

Protocol Development Summary

Protocol: Snow and Ice

Parks Where Protocol will be Implemented: BELA, KOVA, CAKR, NOAT, GAAR

Justification/Issues to be Addressed

This vital sign is primarily concerned with seasonal snow, seasonal river and lake ice, seasonal to inter-annual aufeis, and long-term glacial ice; sea ice is treated in a separate protocol. Seasonal snow, river and lake ice, and long-term glacial ice are dominant ecosystem influences in ARCN parks. Snow affects landscape vegetation patterns, drainage patterns, nutrient cycling, water quality, productivity of plants and animals, the degree and types of disturbance events, the timing of migratory and breeding events of organisms, predator-prey relationships, and the distribution of plants and animals. River and lake ice formation, thickness, and breakup are also key indicators of regional climate, especially in the data-sparse regions that characterize much of the network, and they exert dominant controls on aquatic productivity and aquatic ecosystem dynamics. In some areas of GAAR, changes in glacier ice also impact the landscapes, and these changes influence both terrestrial ecosystems via changes in glacier area and local microclimate, as well as stream ecosystems through impacts to the timing and flux of freshwater and sediments.

Snow and river and lake ice are seasonal features which give us integrative information on the duration and severity of winter. Glaciers are persistent landscape features that give us integrative information of the decadal-scale climate trends. Comprehensively, measurements of all these features give us information on intra- and inter-annual climate trends that cannot be achieved through weather stations alone.

Specific Monitoring Questions and Objectives to be Addressed by the Protocol:

Monitoring questions:

1. Snow Monitoring Questions:

- Are spatial patterns of snow thickness, timing, and extent changing over time?
- What weather patterns and other climate factors control these variables?

2. Glacier Monitoring Questions:

- What can glaciers tell us about the climate of the past?
- How are glacier extents and volume continuing to change, and what does this tell us about current climate?
- If current climate trends continue, when will the glaciers disappear?

3. Lake and River Ice Monitoring Questions:

- Is the timing, duration and thickness of ice on lakes and rivers changing?
- Where does aufeis typically occur in ARCN, how has this varied in the past, and what does this imply about groundwater baseflow?

4. Vital sign linkages:

- What feedbacks exist between snow and vegetation and how are these influencing ecosystem form and dynamics?

- How does glacier loss and its associated reduction in sediment flux affect aquatic ecosystems?
- How is earlier lake and river ice breakup impacting aquatic ecosystems and biogeochemistry?

Monitoring Objectives are as follows:

1. Snow Monitoring Objectives:

- a) Determine long-term trends and variability in snow depth, phenology, and distribution in ARCN parks.
- b) Track daily and annual snow accumulation at selected climate stations in and near ARCN and compare snow data with other weather and climate parameters.

2. Glacier Monitoring Objectives:

- a) Monitor long-term changes in the location and extent of glaciers and perennial snow in GAAR, NOAT, and KOVA using aerial photography, satellite imagery, landscape profiling, and field surveys at selected glaciers.
- b) Monitor mass-balance and glacier-landcover interactions including paleoclimate coring at selected glaciers.

3. Lake and River Ice Monitoring Objectives:

- a) Monitor long-term trends and changes to the timing, duration and thickness of ice on ARCN lakes and rivers.
- b) Determine areas of aufeis in ARCN parks and monitor changes to aufeis location, extent, and duration and impacts to the surrounding hydrological network.

4. Relate changes in snow, river and lake ice, and glaciers to critical environmental drivers such as temperature, precipitation, evaporation, hydrology, and landcover.

Basic Approach:

The monitoring plan for “Snow and Ice” is designed to not only address these features as park resources themselves, but their impact on the overall ARCN ecosystem and other vital signs. Like the other vital signs, the plan is an optimization process, considering economics, logistics, wilderness values, and reliability of measurements. Because of the spatial scales involved, the necessity for human involvement in measurements, and the relative simplicity of some measurement techniques, this plan includes collaboration with local residents.

