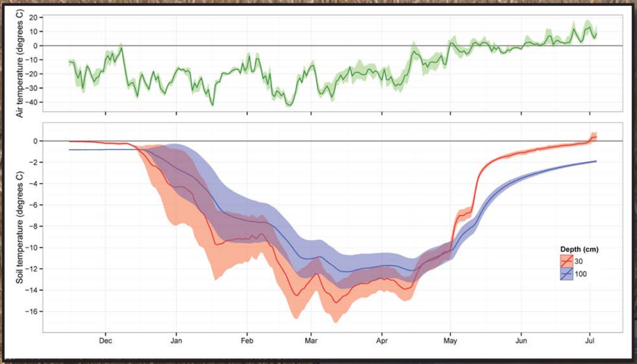
2014 HABITAT MONITORING AND ASSESSMENT: PERMAFROST COMPONENT

CD5 DEVELOPMENT PROJECT



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Cover:

Soil temperature monitoring station deployed on the tundra of the Colville Delta with CD4 drill pad in the background. Photograph by Tracy Christopherson courtesy of ConocoPhillips Alaska, Inc. All rights reserved.

Inset:

(Top) Figure showing a time series of daily average mean soil temperature and standard deviation at 30 cm and 100 cm for Reference Area North, and average daily minimum, mean and maximum air temperature at the Alpine weather station.

(Bottom) Flooded low-center ice wedge polygons on the Colville River Delta, northern Alaska. Photograph by Tracy Christopherson courtesy of ConocoPhillips Alaska, Inc. All rights reserved.

2014 HABITAT MONITORING AND ASSESSMENT: PERMAFROST COMPONENT CD5 DEVELOPMENT PROJECT

FINAL REPORT

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EXECUTIVE SUMMARY

This report presents the results of the first year of the soil temperature monitoring component of the CD5 Habitat Monitoring Study. The objectives of the study were to: 1) initiate the first year of monitoring, including data collection and servicing the temperature monitoring stations following 2014 spring break up flooding; 2) preliminary data analysis and reporting; and 3) present findings at an agency and stakeholder meeting in February 2015.

A total of 16 soil temperature monitoring stations, herein referred to as “Hobo Installations” were installed at Permafrost Temperature Monitoring Plots in the CD5 study area during field surveys between 9–18 September, 2013. Each station is equipped with a Weatherproof HOBO U23-003 External Temperature Data Logger equipped with two permanently attached soil temperature sensors, one set at 30 cm depth, the other at 100 cm. The Hobo Installations collected soil temperature data continuously every hour throughout the winter and spring through early July 2014. A field crew returned to service the permafrost monitoring stations between 3–5 July 2014.

In the office, the raw Hobo data files were backed up on the ABR server, the raw files were converted to comma separated value (csv) files, and the data uploaded to the project database. We ran several data quality control and quality assurance (QAQC) routines using both automated and hand filtering methods to ensure that only the highest quality permafrost temperature data were used in subsequent analyses. Data analysis followed the QAQC procedures. We began by aggregating the high quality soil permafrost temperature data to daily minimum, maximum, mean, standard deviation and median values for each depth and HOBO sensor. These data were combined with hourly air temperatures received from the Alpine Weather Station, similarly aggregated to daily values so that all the temperature data could be examined together. The soil temperature data were also aggregated to daily values and grouped by study area to compare the data at a broader spatial scale.

During the July field trip, the crew observed 7 of the 16 Permafrost Temperature Monitoring Plots with evidence of water inside the waterproof PVC box. Additionally, 1 box was found to be physically damaged by an ice pad that was constructed over it starting in February 2014. Despite water in several of the boxes and the damage sustained to the single box by the ice pad, the Hobo Data Loggers were undamaged and continued to record temperatures and operate normally. As a precaution, the Hobo Installation that was located under the ice pad was removed from the field and replaced with a new Hobo Installation nearby.

Time series plots of daily median soil temperature and average air temperature show that while the absolute soil temperatures differed to varying degrees between each Hobo Installation, the overall trends over the time period of record were similar. The exception to this was the Hobo Installation at plot ts-pc14, which was covered by an ice pad for several months over the winter. Plot ts-pc14 is discussed separately, below. In general, soil temperature trends followed the trends in average air temperature with a lag time in the response depending on depth. Time series plots of median daily temperature for each series showed some common trends across all Permafrost Temperature Monitoring Plots, including near constant temperatures through mid-December, a precipitous drop in temperature with multiple peaks and troughs through mid-April, and a steady rise in temperature through early July. The mean temperature at 30 cm ranged between -6.81 °C (± 6.76 °C) and -4.42 °C (± 4.79 °C). The temperatures at 100 cm were similar to those at 30 cm during the period of record ranging from -6.17 °C (± 6.21 °C) to -4.49 °C (± 3.97 °C). Differences in soil temperature between plots are likely attributable to air temperature and a combination of soil cumulative surface organic thickness and snow depth.

The Hobo Installation at plot ts-pc14 was covered by an ice pad for several months during the winter. Ice pad construction took place between 1–16 February 2014 and the resulting pad was approximately 15–30 cm thick. In general, the temperature trends for plot ts-pc14 were similar to those of other plots, although the absolute temperatures were colder. When ts-pc14 was compared to the nearest plot without an ice pad, the soil temperatures at ts-pc14 were similar to or

slightly warmer than the soil temperatures at the nearest plot before the ice pad was constructed and after it had melted. The soil temperatures at ts-pc14 were much colder than the soil temperatures at the nearest plot when the ice pad was in place.

The aggregated soil temperature time series followed a similar pattern as described above for the individual Permafrost Temperature Monitoring Plots. Reference Area North had the highest variability in temperature over the period of record. Reference Area South had the lowest variability in temperature over the period of record between Permafrost Temperature Monitoring Plots. Mean soil temperatures at 30 cm ranged between -5.92 °C and -5.19 °C across the 4 areas, and between -5.59 °C and -5.03 °C at 100 cm. Overall, the area wide soil temperature at 30 and 100 cm in all 4 areas were similar, in most cases occurring within ±0.20 °C, and in the most extreme case ±0.73 °C.

The mean soil temperatures reported here for individual plots and aggregated by study area for the period September 2013–July 2014 are likely slightly colder, particularly at 30 cm, than the mean annual soil temperatures. This is because the time period summarized for this report excludes the summer months of July and August. Data from the second year of soil temperature monitoring will include a full calendar year, which will be used to summarize soil temperatures on a mean annual basis following the second year of monitoring.

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ACKNOWLEDGMENTS

This study was funded by ConocoPhillips Alaska, Inc. and was managed by Robyn McGhee. Adam Davis-Turak, Exploration Environmental Coordinator with ConocoPhillips Alaska, Inc., provided valuable information regarding ice pad construction techniques. Many thanks to all those at Alpine whose efforts led to a safe and successful field season. Robert McNown provided excellent assistance in the field. Allison Zusi-Cobb provided GIS support and created map figures. Pam Odom produced the report, and Janet Kidd provided a thorough review. Many thanks to you all!

INTRODUCTION

BACKGROUND

As a condition of the permit (POA-2005-1576) to develop CD5 in the Northeast National Petroleum Reserve-Alaska (NE NPRA) and associated infrastructure on the Colville River Delta, the U.S. Army Corp of Engineers (USACE) stipulated that ConocoPhillips Alaska, Inc. (CPAI) implement a monitoring plan with an adaptive management strategy (Monitoring Plan). The Monitoring Plan was developed to monitor changes in site conditions and the efficacy of the proposed mitigation measures developed to minimize impacts to natural resources in the project area (ABR and Baker 2013). The Plan commits CPAI to 1) develop a monitoring program prior to construction; 2) prepare monitoring reports on a variety of monitoring components (see below) for review by key stakeholders; and 3) meet with federal agencies annually to review the monitoring reports and the effectiveness of the mitigation measures developed for the project.

MONITORING PROGRAM GOALS AND OBJECTIVES

Along with fulfilling Special Condition #1 of the USACE permit POA-2005-1576, the CD5 Monitoring Plan’s goal is to monitor changes in site conditions and selected resources and to modify, if appropriate, operational practices to minimize impacts on the hydrologic function of the Colville River Delta as a result of road, bridge, and pad construction. As discussed with federal agencies in meetings during 2011, an outline of the Plan and a table summarizing the Plan’s monitoring components were provided to the USACE in a letter dated 23 November 2011. Subsequent discussions and correspondence through 30 August 2012 resulted in the following list of studies to be included in the Monitoring Plan:

- Habitat Monitoring (vegetation, geomorphology, sedimentation, permafrost, weather)
- Hydrology Monitoring
- Erosion Control Monitoring
- Culvert Monitoring
- Bridge Monitoring (Niġliq and Niġliagvik Bridge)

This report presents the results of permafrost monitoring associated with the habitat monitoring component (herein, CD5 Habitat Monitoring Study) of the overall CD5 Monitoring Plan. As described in the CD5 Monitoring Plan (ABR and Baker 2013), the overall goals of the CD5 Habitat Monitoring Study include 1) determining whether gravel placement associated with construction of the CD5 road alters upstream and/or downstream wildlife habitats; 2) quantifying vegetation and habitats in permanent plots to describe baseline conditions (Wells et al. 2014), and 3) to monitor changes and intermediate trends in vegetation, wildlife habitat, geomorphology, and sedimentation/erosion through time.

The objectives of the first year of the soil temperature monitoring study were to:

1. Initiate the first year of monitoring, including data collection and servicing the temperature monitoring stations, following 2014 spring break up flooding;
2. Data analysis and reporting; and
3. Present findings at an agency and stakeholder meeting in February 2015.

CD5 HABITAT MONITORING STUDY AREA

DESCRIPTION

This study focuses on the CD5 Habitat Monitoring Study Area, which is located along the Niġliq Channel in the southwestern portion of the Colville River Delta on the North Slope of Alaska (Figures 1 and 2). The Alpine Facilities, which include the main Alpine camp and production pad, known as CD-1, satellite drill sites CD-2, CD-3 (roadless), and CD-4, and the associated roads and infrastructure such as flowlines and pipelines, are located to the east of the CD5 Habitat Monitoring Study Area. The village of Nuiqsut, established in 1971, is located at the head of the Colville River Delta, several miles to the south of the CD5 Habitat Monitoring Study Area.

The CD5 Habitat Monitoring Study Area has been partitioned into four subareas, including test

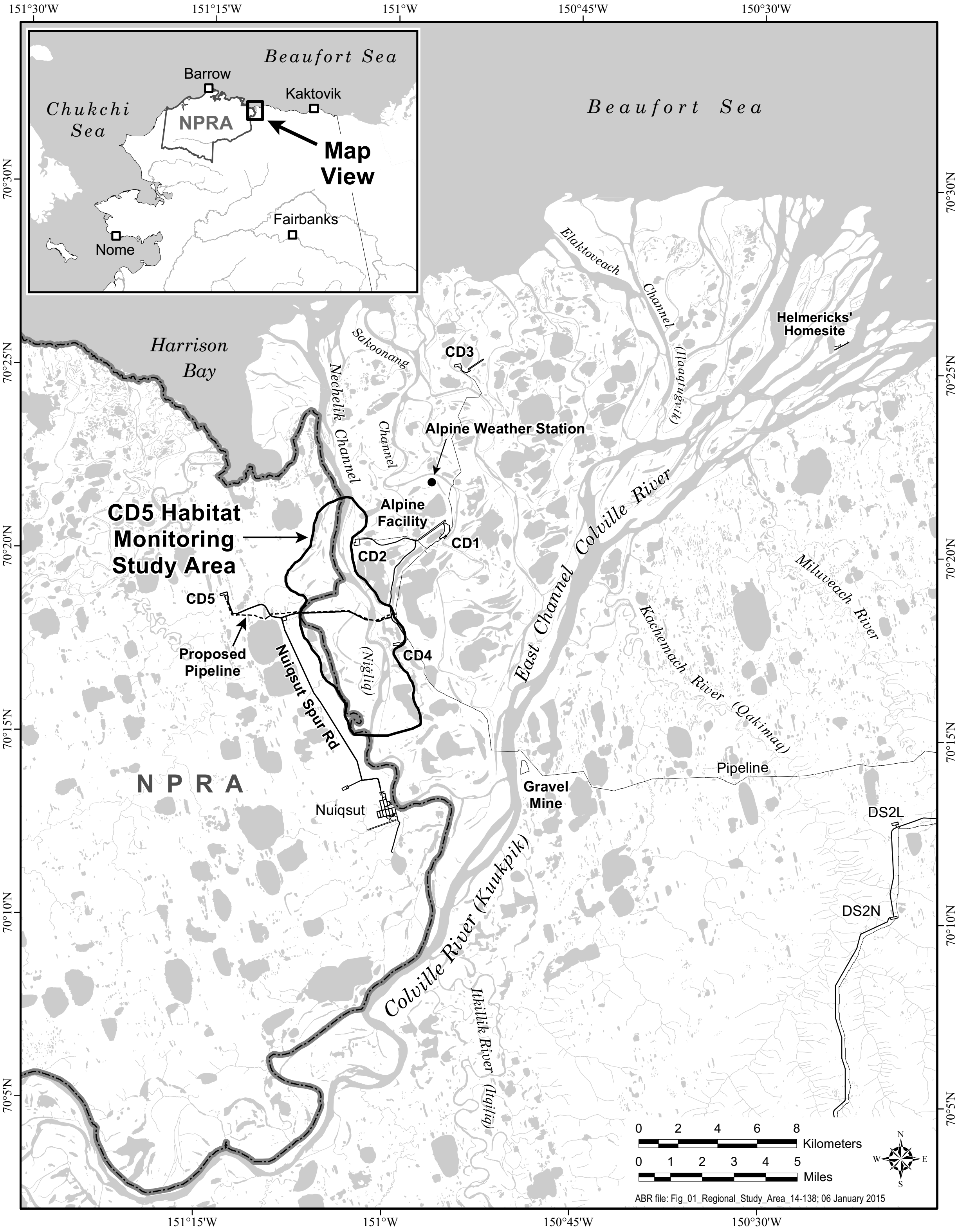
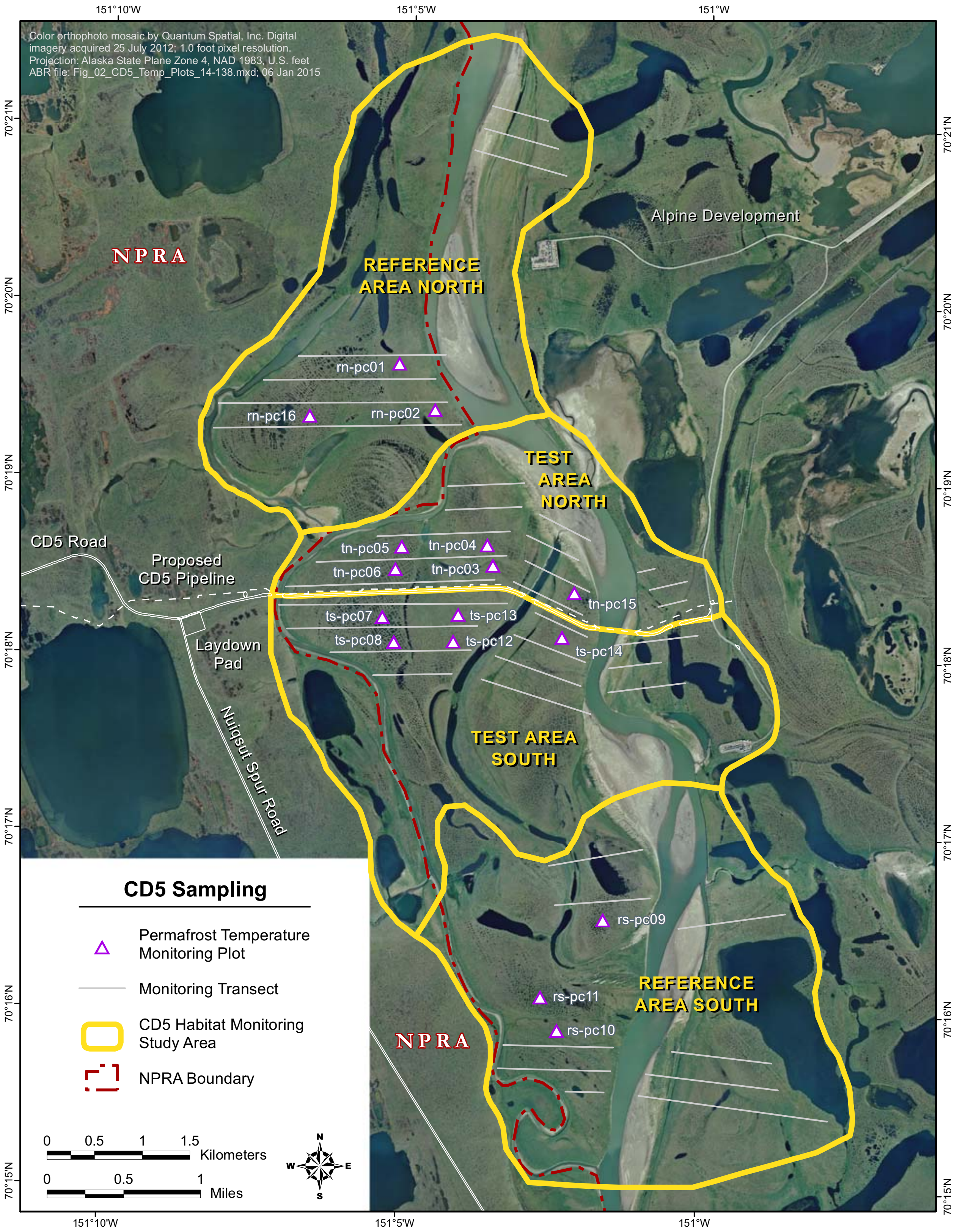


Figure 1. Location of the CD5 Habitat Monitoring Study Area on the Colville River Delta, northern Alaska, 2013.



