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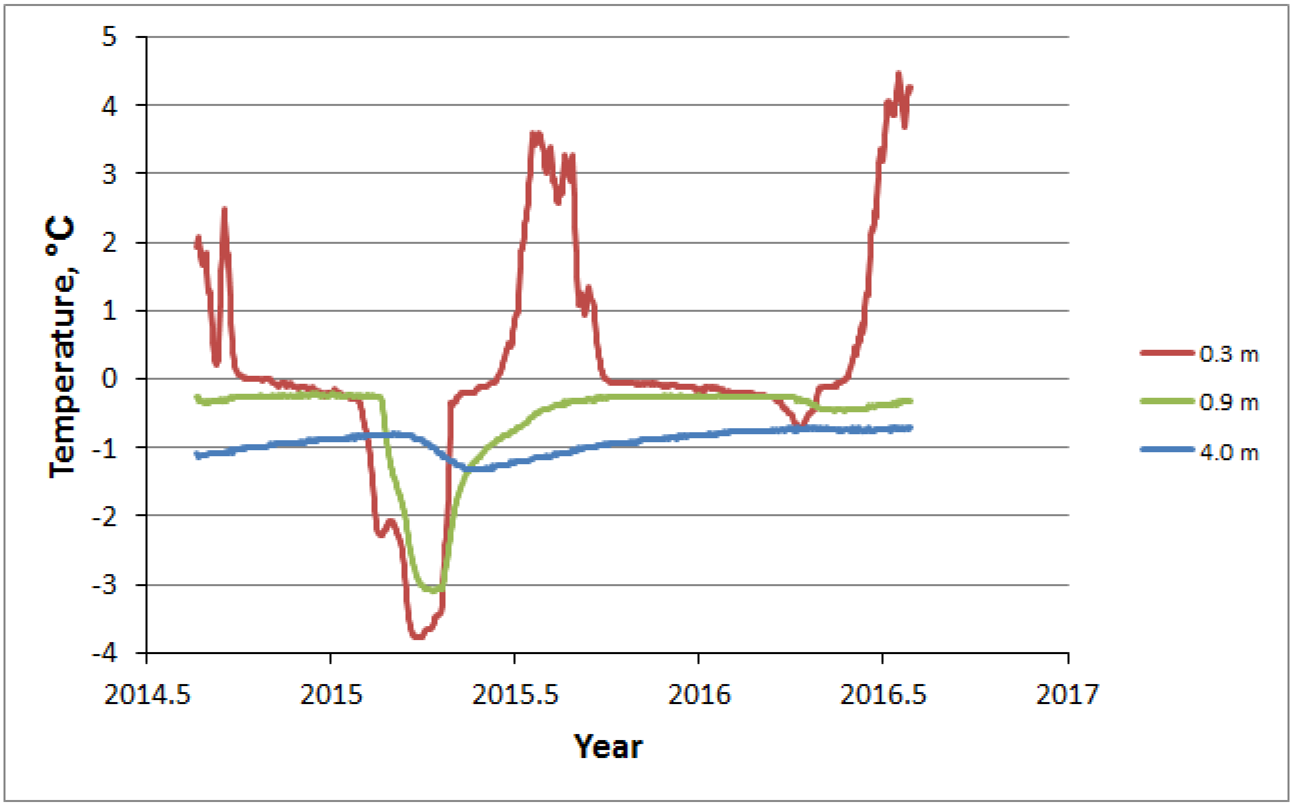
Summary of Ground Temperature Observations in the Kobuk Preserve Unit, Gates of the Arctic National Park and Preserve, 2014-2016

Natural Resource Data Series NPS/GAAR/NRDS—2016/1069



ON THE COVER

Plot of ground temperatures vs. time at location 129 in the Kobuk Preserve Unit, Gates of the Arctic National Park and Preserve. Three depths are shown, 0.3 m (1 ft.), 0.9 m (3 ft.), and 4.0 m (13 ft.). The 0.3 depth was in the active layer (the ground thawed each summer), while the 0.9 and 4.0 depths were in permafrost (temperatures remained below freezing year-round). The annual amplitude of temperature decreased greatly with depth, and temperatures were nearly constant year-round at the 4.0 m depth. During the winter of 2014-2015, the ground chilled to -2 °C at 0.3 m and -1 °C at 0.9 m. During the mild winter of 2015-2016, ground temperatures stayed close to freezing at 0.9 m and decreased less than 1 °C at 0.3 m.

