Navigating the New Arctic: Landscape evolution and adaptation to change in Ice-Rich Permafrost Systems (NNA-IRPS)

Field report of the NNA-IRPS vegetation expedition, Prudhoe Bay, AK, 13 July-3 August 2021

D.A.'Skip' Walker, Jana Peirce, Amy Breen, Anja Kade, Helena Bergstedt, Ronnie Daanen, Emily Watson-Cook

Field work for the vegetation component of the NNA-IRPS project (NSF NNA award 1928237) was conducted 13 July-3 Aug 2021, at the Natural Ice-Rich Permafrost Observatory (NIRPO) and the nearby Jorgenson research site, Prudhoe Bay, AK (Fig. 1). The NIRPO was established to better understand the role that ecosystems play in the development and degradation of ice-rich permafrost. Researchers are studying how differences in vegetation, water, and time influence the accumulation and degradation of ground ice in IRP landscapes, and how the loss of ground ice can radically change these landscapes and the infrastructure built on them. The major goals for the 2021 expedition were to:

- Characterize the vegetation, site factors, and soils on different-age surfaces,
- Characterize the vegetation in the many small thermokarst ponds and determine if aquatic vegetation is affecting pond soil temperatures and the underlying permafrost,
- Characterize the fluxes of trace-gas fluxes on the different surfaces, and
- Date the major surfaces.

Major tasks:

- Establish baseline transects and permanent vegetation plots on five different-age surfaces with distinct landforms at the NIRPO site:
    - Residual surfaces unaffected by thaw-lake processes, but with extensive thermokarst ponds;
    - Drained thaw-lake bluff with high-centered polygons;
    - Old drained-lake basin surface with well-developed low-centered polygons;
    - Intermediate drained-lake basin surface with irregular and disjunct polygon features; and
    - Recent drained-lake basin with featureless surface, hummocks, and a few bird mounds.
- Collect Lidar imagery for the NIRPO site and other nearby areas of interest.
- Conduct baseline vegetation and soil studies at the permanent plots.
- Conduct pond studies (vegetation surveys, water and soil temperature, water level surveys) in thermokarst ponds at the Jorgenson and NIRPO sites.
- Conduct chamber-based trace-gas flux studies on a subset of permanent plots on each surface.
- Collect basal peat samples from each surface for C-14 dating.

