a factor of 10.



SOFTWARE AND METHODS TO ANALYZE, VISUALIZE, AND DISTRIBUTE DATA

ALASKANS HAVE A WIDE VARIETY EXPERIENCE IN ANALYZING DATA FOR SPECIFIC APPLICATIONS.

1. GEOSPATIAL MODELING FOR RESOURCE MAPPING AND TRANSPORTATION

The Geographic Information Network of Alaska (GINA) provides a distributed data system for geospatial information and maintains an enterprise-level geographic information system (GIS) with online archiving, internet mapping, and metadata services. We offer training and assistance in satellite image processing, GIS, and visualization. GINA provides custom processing, server-side analysis, and visualization tools.

Petroleum Development Laboratory (PDL) - Alaska's oil production currently accounts for about 15% of U.S. production. Current study areas at the PDL include coal seam methane, methane hydrates, enhanced viscous/heavy oil recovery, carbon dioxide capture and sequestration, arctic oil well and geothermal well cementing, gas-to-liquid transportation through the Trans Alaska Pipeline System, and enhanced oil recovery through microbial and wettability alteration processes.

FEATURED TECHNOLOGY: SWATHVIEWER

Inventor Dan Stahlke invented the SwathViewer while working for the University of Alaska Fairbanks. SwathViewer is a powerful, lightweight global mapping and imagery Java applet coupled to an efficient, scalable server platform. Through guidance, expertise and collaboration efforts by the Office of Intellectual Property and Commercialization, the invention was successfully marketed and licensed to SeaSpace.

2. RESOURCE EXPORTS

The Mineral Industry Research Laboratory (MIRL) invents new method software to analyze mineral economics, reserve estimation, mineral market evaluation. Further, MIRL invents computational tools and mines data for mine-mill reconciliation, mine optimization, environmental ground water modeling and soil remediation, system engineering, and production simulation.

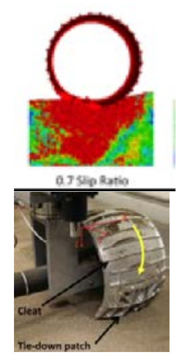
FEATURED TECHNOLOGY: USING UNMANNED AIRCRAFT FOR SURVEYS OF PIPELINES

UAF inventors have created a new method for flying, inspecting, and surveying buried pipelines. The method has the potential to automate the compliance process for registering the location of these pipelines, and the technology was licensed to CR inspection.

3. COMPLEX SYSTEMS MODELING

UAF researchers produce complex computer models to prevent failure of power grids for the California Energy Commission and software to prevent micro grid failure for native corporations in Alaska.[21] Our innovators produce decision support tools to monitor ice roads for the trucking industry, oil industry, and the Alaska Department of Natural Resources. We build control systems, sensors, and software for petroleum and gas monitoring projects. We can reduce uncertainty, improve decisions, increase the effectiveness of actions, and increase net revenue.[22]

FEATURED TECHNOLOGY: DISCRETE ELEMENT MODELING SOFTWARE



Modeling the movement of a large number of particles can be computationally expensive, and may require hours of processing time on a large supercomputer. To reduce the amount of computation needed, researchers at the Institute of Northern Engineering have invented software that can simulate systems with a large number of complex particles. The software can be used to model agricultural chutes, pipelines, asteroid impacts, pharmaceutical drums, and much more. The software has even been used to model the traction of tires on the Mars Rover. For more information, please visit www.coupisoftware.com.

[21] *http://uafcornerstone.net/size-matter/*
[22] *Johnson, JB et al., Discrete element method simulations of Mars Exploration Rover wheel performance, J Terramechanics (2015), http://dx.doi.org/10.1016/j.jterra.2015.02.004*

4. CLIMATE MODELING

The Scenarios Network for Alaska and Artic Planning (SNAP) integrates current research and lessons from the past to help people manage uncertainty and make decisions about the future. SNAP has expertise in data science and analysis, statistics, geographic information systems, remote sensing, visualization and cartography, software programing, engineering, ecological modeling, and project management.

SNAP IS PROVIDING A TOOL FOR COASTAL COMMUNITIES, FISHERMEN, SHIPPING, OIL & GAS INDUSTRIES, OR THE US COAST GUARD TO MAKE DECISIONS BASED ON CLIMATE DATA.

5. SECURITY AND HAZARDS PLANNING

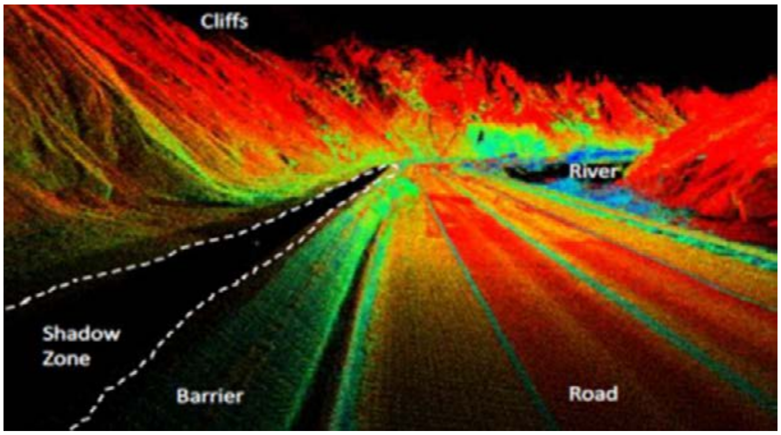
The Center for the Study of Security, Hazards, Response and Preparedness (C-SSHRP) brings together research scientists from across the hazards community at UAF along with training capabilities and educational opportunities in the Homeland Security and Emergency Management (HSEM) Program. The aim of C-SSHRP is to increase the capacity of the HSEM students to be prepared for the next generation of decision support tools and to better understand the hazards that Alaska can bring. The integration of remote sensing data into the decision making process is critical. Through C-SSHRP's work, professionals and students can learn to become more effective emergency managers, build safer communities, and improve decision making in critical environments.

