Snow Datasets for Arctic Terrestrial Applications (SnowDATA)

Workshop Report: 31 October – 1 November 2012
Fairbanks, Alaska

Cooperative Institute for Research in the Atmosphere

Colorado State University

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Workshop Prospectus

Snow Datasets for Arctic Terrestrial Applications (SnowDATA)

A workshop directed by Dr. Glen E. Liston to define Alaska snow datasets needed by ecologists and land managers.

31 October, 9:00 am – 5:00 pm and **1 November**, 8:30 am – 12:00 noon
IARC Building, Rm. 501
University of Alaska, Fairbanks

Motivation: Snow conditions are extremely important to a wide range of hydrologic and ecosystem components and processes, including those related to surface energy and moisture stores and fluxes, vegetation, mammals, birds, and fish. The required snow datasets currently do not exist at the required spatial and temporal resolutions needed by end users such as scientists, land managers, and policy makers.

Goal: To hold a workshop attended by ecologists, biologists, and geophysicists from a range of agencies and universities in order to define the weather and snow information they require to successfully do their jobs and/or enhance their monitoring and research programs. Dr. Liston will use this information to custom-code his meteorological- and snow-evolution models to ingest appropriate datasets and to produce the required outputs; all with the goal of producing spatial maps of climate- and snow-related variables, for the past 30+ years, for northern Alaska that can be used in a wide range of climate, hydrologic, and ecosystem applications of interest to scientists, land managers, and policy makers.

Available Tools: Over the last 20 years, under a variety of NOAA, NSF, and NASA research programs, Dr. Liston has developed a snow-evolution modeling system that includes the MicroMet micrometeorological model, the SnowModel snow-process model, and the SnowAssim data assimilation model. These modeling tools can be thought of as physically-based mathematical descriptions that create value-added information (e.g., snow depth, snow density, snow hardness, rain-on-snow events, and snow cover duration) from basic meteorological variables (e.g., air temperature, humidity, precipitation, and wind speed and direction). The resulting products are based on our physical understanding of environmental processes and features, and their interactions with the atmosphere and surrounding land surface. SnowModel is unique in its representation of blowing snow processes; it includes SnowTran-3D, a model developed initially for Arctic Alaska applications, and arguably the most widely used snow transport model in the world. The model formulations are general enough to allow simulations over temporal domains spanning years to decades, and spatial domains spanning from small watersheds to all of Alaska. MicroMet can use atmospheric forcing ranging from individual meteorological stations, to gridded atmospheric (re)analysis products, to climate change scenario datasets. SnowAssim is able to ingest snow data ranging from ground-based snow observations to remote-sensing data.

Example Output Variables: Using this modeling system, daily distributions, spanning the spatial and temporal domains of interest, are possible for the following variables: air temperature, wind speed and direction, relative humidity, surface temperature, incoming solar radiation, albedo, incoming and outgoing longwave radiation, latent and sensible fluxes, rain and snow precipitation, snowmelt, blowing-snow and static-surface sublimation, blowing and drifting snow flux, snowmelt runoff, snow depth, snow density, snow water equivalent depth, snow hardness, snow trafficability index, rain-on-snow events, changes in snow and growing season lengths, hydrologic budgets, winter soil microbial activity, and snow thermal characteristics. Other output variables are possible depending on the interests of the end users (e.g., blowing snow visibility, wind chill temperature, mosquito activity index, and other variables defined during this workshop).

Example Spatial Domains:

1) Regional domain covering northern Alaska (or more), on a 1-km grid.
2) Local Arctic Alaska domain(s), on a 100-m (or finer) grid.

Example Temporal Domains:

1) 1980 through present, on hourly to daily time increments.
2) Present to future (e.g., climate change scenarios).

Pre-Workshop Preparation: As part of their workshop participation, attendees with shared interests will be asked to work together to provide a short summary (e.g., a few PowerPoint slides) of snow-related questions and data needs pertinent to their field.

