SEARCH 5-Year Goals & Objectives

INTERNAL DRAFT FOR AGENCY INPUT

DRAFT GOAL #1: Improve Understanding And Prediction Of Sea Ice Changes And The Consequences For Ecosystems, Human Activities, And Climate

Arctic sea ice extent has been well below normal starting in 2007. Climate models suggest that this trend is part of a transition towards an Arctic Ocean with greatly diminished or absent summer ice cover by mid-century or earlier. Given the pivotal role sea ice plays for ecosystems, human activities and the global climate system, significant reduction in summer sea ice will have substantial repercussions, including extended open-water seasons fostering offshore resource development and increased maritime activity, changes in the behavior and health of marine mammals, and impacts on Arctic and sub-Arctic weather patterns.

The three overarching sea ice goals, listed below, represent areas for progress that address urgent and timely needs for providing improved sea ice information. Scientific advances made in this context will help resolve over what timescale a seasonally ice-free or greatly ice-diminished Arctic Ocean is to be expected and what the most important impacts on social-ecological systems will be. The science of seasonal-scale ice prediction will be elevated to a level that will bring about useful tools and forecasts currently unavailable for stakeholders. Finally, seasonal forecasts for the sub-Arctic will also be improved through better understanding of linkages between the Arctic and lower latitudes.

The scientific and societal relevance of improved understanding and response to a changing Arctic ice cover has been underscored by a variety of strategic planning documents that prioritize studies of the impacts of a changing ice cover. In focusing a set of SEARCH science objectives on sea ice, we build on past interagency synthesis activities, such as the SEARCH Arctic Sea Ice Outlook, as well as planning efforts, such as i) NOAA's Arctic Vision and Strategy, which places improved sea-ice prediction at the top of their key goals; ii) the National Ocean Policy strategy document, that references the need to improve sea ice prediction and to assess its impacts on Arctic ecosystems and human activities; iii) the priorities set forth in the U.S. Arctic Research Commission's most recent strategy document; iv) the International Study of Arctic Change (2010) recent review of understanding arctic change, which underscores the central role of sea ice in modulating Arctic environmental and socio-economic change; v) the 2009 National Presidential Directive on Arctic Region Policy; and finally, vi) the IARPC 5-year plan that defines interagency efforts related to sea ice research and forecasting . In keeping

with the SEARCH vision and mission, the objectives listed below focus on areas where interagency approaches improve our efforts to understand and predict Arctic sea-ice change.

Objectives (5-year time frame)

1. **Apply diverse and new tools to improve sea ice prediction from daily to decadal timescales**
   a. Develop interagency and international support for the 'Sea Ice Outlook' to expand contributor base, incorporate needed observations, conduct rigorous assessments of predictive success, develop additional products, and improve forecasts through synthesis of different methodologies, targeted observations and focused evaluation.
   b. Define a cross-agency AON implementation plan that facilitates sea ice predictions across time and space scales ensuring optimal observation deployment and identification of critical gaps. Provide summary to agencies for their planning purposes and implementation development. Identify research gaps and needs, including integration of observations and modeling needed to improve forecast products; work with agencies to implement activities to fill research gaps.
   c. Integrate AON sea ice measurements into global observational networks and data assimilation efforts through national and international mechanisms (SAON, CliC Arctic Sea Ice Working Group, Arctic Observing Summit 2012/13).
   d. Contribute to the National Academies study on Sea Ice Forecasting and Science (2012).
   e. Assess present and evolving state of the ice cover, examine overall predictability of sea ice system, improve and evaluate predictive methods and success across timescales. Develop cross-disciplinary scenarios to explore trajectories towards a seasonally ice-free Arctic Ocean.
   f. Support a standing sea ice forecasting 'Community of Practice', that addresses all forecast scales, through innovative networking.

2. **Explore the breadth of consequences of a seasonally ice-free Arctic Ocean across human and natural systems**
   a. Develop capability to link sea ice prediction products to measures of change in marine ecosystems and impacts on Arctic communities, across temporal and spatial scales – from local to regional to basin scales.
   b. Build on the 'Sea Ice for Walrus Outlook' to determine specific information needs of the affected stakeholders, modify standard ice prediction products where possible to address these needs.
   c. Prioritize observation sites for investigating linkages between sea ice, marine ecosystems, and impacts.
   d. Develop suitable measures of marine ecosystem change, identify at-risk infrastructures and ecosystem services.
   e. Advance research on the interactions between Arctic sea ice and societal aspects such as energy and large-scale resource development, transportation, territorial issues, and impacts on ecosystems and living conditions of Arctic residents.