•

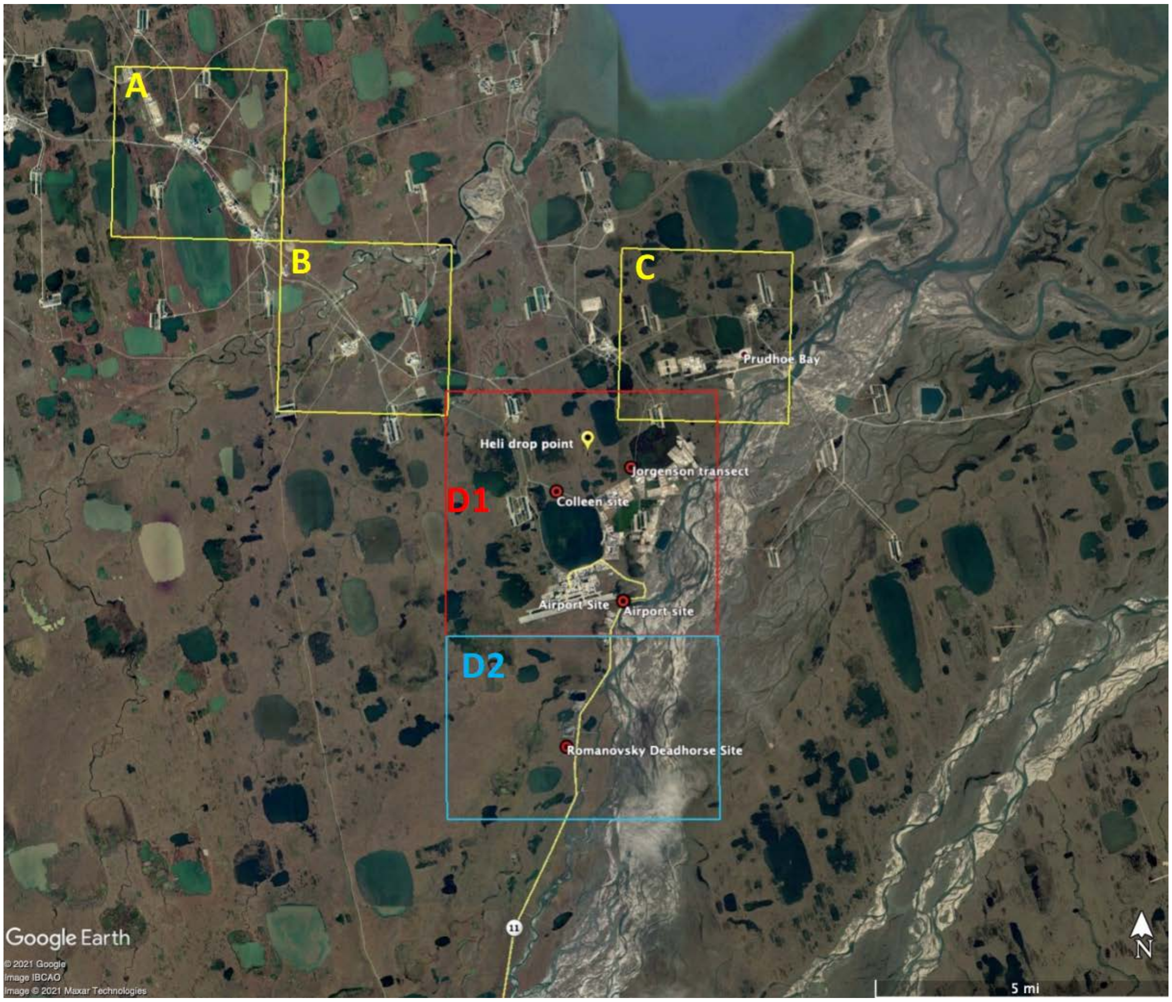

Figure 1. Study areas for the NNA-IRPS project. The studies during the included the area in the vicinity of the helicopter drop point at the NIRPO base camp (yellow dot) and the Jorgenson transect. The red boundary (D1) encloses the NIRPO site, the Colleen site (Walker et al. 2015), and Airport site (Walker et al. 2016). The yellow boxes A, B, and C are geoecological and historical disturbance map areas (Raynolds et al. 2014). The blue boundary (D2) includes the Romanovsky Deadhorse site (Romanovsky and Osterkamp 1995) and areas along the Dalton Highway affected by the 2015 Sagavanirktok flood (Shur 2016).

Expedition members:

Dr. Helena Bergstedt (UAF, Institute of Northern Engineering, Post doc): remote sensing

Dr. Amy Breen (UAF, International Arctic Research Center, Research Assistant Professor): Vegetation surveys

Dr. Ronnie Daanen and Mr. Barrett Salisbury (Alaska Department of Natural Resources, Division of Geological and Geodetic Surveys): Ground topographic control and Lidar acquisition

Dr. Anja Kade (UAF, Dept. of Biology and Wildlife, Assistant Professor): trace-gas fluxes

Ms. Josephine Mahoney (UAF, IAB: research assistant): Trace-gas fluxes

Ms. Zoe Meade (UAF, IAB, research assistant): Pond surveys

Ms. Jana Pierce (UAF, IAB; Project coordinator): Logistics and photographer

Dr. Skip Walker (UAF, IAB; Professor): Project lead and vegetation surveys

Ms. Emily Watson Cook (UAF, IAB and Dept. of Biology and Wildlife; M.S. graduate student): Pond surveys

Most participants were part of the vegetation component of the IRPS project and were divided into four main task groups: terrestrial vegetation surveys (Breen and Walker), trace-gas fluxes (Kade and Mahoney), pond studies (Watson-Cook and Meade), and logistics, communication, and photography (Peirce). Bergstedt joined the group for a few days and collected basal peat samples for C-14 dating. Most of the objectives were completed by August 26. Breen, Kade, Peirce and Walker returned to Fairbanks by truck. Meade returned to Anchorage by plane. Watson-Cook and Mahoney remained to complete the pond studies until Aug 1 and returned to Fairbanks by truck.

Accomplishments and high points:

1. **Logistic support** (Fig. 1): The Batelle ARO provided excellent expedition support, including safety training, two trucks, housing in Wiseman, meals to and from the field site, housing and meals at Prudhoe Bay, and helicopter support for the base camp. The support at the Arctic Oilfield Hotel was excellent and friendly. They allowed us to use of their Conference Room for our daily morning meetings and evening sample preparation and analyses. They also provided freezer space for our samples.

Figure 1. Arctic Oilfield Hotel and conference room during morning meeting. Left to right: Skip Walker, Amy Breen, Emily Watson-Cook, Josephine Mahoney. All photos are by Jana Peirce unless otherwise noted.

2. **Weather:** We had sunny and warm weather 13–21 July. It turned cloudy, cooler and windy for the remaining days with some light rain July 26. Mosquitoes were minimal the entire time.

3. **NIRPO base camp (15 July) (Fig. 2):**

Figure 2. Left: Quicksilver helicopter pilot, Eryk de la Montaña, and Skip Walker preparing sling load. Right: Helicopter dropping the first sling load at the drop point (circle of orange pin flags). Photo by Josephine Mahoney.

The NIRPO base camp was transported from the Deadhorse Airport to the NIRPO in 3 trips (3 trips including 2 sling loads) by a Quicksilver R-44 helicopter stationed at the Teshekpuk Lake Observatory (pilot Eryk de la Montaña). The base camp was used for storing and staging equipment and providing a common area of gathering while in the field. The camp is accessible from the Nabors Drilling Co. pad (1.2 km south of the NIRPO base camp, 25-minute walk).

Figure 3. NIRPO base camp with from left Helena Bergstedt, Amy Breen, Skip Walker.

4. **Lidar acquisition (17-19 July) (Fig. 3):** The Lidar surveys will be used to support the hydrological studies. In addition, the survey will show ground ice degradation in places where the elevation is reduced compared with existing data. Ronnie Daanen surveyed ground control points in the NIRPO study area, and Barrett Salisbury flew high- and low-resolution LIDAR missions using the Toolik Lake helicopter.

