Final Version for Review

Community Based Observing Networks (CBONs) for Arctic Adaptation and Security

Lilian Alessa, Andrew Kliskey, Mark Myers and Pips Veazey, University of Alaska;
Steven Gray and Noelani Puniwai, University of Hawaii;
Elizabeth Shanahan, Montana State;
Kelsey Jencso, University of Montana;
Ed Galindo, Jim Gosz, John Anderson and Alistair Smith University of Idaho

---

Preamble

In a companion White Paper (Noor Johnson et al. 2013) some fundamental concepts are presented which are summarized as follows:

1. CBONs often rely on the inclusion of 'traditional knowledge' (TK) and there is a need to advocate for the utility of TK in arctic observing networks as well as the means to integrate TK with western science.
2. CBONs in the arctic region allow systematic data gathering to augment spotty spatiotemperal coverage from existing instrumented networks.
3. Community engagement in CBONs ranges in intensity, from limited to more robust contact between researchers and community members.
4. CBONs employ both quantitative and qualitative data collection and analysis methods depending on the specific phenomena being observed. This may include the use of technologies such as global positioning systems.
5. Various data management protocols have been established and are based on data sensitivities and protections (e.g., OCAP Principles – Ownership, Control, Access and Possession).
6. Data sharing must be sensitive to the communities' desires to release different types of information while balancing the need to disseminate knowledge that can benefit the overall arctic observing effort.
7. Longer term sustainability of CBONs, once established, depend on a community's motivation and alternative sources of funding to support the effort.

The White Paper concludes that CBONs have the potential to capture the knowledge of residents in situ and are only successful when partnerships are established between communities and academic/government scientists for the purpose of knowledge co-production. To advance CBONs, support is needed for the development of new tools for, e.g., data management.

In this White Paper, we address some intellectual merit and technical aspects of the role of CBONs in a) meeting the need to diversify the practitioner base focused on monitoring environmental change in general, b) advancing the need to embrace the social-ecological systems (SES) paradigm since it reflects that human interactions with local ecosystems over time result in cultural and environmental changes at varied spatial scales, c) developing decision support both for local communities as well as regional management entities through adaptive capacity indices and risk assessment such as Community Based Early Warning Systems (CBEWs) and d) validating existing best practices to establish and utilize CBONs for refining monitoring activities and resource management across the arctic and beyond.

Introduction

Growing global interest in the Arctic focused around natural resource extraction for oil, gas and minerals has led to an increase in multiple activities ranging from increased exploration to shipping to political actions jockeying for control of specific geographical areas. Rapid environmental change and globalization within and beyond the Arctic are hallmarks of our time. While it is clear that environments have always changed, communities throughout the arctic express growing concern because of their reliance on subsistence of primary resources (flora, fauna and water) for their survival which are juxtaposed against increased industrial activities. Current monitoring networks provide critical data on environmental change and allow scientists to better understand change trajectories and, ideally, forecast outcomes based on biophysical variables. However, these networks do not have sufficient spatial and temporal coverage to best reflect environmental changes occurring, particularly at more local scales nor do can they put them in the context of societal implications. CBONs address this limitation by enabling knowledgeable community members, also referred to as High Exposure Observers (HEOs) to share their current observations of local environmental conditions and place them in a historical context, resulting in a unique and much needed type of data. This is especially critical since the current SES baseline that constitutes Arctic communities is poorly characterized and the consequences of different types of change are relatively unknown, greatly limiting the ability of communities, industry, and agencies to develop desired, equitable, and sustainable development, mitigation and response plans. CBONs, as a network of human sensors, better allow the Arctic to be observed as an SES since they simultaneously acquire data at local scales in their societal contexts. That is:

a) what changes are occurring
b) why these changes are of concern to a community
c) what types of response is the community planning and/or initiating
d) what are the consequences to/trade-offs for different outcomes of change

Such types of observations are critical to not only advancing knowledge of a changing arctic SES but also enable communities to become more resilient in place through effective adaptation and response strategies using the idea of “security”, which reflects the spectrum of tradeoffs and their consequences (Alessa et al., 2008). We propose that CBONs should be used as a novel approach to environmental security, following the UN Millennium Project (United Nations 2009), which adopts a focus that is broadened beyond security concerns in the traditional sense, to include both short-term impacts and longer-term outcomes such as food security and overall community well-being (United Nations, 2009). Environmental security is used as an integrating concept, because it offers a more powerful and inclusive perspective for identifying vulnerabilities, planning adaptive responses, and evaluating outcomes, than do ecological sustainability, conservation, or health (individually). Presently, policy makers urgently need technical information that can guide responsible Arctic policies given the political will to open shipping routes and enhance development in the North. Locally- and regionally-scaled vulnerability assessments and adaptation plans remain constrained by a lack of high-quality, locally relevant baseline data about assets such as biota, water and infrastructure, and by a lack of decision-support tools that integrate with the best available sociological and climatic data and projections.

