Pre-ABoVE: Active Layer Thickness and Soil Water Content, Barrow, Alaska, 2013

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Documentation Revision Date: 2018-01-10

Data Set Version: 1

Summary

This data set provides estimates of Active Layer Thickness (ALT) determined with ground-based measurements, and calculated soil volumetric water content (VWC) at four selected sites around Barrow, Alaska in August 2013. ALT was determined using a ground-penetrating radar (GPR) system and traditional mechanical probing. Calculated uncertainties are also included. GPR measurements were taken along four transects of varying length (approx. 1 to 7 km). Mechanical probing included several high-density surveys (every 1 m within 100-m survey line) along each GPR transect. VWC of the active layer soil was calculated at 3-8 calibration points per site where the probe measurement was exactly co-located with a GPR trace.

A total of ~15 km of ALT measurements were made using 500 MHz GPR and ~1.5 km of probing data at the four sites. The four sites were selected as they represent a range of environmental conditions commonly observed in the Barrow area. Data were collected in August to approximate the time of year when the active layer would be at its maximum thickness. GPR was ideal for acquiring ALT at very high spatial density over the long distances.

Mechanical probing was used roughly every kilometer to calibrate the GPR wave velocity used to convert the two way transit time to ALT. For each calibration probe the average of three probe measurements were made adjacent to the GPR antenna. In addition, a 100-m survey line was laid along segments of the GPR track and a mechanical probe was used to make a single ALT measurement every meter. The high-density probe measurements were used to calibrate the average wave velocity and standard deviations at each study site. Uncertainty was estimated in GPR ALT due to soil water variability by propagating the standard deviation of wave velocity through the calculation of ALT from the transit time.

There are five data files with this data set which includes three files in comma-separated format (.csv) and two shapefiles (.shp). There are also companion files included with this data set: the shapefiles provided in .kmz format for viewing in GoogleEarth, and raw GPR instrument readings.

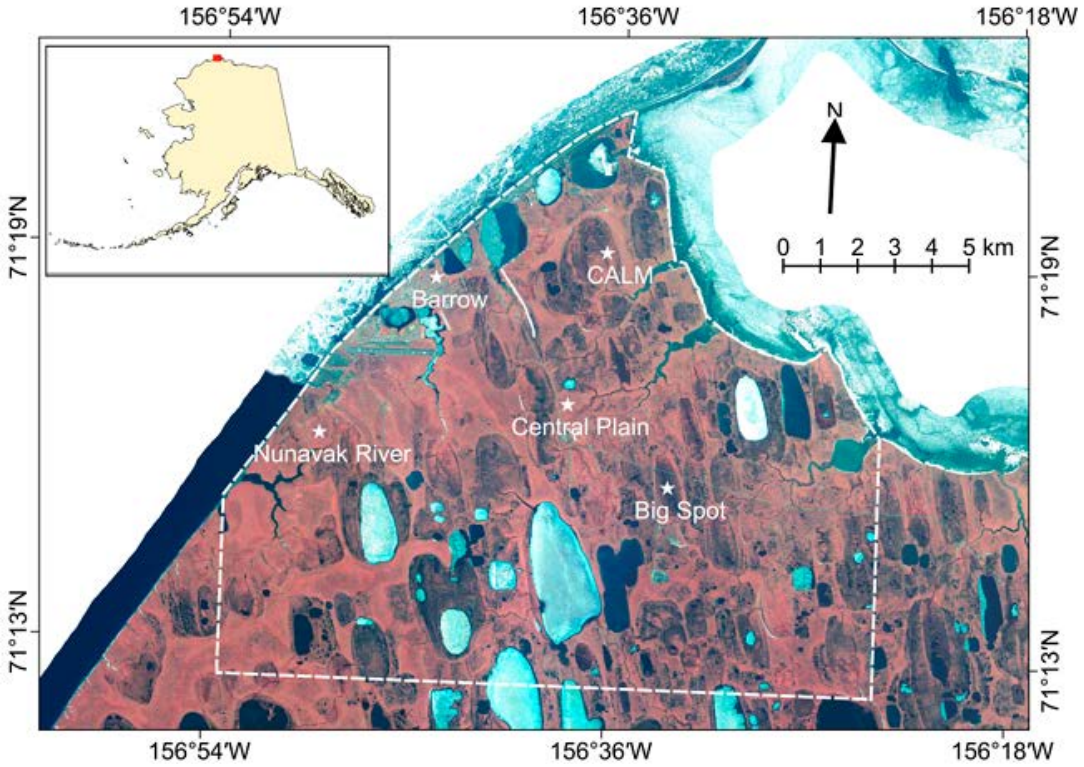

Figure 1. Google Earth Image of the locations of the four sites around Barrow, Alaska (from Fig. 1 in Schaefer et al., 2015).