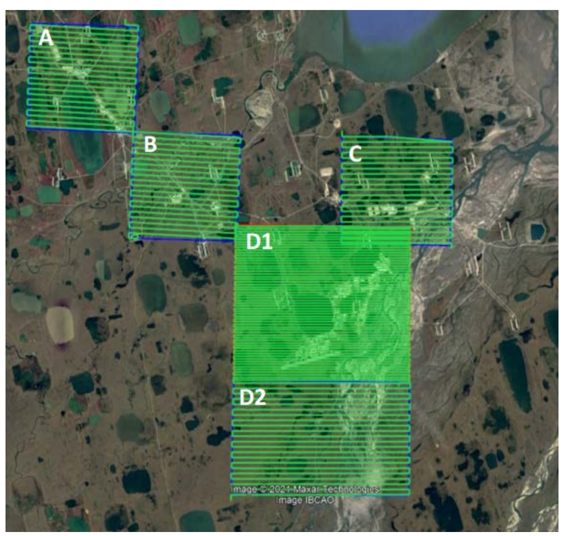

Figure 3. Lidar flight lines for the NNA-IRPS Prudhoe Bay studies. Areas A, B, C, and D2, map areas that are being used for permafrost modeling studies and extrapolation, were surveyed at relatively course resolution (13-18 pts m^{-2}). Area D1contains the IRPS intensive study areas — NIRPO, Jorgeson, Colleen, Airport sites — was surveyed at fine resolution (approximately 110 pts m^{-2}). See Fig. 1 for landscape features. Image by Barret Salisbury. Base image courtesy of Google Maps Maxar Technologies.

5. **Transects and plots (Jul 15–18) (Fig. 4, Table 1):** Four transects were surveyed on surfaces with different ages and geomorphology: Transect T6 (200 m): residual surface

with thermokarst ponds; T7 (200 m): older drained lake basin with low-centered polygons; T8 (200 m): newer drained lake basin with featureless and disjunct polygon features; T9 (100 m): margin of drained lake basin and well drained polygons high centered polygons on residual surface). The 0-, 50-, 100-, 150-, and 200-m points of each transect were marked with 1.2-m tall white PVC stakes with the plot number and orange surveyors' tape at the top of the stake. To make the transects easily visible in drone- and aircraft-acquired aerial imagery, the end points of each transect were marked with 1.2-m x 1-2-m white 'X's made of six 13-gallon trash bags nailed to the tundra. The intermediate 50-m points are marked with circular paper plates. The markers will be removed after completion of the aerial surveys.

Thirty-five terrestrial plots (Table 1). and 40 aquatic vegetation plots (Table 2) were marked for vegetation, trace gas, permafrost, basal peat studies, and temperature monitoring. The centers of the 1-m x 1-m plots were marked with rebar stakes with aluminum caps stamped with the plot numbers (21-01 to 21-35 for the terrestrial plots and 21A-1 to 21A-40 for the aquatic plots) and wooden corner stakes. The center stake of each plot pierces a white 25-cm wide circular paper plate to make the plot visible for aerial surveys. The centers were also marked with a white 1.5-m vertical PVC stake with the plot number and blue surveyors' tape at the top of the stake for locating the terrestrial plots in winter and purple surveyors' tape for the aquatic plots.

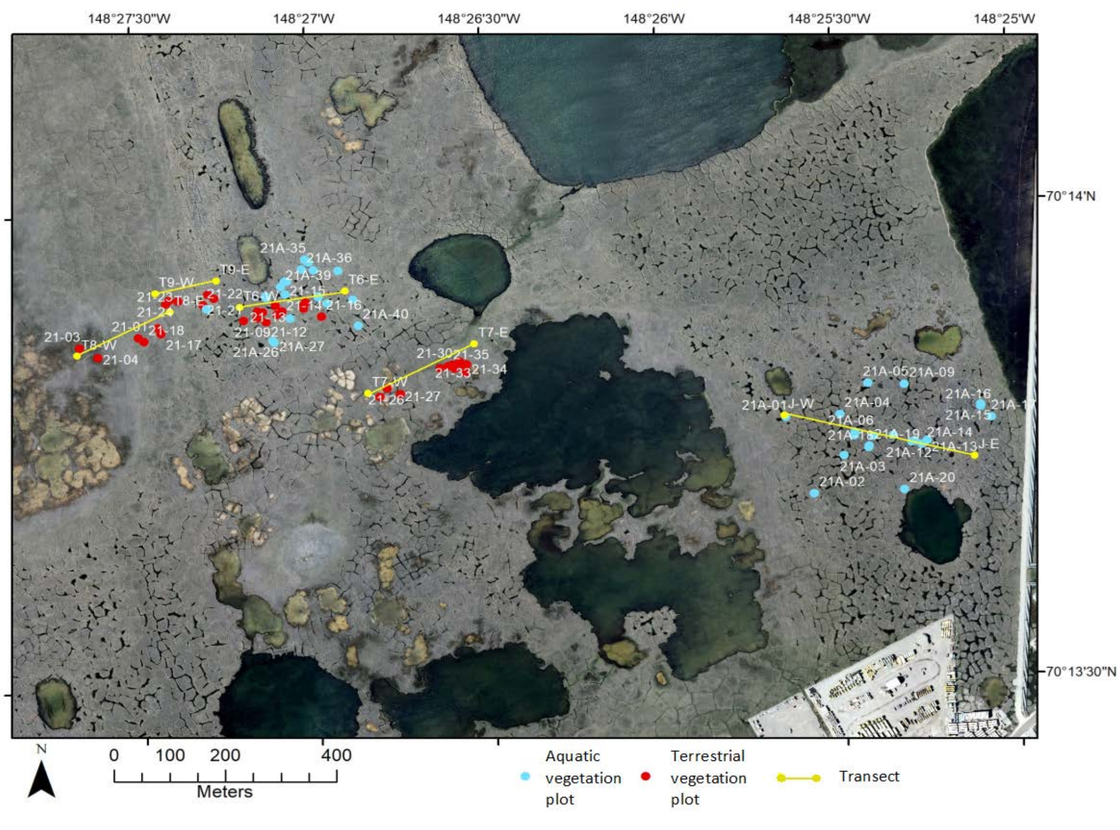

Figure 4. Transects and plots surveyed at the NIRPO site (left group) and Jorgenson sites right group).