Color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution.
Projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet
ABR file: Fig_02_CD5_Temp_Plots_14-138.mxd; 06 Jan 2015

Figure 2. Locations of Permafrost Temperature Monitoring Plots in the CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2014.

and reference areas (Figure 2). The "test" area includes the general area directly upstream (test south) and downstream (test north) of the proposed CD5 road (ca. 1.9 km long) predicted by ABR and Baker (2011) to be affected by moderate and high sedimentation and erosion regime changes during a 200 year flood event. The "reference" areas were located approximately 3–5 km upstream (reference south) and downstream (reference north) of the proposed CD5 road predicted by ABR and Baker (2011) to be unaffected by the proposed development.

ENVIRONMENT

The Colville River is the largest river on Alaska's North Slope and is one of eight major rivers with significant freshwater input to the Arctic Ocean (Walker 1983, Figure 1). It drains approximately 29% (53,600 km^2) of the North Slope of Alaska, including most of the foothills watershed (64%) and smaller areas in the Brooks Range (26%) and coastal plain (10%); Walker 1976). The Colville enters the Beaufort Sea near the northeastern corner of the National Petroleum Reserve–Alaska (NPRA), midway between Barrow and Kaktovik; the river then slows and spreads out across a large river delta. The head of the Colville River Delta is located about 3 km downstream from the mouth of the Itkillik River, and 30 km upstream of the Beaufort Sea (Arnborg et al. 1966).

The delta has two main distributaries, the Niġliq (western) Channel and the Colville East Channel (Figure 1). These two channels combined carry about 90% of the water through the delta during flooding and 99% during low water (Walker 1983). Smaller channels branching from the East Channel include the Sakoonang, Tamayayak, and Elaktoveach channels.

The CD5 Habitat Monitoring Study Area has a typical arctic maritime climate. Winters are cold and windy and last approximately eight months. Summers are cool, with average daily temperatures ranging from -6 °C in mid-May to 9 °C in July; summers also are characterized by low precipitation (less than 76 mm on average), overcast skies, fog, and persistent winds from the northeast (NCDC 2013). The CD5 Habitat Monitoring Study Area occurs in the zone of continuous permafrost (Jorgenson et al. 2008), and the depth of permafrost is shallow (within 1 m of the soil surface) beneath much of the Study Area, with the exception of active river channels.

FIELD METHODS

A total of 16 Permafrost Temperature Monitoring Plots were established in the CD5 study area during field surveys between 9–18 September 2013 (Wells et al. 2014). Five Permafrost Temperature Monitoring Plots were established in each test area, and 3 Hobo Installations were established in each reference area (Figure 2). ABR planned to establish 8 additional Permafrost Temperature Monitoring Plots across the CD5 study area, as per the Monitoring Plan; however, ABR was unable to establish these due to low visibility, helicopter icing, and rapidly deteriorating weather conditions. Several criteria determined the placement of Permafrost Temperature Monitoring Plots, including 1) the plots were placed to encompass all 4 subareas, 2) the plots were placed between the Habitat Monitoring Transects to avoid disturbing the Vegetation and Habitat monitoring plots, 3) the plots were placed whenever possible in low-center ice wedge polygons in wet sedge meadow, the predominant vegetation type in the area, 4) the plots were placed on inactive and abandoned floodplains, the predominant geomorphic surfaces in the area, and 5) a higher number of plots were placed closer to the CD5 road to increase the sample size for detecting any potential changes through time related to the road. At each Permafrost Temperature Monitoring Plot a soil temperature monitoring station, herein referred to as "Hobo Installation", was installed. Table 1 provides a cross reference between the subarea (e.g., Reference Area North), the Permafrost Temperature Monitoring Plot superplot id, the serial number of the Hobo data logger deployed at each associated Hobo Installation, and the date each Hobo Installation was installed. Fieldwork was based out of the Alpine Facilities on the Colville River Delta and all permafrost monitoring locations were accessed via helicopter.

Each Hobo Installation is equipped with a Weatherproof HOBO U23-003 External Temperature Data Logger that includes two permanently attached soil temperature sensors. The

Table 1. Cross-reference table between Hobo Installation data logger serial number, subarea (Area ID), superplot id, and the date each Hobo Installation was installed for 16 Permafrost Temperature Monitoring Plots, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

Hobo Serial No.	Superplot ID	Area ID	Date Installed
10392122	rn-pc01	reference north	September 10, 2013
10392123	rn-pc02	reference north	September 10, 2013
10392124	tn-pc03	test north	September 11, 2013
10392125	tn-pc04	test north	September 11, 2013
10392126	tn-pc05	test north	September 11, 2013
10392127	tn-pc06	test north	September 11, 2013
10392128	ts-pc07	test south	September 11, 2013
10392129	ts-pc08	test south	September 11, 2013
10392130	rs-pc09	reference south	September 12, 2013
10392131	rs-pc10	reference south	September 12, 2013
10392132	rs-pc11	reference south	September 12, 2013
10392133	ts-pc12	test south	September 13, 2013
10392134	ts-pc13	test south	September 13, 2013
10392135	ts-pc14	test south	September 13, 2013
10392136	tn-pc15	test north	September 13, 2013
10392137	rn-pc16	reference north	September 13, 2013
10392643	ts-pc14	test south	July 5, 2014

HOBO data loggers were launched (activated) according to the manufacturer's instructions using a HOBO U-DTW-1 Waterproof Shuttle in the office prior to fieldwork. Each of the two sensors had a label affixed by the manufacturer identifying them as Channel 1 or Channel 2. We pre-measured Channel 1 and 2 from the tip of the metal sensor to a length of 30 cm and 100 cm, respectively, and marked the depth with a permanent marker. To ensure the appropriate sampling depth from the soil surface was being measured, we secured each channel sensor with putty at the pre-measured length to the top of the connector box (at the soil surface) between the waterproof box with the data logger and the PVC tube with the sensor cables. Prior to deployment in the field, each HOBO Data Logger was calibrated in an ice-water bath to within ±0.5 °C, and offsets from 0 °C were recorded. In the field, each HOBO Data Logger was deployed inside a waterproof box and polyvinyl chloride (PVC) tube system (Figure 3). The loggers were set to record soil temperature once every hour at a depth of 30 cm (upper sensor) and 100 cm (lower sensor) below the soil surface. The placement of the upper sensor at 30 cm differs from the Monitoring Plan which states that the upper sensor would be placed at a 5 cm depth. The upper sensor depth was changed from that stated in the Monitoring Plan in order to better represent the temperatures in the active layer (i.e., seasonally frozen ground), which encompasses the upper 36 cm to 55 cm of the soil profile (Table 2).

Following deployment in September 2013, the Hobo Installations were left to collect soil temperature data continuously throughout the winter and spring. A field trip was planned for April 2014 to measure end of winter snow depth at each Hobo Installation. However, the field trip was canceled due to concern that the snow depth measurements would no longer represent cumulative winter snowpack by the time a snow survey crew would have arrived to the field. Consequently, no snow depth measurements are available for the Hobo Installations for winter 2013/2014. A field crew returned to service the Hobo Installations between 3–5 July 2014 following spring break up of the Colville River. Each Hobo Installation was evaluated for damage

Figure 3. Temperature Logger installation and field deployment, CD5 Habitat Monitoring Study Area, northern Alaska, 2013–2014. Installation includes a) drilling a 1-m deep hole with a power drill; b) feeding the HOBO logger cables through the water proof box and into the PVC tube to a depth of 11.8 in (30 cm) and 39.4 in (100 cm) from the soil surface; c) sealing the box and PVC tube and reinforcing connections with waterproof tape; d) removing and restoring the surface organic mat; and e) an image of the final logger installation.

and repaired or replaced if necessary. Any water observed in the boxes was drained, each box was wiped dry, and the spent desiccant packet inside of the Hobo Data Logger was exchanged for an activated desiccant packet. Observations of damage or water were recorded on paper field forms and photos were taken of each station for documentation. Hobo Data Logger batteries were changed out and the data downloaded from each logger in the field using a Hobo Waterproof Data Shuttle. Raw data files from the Hobo loggers were backed up by downloading from the waterproof shuttle to a laptop in the field. The loggers were then re-deployed to continue recording permafrost temperatures once every hour for another year.

OFFICE METHODS

DATA MANAGEMENT

In the office, the raw Hobo data files were backed up on the ABR server. The raw files were converted to comma separated value (csv) files and the timestamps, which were recorded on the Hobos in Alaska Daylight Savings time, were standardized to Coordinated Universal Time (UTC) by adding 8 hours. The csv files were then imported into the project database. All analyses were done using UTC times to avoid issues related to Daylight Saving Time transitions. Data from paper field forms were entered by hand into digital format and the digital files were then proofed and uploaded to the project database.

Table 2. Soil temperature summary statistics at 30 cm and 100 cm, and cumulative organic thickness (cm) within the active layer and active layer depth (cm) for individual Hobo Installations at 16 Permafrost Temperature Monitoring Plots, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

Super-plot ID	Area ID	Hobo Serial No.	Cum. Org. Thick in Active Layer (cm)	Active Layer Depth (cm)	Min. Temp at 30 cm (C)	Mean Temp at 30 cm (C)	Std. Dev. Temp at 30 cm (C)	Median Temp at 30 cm (C)	Max. Temp at 30 cm (C)	Temp Obs. at 30 cm	Min. Temp at 100 cm (C)	Mean Temp at 100 cm (C)	Std. Dev. Temp at 100 cm (C)	Median Temp at 100 cm (C)	Max. Temp at 100 cm (C)	Temp Obs. at 100 cm
rn-pc01	reference north	10392122	48.0	51.0	-13.20	-4.42	4.79	-1.73	1.34	7082	-11.11	-4.35	3.84	-2.63	-0.73	7097
rn-pc02	reference north	10392123	49.0	50.0	-17.86	-6.40	6.62	-2.92	1.62	7084	-14.51	-6.26	5.17	-4.58	-0.82	7094
rn-pc16	reference north	10392137	48.0	50.0	-14.75	-4.74	5.38	-1.33	1.86	7018	-11.72	-4.73	4.12	-2.95	-0.70	7018
rs-pc09	reference south	10392130	49.5	55.0	-16.16	-5.53	6.00	-1.70	2.26	7030	-12.86	-5.35	4.66	-3.39	-0.68	7025
rs-pc10	reference south	10392131	48.0	55.0	-16.00	-5.14	5.80	-1.47	3.88	7027	-12.05	-4.90	4.29	-2.98	-0.73	7025
rs-pc11	reference south	10392132	42.0	49.0	-15.06	-5.13	5.74	-1.30	1.81	7012	-12.27	-5.02	4.49	-2.98	-0.65	7027
tn-pc03	test north	10392124	35.0	37.0	-16.04	-5.05	5.81	-1.33	2.07	7084	-12.27	-4.99	4.37	-2.98	-0.82	7081
tn-pc04	test north	10392125	43.0	46.0	-13.32	-4.52	5.07	-1.47	1.53	7029	-11.08	-4.49	3.97	-2.83	-0.73	7059
tn-pc05	test north	10392126	32.0	36.0	-14.08	-5.26	5.49	-1.87	1.70	7058	-11.79	-5.03	4.20	-3.42	-0.70	7047
tn-pc06	test north	10392127	37.0	37.0	-16.41	-5.99	6.13	-2.45	1.29	7058	-13.20	-5.79	4.69	-4.20	-0.85	7058
tn-pc15	test north	10392136	48.0	51.0	-14.79	-5.24	5.49	-1.84	1.64	7046	-11.69	-4.88	4.14	-3.15	-0.76	7049
ts-pc07	test south	10392128	24.0	42.0	-16.28	-5.85	6.23	-1.70	1.83	7056	-13.32	-5.66	4.80	-3.75	-0.68	7053
ts-pc08	test south	10392129	15.0	46.0	-18.12	-6.81	6.76	-4.05	1.72	7053	-14.12	-6.22	5.17	-4.50	-0.56	7050
ts-pc12	test south	10392133	50.0	52.0	-14.47	-5.28	5.59	-2.19	2.64	7009	-11.87	-4.97	4.24	-3.30	-0.51	7030
ts-pc13	test south	10392134	43.0	44.0	-15.67	-5.73	5.81	-2.65	0.72	7016	-12.64	-5.53	4.41	-3.87	-0.99	7025
ts-pc14	test south	10392135	46.0	51.0	-28.47	-6.53	8.20	-1.30	1.81	7046	-18.25	-6.17	6.21	-3.15	-0.73	7050

DATA ANALYSIS

Data was analyzed using a combination of PostgreSQL (PostgreSQL Global Development Group 2014) queries, scripts written in R (R Development Core Team 2014), and data figures produced with the ggplot2 (Wickham 2009) R package. Database queries were formalized into views in the database, and all R code has been integrated into our revision control system.

Analysis began by aggregating the high quality soil temperature data to daily minimum, maximum, mean, standard deviation and median values for each depth and HOBO sensor. These data are combined with hourly air temperatures received from the Alpine Weather Station (Wells et al. 2014), similarly aggregated to daily values so that all the temperature data could be examined together. All daily aggregations were done after transforming observation timestamps to UTC to eliminate issues related to Daylight Savings Time.

The soil temperature data were also aggregated to daily values and grouped by study area to compare the data at a broader spatial scale. The sensor at plot ts-pc14, which was located under an ice pad during the 2013 winter, was excluded from the Test Area South aggregation. A review of the data for this sensor showed significant differences between it and the nearest sensor (see Results and Discussion, Temperature Trends for Plot ts-pc14).

DATA QUALITY CONTROL AND ASSURANCE

We ran several data quality control and quality assurance (QAQC) routines using both automated and hand filtering methods. The QAQC procedures were designed to ensure that only the highest quality soil temperature data were used in the analysis. The raw data was processed in several steps to exclude low quality data during sensor acclimation and remove obviously poor sensor readings. It should be noted that no data were deleted from the database. Instead poor quality data records were flagged in the database and withheld from subsequent data analysis. A data quality code field (hobo_temp_data_quality_code) was added to the database housing the soil temperature data. We classified data records into several categories depending on the quality of the data or the method used to filter out suspect data records. For instance, records that were hand filtered (or by an automated statistical process) were flagged with an "H". The data records remaining after QAQC was complete were assigned the data quality rating "Q", and only those records were used in subsequent analyses.

The records that occurred prior to deployment of the Hobos in the ground were flagged with "P". The acclimation period, the time between when the Hobos were deployed in the ground and when the temperatures stabilized, was determined by assessing the temperature changes from one observation to the next when plotted against the number of hours after deployment. Records that occurred during the acclimation period were flagged with "A". The results of the acclimation analysis showed that the major changes happened almost immediately (i.e., the acclimation period), and after 24 hours post-deployment, the temperatures had stabilized (Figures 4 and 5).

Next, we used automated statistical procedures to search for data anomalies. To begin, we searched for temperature observations that are clearly impossible and flagged these with a data quality rating "H", e.g., greater than 20 °C, below -30 °C at 30 cm, below -20 °C at 100 cm. Next, we searched for dramatic temperature changes from one hour to the next. We analyzed cumulative density plots of the data to determine temperature change thresholds to use in automated data filtering. An example of a cumulative density plot is provided in Figure 6. To begin, we used a threshold of greater than 0.05 °C, and then repeated our analysis using various thresholds. The goal was to find a threshold which captured erroneous data, without being too aggressive in our automatic filtering, thus resulting in quality data being flagged as suspect. Based on these analyses we selected a change threshold of 0.25 °C for 100 cm and 0.5 °C for 30 cm. All observations reflecting a change in temperature over one hour greater than these thresholds were flagged with a data quality rating of "H".

