Next Steps toward an Arctic Human Dimensions Observing System

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Abstract

The goal of The Arctic Observation Network Social Indicators Project (AON-SIP) was to develop a system of social observations that can answer the question, "Is the arctic system moving to a new state?" Much of the project effort focused on compiling data on human activities in the arctic that might interact with climate change and social indicators of arctic well-being. This paper reviews the adequacy of the data analyzed in the project for three objectives: observing changes in well-being of arctic residents, observing arctic changes relevant to global society, and understanding ongoing social change in the arctic. The review highlights issues of comparability of data across different scales in different nations, as well as key observation gaps. Understanding change in well-being of arctic residents also requires observing additional less-climate-related drivers of change that the AON-SIP did not address, many of which also suffer from the same issues of comparability and data gaps. Two types of recommendations are offered for developing the arctic social observation system: (1) recommendations through the Arctic Council to national statistical agencies to achieve internationally comparable data, and (2) recommendations for essential new primary data collection.

Keywords: arctic change, social indicators, observing system design, system model, arctic observation network

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The Arctic Observation Network Social Indicators Project (AON-SIP) compiled existing data to support future research on the interaction of social systems with environmental change in the Circumpolar Arctic. AON-SIP organized historical information to establish a baseline that researchers might use to help understand arctic change, and that stakeholders might use to respond to ongoing and projected change. The project therefore took the first step toward developing the human dimensions observing system for the Study of Environmental Arctic Change (SEARCH), whose overall goal is “to understand the nature, extent, and future development of the system-scale changes presently observed in the Arctic." (SEARCH 2005: vii)

Anticipating that existing data might be insufficient to support the SEARCH goal, AON-SIP included an assessment of the adequacy of the existing data to meet researchers and stakeholders’ needs, along with recommendations for improvements in the pan-arctic observing system. Each of the other papers in this volume reviews the data for a particular aspect (domain) of arctic change. Addressing the maturity of the observing system as a whole, however, requires a more systematic analysis of the ability of the portfolio of existing data to support inferences about system-level changes in arctic human systems.

The AON-SIP evaluation of the social observing system proceeded in a series of sequential steps, each of which can be phrased as a question:

1. What observations do researchers need to understand how cultural and socio-economic systems interact with arctic environmental change?
2. How well did the AON-SIP scope and focus align with the portfolio of observations needed to understand the human dimensions of arctic change?
3. Do the needed observations exist, and if so, are the data being collected at the appropriate scales?
4. If the observations exist and data are being collected, are they publicly available at the relevant temporal and spatial scales?

The remaining sections of the paper describe how the AON-SIP evaluation addressed each of these four questions about the status of the arctic social observing system. A key aspect of the evaluation approach is the development and application of a prototype arctic social system model that formally links observations most directly tied to arctic environmental change to broader social indicators of well-being. The paper concludes with a set of recommendations for high-priority observation system development, including steps to increase public availability of agency data and recommendations for new data collection.

What observations are needed?

The goal of AON-SIP was to develop a system of social observations to support the SEARCH program. SEARCH is an interdisciplinary science program focused on arctic environmental change. It aims to answer the question, "Is the arctic system moving to a new state?" (SEARCH 2005: x) Since the Arctic is constantly evolving, it is not obvious how one would define when the pattern of change has become a new state, and how would one measure that pattern of change? However, SEARCH science planning documents clearly reveal a focus on arctic environmental change associated with global climate change:

> “These changes include, for example, increasing average annual surface air temperatures, decreasing summer sea ice extent and sea ice mass, changing ocean circulation, northward movement of tree lines and vegetation zones, thawing glacial ice masses and permafrost, and changing socioeconomic dynamics.” (SEARCH 2005: vii)

In the context of climate-associated environmental change, the new state would be defined as the set of physical, biological, and social conditions associated with a directionally warming climate rather than a fluctuating, variable climate:

> “Recent and ongoing change in the arctic physical system appear to be large and, in some cases, unprecedented in the period of instrumental and satellite observations. The magnitude of these changes raises the possibility that the arctic system may be crossing a threshold or approaching a tipping point....” (SEARCH 2005: 5)

The 2005 SEARCH Implementation Workshop report elaborated two high-priority human-dimensions observing activities associated with the main science question about moving to a new state. Activity (d) focuses on indicators of human system changes that might affect arctic physical and biological changes; while activity (h) addresses local observations of arctic environmental change beyond understood experience. Neither sheds much light on what specific aspects of the human subsystem to observe. It is clear, however, that observations should support research on understanding change, including the understanding activity, (k) Synthesize ... data on resident socioeconomic changes, human perceptions (local, regional, and non-arctic) of arctic change, and on local and global-scale development and industrial activities.” (SEARCH 2005: x)

SEARCH apparently envisions two types of activities for observing human dimensions of arctic change. One type would document local perceptions of arctic environmental change, perhaps extending the material compiled and analyzed in Krupnik and Jolly (2002). The other type would characterize the evolving state of the arctic social system. The Implementation Workshop report further elaborates this second direction under science question 6, “How do cultural and socioeconomic systems interact with arctic environmental change?” Here one finds the observing activity, “b) Develop a pan-arctic database of key human dimensions indicators of population, employment, and subsistence.” (SEARCH 2005: xiii) Thus SEARCH appears to acknowledge Fikret Berkes’ (2002) view that both traditional knowledge and civil science are essential ingredients for dealing with complex systems problems such as climate change.

