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ABOVE: Permafrost Measurements and Distribution Across the Y-K Delta, Alaska, 2016

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Summary

This dataset provides field observations of thaw depth and dominant vegetation types, a LiDAR-derived elevation map, and permafrost distribution and probability maps for an area on the coastal plain of the Yukon-Kuskokwim Delta (YKD), in western Alaska, USA. Field data were collected during July 8-17, 2016 to parameterize and to validate the derived permafrost maps. The YKD is in the sporadic to isolated permafrost zone where permafrost forms extensive elevated plateaus on abandoned floodplains. The region is extremely flat and vulnerable to eustatic sea-level rise and inland storm surges. These high-resolution permafrost maps support landscape change analyses and assessments of the impacts of climate change on permafrost in this region of high biological productivity, critical wildlife habitats, and subsistence-based human economy.

Field measurements were recorded at 493 points along nine transects traversing plateaus found on the coastal plain (at 1-m intervals over permafrost and 5-m over non-permafrost areas) and recording thaw depth, permafrost thickness, surface water depth, and ecotype based on dominant vegetation, hydrologic, and thermokarst features. Additionally, observations of the presence/absence of permafrost were recorded at 333 non-transect points in adjacent areas.

LiDAR data collected in 2009 were used to derive an elevation map (DEM) that delineated the boundaries of the plateaus on the coastal plain that, in combination with the thaw-depth measurements, were used to produce a permafrost distribution map. To create a permafrost probability map, elevations were extracted at each transect thaw-depth sample point. The extracted elevations were modeled against the presence or absence of permafrost at each point and the model was used to predict permafrost occurrence.

To augment the LiDAR analysis, an IKONOS image from August 27, 2007 was incorporated with the LiDAR data into a Random Trees (RT) classifier. To improve upon the LiDAR distribution map, the RT classification was trained using the thaw-depth sample points along the transects and area visual interpretation and validated using the 333 presence/absence points.

There are seven data files with this dataset including four maps in GeoTIFF (.tif) format, one measurement file in comma-separated (.csv) format, and two compressed shapefiles (.zip). The data in the shapefiles are provided as companion files in .kmz format for viewing in Google Earth. Photos of the study area transects are also provided in a companion file.

