

## NGEE Arctic Intensive Study Sites (Phases 1–3)

### Barrow Environmental Observatory (BEO)

— Located off Cake Eater Road outside of Utqiāġvik, AK ( $71.35^{\circ}$ ,  $-156.7^{\circ}$  latitude, longitude).

### Council 71 Study Site (C71)

— Located at mile 71 along the Council Road outside of Nome on the Seward Peninsula, AK ( $64.864161^{\circ}$ ,  $-163.785777^{\circ}$ ).

### Kougarok 64 Study Site (K64)

— Located at mile 64 along the Nome-Taylor highway outside of Nome on the Seward Peninsula, AK ( $65.171801^{\circ}$ ,  $-164.844501^{\circ}$ ).

### Kougarok Fire Complex (KFC) Study Site

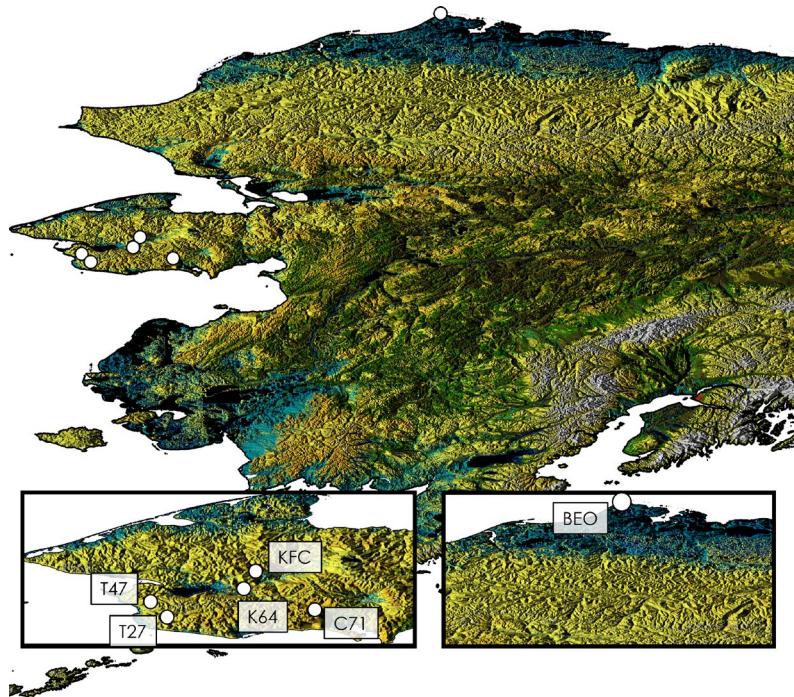
— Located at mile 84 along the Nome-Taylor highway outside of Nome on the Seward Peninsula, AK ( $65.432683^{\circ}$ ,  $-164.667825^{\circ}$ ).

### Teller 27 Study Site (T27)

— Located at mile 27 along the Nome-Teller Highway outside of Nome on the Seward Peninsula, AK ( $64.758839^{\circ}$ ,  $-165.979295^{\circ}$ ).

### Teller 47 Study Site (T47)

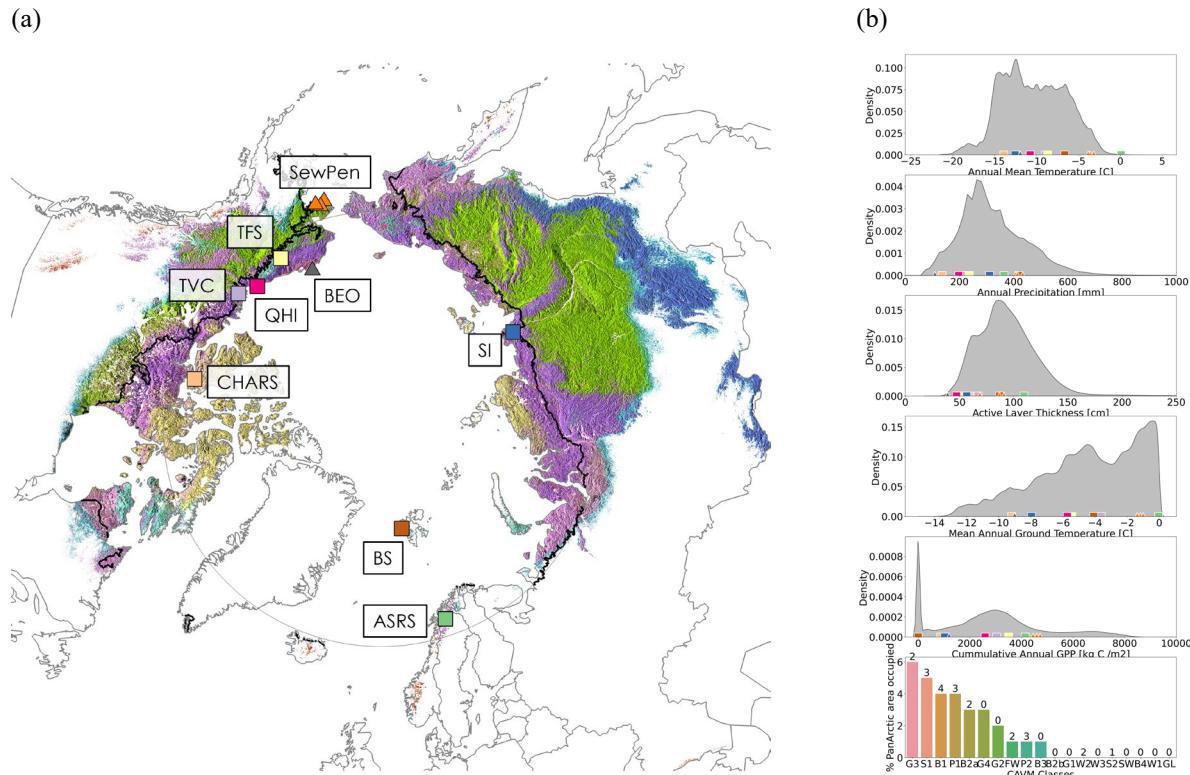
— Located at mile 47 along the Nome-Teller Highway outside of Nome on the Seward Peninsula, AK ( $64.985654^{\circ}$ ,  $-166.218477^{\circ}$ ).