Workshop Tasks: Attendees with shared interests will work together to provide a summary of key snow-related questions and data needs pertinent to their field.

Conclusions, Recommendations, and Priorities

SnowDATA Workshop Summary

- There is considerable overlapping interest and priorities among the represented groups: birds, caribou, other mammals, fish, hydrology, glaciers, vegetation, soils, and land managers.

- SnowDATA will focus on historical simulations (e.g., 1980-present) to allow improved understanding of snow-ecosystem relationships. The workshop also identified the importance of studying future snow-ecosystem interactions and impacts. SnowDATA will perform simulations driven by future climate predictions (e.g., 2050) if time allows.

- There is substantial and group-wide interest in the spatial distribution and temporal evolution of basic snow variables such as snow depth, snow density, snow-onset date, and snow-free date.

- Some new ecosystem-related snow variables (e.g., hardness and rain-on-snow icing events) will be produced as part of SnowDATA.

- Topography (digital elevation model) and land-cover data at sufficient quality and resolution are required for the model simulations of interest. In some applications, resolutions as high as a few meters are required.

SnowDATA Simulation Details

- Domain #1 (Fig. 1) will be simulated on a 2-km grid, 1980-present, to provide a general snow dataset for all users.

- Other domains (e.g., #2 and #3, Fig. 1; details such as exact locations and time periods TBD) will be simulated at higher spatial resolution (e.g., 5-100 m), and for more limited years, corresponding to existing snow-ecosystem datasets and interests. These spatial and temporal domains will be determined by communication with the Workshop participants after the Domain #1 simulations are completed. The group summaries provided in Section 5 of this document will be used to help define potential products that will be created as part of the higher resolution simulations. Decisions on additional

domains will be coordinated by the Arctic LCC, and availability of partner funding will help define the ultimate scope of the higher resolution work.

- A wide range of snow-related variables will be produced and output on a daily time increment, e.g., air temperature, wind speed and direction, relative humidity, surface temperature, incoming solar radiation, albedo, incoming and outgoing longwave radiation, latent and sensible fluxes, rain and snow precipitation, snowmelt, blowing-snow and static-surface sublimation, blowing and drifting snow flux, snowmelt runoff, snow depth, snow density, snow water equivalent depth, snow hardness, snow trafficability index, rain-on-snow events, changes in snow and growing season lengths, hydrologic budgets, winter soil microbial activity, and snow thermal characteristics.

- At least two new snow-ecosystem related variables will be developed as part of this work: an intermediate-complexity Rain-On-Snow (ROS) variable, and a snow-hardness or collapse pressure variable that relates to snow trafficability. These variables will be included as part of the model simulations and output datasets.

- Domain #1 will also be simulated using future-climate atmospheric forcing, if project time allows.