The vast majority of remaining data quality issues were related to multiple erroneous observations in a row of temperature data. These cases are difficult to eliminate when using a procedure like the one described above, which is based on comparing a single observation to other

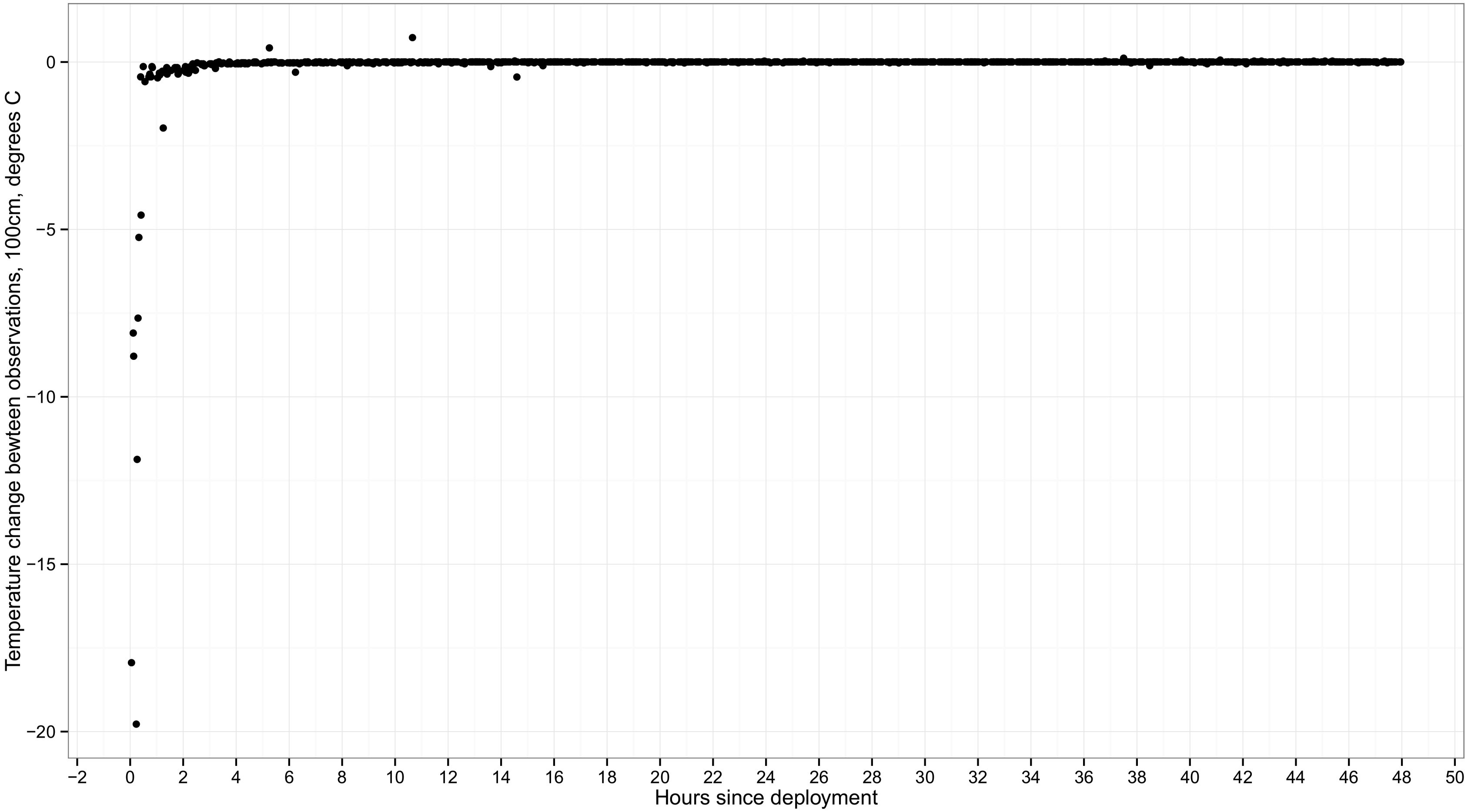


Figure 4. Change in soil temperature between observations for the first 48 hours after deployment at 100 cm depth, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

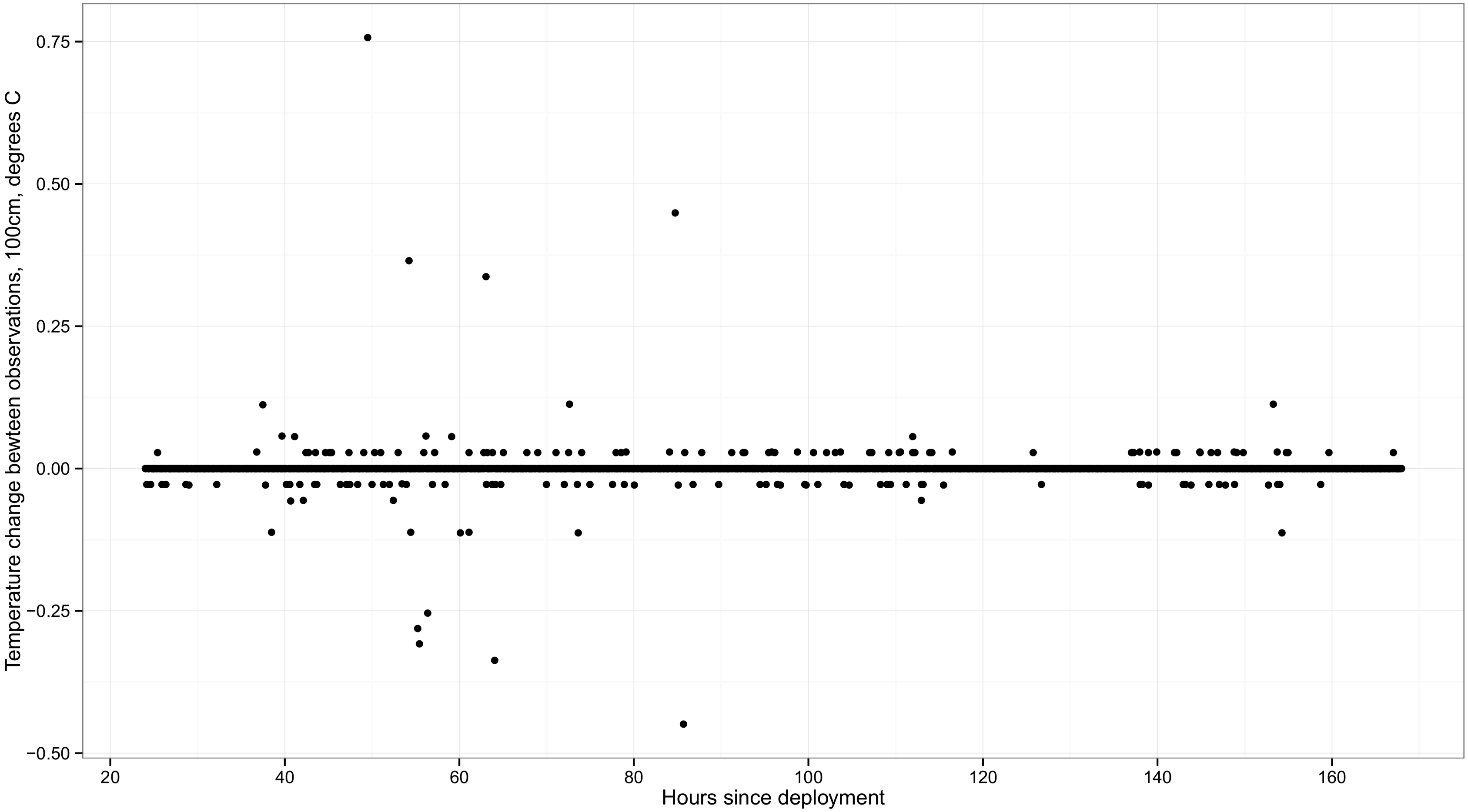


Figure 5. Change in soil temperature between observations 24 hours after deployment at 100 cm depth, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

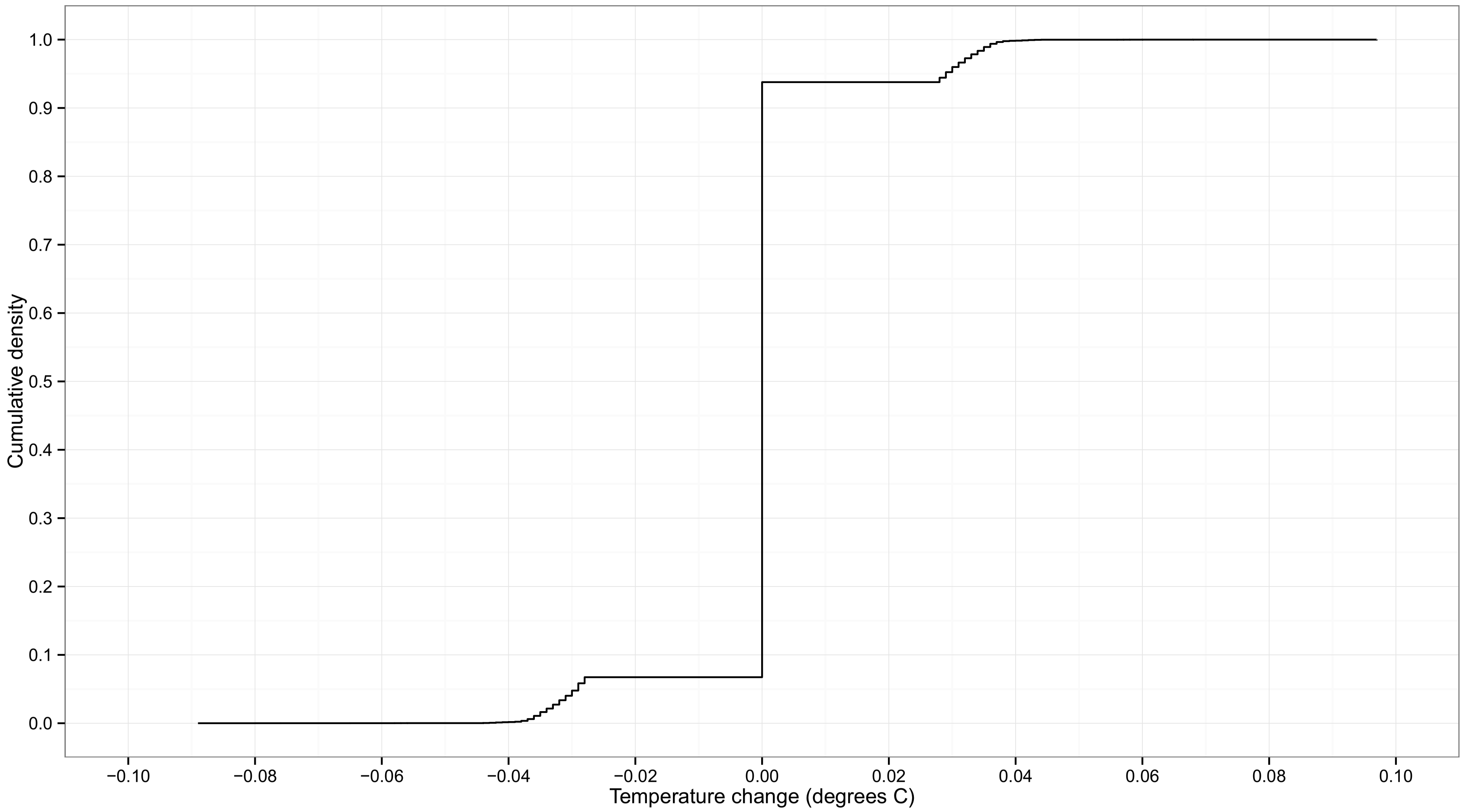


Figure 6. Cumulative density of soil temperature changes between observations at 100 cm depth, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

nearby observations. To limit the potential of missing outliers, we created a database view that generates a list of all the temperature records within three days for all observations where a 10-day moving average (excluding the observation being tested) was more than 0.25 degrees different for 100 cm observations and more than 0.5 degrees different for 30 cm observations. This analysis is designed to detect major temperature jumps in the data over a short time period, but may also flag sections where the temperature has a natural hump in it, thus precluding automated filtering methods. To allow for more control, the database view was used to create graphs (Figure 7) that were reviewed by an analyst who used best professional judgement to hand-filter data records and assign a data quality rating of "H" to suspect temperature observations.

Following the data QAQC review, data with a quality rating of "Q" were used to generate several post-filtering plots summarizing the highest quality data. Figure 8 displays a plot of temperature change over 1 hour at 100 cm for each Hobo. The plot shows very few instances of changes in temperature greater than 0.10 °C. Figures 9 and 10 display post-filtering box-plots for each Hobo at 30 cm and 100 cm, respectively. Hobo 10392135 shows a greater number of low temperature outliers when compared with other loggers, which may be the result of it being located under an ice pad for most of the record (see Results and Discussion, below). However, a plot of the 30 cm and 100 cm data doesn't indicate any obvious problem with the data logger (Appendix A). The record also shows a similar temperature trend through time (albeit, with slightly colder temperatures, particularly at 30 cm) as other Hobo soil temperature data summarized in Appendix A.

RESULTS AND DISCUSSION

FIELD OBSERVATIONS

Observations made during the 3–5 July 2014 fieldwork indicated no evidence of spring break-up flooding or animal disturbance at the 16 Hobo Installations. However, 7 of the 16 Permafrost Temperature Monitoring Plots had evidence of water inside the waterproof PVC box. The amount of water within the Hobo Installation box, ranged from several inches resulting in complete immersion of the Hobo Data Logger, to limited condensation within the box (Figure 11). We believe those instances where several inches of water were found in the box are related to failure of the rubber stopper seals placed at the bottom of the PVC tube that houses the Hobo Logger sensors. As a result of this seal failure, water moved up the PVC tube and into the box. Given that nearly all Hobo Installations were installed in wet sedge meadows in low-center polygons, in some cases in several inches of standing water, it is not too surprising that water was found inside some of the boxes. Despite water penetrating 7 of the waterproof boxes where the Weatherproof U23-003 Hobo Data Loggers were stored, all loggers were functional in July at the time of servicing.

Of the 16 Hobo Installations only 1 was found to be physically damaged. The waterproof box at plot ts-pc14 (hobo serial number 10392135) was damaged due to construction of an ice pad over this Hobo Installation (Figures 11 and 12). Despite the damage to the box, the Hobo Data Logger was undamaged and continued to record temperatures after the construction of the ice pad. Although the Hobo Data Logger at plot ts-pc14 showed no signs of physical damage and continued to function after ice pad construction, as a precaution the field crew decided to pull Hobo Installation 10392135 from the field and replace it with a new Hobo Installation on 5 July 2014 at approximately 0850. The replacement Hobo Installation (hobo serial number 10392643) was installed approximately 7.5 m to the east of the original and in the same low-center ice wedge polygon (Figure 12). The replacement logger was deployed on 5 July 2014 at approximately 1030 and is recording soil temperature every hour at 30 cm and 100 cm.

INDIVIDUAL SOIL TEMPERATURE MONITORING STATIONS

GENERAL TRENDS

Appendix A presents time series plots showing median daily soil temperature and the average daily air temperature at the Alpine Weather Station mid-September 2013, when the Permafrost Temperature Monitoring Plots (and Hobos) were installed, and through early July 2014, when the Hobos at each Plot were serviced. The plots (16 total) show that while the absolute

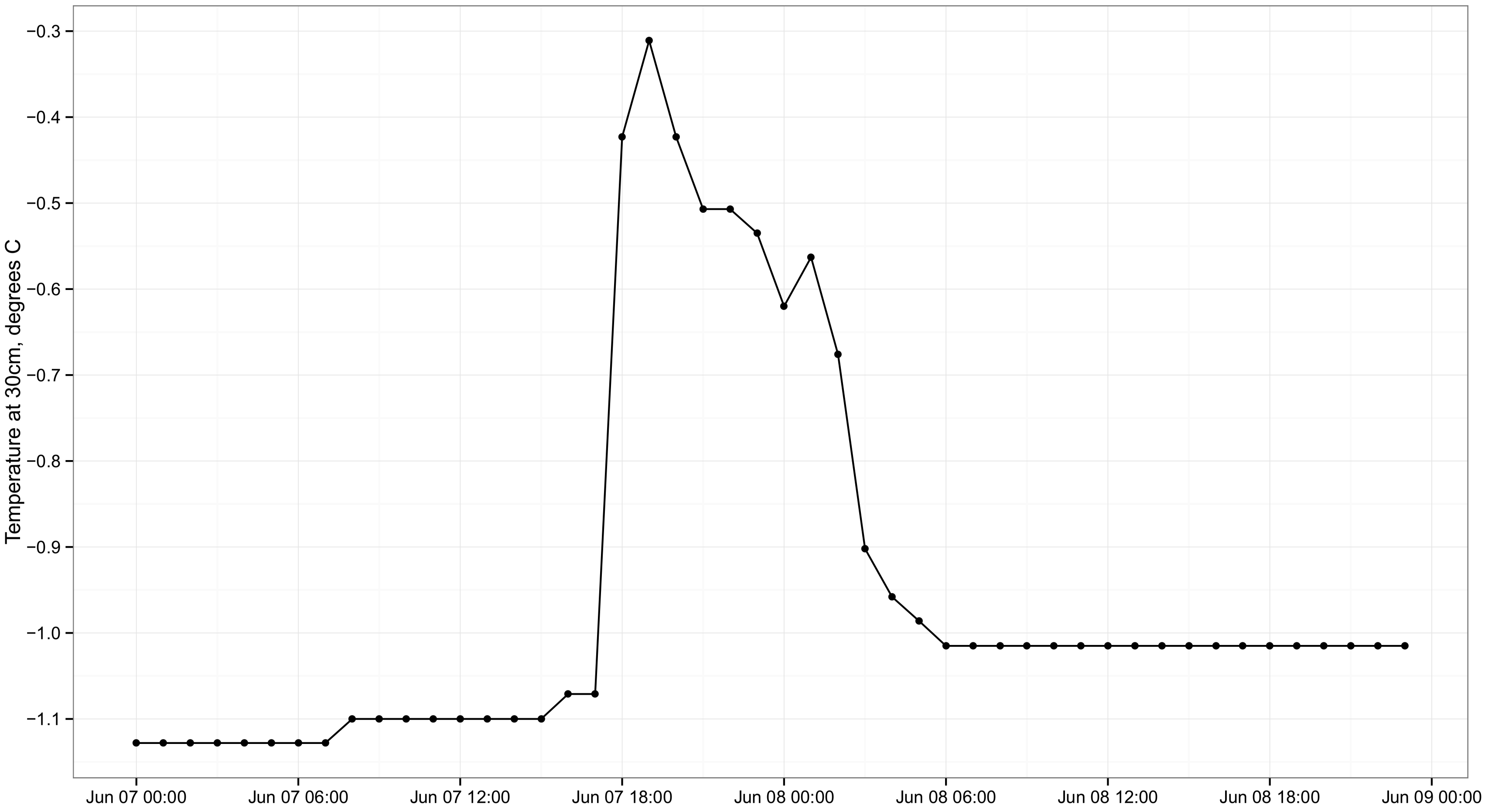


Figure 7. Example of an anomaly in the soil temperature data from a single HOBO that requires hand filtering, 30 cm depth, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