6. TRANSPORTATION AND ENGINEERING

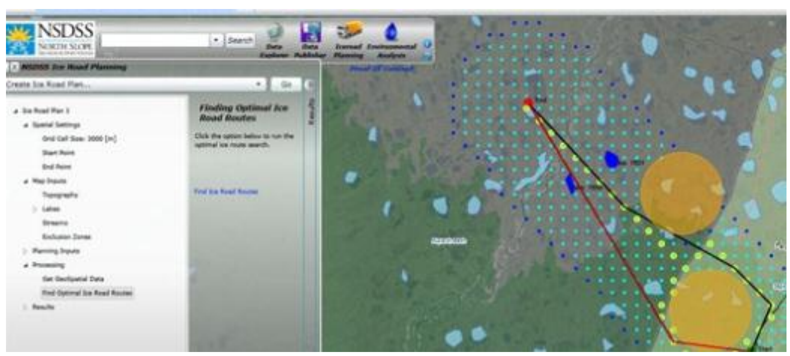
Researchers across the Institute of Northern Engineering collaborate with the Alaska University Transportation Center (AUTC) to improve transportation in cold regions through research. AUTC is one of 10 National Transportation Centers funded by the U.S. Department of Transportation, through the Research and Innovation Technology Program (RITA).

Featured Technology: Platform for Risk-Based Slope Asset Management

Dr. Keith Cunningham has developed a technique that enables highway managers to understand changes in slope characteristics along highways. This change detection and analysis can inform decisions for slope inspection and remediation. Mitigating unstable slopes and their associated hazards reduce threats to safety and regional commerce, and enables resources to be better allocated.



Featured Technology: Ice Road Decision Support Tool



Ice roads are used on the North Slope of Alaska to support the transportation of goods and support the oil exploration process. On average, an ice road requires one million gallons of water per lane per mile to construct, water that is typically extracted from the tundra lakes that dot the landscape. The potential risk of insufficient water supply is critical, and the permitting process can include up to two dozen regulatory agency departments. With multiple firms seeking permits to use a common set of tundra lakes, there is a substantial economic risk if the road is not approved or cannot be constructed due to a lack of water. The North Slope Decision Support Software helps make calculations to determine the availability of water and get through the regulatory process.

7. ENERGY EFFICIENCY AND GENERATION

The Alaska Center for Energy and Power (ACEP) is an applied energy research program based at the University of Alaska Fairbanks. ACEP provides leadership in developing energy systems for islanded, non-integrated electric grids and their associated oil-based heating systems.

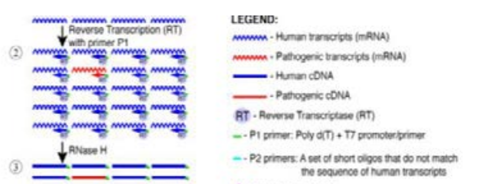
ACEP IS AN EXPERT IN MICROGRID RESEARCH, AND THE FACILITY PERMITS THE TESTING OF GENERATORS, GRID SYSTEMS, AND SOFTWARE.

DATA ANALYTICS SOLUTIONS HAVE ALREADY CREATED BUSINESS OPPORTUNITIES

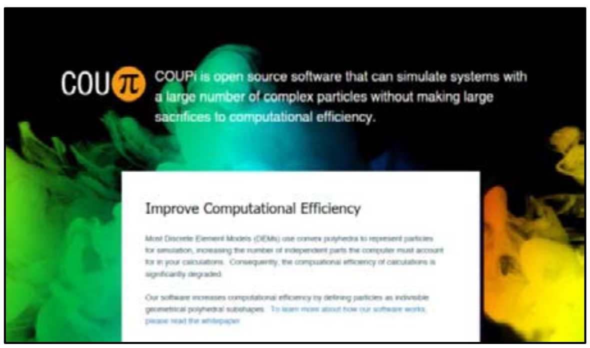
A. Researchers are creating new businesses based on remote data analytics in Alaska.

V-ADAPT, Inc. (www.vadapt.net) provides airborne hazard information to help government, municipalities, and air carriers mitigate the risks of volcanic ash, sand, pollution, and other aerosols.

ArcticFire Development Corp. (www.flyroutinely.com) provides software that makes flying unmanned aircraft a routine for professionals who want to collect data to perform high cost tasks. They are automating expensive tasks like infrastructure monitoring, surveying, and change detection. Demo.



Path-Seq Dianostics, LLC (www.path-seq.com) is developing a small kit that can quickly determine what disease a patient has by detecting the bacterial or viral DNA, and comparing it against a database. The improved Next-Gen sequencing method could significantly change the way we diagnose disease around the world, and allow people to do it in remote areas without a clinician.



[Northern Science Services](#) - NorSS specializes in airborne precision data acquisition and value-added products. These include optical and infrared imagery, lidar, and custom acquisitions from scientific equipment. We can also provide FAA-certified pilots for client-owned aircraft such as Unmanned Aeronautical Systems. Typical users of our products and services include scientists, engineers, government agencies, and search and rescue teams.

[Pridict.us](#) will provide business intelligence software for supervisors at nonprofits and universities. This software can significantly reduce the time that it takes supervisors to determine if a project is meeting budget expectations, and if adjustments are needed.

