Assessing Micrometeorological and Geophysical Differences Related to the Built Environment in Utqiaġvik, Alaska

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Introduction

The effects of permafrost thaw are increasingly felt throughout Arctic communities, due to changes in regional climates, with impacts on homes, businesses, and livelihoods. Understanding and monitoring the shifts in Arctic environments can aid in the remediation and mitigation of permafrost thaw. An array of micrometeorological sensors were deployed throughout Utqiaġvik, Alaska in June of 2022 to monitor and analyze differences in micrometeorological conditions and trends at various locations near buildings and infrastructure over a five-year period. Air temperature, relative humidity, solar radiation, wind direction, wind speed, soil volumetric water content (VWC), and ground temperature measurements are currently being collected at five sites: Taġiuġmiullu Nunamiullu Housing Authority (TNHA), Samuel Simmonds Memorial Hospital (SSMH), Barrow Utilities and Electrical Cooperative, Inc. (BUCEI) (two sites), and the Barrow Environmental Observatory (BEO). These measurements are complemented by annual thaw depth measurements, ground penetrating radar and electrical resistivity tomography analyses of ground ice conditions, as well as repeat LiDAR measurements for ground subsidence and structural changes.

Methods

Meteorological

Installation of five stations (four urban sites surrounding Isatkoak Lagoon, one tundra control site at BEO)

Base stations with data loggers and complementary satellite stations measuring land and air parameters around the perimeter of each building at the urban sites

Collection of data using a data pipeline with HDF5 HSDS and storing subsets of data in NetCDF format

Geophysical

Geophysical Surveying Sites (7) – ground penetrating radar, electrical resistivity tomography, active layer depth

Annual ground penetrating radar (GPR) and electrical resistivity tomography (ERT) analyses of ground ice conditions, as well as repeat LiDAR measurements to explore ground subsidence and structural changes, and observable stability of permafrost

Dipole-dipole ERT (as opposed to vertical)
sampling used for increased sensitivity of lateral variations

Figure 4. Drone image of the current station implementation locations in Utqiaġvik. *Image by M. Jull.*

Figure 5. Left to right, satellite imagery of a) TNHA, b) SSMH, & c) BEO station locations. *Created using ArcGIS Pro Software.*

Meteorological Data

Air temperature, ˚C (TNHA) *(Table 1)*			
Sensor	Max	Min	Mean
BASE	22.51	-0.67	5.97
SA	25.16	-0.47	6.20
SB	21.62	-0.60	6.02
SC	19.32	-1.33	5.61
SD	20.1	-1.01	5.62

Air temperature, ˚C (SSMH) *(Table 2)*			
Sensor	Max	Min	Mean
BASE	20.52	-0.91	5.16
SA	22.28	-0.77	6.17
SB	20.61	-0.75	5.54

Air temperature, ˚C (BEO) *(Table 3)*			
Sensor	Max	Min	Mean
BASE	18.03	-1.27	3.43

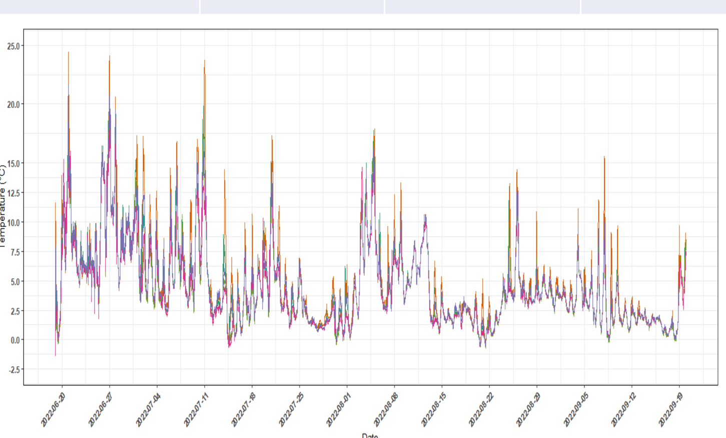

Figure 1.1. Air temperature plots for TNHA for each station over the summer season.