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The Natural Resource Data Series is intended for the timely release of basic data sets and data summaries. Care has been taken to assure accuracy of raw data values, but a thorough analysis and interpretation of the data has not been completed. Consequently, the initial analyses of data in this report are provisional and subject to change.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

Ground temperatures were recorded at five typical lowland permafrost locations along the proposed Ambler Mining District transportation corridor in the Kobuk Preserve Unit, Gates of the Arctic National Park and Preserve, for just under two years in 2014-2016. At 3 locations we monitored temperatures at the surface and 1.8 m depth; at two other locations we monitored temperatures at 7 depths between 0.3 and 4 m depth (0.6 m vertical sensor spacing). All sensors were in permafrost except the ones at the surface and a depth of 0.3 m. The measurements show that permafrost temperatures in this area are relatively warm, near -1 °C. During the mild winter of 2015-2016, permafrost temperatures at all observation depths remained above -1° C, and mean annual ground temperatures in the upper permafrost rose above -0.5° C. Permafrost that is close to the freezing point of water is vulnerable to thaw-subsidence due to warming associated with disturbance or climate change.

Acknowledgments

Thanks to Garret Speeter of the Alaska Department of Transportation and Paul Pribyl of DOWL engineering consulting firm for installation and retrieval of the temperature monitoring instruments, data downloading, and data quality check. Thanks to Joe Durrenberger, Ambler road project manager for the National Park Service, for adding soil temperature data collection to the State of Alaska-funded geotechnical work associated with the Ambler road project and facilitating the instrument deployment and retrieval. Thanks to Joe Durrenberger, Ken Hill, and Eric Wald for manuscript reviews.

Introduction

The proposed Ambler Mining District transportation corridor in the Kobuk Preserve Unit of Gates of the Arctic National Park and Preserve (GAAR) crosses significant distances on ice-rich permafrost (Speeter 2015). Ice-rich permafrost presents special engineering challenges because of the potential for subsidence due to thaw. Ground temperature observations that would allow us to evaluate the thaw-stability of permafrost in this region were lacking prior to the present study. Soil temperature sensors were installed in August 2014 to evaluate the thaw-susceptibility of the permafrost in this area, and this report summarizes these observations.

Methods

Ground temperature data were obtained from 5 sites in the Kobuk Preserve Unit (KPU) (Table 1, Fig. 1). Ground temperature sensors were installed between 19 and 23 August 2014 by Garrett Speeter (Engineering Geologist, Alaska Department of Transportation and Public Facilities) and Paul Pribyl (Geologist, DOWL engineering consulting firm) during geotechnical drilling investigation of the proposed Ambler Mining District access road through the Kobuk Preserve Unit of Gates of the Arctic National Park and Preserve. For a full report of their field and laboratory work, see Speeter (2015). Sensors were retrieved on 27 July 2016 and provided just under two years of continuous data. Sensors were located in typical lowland permafrost terrain along the proposed transportation corridor routes (Table 1, Fig. 1, and Speeter 2015).

Two instrumentation setups were used (Table 1). Three HOBO (Onset Computer Corporation) U23-003 data loggers (serial numbers 10580599, 10580600, and 10580601) were installed with two sensors each, one at the surface and one at the 1.8 m (6 ft.) depth. These are labeled below as locations "599", "600", and "601". Temperatures were recorded at hourly intervals. A fourth HOBO data logger (serial number 16580602, area 2, traverse 5 hole 14-1135) failed, and no data are reported here. Deeper sensor strings (logger numbers DLB00129 and DLB00136) were installed at two sites and are referred to below as locations "129" and "136". These consisted of a D405 data logger by Beaded Stream LLC (Anchorage, Alaska) with sensors at 60 cm (two-foot) intervals from 0.3 m (1 ft.) to 4.0 m (13 ft.) depth. Temperatures were recorded 4 times per day at all sensor depths. Additional sensors on these strings were arrayed along the cable above ground in conduit and in the logger box and are not reported here.

All data were continuous over the study time period except at location "136", which between 27 Jan and 16 Feb 2015 had data missing for 12 days and had only one daily observation for the 9 other days. The sensor array at location "136" was pulled out by a bear on 15 June 2016 and thus has a shorter period of observations that the other sensors, which were retrieved on 27 July 2016.

I computed the maximum temperature at each depth for calendar years and the minima for each winter. I discarded the first week of observations after installation to allow time for the temperatures to re-equilibrate after the drilling disturbance.