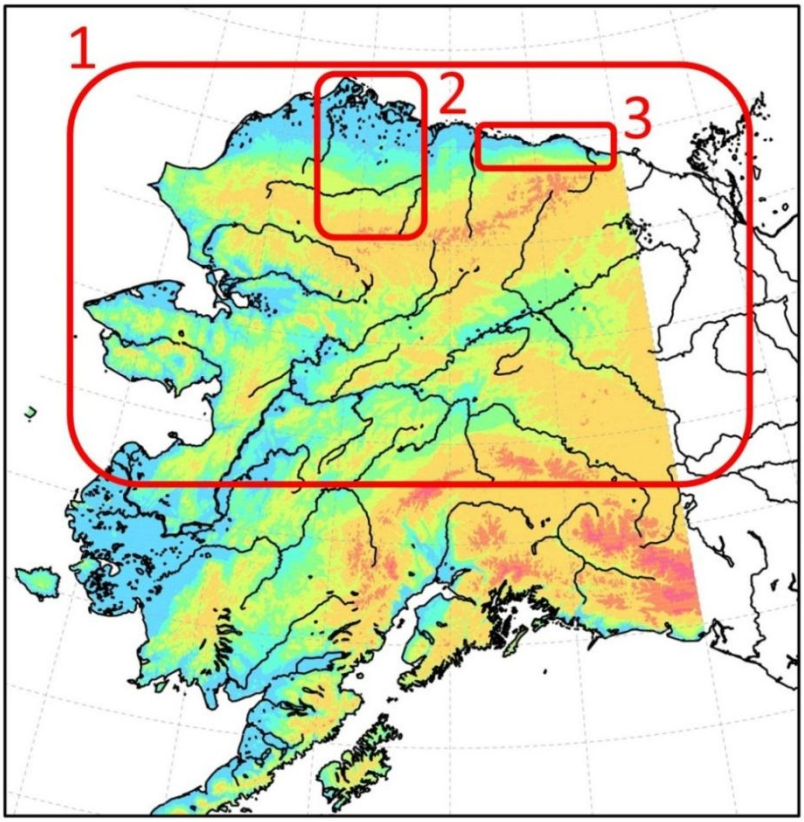


Figure 1. Example SnowDATA simulation domains. See text for discussion.

Workshop Agenda

AGENDA for SnowDATA meeting October 31-November 1, 2012

IARC Building Room 501, University of Alaska Fairbanks

Wednesday, October 31st

8:30 Check In/Registration (coffee, muffins, fruit available all morning)

9:00 Welcome (Philip Martin, Steve Gray, Glen Liston)

9:10 Introduction to Snow Modeling Tools and Datasets (Glen Liston)

10:30 Break

10:45 Group Presentations of Snow Needs (8 Groups, ~10 minutes each)

12:30 Catered Lunch

1:15 Workshop Discussion: How best to meet user snow needs using available snow models and datasets?

2:30 Break (desserts delivered)

2:45 Workshop Discussion: Define snow variables required to meet user needs, including spatial and temporal scales, and spatial and temporal domains.

5:00 Meeting Concludes

Thursday, November 1st

8:00 Doors Open (coffee, pastries, fruit available all morning)

8:30 Workshop Discussion: Continue defining snow variables required to satisfy user needs.

10:30 Break

10:45 Workshop Discussion: Prioritize our variable lists, spatial and temporal scales, and spatial and temporal domains of interest.

12:00 Meeting Concludes (lunch on your own)

Instructions for Reporting Groups

Instructions for the SnowDATA Workshop Reporting Groups

SnowDATA stands for **Snow D**atasets for **A**rctic **T**errestrial **A**pplications. **Our general workshop goal is to define the weather and snow information required to enhance the participants' monitoring, research, and management programs.** Most of our discussions will somehow include interactions among the atmosphere, biosphere, and cryosphere, with a specific focus on how these interactions are relevant to you and the systems you study, manage, and/or work within. Ultimately we will attempt to define snow- and weather-related variables that you need in order to answer your questions and improve your understanding associated with how biologic systems interact with snow and weather. Glen will then work on developing the variables we have defined for your specific application and, sometime in the not-to-distant future, will make them available to you for your work and analyses.

As part of your workshop participation each group is expected to present a 10-minute PowerPoint slide show that does the following:

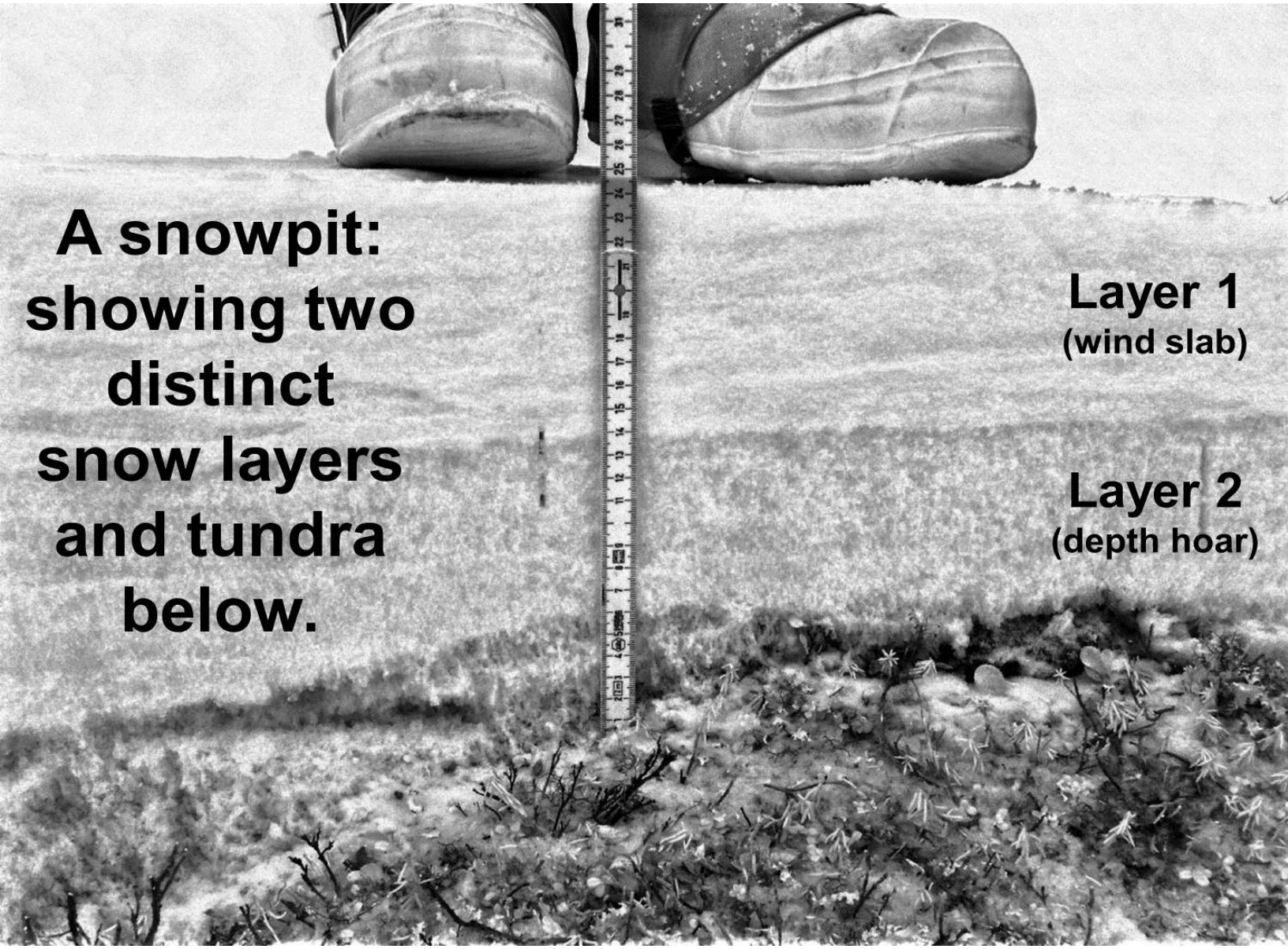
- **Introduce your expertise and interest in the workshop.** For example: (1) We study caribou on Alaska's North Slope and suspect that winter processes play a role in controlling observed caribou population dynamics. (2) We are interested in how spring snowmelt runoff influences nutrient fluxes to the Arctic Ocean. (3) I study Arctic lakes and need to know how much snow is on the lakes and the bulk thermal conductivity of that snow in order to predict end-of-winter lake-ice thickness.

- **Summarize known (or surmised) relationships between the biological and physical (i.e., snow and weather) systems within your field of interest.** Examples include: (1) Taller vegetation reduces the fraction of the snowpack available to be redistributed by wind. (2) Polar bears require snowdrifts at least 1.5 m deep by 1 December in order to dig adequate maternity dens. (3) Peak vegetation biomass in tundra occurs 20 days after the snow-free date. (4) The health of the summer caribou herd is directly related to summer mosquito activity, which increases with increasing air temperature and decreasing wind speed.