SEARCH-related projects such as ELOKA (http://eloka-arctic.org/) and the Bering Sea Subnetwork (http://www.aleut-international.org/Page17.html) address traditional knowledge and local observations of environmental change in the Arctic. AON-HD instead focused on the second strand of human dimensions observing in SEARCH: indicators of socio-economic change and industrial activity in the Arctic that might interact with environmental change. Given this focus, what specific indicators of socio-economic change and industrial activity would be appropriate for observing societal effects of arctic environmental change?

The Arctic Climate Impact Assessment (ACIA 2004) compiled and summarized likely implications of climatic warming for the environment and society. Three of ACIA's 10 main findings relate directly to human impacts. Key Finding 6 discussed the effects of reduced sea ice on marine transport and access to resources, specifically mentioning the likelihood of expanding marine fisheries, offshore oil and gas extraction, tourism, and shipping of goods. Key Finding 7 on melting permafrost included effects on transportation and infrastructure, specifically mentioning effects on oil and gas extraction and pipeline transportation. Key Finding 8 on indigenous communities described the vulnerability of traditional hunting, fishing, and herding economies to climate change, with implications for health, food security, and cultural identity. Key Finding 10 emphasized the cumulative effects of interaction of climate change with other global forces of change on ecosystem health and human well-being. Also mentioned in ACIA were expansion of forestry and agriculture, and freshwater fisheries decline, although these effects are largely confined to subarctic regions.

Using ACIA as a guide, key indicators of changes in industrial activity should include oil and gas extraction and transportation both onshore and offshore, marine shipping, tourism, subsistence, and commercial fishing to the extent it occurs in the Arctic. What, then, would be appropriate indicators of socio-economic change in arctic communities, especially those related to well-being of indigenous peoples?

The Survey of Living Conditions in the Arctic (SLiCA) (Kruse et al. 2008) addressed this question through a collaboration effort of researchers and indigenous people to measure and understand living conditions across the Arctic. Working with local residents, SLiCA included questions on subsistence participation, material well-being, education, language, health, social ties, and community quality of life. Although comprehensive and relevant, the lengthy questionnaire and large size and expense of the survey make it impractical for monitoring changes in well-being over time.

The United Nations Human Development Report (HDR 2009) publishes an annual Human Development Index (HDI) that addresses the need for compact set of indicators of societal well-being at the country level. The three components of the basic HDI -- life expectancy, GDP per capita, and literacy rate -- measuring respectively the three domains of well-being -- health, material well-being, and education -- could easily be down-scaled to produce regional indicators. However, in discussing how to apply the work of the HDR to the Arctic, the Arctic Human Development Report (AHDR 2004) concluded,

> "Most arctic residents value fate control or the ability to determine their own destinies. Highly valued also is cultural continuity in the sense of nurturing traditional values and ways of life, even while embracing some of the obvious benefits of modernization." (AHDR 2004:16)

The AHDR therefore suggested adding three additional domains to those of the HDI: control of destiny, maintaining cultural identity, and living close to nature (AHDR 2004: 240). Following up on the AHDR, the Arctic Social Indicators project (ASI 2010) discussed the issues involved in measuring indicators for the six AHDR domains, emphasizing availability of data. The study recommended seven overall indicators, some of which spanned multiple domains: (1) infant mortality, (2) net migration, (3) consumption/harvest of local foods (4) per-capita household income, (5) percent of students completing post-secondary education, and (6) language retention, and (7) a destiny control index. The index of destiny control contained several components, expressed as percentages, representing indigenous lawmakers per capita, locally controlled land and public revenues, and ability to speak the language of one's ethnicity. The ASI report made a number of recommendations for implementation, foremost of which was to design the monitoring system to meet the following objectives:

1. Data are available at a regional level (i.e., census area or borough in Alaska);
2. Data are available separately for indigenous and non-indigenous populations;
3. Data are available on at least a five-year reporting period. (ASI 2010: 157)

In summary, a series of consensus reports synthesizing the views of a large spectrum of arctic researchers and stakeholders discusses appropriate strategies for observing human dimensions of arctic environmental change. The SEARCH Implementation Workshop report (SEARCH 2005) suggests a need to observe changes in industrial activity and socio-economic conditions of arctic communities. For industrial activity, ACIA (2004) implies that oil and gas extraction and transportation, marine shipping, tourism, subsistence, and commercial fishing are activities most likely to be sensitive to arctic environmental change. For socio-economic conditions in arctic communities, ASI (2010) recommends a set of seven indicators spanning the six domains of well-being identified by the Arctic Human Development Report (AHDR 2004).

Was AON-HD scope and focus adequate?