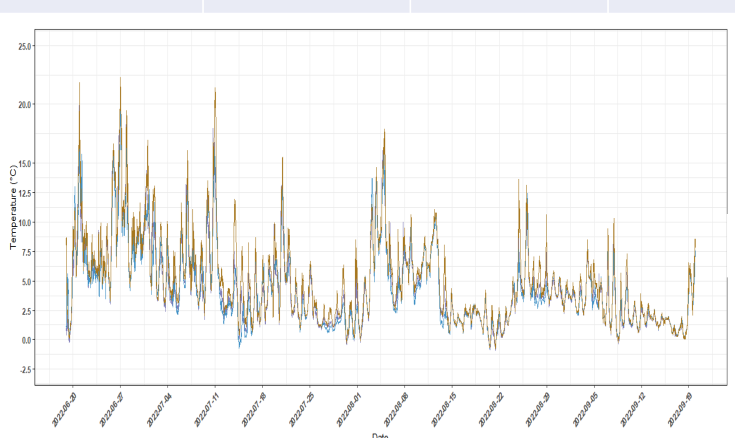

Figure 1.2. Air temperature plots for SSMH for each station over the summer season.

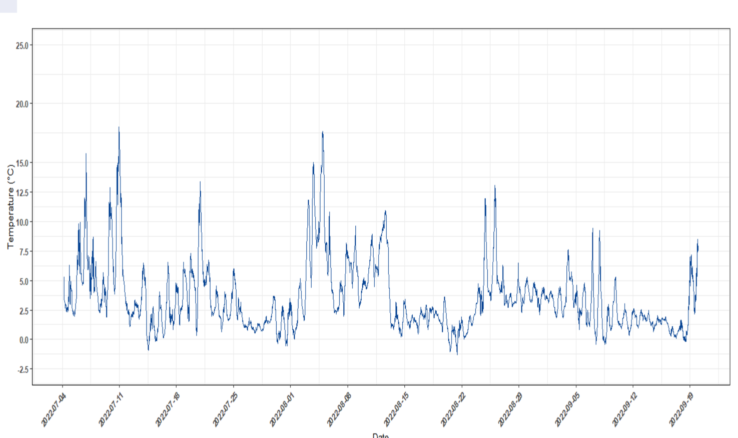

Figure 1.3. Air temperature plots for BEO over the summer season.

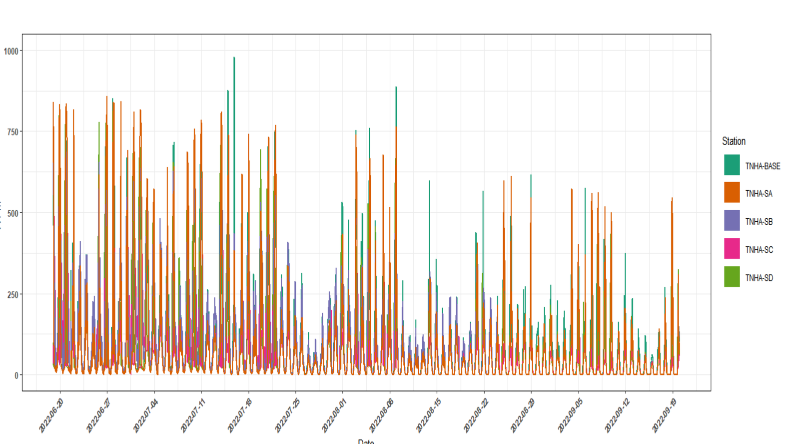

Figure 2.1. Solar radiation plots for TNHA over the summer season.