Table 1. Sensor locations and site information[1]

DOT Hole ID, Area, Traverse	Data Logger ID	General geologic description	Vegetation	Latitude, decimal degrees	Longitude, decimal degrees	Sensor depths, m (ft.)	Date Range
14-1137 Area 2 Traverse 6	HOBO U23 10580599 "599"	Frozen silt	Deep tussocks, blueberries, black spruce 10-15 feet tall	67.01749	-154.32578	0, 1.8 m (0, 6 ft.)	8/21/2014-7/27/2016
14-1161 Area 3 Traverse 7	HOBO U23 10580600 "600"	Silt with massive ice	Deep tussocks, black spruce 2-10 feet tall	66.90474	-154.52248	0, 1.8 m (0, 6 ft.)	8/23/2014-7/27/2016
14-1124.5 Area 1 Traverse 2	HOBO U23 10580601 "601"	Ice-rich silt and massive ice	Tussocks, grasses, black spruce 3-10 feet tall	67.03235	-154.72554	0, 1.8 m (0, 6 ft.)	8/19/2014-7/27/2016
14-1101 Area 1 Traverse 1	D405 DLB00129 "129"	Ice-rich silt and massive ice	Willows, tundra grasses, scattered black spruce	67.03971	-154.7386	0.3, 0.9, 1.5, 2.1, 2.7, 3.4, 4.0 m (1, 3, 5, 7, 9, 11, 13 ft.)	8/19/2014-7/27/2016
14-1125 Area 2 Traverse 4	D405 DLB00136 "136"	Deep ice-rich silt over glacial outwash (silty gravel)	Tussocks, grasses, scattered black spruce	67.01936	-154.29814	0.3, 0.9, 1.5, 2.1, 2.7, 3.4, 4.0 m (1, 3, 5, 7, 9, 11, 13 ft.)	8/22/2014-6/15/2016

[1]Locations and site data from Speeter (2015)

