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Evaluation of Proposed ARCN Climate Monitoring Stations for Soil and Permafrost Temperature Monitoring

David Swanson,
National Park Service
4175 Geist Rd
Fairbanks, AK 99709

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Abstract

The existing and proposed new climate monitoring sites in Bering Land Bridge National Preserve (BELA), Cape Krusenstern National Monument (CAKR), Kovuk Valley National Park (KOVA), and Noatak National Park (NOAT) were evaluated for suitability as ground temperature monitoring sites for the ARCN permafrost and vegetation/soils vital signs. Ground temperature instrumentation is recommended at all sites. Ground temperatures sensors will be integrated with the Campbell Scientific instruments at the proposed new ARCN climate stations. At 5 of these stations, supplementary battery-powered ground temperature installations are recommended a short distance from the climate station to represent other environments. Battery-powered ground temperature installations are also recommended at the existing 4 Remote Alaska Weather Stations (RAWS) in these NPS units.

Introduction

Ground temperature monitoring is an important component of both the permafrost vital sign and vegetation and soils vital sign of the National Park Service Arctic Inventory and Monitoring Network (NPS ARCN). Ground temperatures are key to evaluation of changes in permafrost stability and understanding changes in plant composition and productivity. Ground temperature monitoring stations are efficiently combined with air climate monitoring stations for several reasons: both require annual maintenance visits, ground temperature data is more meaningful if combined with air climate data, ground temperature data can be stored and sent in real-time by the same system as the air data, and both need sites that are well distributed around the network and representative of its many environments. Ground temperatures will be measured at 4 depths (corresponding to the 4 data channels available), or fewer where deep excavation is not possible. The depths will typically be 5, 20, 50, and 100 cm from the surface. Ideally the lowest sensor would be in the upper permafrost, though this placement will rarely be possible with hand tools. In fine-grained material it may be possible with power tools to place a sensor deeper, e.g. at 2 m.

In some situations the air climate station proper is best placed on an elevated, rocky spot where the soil in the immediate vicinity of the station is somewhat atypical of the area in general. Here we prefer to connect one to a few ground temperature sensors to the station and in addition establish a supplementary ground temperature monitoring site nearby, typically within a few hundred meters and on a wetter site than the station proper. The supplementary site will run on batteries and require annual data downloads (i.e. it will not be integrated with the climate station's solar power and real-time data telemetry), but will receive the other benefits of association with a climate station listed above. Ground

temperature installations at RAWS stations will also require supplementary, battery operated instruments, because the RAWS hardware is not configured to allow addition of soil sensors.

In 2009 I and NPS Physical Scientist Pam Sousanes visited the proposed ARCN climate stations in BELA, CAKR, KOVA, and NOAT that are currently undergoing a NEPA evaluation process. This report summarizes the characteristics of these sites for installation of ground temperature monitoring equipment. The sites include 13 proposed new stations, 4 RAWS Stations, and one existing non-NPS research climate station. We did not visit the proposed climate stations in Gates of the Arctic National Park and Preserve (GAAR) and those stations are not discussed here.

Methods

Proposed climate stations were visited in the summer of 2009 by helicopter. I made on-the-ground evaluations of all sites listed in Table 1 except Midnight Mountain (BELA, no visit) and Kelly RAWS (fly-by only).

I evaluated the suitability of the proposed climate station tripod location for boring to place temperature sensors by a combination of observations of surface rockiness and probing with a sharpshooter-type shovel, and I made notes on patterned ground, vegetation, and other site characteristics. I explored the immediate vicinity of the proposed climate station for the availability of supplementary ground temperature sites and made similar notes.