How well did the AON-SIP scope and focus align with the portfolio of observations that the synthesis efforts discussed in the previous section recommended were needed to understand the human dimensions of arctic environmental change? In a broad sense, the goal of AON-SIP -- compilation and assessment of existing data on climate-human interactions and social indicators of well-being -- was properly aligned. Much of the effort in the AON Social Indicators Project focused on compiling and organizing data on four types of human activities likely to interact with climate change. These four focus areas were (1) arctic and subarctic fisheries; (2) development activities: mining, petroleum development, marine transportation, (3) tourism; and, (4) subsistence harvests.

One key area of climate-human interaction in featured ACIA (2004) was not addressed in AON-SIP. ACIA described the potential for melting permafrost, later freeze-up and thinner river and lake ice to disrupt overland transportation in the Arctic, a region with few permanent roads (ACIA 2004: 86). One might argue that the climate observing system provides the relevant observations, so it is not necessary for AON-SIP to duplicate the effort. However, the specific effects of warming on infrastructure, such as dates of ice-road use and approved tundra travel at specific locations around the Arctic, might be considered a relevant set of observations omitted from AON-SIP.

On the other hand, AON-SIP compiled and analyzed data on mineral production and mining employment. ACIA (2004) did not identify non-petroleum mining as a key area of climate-human interactions. While one might argue that climate has little direct effect on hard-rock mining, a relatively small effect on transportation costs could be pivotal in determining the rate of growth of industrial-scale mining in the Arctic. The longer marine shipping season made possible from reduced sea ice cover could lead to expansion of mining activity, with associated social and economic impacts on adjacent arctic communities.

Climate change and external social drivers such as government policies and resource development interact with arctic ecosystems to produce changes in well-being and opportunities for residents of arctic communities. In addition to compiling and organizing data on human activities potentially interacting with climate change, the AON-SIP project included three specific activities related to key social indicators of well-being. One was to compile a pan-arctic database of population and, where available, components of population change (Hamilton and Mitiguy 2009; http://www.carseyinstitute.unh.edu/alaska-indicators-northern.html). A second was to digitize published tables of data on a variety of social indicators linked through the Arcticstat portal (http://www.arcticstat.org/) but not readily accessible in electronic form. The third activity was to compile a data set containing a large set of over 600 variables for Alaska’s 27 census areas, conformed to 2000 Census geography. The Alaska-specific data set covers demography, employment, education, income, mobility, and housing, but is largely a compilation of 1970-2000 decennial census results (http://www.iser.uaa.alaska.edu/Projects/SEARCH-HD/acrdb.htm).

Taken together, the three databases contain data on a wide variety of social outcomes for arctic regions and communities. However, there are numerous gaps for each country, with some indicators available only in certain years, or not at all for some regions or places. In addition, the set of indicators for which observations are available, and the exact definition of those indicators, differs widely from one country to another. This makes it challenging, if not impossible, to develop a gridded database of social indicators comparable to observational databases available for physical systems. In general, it would not be fair to expect AON SIP or any other single research project to resolve all issues of national comparability and data gaps. However, it is possible that AON-SIP investigators focused elsewhere, overlooking some key indicators for which observations are available that, looking forward, might be important to include in future observation efforts.

The approach in AON-SIP to observing climate-human interactions was based on first identifying prospective arenas of change in general terms, then systematically searching for the relevant observations. Project investigators noted that the clearly understood goal -- a gridded database with annual or periodic observations by region (county) -- might be difficult to obtain, with data for some indicators unavailable at the relevant scales. Such an approach could be described as a top-down approach to the social observing system.

On the other hand, the approach to observing indicators of human adaptation, with the exception of total population, appeared based on compiling and organizing into large databases the set of readily accessible, potentially relevant data, without a careful analysis of what specific subset of these indicators would be most desirable or important to observe. This could be described as of a bottom-up approach. The bottom-up approach contributes a resource for knowledgeable researchers, but by itself provides limited information on the status of the observing system, or guidance for design of an integrated system of observations. To assess the status of the observing system with respect to human adaptation to arctic environmental change, and take the next steps toward observing system design, a top-down approach is needed.

To understand what a more top-down approach to the adaptation component of the social observing system would look like, it is necessary to step back to consider the goal of SEARCH: to *understand* system-scale changes in the Arctic. A top-down approach would therefore start with what is needed for understanding change in the human component of the arctic system, and then work backward to design of the observing system. For arctic residents, the six ASI dimensions of well-being measure adaptation outcomes, so we want to know how observations on fisheries, tourism, mining, and subsistence might be connected to changes in different aspects of well-being. Because some social outcomes change at relatively slow time scales, key adaptive strategies might show evidence of change before changes in well-being can be observed. Consequently, a top-down approach to observing system design would also seek direct observations on these important adaptive strategies, especially those likely to show relatively rapid shifts that could serve as leading indicators of change in slower-reacting social outcomes. Design of the complete social observing system suggests the need for a comprehensive, research-based, social-system-wide approach to choosing adaptive strategies to monitor. At the same time, budgetary and information-management concerns require that the set of indicators be compact and straightforward to measure. An observation-based system model can provide a useful tool to assist observing system design, by synthesizing understanding of the main external drivers of a system as well as links between drivers and outcomes.