Embracing the SES Paradigm: Human Sensor Networks

In general, detection and monitoring systems share several features in that they operate by acquiring, organizing and storing data to determine patterns for the purpose of mounting appropriate responses (Balasubramaniyan et al 1997). Using concepts borrowed from immunology, we articulate CBONs as a distributed array of human sensors in communities throughout the arctic who are able to observe their environments on a regular basis (Figure 1). In this capacity, they are capable of detecting events that indicate that the system is operating unusually (Dasgupta and Attoch-Okine 1997). Humans inhabiting northern regions for millennia have developed an exceptional understanding of the environment needed for their survival (Usher 2000, Kliskey et al 2009). The collective memory of humans in the Arctic holds information about past environmental variability that extends beyond the knowledge acquired by science in recent decades. This knowledge makes Arctic residents, and especially indigenous peoples, capable of observing changes with a level of precision that no other sensors can replicate. Moreover, sub populations of Arctic residents, in particular those who have had extensive land-schooling (e.g., elders, hunters) often retain long memories of environmental variability and change (Alessa et al 2007). We propose that such individuals are analogous to memory cells in the immune system. Humans, as sensors, are a valid independent source of information that, when appropriate methods of data collection are used, are capable of providing insight to the questions of Arctic system change, including questions that deal with seasonality.

SES reflect the ability to acquire, distribute, and sustain the acquisition of resources over long periods of time, through tradeoffs that maintain a functional balance between social and ecological well-being. A key reason to adopt an SES perspective is to enhance *Adaptive capacity* which we define as the ability of institutions, systems, and individuals to maintain and control this balance under changing environmental conditions such that they are *resilient*. Communities which lose functionality in both social and ecological systems are referred to as *vulnerable* and said to have poor adaptive capacity, and may trend toward collapse or, more likely, experience deterioration in quality of life and overall function. A key priority across resource management agencies is to better understand sources of vulnerability and ways for communities to become more resilient through effective adaptation strategies. As communities, organizations and governments attempt to anticipate future Arctic system states the modeling of coupled human-natural processes on all scales will increasingly be an important element not only in resource management but also in national security.

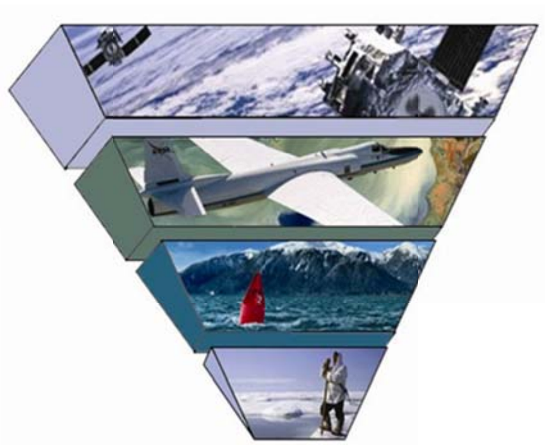

Figure 1. Human sensors via Community-based Observation Networks as a fine-scale contribution to broader scale instrumentation networks in the Arctic.

Through a combination of data mining, local and regional partnerships and the development of an integrated Community Based Observing Network (CBON) we propose that more efficient, inclusive and precise decision-support tools can be develop and applied, from local to pan-arctic scales.

<u>What is a CBON?</u>

A common misconception among scientists is that CBONs are equivalent to Citizen Science (CS), this is reinforced. CBONs differ significantly from CS in several key ways:

a) They are networks of human sensors with particular skills and exposure to land- and waterscapes who are able to make systematic observations with high precision and fidelity.

b) The data are collected with consideration of other instrumented networks, and structured to augment the latter's spatiotemporal coverage (see Figure 1).
c) CBON networks are developed as a partnership between academic/government and community practitioners where the variables of concern are collectively determined in the context of a specific purpose (e.g., developing an Adaptive Capacity Index).
d) CBON networks themselves are adaptive and can modify the format or types of observations if necessary.
e) Observations occur in the context of other variables, reflecting the interconnectivity of biophysical and socioeconomic/political processes, reflective of an SES.
f) Knowledge is generated and shared in an on-going manner, including the education of both types of practitioners in multiple worldviews and approaches to scholarship.
g) The community is a partner in the process of science, rather than a contractee to carry out specific observations for flora and/or fauna counts.
h) CBONs engage a segment of society that is largely missing from Citizen Science efforts whose demographics tend toward upper middle class individuals of Caucasian descent.