**Figure i.** NGEE Arctic Phases 1–3 Intensive Study Sites. In Phases 1–3, we conducted a series of collaborative investigations across a gradient of permafrost landscapes in Arctic Alaska in coordination with landowners from multiple Native Corporations. These landscapes include polygonal tundra underlaid by continuous, cold permafrost on the coastal plain at the BEO outside of Utqiāġvik as well as tundra hillslopes underlaid by discontinuous, warmer permafrost on the Seward Peninsula that span a range of coastal and interior climates and glaciation histories. See Appendix A9 for georeferenced images of study sites with legends that encompass observations made at each location. For descriptions of additional proposed Phase 4 pan-Arctic Model Evaluation Sites, see Section 5.1 and Appendix A10. Note that the map used for this figure emphasizes differing vegetation across Alaska but does not include the data layers that would indicate high elevation glaciers and persistent snowpack rather than vegetation.

### 5.1. Selection of Pan-Arctic Model Evaluation Sites

In Phase 4, part of our Mod-Ex strategy is to evaluate an arctic-informed version of ELM against long-term observations collected from a suite of Model Evaluation Sites across the Arctic, in addition to regional and pan-Arctic model evaluation. Our selected Model Evaluation Sites encompass a range of bioclimatic, edaphic, permafrost, and vegetation conditions needed to extend and test the inferences developed in Phases 1–3 in Arctic Alaska, and to quantify ELM model uncertainty across the heterogeneous pan-Arctic domain. These sites will allow us to quantify model improvement for specific processes, including evolving linkages in permafrost, topography, and hydrology; dynamic changes in vegetation and biogeochemistry; and vegetation–snow–landscape interactions. Based on the expertise and experience of the NGEE Arctic team, feedback from our Science Advisory Board, and resources synthesized by other pan-Arctic teams (INTERACT, 2020; US Long Term Ecological Research Network, [LTER](#)), we have selected seven sites across the Arctic (Figure 5.1.1) that, along with the study sites from NGEE Arctic Phases 1–3, will be the focus of MEQs 1–3 and associated crosscut science activities (CC1–CC4; Sections 5.2 and 5.3). Model Evaluation Sites span 5 of the 8 Arctic nations and include conditions that replicate or extend the biotic and abiotic inference space of NGEE Arctic study sites in Arctic Alaska.



**Figure 5.1.1. Selected Model Evaluation Sites.** (a) We mapped ‘representativeness’ regions (Pallandt et al., 2022) across the boreal and arctic regions based on 16 global surface and subsurface gridded datasets. Tundra regions are defined on the map by the boundaries of the Circumpolar Arctic Vegetation Map (CAVM, thick black line, Walker et al., 2018; thin gray line is the Arctic circle). NGEE Arctic Phases 1–3 study sites are triangles; newly selected pan-Arctic Model Evaluation Sites are squares. (b) NGEE Arctic study sites and newly selected Model Evaluation Sites span biological and environmental gradients of interest, from climate (mean annual temperature and precipitation) to subsurface processes (ALT and mean annual ground temperature) to vegetation function and composition (GPP, gross primary production and CAVM vegetation classes). The color scheme differs between panels a and b to highlight site differences in panel b; see Table 5.5.1.

The seven core, newly selected Model Evaluation Sites (Table 5.5.1), along with the intensive study sites from NGEE Arctic Phases 1–3, span pan-Arctic ecoregions and provide a good representation of a range of arctic environmental conditions (e.g., Pallandt *et al.*, 2022). Note that some of the seven newly selected Model Evaluation Sites also include nearby satellite locations that extend site inference into processes of interest for addressing MEQs 1–3, including hydrological and disturbance gradients.

**Table 5.1.1. Model Evaluation Site Descriptions.** Colors in the table below in column ‘R’ correspond to the representativeness region (a) that each site falls within on the map in Figure 5.1.1 (e.g., BEO, CHARS, and TFS occupy similar representativeness regions). The fill color of the Model Evaluation Site squares or triangles on the map depicted in column ‘K’ (for ‘Key’) corresponds with (b) which shows that the selected sites span several environmental and biological gradients of interest. See Appendix A10 for site descriptions and collaborator contacts for each Model Evaluation Site. Current guidance from DOE BER for the Russian Arctic is to use only publicly available data (see AWI Letter of Collaboration).