CouPi Solutions, LLC (www.CouPisoftware.com) will provide modeling software that can simulate how a large number of particles will react in different situations. Typical uses for software include oil and gas flow prediction, agricultural chute design, food handling, mineral processing, and pharmaceutical manufacturing.

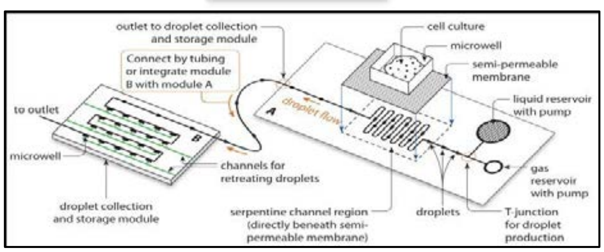
[Dynamic Microgrid Solutions](#) will provide hardware and software that can detect inefficiencies in small electrical grids and generation systems. Using this information, the company can provide feedback that will help communities and companies improve energy usage.

[Fairbanks Fodar](#) is a company that makes topographic maps and ortho photos at unprecedented accuracy and affordability for detecting changes in infrastructure and topography.

[Northern Embedded Solutions (NES)](#) is an engineering design firm dedicated to advancing the commercial and scientific scope of work accomplished by Unmanned Aerial Systems (UAS) by developing new payloads, control systems, communication systems, and user interfaces to the burgeoning UAS market.

Oxergy, Inc. - Everyone poops, but not everyone has a flush toilet. Traditional flush toilets are fabulously effective waste disposal devices, but they require vast amounts of costly energy and water to keep them flushing. Consequently, Western toilets are largely considered to be simply neither achievable nor feasible in many poor, rural areas due to massive infrastructure investments in plumbing and energy systems. To address this problem, Oxergy will commercialize a compact wastewater processing system. The company has developed a proprietary method and device to process sewage and produce energy from waste.

MapPost LLC **-** will provide an easy-to-use app that offers a way for students, faculty, staff, and visitors to communicate and discover local events in their community. The software allows users to post an event to a group, post an event on a campus map, or share information about an event on social media. Further the software allows advertisers to connect with a campus community.



Bhaisa Pi Tech LLC - Intracellular communication is fundamental to understanding physiology and the effects of medicine, but current techniques lack the ability to collect samples continuously autonomously and in small volumes. Bhasia Pi is developing an intracellular sampling method for clinicians and researchers that can continuously measure the impacts that disease and medicines have on intracellerular communication.

Harris Labs, LLC – HarrisLabs is developing a fat metabolism monitor. The fat metabolism monitor is a consumer product for clinicians and everyday exercise enthusiasts that allows the user to identify when fat is burned and how much fat is consumed.

GOVERNMENT ENTITIES ARE CREATING NEW BUSINESS OPPORTUNITIES BASED ON REMOTE TECHNOLOGY AND DATA.

BASED ON MORE COLLABORATION BETWEEN THE GOVERNMENT, THE UNIVERSITY, AND THE PRIVATE SECTOR IN ALASKA, NEW BUSINESS OPPORTUNITIES ARE AVAILABLE.

The university, state government, and the private sector are utilizing a new way to fund ongoing research and commercialize commercial datasets. The effort builds off the success of the Statewide Digital Mapping Initiative (SDMI). Under the project, the Geographic Information Network of Alaska (GINA has been working with the Alaska Department of Natural Resources to produce an accurate, current, and seamless statewide base map. The entities have already generated a number of high resolution images in which each digital pixel represents no more than 2.5 meters on the Earth's surface. The dataset comes from geometrically corrected aerial photographs called ortho-images.

RESOURCE MANAGEMENT, EMERGENCY PREPAREDNESS, AND DISASTER RECOVERY DEPEND ON

ACCURATE LOCATION INFORMATION. THE STATEWIDE DIGITAL MAPPING INITIATIVE IS A COLLABORATION BETWEEN UAF GINA AND THE ALASKA DEPARTMENT OF NATURAL RESOURCES THAT IS PRODUCING AN ACCURATE, CURRENT, AND STATEWIDE BASE MAP.

The collaborative effort represents a new way for government, university, and the private sector to team up on data licensing, and would not have been possible without help from the Nanook Innovation Corporation (NIC). NIC supports the university by licensing new technology and was selected as the entity to commercialize the data by DNR. Afterward, the non-profit contracted with the University and GeoNorth to make the data available.

NIC will work with GeoNorth, a geospatial solutions company, to get the maps into the hands of commercial users. This marks the first time Alaska's SDMI ortho-imagery will be available to commercial users, and NIC plans to give the majority of the revenue to UAF to build more maps for the state.

Alaskan Data Solutions Have an Opportunity to go Worldwide

Numerous best-selling books such as the "$100 Startup," "The Lean Startup," and "The 4 Hour Work-Week" glorify Silicon Valley startups who start with little investment and few employees, and grow into an international business.

Even though these stories seem like fairytales, they are quickly becoming the new dogma of entrepreneurs and innovators worldwide. In the past, companies needed a large workforce and regional offices to reach nationwide customers, but recent experiences and investments point to a new trend. Where Microsoft went from zero to $1 million in revenues in three years, Facebook, by comparison, went from zero to $150 million. Twitter was coded and launched within four months, and now it's a company with a valuation of more than $38 billion, according to the Wall Street Journal. Recently, thirteen staff at Instagram turned 551 days of effort into a $1 billion photo sharing business—a value of $77 million per employee.

These companies are proving the startup dogma, despite the fact that the cost of living in Silicon Valley isn't cheap (It's more than 25% higher than living in a place like Alaska).

So how do their entrepreneurs distribute worldwide and build such big companies with a limited skillset, a limited pool of labor, and limited funding?

They go digital.