Citation

Jafarov, E., A. Parsekian, K. Schaefer, L. Liu, A. Chen, S.K. Panda, and T. Zhang. 2018. Pre-ABoVE: Active Layer Thickness and Soil Water Content, Barrow, Alaska, 2013. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1355

Table of Contents

1. Data Set Overview

Permafrost active layer thickness (ALT) is an important parameter for studying surface energy balance, ecosystems, and hydrological processes in cold regions. In August of 2013, ALT was estimated at four sites around Barrow, Alaska, using a ground-penetrating radar (GPR) system and mechanical probing. GPR measurements were taken along four transects of varying length (approx. 1 to 7 km). Traditional ALT estimates from mechanical probing included several high-density surveys (every 1 m within 100-m survey line) along each GPR transect. In addition, VWC of the active layer soil was calculated at 3-8 calibration points per site where the probe measurement was exactly co-located with a GPR trace.

A total of ~15 km of ALT measurements were made using 500 MHz GPR and ~1.5 km of probing data at the four sites. Data were collected in August to approximate the time of year when the active layer would be at its maximum thickness. GPR was ideal for acquiring ALT at very high spatial density over the long distances.

Mechanical probing was used roughly every kilometer to calibrate the GPR wave velocity used to convert the two way transit time to ALT. For each calibration probe the average of three probe measurements were made adjacent to the GPR antenna. In addition, a 100-m survey line was laid along segments of the GPR track and a mechanical probe was used to make a single ALT measurement every meter. The high-density probe measurements were used to calibrate the average wave velocity and standard deviations at each study site. Uncertainty was estimated in GPR ALT due to soil water variability by propagating the standard deviation of wave velocity through the calculation of ALT from the transit time.

Project: Arctic-Boreal Vulnerability Experiment (ABoVE)

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign that will take place in Alaska and western Canada between 2016 and 2021. Climate change in the Arctic and Boreal region is unfolding faster than anywhere else on Earth. ABoVE seeks a better

understanding of the vulnerability and resilience of ecosystems and society to this changing environment.

Related Publication:

Jafarov, E. E., Parsekian, A. D., Schaefer, K., Liu, L., Chen, A. C., Panda, S. K. and Zhang, T. (2018), Estimating active layer thickness and volumetric water content from ground penetrating radar measurements in Barrow, Alaska. Geosci. Data J.. doi:10.1002/gdj3.49

Related Data Sets:

Chen, A., A. Parsekian, K. Schaefer, E. Jafarov, S.K. Panda, L. Liu, T. Zhang, and H.A. Zebker. 2015. Pre-ABoVE: Ground-penetrating Radar Measurements of ALT on the Alaska North Slope. ORNL DAAC, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1265.

Liu, L., K. Schaefer, A. Chen, A. Gusmeroli, E. Jafarov, S. Panda, A. Parsekian, T. Schaefer, H. A. Zebker, T. Zhang. 2015. Pre-ABoVE: Remotely Sensed Active Layer Thickness, Barrow, Alaska, 2006-2011. Data set. Available on-line [http://daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, USA. http://dx.doi.org/10.3334/ORNLDAAC/1266

2. Data Characteristics

Spatial Coverage: Data were collected at four sites around Barrow, Alaska, USA.

ABoVE Site Designation:

Domain: Core ABoVE region

State/territory: Alaska (study sites around Barrow)

Grid cells: Ahh1Avv0Bh2Bv1

Spatial Resolution: GPR measurements were taken along 4 transects of varying length (approx. 1 to 7 km), approximately .5 m between traces. Mechanical probing included several high-density surveys (every 1 m within 100-m survey line) along each transect.