3. **Assess how Arctic sea ice changes affect mid-latitude weather and climate**
   a. Identify the impacts of sea ice loss on patterns of atmospheric circulation and precipitation, oceanic circulation both within and beyond the Arctic including the meridional overturning circulation in the Atlantic Ocean and weather patterns in middle latitudes.
   b. Convey the importance of uncertainties and potential surprises and develop a probabilistic framework for use by decision-makers.
   c. Advance research on the interactions between Arctic sea ice and global physical systems such snow cover extent, ocean and atmospheric circulation patterns, mid-latitude effects.

DRAFT GOAL #2: Understand the Consequences of the Loss of Shallow Permafrost on Arctic and Global Systems

The arctic landscape is likely to undergo substantial change in response to climate warming. Essential characteristics of the arctic landscape are controlled by its unique climate and by permafrost. Relatively rapid degradation of shallow permafrost caused by climate change has the potential to adversely affect human infrastructure, alter arctic ecosystem structure and function, and increase greenhouse gas emissions. It is, therefore, imperative to address fundamental gaps in scientific knowledge of the arctic to support planning, management, and climate policy efforts. With particular respect to greenhouse gas emissions, shallow permafrost degradation has the potential to result in enhanced emissions of carbon dioxide, methane, and nitrous oxide. Enhanced emissions of these gases – especially methane – could create a positive feedback loop in which future climate warming causes further degradation of permafrost, which releases more greenhouse gases, which leads to further warming. Such a feedback loop could result in accelerated warming throughout the globe, which will strongly impact ongoing climate mitigation efforts and climate adaptation planning. This feedback loop, and the potential damage and costs it could generate, highlights the strong global connections between lower latitude sources for greenhouse gases and environmental dynamics in the Arctic. Specific science knowledge and data gaps of critical importance about the consequences of loss of shallow permafrost are identified in the following objectives.

Objectives (5-Year Timeframe)

Science Objectives:

1. **Improve prediction of the nature, timing, and location of permafrost thaw.**
   - **a.** Identify indicators of change in the state of permafrost, to serve as early warning signs for possible tipping points in the state of the arctic system.
   - **b.** Determine which arctic landscapes are most sensitive to permafrost thaw and pose the greatest risks to human infrastructure and to ecosystem services.
   - **c.** Develop models and probabilistic forecasting tools to quantify uncertainties in the timing and extent of permafrost thaw in the next few decades and centuries.
   - **d.** Characterize the extent and rates of degradation of sub-sea permafrost.

2. **Improve prediction of how permafrost loss will influence ecosystem structure and function.**
   - **a.** Refine estimates of the total mass and quality of soil carbon by depth and region.
   - **b.** Identify the key variables that are likely to control the mobility and availability of carbon from thawed permafrost and how this carbon will be processed by microbes or sunlight.
   - **c.** Support field and modeling efforts to predict how climate change and permafrost loss will alter surface energy and water fluxes at local to regional scales.
   - **d.** Support laboratory, field, and modeling efforts to estimate the amounts of critical greenhouse gases (CO_2, CH_4, and N_2O) released to the atmosphere in the future as permafrost thaws.

3. **Improve prediction of how permafrost degradation will influence ecosystem services including wildlife, and human infrastructure and communities.**

a. Identify important physical, chemical, and biological changes that are likely to occur in the arctic landscape as permafrost thaws.
b. Determine how these changes will affect soil stability, vegetation communities, and the distribution and availability of water.
c. Identify how these factors will influence game and non-games species – especially migratory species.
d. Determine how ecosystem services that are critical to human existence in the arctic will change. This goal ties directly to the "Human Dimensions" goal.
e. Determine the costs of mitigation or replacement of infrastructure that will be at risk from thawing permafrost.

Coordination Objectives:

4. **Identify gaps in arctic observing network datasets and the resources needed to fill those gaps.**
   a. Position SEARCH to coordinate observing efforts focused on permafrost dynamics, identify gaps, and encourage individual science projects to produce data that will complement the data collected by various data collection and observing networks.
   b. Help coordinate the exchange of data necessary for modeling studies and review how model predictions identify new needs for data from observing or data collection networks.