Another misconception surround CBONs, particularly in the North is that they primarily engage "Traditional Knowledge" (TK) which in and of itself is a term that inaccurately reflects the processes of locally-based observation, interpretation and application of findings through what we term Indigenous and Place Based Science. Indigenous science represents the cumulative place-based observations of natural phenomena that includes humans and non-human others, and fully integrates and acknowledges humans as part of the natural world and its processes (Alessa et al. 2012). It also recognizes, develops, and applies appropriate technologies, while accepting their limits, to sustain resilient landscapes. Characteristics of Indigenous science include: spatially localized and place-based; spans immediate short-term periods to extended and ancient long-term periods, and; systematic and integrative understanding of natural and human processes.

Using CBONs to Develop Arctic Adaptive Capacity Indices

Increasingly, subsistence-based communities around the world are seeking tangible and systematic approaches to guide adaptation through ***Adaptive Capacity Indices (ACIs),*** which require a key set of observations that determine the delta between 'acceptable' and 'undesired' change (Figure 2).

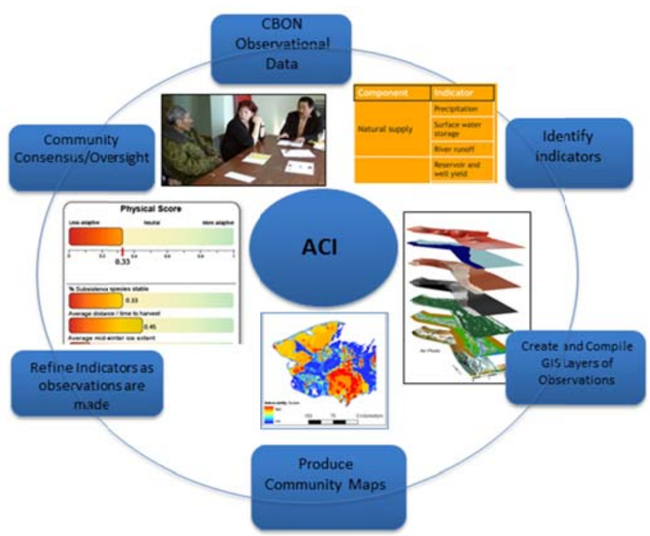

Figure 2. The process for developing Adaptive Capacity Indices through Community based Observation Networks.

The arctic region is recognized by numerous assessment reports (e.g., Arctic Climate Impact Assessment, and reports of the Circumpolar Biodiversity Monitoring Program of the Arctic Council) as a broad region of biological productivity as well as a potentially rich source of fossil fuels and mineral resources (Kopec 2008). More recently, it is also identified as a focal point for growing geopolitical interests (Huettmann 2012, Treadwell 2013) and industrial development (Kumpula et al. 2011, Treadwell 2013). Changes in the Bering and Chukchi Seas as well as land-based development contributing to river-borne transfers into the shallow Arctic basin can have direct impacts on biota, resulting in disturbances for subsistence dependent communities and commercial fisheries (e.g., Grebmeier et al. 2006). Impacts from changes in the physical environment can flow through the lower trophic levels thereby influencing upper trophic level species, where both indirect (bottom-up) and direct impacts (changing habitat) can occur (Hunt et al 2002). In addition, communities increasingly rely on infrastructure and technologies which use fossil fuels, hinging the dynamics of many subsistence activities on their availability and costs (Poppel 2008). We currently have few data and little understanding on how these components are changing and what the collective, cumulative and interactive consequences are (Kumpula et al 2011).