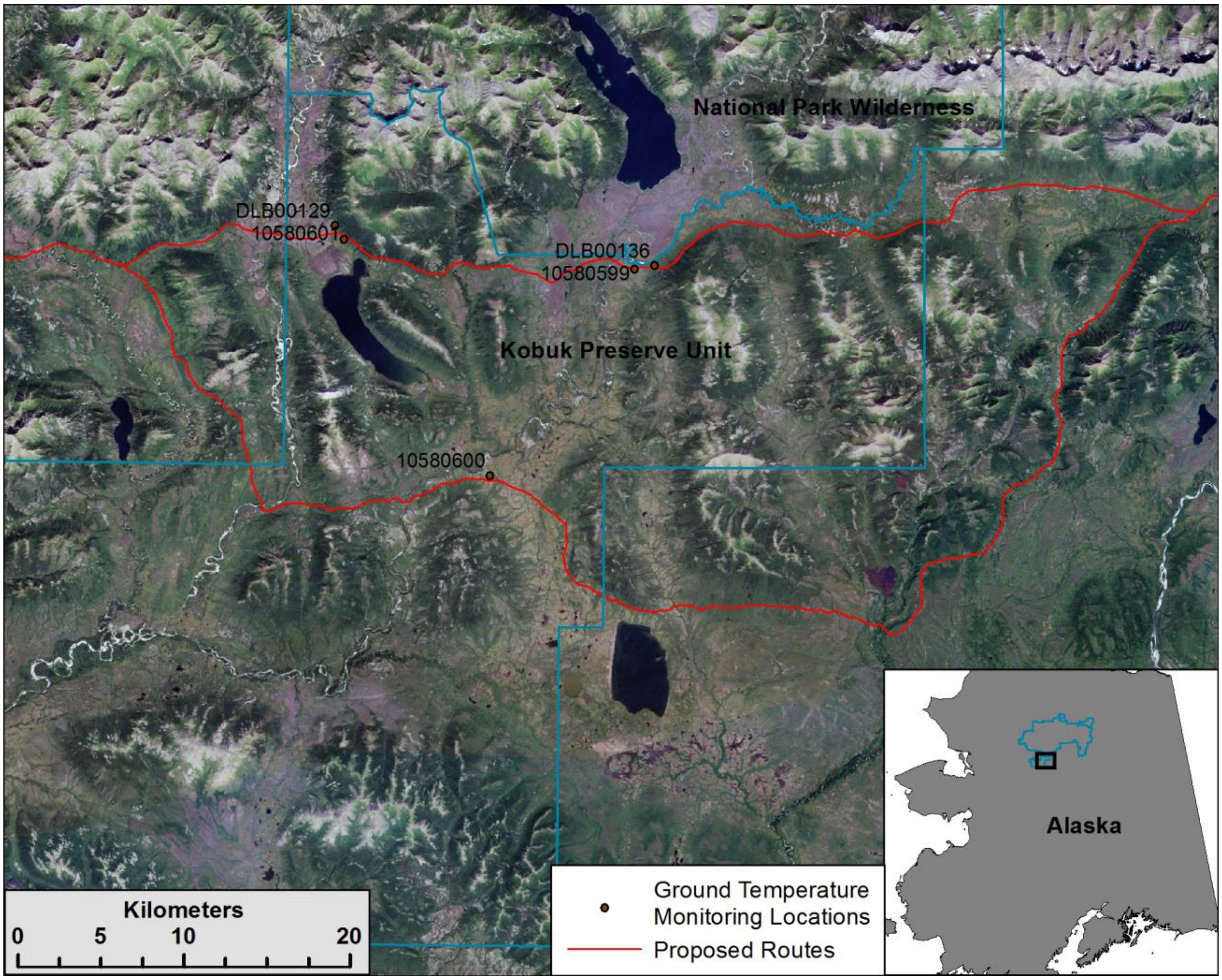

Figure 1. Locations of the ground temperature monitoring in the Kobuk Preserve Unit, Gates of the Arctic National Park and Preserve. Proposed routes for the Ambler mining district transportation corridor are shown in red.

Mean annual ground temperatures (MAGT) were computed as follows. I computed daily means from the multiple daily readings. From the daily means, I computed the mean annual ground temperature for all available 365-day spans of consecutive data. This method for computing MAGT (as opposed to calendar years) allowed me to analyze changes in MAGT during the entire study time period, even though less than two entire years of data were available. The short periods of missing data in January and February, 2015, at location 136 were dealt with as follows. Temperatures changed very little across the days with missing data, due to snow cover and natural damping of ground temperatures by the overlying soil. The temperature change across data gaps was less than 0.1 °C at all depths and for all periods of missing data, except at the 0.3 m depth, where changes of 0.3 °C in six days, 0.2 °C in two days, and 0.1 °C in five days were observed. Thus I estimated the missing daily means by a simple linear interpolation of daily temperatures across the missing days to fill these data gaps and computed the MAGT using these estimates.

Long-term National Weather Service data for Bettles, Alaska (monthly mean temperatures and monthly total snowfall) were obtained from the Applied Climate Information System (ACIS 2016). I computed mean annual air temperature at Bettles using the monthly means, weighted by month length.

Results and Discussion

At the 3 sites with two sensors (at the surface and 1.8 m depth: "599", "600", and "601"), summer and fall ground temperatures at 1.8 m were quite constant and within a few tenths of a degree below freezing, indicating frozen soil that was close to thawing but thermally buffered by the water-ice phase change. During the winter of 2014-15, temperatures at these three sensors decreased to temperatures between -2.6 °C to -4.9 °C, but in the winter of 2015-16 they chilled much less, to -0.4 °C to -0.8 °C (Fig. 2, Table 2).

Mean annual ground temperatures (MAGT) provide an estimate of the deep permafrost temperatures that would equilibrate with these near-surface conditions. MAGTs for the first year of observations at 1.8 m at locations 599, 600, and 601 were -1.0 °C to -1.6 °C, rising to -0.3 °C to -0.4 °C in the second year (Table 2). Mean annual temperatures at the surface were higher than MAGT at 1.8 m depth: the surface MAGT was slightly below freezing during the first year of this study but well above freezing by the end of the study period. MAGT typically declines from the surface to the top of permafrost, a phenomenon known as "thermal offset" (Burn and Smith 1988). In our case the large difference between the surface and 1.8 m MAGT in the second year of the study was probably due to the combined effect of thermal offset and lag in penetration of warmth to depth during this exceptionally warm year.

The two deep sensor arrays ("129" and "136") provide a similar picture (Fig. 3; Tables 3 and 4). The sensors at 0.3 m (1 ft.) depth were in the active layer and those at 0.9 m (3 ft.) depth and below were in the permafrost. More winter chilling occurred near the surface in the winter of 2014-15 than in 2015-16. In fact, temperatures stayed at -1 °C or warmer at all observation depths through the winter of 2015-16 at these two locations. As a result of thermal offset, the MAGT in the active layer at 0.3 m (1 ft.) depth was warmer than at the sensors in the permafrost. The MAGT at 0.3 m (1 ft.) depth at location 129 was barely below freezing in the first year (-0.1 °C) and rose above freezing in the second year (+0.5 °C) while at location 136 the sensor at 0.3 m (1 ft.) depth had MAGT above freezing in the first year (+0.6 °C) and rose to +0.9 °C in the second.