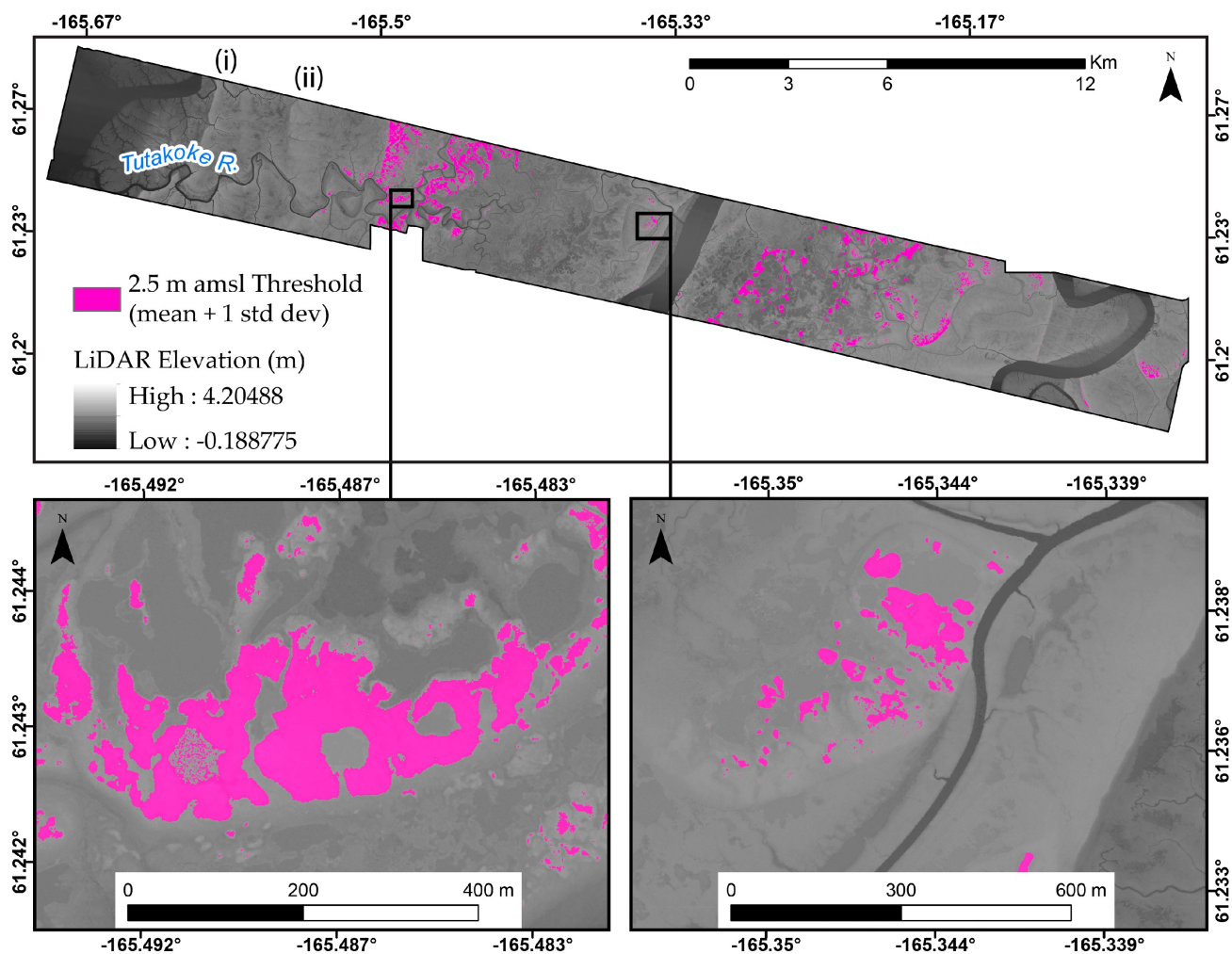


Figure 1. High-resolution map of permafrost distribution created using the 2.5 m amsl (mean + 1 SD) threshold for the entire 2009 LiDAR swath. The insets show detail for areas of high elevation (left) and relative low elevation (right) (Whitley et al., 2018).

Citation

Whitley, M., G. Frost, M.T. Jorgenson, M. Macander, C.V. Maio, and S.G. Winder. 2018. ABoVE: Permafrost Measurements and Distribution Across the Y-K Delta, Alaska, 2016. ORNL DAAC, Oak Ridge, Tennessee, USA. <https://doi.org/10.3334/ORNLDAAAC/1598>

Table of Contents

1. [Data Set Overview](#)
2. [Data Characteristics](#)
3. [Application and Derivation](#)
4. [Quality Assessment](#)
5. [Data Acquisition, Materials, and Methods](#)
6. [Data Access](#)
7. [References](#)

1. Data Set Overview

This dataset provides field observations of thaw depth and dominant vegetation types, a LiDAR-derived elevation map, and permafrost distribution and probability maps for an area on the coastal plain of the Yukon-Kuskokwim Delta (YKD), in western Alaska, USA. Field data were collected during July 8-17, 2016 to parameterize and to validate the derived permafrost maps. The YKD is in the sporadic to isolated permafrost zone where permafrost forms extensive elevated plateaus on abandoned floodplains. The region is extremely flat and vulnerable to eustatic sea-level rise and inland storm surges. These high-resolution permafrost maps support landscape change analyses and assessments of the impacts of climate change on permafrost in this region of high biological productivity, critical wildlife habitats, and subsistence-based human economy.

Project: [Arctic-Boreal Vulnerability Experiment](#)

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign based in Alaska and western Canada between 2016 and 2021. Research for ABoVE links field-based, process-level studies with geospatial data products derived from airborne and satellite sensors, providing a foundation for improving the analysis and modeling capabilities needed to understand and predict ecosystem responses and societal implications.

Related Publication:

Whitley, M. A., G. V. Frost, M. T. Jorgenson, M. J. Macander, C. V. Maio, and S. G. Winder. 2018. Assessment of LiDAR and spectral techniques for high-resolution mapping of sporadic permafrost on the Yukon-Kuskokwim Delta, Alaska. *Remote Sensing* 10(2), 258. <https://doi.org/10.3390/rs10020258>

Acknowledgements

This research was supported by NASA Award NNH16CP09C as part of the ABoVE field campaign.

2. Data Characteristics

Spatial Coverage: Tutakoke River, Yukon-Kuskokwim Delta, Alaska

ABoVE Reference Locations:

Domain: Core ABoVE

State/territory: Alaska

Grid cell(s): Ahh0Avv0Bh1Bv3

Spatial resolution: 1-5 m

Temporal coverage: Field data were collected from 2016-07-08 to 2016-07-17. Lidar data were collected on 2009-06-02. The IKONOS image (not provided) was from 2007-08-27.

Temporal resolution: One time

Study Areas (All latitude and longitude given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Yukon-Kuskokwim Delta, Alaska	-165.69	- 165.03	61.29	61.17

Transect Locations: Beginning and ending coordinates for the thaw-depth measurement transects.

- Coordinates are provided in both latitude and longitude (WGS84) and UTM easting and northing (NAD 1983, UTM Zone 3N).
- Measurements were made along each transect every 1 m over permafrost and 5 m over non-permafrost.
- It is easier to separate the measurement points with Easting and Northing in meters rather than latitude and longitude.
- Only Easting and Northing are provided in the measurement data file.