5. **Identify partners who can facilitate the science objectives in support of the SEARCH effort for Understanding Arctic Change.**
   a. Prioritize knowledge required to support our understanding of how changing permafrost affects the arctic landscape.
   b. Work directly with key partners such as NASA's Arctic-Boreal Vulnerability Experiment (ABoVE), DOE's Next Generation Ecosystem Experiment (NGEE), and DOI's Landscape Conservation Cooperative (LCC) initiative, to leverage resources to achieve the greatest science benefits.
   c. Explore whether industry partners would be willing to share proprietary data that could help fill gaps about the spatial (and perhaps temporal) distribution of permafrost characteristics.

Stakeholder Objectives:

6. **Improve delivery of information and knowledge about change in the arctic landscape to stakeholders.**
   a. Ensure a steady flow of information about the status and findings of permafrost-related science efforts.
   b. Develop effective means to communicate findings and progress in ways that appeal and are useful to the public and to non-technical decision makers.

7. **Create opportunities to receive feedback about permafrost degradation from stakeholders.**
   a. Identify opportunities/mechanisms to ingest experience and knowledge that could help achieve the Science Objectives.

Goal #3: Improve Predictions of Future Land-ice Loss and Impacts on Sea Level

Land ice loss—especially from northern hemisphere glaciers and the Greenland ice sheet—now exceeds thermal expansion in its contribution to rising sea level. While the loss of glacier mass has continued for the past few decades, with a slight increase in recent years, the rate of mass loss from the Greenland ice sheet has dramatically increased in the past decade and continues to increase. These rapid changes are the result of increased discharge from grounded ice into the ocean and from increased ice melting that more than outweigh increases in surface accumulation. In light of these observational facts, it is unsettling that neither quantitative prediction of future land ice loss nor credible estimation of an upper bound of future sea level are possible (IPCC, 2007). Correcting this situation requires a predictive understanding of the processes responsible for land ice loss.

Greenland contains enough ice to raise sea level an average of 6.5 meters. Glaciers and ice caps, occurring mostly in the Arctic, could contribute an additional 0.35 meters. Roughly one third of people live at or near the coast and will be directly affected by rising sea level. The direct impacts of a one-meter sea level rise include the displacement of over 100 million people, loss of nearly one trillion dollars in global GDP and the flooding of 2.2 million km2 (Anthoff et al., 2006). Effective mitigation or adaptation strategies to respond to higher future sea level require credible and accurate projections of future land ice loss.

Objectives (5-Year Timeframe)

1. Determine the Impact of Ocean Waters on Tidewater and Outlet Glaciers

Observations of the spatial patterns and magnitudes of land-ice loss indicate the dominant role ocean heat has in forcing increased ice discharge. Process studies that include circulation of the water near the ice, rapid melting of floating glacier tongues, calving at the glacier terminus, and inland propagation of these changes are at an early stage.

a. Collect bathymetric data proximal and sub-glacially on a number (5-10) large and/or recently responsive tidewater glaciers (including ice sheet outlet glaciers).
b. Develop, adapt, and deploy oceanographic instrumentation to monitor water properties in the vicinity of active tidewater glaciers. Link oceanographic measurements with simultaneous measurements of ice flow and calving.
c. Expand modeling efforts to simulate the intense interactive processes at play between ocean and ice in narrow fjords.
d. Through a combination of existing observations and new models, link oceanographic circulation on continental shelves, extending into the fjord environments, with oceanographic conditions in the deeper ocean and atmospheric patterns.

2. Determine the Intra-annual and Inter-annual Impact of Surface Melting on Land Ice Discharge

It has recently been discovered that meltwater formed at the surface of an ice sheet can cause a large and sudden increase in ice flow speed. A new functional relationship between the

forcing effect of surface meltwater and resulting increases in ice flow must be determined based on extensive field observations to properly incorporate this effect in predictive models of future ice sheet behavior.

a. Collect and analyze new data on surface melt fluxes and corresponding three-dimensional ice motions over multiple seasons and years.
b. Explore whether advanced ice-penetrating radar systems can provide information on the evolution of englacial and subglacial hydrologic networks.
c. Broad-based monitoring of supra-glacial lakes linked to atmospheric information could be exploited to seek predictive relationships between atmospheric conditions and the filling and draining of supra-glacial lakes and any consequent change in ice flow.