A regional arctic social system model to assist observing system design

System models of the atmosphere and oceans have become widely used in the past several decades to analyze and predict weather and climate, and feature prominently in scenarios for climate change reviewed by the Intergovernmental Panel on Climate Change (IPCC 2007). More recently, modelers have been adding biophysical feedbacks from land (vegetation, soil, snow) to climate models, to create more complete Earth System Models (Thompson and Pollard 1995; Foley et al. 1996; Cox 2001; Cramer et al. 2001; Bonan et al. 2002; Krinner et al. 2005; Shevliakova, et al. 2009). Common features of all these models include physical processes that propagate across space and time to yield projected outcomes over a complete global grid. The nature of these models implies a need for gridded global data sets of observations for model development and evaluation. Consequently, data integration is a key aspect of the modeling effort, and there is a close link between the observation system and the modeling system.

Beyond representation of simple land use categories, attempts to incorporate the social system into earth system models have been few and highly specialized. For example, Babiker et al. (2009) built a computable general equilibrium (CGE) model of the world economy, tracking regional GDP, trade flows, and carbon emissions, linked to a global climate model through effects on agriculture and forestry. The primary goal of models such as these is to project sensitivity of aggregated measures of economic activity and trade flows to climate policy in general terms. A secondary goal is to improve model representation of climate feedbacks from land use and associated vegetation changes. The closest counterpart in the Arctic to this type of economic model is the Man-in-the-Arctic (MAP) model of the Alaska state economy (Goldsmith et al 1985). While the MAP model has not been linked to an earth system model, it readily could be in the same way as the Babiker et al. (2009) model, through activity in the forestry, fisheries, and agriculture sectors. Economic models such as these are designed to answer scenario-driven “what if” questions at the state or national level; they are neither designed for nor capable of linking to a spatially detailed social observation system.

In the Arctic, where agriculture and forestry are minor activities, social system links to the earth system are largely unidirectional through the cryosphere’s effects on transportation modes and access, and through local and regional ecological variability and change (ACIA 2004). These biophysical effects on the human system are locally heterogeneous, and human occupation of the Arctic is discontinuous and sporadic across a large geographic space. Consequently, models of human activities aggregated to the level of states or nations link poorly to climate or earth system models. Linked climate-social models of one community or small region (Berman et al. 2004) cannot easily be scaled up. In the Arctic, a social system model to assist design of a broad-area, spatially detailed observing system is a pioneering endeavor.

Such a model would ideally generate basic outcome indicators from all six social domains identified by the ASI (2010) report. It would also include a compact set of intermediate indicators consistent with what is known are can be reasonably hypothesized about the relationship of environmental change to social change in arctic communities. The model would identify and quantify external drivers of social change, such as global market forces, government policies, and climate change, while simulating dynamics of communities and regions as seen through key system processes. By keeping the system structure simple and transparent, the model should address the spatial complexity of the arctic human system, noting barriers created by political and geographic boundaries.

The prototype system model developed along these guidelines projects annual values for a set of 19 social indicators in the six ASI domains, as summarized in Table 1. The 19 indicators closely follow the ASI (2010) recommended seven key indicators, plus important components and key internal drivers.[1] All social indicators for ASI domains other than control of destiny refer to characteristics of the indigenous population. The focus on indigenous people is appropriate for the Arctic, where a majority of the population outside larger industrial centers is typically indigenous, and most non-indigenous people are short-term residents drawn for economic opportunity. For demographic indicators, therefore, *local population* and birth, death, and net in-migration rates represents indigenous residents; *non-local population* refers to non-indigenous residents. The sum of local and non-local population adds to the total population measured by nation census figures. *Total jobs* include employed members of the non-local population, while *local resident employment* refers to employed members of the local (indigenous) population.

Given the appropriate set of social outcome indicators, the next step for model development was identification of external driver domains and specific indicators. Kruse et al. (2004) modeled long-term futures for arctic communities in the Canada-Alaska arctic borderlands as they responded to scenarios for climate change, petroleum and tourism development, and government spending. In other arctic regions, mining development and fisheries might be potential local industries. What these industrial activities have in common across the Arctic is that they are driven by global market forces. National and state or provincial government spending is one type of policy in a set that also includes indigenous rights, land claims agreements, and other forms of local autonomy (control of destiny) granted by higher levels of government. Accordingly, the arctic social system model includes three external driver domains: world economy, government policies, and environmental change.

The internal model structure links the main drivers of change to social outcomes, as summarized in Figure 1. The structure is purposefully kept simple, not trying to incorporate all drivers and feedbacks relevant to human adaptation to environmental change, or even all those relevant to the limited set of outcomes included in the model. Instead, the model focuses strategically on the most quantitatively important and most easily observed drivers that could affect observable social outcomes at a relatively short (annual to decadal) time scale. It represents key strategies people in the arctic use to adapt to environmental and other change only in an abridged form, while nevertheless incorporating guidance from more detailed studies of individual processes where such studies exist.