Temporal Coverage: 2013-08-10 to 2013-08-15

Temporal Resolution: 0.5 seconds between GPR traces.

Study Area: (all latitudes and longitudes given in decimal degrees)

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Barrow, Alaska, USA	-156.820302	-156.557655	71.312020	71.252975

Data File Information:

There are five data files with this data set which includes three files in comma-separated format (*.csv) and two shapefiles (*.zip). Four companion files are also provided and are described at the end of this section.

File name	Description
lvl1_gpr_alt.csv	ALT and uncertainty derived from GPR
lvl1_gpr_alt.zip	ALT and uncertainty derived from GPR. When unzipped, this file provides a shapefile (.shp) file. This file contains the same variables as the corresponding .csv . This file is also provided as a companion file in .kmz format for viewing in Google Earth
prb_gpr_alt_hd.csv	ALT and uncertainties from probe measurements and from GPR
prb_gpr_alt_hd.zip	ALT and uncertainties from probe measurements and from GPR. When unzipped, this file provides a shapefile (.shp) file. This file contains the same variables as the corresponding .csv. This file is also provided as a companion file in .kmz format for viewing in Google Earth
probe_data.csv	ALT estimates from mechanical probing at four sites every 1 m within 100-m survey line along each transect

Variables in the data files

Table 1. Variables in the files lvl1_gpr_alt.csv and **lvl1_gpr_alt.zip**

There are no missing values in the data file.

Variable name (.csv files)	Variable name (.shp files)	Units/format	Description

site_ID	site_ID		Sites where ground measurements were made: CP (Central Plain), BS (Big Spot), CL (CALM), and UNB (Upper Nunavak Bay)
lat_gpr	lat_gpr	Decimal degrees	Latitude of point where GPR measurements were made
lon_gpr	lon_gpr	Decimal degrees	Longitude of point where GPR measurements were made
alt_gpr	alt_gpr	m	ALT determined using GPR
unc_alt_gpr	unc_alt_gp	m	The corresponding uncertainty in calculated ALT determined using GPR

Table 2. Variables in the files prb_gpr_alt_hd.csv and **prb_gpr_alt_hd.zip.** HD in the file names represents high-density 100-m surveys. Missing data are represented as -999.

Variable name (.csv files)	Variable name (.shp files)	Units/format	Description
site_ID	site_ID		Sites where ground measurements were made: CP (Central Plain), BS (Big Spot), or CL (CALM)
lat_prb	lat_prb	Decimal degrees	Latitude of point where probe measurements were made
lon_prb	lon_prb	Decimal degrees	Longitude of point where probe measurements were made
alt_prb	alt_prb	m	ALT determined using probe
unc_alt_prb	unc_alt_pr	m	The corresponding uncertainty in calculated ALT with a probe
lat_gpr	lat_gpr	Decimal degrees	Latitude of point where GPR measurements were made determined with a handheld Global Positioning System (GPS) unit linked to the system
lon_gpr	lon_gpr	Decimal degrees	Longitude of point where GPR measurements were made determined with a handheld Global Positioning System (GPS) unit linked to the system
owtt	owtt	ns [nano seconds]	One-way GPR wave transit time. The unit was a Malå CUII GPR unit with a 500 MHz shielded antenna. A Global Positioning System (GPS) unit was attached to the system to record the location of each trace.
velocity	velocity	m/ns	GPR wave velocity
unc_vel	unc_vel	m/ns	Uncertainty, GPR wave velocity
cv_vel	cv_vel	m/ns	Covariance coefficient of velocity (m/nano seconds)
alt_gpr	alt_gpr	m	ALT determined using GPR
unc_alt_gpr	unc_alt_gp	m	The corresponding uncertainty in calculated ALT determined using GPR
vwc	vwc	fraction of 1	VWC of the active layer soil calculated at 3 to 8 calibration points per site where the probe measurement was exactly co-located with a GPR trace.
unc_vwc	unc_vwc	fraction of 1	Uncertainty of the volumetric water content (VWC)

Table 3. Variables in the file probe_data.csv

ALT determined at the four study sites using traditional mechanical probing. HD in the variable names represents high-density 100-m surveys. All measurements were made between August 10, 2013 and August 15, 2013. Refer to Table 4 below for probing time and location information. Missing data are represented as -999.

