Quantifying micro-topographic impacts in ice-wedge systems: a preliminary assessment

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Introduction: Ice-wedges, forming polygonal terrain, are the most common type of massive ground ice in the Arctic (Kanevskiy et al., 2017). In northern Alaska, approximately 60% of the Arctic Coastal Plain is estimated to be underlain by wedge ice (Brown, 1967; Lara et al., 2018). In this region, ice-wedge surfaces are typically located near the permafrost table, so any increases in active layer thickness will melt the top surface of the ice-wedge, causing thermokarst (Mackay, 2000). This impact on micro-topography further impacts surface hydrology, snow cover distribution, geochemical fluxes, vegetation patterns, and ground temperatures in ice-wedge systems (e.g., Jorgenson et al., 2015; Ward Jones et al., 2020). Our research is using sub-meter LiDAR and UAV datasets to quantify the micro-topography of ice-wedge systems within the ABoVE domain regions of Alaska, and the Yukon and Northwest Territories of Canada. We present preliminary results of using high resolution elevation products (sub-meter LiDAR- and centimeter resolution UAV-derived digital surface models, DSM) and ground temperatures collected in the field from sites in Alaska using field data collected at Prudhoe Bay between 2014 and 2016 and from the Teshekpuk Lake Observatory (TLO) between 2020 and 2021 to model ground temperatures using linear regression equations.

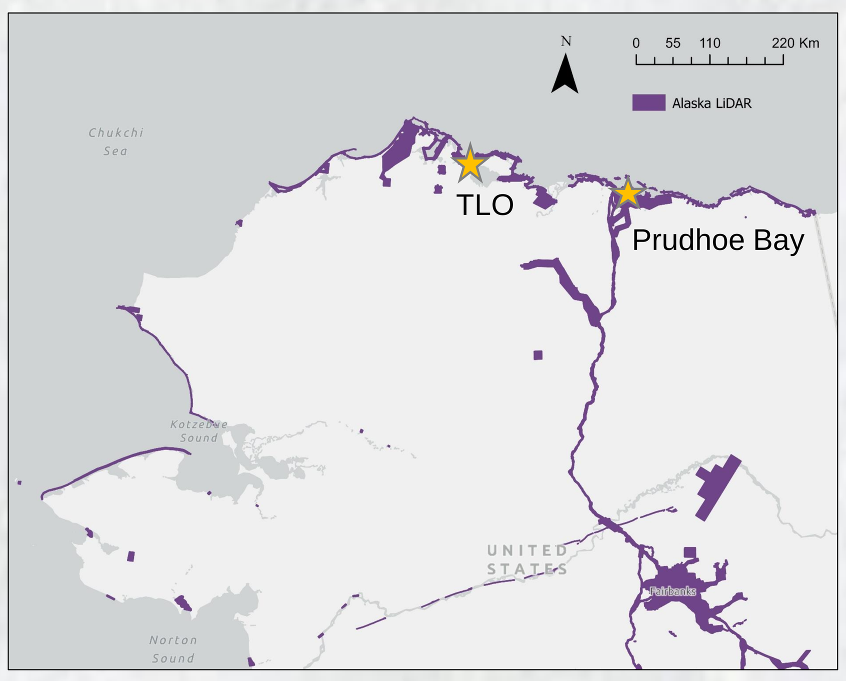

Figure 1: Geographic distribution of LiDAR datasets available in Alaska that will be used to upscale field measurements. Field site locations (Teshekpuk Lake Observatory, TLO, and Prudhoe Bay) are marked by yellow stars. Maps used are ESRI basemap accessed using ArcGIS Pro v.2.7.