6. **Vegetation surveys (18–26 July, Breen and Walker) (Fig. 5):** Surveys were made at 35 permanent plots and included complete lists and estimated cover of vascular plants, lichens and mosses, brief soil descriptions, collection of soils in the upper organic horizon and the mineral horizon, measurement of thaw depth, description of the site factors and vegetation structure. iButton temperature loggers were placed at the ground surface and base of the organic layer of each plot to measure the insulative effect of the vegetation and peat layers. The methods used for the surveys were compatible with previous surveys at the Colleen and Airport sites (Walker et al. 2015, 2016).

Figure 5. Vegetation surveys. Left: Skip Walker and Amy Breen recording plant-community composition in a permanent vegetation plot. Right: Evening moss identification and voucher collections.

Table 1. Terrestrial vegetation plot summary, including coordinates, transect, landform, surface age, and preliminary vegetation type names, basal peat sampled, and iButtons.

PLOT_ID	DATE_SAMPLED (YYYYMMDD)	LATITUDE (North, decimal degrees)	LONGITUDE (West, decimal degrees)	TRANSECT	LANDFORM	SURFACE_AGE	MICROSITE	VEG_CODE	VEG_TYPE_BROAD	VEG_TYPE_SPECIFIC	BASAL_PEAT_SAMPLED	IBUTTONS
21-01	20210722	70.231207	148.458254	T8	Drained lake basin	Young	Flark, interstrang, or interhummock	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	Y
21-02	20210722	70.231378	148.457325	T8	Drained lake basin	Young	Flark, interstrang, or interhummock	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	Y	Y
21-03	20210722	70.231047	148.461073	T8	Drained lake basin	Young	Flark, interstrang, or interhummock	M4	Wet to aquatic tundra	Wet to aquatic Carex aquatilis-Scorpidium scorpoides graminoid tundra	Y	Y
21-04	20210722	70.230879	148.460215	T8	Drained lake basin	Young	Flark, interstrang, or interhummock	M4	Wet to aquatic tundra	Wet to aquatic Carex aquatilis-Scorpidium scorpoides graminoid tundra	Y	Y
21-05	20210719	70.231717	148.450367	T6	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	Y	Y
21-06	20210719	70.231660	148.450367	T6	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	Y	Y
21-07	20210719	70.231568	148.451636	T6	Plain - residual surface	Primary	High center polygon	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-08	20210719	70.231509	148.452599	T6	Plain - residual surface	Primary	High center polygon	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	Y	Y
21-09	20210719	70.231474	148.453238	T6	Plain - residual surface	Primary	High center polygon	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-10	20210719	70.231632	148.452558	T6	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	N	Y
21-11	20210721	70.231615	148.452332	T6	Plain - residual surface	Primary	Polygon Trough	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	Y
21-12	20210721	70.231437	148.452164	T6	Plain - residual surface	Primary	Polygon Trough	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-13	20210721	70.231723	148.451711	T6	Plain - residual surface	Primary	Polygon Trough	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-14	20210721	70.231617	148.451407	T6	Plain - residual surface	Primary	Polygon Trough	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	Y
21-15	20210721	70.231766	148.450267	T6	Plain - residual surface	Primary	Polygon Trough	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-16	20210721	70.231516	148.449526	T6	Plain - residual surface	Primary	Polygon Trough	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	Y
21-17	20210722	70.231273	148.457176	T8	Drained lake basin	Young	Strang, hummock, or disjunt polygon rim	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-18	20210722	70.231143	148.458003	T8	Drained lake basin	Young	Strang, hummock, or disjunt polygon rim	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	Y
21-19	20210723	70.231794	148.456931	T9	Drained lake basin	Intermediate	Flat center polygon	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	Y	Y
21-20	20210723	70.231940	148.454904	T9	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	N	Y
21-21	20210723	70.231873	148.454629	T9	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	N	Y
21-22	20210723	70.231759	148.455148	T9	Plain - residual surface	Primary	High center polygon	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	N	Y
21-23	20210723	70.231835	148.456326	T9	Drained lake basin	Intermediate	Flat center polygon	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	Y
21-24	20210724	70.231859	148.456760	T9	Drained lake basin	Intermediate	Strang, hummock, or disjunt polygon rim	U3	Moist lichen-rich tundra	Moist Eriophorum angustifolium-Dryas integrifolia-Tomenhypnum nitens-Thamnolia subuliformis graminoid dwarf shrub tundra	N	Y
21-25	20210724	70.230085	148.446855	T7	Lake margin	Intermediate	Ephemeral pond	M4-Gyttj	Aquatic tundra	Wet to aquatic Carex aquatilis, gyttja-rich tundra	N	Y
21-26	20210724	70.230235	148.446488	T7	Lake margin	Intermediate	Ephemeral pond	M4-Gyttj	Aquatic tundra	Wet to aquatic Carex aquatilis, gyttja-rich tundra	N	Y
21-27	20210724	70.230130	148.445879	T7	Drained lake basin	Intermediate	Low center polygon	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	Y	Y
21-28	20210724	70.230564	148.443961	T7	Drained lake basin	Intermediate	Polygon Trough	M4	Wet to aquatic tundra	Wet to aquatic Carex aquatilis-Scorpidium scorpoides graminoid tundra	N	Y
21-29	20210724	70.230549	148.443240	T7	Drained lake basin	Intermediate	Low center polygon	M2	Wet tundra	Wet Carex aquatilis-Drepanocladus brevifolius graminoid moss tundra	N	N
21-30	20210725	70.230614	148.443354	T7	Drained lake basin	Intermediate	Polygon rim	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	N
21-31		70.230481	148.442761	T7	Drained lake basin	Intermediate	Polygon Trough	M4/E1	Aquatic tundra	Aquatic Carex aquatilis graminoid tundra	N	Y
21-32	20210725	70.230606	148.442825	T7	Drained lake basin	Intermediate	Low center polygon	M4	Wet to aquatic tundra	Wet to aquatic Carex aquatilis-Scorpidium scorpoides graminoid tundra	N	Y
21-33	20210726	70.230670	148.443007	T7	Drained lake basin	Intermediate	Low center polygon	M4	Wet to aquatic tundra	Wet to aquatic Carex aquatilis-Scorpidium scorpoides graminoid tundra	Y	N
21-34	20210726	70.270617	148.442673	T7	Drained lake basin	Intermediate	Polygon rim	U4	Moist tundra	Moist Carex aquatilis-Dryas integrifolia-Salix arctica-Tomentypnum nitens graminoid dwarf shrub tundra	N	N
21-35	20210726	70.230593	148.443552	T7	Drained lake basin	Intermediate	Polygon Trough	M4/E1	Aquatic tundra	Aquatic Carex aquatilis graminoid tundra	N	Y