- **Provide key questions you would like to answer that somehow involve interactions among the biology and snow and/or weather.** Examples include: (1) How has the spring snow-free date changed north of the Brooks Range over the last 30 years? (2) How do the snow depth, density, and hardness change from windblown areas to forested areas in northern Alaska? (3) Have rain-on-snow events increased in Alaska over the last 30 years? (4) What is the role of shrubs in controlling snow distributions on Arctic tundra?

- **Provide a summary of the length and time scales, and spatial and temporal domains you are interested in.** For example: (1) For my polar bear maternity den application, I need to be able to resolve snowdrift depths on a 1-m horizontal grid and I need to know the snow depth on any given day during the winter; my spatial domain is Alaska's Arctic coast; my temporal domain is 10 years ago through present. (2) I need to know how the snow-free date (day) varied over Alaska's North Slope during the last 30 years on a 500-m grid. (3) I want to understand how the daily frequency of rain-on-snow events will change over the next 50 years over all of Alaska on a 1-km grid.

In addition, as part of your workshop participation, each group is expected to work together to provide a listing of Key Questions and the Variable Names, Priority, Time Increment, Horizontal Grid Increment, Spatial Domains, and Temporal Domains required to answer those questions.



Group Summaries

As part of the Workshop each group provided a list of Key Questions and the Variable Names, Priority, Temporal and Spatial Resolution, and Temporal and Spatial Domains required to answer those questions. The highlighted rows (in light blue) identify questions that can be addressed, at least in a general sense, as part of the Domain #1 SnowDATA simulations and analyses (see Figure 1 in the Conclusions, Recommendations, and Priorities section of this document).

Group Name	***Key Questions***	***Variable Names***	***Priority (1-3)***	***Temporal Resolution***	***Spatial Resolution (meters)***	***Temporal Domain***	***Spatial Domain***
Birds							
	What is the distribution of snow cover on the ACP and Seward Peninsula over the last 30 years and projected into the next 50 (important for various scientific questions)?	% snow cover	1	1 day	5	1981 to 2050, spring and fall	Arctic Coastal Plain + Seward Peninsula
	How are snow depth, density, and hardness associated with land cover type and topography? (How does snow depth impact the foraging and roosting ability of resident birds over winter (ptarmigan))?	snow depth, density, hardness	2	1 week	100	recent to current years, during snow period	Northern half of Alaska
	How protected are lemmings from predators during the snowy period?	lemming protection and predation index, snow strength, snow depth, position of ice lens in snow column	3	1 week	100	during snow period	Arctic Coastal Plain

Birds, continued							
	How does snow affect pond ice breakup, which affects soil substrate temperature and breakup date, which affects invertebrate emergence?	snow insulation on lakes and heat transfer via water from surrounding tundra	3	1 day	100		Arctic Coastal Plain
	Will the frequency of late season snow events increase?	frequency of summer snow events, duration of snow cover	3	1 day	100	1981 to 2050	Arctic Coastal Plain + Seward Peninsula
	Forcing data: We need the forcing weather data.	air temperature, relative humidity, wind speed, solar radiation	1	1 day	100	1981 to 2050	Arctic Coastal Plain + Seward Peninsula
Caribou							
	What are the historical and predicted spatial-temporal patterns of snow ablation, deposition, depth and hardness?	liquid and solid precipitation, snow depth, snow density	2	1 day	60	1979-2050	WAH, TCH, CAH, PCH
	How does the influence of snow conditions, phenology of snow melt and deposition, and vegetation type interact to affect nutritional phenology of forages for large herbivores?	snow depth, snow density	1	1 day	60	1979-2050	WAH, TCH, CAH, PCH
	How variable are these influences over space and time?	snow depth, snow density, snow hardness	1	1 day	60	1979-2050	WAH, TCH, CAH, PCH
	How does wildlife respond (migration phenology, space use, resource selection) to these factors?	snow hardness, snow depth	1	1 day	60	1979-2050	WAH, TCH, CAH, PCH