3. Improve Predictions of Pan-Arctic Surface Precipitation and Methods to Accurately Downscale Precipitation Patterns to the Glacier Basin Scale

Precipitation and melting are major components of determining the overall growth or loss of land ice. Nearly half of the ice loss experienced by the Greenland ice sheet during the past 50 years has been attributed to changes in its surface mass balance (sum of all accumulation effects minus all ablative effects). Meteorological modeling of precipitation patterns over the large ice sheet are robust in the relatively broad, featureless interior, but more difficult at the mountainous coast and very poor in the alpine regions occupied by much of the remaining Arctic land ice. Global circulation models provide the best predictions of future precipitation magnitude and distribution but lack spatial detail. Downscaling GCM data to account for the influences of local orography is poorly developed and must be improved. This is a relatively specialized area of climate modeling, but requires attention before it becomes the limiting uncertainty in projections of future land ice loss.

a. Meteorological modeling of alpine environments should be expanded to include the various components of glacier accumulation and ablation.
b. Test areas where densely sampled data in both space and time exist should be incorporated into meteorological models at both the local scale (0.1 – 1 km) and meso-scale (10 – 100km) to investigate accurate downscaling strategies.

4. Quantify the Regional Pattern of Relative Sea-level Change Driven by the Predicted Pattern of Land Ice Loss

The magnitude of future sea level is usually stated as a globally averaged value.Regional changes in sea level can vary up to many tens of percent from the global mean depending on how additional water from lost land ice and thermal expansion of the upper mixed layer of the ocean are distributed by ocean currents and the changes in the gravity field resulting from changes in mass redistribution (Mitrovica et al., 2001). Because much of the expected land ice loss is sourced in various locations distributed across the Arctic, the variability of sea level change is expected to be particularly large in the Arctic.

a. Global gravity models should be employed to explore the possible patterns of isostatic (i.e., local) sea level change. Recent observations of ice mass loss can be extrapolated to future decades. Along with predictions of possible future land ice loss these future patterns provide a rich sample space within which ranges of possible and likely sea level change across all Arctic coastlines.
b. The ever-increasing set of observations of local sea level can be compared with predictions based on the observed pattern of land ice loss to improve the veracity of gravity models.

Goal #4: Analyze Societal and Policy Implications of Arctic Environmental Change

Against the backdrop of rapidly changing Arctic environments, it is critical to understand how people living in the Arctic perceive, understand, and respond to these changes. Additionally, decisions made outside of the Arctic both affect Arctic environments, and are affected by Arctic change through global physical and socioeconomic linkages. Consequently, it is also imperative to understand how Arctic realities and science are perceived outside the Arctic, and how these perceptions, accurate or not, influence the development of policy. Arctic realities can vary dramatically across time and place, requiring collaboration with local communities in the careful investigation, analysis and communication of studies for the most comprehensive understanding in place and at regional, national, and global levels. As Arctic societies perceive, anticipate and respond to Arctic change, their active role complicates modeled and other natural science prediction. Human response, shaped by cultural norms and other social and economic forces, is most appropriately studied through social research. Therefore, to address human responses to Arctic change both within Arctic societies, and in the more distant but also critically involved society outside the Arctic, goal #4 requires strong linkages with social science.

Objectives (5-Year Timeframe)

1. Understand Arctic inhabitants' innovative responses to rapid environmental change and design methods to identify and anticipate future innovations accordingly.

a. Summarize findings to date on how Arctic communities, both urban and rural, are perceiving, understanding, responding and adapting to Arctic change.
b. Generate a comprehensive assessment of societal response based on that summary.
c. Develop community-relevant scenarios of sea ice loss, permafrost degradation, coastal erosion, and other environmental change that will affect communities into the future.
d. Develop methods to anticipate societal response, using empirically-based predictions and scenarios that address emerging challenges and planning needs, for example with respect to relocation of threatened communities, changes in transportation modes and routes, and access to and location of resources.
e. Test those methods by conducting cross-sectional and longitudinal studies of responses, policies, and unintended consequences of change (such as sea level and weather effects) to provide insights for near-future choices.

2. Assess and improve public and policy perceptions and knowledge about Arctic environmental issues

a. Design and conduct rigorous studies of perceptions and knowledge about Arctic environmental issues among the general public, Arctic residents, and other stakeholders.
b. Evaluate the progress to date, the gap in and the successes and failures of, efforts to communicate and educate the broad public about Arctic change.
c. Develop innovative ways to strengthen those efforts especially through effective outreach and education approaches that build on the findings of this research.