Transect number	Transect length	Measurement count	Measurement ID	Longitude	Latitude	Easting UTM	Northing UTM
1	0		0	-165.503006	61.2504005	473008.9332	6790781.807
1	68	45	44	-165.5019989	61.2504005	473076.7923	6790786.183
2	1		45	-165.4989929	61.2549019	473249.2222	6791280.554
2	75	63	107	-165.496994	61.2550011	473322.7027	6791289.307
3	0		108	-165.496994	61.2510986	473321.0302	6790862.877
3	100	49	156	-165.496994	61.2519989	473346.6902	6790959.529
4	0		157	-165.5010071	61.2288017	473083.7552	6788376.063
4	50	28	184	-165.5019989	61.2290001	473039.9903	6788400.242
5	0		185	-165.5050049	61.2318993	472875.4452	6788725.936
5	50	33	217	-165.5039978	61.2321014	472922.713	6788742.238
6	0		218	-165.503006	61.2370987	473019.9162	6789304.453
6	88	77	294	-165.5010071	61.2369003	473104.9655	6789281.856
7	0		295	-165.5299988	61.2402992	471554.815	6789667.324
7	50	51	345	-165.5310059	61.2402	471506.7237	6789653.641
8	0		346	-165.4839935	61.2397995	474029.5753	6789592.385
8	130	80	425	-165.4850006	61.2388992	473947.7469	6789491.37
9	0		426	-165.4869995	61.237999	473859.8583	6789394.832
9	66	67	492	-165.4880066	61.2374992	473825.83	6789338.281

Data File Information

There are seven data files with this dataset including one measurement file in comma-separated (.csv) format, two compressed shapefiles (.shp in .zip format), and four maps in GeoTIFF (.tif) format.

Table 1. Data file names and descriptions

File name	Description
PermafrostDepth_Fielddata_2016.csv	A comma-separated (.csv) file with measurements at 493 locations
Tutakohe_Permafrost_Plateau_Transects.zip	A compressed shapefile (.shp) with the 493 measurement locations
Tutakohe_permafrost_validation.zip	A compressed shapefile (.shp) with 333 validation permafrost locations as 0 if permafrost was present, or 1 if no permafrost
Elevation.tif	LIDAR DEM
Permafrost_Extent_Elevation_Threshold.tif	A map of permafrost distribution created using a 2.5 m a.m.s.l. (mean + 1 SD) threshold for the entire 2009 LiDAR swath
Permafrost_Predicted_Probability.tif	A map of the probability of near-surface permafrost as predicted by 0.1 m elevation bins
Permafrost_Extent_Random_Trees.tif	Permafrost map created from LiDAR data integrated with IKONOS imagery into a Random Trees (RT) classifier, trained with thaw-depth sample points along transects

Field Measurements

The field data are provided in .csv and .shp formats. The variables are described below.

Data Dictionary

User Notes: Thaw depth (frost_top) measurements were made from the surface, where surface was defined as either the top of the vegetation present, or soil if no vegetation was present. If standing water was present at the surface, the thaw depth was measured by reaching down through the water to the surface to mark the thaw depth on the probe. Water_depth is not included in the frost_top or frost_bottom values.

Data not applicable or missing are recorded as -9999.

Table 2. Variables in the file **PermafrostDepth_Fielddata_2016.csv**

Column name	Units/format	Description
FID		Id number
transect		Transect number
distance	m	Spot of measurement distance in meters from the transect start. Transect length- ranging from 50 to 130 m
trans_distance		Transect number and transect length concatenated
Easting		X coordinate for measurement location is Easting, UTM Zone 3N. See spatial data information below.
Northing		Y coordinate for measurement location is Northing, UTM Zone 3N. See spatial data information below.
ecotype		Ecotypes present along the transects
permafrost	0 or 1	Permafrost presence or absence; 0 stands for no permafrost found within 125 cm of the surface, and 1 stands for permafrost found within 125 cm of the surface. <i>See user note above.</i>
frost_top	cm	Depth to the top of frost from the surface, measured in cm. Measurements were made with a 1.25 m probe. A value of 125 signifies that no frost was found within 125 cm of the surface. frost_top_depth_flag is set to GT. <i>See user note above.</i>
frost_top_depth_flag		Flag=GT (for Greater Than, '>') when frost_top measurement value is reported but the actual depth exceeded the length of the probe (125 cm). Greater than (>) was originally reported.
frost_bottom	cm	Depth to the bottom of frost measured in cm, if the frost was soft enough to break through with a thaw probe. A value of -9999 signifies that no measurement was made because there was no frost encountered in the top 125 cm or the frost was too hard to break through with a thaw probe.
frost_bottom_depth_flag		Flag=GT (for Greater Than, '>'). A GT flag (>) was added to denote that *frost bottom measurement* was at least that deep, but could not be recorded further. Greater than (>) was originally reported.
frost_thickness	cm	Frost thickness calculated where both frost_top and frost_bottom measurements were obtained (frost_bot - frost_top). A value of -9999 signifies no calculation could be made due to no frost being found within the top 125 cm or no measurement for the frost bottom was obtained because the frost was too thick or too hard to break through.
frost_thickness_flag		Flag=GT (for Greater Than, '>'). A GT flag was added to denote that *frost thickness measurement* was at least that deep, but could not be recorded further. Greater than (>) was originally reported.
water_depth	cm	The depth of any standing water found at the surface measured in cm. A value of -9999 signifies there was no water at the surface or it was not measured.
photos		Photos taken along the transects. These are available in the companion file Permafrost_Thaw_Depth_YK_transect_fieldwork_pictures.zip
notes		Field notes

Table 3. Spatial Data Information for measurement point coordinates

Projected Coordinate System: NAD_1983_UTM_Zone_3N
 Projection: Transverse_Mercator
 False_Easting: 500000.00000000
 False_Northing: 0.00000000
 Central_Meridian: -165.00000000
 Scale_Factor: 0.99960000
 Latitude_Of_Origin: 0.00000000
 Linear Unit: Meter
 Geographic Coordinate System: GCS_North_American_1983
 Datum: D_North_American_1983
 Prime Meridian: Greenwich
 Angular Unit: Degree

Table 4. Variables in the shapefile **Tutakoke_Permafrost_Plateau_Transects.shp**

For units and a description of the variables, refer to the descriptions in the above file **PermafrostDepth_Fielddata_2016.csv**.