Table 2 lists the set of external drivers for the three domains, and the specific outcome indicators that each driver directly affects. Indirect effects appear throughout the system, through modeled secondary effects and feedbacks. External drivers alone determine values for seven of the outcome indicators in Table 2. The others have internal as well as possibly external drivers.

Table 3 elaborates the internal structure summarized in Figure 1, displaying additional detail on internal drivers and feedbacks for the 12 outcome variables with internal drivers. The main indicator for the material well-being domain, real per-capita personal income, is defined as the sum of earnings -- local jobs times real wage rate -- and non-wage income, adjusted for inflation. Incomes in different communities and regions are then adjusted for changes in local living costs relative to national averages (relative cost of living indicator). Total jobs represent the sum of industrial driver jobs and jobs financed by government spending, adjusted for residency of workers, plus jobs in local support industries such as retail trade and services created by the "multiplier effect" (Krikelas 1992). Non-wage income from individual wealth, government transfers, and payments by local industrial activities such as oil production also create jobs through multiplier effects. In general, multiplier effects are very modest in small arctic communities (Goldsmith 2007), meaning that there are relatively few support sector jobs.

Educational attainment is the main driver of differences in real wages and affects the ability of local residents to obtain employment (Huskey et al. 2004); therefore, it strongly influences material well-being. As mentioned above, the model includes non-local population as a destiny control indicator. Residents of small arctic communities have mentioned this as a sustainability indictor (Kruse et al. 2004). Lower local education levels suggest that fewer jobs that do exist can be filled by local (indigenous) residents, increasing the non-local population (Berman et al. 2004). Non-local population and other destiny control factors may directly influence injury deaths through local ability to control alcohol policies (Conn 1986; Landen et al. 1997; Berman et al. 2000; Berman and Hull 2001), and possibly indirectly through complex social forces (Hicks 2007). Educational attainment in local populations is driven by complex processes that are difficult to model in a simple system model. However, government spending and policies are clearly important drivers.

Three indicators in Table 3 shown in italics represent key model indicators that lie at the intersection of multiple processes important to community dynamics and social change. Local resident jobs, determined as described above by total available jobs and local education levels, is the most important driver of material well-being. Participation in subsistence harvesting (household production of local food and other basic necessities) indicates cultural vitality as well as contact with nature (ASI 2010). Empirical analyses of harvesting, including Kruse (1991), Kerkvliet and Nebesky (1997), and Berman and Kofinas (2004), discuss how employment and income interact with subsistence harvesting through household time and money budgets. Berman (2009) found that indigenous language use was strongly associated with subsistence activity. Migration, the main driver of population change in many small communities, is a key indicator for the health and demography domain. Hamilton and Otterstad (1998), Hamilton (2003), Huskey et al. (2004), and Berman (2009) discuss how commercial and subsistence resource harvests, jobs, and quality of life indicators play a role in migration decisions.2

Given the general structure of the model outlined above, three additional steps are required to finish the model. Since all ASI outcome indicators are quantitative, one must select an appropriate form for an equation to estimate each outcome indicator as a function of its internal and external drivers. The specific data sources and observation units need to be identified. Finally one must establish a method to estimate the parameters for each of the model equations. For the purposes of the current study -- evaluation of the observation system -- , the focus is on the data; functional form and parameter values are of lesser concern. Nevertheless, it is useful to construct a fully articulated model for an example region to demonstrate that the logical structure is complete and that data are sufficient to estimate a version of the model and simulate it over time. The demonstration addresses two main questions: (1) are the observations needed to simulate the model being collected? (2) if the observations exist, are they available to researchers and stakeholders at the relevant scales needed to observe human adaptation to arctic environmental change and plan for its consequences?

Are the needed observations being recorded at the useful scales?

Using arctic Alaska as an example, a prototype model was constructed to simulate the dynamics of the three census areas and 35 communities in arctic Alaska, represented by the North Slope and Northwest Arctic Boroughs and the Nome Census area. Table 4 summarizes the data sources used to estimate and test the model. Relative cost of living indicators available for three communities (McDowell 2009) were extrapolated to other places in their respective census areas. Initializing the model to the 1980 U.S. Census, the model simulates community and census area dynamics from 1981 to 2007 with an annual time step. Parameters were estimated by weighted full-information maximum likelihood, assuming a Gaussian distribution of the percentage deviation of the predicted from observed changes of the full set of indicators. Likelihood function weights are constructed from the normalized variance of the observations: variances are assumed to be proportional to the sample sizes for each observation.

As implemented with the current set of observations for communities in the three census areas, the model solution has mean-squared error of about 15 percent, varying somewhat by indicator, for a largely decadal set of observations (1.5 percent per year). This may seem to suggest that the model is a rather inaccurate predictor of social outcomes. However, the prediction error simply illustrates the status of the existing arctic social observation system. Model indicators are observed on average only about three times in the decennial census over the 27-year period, and many have a coefficient of variation among communities and across decades of over 50 percent for observations that are available.