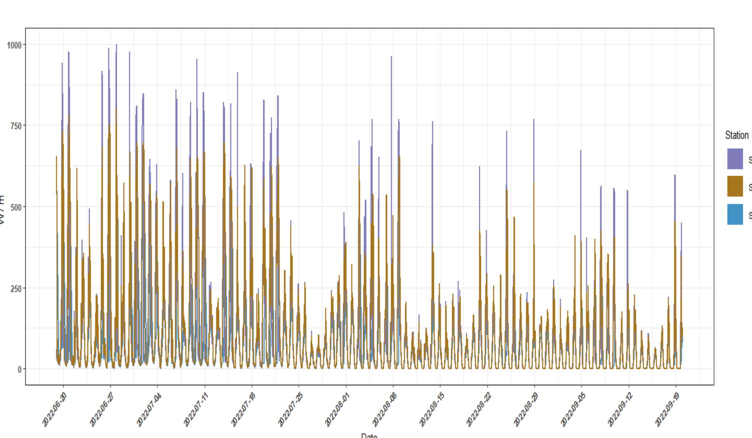

Figure 2.2. Solar radiation plots for SSMH over the summer season.

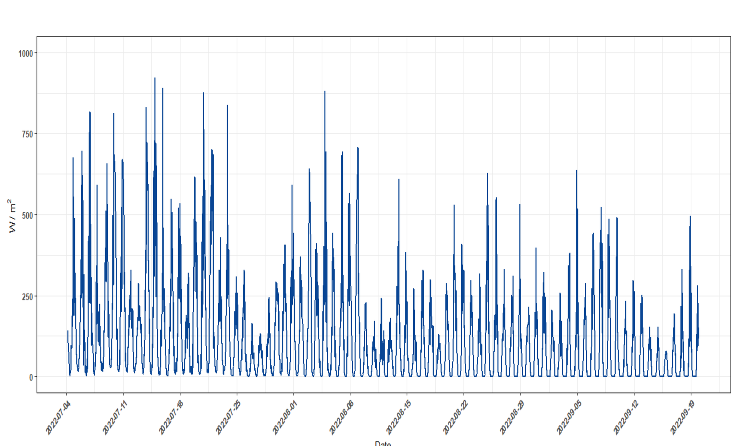

Figure 2.3. Solar radiation plots for BEO over the summer season.