Column(s)	Variable name	Units/format	Description
1	Distance	m	Distance along survey, 1 - 100 m

2 - 3	UNB_HD_1 and UNB_HD_2	cm	ALT measurements at site UNB
4 - 9	BS_HD_x Where x is 1 – 5, 7	cm	ALT measurements at site BS
10	CP_HD_1	cm	ALT measurements at site CP
11-16	CL_HD_x Where x is 1 - 6	cm	ALT measurements at site CL

Table 4. Active layer thickness mechanical probe survey time and locations of the start and end points. High density data measured by ground penetrating radar are missing from the UNB surveys.

Num	Code	Date	Start	Lat	Lon	End	Lat	Lon
1	UNB_1	2013-08-10	3:45	71.26644444	-156.82070830	4:36	71.26555556	-156.82041670
2	UNB_2	2013-08-10	5:22	71.26275000	-156.80930560	5:45	71.26336111	-156.81108330
3	BS_1	2013-08-11	9:40	71.26152778	-156.61797222	10:27	71.26161111	-156.61533333
4	BS_2	2013-08-11	11:00	71.25977778	-156.59388889	11:38	71.25902778	-156.59338889
5	BS_3	2013-08-11	12:55	71.25708333	-156.56508333	1:23	71.25661111	-156.56283333
6	BS_4	2013-08-11	2:05	71.25566667	-156.55086111	2:36	71.25536111	-156.54836111
7	BS_5	2013-08-12	1:15	71.25583333	-156.55372222	1:37	71.25492222	-156.55313889
8	BS_7	2013-08-12	2:35	71.24638889	-156.55869444	3:11	71.24666667	-156.56113889
9	CP_1	2013-08-12	11:13	71.27336111	-156.63983333	11:58	71.27380556	-156.63794444
10	CL_1	2013-08-14	9:55	71.32127778	-156.61750000	10:26	71.32072222	-156.61952778
11	CL_2	2013-08-14	11:30	71.31127778	-156.63036111	11:52	71.31063889	-156.62900000
12	CL_3	2013-08-14	1:11	71.30433333	-156.61033333	1:36	71.30513889	-156.61147222
13	CL_4	2013-08-14	2:41	71.31540000	-156.61094444	3:12	71.31622222	-156.61347222
14	CL_5	2013-08-15	11:09	71.31492000	-156.59113000	11:32	71.31434000	-156.58940000
15	CL_6	2013-08-15	1:25	71.31026000	-156.58823000	1:46	71.31112000	-156.58922000

Companion files

Four companion files are provided with this data set: two *.kmz files, a compressed (*.zip) directory containing raw GPR instrument readings from the study, and a document (.pdf) describing this raw GPR data.

File name	Description
lvl1_gpr_alt.kmz	ALT and uncertainty derived from GPR. This file contains the same data as the corresponding shapefile and is provided for viewing in Google Earth
prb_gpr_alt_hd.kmz	ALT and uncertainties from probe measurements and from GPR. This file contains the same data as the corresponding shapefile and is provided for viewing in Google Earth

Raw_GPR_Data_Barrow_2013	Raw GPR data. There are five folders of data.
ALT_GPR_Barrow.pdf	A pdf of this document

3. Application and Derivation

ALT is a critical parameter for monitoring the status of permafrost that is typically measured at specific locations using probing, in situ temperature sensors, or other ground-based observations. These data are useful for comparing the accuracy of ground-penetrating radar (GPR) as a method of estimating permafrost ALT.

4. Quality Assessment

The uncertainty sources are independent of one another, so the total uncertainty in the GPR ALT values is the wave velocity and time-average uncertainty added in quadrature. Covariance coefficients were calculated for two way travel time and velocities by dividing the corresponding standard deviations over means (Jafarov et al., 2016, in review). The corresponding uncertainty is provided for every measured and derived parameter in the calibrated data set using Gaussian error propagation.

Missing GPS data prevented the calibration of the GPR data using all probe points at Nunavak River, resulting in a high uncertainty and a probable bias towards wetter conditions (Jafarov et al., 2016, in review). Good GPR data at two HD surveys were not collected at the UNB due to gravel type soil texture.