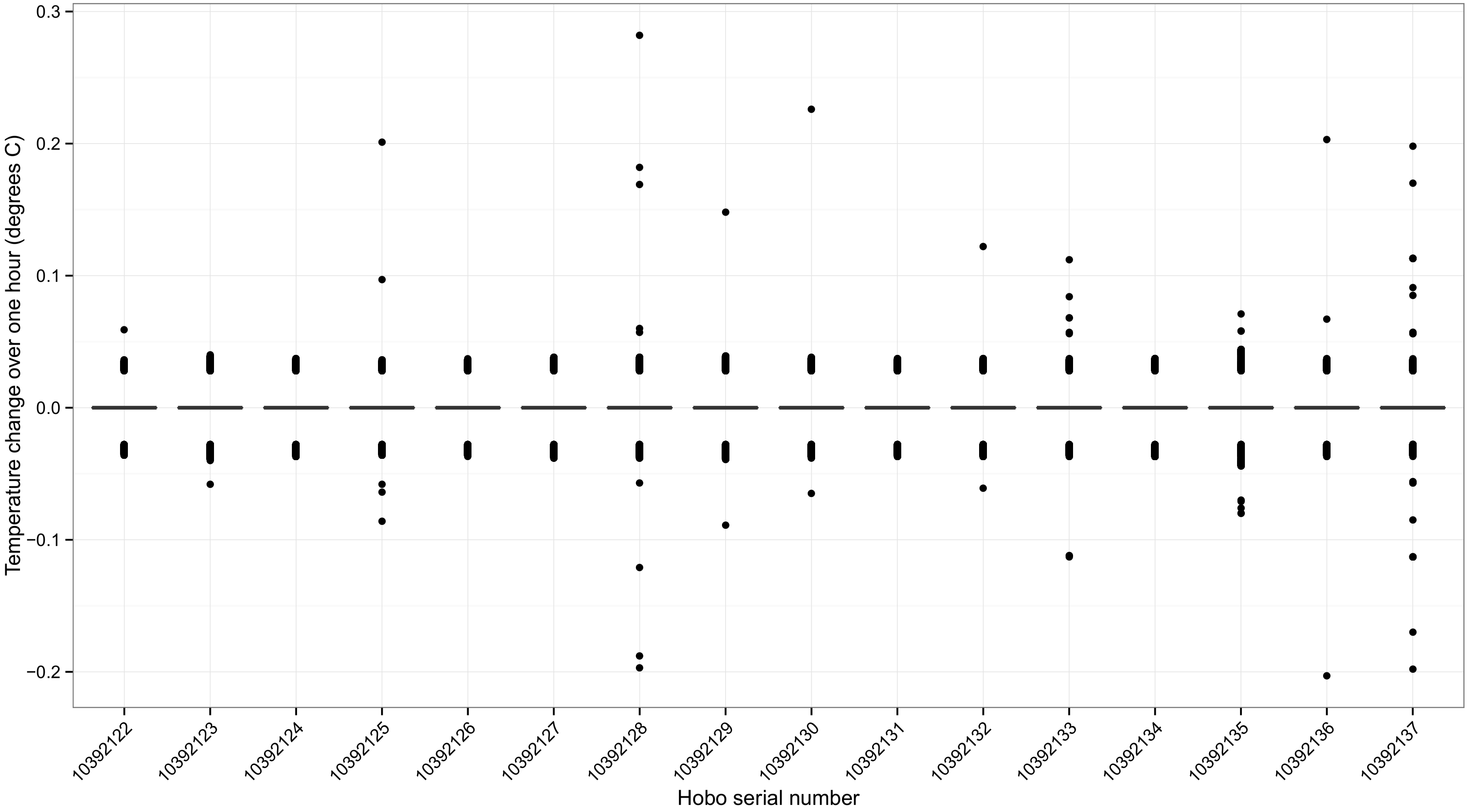


Figure 8. Box and Whisker plots showing distribution of soil temperature changes from one observation to the next for each HOBO, 100 cm depth, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

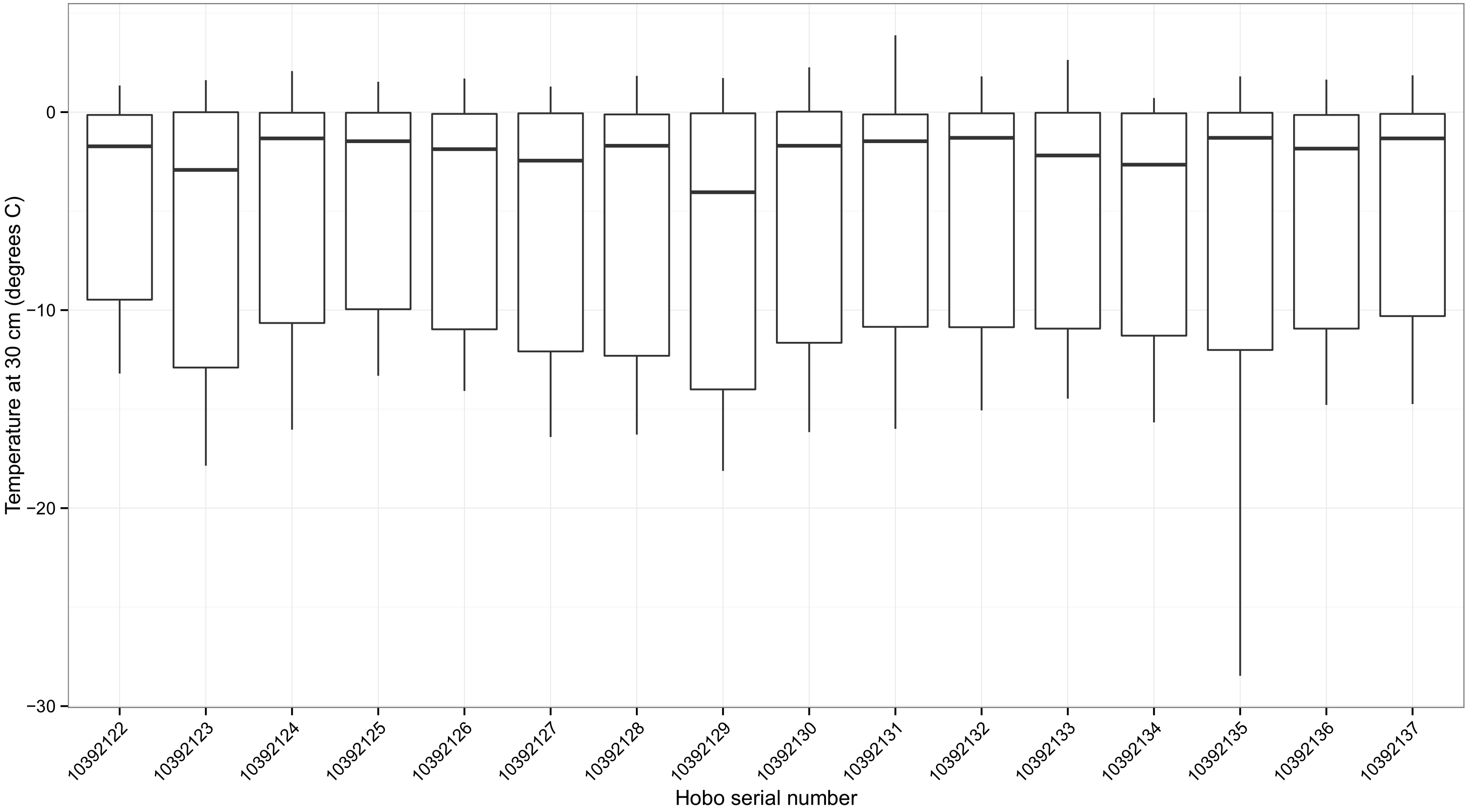


Figure 9. Box and Whisker plots showing distribution of 30 cm soil temperatures for each HOBO, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

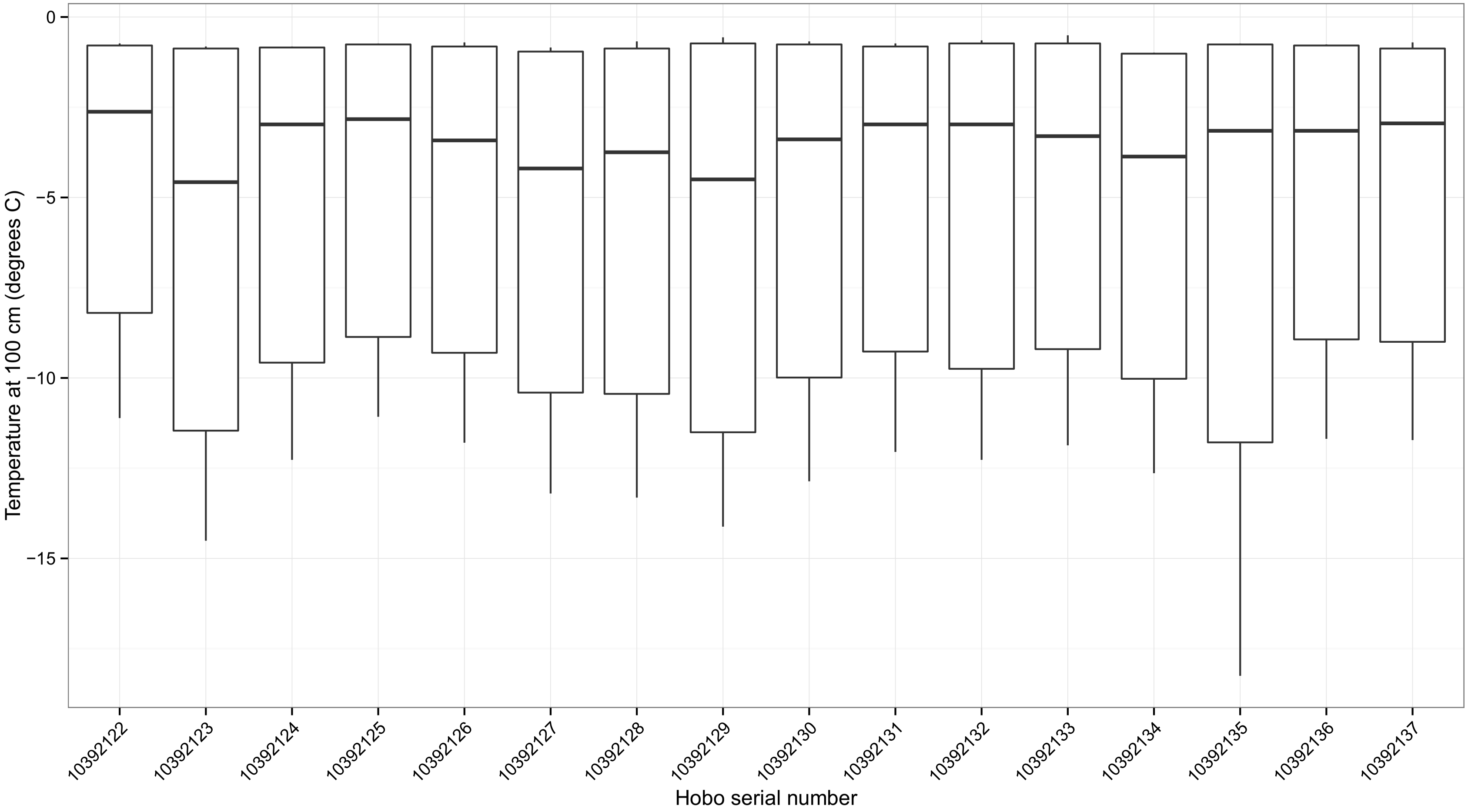


Figure 10. Box and Whisker plots showing distribution of 100 cm soil temperatures for each HOBO, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

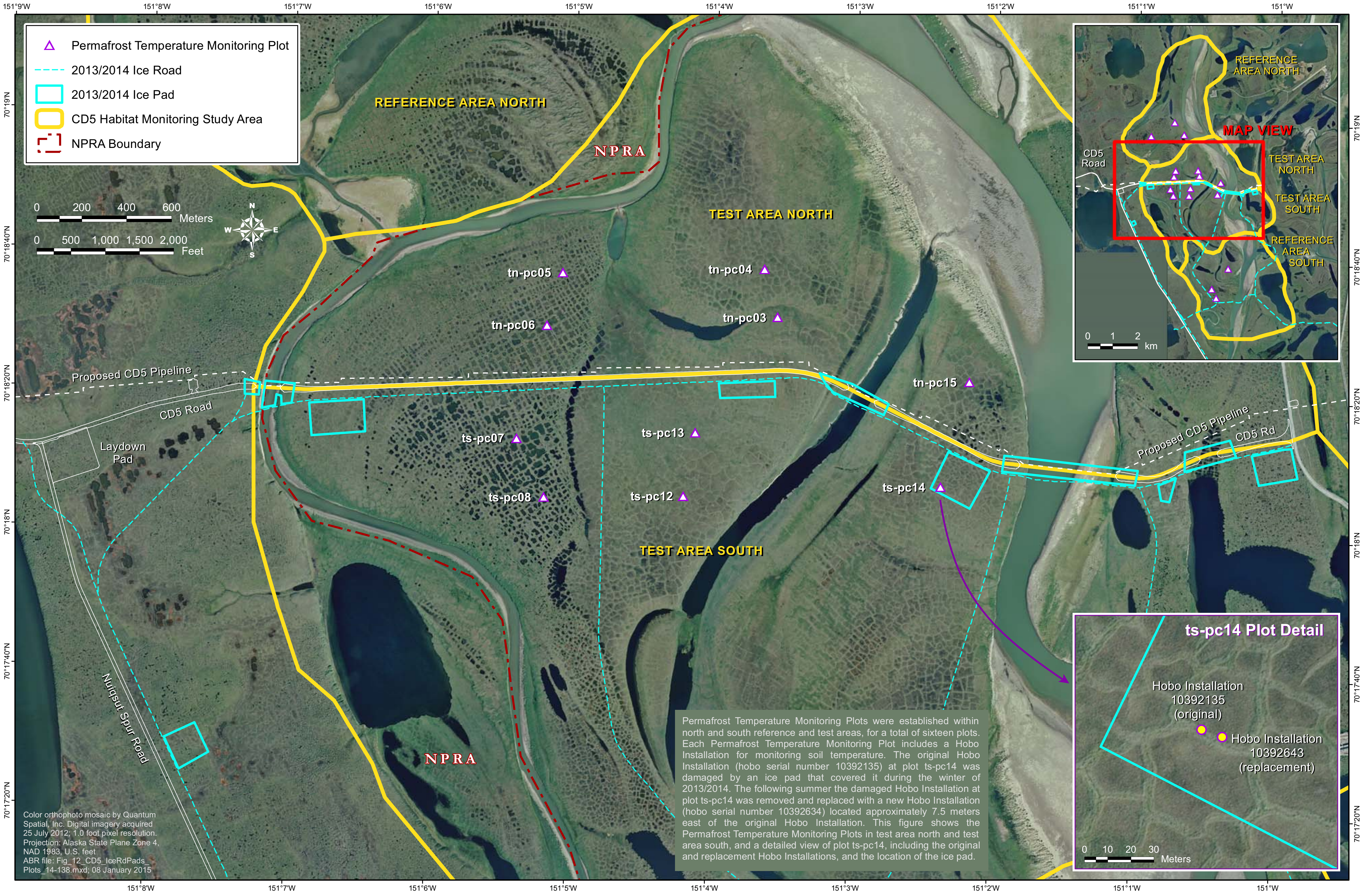
Figure 11. View of water in the bottom of a Hobo Installation box at plot rs-pc11 (above) and damage to the Hobo installation box at plot ts-pc14 caused by an ice pad (below), CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

soil temperatures differed to varying degrees between each Hobo Installation, the overall trends over the time period recorded were similar. The exception to this is the Hobo Installation at plot ts-pc14, which was covered by an ice-pad for several months over the winter (Figure 12). Plot ts-pc14 will be discussed below, in a separate subsection.