Traditionally, companies needed to have a plethora of skilled personnel in the region, but e-commerce tools make farming out these activities efficient. Now, entrepreneurs are purchasing cheap, automated, and online services for their businesses. Companies can hire independent contractors by using Fiverr or ODesk. Startups can handle payroll or generate IRS forms using Justworks to keep proper books and send out tax notices to independent contractors - for free. Entrepreneurs can access large amounts of computing power and server space without having to invest in infrastructure or labor upfront. At one time, companies had to purchase servers and hire information technology managers in-house, but companies like Google, Amazon and Rackspace are now providing this same power on demand, and at a fraction of the cost.[23] Startups design websites using Shopify, they provide licensing terms through click-through agreements, and they collect online payment using Gumroad. They can setup software subscriptions through Saasy. Startups can eliminate the need for a warehouse for physical goods by using drop shipping through Shipwire.

Entire websites provide lists of tools that automate pieces and parts of a business. Steve Blank, author of the "Startup Owner's Manual" and thought leader behind the "lean startup" business

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[23] *Diamandis, Peter H and Steven Kotler. Bold. Simon and Schuster. 2015. Page 47.*

model has a multitude of tools listed as well as *a list of lists*. The website, "A Better Lemonade Stand" provides a list of tools as well.   Another website, Startup Stash, provides over 400 tools for startups. From these lists, entrepreneurs can learn how to automate manufacturing, sales, distribution, payroll, hiring, and even taxes.

In this new world, online services now provide the same capabilities as having the same expertise in-house. These tools are changing the way we do business because they allow entrepreneurs to focus on selling their core products instead of worrying about having to employ every type of skilled laborer at their company. Further, online tools allow an entrepreneur to produce in their corner of the world and reach a worldwide audience.

Data Analytics shares a common value chain That Can be Digitized

EXPERTS DEFINE THE PROBLEM TO BE SOLVED

The below steps are often times referred to as a “model.”[24]

Data Capture	Sensor Integration	Data Collection and Storage	Data Analysis	Data Delivery
We build or provide vehicles and systems for remote data collection.	We build and integrate new devices that can collect remote data.	We collect and store data.	We generate substantive and financial value from data.	We get information into the hands of users.
Aircraft, Unmanned Aircraft Watercraft Autonomous Underwater Vehicles Satellites Microsats Light Rockets Remote data collection systems	Electronics integration Embedded Systems Control systems Medical Assays and Kits	Signal processing software and hardware High Performance Computing infrastructure Large dataset storage	Scenarios Planning software Statistical analysis software, Machine Learning software Change Detection software Complex systems modeling software	Data streaming software Data Portals Visualization software

OUR SOLUTION REVEALS HOW TO CORRECT THE PROBLEM

[24] *In this overview we focus on technology for the purposes of time. We do not discuss the sociological or training aspects of decision analysis even though this is a major aspect of the initial creation of the technology.*

DIGITIZING THE SOLUTION

READY-TO-USE SOFTWARE TOOLS FOR ONLINE DECISION SUPPORT

Setting up a decision support tool online is difficult. A company could code their online system and website from scratch, and pay someone to maintain the underlying software, but this is extremely expensive especially for a new startup. Alternatively, a company could use online tools. A number of tools already exist that would make the creation of an online decision support tool easier than ever.

Tableau – This software allows a company to filter data, “drill down” or add entirely new data to your analysis. Tableau also allows users to collaborate on data analysis, process data, and rapidly visualize new data. Tableau Online is a hosted, SaaS version of Tableau Server. It makes business intelligence faster and easier than ever before without the upfront costs of buying or configuring servers.

Amazon eC2 - Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute capacity in the cloud. It is designed to make web-scale cloud computing easier for developers. Amazon EC2’s simple web service interface allows you to obtain and configure capacity with minimal friction. It provides you with complete control of your computing resources and lets you run on Amazon’s proven computing environment. Amazon EC2 reduces the time required to obtain and boot new server instances to minutes, allowing you to quickly scale capacity, both up and down, as your computing requirements change. Amazon EC2 changes the economics of computing by allowing you to pay only for capacity that you actually use. Amazon EC2 provides developers the tools to build failure resilient applications and isolate themselves from common failure scenarios.[25]

Pagely – allows hosting of a WordPress site on Amazon servers without hassle. This provides users with a stable location of their website that provides ‘one web address’ for the user, without the need for local server in the home location of the company.

Wordpress - WordPress is a free and open-source content management system (CMS) for building websites and blogs. The system is based on PHP and MySQL. Features include a plugin architecture and a template system. WordPress was used by more than 23.3% of the top 10 million websites as of January 2015.

Woocommerce - WooCommerce is the most popular WordPress eCommerce plugin. And it's available for free. Packed full of features, perfectly integrated into your self-hosted WordPress

[25] *http://aws.amazon.com/ec2/*

website. With WooCommerce, users can sell tangible goods like hardware or t-shirts, sell software subscriptions, or sell digital downloads.[26]

Amazon Simple Pay - Millions of Amazon customers can login and pay on your website with their stored account information on Amazon.com. Login and Pay with Amazon can help you add new customers, increase sales and turn casual browsers into buyers. It's fast, easy and trusted, where you can leverage the Amazon brand to grow your business. It has the capability to build in automatic payments. They offer subscription and recurring payment options to your customers, and then go beyond the transaction and start establishing long-term, ongoing payment relationships. There is an inline checkout system so customers won't leave your website to enter payment information. Therefore, one can maintain a consistent brand experience and help increase the likelihood of conversion by keeping more customers on your site.[27]

Amazon FPS - Amazon Flexible Payments Service™ (Amazon FPS) is the first payments service designed from the "ground up" for developers. This set of web service APIs differs from other Amazon Payments products such as Amazon Simple Pay and Checkout by Amazon because it allows the development of highly customized payment solutions for a variety of businesses. Amazon FPS is built on top of Amazon's reliable and scalable payments infrastructure, and it provides developers with a convenient way to charge the tens of millions of Amazon customers (with their permission, of course!). Amazon customers can pay using the same login credentials, shipping address, and payment information they already have on file with Amazon.