Example: A Prototype Adaptive Capacity Index for the Bering Sea Region

A key question within arctic observing networks is whether it is possible to identify the characteristics of communities that influence their propensity or ability to adapt (or their priorities for adaptation measures). The IPCC (2008) identifies eight broad classes of determinants of adaptive capacity, namely (i) available technological options, (ii) resources, (iii) the structure of critical institution and decision-making authorities, (iv) the stock of human capital, (v) the stock of social capital including the definition of property rights, (vi) the system's access to risk-spreading processes, (vii) information management and the credibility of information supplied by decision-makers, and (viii) the public's perceptions of risks and exposure. These metrics have rarely been evaluated or quantified and we propose to advance our understanding of this while providing real decision-support tools to the communities in the region. To date, we have found that (i), (ii), (iv), (v) and (viii) appear to be critical in the Bering Sea region. However, we have also found that four additional indicators are needed: level of protection for key subsistence harvest areas, willingness to substitute one resource for another, intactness of traditional knowledge regarding land and seascapes, and ability to preserve key cultural elements while viewing globalization as an opportunity (Figure 3).

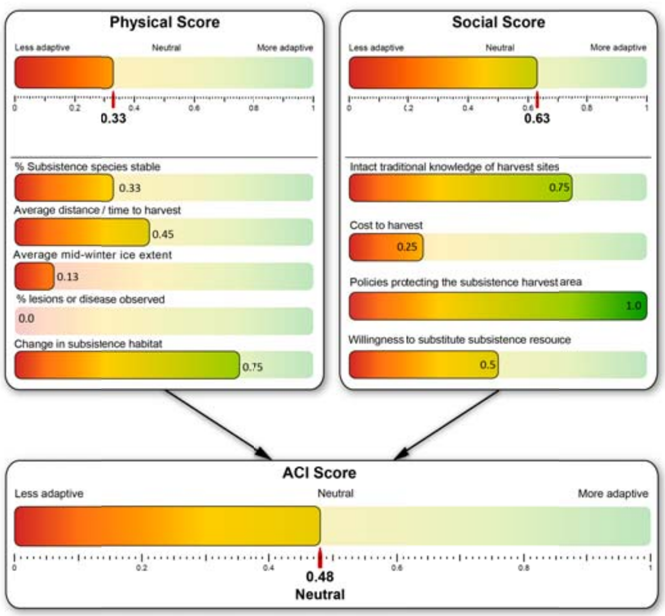

Figure 3. A prototype ACI for an arctic community in Alaska.

CBONs: Applications Toward Community Based Early Warning Systems (CBEWS)

A community based early warning system (CBEWS) is one that is developed, managed and maintained by the community itself. It is based on a "people-centered" approach that empowers individuals and communities threatened by rapid and/or undesired changes to act in sufficient time and in an appropriate manner to reduce the possibility of personal harm, loss of well-being, damage to valued ecosystems, and loss of livelihood. It provides communities, practitioners and organizations involved in resource management with advance information of risks that can be readily translated into prevention, preparedness and response actions. CBEWS helps to reduce economic losses by allowing people to better protect their assets, livelihoods and ways of life. In this process the goals, desires and definitions of the people/ community will be in the center.

The role of supporting organizations, including governmental, will be to facilitate active and meaningful participation of all community members. Ultimately the EWS will be owned by the community for them to use to capitalize on opportunities and avoid or mitigate adverse events. The term ‘early warning’ is used in many fields to describe the provision of information on any given emerging undesired circumstance where that information can enable action in advance to reduce acute risks later on. Early warning systems exist for natural geophysical and biological hazards, complex socio-political emergencies, industrial hazards, personal health risks and many other related hazards but few exist that are driven by indigenous communities for the purpose of optimizing their resilience.

The significance of an effective early warning system lies in the recognition of its benefits by the members of the community itself: the community MUST accept responsibility for their own futures. In the United Nations International Strategy for Disaster Reduction (UNISDR) terminology the early warning system is the set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by hazards to take necessary preparedness measures and act appropriately in sufficient time to reduce the possibility of harms or losses. This definition encompasses the range of factors necessary to achieve timely warnings for effective response. A people-centered early warning system necessarily comprises four key elements: I) knowledge of the risks; II) monitoring, analysis and forecasting of the hazards; III) communication or dissemination of alerts and warnings; and IV) local capacities to respond to the warnings received. The expression "end-to-end warning system” emphasizes that early warning systems need to span all steps from detection of critical changes to community response.

Reliable early warning systems developed globally have been instrumental in saving lives and protecting assets and livelihoods. However, they have not yet been developed in the arctic for the purpose of anticipating changes that require adaptation through targeted responses. CBONs allow environmental change data to become more accessible in a timely manner to individuals and communities at risk thus enabling them to take appropriate action. The linkages to instrumented monitoring networks must be established effectively to better integrate instrumented data with local observations if an arctic CBEW is to be developed.