In general, soil temperature trends followed the trends in average air temperature with a lag time in the response, depending on depth. Time series plots of median daily temperature for each series showed some common trends across all Permafrost Temperature Monitoring Plots (Appendix A). Shortly after installation, the 30 cm temperatures were above 0 °C and then dropped, which corresponds with the trend in air temperature at the time. In contrast, the 100 cm temperatures were constant at approximately -1 °C. After several days, the 30 cm temperature dropped to 0 °C and held there for nearly 3 months, despite fluctuations in air temperature between 0 °C and -30 °C. In mid-December, the 30 cm temperatures began dropping, corresponding to a drop in air temperature, to -35 °C. The 100 cm temperature lagged behind the 30 cm for several days to a few weeks but eventually also began dropping in temperature. During this time, the 30 cm temperatures dropped below the 100 cm temperatures, a trend that was maintained through mid-April. The cooling trend continued until the first trough for both 30 cm and 100 cm temperatures in mid-January, corresponding to a drop in air temperature to approximately -40 °C. This drop in temperature was followed by several more peaks and troughs through mid-April, each peak and trough corresponding to peaks and troughs in air temperature. The coldest temperatures were achieved in late February and mid-March. In early-April the air temperature climbed to the highest point since early-December, and the 30 cm and 100 cm soil temperatures began to steadily and consistently climb. The 30 cm soil temperature exceeded the 100 cm soil temperature in mid-April. By mid-May, the soil temperature at both depths reached asymptotes at approximately the same time that the air temperatures began rising above 0 °C. From mid-May through early July, the temperature began to climb slowly, in some cases rising above 0 °C at 30 cm in late June/early July.

Table 2 shows summary statistics including daily minimum, maximum, mean, standard deviation and median values for each depth; cumulative thickness of organic soil materials; and active layer depth at the 16 Permafrost Temperature Monitoring Plots September 2013–July 2014. The 30 cm sensor at all Hobo Installations was positioned within the active layer (seasonally frozen soil), which is evident in the time series plots in Appendix A, where the 30 cm temperatures are in most cases above 0 °C at the beginning and end of the time series. Soil temperature data for the summer months (currently not available) should show a similar pattern of above 0 °C temperatures at 30 cm. The mean temperature at 30 cm ranged between -6.81 °C (± 6.76 °C) and -4.42 °C (± 4.79 °C). The coldest mean temperatures at 30 cm were observed at plot ts-pc08 and the warmest at rn-pc01. The temperatures at 100 cm were similar to those at 30 cm during the period of record ranging from -6.17 °C (± 6.21 °C) to -4.49 °C (± 3.97 °C). However, the coldest and warmest temperatures at 100 cm were not observed at the same plots as the 30 cm coldest and warmest temperature plots. The coldest temperatures at 100 cm were observed at plot ts-pc14, the plot that was covered by the ice pad (see next section for more details), and the warmest temperatures were observed at tn-pc04.

The absolute temperature differences observed between the individual Permafrost Temperature Monitoring Plots may in part be related to differences in site specific air temperatures. The Alpine Weather Station is located approximately 7–12 km to the northeast of the Permafrost Temperature Monitoring Plots. While this station data is broadly representative of the western Colville River Delta, it may not represent the site specific air temperature at each Hobo Installation. Air temperature is not available for each Hobo Installation, therefore our comparisons are limited to the air temperature of the general area. In general, we observed that soil temperature was quite responsive to changes in air temperature. The 30 cm temperatures tended to respond more quickly and to a greater magnitude than the 100 cm temperatures. In addition, whereas the average air temperatures can fluctuate rapidly up or down, sometimes on a daily basis, the soil temperatures were more stable and typically



Permafrost Temperature Monitoring Plots were established within north and south reference and test areas, for a total of sixteen plots. Each Permafrost Temperature Monitoring Plot includes a Hobo Installation for monitoring soil temperature. The original Hobo Installation (hobo serial number 10392135) at plot ts-pc14 was damaged by an ice pad that covered it during the winter of 2013/2014. The following summer the damaged Hobo Installation at plot ts-pc14 was removed and replaced with a new Hobo Installation (hobo serial number 10392634) located approximately 7.5 meters east of the original Hobo Installation. This figure shows the Permafrost Temperature Monitoring Plots in test area north and test area south, and a detailed view of plot ts-pc14, including the original and replacement Hobo Installations, and the location of the ice pad.

Color orthophoto mosaic by Quantum Spatial, Inc. Digital imagery acquired 25 July 2012; 1.0 foot pixel resolution.
Projection: Alaska State Plane Zone 4, NAD 1983, U.S. feet
ABR file: Fig_12_CD5_IceRdPads_Plots_14-138.mxd; 08 January 2015

Figure 12. Location of the winter 2013/2014 ice road centerlines and ice pad outlines overlaid on the Permafrost Temperature Monitoring Plots, including close-up view of plot ts-pc14 showing the location of the original hobo installation and the replacement, CD5 Habitat Monitoring Study, northern Alaska, 2013–2014.

trended in a given direction (flat line, up, or down) for several days to weeks before changing direction. While air temperature is an important factor influencing soil temperatures (Shur and Jorgenson 2007), particularly in areas of continuous permafrost, other factors, including edaphic factors (Nossov et al. 2013), such as surface organic thickness, also affect soil temperature. Surface organic layers act as insulation from the effects of air temperature; soils with thicker surface organic layers tend to have more stable temperatures, and remain cooler in the summer and warmer in the winter, than soils with thinner surface organic layers. For instance, plot ts-pc08 has the thinnest cumulative organic thickness in the active layer (15 cm) when compared to the other 15 plots (avg. 42.8 cm). This plot was also shown to have the coldest soil temperatures on average at 30 cm. However, cumulative organic thickness is not the only factor affecting soil temperatures. Soil temperatures are related to a complex relationship between air temperature, surface organic thickness, vegetation, topography, and snow depth (Jorgenson et al. 2010). Snow insulates the ground surface from fluctuations in air temperature during the winter months. Sites with deep snow throughout the winter tend to have more stable and generally warmer soil temperatures than sites with a shallow snowpack. Snow depth can vary widely depending on microtopographic characteristics of a site, particularly in areas like the Colville River Delta, that regularly experience high winds. Winds move snow from exposed areas (convexities) and deposit it in sheltered areas (concavities). Therefore even slight micro-topographic differences on the scale of 10–20 cm can influence snow depth and, ultimately soil temperature. For instance, plot ts-pc08 was shown to have the coldest soil temperatures on average at 30 cm of all plots. Plot ts-pc08 was also the only plot where the Hobo Installation was installed on an ice wedge polygon rim (convex surface) in moist sedge-shrub tundra where it is more exposed and likely experiences a shallower snow depth. Snow depth is likely the remaining factor contributing to temperature differences between the individual Permafrost Temperature Monitoring Plots. However, as described in the Field Methods section, above, we were unable to obtain snow depth data at the Hobo Installations for the 2013–2014 winter. A field trip is planned in late March 2015 to collect end of winter snow depth data at the Hobo Installations.

TEMPERATURE TRENDS FOR PLOT TS-PC14

As indicated above, the Hobo Installation (hobo serial number 10392135) at plot ts-pc14 was covered by an ice pad for several months during the winter (Figure 12). The “L” ice pad construction took place between 1–16 February 2014, and the pad was approximately 15–30 cm thick (pers. comm. A. Davis-Turak). The ice pad was closed to traffic on April 28. An overflight of the ice pad on May 12 showed the pad still intact but the ice significantly degraded. Hence, the Hobo Installation was covered by the ice pad from early February through at least mid-May. Generally, the temperature trends for plot ts-pc14 were similar to those of the other plots, although the absolute temperatures were colder (Figure A-16). During the time period prior to February 1 the temperature trends for ts-pc14 match those of the other Permafrost Temperature Monitoring Plots, including a steady drop to 0 C shortly after installation at 30 cm and steady temperatures at 100 cm, followed by stable temperatures through mid-December at both depths, and then a steady drop to the first trough in mid-January. Figure 13 shows a time series of the difference in temperature between plot ts-pc14 and plot tn-pc15 (hobo serial number 10392136), the nearest plot not affected by an ice pad. During the September through January period the temperatures at ts-pc14 were slightly warmer than the temperatures at plot tn-pc15, as indicated by the short red vertical lines above the trend line. At the beginning of February, there was a spike in temperature at 30 cm from approximate -10 °C to nearly -5 °C, a change in temperature that briefly exceeded the 100 cm temperature (Figure 13). The temperature at 100 cm shows a less dramatic rise in temperature, lagging a day or two behind the 30 cm spike. This spike in temperature corresponds with the day that ice pad construction began. This spike is shown in Figure 13 for the 30 cm depth as two red vertical lines significantly longer than the surrounding red lines. Following the temperature spike, the soil temperatures at plot ts-pc14 plummeted to -28 °C by late February. A

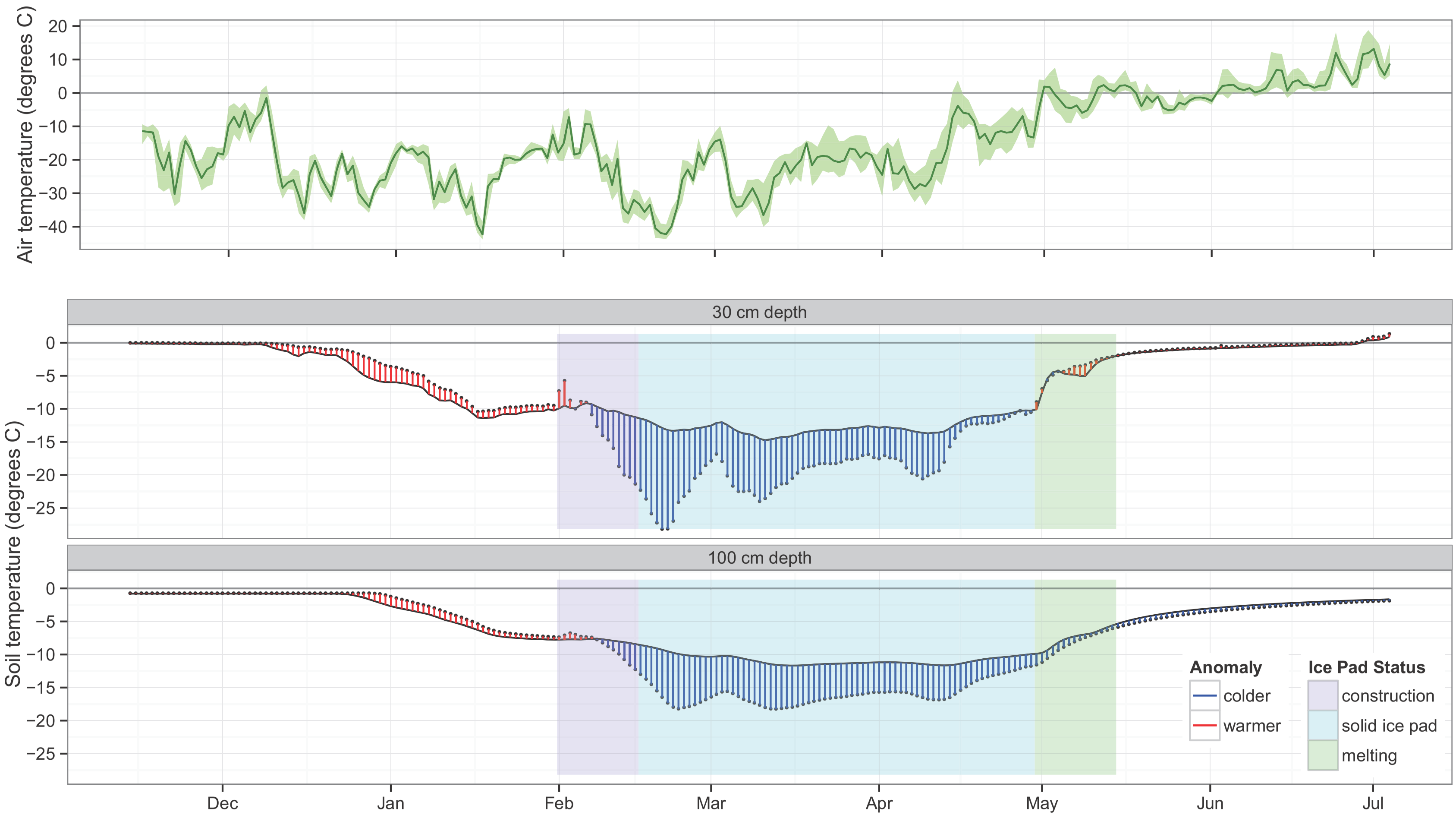


Figure 13. Time series of daily average mean soil temperature at 30 cm and 100 cm for difference between Hobo buried under an ice pad at plot ts-pc14 and the nearest normal Hobo at plot tn-pc15; and average daily minimum, mean and maximum air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, November 2013–July 2014.

series of peaks and troughs occur through mid-April that are comparable among the other Permafrost Temperature Monitoring Plots. The difference in temperature during this time period at ts-pc14 compared to at tn-pc15, however, is quite dramatic. This is reflected in Figure 13 as long blue vertical lines below the trend line beginning in mid-February. Starting in mid-April, the temperature trend at plot ts-pc14 begins to match the trends observed at the other Permafrost Temperature Monitoring Plots, with soil temperatures climbing steadily and consistently, and the 30 cm soil temperature exceeding the 100 cm soil temperature (Figure 13). The temperatures during this period at ts-pc14 remained colder than at tn-pc15, but less dramatically so. Starting in early May the 30 cm temperatures at ts-pc14 very closely matched those of tn-pc15, followed by a transition to warmer temperatures at the 30 cm depth at ts-pc14 when compared to tn-pc15 (Figure 13). This transition likely indicates the approximate time the ice pad had melted thus returning plot ts-pc14 to similar thermal conditions as plot ts-pc 15. During this time period the 100 cm temperatures at plot ts-pc14 remained slightly colder than those at tn-pc15 (Figure 13). Plot ts-pc14 had the second coldest mean temperature and widest variability (as measured by standard deviation) at 30 cm (-6.53 °C ± 8.20), and the coldest 100 cm temperature (-6.17 °C ± 6.21, Table 2). The colder mean temperatures at ts-pc14, and the relatively cold temperatures observed from late February through April, are likely related directly to the ice pad. Ice is a less effective insulator than snow, and as a result the soil temperatures at ts-pc14 responded to a greater magnitude to the changes in air temperature resulting in overall colder soil temperatures.

DATA SUMMARIES BY REFERENCE AND TEST AREAS

Figures 14–17 display the time series of mean soil temperature and standard deviation at 30 cm and 100 cm aggregated by study area and the average daily air temperature at the Alpine Weather Station for the period from mid-November to early-July. We focused on this shorter time period in Figures 14–17 because the soil temperatures showed little to no change during the September to mid-November period (Appendix A) and limiting the period displayed allowed us to display more detail during the months with regular temperature fluctuations. The time series of aggregated data represent the soil temperatures at a broader spatial scale, which we used to compare the test areas (closer to the CD5 road) with the reference areas (further from the CD5 road). In general, the aggregated soil temperature time series follow a similar pattern as described above for the individual Permafrost Temperature Monitoring Plots. Reference Area North had the highest variability in temperature over the period of record, as indicated by the broad, overlapping standard deviation ribbons in Figure 13. Reference Area South had the lowest variability in temperature over the period of record between Permafrost Temperature Monitoring Plots, as indicated by the relatively narrow and rarely overlapping standard deviation ribbons in Figure 14. Table 3 displays the summary statistics including daily mean, standard deviation and median values for each depth for the period of record aggregated by study area. Mean soil temperatures at 30 cm in the two reference areas were very similar, ranging between -5.19 °C (± 5.71) at Reference Area North and -5.27 °C (±5.85) at Reference Area South. The mean temperature at 30 cm in Test Area North was similar to the two reference areas (-5.21 °C ± 5.63), while Test Area South was slightly colder than the other 3 areas with a mean temperature of -5.92 °C (± 6.14) at 30 cm. The trend was similar for temperature at 100 cm with very similar temperatures at the two reference areas and Test Area North, and slightly colder temperatures at Test Area South. The slightly cooler temperatures in Test Area South may be attributed in part to the on average thinner cumulative organic thickness in this area (33.0 cm) compared to the other three areas (39.0–48.0 cm). However, as discussed in the previous section for the individual plot summaries, area specific air temperatures and snow depth likely also play a role in the differences observed. Overall, the area-wide soil temperature at 30 and 100 cm in all 4 areas were similar, in most cases occurring within ±0.20 °C, and in the most extreme case at ±0.70 °C.