Wikis – A wiki is a website that allows collaborative editing of its content and structure by its users. Wiki for WordPress supports creating and editing Wikis by users who can edit posts in your blog. Users can edit the Wiki from the frontend as well as the Admin Dashboard.[28] With advanced functionality, companies could create an online knowledgebase with text, videos, and pictures of how to use a decision support system. Further a company could easily provide educational materials for students of all ages.

Product Retailers - The WooCommerce Product Retailers extension allows you to easily setup retailers or distributors for products in your store, including a URL to their website/product page, then assign them to individual products. Customers can then purchase the item directly on your store, or they can visit the retailer or distributor's website to purchase.

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[26] *https://www.youtube.com/watch?v=b9FnffQ2Gxo*
[27] *Amazon Simple Pay Website.*
[28] *https://wordpress.org/plugins/wordpress-wiki-plugin/. For extended functionality look at Wiki Pro.*

Steps for a supplier to sell a decision support solution online.		Online Software Solutions		Steps for a customer to buy a decision support solution.
A supplier has a solution to a particular problem.				A customer has a specific problem that he wants to solve.
The supplier deploys specialized **platforms** that capture data.				
Supplier uses specialized **sensors** and software to capture data.				
Supplier uses specialized software for **signal communication and data processing.**		http://aws.amazon.com/testdrive/cms/		
Supplier uses software for data analysis.		Tableau		
Supplier uses software for **data storage.**		Amazon EC2		
A supplier creates a website.	http://	Wordpress+ WooCommerce	http://	A customer goes to the website.
A supplier creates a system to allow multi-pass login.		Amazon FPS or Simple Pay		Customer creates a user name and password.
The supplier connects the data and software products from storage, and lists products for sale.		Wordpress+ WooCommerce		Customer uses website to browse for products, software, or data.
The supplier adds shopping cart functionality.		Amazon FPS or Simple Pay		Customer either subscribes to services or buys products via a shopping cart application.
Supplier sets up terms.				Customer agrees to terms and conditions.
Supplier sets up payment processing.		Amazon FPS or Simple Pay		Customer pays using automated payment processing software.
Supplier provides data visualization tools.		Tableau		Customer download or views data, uses software, or waits to receive hardware they purchased.
Supplier provides an online forum and e-learning tools for users to learn how to perform decision analysis and use software.		Wikis		Customer uses an online forum and e-learning tools to learn how to perform decision analysis and use software.
Supplier sets up marketplace for other companies to sell using supplier's marketplace. Supplier takes a cut of earnings.		Product Retailers		Customer can access and buy additional data.

The Impact

As America's only Arctic state, our research institutions, companies, and government are focused on the problems of living under Alaskan and Arctic circumstances. The federal government, state entities, and local industry dedicate a significant amount of financial resources to solving problems, such as:

- finding cheaper ways to generate energy and increase energy efficiency,
- overcoming the challenges of arctic engineering,
- effectively and cheaply transporting goods via waterways or roadways;
- discovering new opportunities for resource extraction (mapping, and surveying),
- assessing environmental impact of resource based industries
- communicating over large distances, and
- providing services over vast distances (education, remote healthcare, and management of employees).

To address these problems, Alaskans create software, hardware, and a variety of technologies. Commonly, these tools are known as data analytics or business intelligence tools. The tools help companies save money, do jobs more efficiently, and mitigate risk.

There are millions around the world that face the same problems as we do, and if we could automate the delivery of these solutions, then we could export them around the world and generate revenue. The problem is that these solutions are rarely turned into scalable products. Many Alaskans do not know how to package their solutions for an international market, and they do not know how to utilize digital software to automate the delivery of their products.

To replicate the success of other entrepreneur communities, Alaskans should focus on their core expertise, use a common set of software to automate their business processes, and create a platform for sharing knowledge among entrepreneurs.

A simple pilot project could demonstrate a digital software solution that

- Is accessible by anyone across the state;
- Is affordable;
- Is scalable;
- Is flexible to needs of each business, regardless if they sell data, software, services, or tangible devices;
- Is suitable to the technology that Alaskans produce;
- Makes it easy to deliver end products around the globe;
- Takes the guesswork out of starting a business for a technical entrepreneur in the area of data analytics.

Indigenous Knowledge: Key Considerations for Arctic Research and Data Management

By the participants of the Sharing Knowledge: Traditions, Technologies, and Taking Control of our Future Workshop[1]
held 22-24 September 2015, Boulder, Colorado
Organized by the Exchange for Local Observations and Knowledge of the Arctic (ELOKA)

Contact: Peter Pulsifer (pulsifer@nsidc.org)

Introduction

Indigenous Peoples are increasingly leading and contributing to science and research activities across the Arctic. Indigenous Knowledge is being documented in myriad ways in these activities and there is a need for this knowledge to be preserved, managed, and shared along side other data.

Indigenous Knowledge is not western scientific knowledge and we should not try to make it so. We must recognize and embrace the differences and avoid a singular dominance of "hard data" or "hard science" based solely on quantitative methods. We must be aware and careful of privileged perspectives in Arctic research and data management.