The model was not designed to serve as a forecasting tool, and the simulation output of the prototype version is too imprecise for that purpose. On the other hand, the model helpfully illustrates the state of the data available to measure well-being in arctic communities, and highlights important data gaps. For Alaska, as Table 4 illustrates, some data exist at least at the regional (census area) level for nearly every indicator. Living costs provide the main exception. Living cost differentials have been observed only sporadically, and for only the largest, and presumably least costly communities in the region.

Table 4 also shows that some arctic Alaska observations exist at the regional scale for all drivers except marine mammal stocks. The challenge with marine mammal stocks and other climate-sensitive drivers is to observe indicators at the relevant local scales. Climate may change unevenly within a broad geographic region such as Alaska or Arctic Canada, and physical and ecological effects of climate change in coastal areas may differ markedly from effects in adjacent inland areas. The need to observe change at the relevant local scale also limits observations for indicators of non-environmental drivers of change. While minimal baseline observations exist for all other indicators, observations on government transfer and non-transfer spending rely on a one-time study -- Goldsmith (2007) -- that may not be replicated for many years, if ever, at the requisite geographic scale. This is a serious concern, since several studies (Knapp and Huskey 1988; Berman et al. 2004) have identified government spending as the dominant driver of cash economies in small arctic communities.

Are the relevant data available for research and planning?

While the status of the social indicator data to simulate the Arctic Social System Model is encouraging for arctic Alaska, Table 4 suggests that the situation is somewhat less favorable for arctic regions of Canada. In that country, the main government statistical agency, Statistics Canada, does collect many of the key observations at relevant community scales. However, the agency declines to publish data at those scales. Members of the public may request special statistical tabulations from the agency for a fee, and researchers, wishing to use the data for research may apply for access through Statistics Canada's Research Data Centre (RDC) program. However, approval is at the discretion of the agency, and publication of data for communities and regions obtained from special tabulations or through RDC research remains subject to strict disclosure rules and rounding requirements (Statistics Canada 2005). The rounding requirements introduce further errors to estimates already subject to the usual limitation imposed by sampling error.

Outside North America, the status of social indicator data for arctic regions is quite varied.[3] Observations for many if not all the indicators are available for Greenland communities from Statistics Greenland. However, except for total population, it is not generally possible to separate indigenous Greenlanders from those who identify as Danish or another ethnic origin. An analogous problem exists in Scandinavian countries and Finland.[4] Observations for the Sami minority exist only for Sami living in Norway (Statistics Norway 2010). For arctic regions of Russia, data are available at the regional (*oblast*) level, but likewise rarely separate characteristics of indigenous residents from those of the non-indigenous residents, except for indicators of total population.

The status of observations for non-environmental drivers of social change, where separate observations for indigenous people is typically not an issue, is generally better in Greenland and Fennoscandia -- but not in Russia -- than in North America. Indicators that are sensitive to arctic environmental change are available in only some arctic areas, and suffer serious problems with consistency of definition and measurement. Fay (2011) found little comparability in tourism measures across the arctic at either national or regional scales. Scandinavian countries track monthly accommodation overnights, while data only exist for total annual visitors for Alaska as a whole and for a portion of arctic Canada. Alaska, Canada, Norway, and Finland report tourism employment data at the regional scale, while Russia makes annual earnings available. Haley et al. (2011) found inconsistent reporting of mining industry employment among arctic regions (e.g. reporting total employees vs. full-time equivalent employment, reporting employees by place of work vs. place of residence), with some countries reporting no data at all below the national scale.

With few firms operating in any local area, confidentiality issues affect availability of data for commercial fisheries harvest as well as mining (Lowe 2011, Haley et al. 2011). Lowe (2011) discussed limitations and consistency issues with fisheries employment figures, which may not adequately measure part-time participation and ancillary employment. Data for traditional food use are similarly problematic. Kruse (2011) found that although data are available for some communities or regions in selected years, no regular effort exists to collect harvest data in Alaska, Canada, or Russia that can measure change over time. Harvest data are collected in Greenland, but are not published. With the exception of Greenland, comparable harvest data are not available at all for the rest of the Arctic (ASI 2010, p. 125).

Conclusion and Recommendations

This evaluation of the Arctic Observation Network Social Indicators Project examined a series of questions about the appropriate scope of the project and availability of observations relating to human dimensions of arctic environmental change. It found that the scope is generally consistent with the SEARCH program goals for human dimensions of environmental change, and consistent with recommendations of ASI (2010) regarding social indicators. However, an arctic social system model constructed to assist observing system design revealed a significant shortcoming of the project: the lack of attention to key drivers and indicators related to government spending at local scales.

The arctic social system model proved a useful tool for evaluating the operational status of social indicator data and exposing data gaps for key social indicators at relevant local scales. The prototype model simulations suggest that relatively few serious data gaps exist for arctic Alaska and some other regions such as arctic Norway. However, the large forecast errors from attempts to simulate the historical period with the prototype Alaska version of the model raise concerns about the quality of some of the observations that do exist. Further research is required to determine the extent that the model errors are due to problems with inaccurate data, or due to the fact that relationships among key indicators are too complex, or subject to too many local idiosyncrasies, to capture in the purposefully simple structure of the system model.