Variables
Transect
Distance
Trans_Dist
Permafrost
Frost_Top
Frost_Bot
Frost_Thic
H2O_Depth
Ecotype
Notes
Photos

Table 5. Variables in the permafrost validation file **Tutakoke_permafrost_validation.shp**

The only variable is permafrost, with a value of **0** indicating no permafrost, or **1** indicating the presence of permafrost.

Table 6. Coordinates of the shapefile **Tutakoke_permafrost_validation.shp**

Northernmost Latitude	Southernmost Latitude	Westernmost Longitude	Easternmost Longitude
61.25879	61.23433	-165.619	-165.484

GeoTIFF (.tif) files

Table 7. Individual GeoTIFF information

File name	Variable Units/Map units	Data type	Min-max values	No data value
Permafrost_Extent_Random_Trees.tif	None/meters	Byte	0 - 2	255
Permafrost_Extent_Elevation_Threshold.tif	None/meters	Byte	5 - 7	15
Permafrost_Predicted_Probability.tif	Percent/meters	Byte	4 -100	-128
Elevation.tif	Meters/meters	Float 32	-0.1- 4.2	-9999

Table 8. Spatial information for GeoTIFFs

Proj: NAD_1983_UTM_Zone_3N, North_American_Datum_1983
Spheroid: GRS 1980,6378137,298.2572221010042
AUTHORITY: EPSG, 7019; AUTHORITY: EPSG, 6269
Primemem: Greenwich,0
Unit: degree, 0.0174532925199433
AUTHORITY: EPSG, 4269
Projection: Transverse_Mercator
latitude_of_origin: 0
central_meridian: -165
scale_factor: 0.9996
false_easting: 500000
false_northing: 0
units: meter, 1
UTHORITY: EPSG, 9001; AUTHORITY: EPSG, 26903

Table 9. Companion files

File name	Description
Permafrost_Thaw_Depth_YK_transect_fieldwork_pictures.zip	Photos taken along the transects. Photo I.D. numbers are provided in the .csv data file PermafrostDepth_Fielddata_2016.csv
Tutakoke_Permafrost_Plateau_Transects.kmz	A .kmz with the same data as the shapefile
Tutakoke_permafrost_validation.kmz	A .kmz with the same data as the shapefile
Permafrost_Thaw_Depth_YK.pdf	A pdf of this document

3. Application and Derivation

These data could be useful to climate change studies. With increasing air and ground temperatures across the Arctic, monitoring permafrost degradation (e.g., thermokarst) is important for understanding processes at both the local and the larger regional and global scales. Since nearly half of Alaska lies within the zones of isolated permafrost (>0–10% permafrost landcover), sporadic permafrost (10–50%), or discontinuous permafrost (50–90%), large areas are at risk of being affected by permafrost thaw in the future (Whitley et al., 2018).

4. Quality Assessment

Validation from the 333 GPS points within the LiDAR swath showed that the LiDAR map achieved 94.9% total accuracy in mapping permafrost occurrence. Elevation was found to be a highly significant indicator of near-surface permafrost in the region. The model was 98.9% accurate in mapping areas without permafrost, but only 80.3% accurate in mapping areas without permafrost.

5. Data Acquisition, Materials, and Methods

Study Area

This study focused on the Yukon-Kuskokwim Delta (YKD) in western Alaska, south of the village of Chevak and west of Hazen Bay (Figure 2). The region is extremely flat and vulnerable to eustatic sea-level rise and inland storm surges. The landscape is in the sporadic to isolated permafrost zone, with a mean annual temperature in Bethel, AK at -1.2 degrees C. Permafrost in the area predominantly manifests on the abandoned floodplains.