Differences in ALT at sites could be attributed to the positioning error between GPR track and probe line. Even a slight deviation from the GPR track could create a mismatch between the ALT GPR and probe data (Jafarov et al., 2016, in review).

5. Data Acquisition, Materials, and Methods

This data set provides permafrost ALT and calculated uncertainties determined using a ground-penetrating radar (GPR) system in the field in August 2013 at Barrow, Alaska. GPR measurements were taken along 4 transects of varying length (approx. 1 to 7 km). Traditional ALT estimates from mechanical probing include several high-density surveys (every 1 m within 100-m survey line) along each transect.

The GPR and probe data were collected in the field in August 2013. The four sites were selected as they represent a range of environmental conditions commonly observed in the Barrow area.

Study sites

The four study sites included:

Big Spot (BS): This site is a series of drained thermokarst lake basins (DTLBs) of varying ages. This site was chosen because it represented conditions typical of DTLBs around Barrow.

The **CALM site (CL):** This site has two large DTLBs separated by a narrow strip of undisturbed tundra. This site was chosen to evaluate conditions within and outside of large DTLBs and because of the availability of long-term measurements of ALT at the two Barrow sites in the CALM network, U1 and U2. U1 consists of a 1-km square grid of measurement sites, called nodes, placed 100 m apart where ALT has been measured using probing since 1995. U2, also known as the Cold Regions Research and Engineering Laboratory (CRREL) site, consists of a 10-m square plot of 320 randomly placed probe measurements.

The **Central Plain site (CP)**: This site is a matrix of high-center polygons with fully saturated soil and standing water over the ice wedges. This site was chosen because it represented typical undisturbed tundra around Barrow.

The **Upper Nunavak Bay (UNB)**: This site covers the upper portion of the Nunavak drainage basin, just south of the Barrow airport. The site consists of undisturbed tundra surrounded on three sides by the Nunavak River and its tributaries. The undisturbed tundra consists of a matrix of high-centered polygons similar to Central Plain, but with less standing water over the ice wedges. The elevation drops 3-4 m near the Nunavak River, with fully saturated soils and no polygons. This site was chosen because a mix of saturated and unsaturated soil conditions were expected.

In summary, the four sites represented typical undisturbed tundra conditions (Central Plain), drained soils (Nunavak River), the largest and typical DTLB conditions (Big Spot), and large DTLBs with the greatest amount of historical ALT observations (CALM) (Jafarov et al., 2016, in review; Schafer et al., 2015).

Ground Penetrating Radar (GPR)

A total of ~15 km of ALT measurements were made using 500 MHz GPR at the four validation sites in August of 2013. August was chosen to approximate the time of year when the active layer would be at its maximum thickness. GPR uses pulsed radio-frequency electromagnetic waves to noninvasively image the subsurface. Energy emitted from a transmitting antenna travels into the ground and some of the energy is reflected back towards the receiving antenna at the surface, which records the travel time. The digitized record of reflected energy, known as a trace, is made at regular time intervals as the GPR unit is pulled along the ground and the graphic representation of a series of traces is a radargram.

The GPR unit was a Malå CUII with a 500-MHz shielded antenna mounted in a box for protection and stability. A Garmin GPS 18 unit was on top of the box to record the location of the GPR. The reflection at the bottom of the active layer was clearly visible in the raw data, so data filters were not required. Instead, the standard time-zero correction was applied by setting the position of the first arrival as time-zero for each trace and the unambiguous reflection event was digitized directly from the radargrams by hand. The radar reflections were manually digitized, commonly known as picking, as a quality control measure to verify the signals and reduce interpretation errors due to spurious reflections. The GPR traces represent ALT values for a footprint of less than 0.15 m^2, based on the antenna frequency and physical properties of the active layer (Jafarov et al., 2016, in review; Schafer et al., 2015).