Caribou, continued							
	What is the threshold of winter severity (or suite of combined variables) that will affect caribou winter distribution, survival and reproduction?	phenology of snowmelt and deposition	1	1 day	100	1979-2050	WAH, TCH, CAH, PCH
	Can we determine icing-event layer thickness and extent using remote sensing and/or SnowModel?	rain on snow events	1	1 day	100	1979-2050	WAH, TCH, CAH, PCH
	Can wind-hardened snow be detected and mapped?	wind and storm events	1	1 day	60	1979-2050	WAH, TCH, CAH, PCH
	How do snow conditions affect energetic costs of movement and susceptibility to predation?	freeze-thaw events, rain on snow events, presence / absence of ice and type (e.g., ground vs. surface) and thickness, snow temperature, vertical structure (depth hoar?), collapse pressure	1	1 day	60	1979-2050	WAH, TCH, CAH, PCH
	What is the spatial and temporal extent of insect harassment period as well as habitat for insect relief?	air temperature, wind speed, wind direction	3	1 hour	60-500	1979-2050	WAH, TCH, CAH, PCH
	Can we predict where caribou will winter and/or give birth in any given year?		1	1 day	60-500	1979-2050	WAH, TCH, CAH, PCH

Caribou, continued							
	Can we determine if past population declines (or changes in distributions) were influenced by snow conditions?		1	1 day	60-500	1979-2050	WAH, TCH, CAH, PCH
	Can we predict them in the future?		2	1 day	60-500	present-2050	WAH, TCH, CAH, PCH
Fish & Hydrology							
	What is the depth and density of snow in Fish Creek (Nuiqsut) watershed?	depth, density, sublimation, runoff	1	1 day	5	13 year hind cast and 25 years into future	6000 km^2
	What is the depth and density of snow in Chipp River watershed?	depth, density, sublimation, runoff	1	1 day	1	2012-2062 50 years in future	7 km^2
	Can we couple SnowModel with a soil heat flux model and lake ice model to simulate spatial distributions of soil and lake-ice processes?	snow-soil column temp gradient, depth hoar thickness, ice thickness	1	1 day	1	10 years	40 km^2
	What probability of lake recharge from snowmelt given maximum extraction scenarios?	runoff	1	1 day	5	1998 - present	1000 km^2
	Estimate uncertainty in model using various input datasets from GCM, RCM (5-km) or reanalysis data.	runoff timing, snow cover extent, snow depth	1	1 day	<500		
	Index of extreme snow event (e.g., probability of 1-day max snowfall).		2				
	Listing of what goes into MicroMet (i.e., what forcing data).		3				
	What are the governing snow processes in Arctic network national parks?	depth, density, sublimation, runoff	2	1 day	100		100000 km^2 (Arctic NP)

Fish & Hydrology, continued							
	What are the key snow stratigraphy variables and features in Arctic Alaska?	snow stratigraphy (density, thermal profile, thermal conductivity)	3				
	What are the Arctic Alaska snow water equivalent distributions?	snow depth, snow density	1	1 day	100	1981-present	Arctic Alaska
	What is the role of snow on lake ice thickness among regions, lake depth, orientation, and shoreline morphometry?	depth, density, sublimation, runoff	2	1 day	10	25 years + 25 years future	1000000 km^2 (NPRA)
	What is the role of individual wind events on snow transport and metamorphosis?	snow depth, density	3	1 hour	1	10 years	10 km^2 (various)
	How does water from snowpack get into watershed storage compartments (active layer, lakes, wetlands, stream runoff)? Can snow model be coupled easily to permafrost and watershed model?	runoff, sublimation	2	1 day	1	5 years	10 km^2 (Fish Creek, Chip River)
	Can you hind cast basic snow parameters over long time periods for Arctic Alaska (e.g., Holocene)?	depth, density, sublimation, runoff	2	1 month	5000	20 kya - present	100000 km^2 (NPRA)
	Can you hind cast snow depth and distribution for Barrow region since 1918?	depth, density, sublimation, runoff	2	1 day	1000	1918 - present + 50 years future	1000 km^2 (Barrow Peninsula)
	Light penetration through lake snow at varying scales? What is the percentage of bare ice on lakes relative to snow covered ice?	light penetration	3	1 day	10	1998 - present	100 x 9 (CALON Nodes)