R	K	Model Evaluation Site (Abbreviation in Text)	Location (Latitude, Longitude)
		Barrow Environmental Observatory study site (BEO)	Utqiāġvik, AK, USA (see Figure i)
		Seward Peninsula study sites (C71, K64, KFC, T27, T47)	Seward Peninsula, AK, USA (see Figure i)
		Abisko Scientific Research Station (ASRS)	Abisko, Sweden (68.354444, 18.815833)
		Bayelva Station (BS)	Ny-Ålesund, Spitsbergen, Svalbard, Norway (78.9325, 11.835)
		Canadian High Arctic Research Station (CHARS)	Cambridge Bay (Iqaluktuutiaq), NU, Canada (69.1198, -105.0415)
		Qikiqtaruk–Herschel Island Territorial Park (QHI)	Yukon North Slope, YT, Canada (69.568733, -138.919294)
		Samoylov Island Research Station (SI)	Samoylov Island, Siberia, Russia (72.3811, 126.4823)
		Toolik Field Station (TFS)	Brooks Range, AK, USA (68.6272, -149.5912)
		Trail Valley Creek Arctic Research Station (TVC)	Inuvik, NT, Canada (68.77208, -133.41497)

Phase 4 Model Evaluation Sites were chosen based on whether they encompassed a range of conditions needed to evaluate ELM model uncertainty but also based on availability of long-term observations that inform ELM configuration, parameterization, and evaluation. NGEE Arctic study sites on the North Slope and Seward Peninsula will be included in site-level analyses where possible to provide a baseline for assessing improvements in model predictive capacity at new Model Evaluation Sites. Including the six NGEE Arctic study sites from Phases 1–3, there are 13 Model Evaluation Sites in total. However, Phase 4 investigations will tend to focus on the seven newly selected pan-Arctic Model Evaluation Sites.

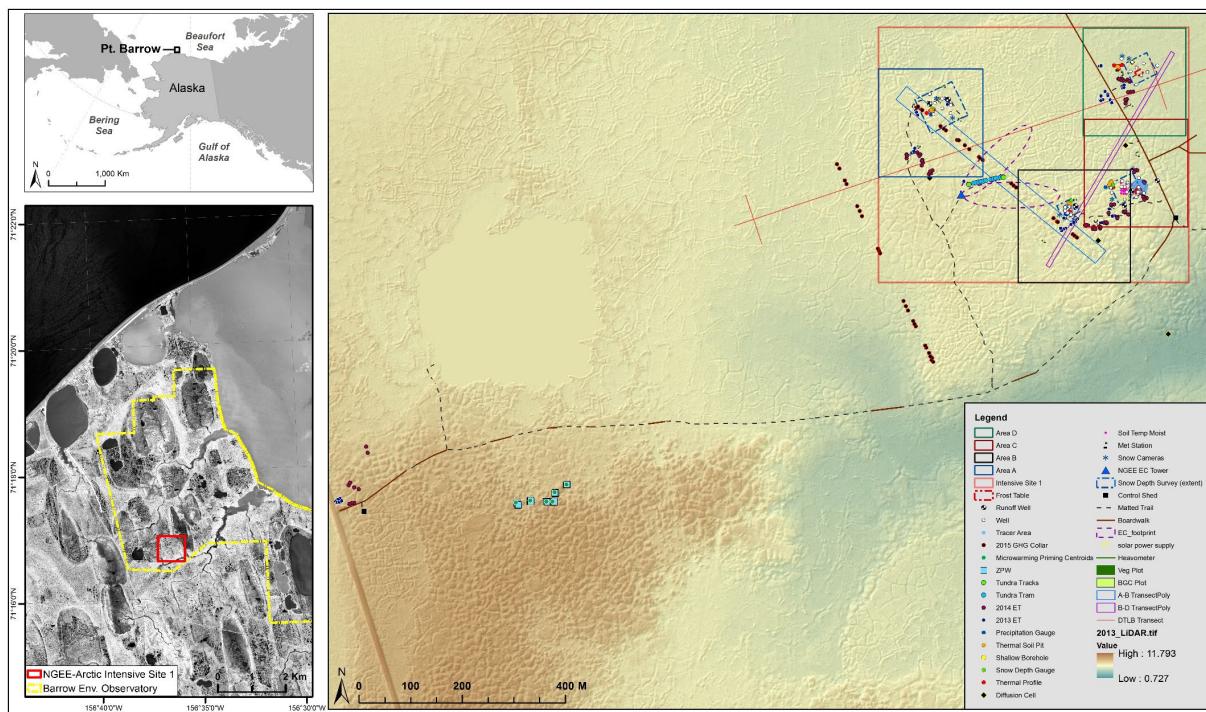
**Observations for Model Configuration and Forcing Data:** Data needs include, for example (but are not limited to): Meteorological data, including air temperature, humidity, wind, rain and snow precipitation, radiation; fractional PFT distributions across the land surface; fraction of inundated or wetland area; disturbance history; soil texture and soil hydraulic characteristics; digital elevation models (DEM); site-specific and regional downscaled future forcings.