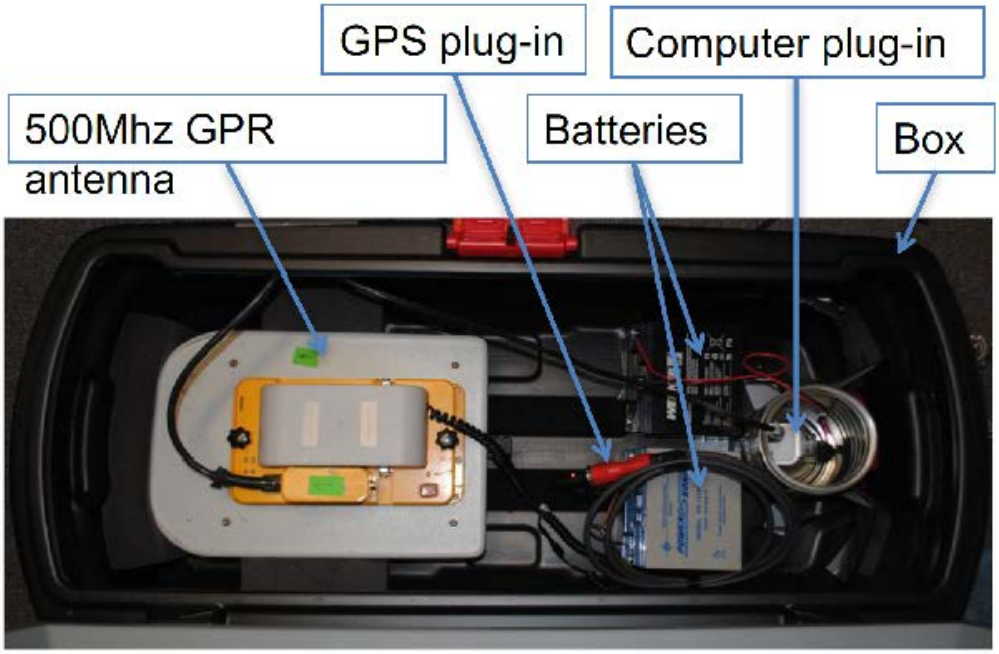

Figure 2. A photo of the GPR unit setup (Jafarov et al., 2016, in review).