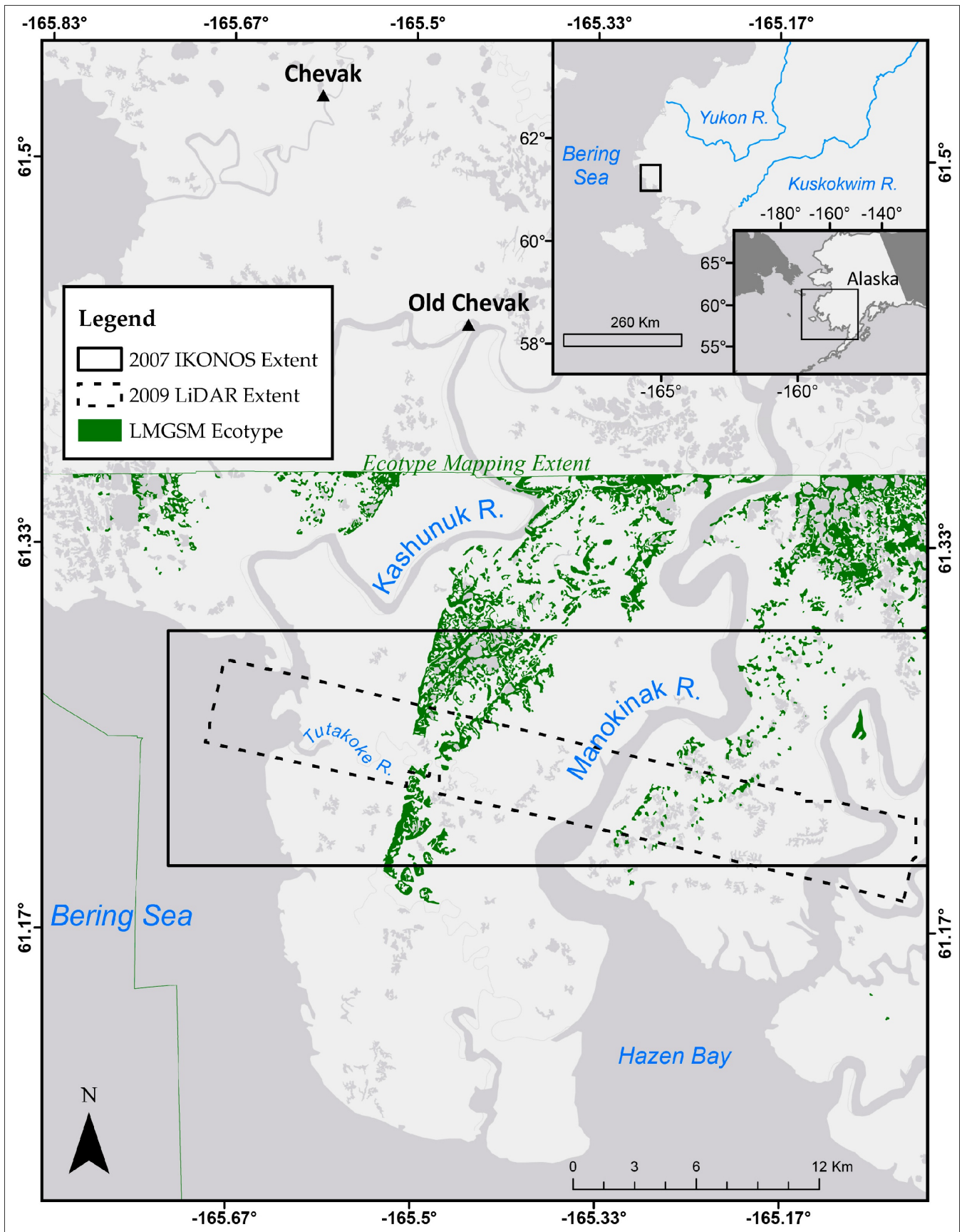


Figure 2. Study area located on the Yukon-Kuskokwim Delta (YKD) in western Alaska, USA (Whitley et al., 2018).

Field Measurements

Field data were collected during July 8–17, 2016, to support mapping analysis and validation. Transects running perpendicular to the boundary of permafrost plateaus were established subjectively according to topographic breaks, vegetation, presence of storm indicators (e.g., driftwood), and evidence of thermokarst (e.g., thermokarst pits, moats, thermo-erosional gullies). Field data were collected along nine transects, with transect lengths ranging from 50 to 130 m (Figure 3). Measurements were made along each transect every 1 m over permafrost and 5 m over non-permafrost using a 1.25 m thaw probe and a Delorme PN-60 GPS (coordinates were originally recorded in the WGS84 Geographic Coordinate System, but projected to match the raster data). When possible, frost thickness and/or permafrost was measured by breaking through frozen ground along the plateau margins. The surface was defined as the top of the vegetation present, or soil if no vegetation was present. If water was present, the thaw depths were calculated from reaching down to the surface (not the surface of the water; i.e. thaw depth + water depth = water surface to frost top). Since sampling was conducted in mid-July, seasonal frost was likely encountered in addition to the permafrost along these margins.

For validation, 333 GPS points and permafrost observations were collected opportunistically along the coast-inland gradient, separate from those collected along the transects. These validation points were later categorized as binary permafrost/non-permafrost for use in validating the map products.

The transect data were analyzed by ecotype and elevation. Similar ecotypes were grouped together to ensure a minimum sample size of at least 10 observations per ecotype. The ecotypes analyzed included: Lowland Moist Graminoid Shrub Meadow (LMGSM), Lowland Wet Graminoid ShrubMeadow (LWGSW), LowlandWet SedgeMeadow (LWSM), LowlandWet Sedge-ShrubMeadow (LWSSM), Riverine Moist Graminoid Shrub Meadow (RMGSM), Thermokarst Pits (TP), Water (W), and Wrack Lines (WL) from previous storm surges.