Lastly, the mean soil temperatures reported here for individual plots and aggregated by study area for the period September 2013–July 2014 are likely slightly colder, particularly at 30 cm, than

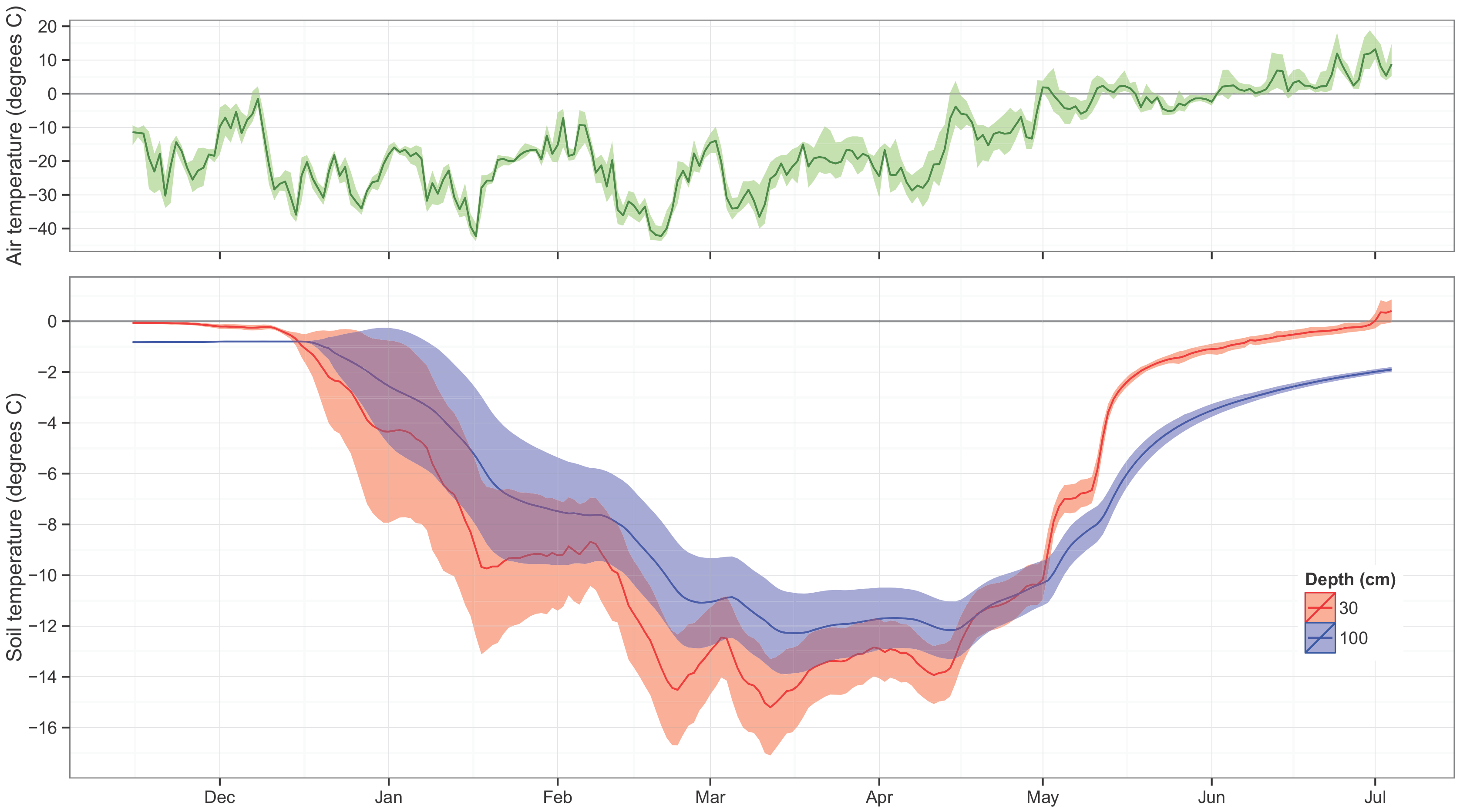


Figure 14. Time series of daily average mean soil temperature and standard deviation at 30 cm and 100 cm for Reference Area North, and average daily minimum, mean and maximum air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, November 2013–July 2014.

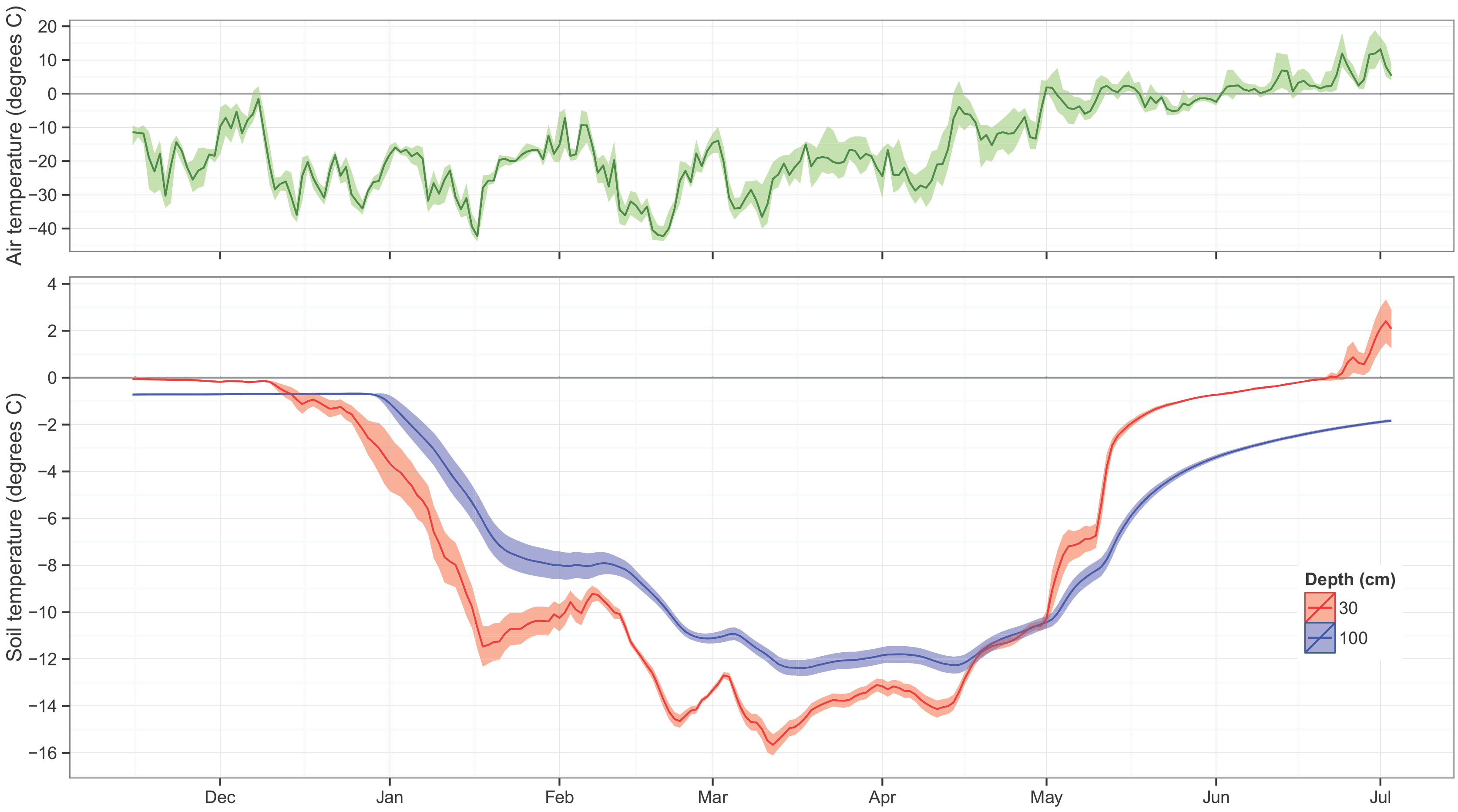


Figure 15. Time series of daily average mean soil temperature and standard deviation at 30 cm and 100 cm for Reference Area South, and average daily minimum, mean and maximum air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, November 2013–July 2014.

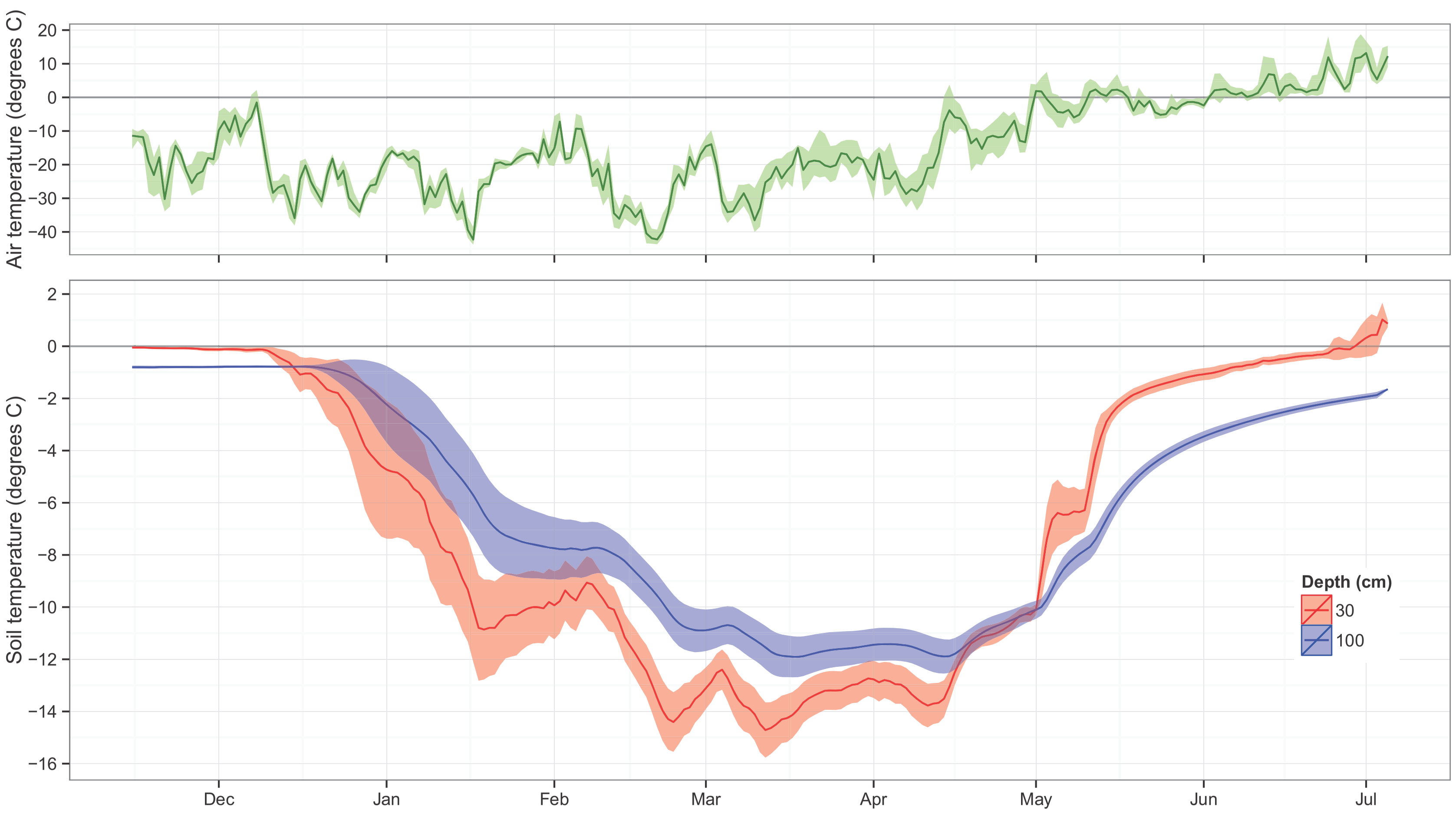


Figure 16. Time series of daily average mean soil temperature and standard deviation at 30 cm and 100 cm for Test Area North, and average daily minimum, mean and maximum air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, November 2013–July 2014.

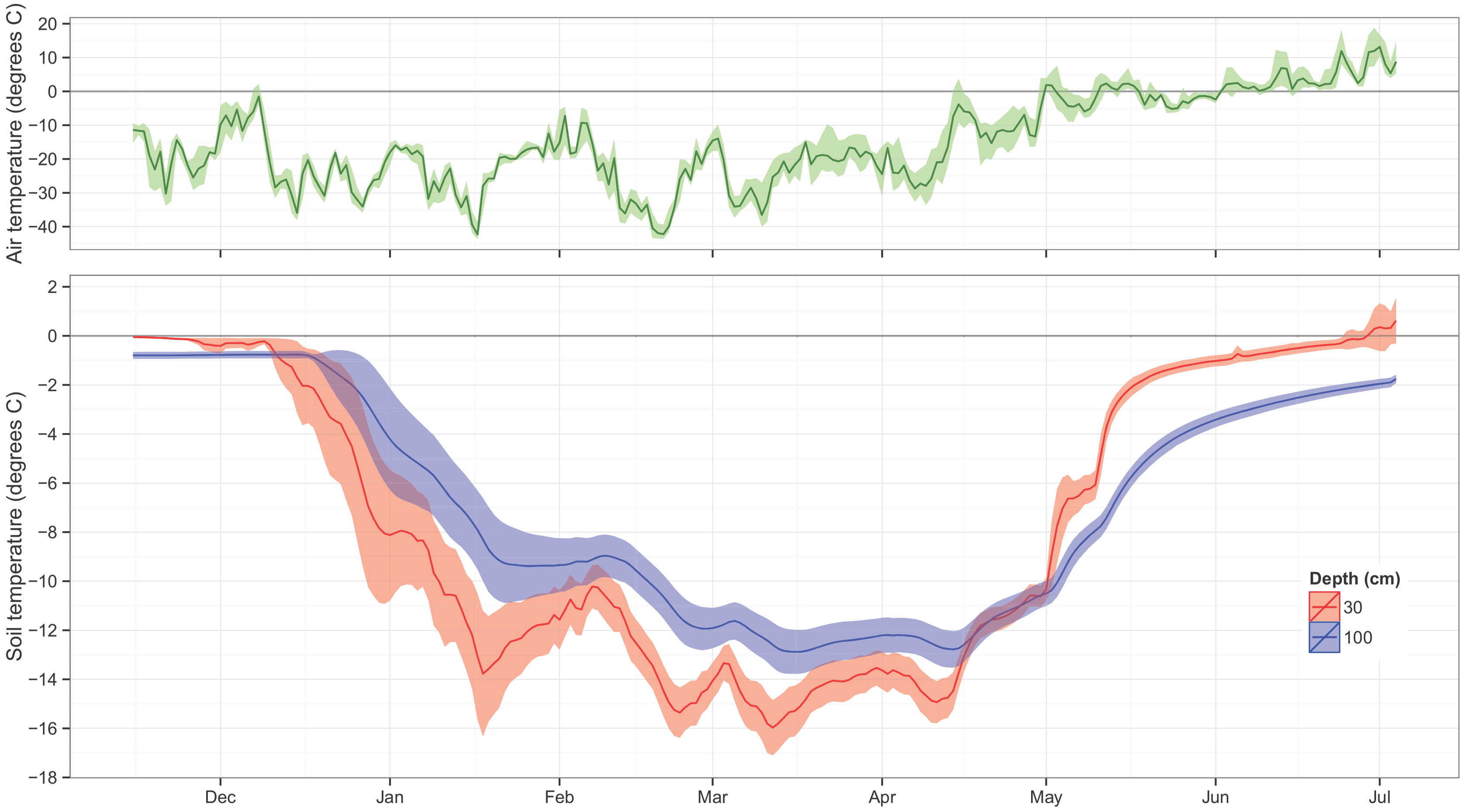


Figure 17. Time series of daily average mean soil temperature and standard deviation at 30 cm and 100 cm for Test Area South, and average daily minimum, mean and maximum air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, November 2013–July 2014.

Table 3. Soil temperature summary statistics at 30 cm and 100 cm and cumulative organic thickness (cm) within the active layer summarized by subarea, including Reference North, Reference South, Test North, and Test South, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

Area ID	Mean Temp 30 cm (C)	Std. Dev. Temp 30 cm (C)	Median Temp 30 cm (C)	Mean Temp 100 cm (C)	Std. Dev. Temp at 100 cm (C)	Median Temp 100 cm (C)	Mean Cum. Org. Thick in Active Layer (cm)
reference north	-5.19	5.71	-1.67	-5.11	4.49	-3.18	48.0
reference south	-5.27	5.85	-1.53	-5.09	4.48	-3.12	46.5
test north	-5.21	5.63	-1.76	-5.03	4.30	-3.27	39.0
test south	-5.92	6.14	-2.31	-5.59	4.69	-3.81	33.0

the mean annual soil temperatures. The reason for this is that the time period summarized for this report includes late fall, winter, spring, and early summer (mid-September through early July). Soil data for the summer and early fall (remainder of July and August 2014) were not available to be summarized at the time this report was prepared. This is because the Hobo Installations were serviced, and data downloaded, in early July 2014. Data from the second year of soil temperature monitoring will include a full calendar year, which will be used to summarize soil temperatures on a mean annual basis following the second year of monitoring.

