RE-THINKING THE ARCTIC OBSERVING SYSTEM FOR IMPROVED DATA INTEGRATION AND INFORMATION SHARING

Authors
Dr. L. Alessa; President's Professor, University of Idaho; Big Data Advanced Analytics.
alessa@uidaho.edu
Dr. William Ambrose; Department of Biology, Bates College. wambrose@bates.edu
Dr. Andrew Kliskey; Director, the Center for Resilient Communities, University of Idaho
akliskey@uidaho.edu.

Abstract
In order to support a business case for an Arctic Observing Network it is first important to understand: a) critical threats to Arctic security; b) capability gaps in current observing networks, and; c) the means to address these through innovative data analysis and fusion. This white paper presents: a) preliminary results from several community workshops; b) a tangible community-driven effort to address capability gaps, and; c) recommendations for operationalizing a more integrated arctic observing network for decision-support to a range of stakeholders.

Arctic Observing Networks for All Domain Awareness
All domain awareness (ADA) is the integration and application of knowledge from cyber, land, maritime, and space observing networks and systems. Achieving ADA in the Arctic is emerging as a critical task that encompass a range of security needs: from protecting the livelihoods and security of Arctic residents to ensuring the Arctic is not exploited as a seam by threat actors. Changes in environmental, geopolitical, and economic dynamics have led to an asymmetric environment. Currently we lack both a framework that we can use to accurately characterize the consequences of such changes and the means to fuse data-streams from any Arctic Observing Network (AON) for multiple scales of situational awareness. ADA must be achieved based on a more evolved, progressive, and diversified observing system that enables forward and central data fusion[1] so rapid and precise situational context can be achieved. This is critical for operations ranging from search and rescue to subsistence hunting to law enforcement to commercial ship traffic. A more diversified and integrated observing system will allow the establishment of the *context* of information developed, so as to enhance *preparedness, coordination, and deployment* of operations across Federal, State, Local, Tribal and Territorial partners (FSLTTP). This white paper presents the results of several community workshops regarding the current diversity of data and sensors for the Arctic and introduces an initiative, Neural Analytics for Understanding Threats and Change Assessment (NAUTICA, see below) to establish a proof of concept demonstrating the feasibility of enterprise-level integration across existing AON sensors.

Problem Statement
While much discussion has occurred regarding the development of a diverse AON there remain significant gaps in: a) a community-wide understanding of the range of applications of data, b) a systematic assessment of sensor and data feeds, and c) innovation in data fusion for decision-support across FSLTT partners. Recent advances in a range of technologies that support ADA through observing systems have enhanced

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[1] Forward fusion is the integration of *in situ* data in the locale of an incident or a suspected emergence. Data-streams must, by nature of the operational environment, be finished data that is bandwidth frugal. Central Fusion refers to data integration and intelligence that can accommodate a broad range of ingests including imagery and analytic models that can take advantage of larger bandwidth.

the available data to help inform operational decision-making. Despite the increase in data-streams their diversity remains fairly low and they frequently fail to provide contextual information that makes the raw data useful. As a result, advances in acquiring improved situational context, particularly at fine local scales, remain poorly developed. In other words, operators are starving for ***operationally relevant context*** and we consistently fail to forecast the evolution of change, particularly on timescales of hours to days which is the period in which most incident-response (such as during an oil-spill or search and rescue) occurs.

Current Observing Systems

Arctic observing assets are currently deployed from the sea-floor to space, ranging from fixed and mobile sensors dedicated to classified data-streams to open-source platforms (Figure 1). However, the spatiotemporal coverage of these sensors remains poor, they are disproportionally focused in tight proximity to population centers, they have wide border spaces with extremely sparse information, and funding and infrastructure will remain problematic. At the widest scale, space-based systems provide broad views of activities, but current capabilities have limited durations and low frequency. Supporting space-based platforms are aerial sensors, including random patrols and targeted flights necessitated by risk or threat indicators. At an even finer scale, local sensors provide dedicated data-streams, though they are also challenged by range and number. In the Arctic, there have traditionally been few satellites in polar orbit, flights face significant obstacles of distance and weather, and local sensors are primarily concentrated around populated areas – none provide context.

For the Arctic, an overall low diversity, fidelity, and infrequent revisit rates of sensors results in consistently poor local and situational context (Figure 2). This creates a vulnerability that renders all Arctic nations relatively uncoordinated across their collective Arctic endeavors. Without a re-configured AON and an enterprise-level data fusion framework we lack the means to achieve environmental intelligence in a way that supports forecasting trajectories for a range of operations.