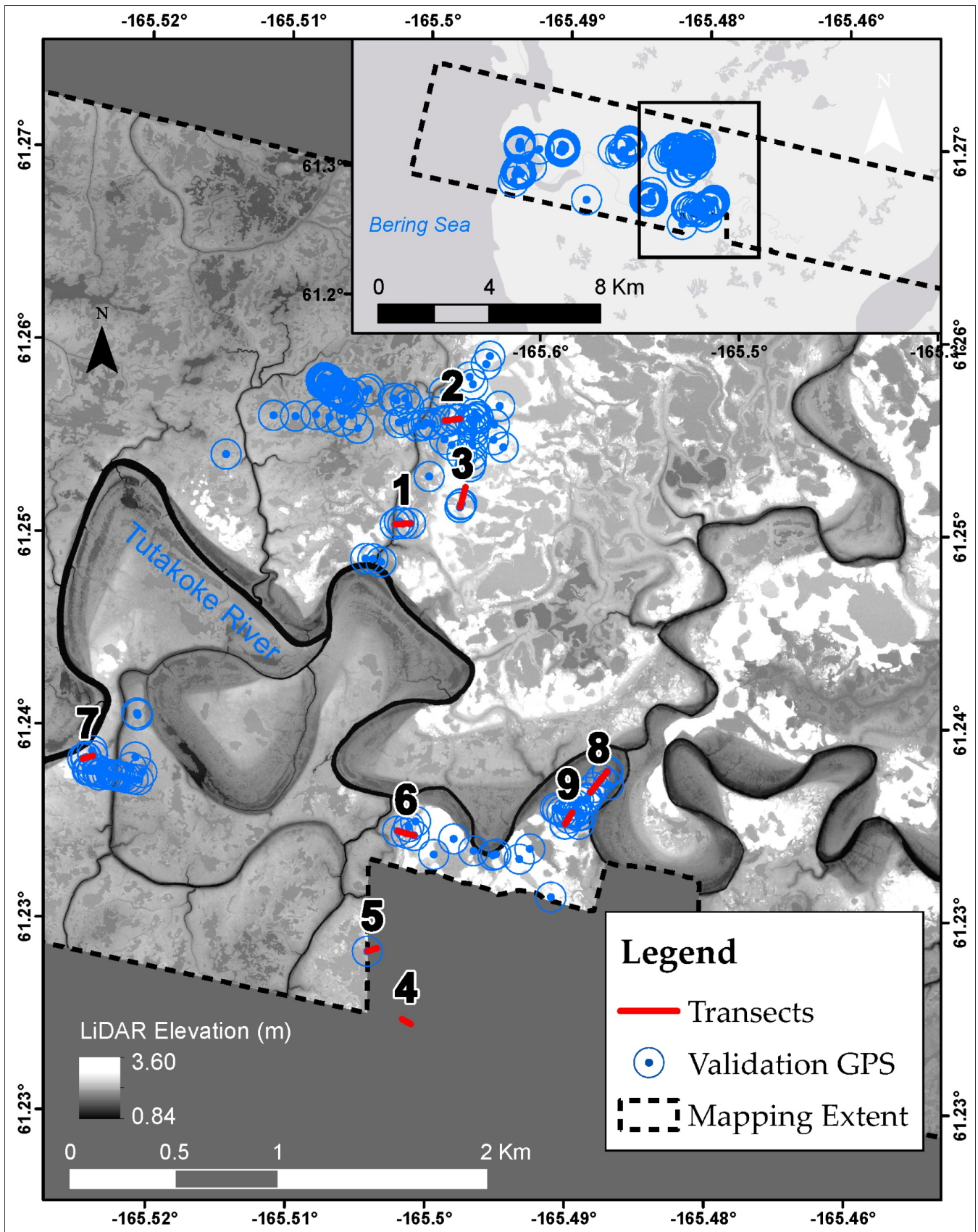


Figure 3. Transect locations and field validation sampling points, and the mapping extent (dashed line) near the Tutakoke River, YKD. Thaw depth transects (bold numbers) are in red, validation points used for spectral analysis are in black, and field points used for LiDAR analysis are in blue (Whitley et al., 2018).

LiDAR

A LiDAR mission flown between June 27 and July 2, 2009, by Kodiak Mapping, Inc. (Palmer, AK, USA) was the base dataset (Airborne Imaging, 2011)

used for mapping (Figure 1). When processing the LiDAR data, only the last returns were considered to create a DEM with 1-m horizontal resolution and 0.05-m vertical resolution. The DEM was subsequently adjusted to elevation a.m.s.l. Mean sea level was calculated from a HOBO Data Logger tide gauge (Onset Computer Corporation; Bourne, MA, USA) deployed from July 28, 2009 to November 30, 2010; LiDAR data were tide-corrected (Whitley et al., 2018).

Permafrost Mapping

Using the corrected LiDAR dataset, elevations of the permafrost plateau margins were extracted at the points sampled along the transects in the field. This was performed through photo-interpretation of the transitions from permafrost plateau to coastal meadows using high-resolution imagery. To map permafrost extent in the LiDAR swath, a threshold was selected based upon mean elevation of the boundaries + 1 standard deviation (SD). This threshold was then used to create a binary mask of areas with permafrost (elevations above the threshold) and areas without permafrost (elevations below the threshold). The map was subsequently validated using the 333 GPS points and observations collected in the field that fell within the LiDAR swath. To augment the LiDAR analysis, an IKONOS image from August 27, 2007 was incorporated with the LiDAR data into a Random Trees (RT) classifier. The RT classification was trained using the thaw-depth sample points along the transects. A separate RT classification was conducted using IKONOS and LiDAR but was trained using manually delineated polygons (Whitley et al., 2018).