7. **Pond surveys (July 16–Aug 1, Watson-Cook, Meade, and Mahoney) (Fig. 6, Table 2):** 40 pond vegetation plots were surveyed (20 at the Jorgenson site and 20 at the NIRPO Transect 6). These transects are on older primary (residual) surfaces with abundant thermokarst ponds. Short-term temperature sensors were placed in three positions in the water column of each pond. Long-term temperature sensors were placed in 20 ponds. Water depth sensors were placed in 20 ponds at the Jorgenson site.

Figure 6. Pond surveys. Left: Emily Watson-Cook and Zoe Meade monitoring pond temperature, pH, and conductivity in thermokarst pond. Right: Recording plant community composition and site factors in a Sparganium hyperboreum *aquatic plant community.*

Table 2. Aquatic vegetation plot summary.

PLOT ID	DATE SAMPLED (YYYYMMDD)	LATITUDE (decimal degrees)	LONGITUDE (decimal degrees)	TRANSECT	LANDFORM	SURFACE_AGE	VEG_TYPE_BROAD	VEG_TYPE_NAME	IBUTTONS	WATER DEPTH SENSOR	SOIL SAMPLES
21A-01	20210723	70.2296	-148.42756	JS	Pond	Primary	Aquatic forb	*Hippuris vulgaris, Calliergon giganteum*	Y	Y	Y
21A-02	20210724	70.2282	-148.42631	JS	Pond	Primary	Moss mat	*Scorpidium scorpioides*	Y	Y	Y
21A-03	20210724	70.2289	-148.42485	JS	Pond	Primary	Aquatic forb	*Hippuris vulgaris, Utricularia vulgaris*	Y	Y	Y
21A-04	20210723	70.2296	-148.42499	JS	Pond	Primary	Shallow moss	*Scorpidium scorpiodes*	Y	Y	Y
21A-05	20210724	70.2301	-148.42363	JS	Pond	Primary	Moss mat	*Calliergon giganteum, Hippuris vulgaris*	Y	Y	Y
21A-06	20210724	70.2293	-148.42429	JS	Pond	Primary	Moss mat	*Calliergon giganteum, Hippuris vulgaris*	Y	Y	Y
21A-07	20210729	70.2292	-148.42432	JS	Pond	Primary	Bare	N/A	Y	Y	Y
21A-08	20210724	70.2292	-148.42342	JS	Pond	Primary	Shallow moss	*Scorpidium scorpioides*	Y	Y	Y
21A-09	20210724	70.2301	-148.42189	JS	Pond	Primary	Shallow moss	*Drepanocladus* sp., *Calliergon giganteum*	Y	Y	Y
21A-10	20210725	70.2292	-148.42247	JS	Pond	Primary	Moss mat	*Calliergon giganteum*	Y	Y	Y
21A-11	20210725	70.2291	-148.42160	JS	Pond	Primary	Shallow moss	*Scorpidium scorpioides*	Y	Y	Y
21A-12	20210729	70.2291	-148.42145	JS	Pond	Primary	Bare	N/A	Y	Y	Y
21A-13	20210725	70.2291	-148.42088	JS	Pond	Primary	Aquatic forb	*Hippuris vulgaris*	Y	Y	Y
21A-14	20210729	70.229	-148.42111	JS	Pond	Primary	Bare	N/A	Y	Y	Y
21A-15	20210725	70.2297	-148.41828	JS	Pond	Primary	Moss mat	*Calliergon giganteum*	Y	Y	Y
21A-16	20210716	70.2297	-148.41829	JS	Pond	Primary	Bare	N/A	Y	Y	Y