Working with Indigenous Knowledge requires understanding the context of the knowledge and the context of Indigenous Peoples in the Arctic. For example, Indigenous Peoples should not be viewed as a group of "stakeholders" in the Arctic. The Arctic is a homeland to Indigenous Peoples and there are critical issues related to the assertion of rights, sovereignty, security, de-colonization and self-determination. These contexts must be considered when working with Indigenous data.

This short statement summarizes some of the key points raised by participants at the *Sharing Knowledge: Traditions, Technologies, and Taking Control of our Future Workshop* held September 22-24th, 2015 in Boulder, Colorado. The points stem specifically from discussions around (i) Indigenous Knowledge and its documentation and use with information and communication technologies (ICTs) and (ii) Indigenous Knowledge as it relates to research and data management practices.

Indigenous Knowledge and Information and Communication Technologies (ICTs)

There have been tremendous changes and advancements in ICTs in recent years. These have had an impact on the documentation, preservation, and sharing of Indigenous Knowledge in a number of ways, positive and negative. For example, social media has linked many remote Arctic communities like never before, but what is shared, by whom, and how it is used is difficult to control. Social media gives our youth an opportunity to express themselves, share their voice, but it can also draw them in to endless hours on a computer screen. There is great interest in providing technology to youth (social media, gaming, etc.) to expand their horizons,

[1] See List of Participants at the end of the document.

but we must be careful this is not at the cost of human relationships, or learning knowledge from Elders, on the land, or person-to-person. We cannot depend or rely too much on technology as technology cannot replace knowledge or traditions, and we need to maintain our patience for the traditional ways of learning from Elders (not the instant gratification of the Internet). One cannot learn Indigenous Knowledge by pointing and clicking on the Internet – this must be stressed. It is only learned through relationships and learning with people who have learned it as it should be (e.g. on the land and water, through practice) and who have lived it. Knowledge is not from a book or from a webpage; it is from experience. We must be clear that people cannot become experts on Indigenous knowledge from reading or even multimedia. We must also caution that technology can create addictions and that the artifacts of technology (devices), cause stress on the environment, the need for mines for metals to make them work, mines that are having an impact on many Indigenous communities around the world. We need to take care to explore all the positive and negative aspects of ever-changing ICTs and balance these, especially when it comes to empowering our youth.

Language and Place

Language is more than a way of communicating, it is a way of thinking. Language is deeply connected to knowledge. When working with Indigenous Knowledge, we need to respect the language in which it was shared. We need technologies and data sharing mechanisms that maintain and promote Indigenous languages.

We borrow the following phrase from Keith Basso; “wisdom sits in places”. Fundamentally, the greatest insights from Indigenous Peoples are those that emerge out of landscapes, seascapes, and icescapes.

Space and place are central to Indigenous ways of knowing and identity and so mapping technologies are an important platform for representing Indigenous Knowledge. These tools provide an excellent opportunity to connect knowledge to place and to create content rich atlases that bring together maps, images, narrative and other multimedia. This technology can be used as a tool to re-connect youth to their heritage, and as a bridge to connect Indigenous and western science data and knowledge. As with any technology, it must be used in a mindful way, particularly when used to document sacred or other sensitive places.

We need to highlight that Indigenous Peoples and communities are very diverse in the Arctic. There are many similar ways of life and issues across the North, but there are important differences and contexts, too. For example, in Canada and Alaska, Indigenous Knowledge has gained increasing respect and leadership roles in research circles over the last decades. This is not as much the case in Greenland, and in places like Russia and Finland, where Indigenous Peoples struggle to gain rights, and in some places even experience violence. What is accessible or sensible for one community may not be the case for the next.

The Power of the Digital Age

While there are risks for Indigenous Knowledge in the digital age (we have touched on some of these), there can also be great power. For example, there is power in digitizing tapes of Elders’ stories, digitizing old photos, maps. This allows for the wide and easy sharing of language, of images, of knowledge. This supports the mobilization of knowledge and language as it can be moved or shared anywhere. An important note to interject here is that however we document or share Indigenous Knowledge, we must be careful not to pull out information in isolation or out of context. This is important for the responsible use of all kinds of knowledge in our digital age.

The digital age provides Indigenous People from around the Arctic and the world with an enhanced ability to communicate and share their observations and knowledge. Moreover, it provides them with a method to share experiences, ideas and questions about how to best share their knowledge within and between communities and with researchers, different levels of government, and the general public. These questions include how to maintain sovereignty and authority over the documentation and sharing process, how to best evaluate the ethics of a project, establishing and maintaining funding, and identifying appropriate means of publication.

The "Use" of Indigenous Knowledge and Technology

Sharing knowledge is an important part of Indigenous culture. When knowledge is shared the recipient accepts a responsibility to use the knowledge appropriately and wisely, including giving credit and acknowledgement. A person must have the experience and wisdom necessary to effectively understand and analyze Indigenous data or observations, information, or knowledge. This is also the case in Western science where a certain level in expertise is required to responsibly draw conclusions from data and knowledge. Indigenous knowledge systems do not separate data, from knowledge or wisdom. They are used in together as part of a holistic knowledge system.

Communities and Indigenous organizations are using technology in different ways. Inuit are faced with many decisions on how to share information and at different levels (community, local, national, international). For example, the Inuit Circumpolar Council-Alaska office uses a variety of methods for communication including social media tools like Facebook. Their "I am Inuit" Facebook page sends out regular posts highlighting Inuit throughout Alaska sharing aspects of their life. They also look to technology to communicate information and a consistent message about an issue, for example the nature and benefits of community-based monitoring through the Atlas of Community Based Monitoring and Indigenous Knowledge in a Changing Arctic (http://arcticcbm.org).