## A9. NGEE Arctic Phase 3 Intensive Study Sites

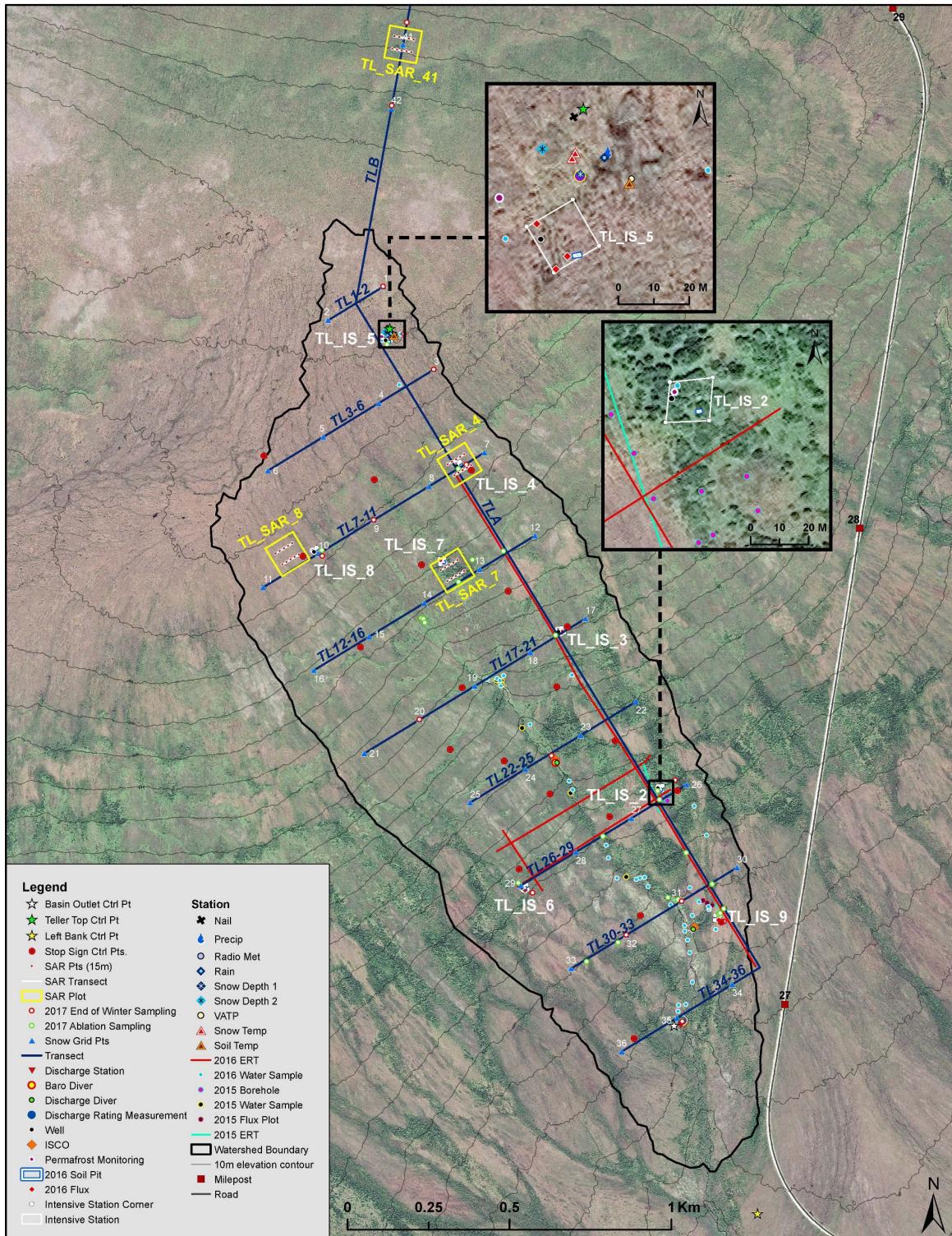
**Intensive Study Sites.** The NGEE Arctic team began Phase 1 of their investigations on the BEO in Utqiāġvik, AK. In Phase 2, the team selected three study sites to represent the range of environments across the Seward Peninsula, AK. Each site provided an opportunity to explore one or more of Science Questions 1–5 in detail. These sites were chosen based on location, climate, watershed structure, geology, vegetation, and microtopography. In Phase 3, two additional sites were selected to encompass disturbance-related research associated with newly developed Science Question 6.

Once specific study sites were chosen, the layout and design of each study site were determined. Transect design and Intensive Station locations were chosen to allow for the best possible co-location of instrumentation, sampling, and measurements across the study sites. The design and the experimental or observational plan for each study site were driven by a set of data needs determined by model development and application with an emphasis on co-location of instrumentation, sampling, and observations.