Figure 1: *Nested observing framework for Arctic observing.*

Data Fusion from Current Observing Systems

Agile decision-support requires information fusion that extends and expands the existing work of several agencies who have created common operating pictures and/or data fusion capabilities. Increased capacity for information fusion creates an opportunity for improved information sharing, aiding cost effectiveness, and capability transition as opposed to creating distinctly new and 'siloed' systems. Arctic information fusion spans a wide range of topics that includes information systems in use today, methods for data fusion,

machine intelligence, and information visualization techniques. Information fusion can support decisions in everything from hunting routes by subsistence hunters to cruise ship passages to security missions by developing a suite of capabilities, supporting agile decision-support, leveraging data from the tactical edge, enabling use-case oriented course of action development, and informing decision management. More specifically, in addressing security concerns in Arctic spaces, decision-makers need intelligently fused and visualized data to support Arctic ADA for operators in both the field and in command centers. Accordingly, extracting key features from heterogeneous data sources and media types (e.g. machine sensors, human sensors, historical records, multispectral imagery, etc.) and presenting a fused, context-rich decision aid remains a significant challenge. As such, information fusion supports a platform upon which data of all types can be disseminated, processed, delivered, and visualized for others that may need high fidelity contextual information related to the Arctic domain.
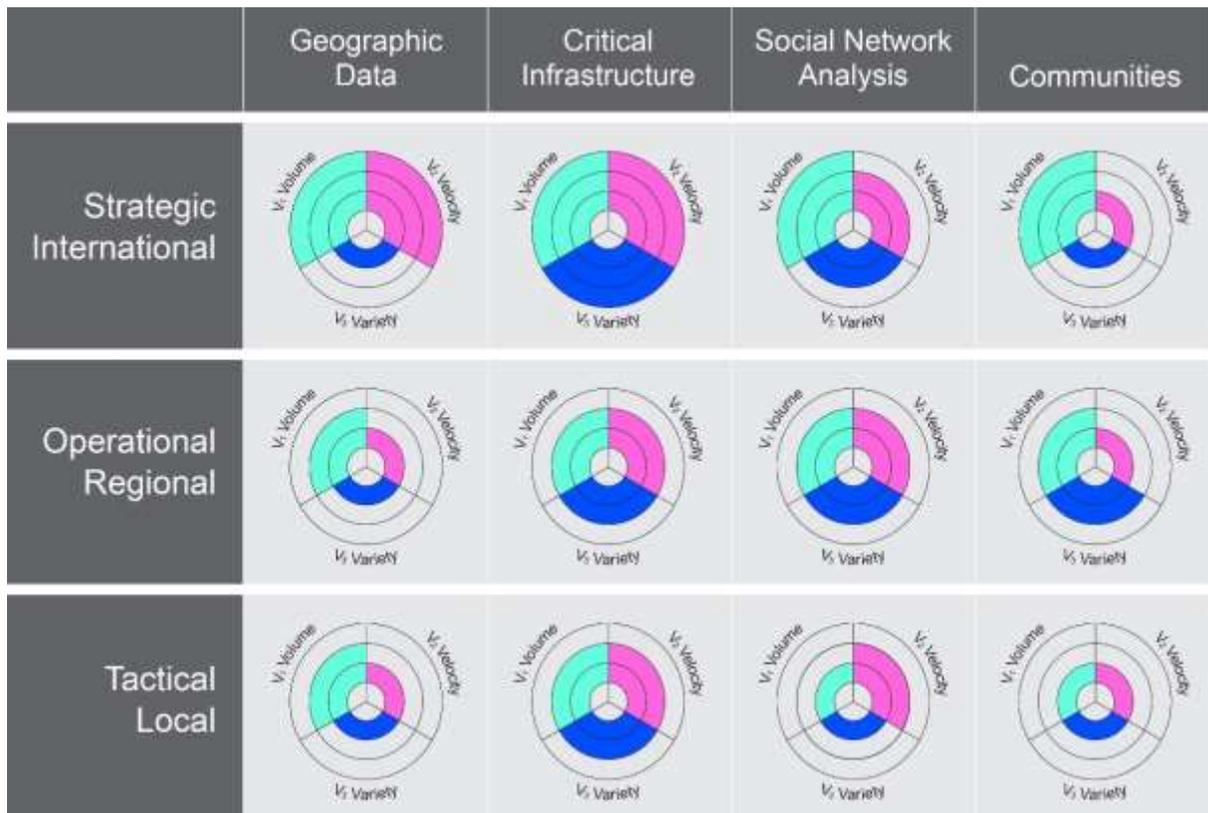

Figure 2: Data types and diversity as derived from 148 Data Experts during, and following an EyesNorth (CAPRRI) QED Workshop, November 2017. There is an over-emphasis on satellite systems which do not convey context.

To address these issues, the EyesNorth, a National Science Foundation supported Research Coordinating Network (RCN) held a quadrant-enabled Delphi workshop in February 2018 focused on Data Interoperability and Information Sharing. The workshop participants identified the ten most important challenges in data interoperability and information sharing (Table 1). Three top themes were identified: 1) lack of local, situational context for understanding data and/or analytical products by field operators; 2) lack of standardized workflows across the enterprise; and 3) lack of personnel capable of working within enterprise scale data for decision-support across FSLTT operations.