MAGTs in the permafrost were near -1 °C at location 129 and -0.5 °C at location 136 during the first year. The MAGT of the upper permafrost warmed in the second year both locations to -0.3° C at 0.9 m depth, with less warming at greater depths. Temperatures at the greatest depths, 3.4 m (11 ft.) and 4.0 m (13 ft.), hovered year-round near the MAGT and changed little between the first and second years.

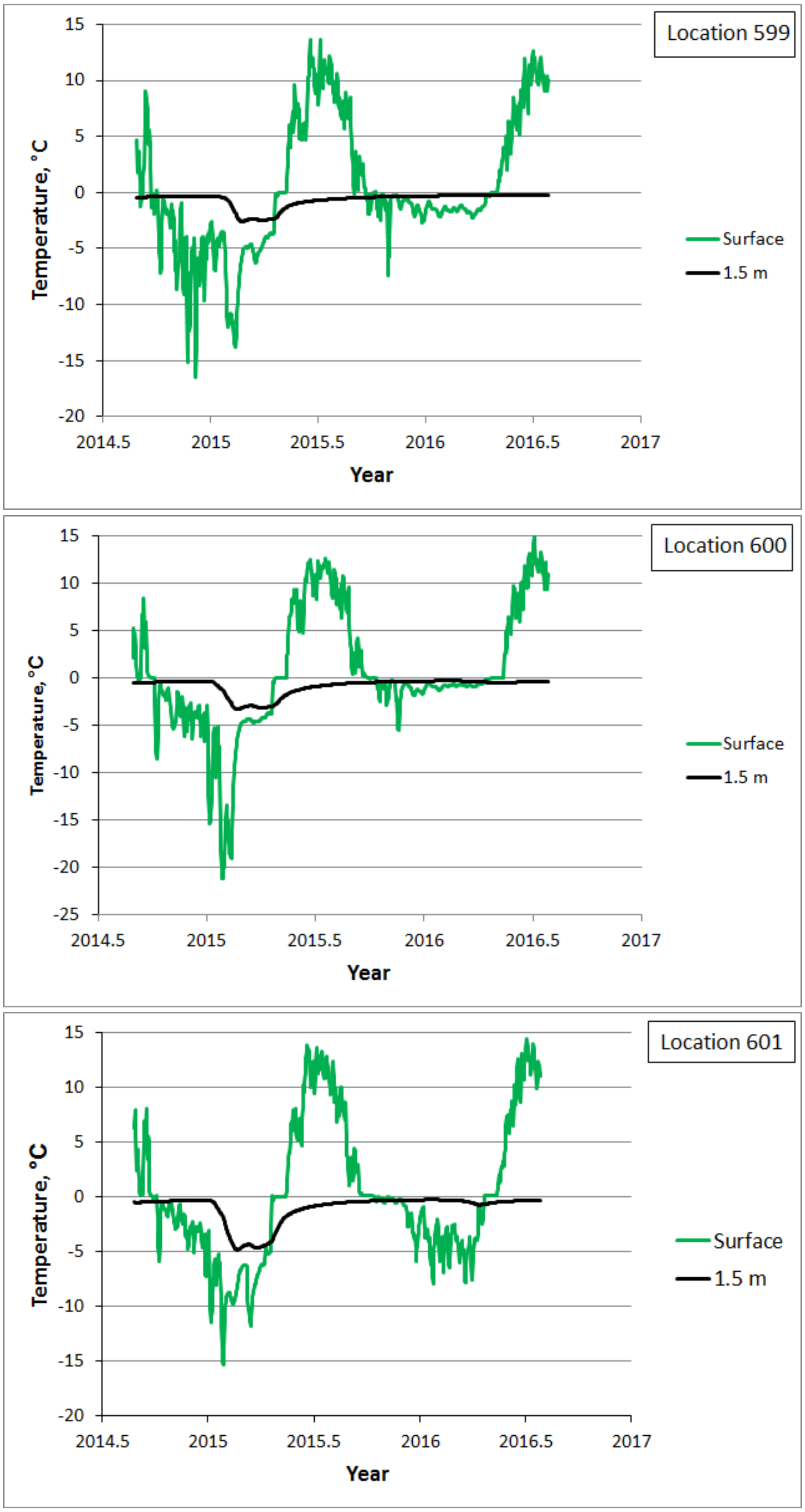

Figure 2. Plot of ground temperature vs. time at locations 599 (upper), 600 (center), and 601 (lower) for two depths, the surface and 1.5 m (6 ft.).