Results

The 13 proposed new climate station sites are predominantly on dry, convex landforms with coarse-grained soils and dwarf shrub tundra vegetation (Table 1). This is the result of preferential placement of climate stations 1) at high elevations because this is currently our largest data gap, 2) on local high spots to allow an unobstructed view of the sun and telemetry satellites, and 3) on dry sites less prone to frost heave. Ground temperature installations at these sites will by necessity be shallow but still yield valuable information on mean annual ground temperature for dry sites. Six of the 13 new sites have potential for a nearby supplementary station, of which 5 were judged to be moderate to high priority. These supplemental stations would be on finer-grained, moister soils with greater vegetation cover. Sites not chosen for supplemental soil instrumentation either have no moist-soil alternative at convenient walking distance from the proposed tripod location, or the proposed tripod site is already in a moist environment representative of the surrounding area.

The 4 existing RAWS sites are on typical lowland vegetation that are a high priority for ground temperature monitoring. The ground temperature installations at these sites will be supplementary battery-powered stations near the existing stations and under similar vegetation.

The Asik - Low Elevation site is a research area maintained since 1990 by Robert Stottlemyer (Robert_Stottlemyer@USGS.gov, USGS Fort Collins Science Center, 2150 Centre Ave., Bldg. C Ft. Collins, CO 80526-8118). ARCN should consider adding this site to its ground temperature monitoring program if it is allowed to lapse by the researchers in the future.

Instrumentation of the climate stations for soils will require 30 to 35 Campbell Scientific model 107 temperature probes. Instrumentation of the 4 RAWS stations and the 5 moderate to high-priority supplementary sites will require 9 HOBO data loggers and approximately 30 HOBO S-TMB-M002 soil temperature probes.

Additional information about the sites is available in “Arctic Network Climate Monitoring Site Evaluation 2009” by Pam Sousanes (O:\Projects\ARCN00065_Climate_Monitoring_Station_Scoping_Field_Work_2009\Reports_and_Presentations\Site Evaluation\ ARCN Climate Station Site Evaluation_Final.pdf), and in the Appendix to this report. Photographs from the site visits are also available in (O:\Projects\ARCN00065_Climate_Monitoring_Station_Scoping_Field_Work_2009\Photographs\Originals\DKS*)

Table 1. Summary of Recommended Ground Temperature Installations at Proposed ARCN Climate Stations

				At Climate Station Tripod			At Supplementary Ground Temperature Site			
NPS Unit	**Climate Site**	**Latitude**	**Longitude**	**Setting**	**Installa-tion Type***	**Number of Sensors**	**Setting**	**Installa-tion Type***	**Number of Sensors**	**Priority**
BELA	Devil Mountain (2009)	66.27588333	-164.53085	Tussock tundra	B	3 or 4		None		
BELA	Ella Creek	65.27468333	-163.8196	Rock	A	1 or 2	Loamy-skeletal mudboil tundra	B	2 or 3	low
BELA	Hoo Doo Hills RAWS	65.5931	-163.4067	Tussock-low shrub tundra	None	0	Tussock-low shrub tundra	B	2 or 3	high
BELA	Midnight Mountain	65.82058333	-164.5398833	Dwarf shrub tundra	B	2 or 3		None		
BELA	Serpentine Hot Springs – Low Elevation site	65.85201667	-164.7070333	Low shrub tundra	B	2 or 3		None		
CAKR	Mt. Noak (2009)	67.14143333	-162.9945333	Dwarf shrub tundra	B	3 or 4		None		
CAKR	Rabbit Creek	67.55015	-163.5671833	Dwarf shrub tundra	B	3 or 4		None		
KOVA	Salmon River	67.4599	-159.84125	Dwarf shrub tundra	A	1 or 2	Alders	B	3 or 4	high
KOVA	Kavet Cr RAWS	67.13755	-159.0461	Spruce-tall shrub	None	0	Spruce-tall shrub	C	3 or 4	high
NOAT	Asik - Low elevation	67.47797222	-162.2136111	Floodplain spruce-shrub	**			None		
NOAT	Asik - High elevation	67.47488333	-162.2664333	Dwarf shrub tundra	B	2 or 3		None		
NOAT	Howard Pass	68.15573333	-156.8954833	Dwarf shrub tundra	B	2 or 3	Wet Loamy-skeletal, sedge-low shrub	B	2 or 3	medium
NOAT	Imelyak	67.54481667	-157.0774333	Dwarf shrub tundra	B	2 or 3		None		
NOAT	Kelly RAWS	67.933	-162.3	White Spruce forest	None	0	White Spruce forest	B	3 or 4	high
NOAT	Kaluich Creek	67.57338333	-158.4317167	Dwarf shrub tundra	A	1 or 2	Loamy-skeletal mid-tall shrub	B	3 or 4	medium
NOAT	Kugururok	68.33311667	-161.3758833	Rock	A	1 or 2	Tussock-low shrub tundra	B	3 or 4	high
NOAT	Noatak RAWS	68.071	-158.704	Wet loamy-skeletal, sedge-low shrub	None	0	Wet loamy-skeletal, sedge-low shrub	B	3 or 4	high
NOAT	Sisiak	67.99503333	-160.39565	Dwarf shrub tundra	B	2 or 3	Loamy-skeletal low shrub	B	2 or 3	medium