Table 1: *Top ten capability gaps/challenges in data interoperability and information sharing across combined sensors.*

Issue/Topic	Domain
1. Policy / Legal / Organizational Reticence to Share	Information Sharing
2. How Data/Info are fused: Too much manual vs. automated	Data Fusion
3. Wrong People/Position Performing Analysis	Data Analysis
4. Analysts subjectively holding data; Data available in cloud but not accessible	Data Discovery
5. Analysis Without a Clear Goal (or Question)	Data Analysis
6. Local Data Storage/Limited Access (Agency/Subnetworks): data stored within components versus enterprise-wide	Data Production
7. Co-production/Collaborative Production designed for CTOC as Opposed to Sharing Products	Data Production
8. Manual Extraction from Text/Data-Streams	Data Production
9. Lack of Understanding of Other Data Ecosystems	Data Analysis
10. Data Discoverability	Information Sharing

Initial Solutions Identified:

1. Bring situational context to data for field operations: diversify data feeds by incorporating systematic and standardized inputs from field.
2. Establish an Arctic Security Office with integrated/joint personnel trained in data production, discovery and fusion processes to advise bottom-up and top-down information sharing agreements and protocols.
3. Utilize genetic algorithm-class artificial intelligence to acquire knowledge of data ecosystem.
4. Minimize data pool silos by leveraging AI capabilities to create enterprise level data access.
5. For bulk data: enhance information sharing by creating a systematic set of protocols to protect data and PII.

EyesNorth Use-Case: Neural Analytics for Understanding Threat Indicators and Change Assessment (NAUTICA) in the Arctic Maritime Environment

Toward operationalizing the solutions outlined by the attendees of the Data Interoperability and Information Sharing workshop, we are conducting a best practice use-case to operationalize the solutions identified by the conference participants. This use-case proves the feasibility, and accessibility, of accomplishing central fusion (from a command center vantage, e.g., National Weather Service, United States Coast Guard and other public service agencies) and forward fusion for on-scene responders and local communities. This effort, NAUTICA, is currently underway through a FSLTT partnership that includes academia, federal

agencies such as the National Atmospheric and Oceanographic Administration, the National Maritime Intelligence-Integration Office, State, tribal and industry partners. NAUTICA has completed a phase 1 set of composite genetic algorithms to work with a range of Arctic data sources without physically moving the data themselves. In other words, this is a revolutionary way to create a data ecosystem from data pools that can remain in their own niches. NAUTICA ground-truth historic trends of key variables in North Pacific and Arctic Ocean resources and patterns so as to project future trajectories. This enables patterns that are currently invisible using conventional data analytic approaches to be revealed and establishes authoritative retrospective and anticipatory trends for key oceanic variables that affect ocean resources, impact ecosystem stability, and have implications for resource security and maritime operations. NAUTICA serves the following Objectives, as identified by the EyesNorth community:

Objective 1: Establish best practices for applying AI to create an enterprise level data ecosystem for Arctic Observing Networks.
Objective 2: Assess the gaps in the data ecosystem food web with an emphasis on providing local situational context through community based observing networks.
Objective 3: Use forensic analytics on big data sets to inform abductive, anticipatory, and alternative futures analytics to model plausible scenarios that enable decision-support across a range of critical societal and operational challenges, specifically food security (as a consequence of marine ecosystem stability) and maritime operations related to economic and security resilience.

Conclusion and Recommendations:
The EyesNorth RCN has, to date, focused on the task of bringing a diverse community of Arctic scientists, practitioners and policy makers to re-examine our current AON systems such that they are capable of detecting environmental and security changes for the purpose of rapid and effective data fusion and information sharing.

We offer three core recommendations representing the inputs of several hundred attendees from across our EyesNorth FSLTT partners:

1. Develop more progressive mechanisms to foster information sharing among the Arctic nations to expand regional ADA into that which covers the circumpolar North. This ADA must be focused not only on the production of academic knowledge but also in support of operators and policy makers. A re-structured and more integrated AON will require that the human capital involved is properly trained to understand not only the production of data but also the way it is integrated, fused, and made available for decision-support at both central and forward fusion levels.

2. Utilize enterprise level data fusion capabilities that enable machine learning to work from a data ecosystem instead of 'siloed' data pools. This will allow us to not only *anticipate and prepare* for emerging threats (rather than merely respond to incidents as they occur) but also coordinate for better, and more successful, responses on the ground.

3. Everyone, from the federal government to local communities, needs to begin viewing data as a national asset. *Data must be made available to the entire enterprise without compromising security and personal identifier protocols.*