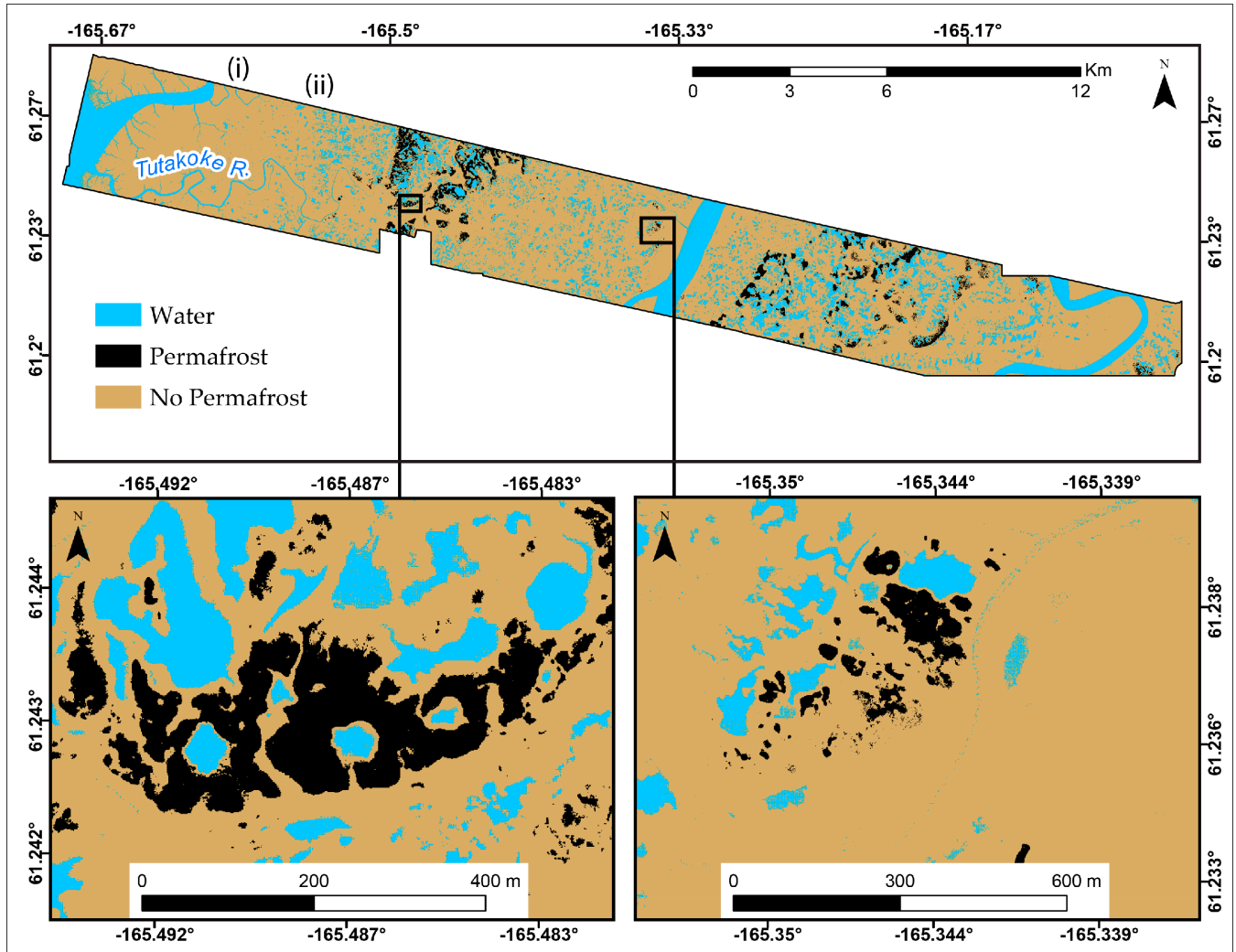


Figure 4. Permafrost map from integrated RT classification trained with visual interpretation of the landscape. The insets show detail for areas of relative high elevation (left) and relative low elevation (right). Transitions between the mudflat and active floodplain deposit (i), and the active and inactive floodplain deposits (ii) are also shown (Whitley et al., 2018).

Permafrost Probability Mapping

The relationship between elevation and permafrost occurrence was analyzed using logistic regression by assessing whether or not permafrost was encountered at each thaw-depth sample point along the transects (not just those on the boundaries of the plateaus). Elevations were extracted from the LiDAR DEM at each thaw-depth sample point and modeled against the presence or absence of permafrost at each point. The resulting model was used to predict the probability of permafrost occurrence in 0.1 m elevation bins that spanned all observed elevations. This resulted in a permafrost probability map that quantifies the uncertainty of whether or not permafrost is present (Whitley et al., 2018).