Results: Teshekpuk Lake Observatory (TLO)

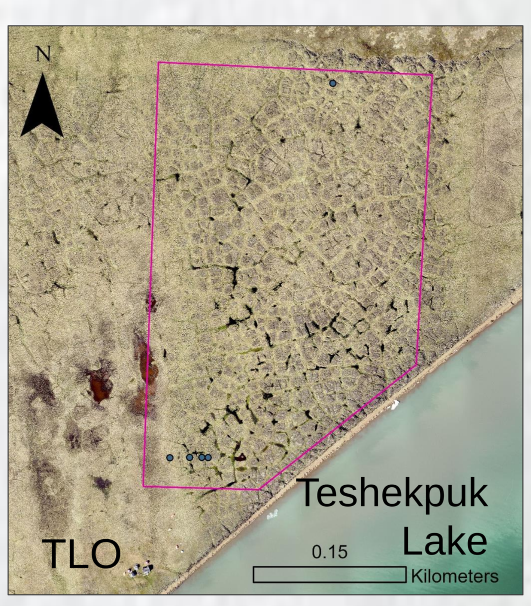

Figure 2: Study area located northwest of the Teshekpuk Lake Observatory cabin (TLO) on the shore of Teshekpuk Lake. Study area image is a mosaic of UAV images collected during a survey in August 2020.

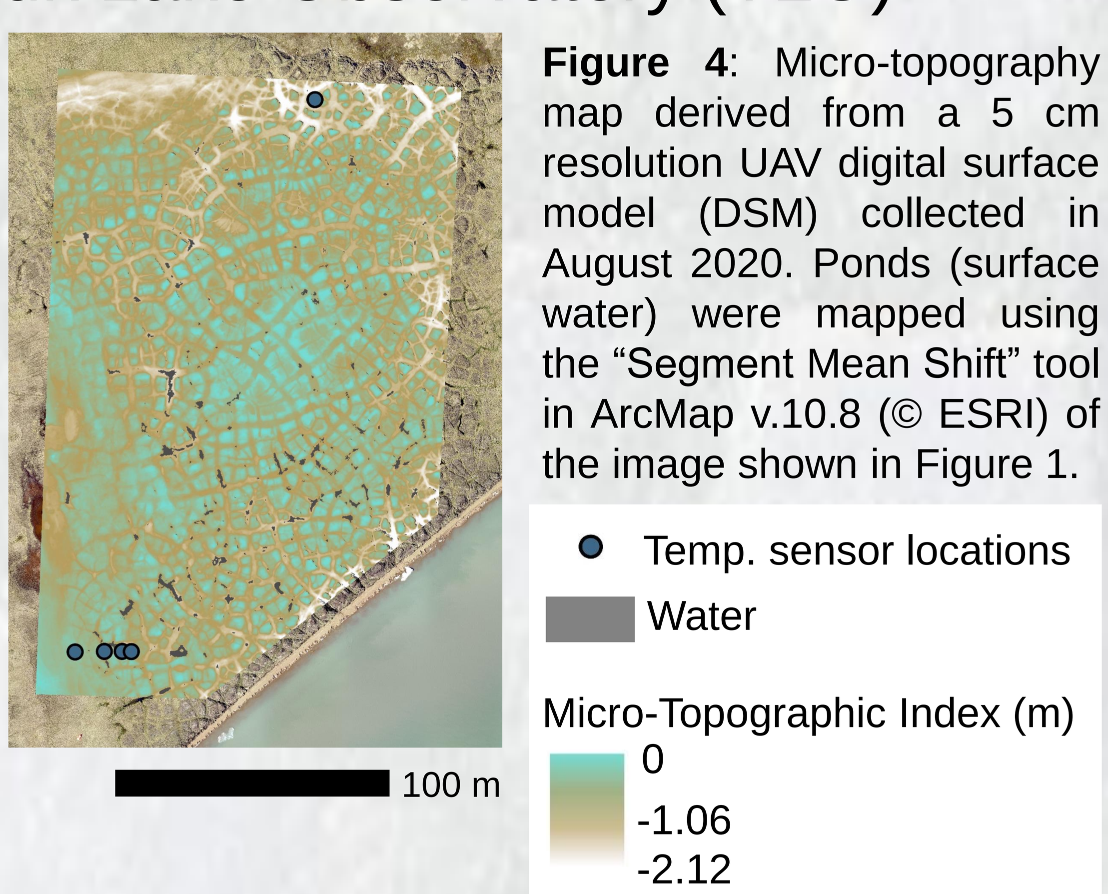

Figure 4: Micro-topography map derived from a 5 cm resolution UAV digital surface model (DSM) collected in August 2020. Ponds (surface water) were mapped using the "Segment Mean Shift" tool in ArcMap v.10.8 (© ESRI) of the image shown in Figure 1.