In order to effectively understand and manage the arctic SES as well as respond to its on-going, rapid changes, there must be knowledge and understanding of locally, and sometimes uniquely nuanced, characteristics. This understanding is best gained through partnerships with indigenous, place-based observers. Through CBONs, communities are better equipped to devise their own ways to manage undesired change and reduce their own exposure and vulnerability. CBONs also heighten the awareness of community members of their own risks, vulnerabilities and capacities and further enabling them to articulate specific needs such as access to services and basic infrastructure, (e.g., health and education); meet their everyday basic needs on food, water, sanitation and shelter; practice safe and diverse sources of livelihood; have adequate coping strategies in times of stress; and gain overall security, free from conflict and fear. Ultimately, in order to develop an arctic CBEWS carefully structured partnerships with resident communities must occur, engaging also governmental and private entities which may contribute to driving the change (e.g., shipping companies) as well as responding (e.g., Coast Guard). This requires the following (also see Best Practices, below):

1. Systematic protocols for data collection, sorting, analysis, archiving and access (sharing);
2. A spatial platform capable of integrating CBON data with data from other instrumented networks in as close to real-time as possible, even if this is ‘seasonal time’;
3. The recognition that Community Coordinators are fully part of the Science Team in all CBON-associated efforts and require on-going education and reimbursement;

4. A clear understanding of all entities engaged in an area, their efforts and the collective information they contribute to the overall understanding of a given arctic SES.

Best Practices for CBONs

Best practices to structure and apply CBONs within the context of SES and environmental security within the arctic are currently in their early stages. A key challenge is developing methods to integrate CBON observations with instrumented data to build more robust strategies to respond to rapid environmental and geopolitical changes. However, we have sufficient early insights to propose approaches which ultimately will need to refined and modified to accommodate specific locales and cultures with the intention of ensuring the transferability of CBONs developed in the arctic to other parts of the nation and world.

Community Coordinators

Critical to a successful CBON are community coordinators – respected, longtime members of a community who themselves have had a high level of exposure to the conditions of change being observed. Community coordinators collaborate with researchers to select suitable observers for the CBON, to provide training for CBON observers, and to liaise with observers including assisting with the documentation and interpretation of observations.

Precision and Calibration of a CBON

One challenge faced when utilizing human observations in conjunction with biophysical data is the problem of recall accuracy (Shiffman et al 1997). In other words, humans often have highly subjectively filtered recall of events, particularly those outside the extremes, which makes retrospective observations potentially inaccurate. Thus, a valid concern in the application of human sensor arrays is the extent to which local observations from human observers match measured change. Recent studies of human -hydrological systems in Alaska highlight the close coincidence between measured perceptions of change in precipitation and temperature and long-term weather station data (Alessa et al 2008). Our data indicate that the periods of time during the last 80 years that community observers in an existing CBON noted as periods of considerable environmental change coincide with periods of warming in the temperature record for the Arctic. This continues to represent a calibration of an existing CBON sensor array (The Bering Sea Sub Network; NSF award #856305).

Utilizing emerging communication tools is essential but relying on hand-held technologies is not always desired

Despite the distances between the scientists and member communities, extensive communications are usually possible due to the use of communication tools, such as Skype, to supplement scheduled teleconferences. These tools allow real time audio and visual interactions on a daily basis and enable a distributed, coordinated network to function smoothly and acquire systematic data, reliably. Communities may not always desire to utilize hand-held technologies citing risks associated with loss/damage of equipment, interruption of data collection and an unfamiliarity with their role in their accustomed data acquisition methods, among other factors (Borgstrom et al. 2005). In many cases communities have expressed concerns with interrupting person-to-person dialogue and interactions which they state is a highly desired outcome of the CBON since it promotes information exchange between elders and younger generations, something that is rapidly being displaced by hand-held and other technologies.

Face to Face Meetings for Community Coordinators are Essential

Periodic in-person meetings are highly valued by communities. The development of a Manual for Community Coordinators (The Bering Sea Sub Network; NSF award #856305) has significantly improved both efficiency and precision but in-person workshops ensure that it is up to date and sensitive to nuances that cannot otherwise be captured remotely.

It is possible to reduce 'filtering' by respondents

One of the significant benefits of utilizing a standardized survey design is the reduction of "filtering" by respondents. This can be achieved by focusing on actual events and individual life experiences while extracting information on various physical and natural phenomena. Special attention must be paid to avoiding "driving" respondents to any "well-known" facts or media-publicized conclusions which are widely distributed particularly in the U.S. This approach has increased objectivity as respondents make observations, "viewing the environment without emotion". Of equal importance is the improvement of data accuracy as questionnaire entries are entered in their original languages, as desired by communities.