Indigenous youth are embracing technology and this has implications for identity. Technology allows them to connect with other youth in the community, in other Indigenous communities around the world, to access news and information about Indigenous issues. Youth who attended the workshop indicated that they have three identities: Indigenous identity, Identity within general society, and their digital identity (email and social media identity). Holding these identities simultaneously can be a challenge, but they need not be in conflict.

Indigenous Knowledge and Data Management

Indigenous Knowledge is geographically and culturally specific. Information systems design should reflect this through the establishment of distributed data management systems. We need to avoid aiming to establish a single, centralized system but rather focus on meeting the needs of individual communities, regions or cultural groups and on interoperability between systems.

Indigenous communities in the Arctic are the providers of information, users of information, monitors of information, and decision-makers. The uses of data technology are changing rapidly in these communities. We need to continue to work to put control of technology in local hands and invest in improving bandwidth, access to technologies, training, and capacity building.

Establishing protocols for proper consent related to data collection and use, and for data management for Indigenous knowledge is critically important and urgent. There is a need for research and data management planning to be driven by Indigenous Peoples, communities, families, and organizations. There is a need for infrastructure and resources so this can be realized.

Protocols are needed for documenting and using Indigenous Knowledge in a digital form, however, these must be reflexive and consider cultural, historical, and geographical contexts rather than focusing on technical aspects of standards. Adaptability is key.

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Scenarios of Arctic Climate and Land-use Change as a Unifying Framework for Integrating Long-term Monitoring with Interdisciplinary Research in a Focal Watershed

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Summary

Ecosystem responses to climate change are occurring in the Fish Creek Watershed at the same time that resource development is expanding, primarily oil exploration and extraction. Because this watershed is located entirely within the National Petroleum Reserve – Alaska (NPR-A), the Bureau of Land Management (BLM) has been monitoring and studying these changes in cooperation with a wide range of stakeholders. The protection of wildlife, habitat, and water resources are key concerns to all stakeholders here and they recognize that making scientifically sound decisions in the face of uncertain climate change responses is challenging. Breaking down this complexity in terms of observations, advanced modeling techniques and scenarios analysis provides an opportunity for scientists, managers, and other stakeholders to interactively bring their expertise and interests to bear on uncertainty and future decisions. An expanding monitoring network, the Fish Creek Watershed Observatory, coupled with an interdisciplinary science project, Fish CAFÉ, is providing a test case for scenarios analysis in a focal Arctic watershed ripe for decision support.

The Fish Creek Watershed Observatory

The Fish Creek Watershed (FCW, Figure 1) is of interest to multiple Arctic stakeholders because of its valuable natural resources and vulnerability to both climate and land-use change. Located in the National Petroleum Reserve-Alaska

(NPR-A) between Prudhoe Bay and Barrow, Alaska, this hydrologic unit drains a 4500 km^2 land area that is *de facto* wilderness of the Arctic Coastal Plain. Yet petroleum exploration in the winter has occurred here since the 1940's and the first oil development in the NPR-A began in the lower FCW last year and is expected to progress deeper into the watershed during the next decade. The Native Village of Nuiqsut is located outside of FCW's North Eastern corner, making this area important for traditional subsistence harvest and also increasing tundra travel by all-terrain vehicles.

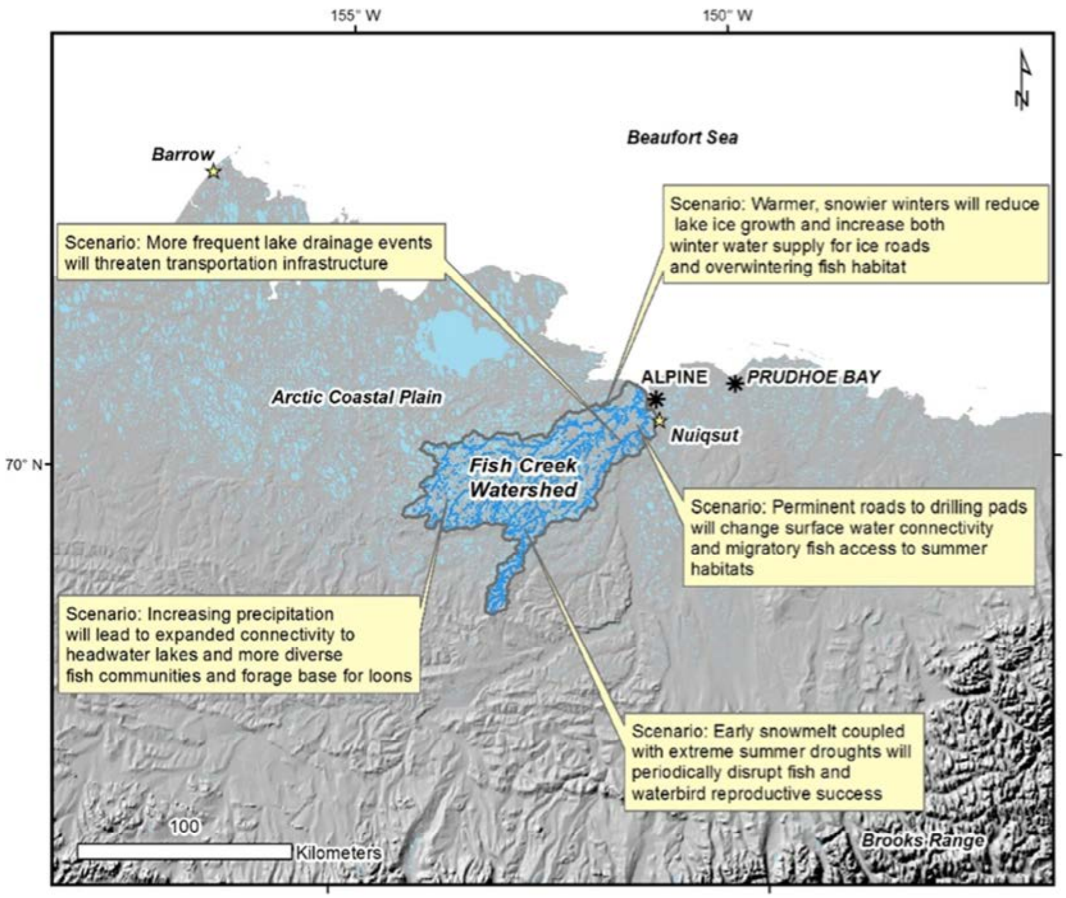

Figure 1. Location of the Fish Creek Watershed in northern Alaska, USA with example scenarios of climate and land-use change.