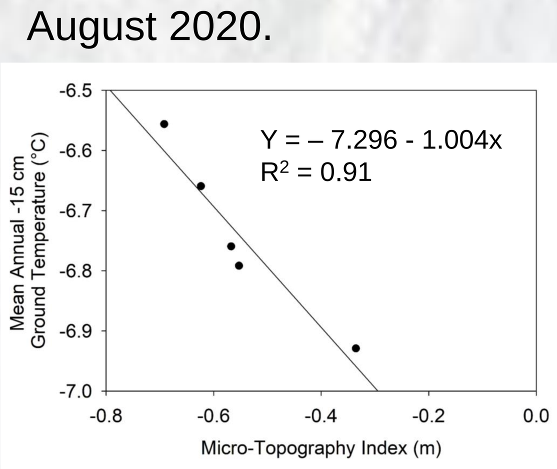

Figure 3: Linear regression equation created using ground temperature measurements at 15 cm depth using Onset 2-channel Hobo dataloggers (locations shown in Figures 4 and 5) between 2020 and 2021 and the micro-topography map shown in Figure 4.

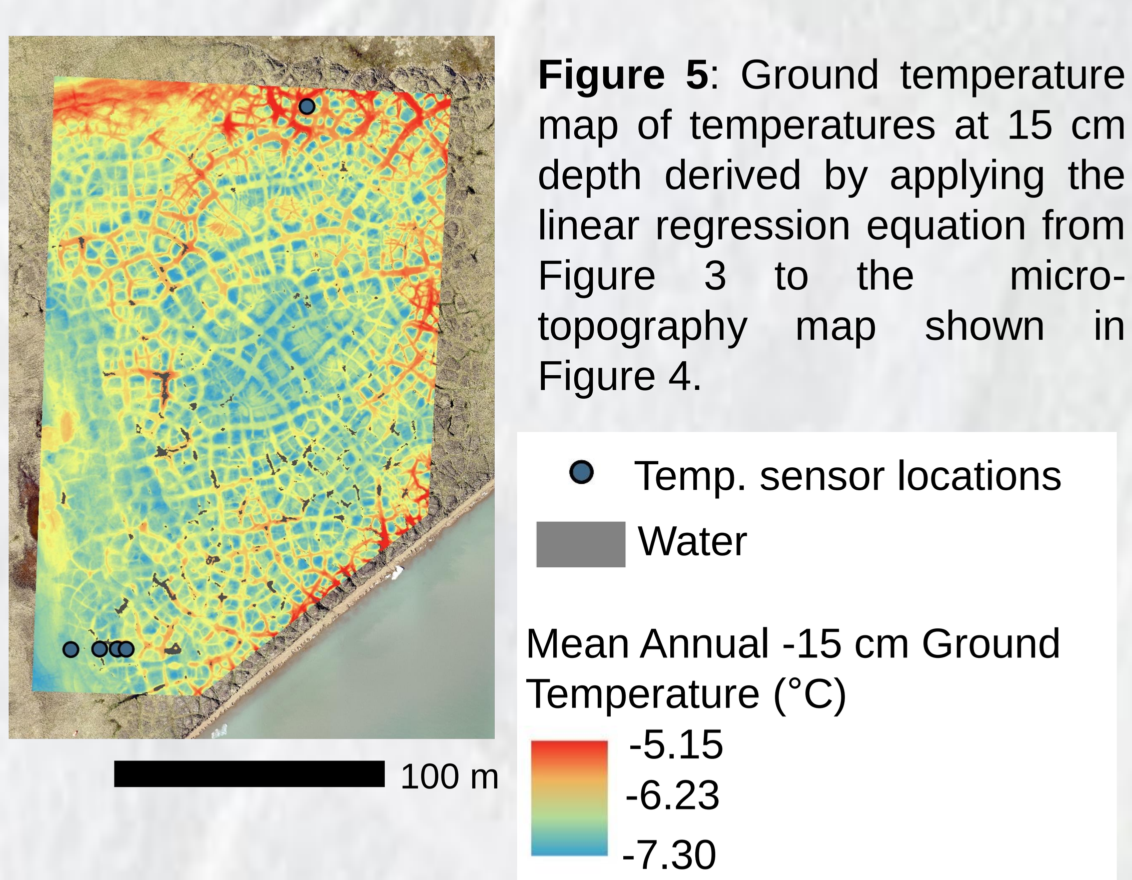

Figure 5: Ground temperature map of temperatures at 15 cm depth derived by applying the linear regression equation from Figure 3 to the micro-topography map shown in Figure 4.

Results: Prudhoe Bay

Figure 6: Study area (orange box) located north of the Prudhoe Bay airport. Ground temperature data used (locations shown as points in figures 6, 8 and 9) provided by Walker et al., (2015 and 2016). Measurements taken at 5 m from the road were omitted from analysis. Measurements included were 10 m, 25 m, 50 m, 100 m and 200 m from the road. Image is an ESRI World Imagery basemap image (7/15/2019) accessed using ArcGIS Pro v.2.7.

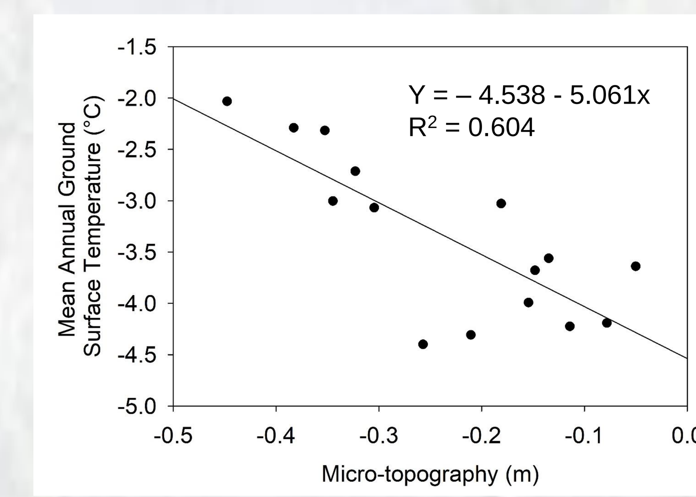

Figure 7: Linear regression equation created using ground temperature measurements at the ground surface (ibutton temperature sensors from Walker et al., 2016; locations shown in Figures 6, 8 and 9) between 2014 and 2016 and the micro-topography map shown in Figure 7.