*Installation type codes are as follows:

A. Extremely rocky situations where probing or coring with hand tools is not possible. Sensors will be placed by excavating a small hole and replacing material in as natural a fashion as possible after placement of the sensors. Typically two sensors will be placed, one at 5 cm and a second at 20 or (if possible) 50 cm. In fractured bedrock or talus material, attempt to place a single sensor in a small crevice where it will contact as much matrix material as possible, at 20 or 50 cm depth.

B. Substrate with gravel or stones in a finer matrix. It is usually possible to hammer a hole for the sensors using a tile probe and slide hammer. Hammer as deeply as possible and install up to 4 probes at 5, 20, 50, and 100 cm depths. Install sensors even if rocks restrict us to the 5 and 20 cm depths. If the maximum penetration is between 70 and 100 cm, install the first 3 probes at the standard depths (5, 20, and 50 cm) and the 4th probe at the maximum possible depth.

C. Fine-grained material where the deepest sensor can be placed in the upper permafrost. Follow the same procedure as in #2 above. If possible, use a portable drilling apparatus to place a sensor into the permafrost at 2 m depth. If a 2 m placement is possible, skip one of the shallow sensors (preferably the 20 cm depth) to reduce the number of channels occupied.

**The Asik low elevation site is research area (see Results for an explanation)

Appendix I. Summary of climate monitoring station reconnaissance trip, NOAT and KOVA, 16-18 June 2009

16 June. Afternoon and evening visits to Howard Pass and Imilyak Cr proposed monitoring sites.

Stop 1. Rounded mountaintop with tors at 68deg 09.351min, 156deg 53.750min. Vicinity of potential tower location is *Dryas* tundra with stone nets. One could set a couple of soil temperature probes near the tower using a shovel and backfilling. Options for a supplementary soil temperature monitoring station are available to the west and north. The best options appear to be 1) the west slope of the saddle between the hill where the station would be and the next mound to the northwest, and 2) the toeslope that leads to the creek to the north. DS visited option (1) and found a wet loamy-skeletal soil with a peaty surface, *Carex, Salix, Cassiope* (68deg 09.514min, 156deg 54.055min). This is probably about a 15 min walk from the top. Soil is quite wet with some standing water now. Due to the coarse fragments there would be limited possibilities to penetrate into the permafrost here. Option (2) is a bit further away but there is a better chance to find a fine-grained soil that one could penetrate with hand tools. I recommend looking there first if this site is chosen.

Flyover of previous year's choice for Howard Pass site. There appeared to be wet patterned ground very close to this site. Pam felt that this hilltop might be a little more distracting for caribou because it has no tors and the tower would be more obvious as a result.

Stop 2. Rounded mountain further south that is also a possibility for the Howard Pass area (68deg 03.619min, 156deg 58.555min. *Dryas* tundra with stone nets again. A wetter soil is available along the drainage to the southeast, but it would likely be loamy-skeletal and hard to place sensors unto deeply, and could be up to a half hour walk.