Data protections are necessary but communities are willing to participate in data sharing particularly when the implications to policy-making are high.

This is evidenced by a willingness to share sensitive data regardless of laws governing them. In addition, communities are often willing to share information that can help establish policies regarding their mobility and access to traditional harvest locales.

Data Collection, Management, Integration and Sharing

Surveys

Systematic data collection using structured and semi-structured surveys administered through the Community Coordinators (CC) serves several functions: a) As mentioned above it sustains the transmission of oral histories and knowledge between members of a community, helping to stem the current deterioration of these skills, b) Builds trust within the community to freely exchange and deliver information through the CC while allowing internal discussions as to their limitations and contexts for use and application more broadly and c) maintains quality assurance for data streams. Surveys can be administered at any frequency desired by the community but this temporal regularity, or vice versa, needs to be carefully monitored so as to carefully structure data integration with other instrumented networks. In addition to survey instruments, discourse through interviews and open ended narratives provide a range of: 1) community views of the relevant changes, including how the change affects either the livelihood of the observer and the community in general, the profile of change over time, and how community members respond both individually and collectively; 2) biophysical changes and indicators associated with the anticipation of specific outcomes as a consequence; 3) historic and current use of local knowledge in understanding, preparing for and responding to change; and 4) historic and current utility and use of sensor data by the individual and community. These approaches, when combined with interactive mapping tools that enable participants to represent observations spatially, allow the construction of an integrated spatial database that includes other monitoring networks ranging from remote sensing to buoy data.

Interviews are often recorded (whenever permissible), and transcribed verbatim by data analysts, students and/or researchers. Qualitative analysis software such as NVivo 10 may be used as an organizing system, and enables researchers to derive basic relationships from narratives. More sophisticated analysis of observations should utilize structured tools such as the Architecture for Integrated Data Analysis (AIDA), which is an open-source software package and allows both content, relationship and network analysis to be made of recorded observations over time *(also see Data Mining, below*).

In addition to qualitative survey tools and interactions, quantitative surveys administered regularly over the course of a year allow researchers to track changes within specific seasons.

Quantitative surveys are constructed and vetted as a collaborative process between academic/government and community scholars. Surveys and interviews are managed and administered by the CC with assistance from other researchers on the CBON team and can either be paper-based or iPad-based, depending on the preference of the community or observer.

Data Mining Augments In-Situ Observations

Arctic CBONs are based on partnerships with resident communities equals in the process of science and it is a given that the overall approach is based on scientific rigor, inclusiveness, collaboration, collective problem solving, and the incorporation of multiple worldviews. The use of surveys and narratives are central to operating CBONs but we have found that data mining such as AIDA (Altaweel et al. 2010) greatly enhances the range and quality of information regarding environmental changes and their contexts. We propose that data mining is increasingly necessary to Arctic Observing Network (AON) monitoring efforts due to the range of information necessary for more accurate understanding of the complex arctic SES and realistically cannot be fully obtained through traditional social-science methods. Data mining tools are able to sort qualitative social data (such as interviews, narratives and media communications) using algorithms which quantify term rates, semantic patterns and other spoken information so that qualitative speech becomes quantitative data. This process minimizes translational errors and enhances the integration with numerical, instrument-derived data. A data mining tool such as AIDA can, for instance, determine perceptions of landscape changes, based on how respondents' qualitative descriptions vary over time. (Altaweel et al., 2010).

Cognitive Mapping

Another option to enhance CBON data is that willing CBON team members may also engage in a cognitive mapping exercise using software tools such as Mental Modeler (Gray et al. 2012). This allows community participants to build fuzzy-logic cognitive maps that display their perceptions of environmental cues, hazards, anticipated impacts of changes, and the structural relationships between these variables. This allows community leaders to better build an understanding of adaptive responses and the importance of specific change events and impacts, and can enhance knowledge systems held by individuals and communities across CBONs as well as allow them to be standardized, compared, and integrated qualitatively and quantitatively.

Data from both CBONs and other non-human instruments require integration into a centralized data store. However, several steps regarding standardized data treatments (e.g., coding and analysis) as well as data protections must occur before a coordinated spatial database can be constructed.