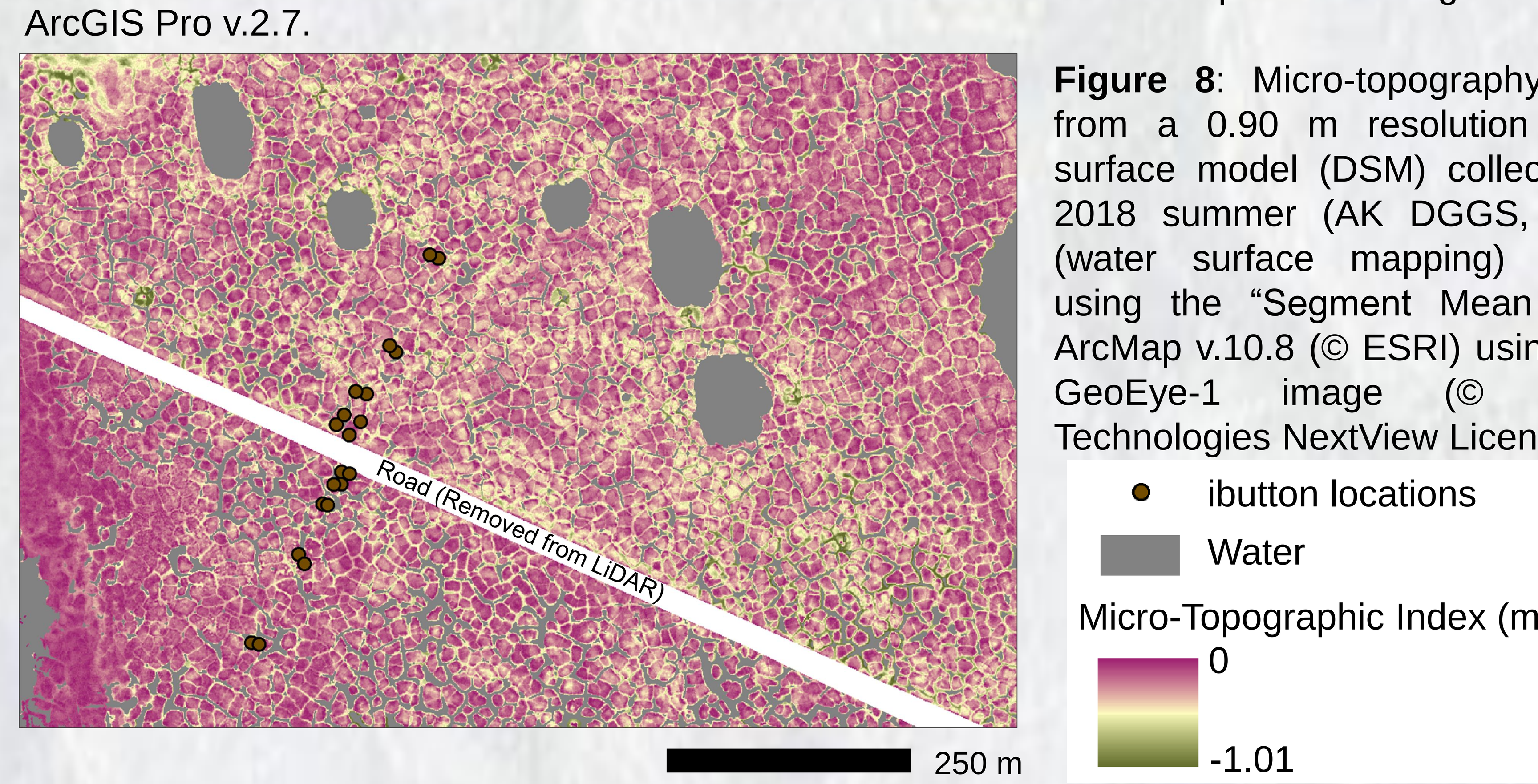

Figure 8: Micro-topography map derived from a 0.90 m resolution LiDAR digital surface model (DSM) collected during the 2018 summer (AK DGGS, 2019). Ponds (water surface mapping) were mapped using the "Segment Mean Shift" tool in ArcMap v.10.8 (© ESRI) using a 7 Jul 2018 GeoEye-1 image (© 2018 Maxar Technologies NextView License).