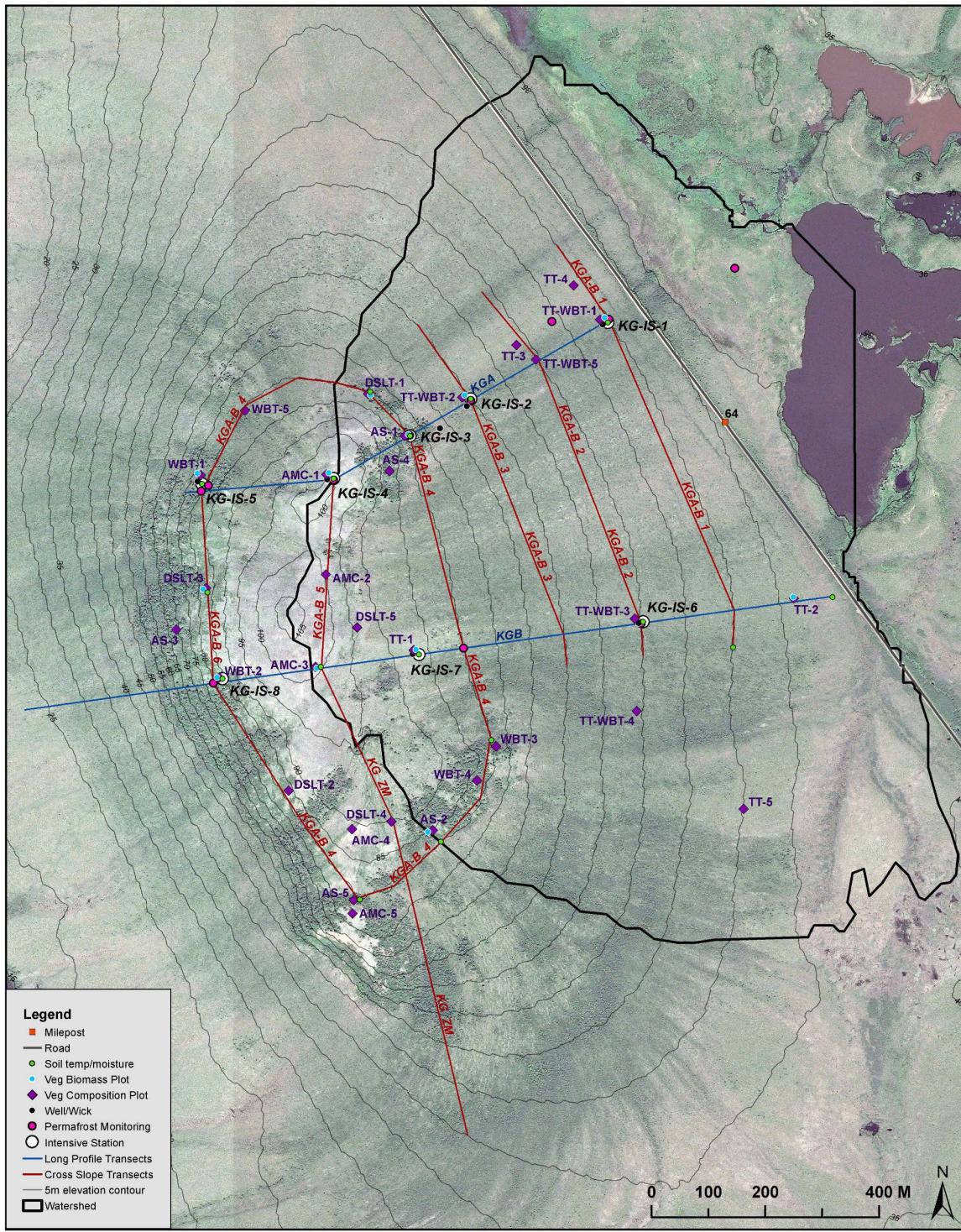
**Geospatial PDF Map Products.** Geospatial PDF products include georeferenced metadata that relate a region in the document to a region in physical space. NGEE Arctic site maps were created using ArcGIS and then exported as geospatial PDF documents. These maps can be imported into applications that support geospatial software. The most used application for viewing geospatial PDF map products by the NGEE Arctic team is Avenza Maps (Avenza Systems, Inc., Toronto, Ontario, Canada) and is supported on both Apple and Android devices. The use of geospatial PDF maps paired with handheld personal devices, such as smartphones and tablets, greatly improved the ability of the NGEE Arctic team to navigate each study site, locate existing infrastructure and instrumentation, and locate proposed sampling locations, including during adverse weather conditions. geoPDFs for each of the six NGEE Arctic study sites are located below.



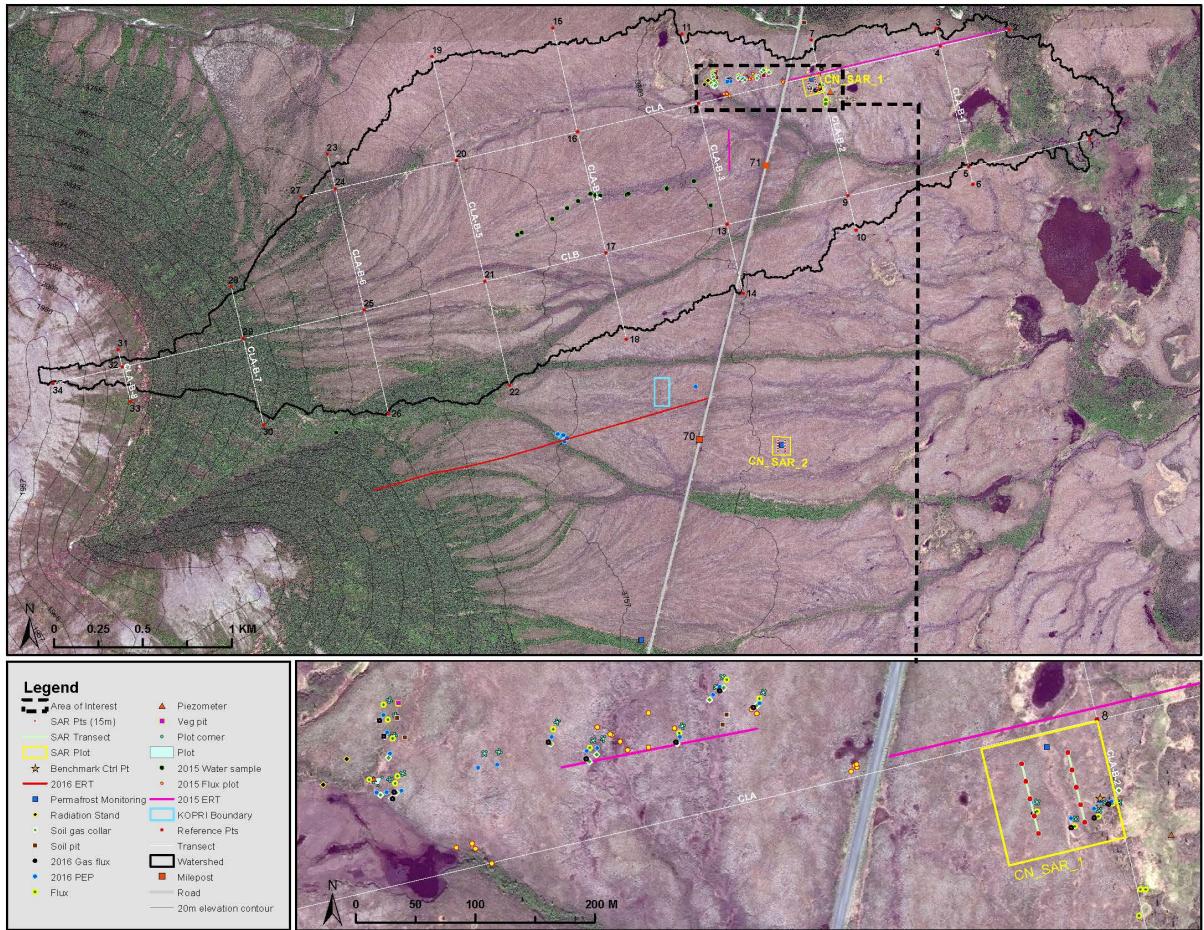
**Figure A9.1.** Overview map of activities and sampling at the Utqiāġvik, AK study site on the nearby BEO. Examples of data collected during field campaigns are displayed on the map and in the legend.



