<u>REVISED</u> <u>DRAFT</u>

SEARCH Understanding Change Panel

The present Arctic Observing Network: Gaps, needs and priorities

The following is an informal review by the SEARCH Understanding Change Panel (UCP) addressing gaps, needs and priorities in the evolving Arctic Observing Network (AON). The review draws upon the SEARCH Implementation Plan (ARCUS, 2005), the Arctic Observation Integration: Workshops Report (17-20 March, 2008), input from the International Study of Arctic Change (ISAC, 2009), the SEARCH UCP members, and various colleagues contacted by the UCP. The review is by no means comprehensive, especially in view of the limited number of contributors. Rather, by drawing upon and updating of the driving questions of SEARCH, it highlights several scientific and stakeholder issues most in need of information that could be—but is not presently being—provided by systematic observations. The issues identified here are ones in which understanding and responding would benefit from enhanced observations in the Arctic. As should be apparent in this report, the UCP and its contributors have paid special attention to newly emergent (post-2005) driving science questions for which answers demand enhancement of the present AON.

An overarching concern is that the observing and measurement strategies that work best for physical systems may not be optimal for the human/social components and their ecological linkages. There seems to be confusion in the SEARCH community between stakeholders' needs for data on environmental change, on the one hand, and researchers' needs for data on ecological/social responses to change, on the other hand. Stakeholders and governments that need to make informed decisions about how to address ongoing and projected environmental change have specific needs for data at spatial and temporal scales relevant to their particular decisions. Ecologists and social scientists have different data needs related to assessing the pace of change and the understanding and modeling of adaptive processes. In both cases, access to observations already being collected (and, in the case of the human system, control over access to collected data) is a major issue that the observing system design needs to address.

The presentation below is shaped by key driving questions targeted at understanding and responding. In each case, the associated needs are addressed in terms of the variables that are direct drivers of change or that can be expected to contribute to feedbacks in the Arctic system.

1. Marine changes

- *Are changes in marine mammal and fish distributions in the Arctic outside the ranges of natural variability?*

The Arctic research community was recently given a golden opportunity to shape policy through the solicitation of information prior to the listing of the polar bear as a threatened species. Similar questions are arising with whales, seals and walrus. Unfortunately, conclusions from the scientific community have been less than robust, especially with regard to the future. A key factor in the uncertainty is the absence of quantitative information on marine mammal and fish distributions needed to document recent changes, to understand them and to respond to them. The lack of such information is an impediment to the understanding and responding components of SEARCH. More systematic information on spatial and temporal variations of populations is essential to an understanding of the linkages between mammal/fish distributions and human activity, so it is highly relevant to the human dimension of SEARCH and its international counterparts (e.g., ISAC, 2009). There is a notable lack of systematic subsistence harvest data for terrestrial as well as marine species, even for top harvested species. There is no organized effort to collect non-commercial harvest data in most of the Arctic, including the U.S. Arctic. Given the relevance of such information for understanding and responding to change, data on marine mammal and fish distributions has to be considered a high priority.

- *What is happening with Arctic sea ice?*

The extreme retreat of Arctic sea ice during the past three summers (2007-2009) can be considered a fortuitous experiment by Mother Nature, spanning the International Polar Year and the ramp-up of SEARCH following the preparation of the Implementation Plan in 2005. Hypotheses abound on the causes (preconditioning if the pack ice by ice export, intrusions of warmer water from the Atlantic and Pacific, abnormal wind-forcing, unusually clear skies), although there is neither a smoking gun nor even a relative ranking of the importance of the contributing factors. Perhaps more importantly, there are indications that the albedo-temperature feedback to arctic system change may have been triggered by the recent summer retreat—summer water temperatures measured on cruises have been abnormally warm, the autumn freeze-up has been exceptionally late during the past three years, and autumn air temperatures have been far above previous norms over the western Arctic. If this feedback has indeed set in, knowledge of upper ocean conditions in the Arctic are vitally important to our understanding.