Fish & Hydrology, continued							
	What is the SWE of Teshekpuk over long time period?	depth, density, sublimation, runoff	3	1 day	1000	1973 - present	1000 km^2 (TLSA)
Glaciers							
	How much water comes from glaciers in the Arctic Refuge?	glacier melt runoff; winter and summer mass balance	1	1 hour	1-10	1800s to future	5000 m x 5000 m
	What are the glacier-ice evolution processes in the Arctic, and can we use point water equivalent and thickness accumulation in firn to match with ice cores?	glacier surface elevation, thickness, and area; internal accumulation rate	1	1 hour	1-10	1800s to future	5000 m x 5000 m
	How much sediment comes from glaciers in the Arctic Refuge?	sediment discharge	1	1 hour	1-10	1800s to future	5000 m x 5000 m
	How much melt water comes from seasonal snow into the Hulahula River?	snow thickness, SWE, and runoff	1	1 hour	5-100	1800s to future	100 km x 100 km
Non-Caribou Mammals							
	Muskox: Does annual variability in snow characteristics affect distribution and survival/recruitment?	depth, density, hardness	1	1 month	1000	since 1980	Colville River-Babbage River
	Muskox: Will future annual variability in snow characteristics affect distribution and survival/recruitment?	depth, density, hardness	2	1 month	1000	2012-2100	Colville River-Babbage River
	Polar Bears: What are the snow and wind conditions necessary to allow maternal polar bears to excavate dens (>1.3m)?	precipitation, wind velocity and direction, snow density	2	1 day	<5	1981-present	Arctic Coastal Plain

Non-Caribou Mammals, continued							
	Polar Bears: Can rain-on-snow events and/or saturation of snow layers result in den collapse?	precipitation, temperature	3	1 month	1000-10000	1981-present	Arctic Coastal Plain
	All Mammals: How do rain-on-snow events impact the location of ice layers within the snow cover?	precipitation, temperature	1	1 month	1000-10000	1981-present	Arctic Coastal Plain
	Brown Bears: Can we simulate the distribution of snow drifts in fall for den site selection?	precipitation, wind velocity and direction, snow density	2	1 day	<5	1985-2012	Arctic Coastal Plain
	All Mammals: Can we define the extent and duration of the open water season and its effect on initiation of ACP snow and over-all snow depth over season?	precipitation	2	1 month	1000-10000	1981-present	Arctic Coastal Plain
	Muskoxen, grizzly bears, others: What is the persistence of snow drifts though summer, which create isolated patches of green up - may affect nutritional status and distribution?	depth, density	3	1 day	30-50	1981-present	Arctic Coastal Plain
Vegetation & Soils							
	How have changing snowpacks impacted permafrost temperature? Can SnowModel be linked with a land surface model that simulates permafrost-snow-atmosphere permafrost processes?	insulation, energy balance	1	1 day	point-30	1980 to present	Alaska

Vegetation & Soils, continued							
	How is the preceding snowpack related to fire and drought?	snowmelt duration, percent of climatological average	1	1 day	100	1979-present	Alaska
	How do changing canopy properties impact snow distributions? (Canopy gaps, plant spacing, disturbances, model parameterization addressing canopy interactions).	canopy forcing, windiness, sublimation, canopy impact	1	1 hour	1 through 30	1940s to present	Alaska
	How do we surmount data resolution and access issues?	physical classification vs. floristic classification	1		1-300	1940s to present	Alaska

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