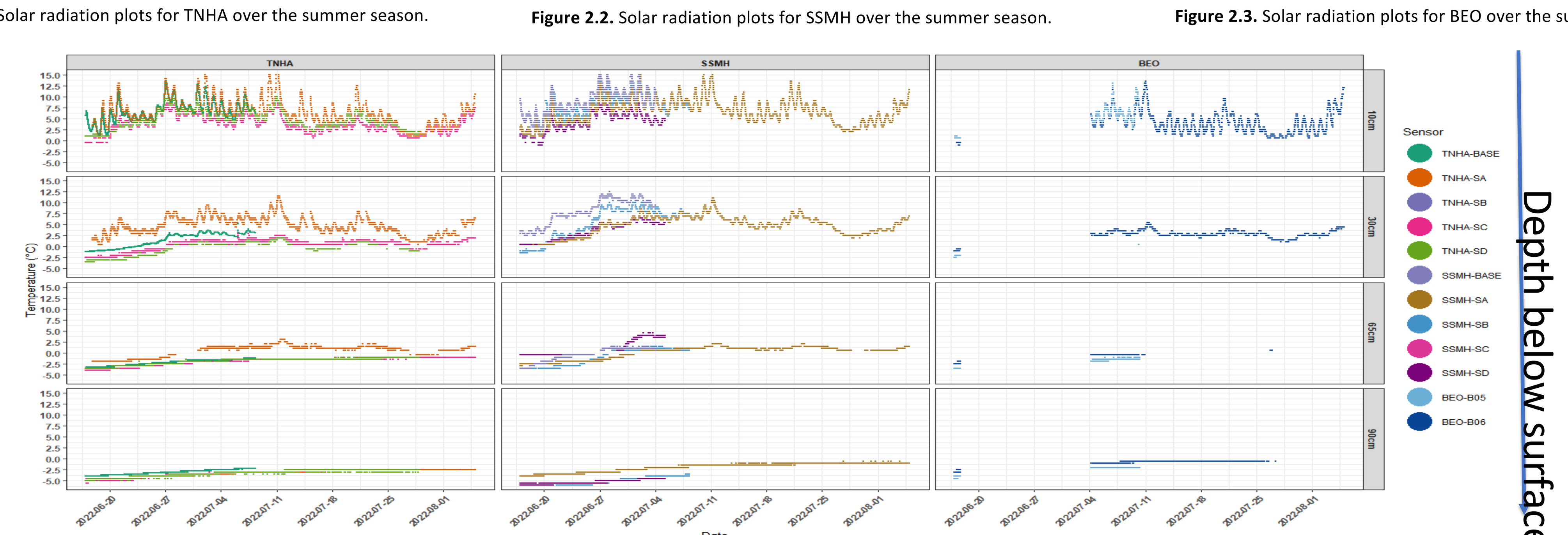

Figure 3. Ground temperature plots show heat transitions between shallower and deeper transects at the TNHA building (Left). At 65cm, TNHA-SA is the only sensor seemingly above freezing (0°C). TNHA-SA is located behind a vehicle and ATV parking area which may influence the increased ground temperature of this location. SSMH (middle) exists on the opposite side of the lagoon from TNHA. Multiple sensors went down in mid-July due to a break in the daisy chain and/or low battery. The BEO (Right) acts as our control station in the tundra. Both sensors were placed within 0.5m of each other. BEO-B05 was installed into the polygon with no notable geophysical features. BEO-B06 was installed into a frost circle within the polygon. Multiple gaps in data are present throughout all station deployments during the Summer 2022 field season due to sensor failures, daisy chain breaks, and premature battery failures.

Preliminary Results

Meteorological

Ground temperatures at certain sites within a location (e.g. TNHA) at 10cm depth can vary by 5˚C. These differences are maintained at 30cm depths and then decrease with depth (**Figure 3**).

Lagoon-facing locations track longer periods of colder ground temperatures during the summer at TNHA

Most locations across sites show below 0 ˚C temperatures at 65cm depth and below for the entire summer (**Figure 3**).

Geophysical (TNHA)

Permafrost and subsurface layering are largely obscured by (1) saturated surface vegetation/topsoil reflection, (2) scattering due to gravel, and (3) EM wave attenuation due to conductive subsurface.

ERT cross section indicates less resistive ground (blue coloring (**Figure 5**).

The low resistivity region from 54-84 m along the transect likely results from lower water content of the well-drained gravel pad.

Specific Questions

- **How does infrastructure in Utqiaġvik, Alaska influence ground temperatures in the top 90 cm relative to control tundra sites?**
- **How do specific locations around buildings (e.g. north/south facing, proximity to the lagoon) regulate summer ground temperatures and thaw?**
- **What meteorological factors (e.g. solar radiation, air temperature) control ground temperature across the various locations around buildings?**
- **What are the spatial patterns of active layer depths, ground moisture, and ground ice at specific locations in Utqiaġvik?**

Geophysical Surveys (TNHA)

2022

TNHA thaw probe depths 121 +/- 39cm (Figure 5)
GPR and ERT indicate relatively high ground moisture within 5m of gravel pad (**Figures 5,6**)
GPR suggests permafrost approximately 1m deep at TNHA site (Figure 5**)**