Further research is warranted to extend the model to other arctic regions and perform the same formal test of the operational status of social indicator data discussed here for Arctic Alaska. This may be challenging for some arctic nations, as social indicators are not always available at local scales. Where indicators are available, AON-SIP researchers found widespread problems with definitional consistency across nations, making it difficult to compare change over time in different arctic regions. The review of social indicator data conducted for this evaluation, guided by the arctic social system model revealed a lack of availability of observations at local scales, as well as a lack of indicators separately reported for indigenous people, in many arctic regions. Lack of systematic, separate observations for indigenous people presents a special problem in arctic regions where indigenous people represent a minority population that continues to participate in traditional activities, raising the likelihood that statistics for the region as a whole may mask different trajectories for indigenous and non-indigenous residents.

AON-SIP participants suggested a number of recommendations for specific improvements to the observation system related to individual indicator or driver domains. Haley et al. (2011) concluded that developing comparable measures of employment constituted the most critically needed improvement for monitoring the mining industry as a driver of change in arctic communities. Fay (2011) recommended a pilot program to collect more complete data on visitor expenditures at the local level to increase understanding of tourism as an environmentally sensitive driver of social change. Writing about fisheries data, Lowe (2011) recommended publication of rights-based indicators as well as fisheries landings at local scales for understanding how changes in fisheries affect arctic residents. For addressing the lack for observations on local use of traditional foods, Kruse (2011) recommended a strategy of systematically collecting data on harvests of the 10 top species in each region, which he determined accounted for 90 percent of total harvests in the comprehensive surveys that are available for selected communities in selected years. Kruse also recommended engaging local hunters and fishers to track changing local environmental conditions and their effects on subsistence resources and harvests as part of a continuously maintained system of indigenous observations of environmental change at locally relevant scales.

The best approach for addressing the absence of indicators of well-being reported at local scales, with separate measures for indigenous people, would be to persuade government statistical agencies to make available special tabulations for arctic communities from the data they already collect. Solving the sampling error and disclosure issues associated with such special tabulations for small samples and small populations, as well as implementing the recommendations of AON-SIP investigators regarding individual indicator domains, requires mainly a certain degree of political will. The most promising strategy for building that political will would be for the AON community to work with arctic communities to develop an international initiative to bring before the Arctic Council.

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Endnotes:

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1. One of the components of the destiny control index is the rate of indigenous lawmakers per capita. It is not clear at what level of government the ASI (2010) study team intended the indicator to apply, or how it should be defined for small regions and communities that may have limited self-government powers. The main driver of indigenous representation in a democratic society is the ratio of indigenous (local) to non-indigenous (non-local) population: hence, the inclusion of the *non-local population* indicator. For the health domain, injury deaths were chosen as a readily observed indicator of behavioral health. The injury death rate among rural Alaska Natives, for example, is over four times the national rate (Berman et al. 2000). After development of the model, the ASI (2010) report was published, suggesting infant mortality as the preferred health outcome indicator. Due to the low incidence of infant mortality and small population sizes, infant mortality contributes little information at an annual or even semi-decadal time scale for small communities and regions. However, future model development will include the addition of the infant mortality rate as a 20th indicator, to maintain consistency with the published ASI (2010) recommendations.

2. In many arctic regions and communities, higher rates of net out-migration by women have created gender imbalances that may generate additional social problems (Hamilton and Seyfrit 1994; Hamilton and Rasmussen 2010). While modeling gender balance would increase the power of the system model, keeping track of community and regional populations by gender (and age) would add another layer of complexity to the model, moving it away from its primary purpose as a tool for assessing the state of the arctic social observing system.

3. This analysis of social indicator data available for arctic regions outside North America relies on the database of social indicators compiled and accessible at the ArcticStat portal, http://www.arcticstat.org/ (accessed April 5, 2011).

4. A new initiative, the Sami statistics project, aims to address this deficiency. See http://www.sami-statistics.info/english/ (accessed April 5, 2011).

Table 1. Outcome Indicators for a Prototype Arctic Social System Model

Model outcome indicator	ASI (2010) indicator domain
Total local jobs	Material well-being
Local resident employment	Material well-being
Real wage rate	Material well-being
Real per-capita non-wage income	Material well-being
Relative cost of living	Material well-being
Real per-capita personal income	Material well-being
Local population	Health/demography
Net in-migration rate	Health/demography
Birth rate	Health/demography
Injury death rate	Health/demography
Other death rate	Health/demography
Percent of adults with high school diploma	Education
Percent of adults with post-secondary degree	Education
Non-local population	Control of destiny
Locally controlled gov't spending percent	Control of destiny
Locally controlled land percent	Control of destiny
Local harvests per capita	Contact with nature, cultural vitality
Harvesting participation rate	Contact with nature, cultural vitality
Indigenous language percent	Cultural vitality