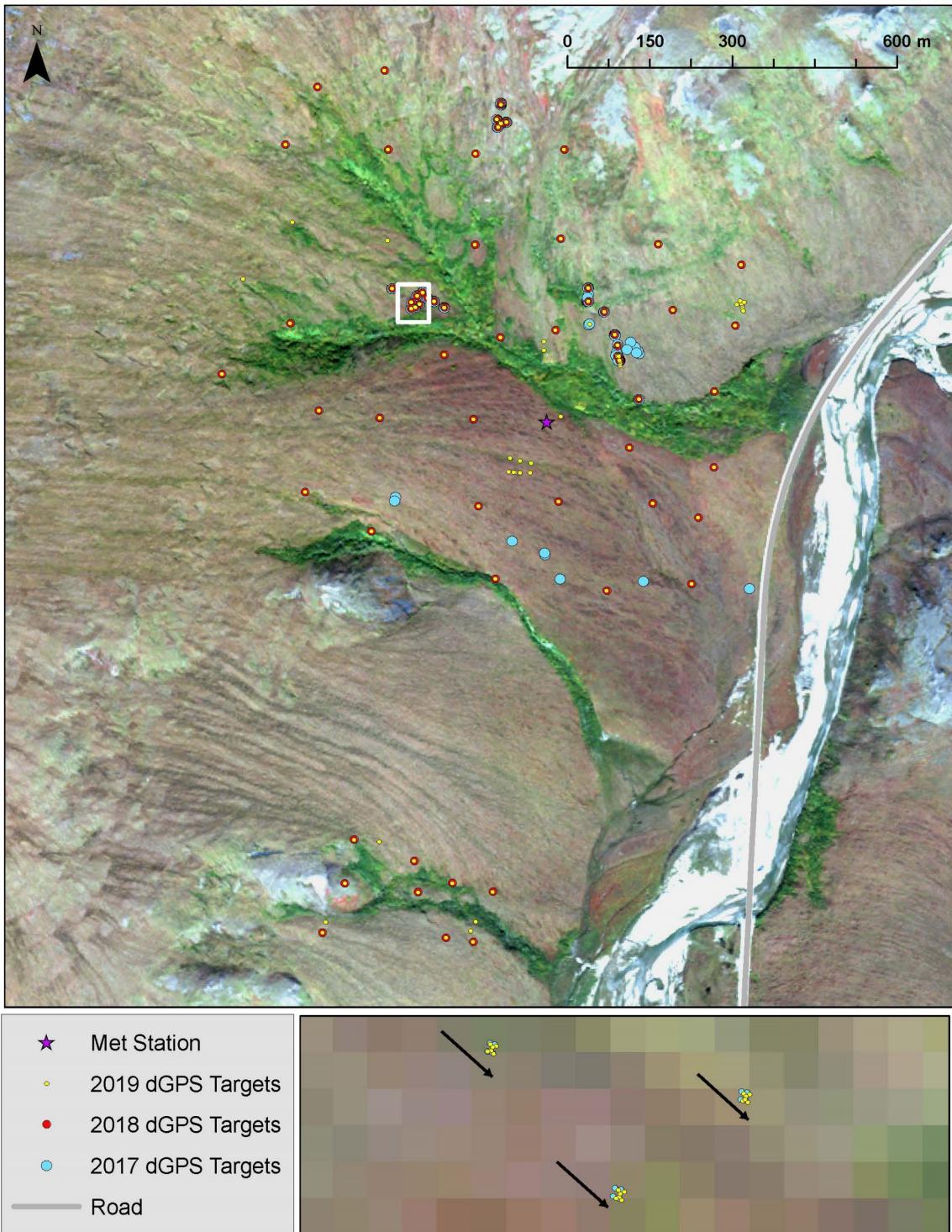
**Figure A9.2.** Teller 27 (T27) study site located at mile 27 along the Nome-Teller highway outside of Nome, AK. Examples of data collected during field campaigns are displayed on the map and in the legend. Closeup views of Intensive Stations 2 and 5 are inset in the map to provide a detailed view of infrastructure.