Stop 3. The Imilyak proposed climate monitoring site (67deg 32.710min, 157deg 04.622min). This mountaintop forms the southern boundary of NOAT. We would literally have to put the tower north of the high point on this hill to stay inside the NPS boundary. *Dryas* tundra with pincushion plants. Loamy-skeletal soil with nonsorted circles. No opportunity for supplementary soil temperature stations. Flyovers of other options to the west after departing looked similar.

17 June. NOAT and KOVA climate site recon.

Stop 1. The Noatak RAWS. *Betula-Ledum-Carex-Eriophorum* tundra. Both earth hummocks and tussocks. Material is loamy-skeletal glacial till, so there could be problems penetrating permafrost. Appears to have been a little disturbance directly under the tower, but with the RAWS setup I wouldn't be trying to attach to their data logger anyway; I will have to set up a battery-powered system nearby. Lakes in this area are deeply inset, there could be relict glacial ice susceptible to thaw here. This site is representative of a very large area of the Noatak lowlands and is definitely worth monitoring.

Stop 2. The proposed Kaluich Creek monitoring site. Tripod site is *Dryas* tundra with loamy-skeletal soil, would probably need to dig a hole to get probes in. A mid- to tall-willow thicket site is available nearby (approx 15 min walk) in saddle to west at 67deg 34.486min, 158deg 26.602min, with *Salix richardsonii, Carex bigelowii, Equisetum*. Soil is still loamy-skeletal, so deep boring is not likely.

Stop 3. The Kavet Cr RAWS (67deg 08.253min, 159deg, 02.766min). Tall *Betula* shrubs with *Vaccinium uliginosum, Ledum*, some alder, sparse white and black spruce. Spruce encroachment is occurring, but trees show some snow-wind damage. This would be a good spot for a camera point. Disturbance is minor around the tower so soil probes could be quite close to it. This is a deep eolian deposit, so we should be able to get sensors down a couple of

meters. It might be worth bringing in a drill setup. Abundant rodent diggings in mineral soil and bear scratchings on a tree. This site represents a large area of the plains in the Kobuk Valley that are relatively warm but also ice-rich.

Stop 4. Nikok-Salmon interfluve potential climate site. We visited two sites in this general vicinity, the first at 67deg 28.624min, 159deg 55.110min. The landing site has dwarf shrub tundra (including *Betula*, reflecting the lower elevation here than previous mountaintop sites) on a loamy-skeletal soil (phyllite bedrock) with nonsorted circles. It was thawed to a shovel depth on 17 June and one could probably pound a couple of sensors in here with a probe. There are several small spruce seedlings here, all wind damaged. The seed source is quite far away, but obviously it's a bit warmer here than other summits. A possible supplementary site is available in a saddle to the northwest (67deg 28.747min, 159deg 55.454min), approximately 15 min away by foot. The vegetation here is low willow scrub with *Lycopodium* and scattered spruce seedlings. This site represents extensive slopes of low willows (visible as brighter green areas below the summits). Flying out I noticed a closer shrub site southeast of the landing site, check this first for a supplementary soil location if this site is chosen.

Stop 5. Nikok-Salmon interfluve potential climate site, overlooking the Salmon river (67deg 27.598min, 159deg 50.481min). This site is lower than the previous one, a bald ridge with alder thickets and invading spruce nearby. The likely tower site is *Dryas* and low birch scrub on frost-churned channery material (phyllite); one could probably get a sensor in 30 cm or so by digging. A good supplementary site is available in an alder thicket on east side of ridge just 50 m or so away (67deg 27.612min, 159deg 50.400min). Healthy spruce encroachment into alders. Also *Ribes* and fireweed in the understory. This site would represent extensive treeline alder communities and could convert to spruce forest over time. Loamy-skeletal soil will limit our ability to put sensors in deep. Thawed to 30 cm on 17 June.