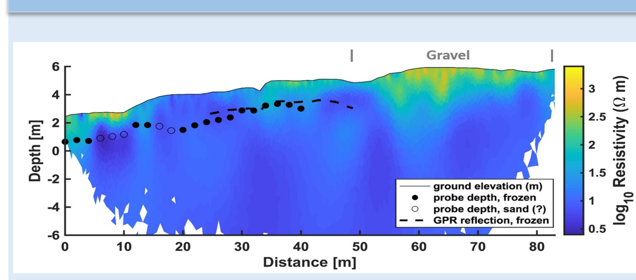

Figure 5. North-to-South inverse solution of ERT data from TNHA transect with topography, probe data, interpreted GPR permafrost reflection, and gravel extent. Blue shading on ERT cross section indicates less resistive ground (probably wet or unfrozen) and yellow shading indicates more resistive ground (probably dry or frozen). The anomalous low resistivity region from 5-10 m may be an inversion artifact or the result of pebbles beneath a walking path along the lagoon shore. The low resistivity region from 54-84 m likely results from lower water content of the well-drained gravel pad.

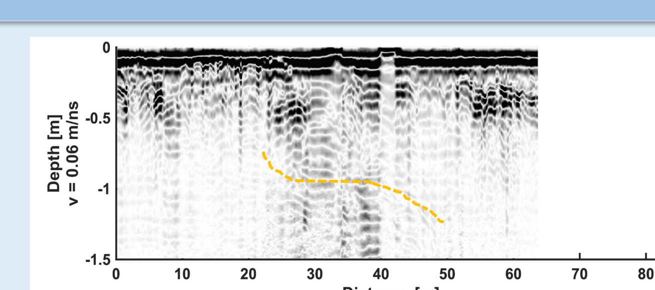

Figure 6. North-to-South GPR cross-section, i.e. radargram, of TNHA transect relative to ground level (no topographic correction) with possible permafrost reflection indicated by the dashed yellow line. Depth axis estimated from two-way travel time of radar wave assuming a wave velocity of 0.06 m/ns—typical for saturated silt. Permafrost and subsurface layering are largely obscured by (1) saturated surface vegetation/topsoil reflection, (2) scattering due to gravel on the south side of the transect, and (3) EM wave attenuation due to conductive subsurface.

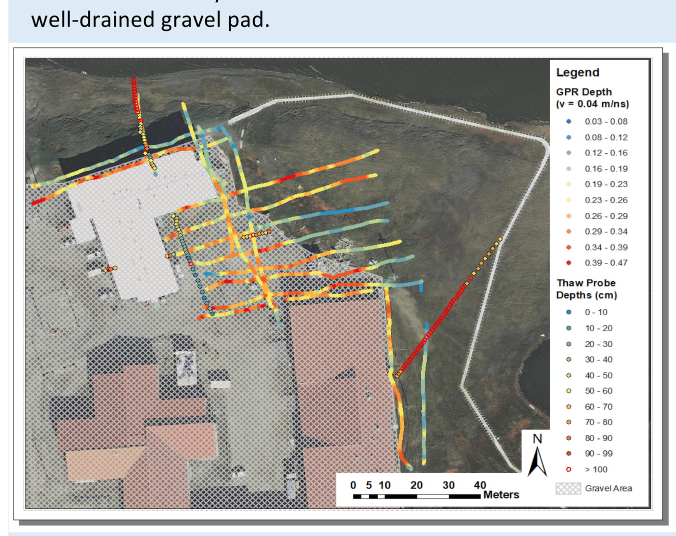

Figure 7.1. GPR/ ERT/ Thaw Probe tracts at TNHA, 2021.

Figure 7.2. -GPR & ERT tracts at TNHA, 2022.

Next Steps

Robust analyses of meteorology (e.g. radiation, air temperature, snow depth) and controls on ground temperature dynamics.

Community input on future sensor locations and potential additional parameters of interest.

Additional sensor array installations around the High School, near snow fences, and at the BEO.

Additional GPR/ERT measurements in accepted residential areas, over ice cellars, and repeated over previously run tracts.

Repeat LiDAR measurements at existing sites.

Implementation of Particulate Matter (PM2.5) sensors around the major roads to analyze air quality / black carbon

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