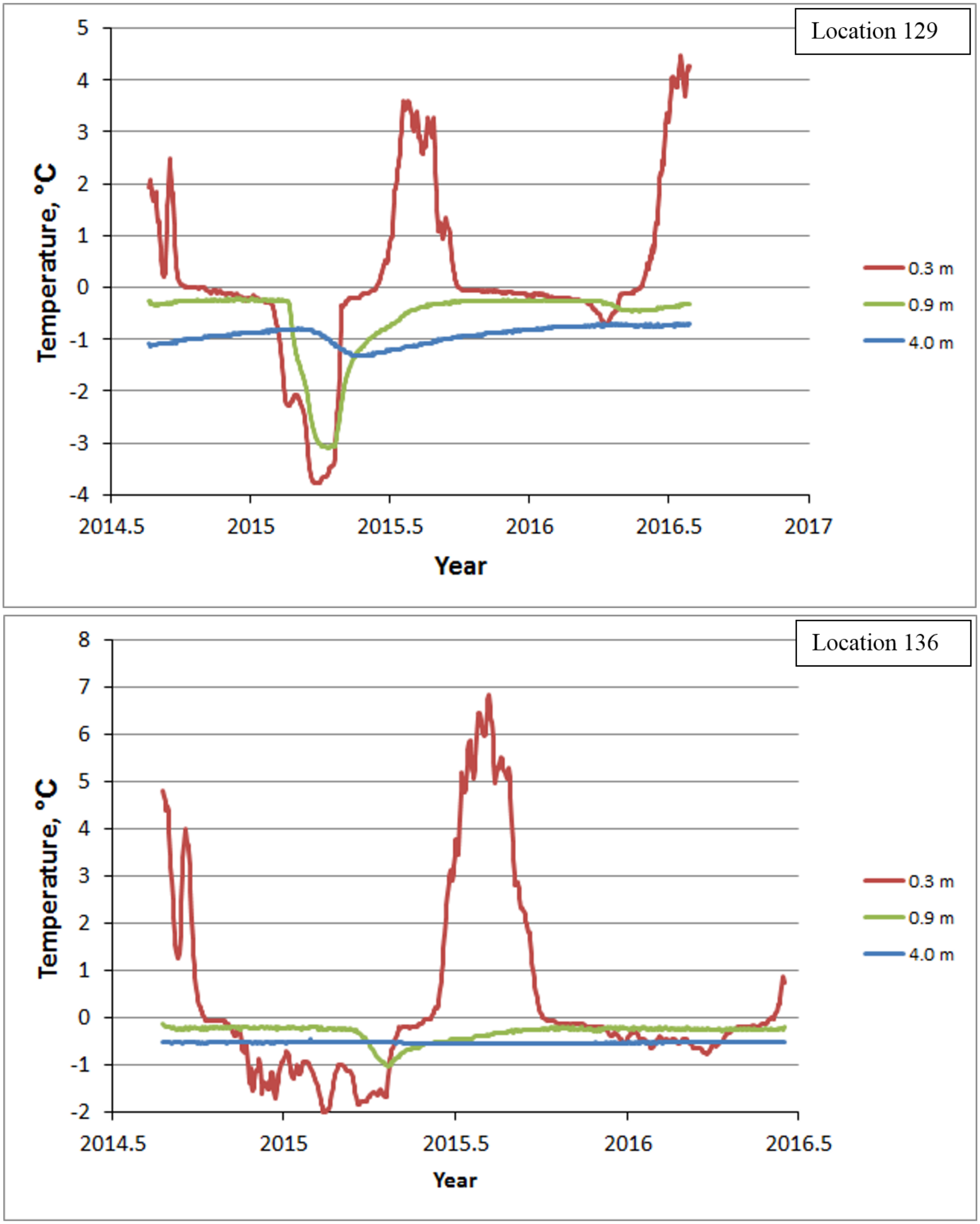

Figure 3. Plot of ground temperatures vs. time at locations 129 (upper) and 136 (lower) for 3 depths: 0.3 m (1 ft.), 0.6 m (3 ft.), and 4.0 m (13 ft.).