Appendix II: Summary of climate station reconnaissance trip, BELA, 8-9 July 2009

8 July. Visits to Devil Mountain and Ear Mountain sites

Stop 1. On south toeslope of Devil Mountain 66deg 16.553'N, 164deg 31.848'W, east of the first thaw lake on that side of the mountain. Tussock tundra with *Ledum, Rubus chamaemorus, Sphagnum*. Peat hummocks. A mudboil exposed nearby showed saturated silty soil without rocks. Nearby thermokarst depression does not contain a uniform area that could be used as a supplementary site. Though the landform is a bit atypical (the only bedrock-controlled hill around), this site is probably representative of other tussock tundra sites in the area. Flying in and out we looked at interfluves between thaw lakes further south 1-2 km. These have a more typical landform and one could possibly put a supplementary station in a drained thaw lake basin. Would need to consider what such a station would tell us. If it showed that a recent thaw lake was not freezing back that would be interesting, but results are likely to be site-specific.

Stop 2. Ear Mountain landing strip. This is a gentle ridgetop with nonsorted circles in a channery loamy-skeletal soil. One could probably pound a hole to a rather deep permafrost table. Vegetation is sparse with *Dryas integrifolia, Oxytropis, Saxifraga oppossitifolia*. No nearby supplementary station possibilities.

Stop 3. Serpentine Hot Springs. Inspected possible site between tors west of the springs. Soil is granitic grus, vegetation is *Betula, Arctous, Empetrum*, lichens. Soil thaw is probably deep, soil temperatures may be anomalous due to geothermal heat in this vicinity. Clearance to install here seems unlikely. I suggested something across the river to the north if a lowland site here is desired. There is a repeater nearby that would be the high half of a paired site.

9 July. Visits to Hoodoo Hills RAWS and southern boundary sites.

Stop 1. Hoodoo Hills RAWS 65deg 35.717'N, 163deg 24.659'W. A small basalt plateau. Tussock tundra veg with *Ledum, Betula, Petasites, Vaccinium, Eriophorum vaginatum, Sphagnum, Rubus chamaemorus*. Rare mudboils expose very cobbly loam. Big boulders in the vicinity. The area is probably representative of extensive lava plateaus to the north and east of the site. Rocks would probably stop you before getting very deep here but a couple of shallow sensors to give mean annual temperatures would be valuable. No supplementary station options.

Stop 2. Southwest of Kuzitrin Lake (65deg 21.353'N, 163deg 19.744'W). A slope with big solifluction lobes, wetter sedge areas on treads, dryer with big boulders on risers. Vegetation is earth hummocks with prostrate *Betula, Vaccinium, Diapensia, Carex, Salix arctica*. Occasional mudboils with loamy-skeletal material. This is another site with reasonable possibility for sensors to about 0.5 m.

Stop 3. "SB2", southern boundary of park #2, 65deg 20.880'N, 163deg 32.723'W. Syenite(?) barrens. Boulders with gravel and sparse prostrate shrub vegetation. *Dryas integrifolia, Saxifraga oppossitifolia, Potentilla biflora*. Possibility for 1-2 shallow sensors here. This site is right on the park boundary.

Stop 4. "SB3" southern boundary #3, 65deg 16.302'N, 163deg 48.684'W. Rocky knob consisting of schist flags with no matrix at surface. Could install one sensor by picking away and replacing rocks. Possible supplementary station in saddle to the northwest, 65deg 16.372'N, 163deg 48.940'W. Sorted and nonsorted circles with loamy-skeletal soil. Could probably pound sensors in to 0.5 m or more. Vegetation is prostrate shrub with *Loiseleuria, Diapensia, Therorhodion, Empetrum, Dryas, Salix, Hierchloe alpine*.