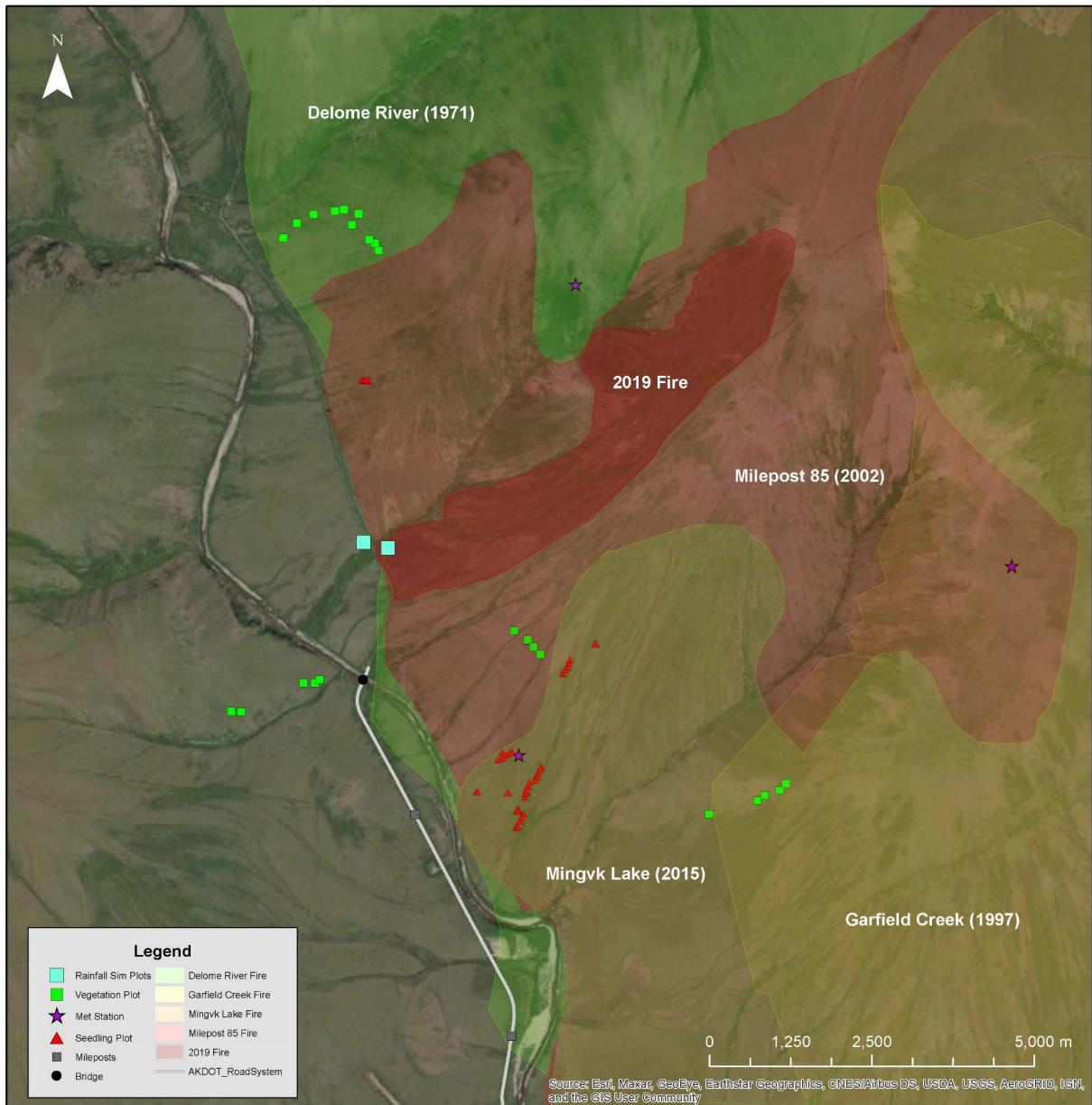
**Figure A9.3.** Kougarok 64 (K64) study site located at mile 64 of the Nome-Taylor highway outside of Nome, AK. Examples of data collected during field campaigns are displayed on the map and in the legend.



**Figure A9.4.** Council 71 (C71) study site located at mile 71 of the Council Road outside of Nome, AK. Examples of data collected during field campaigns are displayed on the map and in the legend. Closeup views of Intensive Stations 4, 5, and 6 are inset in the map to provide a detailed view of infrastructure not visible in the overview map.



**Figure A9.5.** Teller 47 (T47) study site located at mile 47 along the Nome-Teller highway outside of Nome, AK. Examples of data collected during field campaigns are displayed on the map and in the legend. Ground control points were installed in 2017 and subsequently re-surveyed in 2018 and 2019 to measure displacement. One such set of points is shown in the inset map, where downslope movement of points can be observed.



**Figure A9.6.** Kougarok 84 study site located at mile 84 along the Nome-Taylor Highway (referred to as the Kougarok Fire Complex, KFC) outside of Nome, AK. Examples of data collected during field campaigns are displayed on the map and in the legend.

## A10. NGEE Arctic Phase 4 Selected Model Evaluation Sites

**Table A10.1.** Model Evaluation Site Descriptions and Site Contacts. Colors in the table below correspond to the map in Figure 5.1.1. Current guidance from DOE BER for the Russian Arctic is to use only publicly available data (see Letter of Collaboration from colleagues at the Alfred Wegener Institute, AWI). Note that while Iversen is listed as contact for the NGEE Arctic sites, NGEE Arctic field campaigns were conducted on land owned and stewarded by the UIC Science Native Corporation (BEO, Utqiagvik) and the Sitnasuak, Mary's Igloo, and Council Native Corporations on the Seward Peninsula. MAT is mean annual temperature, MAP is mean annual precipitation, ALT is active layer thickness.