21A-17	20210725	70.2295	-148.41779	JS	Pond	Primary	Aquatic forb	*Utricularia vulgaris, Ranunculus aquatilis*	Y	Y	Y
21A-18	20210724	70.229	-148.42367	JS	Pond	Primary	Moss mat	*Scorpidium scorpioides*	Y	Y	Y
21A-19	20210729	70.229	-148.42364	JS	Pond	Primary	Bare	N/A	Y	Y	Y
21A-20	N/A	70.22826	-148.42200	JS	Lake	Primary	N/A	N/A	Y	Y	Y
21A-21	20210720	70.2318	-148.44802	T6	Pond	Primary	Moss mat	Unknown moss, *Drepanocladus* sp.	Y	N	Y
21A-22	20210722	70.2317	-148.44923	T6	Pond	Primary	Aquatic forb	*Hippuris vulgaris, Ranunculus aquatilis*	Y	N	Y
21A-23	20210722	70.2319	-148.44967	T6	Pond	Primary	Shallow moss	*Calliergon giganteum*	Y	N	Y
21A-24	20210727	70.2319	-148.44965	T6	Pond	Primary	Bare	N/A	Y	N	Y
21A-25	20210722	70.2315	-148.45101	T6	Pond	Primary	Aquatic forb	*Hippuris vulgaris, Calliergon giganteum*	Y	N	Y
21A-26	20210723	70.2311	-148.45188	T6	Pond	Primary	Moss mat	*Calliergon giganteum*	Y	N	Y
21A-27	20210727	70.2311	-148.45180	T6	Pond	Primary	Bare	N/A	Y	N	Y
21A-28	20210723	70.2317	-148.45499	T6	Pond	Primary	Aquatic forb	*Hippuris vulgaris*	Y	N	Y
21A-29	20210722	70.2319	-148.45213	T6	Pond	Primary	Shallow moss	*Calliergon giganteum, Drepanocladus* sp.	Y	N	Y
21A-30	20210727	70.2319	-148.45215	T6	Pond	Primary	Bare	N/A	Y	N	Y
21A-31	20210722	70.2319	-148.45123	T6	Pond	Primary	Aquatic forb	*Ranunculus aquatilis*	Y	N	Y
21A-32	20210720	70.2323	-148.44869	T6	Pond	Primary	Moss mat	Unknown moss, *Drepanocladus* sp.	Y	N	Y
21A-33	20210721	70.2323	-148.44986	T6	Pond	Primary	Shallow moss	*Calliergon giganteum*	Y	N	Y
21A-34	20210720	70.2325	-148.45009	T6	Pond	Primary	Moss mat	*Calliergon giganteum, Hippurus vulgaris*	Y	N	Y
21A-35	20210727	70.2325	-148.45025	T6	Pond	Primary	Bare	N/A	Y	N	Y
21A-36	20210721	70.2324	-148.45041	T6	Pond	Primary	Moss mat	*Calliergon giganteum*	Y	N	Y
21A-37	20210721	70.2322	-148.45123	T6	Pond	Primary	Shallow moss	*Calliergon giganteum*	Y	N	Y
21A-38	20210727	70.2321	-148.45113	T6	Pond	Primary	Bare	N/A	Y	N	Y
21A-39	20210722	70.2321	-148.45144	T6	Pond	Primary	Shallow moss	*Calliergon giganteum, Drepanocladus* sp.	Y	N	Y
21A-40	20210720	70.2313	-148.44779	T6	Pond	Primary	Aquatic forb	*Hippuris vulgaris, Sparganium* sp.	Y	N	Y

8. **Trace-gas flux plots (Kade and Mahony) (Fig. 7, Table 3): Trace-gas flux measurements (A. Kade)**

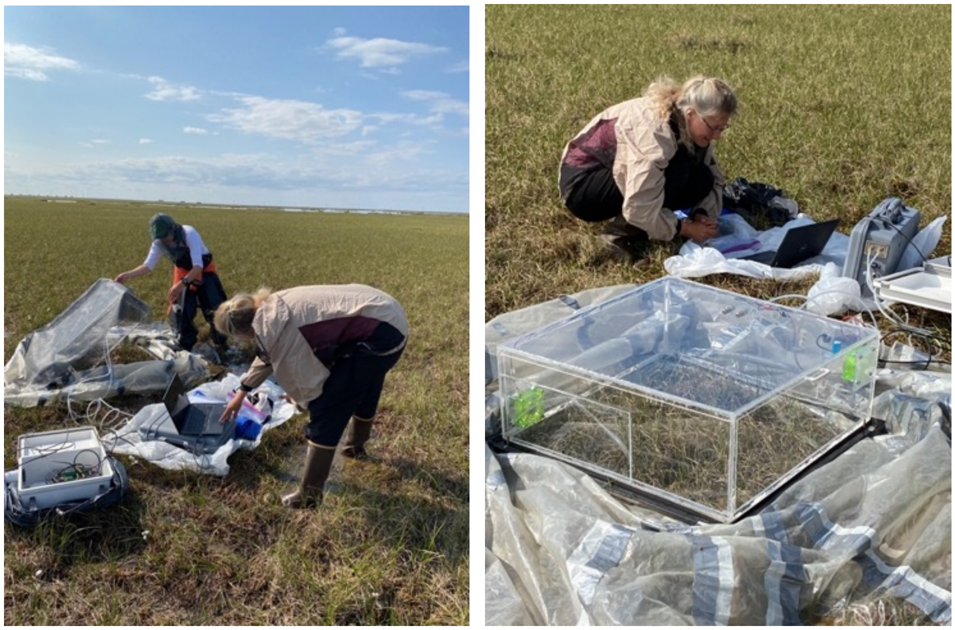

Figure 7. Trace-gas flux measurements. Left: Anja Kade and Josephine Mahoney preparing to make flux measurements using a 0.7-m x 0.7-m chamber. Right: Anja Kade recording trace-gas flux and respiration in a wet-tundra plant community.