Appendix III: Summary of climate monitoring station reconnaissance trip, CAKR and NOAT, 26-27 Aug 2009

26 Aug. CAKR and far western NOAT climate site recon

Stop 1. Rabbit Creek potential monitoring site, a low-elevation alternative to the Igarich site visited by Pam in 2008. 67deg 33.010', 163deg 34.029'. Dwarf shrub tundra with weak earth hummocks and nonsorted circles. *Lupinus, Betula nana, Empetrum, Arctous alpina, Artemisia arctica, Ledum, Hierchloe alpine, Dryas octapetala*. Bare patches expose small channers in loamy soil, suggesting that we could pound a probe to at least 0.5 m and probably more. No need for supplementary a site here. Site is representative of extensive low mountains and plateaus here.

Stop 2. Tasaychek Lagoon (67deg 16.590', 163deg 46.282'). Visited to gain familiarity with lagoon barriers as potential low-elevation sites to augment village stations. The lagoon barrier has driftwood over entire surface, suggesting that storm waves could wash away a weather station. Beach berm is sandy-skeletal material, probably unfrozen but gravel would hinder pounding of probe. *Leymus arenarius, Angelica lucida, Senecio pseudo-arnica, Festuca* sp*., Epilobium latifolium, Artemisii tilesii. Lathyrus maritimus*.

Stop 3. Below Mount Noak, possible low-elevation alternative to 2008 Mt. Noak site. 67deg 08.487', 162deg 59.672'. Dwarf shrub tundra. Channery metamorphic rock in loamy soil could probably penetrate with probe. No supplementary site possibilities here. Not far from trees and also possible vegetation sampling node. Dryas integrifolia, Potentilla biflora, Salix arctica, Arctous; Vaccinium uliginosum in low spots. A good site to help characterize this area of tree expansion.

Stop 4. Asik Creek research site. Landed on east side of Agashashok River, where there are 3 weather stations with soil probes, some with bear damage. Site looks like its undergoing river bar succession. *Potentilla fruticosa, Salix, Oxytropus, Hedysarum*, many young white spruce, *Dryas, Shepherdia, Bromus pumpellianus, Festuca altaica, Calamagrostis purpurascens*, few poplars.

Stop 5. Knob above Asik Creek research site, possible high-elevation alternative (67deg 28.496, 162deg 15.990'). Stongly skeletal soil here would only allow shallow probing. Could probably dig fairly deep, however. Trees reach nearly to the site as sparse krumholz. This could make it very interesting for future tree expansion. Sites has *Dryas octapetala*, lupine, *Calamagrostis purpurascens*. Its near a geologic contact between limestone and noncalcareous metamorphic rock.

27 Aug. Western NOAT climate site recon.

Stop 1. Lower elevation alternative to Imikneyak site of 2008. Located very near a USGS benchmark named "View". 67deg 59.720', 160deg 23.869'. Dwarf shrub (*Dryas octapetala*) tundra with channery metamorphic rock. Deep thaw is likely here but coarse grain size would probably preclude deep probing. Site is representative of extensive low plateaus in the area.

About 100 m to W is a wetter site with nearly complete vegetation cover and surface soil organic layer. There is probably still loamy-skeletal mineral soil under the O horizon that would prevent probing into permafrost if not before the permafrost. *Betula nana, Vaccinium uliginosum, Hierchloe alpine, Salix pulchra*, moss; earth hummocks. This spot is representative of extensive vegetated plateaus in area. Caribou were grazing there when we arrived.

Stop 2. Lower elevation alternative to the Kugururok site of 2008, 68deg 19.986', 161deg 22.557'. Site is on a gravelly knob just west of the Kugururok River. The knob proper has little vegetation and rock consists of gravel and cobble-sized blocky chert. Probing in this material would be impossible. About 50 m to the south is a potential supplementary site on tussock tundra (68deg 19.958, 161deg 22.559'). Vegetation is *Betula nana, Carex bigelowii, Eriophorum vaginatum, Sphagnum* moss, *Ledum*. Microtopography is mixed earth hummocks and tussocks. An excellent spot for access to widespread tussock tundra, plus this area is of interest for tree expansion because there is lots of young poplar on the nearby floodplain but no spruce.