R	K	Model Evaluation Site Abbreviation	Location (Latitude, Longitude)	Site Contact (see Appendix A8)	Brief Site Description
	▲	Barrow Environmental Observatory (BEO)	Utqiagvik, AK, USA (see Figure i, Appendix A9, Figure A9.1)	Dr. Colleen Iversen Oak Ridge National Laboratory NGEE Arctic	<ul style="list-style-type: none"> <li>– Coastal polygonal tundra, thermokarst lakes, and drained lake basins</li> <li>– MAT: -12°C</li> <li>– MAP: 106 mm</li> <li>– Continuous permafrost (300+ m depth)</li> <li>– ALT: 20–70 cm</li> <li>– Tundra vegetation: Dominated by wet tundra graminoids, mosses</li> </ul>
	▲	Seward Peninsula Study Sites (C71, K64, KFC, T27, T47)	Seward Peninsula, AK, USA (see Figure i, Appendix A9, Figures A9.2–A9.6)	Dr. Colleen Iversen Oak Ridge National Laboratory NGEE Arctic	<ul style="list-style-type: none"> <li>– Defined watersheds; extensive shallow bedrock; thermal erosion; wildfire</li> <li>– MAT: -2.6°C (1970–2000, Nome)</li> <li>– MAP: 430 mm (1970–2000, Nome)</li> <li>– Discontinuous (C71, K64, T27, T47) and continuous (KFC) permafrost (between 0–100 m depth)</li> <li>– ALT: 40 + cm</li> <li>– Tundra vegetation: Variable depending on site, wet tundra to alder savanna</li> </ul>
	■	Abisko Scientific Research Station (ASRS)	Abisko, Sweden (68.354444, 18.815833)	Dr. Magnus Augner Swedish Polar Research Secretariat	<ul style="list-style-type: none"> <li>– Variable topography, geomorphology, geology, climate, and biocomplexity across a range of landscape types</li> <li>– MAT: <math>-0.4 \pm 1^\circ\text{C}</math> (2009–2019)</li> <li>– MAP: 310 mm (1913–2000)</li> <li>– Sporadic permafrost</li> <li>– ALT: 44–91 cm</li> <li>– Tundra vegetation: Tussock tundra and wet sedge tundra</li> </ul>

R	K	Model Evaluation Site Abbreviation	Location (Latitude, Longitude)	Site Contact	Brief Site Description
		Bayelva Station <u>(BS)</u>	Ny-Ålesund, Spitsbergen, Svalbard, Norway (78.9325, 11.835)	Dr. Julia Boike Alfred Wegener Institute	<ul style="list-style-type: none"> <li>- High Arctic, Svalbard archipelago; patterned ground; study site is 25 m above mean sea level on a small hill</li> <li>- MAT: -6.0°C</li> <li>- MAP: 400 mm</li> <li>- Continuous permafrost (100 m depth)</li> <li>- ALT: 100–200 cm</li> <li>- Tundra vegetation: Lichen heath and bare ground</li> </ul>
		Canadian High Arctic Research Station <u>(CHARS)</u>	Cambridge Bay (Iqaluktuutiaq), NU, Canada (69.1198, -105.0415)	Dr. Scott Williamson Polar Knowledge Canada (POLAR)	<ul style="list-style-type: none"> <li>- High Arctic dry tundra</li> <li>- MAT: -13.8 °C (1981–2010)</li> <li>- MAP: 100–150 mm</li> <li>- Continuous permafrost</li> <li>- ALT: 30 cm wetlands, 150 cm uplands</li> <li>- Tundra vegetation: Dwarf shrubs, graminoids, lichens</li> </ul>
		Qikiqtaruk – Herschel Island Territorial Park <u>(QHI)</u>	Yukon North Slope, YT, Canada (69.568733, -138.919294)	Dr. Isla Myers-Smith University of British Columbia	<ul style="list-style-type: none"> <li>- Offshore of Yukon Coastal Plain in southern Beaufort Sea (100 km<sup>2</sup>); 183 m above sea level</li> <li>- MAT: -11°C</li> <li>- MAP: 160 mm</li> <li>- Continuous permafrost (600+ m depth)</li> <li>- ALT: 55 cm</li> <li>- Tundra vegetation: Tussock tundra</li> <li>- Coastal slopes subject to intense thermokarst activity, retrogressive thaw slumps</li> </ul>

R	K	<b>Model Evaluation Site Abbreviation</b>	<b>Location (Latitude, Longitude)</b>	<b>Site Contact</b>	<b>Brief Site Description</b>
		Samoylov Island Research Station ( <a href="#">SI</a> )	Samoylov Island, Siberia, Russia (72.3811, 126.4823)	Dr. Julia Boike Alfred Wegener Institute	<ul style="list-style-type: none"> <li>– Lena River Delta; 5 km<sup>2</sup>; characterized by low-centered ice-wedge polygons</li> <li>– MAT: -12.3 °C (1998–2017)</li> <li>– MAP: 169 mm (1998–2017)</li> <li>– Continuous permafrost (400–600 m)</li> <li>– ALT: 41–57 cm (2002–2017)</li> <li>– Tundra vegetation: Wet tundra graminoids and dwarf shrubs</li> </ul>
		Toolik Field Station ( <a href="#">TFS</a> )	Brooks Range, AK, USA (68.6272, -149.5912)	Dr. M. Syndonia Bret-Harte University of Alaska Fairbanks	<ul style="list-style-type: none"> <li>– Arctic foothills, north slope of Alaska, 190 km from the Arctic Ocean</li> <li>– MAT: -9°C</li> <li>– MAP: 316 mm</li> <li>– Continuous permafrost (~240 m depth)</li> <li>– ALT: 30–50 cm</li> <li>– Tundra vegetation: Tussock tundra with low shrubs between tussocks</li> <li>– Nearby Anaktuvuk River tundra wildfire disturbance gradient</li> </ul>
		Trail Valley Creek Arctic Research Station ( <a href="#">TVC</a> )	Inuvik, NT, Canada (68.77208, -133.41497)	Dr. Philip Marsh Wilfrid Laurier University	<ul style="list-style-type: none"> <li>– Northern boundary of tundra-boreal forest; 80 km south of Arctic Ocean</li> <li>– MAT: -10°C</li> <li>– MAP: 266 mm (66% snow)</li> <li>– Continuous permafrost (100–150 m depth)</li> <li>– ALT: 30–100 cm</li> <li>– Tundra vegetation: Erect low-shrub tundra, graminoid tundra</li> </ul>