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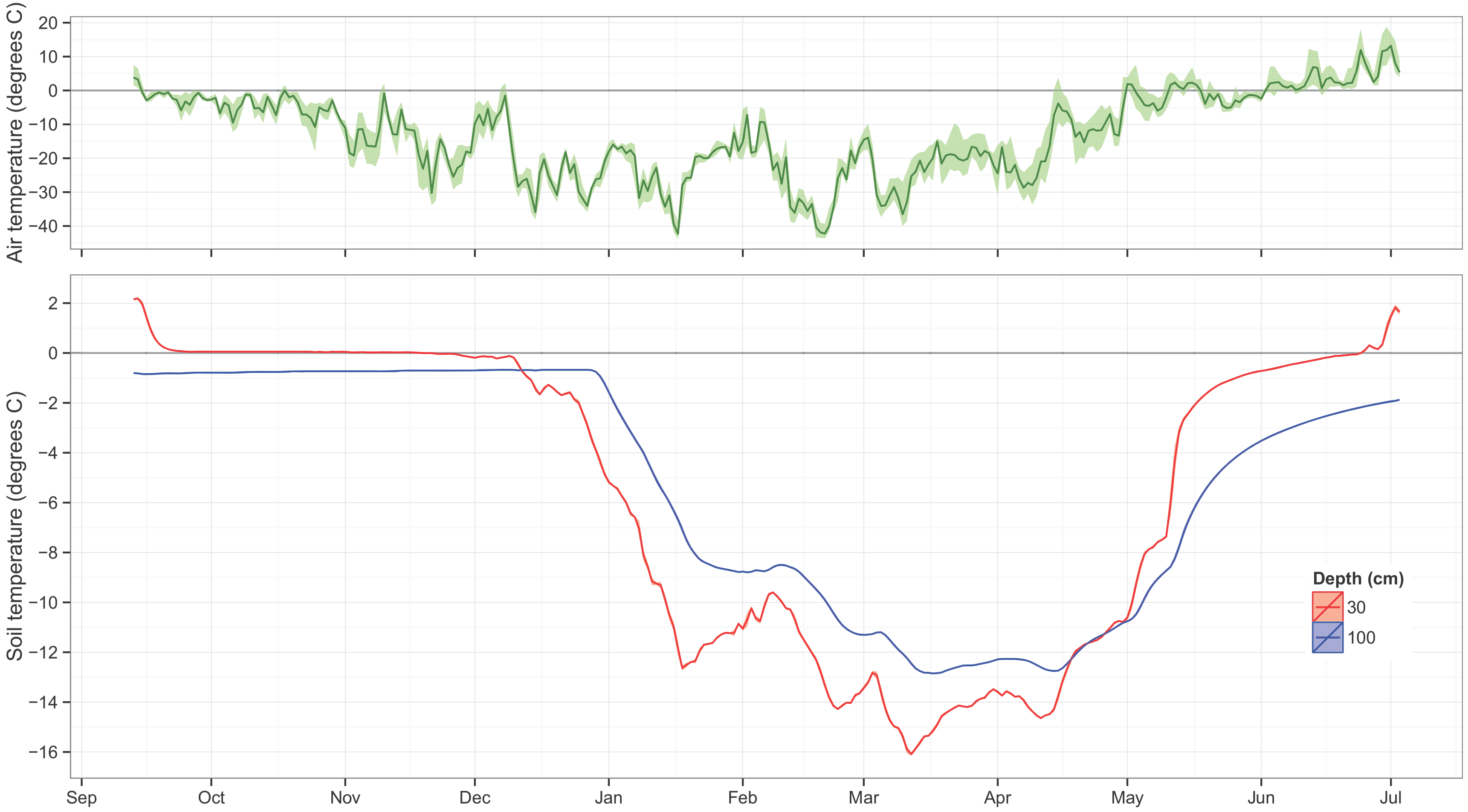
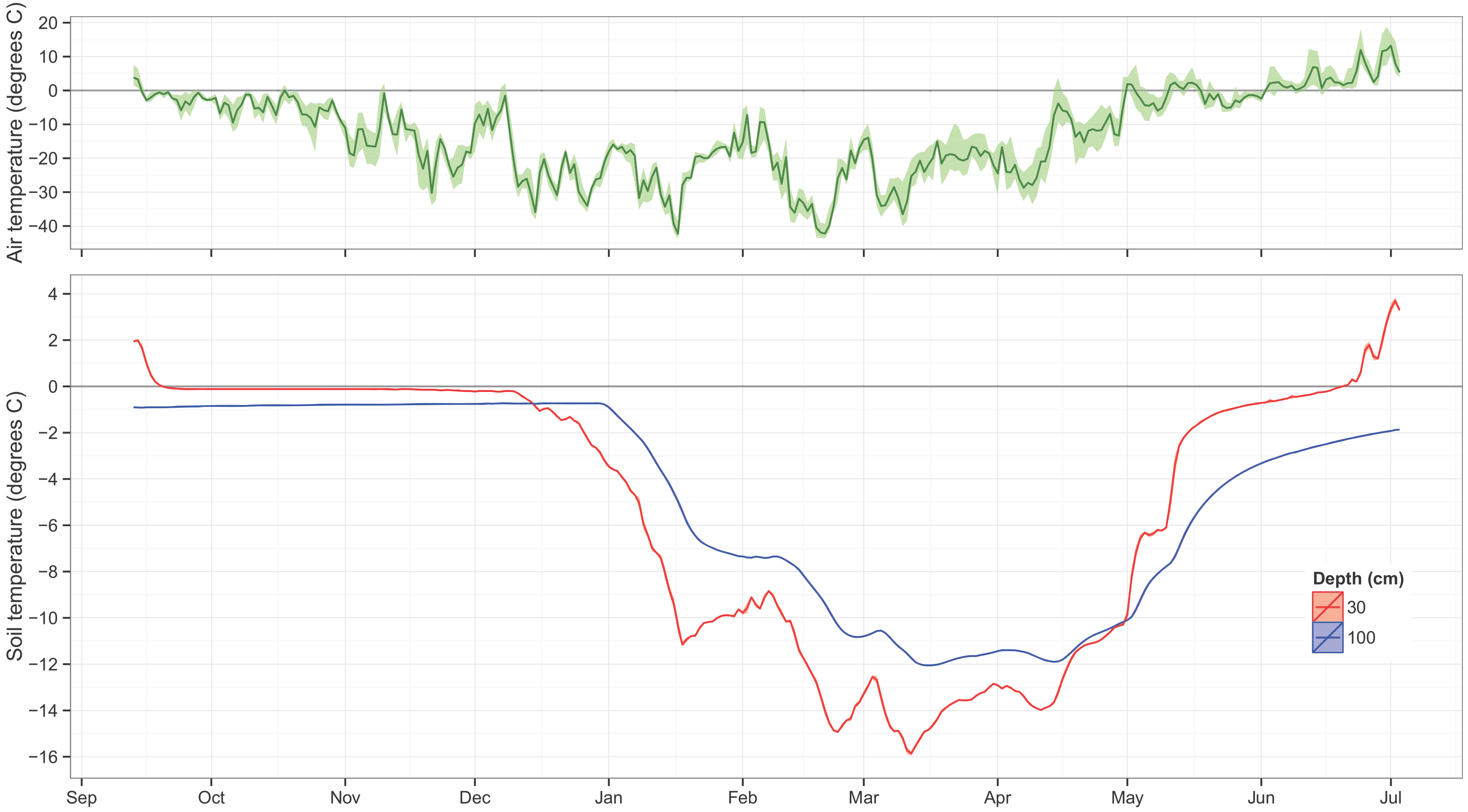
Appendix A-1. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rn-pc01 (hobo serial number 10392122) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

Appendix A-2. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rn-pc02 (hobo serial number 10392123) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

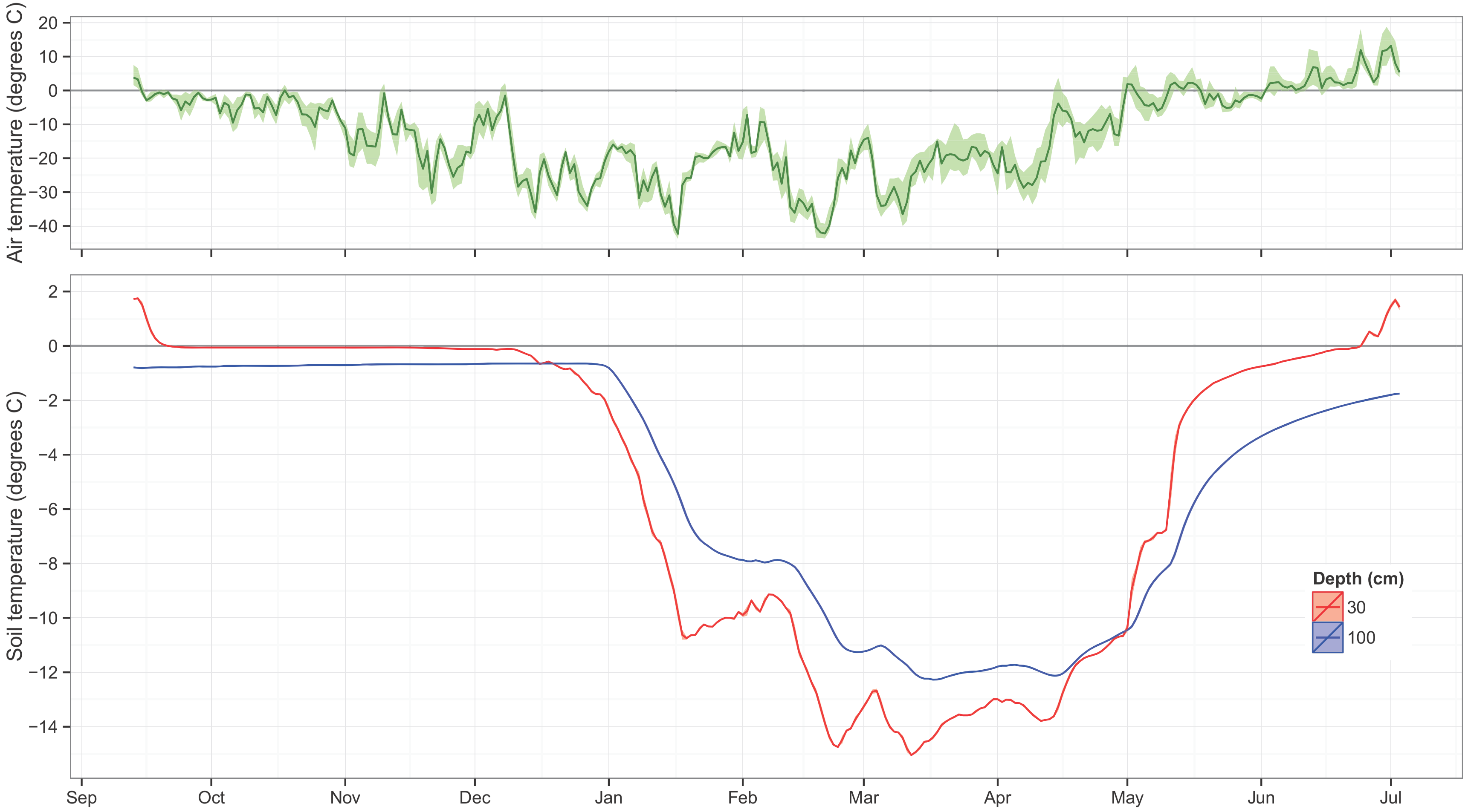
Appendix A-3. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rn-pc16 (hobo serial number 10392137) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



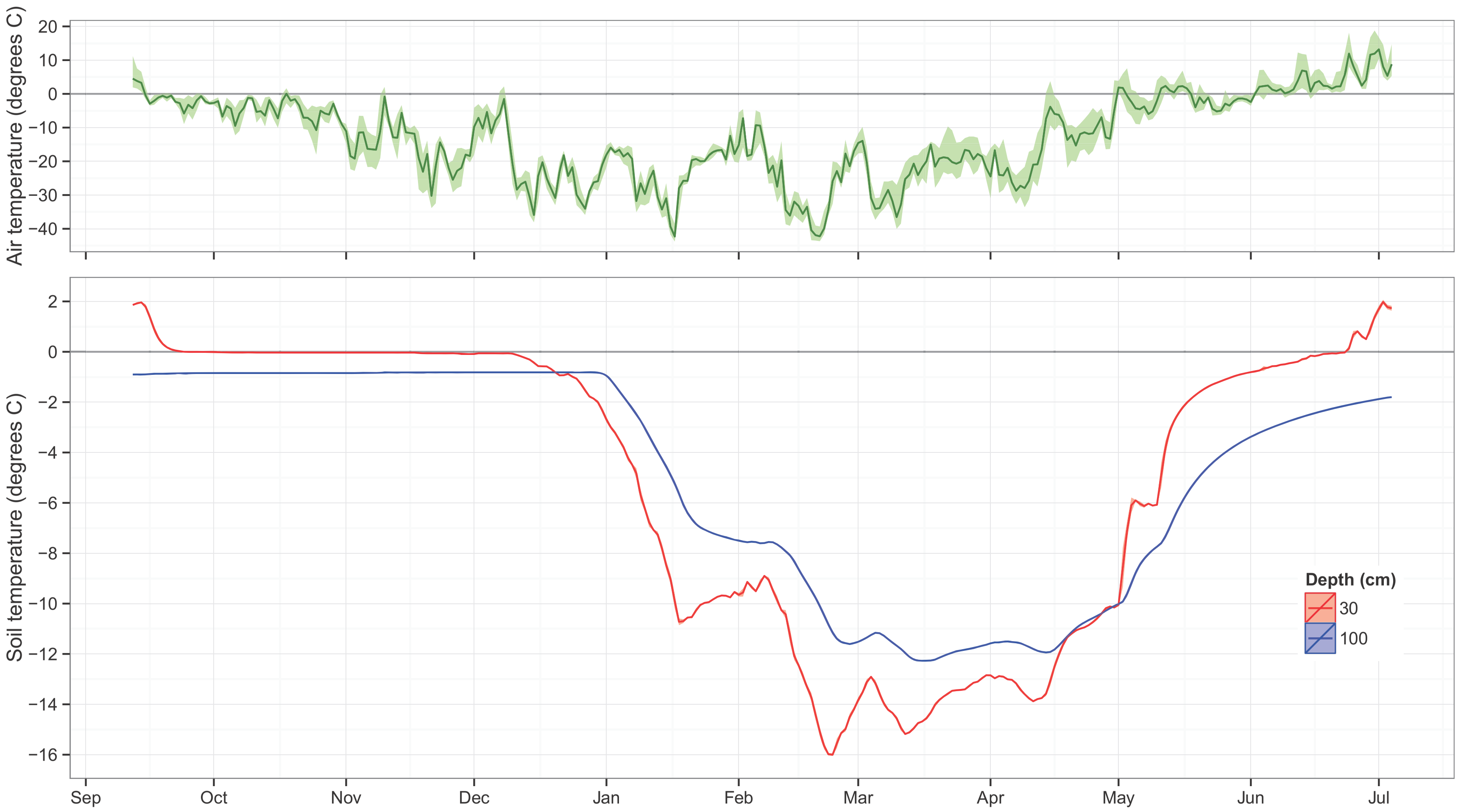
Appendix A-4. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rs-pc09 (hobo serial number 10392130) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



Appendix A-5. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rs-pc10 (hobo serial number 10392131) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

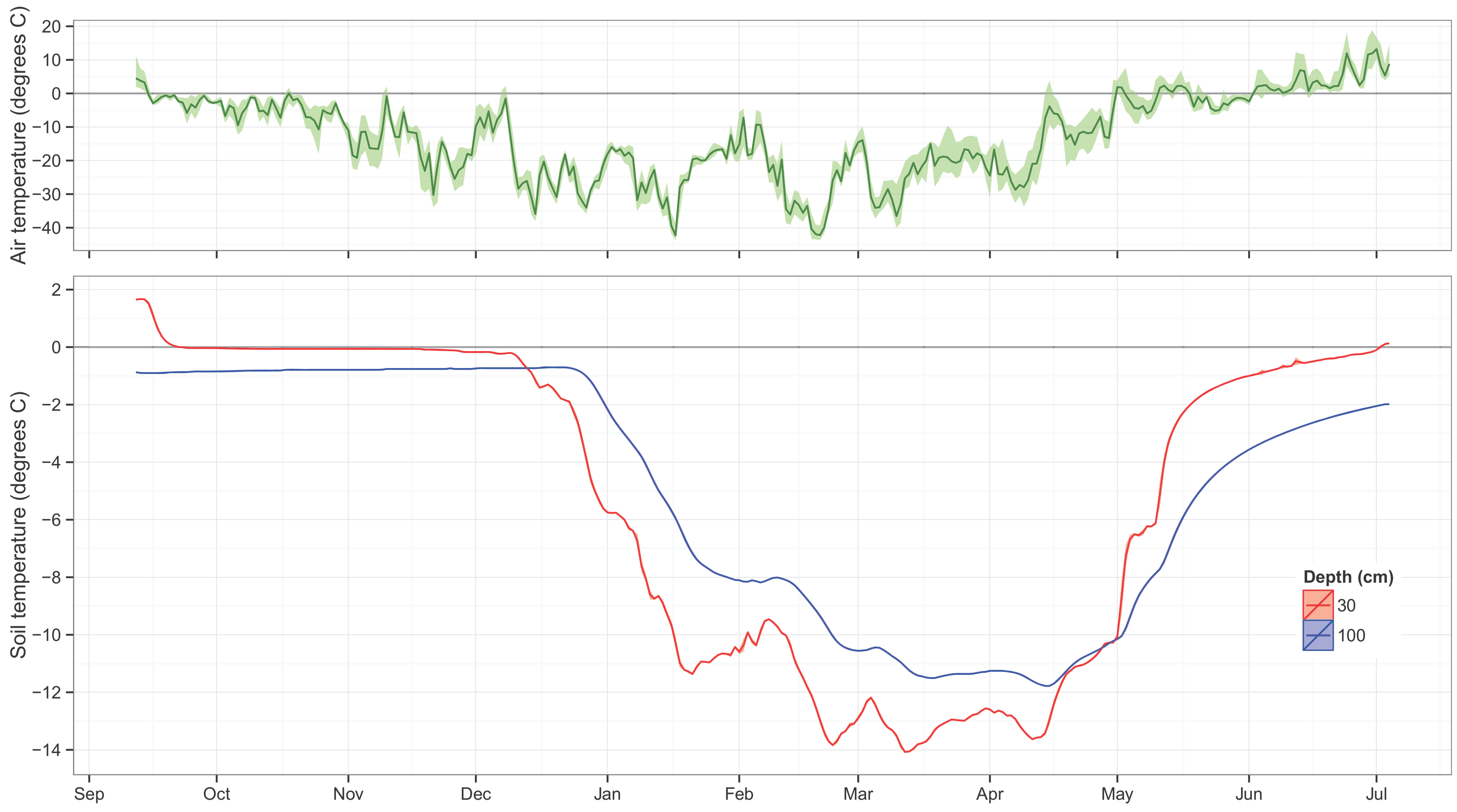


Appendix A-6. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot rs-pc11 (hobo serial number 10392132) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