The recent sea ice anomalies have been well observed, at least in terms of ice coverage, with satellite passive remote sensing. However, the situation with ocean observations is a different story. While the SEARCH Implementation Plan includes observations of the ocean and sea ice, there are significant organizational and coordination gaps in the actual ocean observing activities that are ongoing in the Arctic Ocean and its peripheral seas. These gaps in organization hinder advances in understanding of ongoing ocean changes and their causes. Existing projects are generally driven by individual scientific interests, leading to a set of process studies done in different locations and different times. These projects compete with each other and often do redundant work. Similarly, cruises to the Arctic and the subarctic seas are undertaken by different agencies and countries with little coordination. There is a need for a comprehensive science-driven plan for "what, where and how" to observe the ocean in the Arctic. The observations need to be well coordinated with observations in the North Atlantic and North Pacific. Year-round observations and the longer observing time horizon (30-40 years) need to become part of the planning of agencies such as NSF, NOAA and NASA if understanding of ocean changes in the Arctic is to be advanced.

- *Are carbon pathways in the Arctic marine system undergoing changes that are consequential locally and globally?*

In the time since the preparation of the SEARCH implementation plan, ocean acidification has come to the fore as a potential threat to marine ecosystems (USGCRP, 2009). The threat of ocean acidification is especially strong in high latitudes, where the low water temperatures increase the solubility of carbon dioxide. While observations of ocean carbon (e.g., pCO_2) are clearly needed to document the course of ocean acidification in the Arctic, the acidification problem is only part of a more general need to better document carbon pathways in the Arctic marine system.

A recent review of the Arctic carbon budget (McGuire et al., 2009) contains a synthesis of the major stocks of Arctic carbon, together with their uncertainties. Various measurement and monitoring projects are in place in the terrestrial Arctic, through SEARCH and in other programs. There is less observational activity in the marine component, where uncertainties in Arctic carbon stocks and pathways are especially large. Reducing these uncertainties is important because of (1) the risks of ocean acidification now recognized, as noted above, (2) carbon stocks in the Arctic seas and shelves are large potential source of atmospheric carbon dioxide and methane, especially if subsea permafrost thaws; and (3) carbon pathways are clearly important to ocean biogeochemistry and the functioning of marine ecosystems. Both monitoring and understanding of the changes in the marine carbon pathways will be increasingly important in terms of impacts on humans, ecosystems and the other parts of the global system. A strong case can be made for a coordinated observing network that will address Arctic carbon pathways.

Atmospheric changes

- *Are changes in aerosols, particularly black carbon, playing a role in Arctic warming?*

The topic of black carbon, and aerosols in general, has assumed prominence since the preparation of the SEARCH Implementation Plan (SEARCH, 2005). Simulations from coupled global climate models that include observed increases in atmospheric greenhouse gas concentrations consistently show declining September ice extent over the period of observations. However, with few exceptions, simulated trends are smaller than observed. Possible linkages between the recent warming and decreased sulfate aerosol/cloud concentrations ("solar brightening" – Wild, 2009) have been proposed, and there have been suggestions that and increasing concentrations of black carbon may be accelerating ice loss (Shindell and Faluvegi, 2009). However, direct observations are sorely needed in order to clarify the role of black carbon in the Arctic system. The required sampling would include both the atmosphere and the snow surface over frozen ocean and land. There is a particular need to quantify the impact of black carbon on the albedo of snow-covered surfaces, especially during the late-winter and spring when insolation is strong.

Terrestrial changes

- *What are the drivers of recent Arctic terrestrial changes?*

Changes in river discharge and vegetative greenness have documented with increasing confidence in the past few years. Heterogeneous evidence of permafrost warming and degradation have been presented (IPCC, 2007; USGCRP, 2009). Increases in wildfire frequency and insect infestations have also been documented. However, the potential drivers and their relative importance are highly uncertain. Two variables are particularly noteworthy in the context of arctic terrestrial change because they are likely key drivers yet poorly monitored on a pan-Arctic scale: evapotranspiration and snow water equivalent. The lack of information on these variables represents an impediment to the diagnosis and understanding of ongoing terrestrial changes in the Arctic.