Coordinated Geo-Database

One tool for integrating CBON observations, and for subsequent sharing of this information, is through its compilation in a geo-database. Geographic information systems (GIS) provide a platform for organizing observations based on location, including well understood landscape features. The aggregation of many observers' knowledge can provide a mosaic of information across a landscape infilling the sometimes limited geographic distribution of instrumentation networks. A geo-database also provides a platform for bringing together CBON observations with instrumentation networks providing an integrated, and potentially rich, approach to observations of change.

Moving Beyond Community Engagement: Partnerships in the Process of Science

Diversifying the Practitioner Base in Environmental Monitoring

To date much of arctic science has been conducted by practitioners who have relatively little year round exposure as well as an external, and often Eurocentric, perspective on non-Western cultures. In most cases western practitioners have engaged local, place-based indigenous peoples in their research and outreach. We propose that CBONs are a means to move beyond 'community engagement' and start developing partnerships where communities are equally engaged in the process of science itself. By doing this knowledge is exchanged in both directions.

Minimizing the Dichotomy between Western and Indigenous/Place-Based Science

At the heart of CBONs is a goal of increasing individual and community involvement in science by empowering arctic residents to become partners in improving knowledge about environmental change. The CBON process has the potential to appreciably improve communities' capacity to engage with data from multiple sources, and to act on that information to improve hazard prediction and response. By examining different changes in disparate environments and communities, CBONs can yield information with application to varied scenarios at different spatial and temporal scales. The information and data generated from a combined CBON-instrumented networks platform can better inform and assist planners, managers, and policymakers to make more timely and appropriate decisions regarding arctic resource management and development. CBONs can also inform and ensure better placement and methodologies for non-human monitoring networks.

CBONs link Western science with Indigenous science through education of both types of practitioners in methods and approaches inherent in each tradition. We believe this will minimize the dichotomy between the two and harness the strength of more diverse approaches to understanding the arctic SES. CBONs also improve information flows among residents, community leaders, scientists, and policymakers. CBON membership can have psychological advantages for local residents, particularly those in rural areas with minimal infrastructure, who have reported that CBON membership has made them feel "re-connected to a greater community that we once belonged to" by linking communities together and allowing them to share similar experiences, responses and lessons learned. CBONs also strengthen the transfer of deep and long-term knowledge between generations of community members, helping to counteract the ongoing erosion of this human resource and process (Alessa et al. 2008, Bone et al. 2011). Ultimately, CBONs create a culture where participants, regardless of their backgrounds, must cooperate, collaborate, and exchange information critical to understanding environmental change and planning adaptation strategies.

We need to better understand how CBON development, implementation, and participation have changed the way participants view the hazard, engage with science, and use different types of data in formulating hazard responses. These interviews will also assess the utility of the integrated CBON and sensor data, how this integrated data stream could be shared most effectively, and opportunities and barriers associated with using integrated data in decisions about hazards.

Sustainability of CBONs

CBONs can be sustainable over long periods of time as it is changing the 'observation culture' in participating communities, reviving interest in elders' knowledge in some, encouraging residents to be more alert to changes in others, and teaching a systematic approach as an effective way to translate their observations into scientific and policy relevant results – augmenting the conclusions of the Johnson et al. (2013) companion White Paper.

Conclusions: Key Issues to be Addressed

We need to better understand how CBON development, implementation, and participation have changed the way participants view their abilities to respond to change, engage with science, and use different types of data in formulating adaptive responses. There is also a need to assess the utility of the integrated CBON and sensor data, specifically how this integrated data stream enhances our ability to anticipate the consequences of change and it can be shared most effectively for decision making at multiple scales. Specific questions that must be addressed in the short term are as follows:

1. How can CBONs be calibrated and how can CBON data be best integrated with those from other instrumented networks (INs)?
2. What platform(s)/designs could a Coordinated Spatial Database adopt or does one need to be developed de novo to accommodate the potentially sensitive nature of some CBON data?
3. How can international coordination yield a pan-arctic CBON network that is both coordinated but robust to local and regional needs?
4. How well do the integrated CBON-INs perform in terms of predictive ability versus one or other alone?
5. Based on the above questions, how can the CBON-INs data be accessed and used as timely as possible to respond to arctic change?

References

Alessa, L., Kliskey, A., Williams, P. 2007. The distancing effect of modernization on the perception of water resources in Arctic communities. Polar Geography 30, 175-191.

Alessa, L., Kliskey, A., Williams, P., White, D., Barton, M. 2008. Memory, water and resilience: Perception of change in freshwater resources in remote Arctic resource-dependent communities. Global Environmental Change 18, 153-164.