We measured trace-gas fluxes during our peak-season measurement campaign (16-24 July 2021) at 27 terrestrial and 6 aquatic plots that were co-located with the plots selected for the vegetation and pond surveys. We selected 3 representative plots for each common vegetation on various patterned-ground locations such as polygon centers, rims and troughs. We used chamber-based methods to measure ecosystem respiration (ER) and the light response of net ecosystem exchange (NEE), and we calculated gross ecosystem exchange (GEE) at each study plot. We measured midday carbon dioxide, humidity and methane concentrations by connecting a clear Plexiglas chamber (0.7x0.7x0.25 m) to a LI-7810 portable infrared gas analyzer in closed-path configuration (Li-Cor Inc., Lincoln, Nebraska) and fitting the chamber to a portable rectangular base with an airtight polyethylene skirt. Two small fans mixed the air within the chamber. The LI-7810 recorded internal trace-gas concentrations, while temperature, barometric pressure and photosynthetic active radiation (PAR) were logged simultaneously to a Campbell CR-6 data logger every second over a 40-second period.

At each study plot, we took two to three measurements each under full sunlight, three levels of successive shading and complete darkness. Shading was provided with layers of fiberglass window screen material (approximately 1.5 mm mesh), and each successive layer of shading reduced the ambient light intensity by approximately 50%. To obtain complete darkness for the ER measurements, we covered the chamber with an opaque tarp. The chamber was ventilated between measurements.

For each data set, only periods with stable PAR values were used to calculate net CO_2 flux. From these data, we constructed a light-response curve for each plot by interpolating between measured light intensities. We calculated net CO_2 flux as NEE = (r*V/A)*(dC/dt), where r is air density (mol/m^3), V is the chamber volume (m^3), dC/dt is the rate of change in CO_2 concentration (μmol/mol/s) and A is the surface area of the chamber (m^2). GEE was calculated as the difference between NEE and ER. In our preliminary analysis of CO_2 fluxes, we report NEE values at 600 μmol photons/m^2/s, because we achieved this light level consistently in the field and did not wish to extrapolate beyond the measured values of PAR. GEE was calculated as the difference between NEE and ER. We used negative GEE and NEE values to indicate carbon uptake by the vegetation, according to the micrometeorological sign convention.

Our preliminary analysis of peak-season CO_2 fluxes shows that NEE was generally greater in troughs than polygon centers or rims, with the highest CO_2 uptake occurring in the very wet M4 troughs(F ig. NEE). For example, when comparing results within the same vegetation type such as moist tundra U4 or wet tundra M4, troughs took up significantly more CO_2 than polygon centers or rims. Presumably, nutrient dynamics in the troughs are more favorable. The CO_2 flux data showed no consistent pattern when considering the chronosequence from old residual surfaces to more recently drained lake basins. Unfortunately, the data from the pond plots were erratic without clear trends, possibly due to methodological errors. We will investigate how we can better transfer our measurement methodology from a terrestrial to an aquatic setting and hopefully get meaningful results for the pond plots during our next measurement campaign in July 2022.

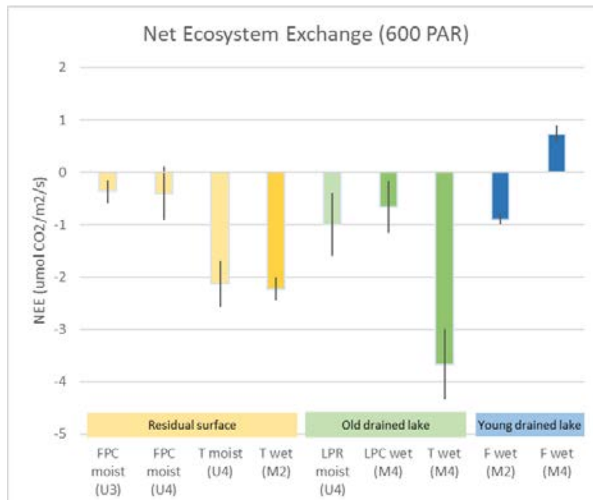

Fig. 8. Mean net ecosystem exchange and standard error at 600 μmol photons/m^2/s. FPC = flat center polygon; T = trough; LPC = low center polygon; F = featureless.

Table 3. Summary of flux measurements

Transect	Landform	Surface form element	Vegetation type	Number of samples
T6	Residual surface	Polygon flat center	U3	3
T6	Residual surface	polygon flat center	U4	3
T6	Residual surface	polygon trough	U4	3
T6	Residual surface	polygon trough	M2	3
T6	Residual surface	pond, moss mat	?	3
T6	Residual surface	pond, bare	?	3
T7	Older drained lake basin	Low-centered polygon rim	U4	3
T7	Older drained lake basin	Low-centered polygon center	M2	3
T7	Older drained lake basin	Low-centered polygon trough	M4	3
T8	Younger drained-lake basin	Featureless	M2	3
T8	Younger drained-lake basin	Featureless	M4	3
Total				33

9. **Basal peat collections (Bergstedt and Peirce) (Fig. 8, Table 4):** Eleven basal peat samples were collected 19 Aug 2021 from three lake-basin sites with different drainage histories and the residual surface for C-14 dating.

Figure 8. Helena Bergstedt and Skip Walker examining soil plug from a vegetation plot for possible C-14 dating.