Table 2. Ground temperature seasonal maxima and minima, and mean annual temperature, at 6 ft. depth at 3 locations in the Kobuk Preserve Unit, 2014-2016

	Temperature, °C at Location and depth					
Measure	**599 surface**	**599 1.8 m**	**600 surface**	**600 1.8 m**	**601 surface**	**601 1.8 m**
Maximum, summer 2014[1]	12.4	-0.0	10.8	-0.0	14.1	-0.1
Minimum, winter 2014-15	-17.7	-2.6	-21.5	-3.3	-15.6	-4.9
Maximum, summer 2015	19.4	-0.3	18.1	-0.3	19.4	-0.3
Minimum, winter 2015-16	-9.2	-0.4	-5.8	-0.5	-8.8	-0.8
Maximum, summer 2016[2]	18.0	-0.2	18.9	-0.3	19.7	-0.3
MAGT 9/2014-8/2015	-0.4	-1.0	-0.5	-1.3	-0.2	-1.6
MAGT 7/2015-6/2016	1.9	-0.3	2.3	-0.4	1.3	-0.4

[1]Sensors were installed in late August 2014 and probably missed the surface maximum in that year.

[2]Sensors were removed in late July 2016, some additional warming may have occurred after that date.

Table 3. Ground temperature seasonal maxima and minima, and mean annual temperature, at multiple depths at location 129 in the Kobuk Preserve Unit, 2014-2016

	Temperature, °C at depth						
Measure	**0.3 m 1 ft.**	**0.9 m 3 ft.**	**1.5 m 5 ft.**	**2.1 m 7 ft.**	**2.7 m 9 ft.**	**3.4 m 11 ft.**	**4.0 m 13 ft.**
2014 maximum[1]	2.5	-0.2	-0.4	-0.6	-0.7	-0.8	-0.9
2014-15 minimum	-3.8	-3.1	-2.7	-2.3	-1.9	-1.6	-1.3
2015 maximum	3.7	-0.2	-0.4	-0.6	-0.6	-0.8	-0.8
2015-16 mininum	-0.8	-0.5	-0.7	-0.8	-0.9	-1.0	-1.0
2016 maximum[2]	4.5	-0.2	-0.3	-0.5	-0.6	-0.8	-0.7
MAGT 9/2014-8/2015	-0.1	-0.8	-1.0	-1.0	-1.1	-1.1	-1.0
MAGT 7/2015-6/2016	0.5	-0.3	-0.6	-0.7	-0.8	-0.9	-0.9

[1]Sensors were installed in late August 2014, may have missed the maximum temperature at 0.3 m depth in that year.

[2]Sensors were removed in late July 2016, some additional warming may have occurred after that date.

Table 4. Ground temperature seasonal maxima and minima, and mean annual temperature, at multiple depths at location 136 in the Kobuk Preserve Unit, 2014-2016

	Temperature, °C at depth						
Measure	**0.3 m 1 ft.**	**0.9 m 3 ft.**	**1.5 m 5 ft.**	**2.1 m 7 ft.**	**2.7 m 9 ft.**	**3.4 m 11 ft.**	**4.0 m 13 ft.**
2014 maximum[1]	4.5	-0.2	-0.3	-0.4	-0.4	-0.4	-0.5
2014-15 minimum	-2.0	-1.0	-0.8	-0.7	-0.6	-0.6	-0.6
2015 maximum	6.9	-0.1	-0.3	-0.4	-0.4	-0.4	-0.4
2015-16 mininum	-0.8	-0.4	-0.4	-0.4	-0.6	-0.5	-0.6
2016 maximum[2]	0.9	-0.1	-0.3	-0.4	-0.4	-0.4	-0.5
MAGT 9/2014-8/2015	0.6	-0.4	-0.4	-0.5	-0.5	-0.5	-0.5
MAGT 6/2015-5/2016	0.9	-0.3	-0.3	-0.4	-0.5	-0.5	-0.5

[1]Sensors were installed in late August 2014, may have missed the maximum temperature at 0.3 m depth in that year.

[2]Sensors were pulled out of the ground by a bear on 15 June 2016, some additional warming probably occurred after that date.