Table 2. Arctic Social System Model External drivers

Domain/driver	Outcome indicator direct effect
World economy	
Oil prices	Total jobs, non-wage income, relative cost of living
Oil and gas production	Total jobs, non-wage income, harvest participation rate
Mining employment	Total jobs, harvest participation rate
Tourism employment	Total jobs
Fisheries employment	Total jobs
Government policies	
Real gov't non-transfer spending	Total jobs, relative cost of living, other death rate, locally controlled gov't spending %
Locally controlled gov't spending %	Total jobs, relative cost of living, net in-migration, Adults % w. high school degree, Adults % w. post-secondary degree
Locally controlled land %	Total jobs, non-wage income, harvest participation rate
Real per-capita gov't transfers	Total jobs, non-wage income
Indigenous language policy	Indigenous language %, adults % w. high school degree
Environmental change	
Fish stocks	Total jobs, local harvests
Marine mammal stocks	Local harvests
Caribou stocks	Local harvests
Regional mean temperature	Relative cost of living, harvest participation rate

Table 3. Arctic Social System Model Internal Feedbacks

Outcome indicator	Internal drivers affecting that outcome
Local resident jobs	Total jobs, Adults % w. high school degree, Adults % w. post-secondary degree, Local population
Real wage rate	Adults % w. high school degree, Adults % w. post-secondary degree
Real per-capita income*	Local resident jobs, Real wage rate, Real per-capita non-wage income, Relative cost of living
Non-local population	Total jobs, Local resident jobs
Net in-migration rate	Local resident jobs, Real wage rate, Local population, Relative cost of living, Local harvests per capita
Birth rate	Adults % w. high school degree, Adults % w. post-secondary degree
Injury death rate	Real per-capita non-wage income, Real per-capita income, Non-local population, Local population, Harvesting participation rate, Indigenous language %
Other death rate	Local harvests per capita
Local population*	Birth rate, Injury death rate, Other death rate, Net in-migration
Local harvests per capita	Non-local population, Local population, Harvesting participation rate, Indigenous language %
Harvesting participation rate	Local resident jobs, Local population, Real per-capita income, Relative cost of living, Indigenous language %
Indigenous language %	Non-local population, Local population

* Local population and real per-capita income are constructed by definition from the listed drivers.

Table 4. Existence and Availability of Observations for System Model Indicators for Arctic North America Regions

Outcomes	Arctic Alaska	Arctic Canada
Total jobs	Place[a, b], Region[e]	Place[g]
Local resident jobs	Place[a, b]	Place[g]
Real wage rate	Place[a, b], Region[e]	Place[g]
Real per-capita non-wage income	Place[a], Region[e]	Place[g]
Relative cost of living	†	Place[i]
Real per-capita income	Place[a], Region[e]	Place[g]
Local population	Place[a], Region[e]	Place[g]
on-local population	Place[a]	Place[g]
Net in-migration rate	Place[a]	Place[g]
Birth rate	Region[c]	Region[k]
Injury death rate	Region[c]	Region[k]
Other death rate	Region[c]	Region[k]
Adults % w. high school degree	Place[a]	Place[g]
Adults % w. post-secondary degree	Place[a]	Place[g]
Locally controlled gov't spending %	Place[f]	†
Locally controlled land %	Region[f]	Region[j]
Local harvests per capita	Place[d]	†
Harvesting participation rate	Place[d]	Place[h]
Indigenous language %	Place[a]	Place[h]
Drivers		
Oil prices	Region[l]	Region[l]
Oil and gas production	Place, Region[l]	†
Mining employment	Region[b]	Region[g]
Tourism employment	Region[b]	Region[g]
Fisheries employment	Place[m]	†
Real gov't non-transfer spending	Region[p]	Region[g]
Locally controlled gov't spending %	Place[f]	†
Locally controlled land %	Region[f]	Region[q]
Real per-capita gov't transfers	Region[p]	Region[g]
Indigenous language policy	Region[q]	Region[q]
Fish stocks	Region[q]	†
Marine mammal stocks	†	†
Caribou stocks	Region[q]	Region[q]
Regional mean temperature	Region[n]	Region[o]

[a]U.S. Census, American Community Survey, annual 5-yr moving average
[b]Alaska Department of Labor, annual
[c]Alaska Division of Vital Statistics, annual
[d]Alaska Division of Subsistence, selected places and years
[e]U.S. Bureau of Economic Analysis, *Local Area Personal Income*, annual, all residents

[f]Alaska Department of Community and Economic Development, annual
[g]Statistics Canada, Census, semidecadal, subject to disclosure restrictions
[h]Statistics Canada, Aboriginal Peoples Survey, semidecadal, subject to disclosure restrictions
[i]Canada Department of Indian and Northern Development, annual food cost surveys
[j]Canada Department of Indian and Northern Development, land claims settlement areas
[k]Statistics Canada, Vital Statistics, annual, subject to disclosure restrictions
[l]Alaska Department of Revenue
[m]Alaska Commercial Fisheries Entry Commission, annual
[n]U.S. National Weather Service, annual
[o]Environment Canada, annual
[p]Estimated from Goldsmith (2007), for one year
[q]Estimated from a variety of published and unpublished sources
[†]Data may be available for some locations and years, but are not systematically available on a recurring basis for arctic communities and regions. Model simulations rely on author's estimates.

Figure 1. Arctic Social System Model General Structure