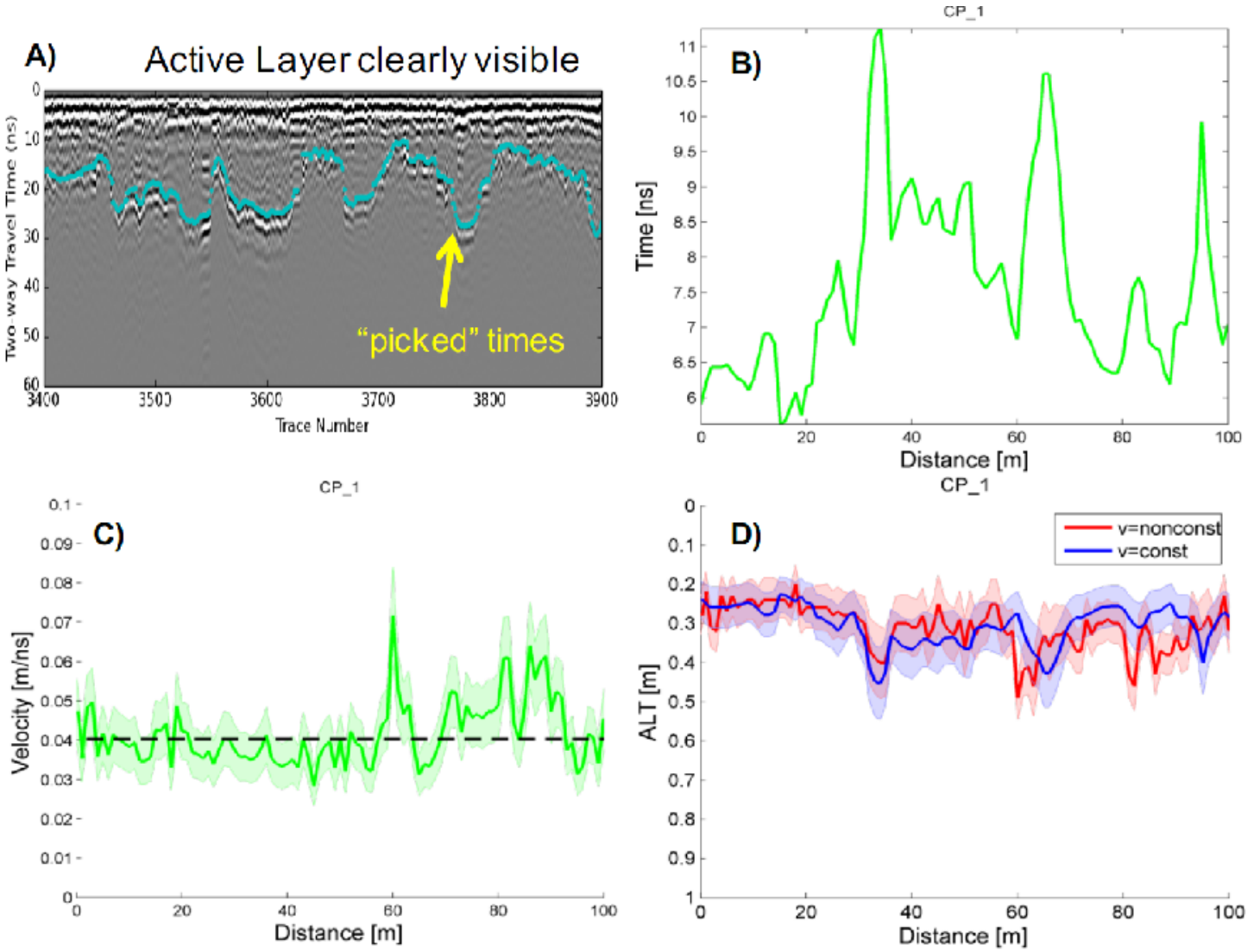

Figure 3. The GPR signal processing workflow: A) picking of the visible GPR travel time, B) one way travel time, C) velocity calculated from probed active layer thickness (ALT) and one way travel time, D) ALT calculated using constant and non-constant velocities (Jafarov et al., 2016 in review).

Mechanical probing

Mechanical probing was used roughly every kilometer to calibrate the GPR wave velocity used to convert the two way transit time to ALT. For each calibration probe we took the average of three probe measurements adjacent to the GPR antenna. In addition, a 100-m survey line was laid along segments of the GPR track and used a mechanical probe to make a single ALT measurement every meter. These high-density probe measurements were used to calibrate the average wave velocity and standard deviations at each study site. Uncertainty was estimated in GPR ALT due to soil water variability by propagating the standard deviation of wave velocity through the calculation of ALT from the transit time (Jafarov et al., 2016, in review; Schafer et al., 2015).

Soil volumetric water content (VWC)

VWC of the active layer soil was calculated at 3-8 calibration points per site where the probe measurement was exactly co-located with a GPR trace. The Engstrom et al.2005 empirical VWC model developed for active layer soils in Barrow was used for most calibration points. To get the most reliable results, only probe locations were used where a GPR trace was available. The one-way travel time was extracted from the raw GPR data for the traces where probe measurements were made within ~20 cm of the GPR antenna based on the recorded "GPR time" that provided the exact trace of interest. The 90% threshold was selected for the calculated VWC. Everything greater than the assigned threshold is associated with pure water and not included in the calibrated data set (Jafarov et al., 2016, in review).

6. Data Access

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

Pre-ABoVE: Active Layer Thickness and Soil Water Content, Barrow, Alaska, 2013

Contact for Data Center Access Information:

- E-mail: uso@daac.ornl.gov
- Telephone: +1 (865) 241-3952

7. References

Jafarov, E. E., Parsekian, A. D., Schaefer, K., Liu, L., Chen, A. C., Panda, S. K. and Zhang, T. (2018), Estimating active layer thickness and volumetric water content from ground penetrating radar measurements in Barrow, Alaska. Geosci. Data J.. doi:10.1002/gdj3.49

Engstrom, R.; Hope, A.; Kwon, H.; Stow, D.; Zamolodchikov, D. Spatial distribution of near surface soil moisture and its relationship to microtopography in the Alaskan Arctic coastal plain. Nordic Hydrol. 2005, 36, 219–234.

Schaefer, K., L. Liu, A. Parsekian, E. Jafarov, A. Chen, T. Zhang, A. Gusmeroli, S. Panda, H.A. Zebker, and T. Schaefer. 2015. Remotely Sensed Active Layer Thickness (ReSALT) at Barrow, Alaska using Interferometric Synthetic Aperture Radar. Remote Sens. **2015**, *7*(4), 3735-3759; doi:10.3390/rs70403735