Table 4. Summary of basal peat samples collected for C-14 dating samples.

Sample ID Transect	21-02 FL M2 RC T8	21-03 FL M4 RC T8	21-04 FL M4 T8	21-05 C U3 T6	21-06 C U3 RC T6	31-08 C U4 RC T6	21-19 C M2 RC T9	21-27 C M2 RC T7	21-33 C M4 RC T7	21-X (rogue) C RC T7
GPS Coordinates	70.231378; -148.457424	70.231056; -148.461261	70.230895; -148.460234	70.231693; -148.450438	70.231685; -148.451058	70.231547; -148.452610	70.231796; -148.456901	70.230145; -148.445852	70.230647; -148.442998	70.230320; -148.443046
Thaw depth (cm)	24	33	32	33	30	27	36	39	43	35
Total depth (cm)	25	33	32	34	33	27	35	37	39	37
Cumulative organic (cm)	24	25	22	Unclear (1st 8 cm fibric to hemic then almost mineral soil)	10	13	32	25	32	29
Surface org thickness (cm)	18	21	24	10	13	19	21	20	22	16
Dominant mineral	sandy silt	silt	silt	sandy silty clay	silt	silty clay	silt	sandy silt	sandy silt	sandy silt
Dominant texture	organic	organic	organic	mineral	mineral	organic	organic with a lot of mineral in organic horizon	organic	organic	organic
State of the organic horizon	hemic/fibric	hemic/fibric	hemic (a lot of silt in organic horizon)	very sapric/hemic (Nicely aged soil; stones)	sapric	sapric	sapric/hemic	sapric/hemic (1st 5 cm fibric)	sapric (a lot of mineral deposits in organic)	sapric/hemic
Water depth (cm)	17	33	32	0	0	0	10	14	20	1
Water above/below	below	above 4 cm	below (rapidly rising)	No	No	No	below	below	below	below
Sample depth	23-24	24-25	21-22	2 samples: 1) 8 cm; 2) 28 cm (buried organic layer?)	No sample	13-14	31-32	24-25	32-33	28-29
Notes	Fibric part is 18-25 cm	Pit immediately filled with water		Buried organic horizon (cryoturbation). No drained lake history	Org boundary no longer visible	Saprc layer well-developed, decomposed				Some rocks in mineral layer. Site is south of T7 closer to lake than transect plots.
Date sampled	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20	19-Jul-20
Image numbers										
Image credit	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt	H Bergstedt

Plans for August 2021

We are planning a second trip 18 Aug–3 Sep 2021 with members of the permafrost, hydrology, and remote-sensing groups. The goals are:

- Familiarize the IRPS team with the NIRPO, Jorgenson, Colleen, and Airport study sites (IRPS Team),
- Conduct thaw-depth surveys of the transects and plots at all sites (IRPS Team),
- Retrieve data loggers from the ponds (Watson-Cook),
- Clip-harvest all terrestrial and pond plots (Walker, Breen, Watson-Cook),
- Place permafrost temperature loggers in representative landscapes,
- Drill permafrost boreholes in representative landscapes to examine the cryostructure of the permafrost (Nikolsky),
- Obtain detailed elevation surveys of the four NIRPO transects (Jones),
- Obtain UAV imagery of the NIRPO transects and plots (Jones), and
- Visit area B and possibly Areas A and C (Fig. 1) to examine typical areas of dry, moist, wet, and aquatic tundra that have been heavily impacted by climate- and road-related disturbances (IRPS Team).

References

Raynolds, M. K., D. A. Walker, K. J. Ambrosius, J. Brown, K. R. Everett, M. Kanevskiy, G. P. Kofinas, V. E. Romanovsky, Y. Shur, and P. J. Webber. 2014. Cumulative geoecological effects of 62 years of infrastructure and climate change in ice-rich permafrost landscapes, Prudhoe Bay Oilfield, Alaska. Global Change Biology 20:1211–1224. http://doi.wiley.com/10.1111/gcb.12500.

Romanovsky, V. E., and T. E. Osterkamp. 1995. Interannual variations of the thermal regime of the active layer and near-surface permafrost in Northern Alaska. Permafrost and Periglacial Processes 6:313–335. https://doi.org/10.1002/ppp.3430060404.

Shur, Y., M. Kanevskiy, D. A. Walker, M. T. Jorgenson, M. Buchhorn, and M. K. Raynolds. 2016. Permafrost-related causes and consequences of Sagavanirktok River flooding in Spring 2015, Abstract 1065. Pages 1014–1016 *in* F. Gunther and A. Morgenstern, editors. 11th International Conference on Permafrost, Potsdam, Germany.

Walker, D. A., M. Buchhorn, M. Kanevskiy, G. V. Matyshak, M. K. Raynolds, Y. L. Shur, and J. L. Peirce. 2015. Infrastructure-Thermokarst-Soil-Vegetation Interactions at Lake Colleen Site A, Prudhoe Bay, Alaska. AGC Data Report. Fairbanks. https://www.geobotany.uaf.edu/library/pubs/WalkerDA2015_agc15-01_datarpt.pdf.

Walker, D. A., M. Kanevskiy, Y. L. Shur, M. K. Raynolds, M. Buchhorn, and L. M. Wirth. 2016. Airport study site, Prudhoe Bay, Alaska, Summer 2015: Road effects data report. Pages 1–74. Alaska Geobotany Center, Fairbanks, AK. https://cn.dataone.org/cn/v2/resolve/urn:uuid:614dcab5-9be8-472e-a13f-6883ae963ba1.