Accordingly, the BLM in cooperation with the UAF's Water and Environmental Research Center (WERC) initiated a stream and lake monitoring program in 2009 in catchments where petroleum development is being planned to collect baseline data [*Whitman et al., 2011*]. Data from this project is publically available (http://www.fishcreekwatershed.org/data.html) and has been used in scientific papers on Arctic hydrology [*Arp et al., 2012a*] and beaded stream habitat [*Arp et al., 2015a*]. Lakes are prevalent on the Alaskan North Slope and thus play a key role in regional hydrology. There is particular interest in lakes in the NPR-A beyond ecosystem services because they supply water for winter ice roads used for petroleum exploration. Since many Arctic lakes are shallow and ice grows thick (historically 2m or greater), seasonal ice commonly freezes to the lake bed (bedfast ice) by winter's end. Analysis shows a trend towards thinner ice that is causing more lakes to maintain floating ice regimes, which is potentially beneficial to winter water supply and overwintering fish habitat, but detrimental to sub-lake permafrost [*Arp et al., 2012b*]. Summer analysis of lakes in northern Alaska indicated that ice-out of bedfast ice lakes occurred on average 17 days earlier (22 June) than ice-out on adjacent floating ice lakes (9 July) [*Arp et al, 2015*]. This dynamic helps explain varying hydrologic response of Arctic lakes and downstream fluvial systems and their sensitivity to winter climatology.

FishCAFE project (http://www.fishcreekwatershed.org/fishcafe.html) funded by the Arctic Landscape Conservation Cooperative (Arctic LCC) links temporal aquatic habitat dynamics with spatial lake distributions and takes this several steps further by considering multiple habitat types and using models to make future predictions and explore various scenarios of environmental change. This type of approach that couples classification and mapping with process models provides managers and other stakeholders with a simple but comprehensive view of environmental change in time and space that can be applicable to both local and regional planning. Such a research framework will foster the Arctic LCC objective of providing reliable forecasts of future conditions under various climate and land use change scenarios, so that managers may incorporate these considerations into decision making processes.

Scenarios-based Interdisciplinary Science Supported by Long-term Datasets

Scenarios are hypotheses about what might take place and can provide guidance in the adaptive management process when stakeholders actively engage in scenarios development and analysis. In order understand impacts of climate change on thermokarst lakes, permafrost, and the regional ecosystems, meteorological downscaled products were created with a domain covering the central Arctic Coastal Plain (Fish Creek Watershed) and the surrounding Alaska North Slope region. Weather Research & Forecasting (WRF) model forced with ERA-Interim Reanalysis, NCEP/NCAR Reanalysis and the Community Earth System Model (CESM) model is used as a downscaling tool. The downscaled output consists of multiple climatic variables for 10 km grid spacing at three-hour intervals, covering so far 1950-2050 [Cai et al, in prep].

Our first experiments with WRF-downscaled output demonstrated the linkage between early winter ocean conditions (declining sea ice and late freeze-up) and late winter freshwater response along lake-rich Arctic lowlands. The projected future reduction in sea ice extent is expected to continue and accelerate a landscape-wide regime shift in shallow thermokarst lakes leading to sub-lake permafrost thaw and a range of habitat and biogeochemical responses [*Alexeev et al, 2016*]. WRF output is also used as a forcing for detailed permafrost/hydrology model WaSiM (http://www.wasim.ch/en/index.html). Using WaSiM, all aspects of the water cycle are simulated as well as heat processes in the subsurface. The analysis specifically addresses changes in surface water connectivity (lakes and streams) under past, present and future climate.

Discharge, snow depths, and meteorological variables have been measured since 2009. A LiDAR digital elevation model of 0.25 m horizontal resolution facilitates the representation of micro-topographic landscape features (i.e. ice wedge polygons). In addition, 1052 fish were captured and 781 fish were tagged using a half-duplex passive integrated transponder. The observations have not only allowed analysis of fish migration patterns [*Heim et al.*, 2014; *Heim et al.*, 2015], but is also be utilized as input to drive WaSiM model.

Hydrological and meteorological data collected at various FCW locations are available online: http://www.fishcreekwatershed.org/data.html. Meteorological downscaled fields are stored at the Arctic Region Supercomputing Center and the international Arctic Research Center's data server http://data.iarc.uaf.edu/. Project contributes to other data portals: Circum-Arctic Lakes Observation Network (CALON), Arctic Lake Ice Systems Science (ALISS, http://arcticlakeice.org/), also to ACADIS portal (https://www.aoncadis.org/home.html).

The analyses will ultimately provide regional stakeholders (e.g. Bureau of Land Management) with information on the hydrologic impacts of climate change within the National Petroleum Reserve Alaska to mitigate impacts on aquatic ecosystems as well as the local population. The experience gained in this study may also serve as a benchmark for future studies and developments in similar environments.

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