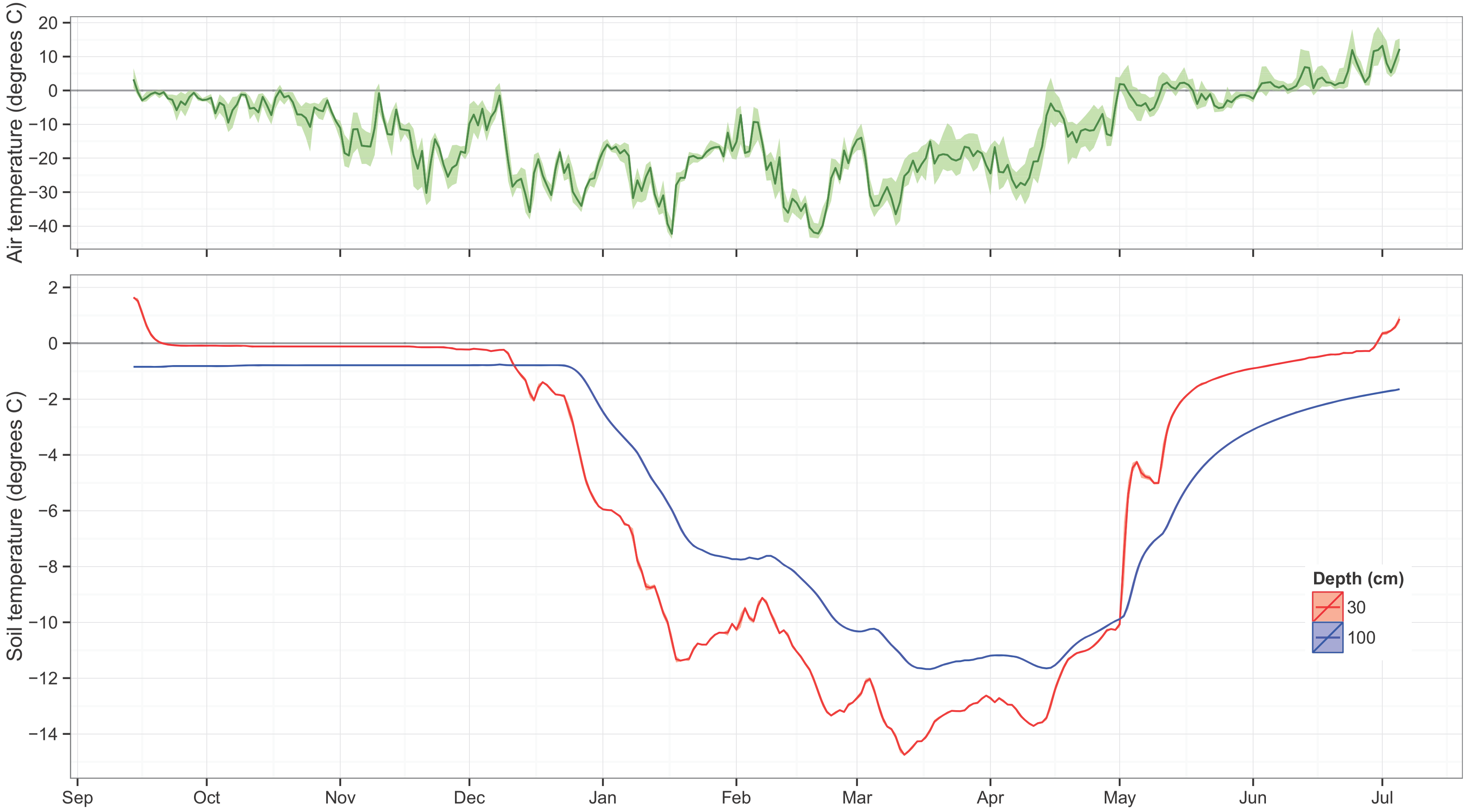
Appendix A-7. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot tn-pc03 (hobo serial number 10392124) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

Appendix A-8. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot tn-pc04 (hobo serial number 10392125) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



Appendix A-9. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot tn-pc05 (hobo serial number 10392126) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

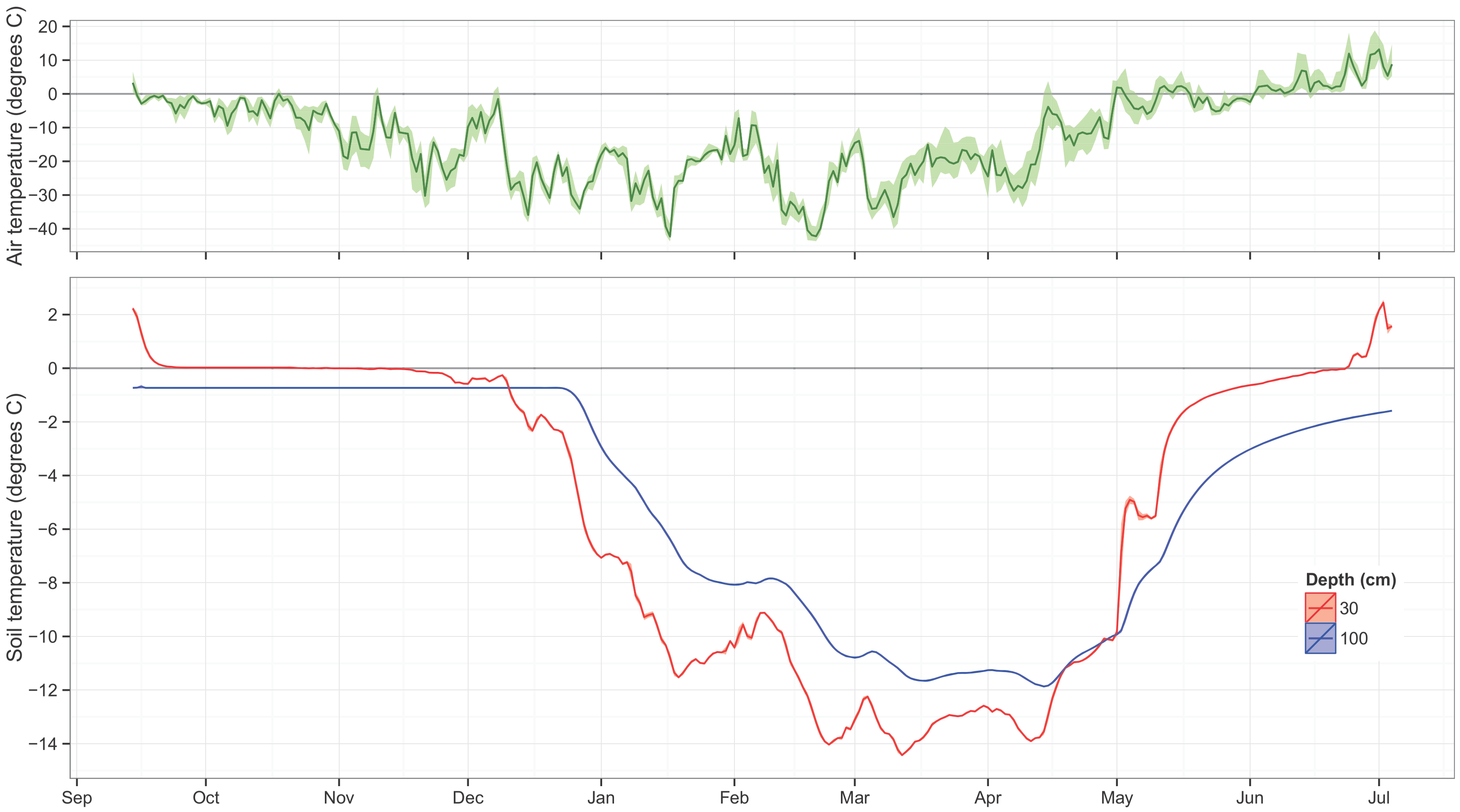
Appendix A-10. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot tn-pc06 (hobo serial number 10392127) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



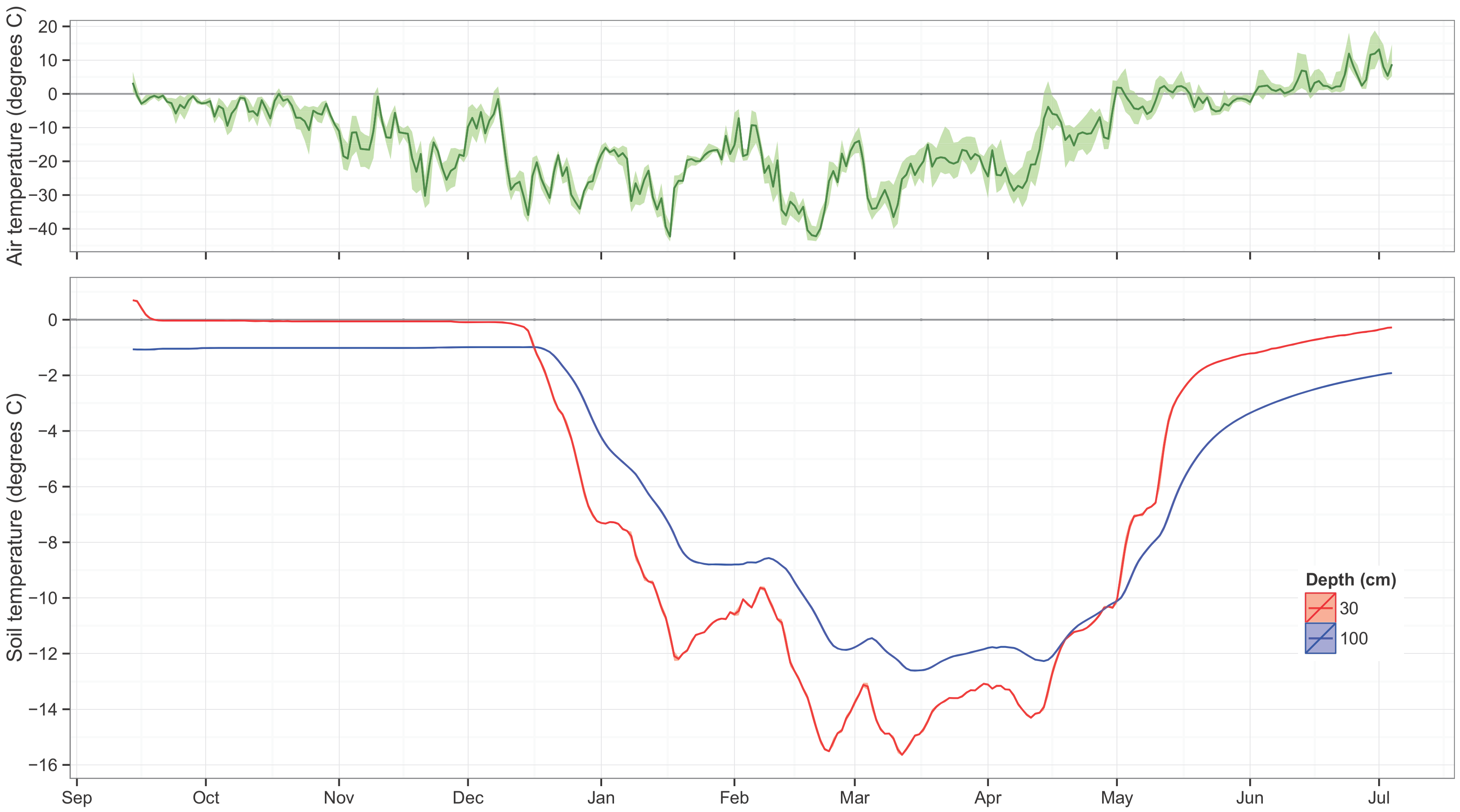
Appendix A-11. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot tn-pc15 (hobo serial number 10392136) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

Appendix A-12. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot ts-pc07 (hobo serial number 10392128) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.

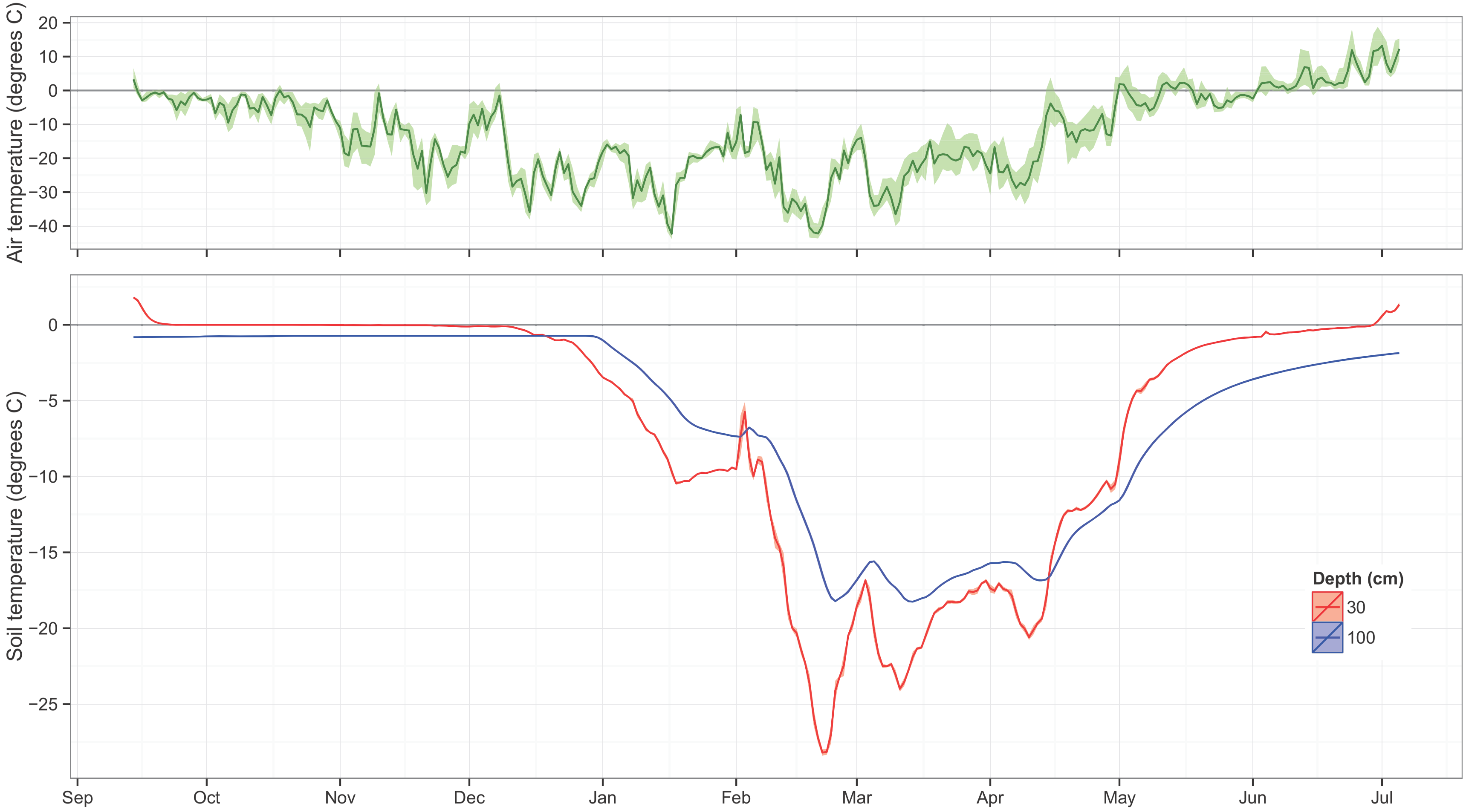
Appendix A-13. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot ts-pc08 (hobo serial number 10392129) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



Appendix A-14. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot ts-pc12 (hobo serial number 10392133) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



Appendix A-15. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot ts-pc13 (hobo serial number 10392134) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.



Appendix A-16. Time series of daily median soil temperature at 30 cm and 100 cm at Permafrost Temperature Monitoring Plot ts-pc14 (hobo serial number 10392135) and average daily air temperature at the Alpine weather station, CD5 Habitat Monitoring Study, northern Alaska, September 2013–July 2014.