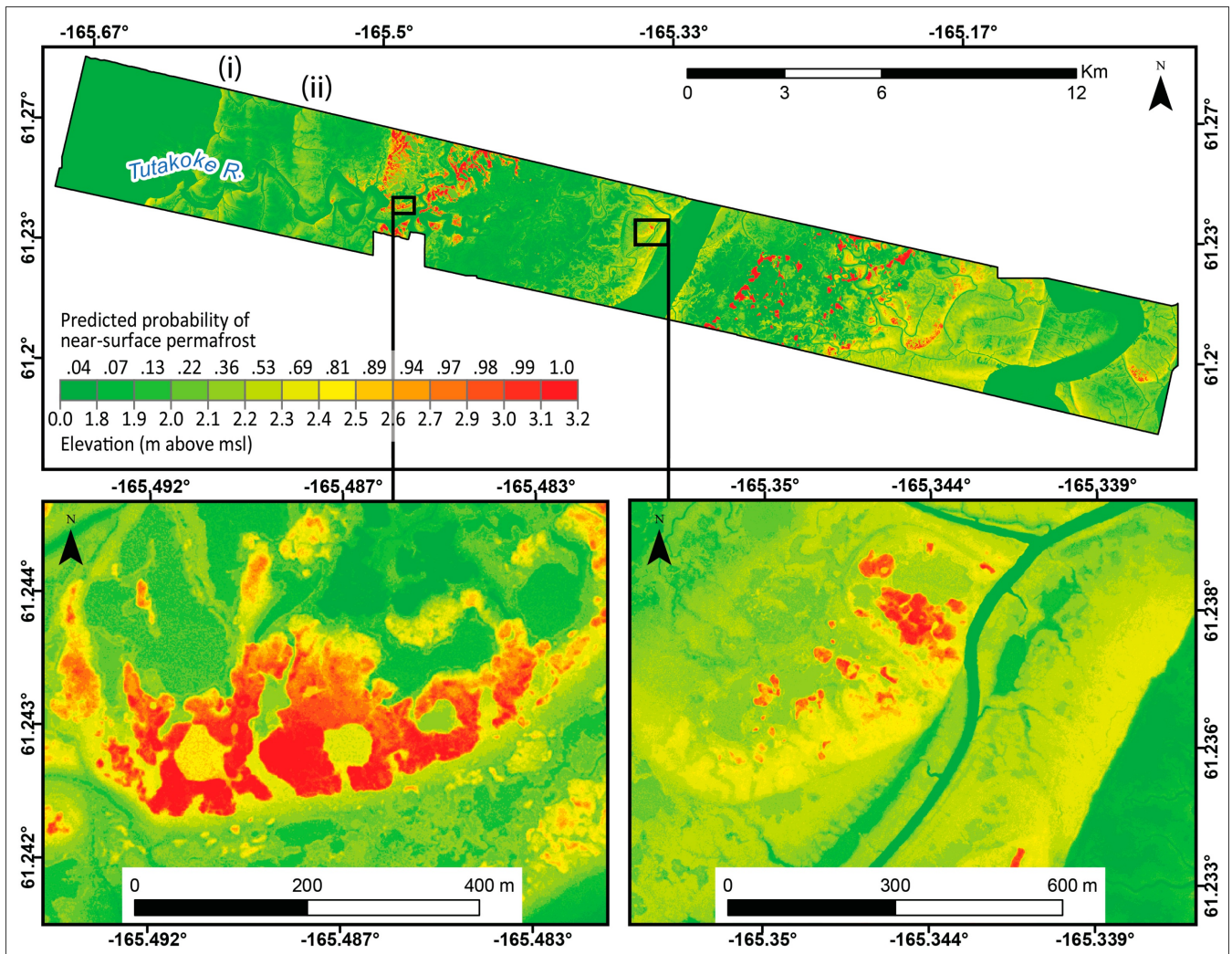


Figure 5. Map of predicted near-surface permafrost probability calculated by 0.1 m elevation bins for the entire 2009 LiDAR swath. The insets show detail for areas of relative high elevation (left) and relative low elevation (right) (Whitley et al., 2018).

6. Data Access

These data are available through the Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

[ABOVE: Permafrost Measurements and Distribution Across the Y-K Delta, Alaska, 2016](#)

Contact for Data Center Access Information:

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- Telephone: +1 (865) 241-3952

7. References

Airborne Imaging. Final LiDAR processing & vertical accuracy report: Prepared for the U.S. Fish and Wildlife Service. In *LiDAR Imagery & DEM Model for Yukon Delta National Wildlife Refuge—Near Angyaravak Bay, Alaska*; Airborne Imaging: Calgary, AB, Canada, 2011; p. 28.

Whitley, M. A., G. V. Frost, M. T. Jorgenson, M. J. Macander, C. V. Maio, and S. G. Winder. 2018. Assessment of LiDAR and spectral techniques for high-resolution mapping of sporadic permafrost on the Yukon-Kuskokwim Delta, Alaska. *Remote Sensing* 10(2), 258. <https://doi.org/10.3390/rs10020258>



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Home

About Us

Who We Are
Partners
User Working Group
Data Citation Policy
News

Get Data

Complete Dataset List
Search for Data
Field Campaigns
Land Validation
Regional/Global
Model Archive

Submit Data

Submit Data Form
Data Scope and Acceptance
Data Authorship Policy
Data Publication Timeline
Detailed Submission Guidelines

Tools

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Resources

Learning
Data Management

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