-- *Are changes occurring in evapotranspiration at the pan-Arctic scale?*

As noted in the SEARCH Implementation Plan and elsewhere, a fundamental question concerning the trajectory of the Arctic system is whether the terrestrial surface is becoming (and will become) drier or wetter. Implications for humans, terrestrial ecology, including fire frequency, vulnerability to insect infestation, and permafrost degradation are substantial. Indications of drying of the boreal forest contrast with greening of the tundra in recently published work. A key determinant of the surface moisture trends is evapotranspiration (ET), which should increase in a warming climate. However, whether this increase in ET will exceed the expected increase of precipitation in a warmer Arctic is not known. In addition, increasing areas of open water in the Arctic Ocean during summer imply that evaporation from marine surfaces may increase substantially. Understanding and anticipating changes in the Arctic's freshwater cycle requires reliable estimates of evapotranspiration. Given the large variability in ET across the Arctic, additional point measurements will be of limited value. The more viable options are to make use of numerical weather prediction models through data assimilation or offline simulations with land surface and ocean models driven by temperature, precipitation, wind and radiation inputs. Such simulations will need validation data. A related need is for measurements of soil moisture and vegetative stress over non-local scales.

-- *How will changes in snow impact the arctic terrestrial environment?*

Snow duration has profound implications for Arctic ecosystems, and snow loads have important impacts on structures and human activities in the North. Global climate models project that coming decades will see a shorter seasonal duration of snow cover, but increased winter snow depth and water equivalent/snow loads (Räisänen, 2008). The shorter duration of snow cover follows intuitively in that a warmer climate will lead to later snowfall in autumn and earlier snow melt in spring. A deeper winter snowpack is consistent with projections of increased net precipitation in high latitudes associated with a stronger poleward convergence of water vapor. Snow cover acts as an insulating barrier between the winter atmosphere and the ground. The effect of projected higher summer air temperatures over land in promoting increased soil temperatures will persist through the winter due to the insulating effects of snow cover. Higher winter temperatures will help in keeping soil temperatures high. At the end of the cold season, less energy would be required to raise soil temperatures above the freezing point, leading to earlier thaw. This process could occur even in the absence of changes in seasonal snow conditions. However, increased winter snow depth could serve to further insulate the ground from the atmosphere, contributing further to higher winter soil temperatures and earlier spring thaw. Higher summer air temperatures will thicken the active layer and delay autumn freeze-up, which in conjunction with the insulating effect of snow will ultimately lead to thermokarst and talik development. How will we know if such changes are occurring and our hypothesized scenario is correct? High resolution surveys of snow conditions and soil temperatures from autumn through spring, conducted at multiple sites in different climate regimes, would help clarify the relevant processes and may provide a basis for enhanced remote sensing algorithms for snow water equivalent.

Arctic-global connections

- *How is the Arctic contributing to global sea level rise?*

Given the importance of sea level rise and the Arctic's potential contribution to it, there has been heightened interest over the post-2005 period in the two major Arctic freshwater sources, Greenland and the total loss from smaller glaciers. At present, there is considerable debate about the relative contributions to sea level rise from these two sources—it is not apparent which of the two Arctic freshwater sources is now making the greater contribution. This represents a fundamental uncertainty that is globally relevant. One of the primary impediments is the absence of information on regionally integrated glacier discharge.

Mass balance estimates exist for some Canadian Arctic glaciers, two Alaskan glaciers, and a small number of glaciers in the Eurasia. The mass balance of Greenland still contains large uncertainties. More comprehensive information on glacier mass balance, whether from satellites, aerial surveys or in situ measurements, should be part of an Arctic Observing Network.

Integration of community/industry networks and ecological knowledge cooperatives

- *How can diverse types of local information be more effectively integrated into the study of Arctic change?*

The preceding question has long been recognized, yet it continues to challenge the study of Arctic change. It is assuming greater importance as science must respond increasingly to stakeholder needs. There is presently one AON project on "Geographically integrated (i.e., internationally coordinated) community/industry networks and ecological knowledge cooperatives". The Bering Sea Subnetwork project (www.bssn.net) is an international co-op to share ecological knowledge and observations. There are also some IPY projects directed toward ecological knowledge networks, although the continuation of these activities in the post-IPY period is uncertain. Such cooperatives, especially if expanded to include industry and related sectors, have the potential to provide information on linkages between the physical components and the human/social components of an AON. As just one example, while improved marine access to the Arctic with loss of summer sea ice has important economic and social implications, there is little publicly available data on shipping in the Arctic.

Finally, we note that other potential observational needs surfaced during the panel's exchanges. These include surface albedo, atmospheric water vapor (in the context of the water vapor feedback), upper atmosphere measurements, and a high-resolution (~5m) terrain map of the Arctic terrestrial region. While these may be considered valid needs, they were ranked below the observations listed above in terms of the potential to advance scientific understanding and to serve stakeholder needs.

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