Alessa, L., Johnson, J., Kliskey, A., Loius, R. 2012. White paper on Indigenous Science.

Altaweel, M., Alessa, L., Kliskey, A. 2010. Visualizing situational data: applying information fusion for detecting social-ecological events. Social Science Computer Review 28(4). doi:10.1177/0894439309360837.

Balasubramaniyan, J., J. O. Garcia-Fernandez, D. Isacoff, E. H. Stafford, and D. Zamboni. 1997 . Software Agents for Intrusion Detection, Department of Computer Sciences, Purdue University, URL: http://www.cs.purdue.edu/coast/coast-library.html.

Bone, C., Alessa, L., Altaweel, M., Kliskey, A., Lammers, R. 2011. Assessing the impacts of Local Knowledge and Technology on Climate Change Vulnerability in Remote Communities. *International Journal of Environmental Research and Public Health* 8: 733-761. doi:10.3390/ijerph8030733.

Borgstrom, A., Duker, D., Sparrow, J. 2005. The technology opportunities program (TOP): Networking our nation – a decade of lessons learned. Community Development 36 (1): 103-119. **DOI:**10.1080/15575330509489875.

Dasgupta, D.; Attoch-Okine, N., 1997, "Immunity-Based Systems: A Survey", *Proceeding of the IEEE International Conference on Systems, Man and Cybernetics*, Orlando.

Gofman, V. 2010. Community based monitoring handbook: lessons from the Arctic. CAFF CBMP Report No. 21. CAFF International Secretariat, Akureyi, Iceland.

Gray, S., Chan, A., Clark, D. and R.C. Jordan. 2012. Integrating stakeholder knowledge in socialecological system decision-making: Benefits and limitations to knowledge diversity *Ecological Modeling* 229: 88-96.

Grebmeier, et al. 2006. A major Ecosystem Shift in the Northern Bering Sea. *Science* 311,1461.

Huettmann, F. 2012. Protection of the Three Poles. Springer: New York.

Hunt, G.L., Stabeno, P., Walters, G., Sinclair, E., Brodeur, R.D., Jeffery M. Napp, J.M., Bond, N.A. 2002. Climate change and control of the southeastern Bering Sea pelagic ecosystem. *Deep Sea Research Part II: Topical Studies in Oceanography* 49, 5821-5853.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate Change 2007: Working Group II Report "Impacts, Adaptation and Vulnerability". Cambridge University Press: Cambridge, UK.

Kliskey, A., Alessa, L, and Barr, B. 2009. Integrating local and traditional ecological knowledge for marine resilience. In: Managing for resilience: new directions for marine ecosystem-based management. K. McLeod and H. Leslie (eds.). Island Press Publishers. pp. 145–161.

Kopec, G.M. 2008. Facilitating International Cooperation in an Arctic Transformed by Global Warming. Unpublished thesis, Cambridge Judge Business School. URL: http://www.spri.cam.ac.uk/people/kopec/mphil.pdf.

Kumpula, T., Pajunen, A., Kaalejarvi, E., Forbes, B., Stammler, F. 2011. Land use and land cover change in Arctic Russia: Ecological and social implications of industrial development. Global Environmental Change 21: 550-562.

Johnson, N. et al. 2013. Strengthening community-based monitoring in the Arctic: Key challenges and opportunities. White Paper for Arctic Observing Summit.

Poppel, B. 2008. Interdependency of subsistence and market economies in the Arctic. In: *The Economy of the North*; Ed: Statistics Norway. pp. 65-80. Statistical Analysis 84.

Shiffman, S., Hufford, M., Hickcox, Paty, J., Gnys, M., Kassel, J. 1997. Remember That? A comparison of real-time versus retrospective recall of smoking lapses. *Journal of Consulting and Clinical Psychology*. 65, 292-300.

Treadwell, M. 2013. Safe, secure and reliable at sea: the geopolitics of a new ocean. Arctic Frontiers Conference: Geopolitics and Marine Production in a Changing Arctic. January 21, 2013, Tromsø, Norway. URL: http://ltgov.alaska.gov/treadwell/press-room/full-press-release.html?pr=169.

Usher, P. 2000. Traditional ecological knowledge in environmental assessment and management. *Arctic* 53, 183-193.

United Nations. 2009. The United Nations Millenium Development Goals Report. United Nations, New York. http://www.un.org/millenniumgoals/pdf/MDG_Report_2009_ENG.pdf.