A long-term perspective on the time interval covered by these ground temperature observations is provided by National Weather Service data from Bettles, Alaska, approximately 125 km east of the study area. At Bettles, the 30-year (1986-2016) mean annual air temperature (MAAT) was -4.6 °C. During the period of our ground temperature observations, the MAAT at Bettles was rebounding from a relatively cold period centered in the winter of 2011-12 (when the MAAT was near -6 °C) to near -2 °C in 2015-2016, the warmest MAAT recorded since the start of observations in 1951. In the year prior to installation of the temperature sensors (Aug 2013-Jul 2014), the MAAT at Bettles was -4 °C, only slightly above the long-term average, and snow depths were near long-term normals (Table 5 and Fig. 4). Thus the ground temperatures soon after installation (especially the deeper sensors) provide a picture of conditions near the long-term normal. The MAAT during the final year of observations (Aug 2015-Jul 2016) was -2.3 °C and snow depths again were near the long-term normals. Since the second year of observations were made during the warmest MAAT ever recorded at Bettles, they provide a picture of how ground temperatures could behave in the future under a warmer climate.

Table 5. Mean Annual Air Temperatures (MAAT) at Bettles, Alaska 2013-2016

Season	**MAAT, °C**
Aug 2013-Jul 2014	-4.0
Aug 2014-Jul 2015	-3.0
Aug 2015-Jul 2016	-2.3
30-year Average	-4.6

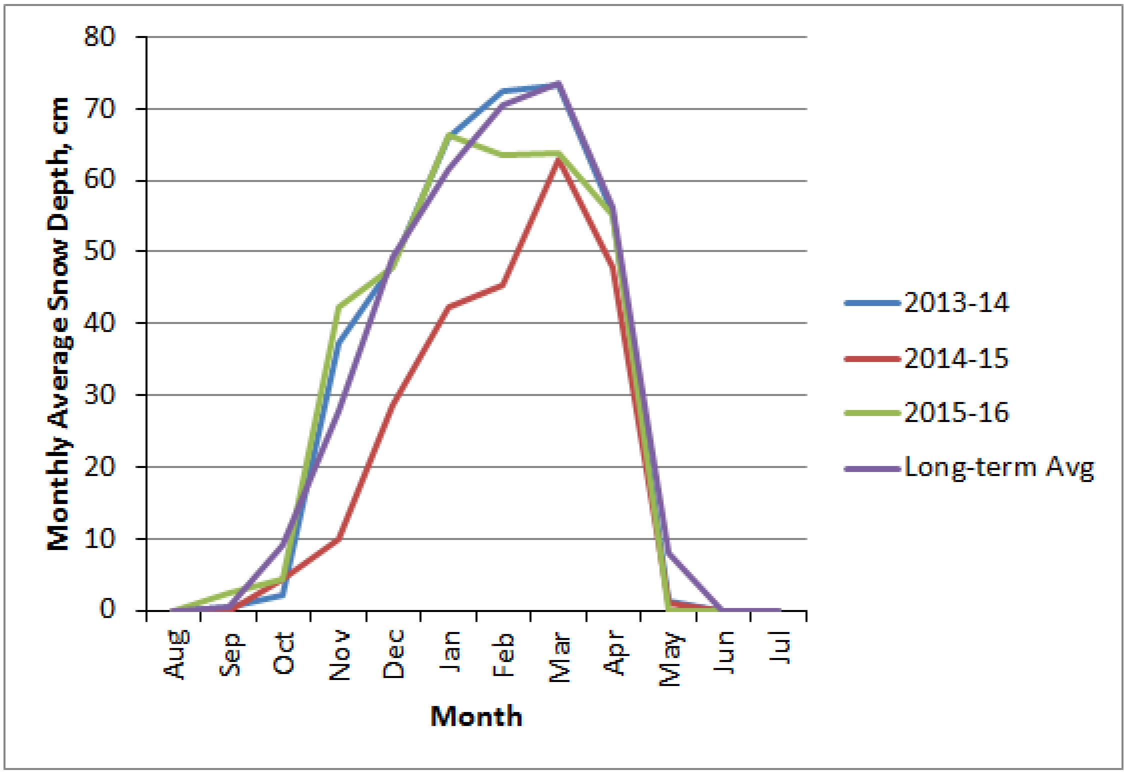

Figure 4. Monthly average snow depths at Bettles, Alaska 2013-2016

These ground temperature data show that the ice-rich lowland permafrost in the Kobuk Preserve Unit of GAAR is relatively warm, about -1 °C, as is typical of much of Interior Alaska (Péwé 1970, Jorgenson et al. 2008). Permafrost with temperatures close to the freezing point of water when in an undisturbed state are particularly prone to thaw as a result of disturbance. They are also more vulnerable to thaw resulting from climate change. Permafrost at all depths at all 5 study sites remained above -1 °C throughout the mild winter of 2014-2015, indicating that this permafrost is highly vulnerable to thaw from either engineering disturbance or continued climatic warming.

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