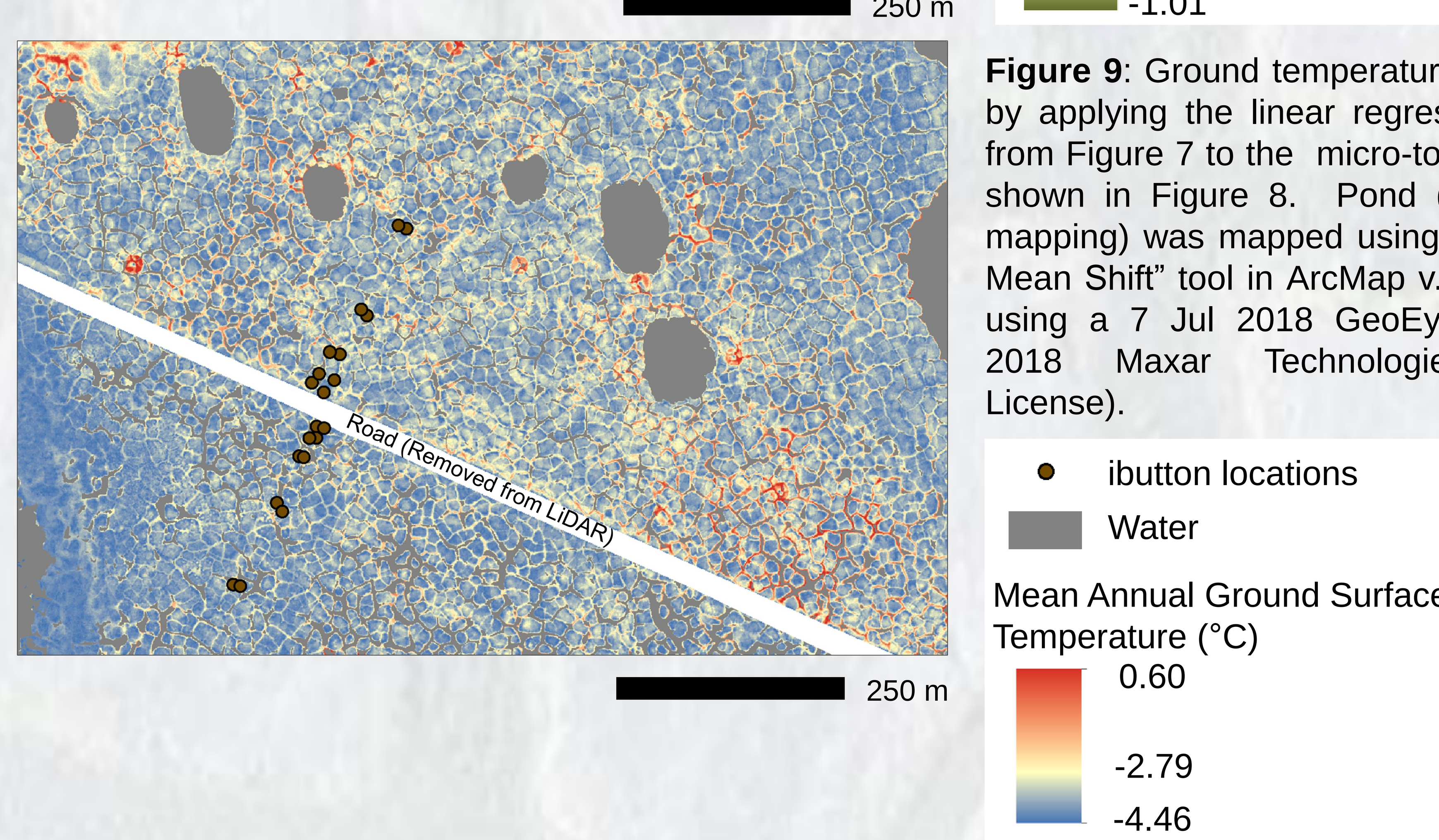

Figure 9: Ground temperature map derived by applying the linear regression equation from Figure 7 to the micro-topography map shown in Figure 8. Pond (water surface mapping) was mapped using the "Segment Mean Shift" tool in ArcMap v.10.8 (© ESRI) using a 7 Jul 2018 GeoEye-1 image (© 2018 Maxar Technologies NextView License).

Future Work: Recent observations show ice-wedges are degrading rapidly throughout the Arctic. Micro-topography evolution will drive significant ecosystem changes and feedbacks. It is critical to better understand these fine-scale system processes to ensure we understand the large-scale impacts of these ubiquitous features in permafrost affected areas. Future research will focus on the variability in ice-wedge system micro-topography as a driver of key Arctic ecosystem characteristics and processes, including ground temperature, thaw depth, soil moisture, snow depth, vegetation height and type, CO2, and CH4 fluxes. Future work will build on the methodologies and analyses presented.

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