Snow Monitoring

Measurement of arctic snow is expensive and difficult even when human observers are available, thus this plan focuses on optimizing automated and human measurements and prioritizes integrative, accurate metrics. Snow fall is difficult to measure accurately in part due to wind redistribution, whereas end-of-winter snow thickness and water equivalent are comparatively easy and valuable data to measure. To improve quality assurance and control as well as failure redundancy, automated weather stations will utilize more than one type of sensor typically, and an automated camera taking pictures of a snow stake. These data will add to and be compared with other snow monitoring sites near ARCN parks. Nearby Kanuti National Wildlife Refuge currently has an aerial snow marker course and there are SNOTEL sites at four locations on the eastern

boundary of ARCN (Imnaviat Creek, Atigun Pass, Coldfoot, and Gobblers Knob) and one site between NOAT and CAKR (Ikalukrok Creek).

To understand overall snow-pack and long-term temporal trends, a snow-machine traverse of the network is planned once per year in late spring. Snow thickness, snow water equivalent, and snow chemistry measurements will be made at index sites along the transect with consideration for latitudinal and longitudinal (i.e., coastal to interior and montane) influences. Prior research has found that information from such traverses can be extrapolated over broad regions, as snow-packs tend to vary primarily with latitude. Snow-vegetation interactions will also be monitored at index sites. This traverse may also serve as a primary weather station deployment/maintenance mission, as overland travel is much easier in winter than summer and is significantly cheaper than alternatives involving aircraft. Field surveys of aerial snow stakes may occur via airplane one or more times per winter to increase temporal coverage and spatially extrapolate weather station measurements.

River and Lake Ice

Lake ice monitoring will occur as a nested study and focus on ice thickness as a simple integrative metric. Water temperature and weather information will be collected along with ice thickness. Other lake ice thickness measurements will be made as part of the snow machine traverse, and a more distributed set of measurements may be made at lakes near villages in coordination with local residents. Field data will be used to calibrate models to predict or hindcast lake ice freeze-up and break-up dates. River ice breakup dates provide an integrative measure of both winter and spring severity, and this could be monitored by local residents, who have an existing interest in this for transportation needs. Lake and river ice monitoring will be concentrated at sites identified for sampling for the Lakes, Streams, and Surface Water Dynamics and Distribution vital signs where possible. Both river and lake ice monitoring will be supplemented by automated cameras and remote sensing (such as Modis and SAR).

Glacial Ice

Glacier ice dynamics are closely linked with long-term climate dynamics and thus can serve as both a repository for climate information and an indicator of climate change. This plan focuses on comprehensively monitoring glaciers through the metrics of area and volume change, with intensive studies on a few glaciers to understand the mechanisms of these changes. A baseline monitoring project will photographically document the size and shape of all glaciers in ARCN through a combination of aerial and ground-based photography. New digital elevation models will be acquired to supplement other recently-acquired models to determine ice volume change through comparisons with USGS maps. This process will serve as a baseline for future volume change monitoring, to occur every 10 years or so. A representative set of glaciers will be selected for more intensive glacier-climate interaction study, such as mass balance monitoring, and one or more of these will be cored for paleoclimate investigation. Comparisons will be made between these ARCN glaciers and McCall Glacier in the eastern Brooks Range, which is the only glacier in arctic Alaska with a long-term history of research.

Principal Investigators and NPS Lead

Portocols for this vital sign will be written by the ARCN Physical Scientist (to be hired in FY 2008) with collaborative help from Dr. Matt Nolan (University of Alaska Fairbanks).

Development Schedule, Budget, and Expected Interim Products:

Matt Nolan (UAF) will conduct baseline aerial photography for GAAR glaciers in FY 2008 (budget \$27,000). A protocol will be developed and tested by FY 2010. The protocol will be peer reviewed and finalized in FY 2011.