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ABoVE: Active Layer and Soil Moisture Properties from AirMOSS P-band SAR in Alaska

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Documentation Revision Date: 2019-04-25

Dataset Version: 1

Summary

This dataset provides estimates of soil geophysical properties derived from Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) P-band polarimetric synthetic aperture radar (PolSAR) data collected in August and October of 2014, 2015, and 2017 over 12 study sites (with some exceptions) across Northern Alaska. Soil properties reported include the active layer thickness (ALT), dielectric constant, soil moisture profile, surface roughness, and their respective uncertainty estimates at 30-m spatial resolution over the 12 flight transects. Most of the study sites are located within the continuous permafrost zone and where the aboveground vegetation consisting mainly of dwarf shrub and tussock/sedge/moss tundra has a minimal impact on P-band radar backscatter.

The data products were produced using a time-series retrieval algorithm approach applied to the AirMOSS P-band polarimetric synthetic aperture radar (PolSAR) data. The retrieval process is an inversion of a forward radar backscattering model, where a three-layer dielectric structure is used to model the active layer (surface and subsurface layers) and the underlying permafrost. Multiple retrieval runs were performed for each pixel during the inversion process, from which the mean and standard deviation are reported as the retrieved value and associated uncertainty for the desired geophysical parameters. Soil dielectric constants (representing soil with unfrozen water content), soil layer depths, and surface roughness were retrieved.

There are 29 data files with this dataset in NetCDF (.nc4) format. Not all sites were surveyed each year.
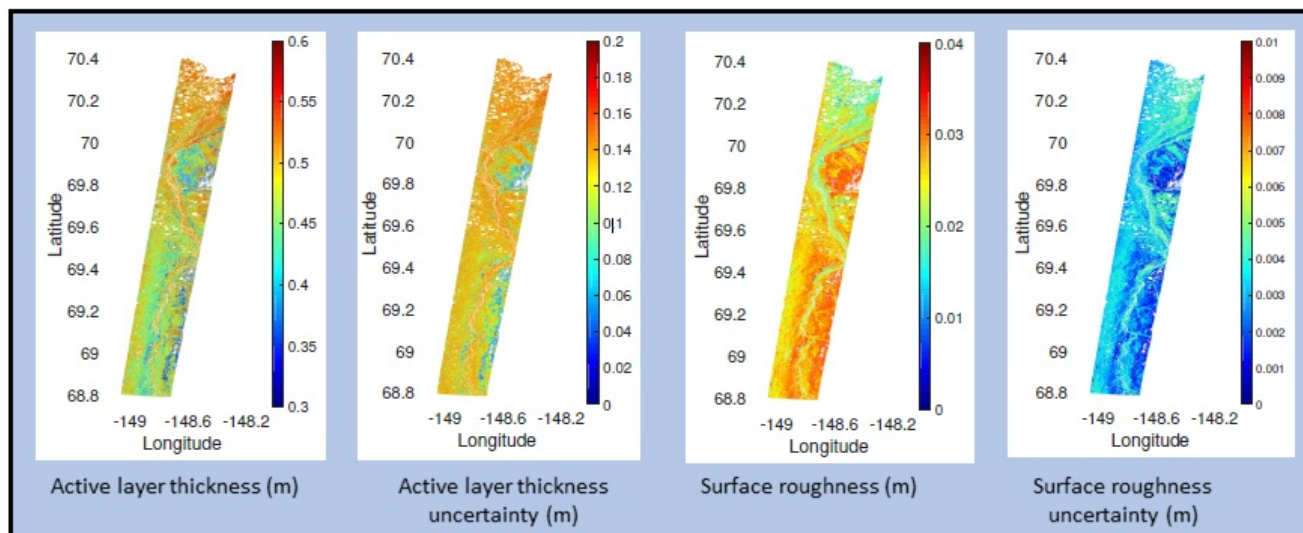
Figure 1. Active layer thickness with uncertainty and surface roughness with uncertainty for the Deadhorse flight line over the northern section of Dalton Highway in 2015. Images from Chen et al. (2019).

Citation

Chen, R.H., A. Tabatabaeenejad, and M. Moghaddam. 2019. ABoVE: Active Layer and Soil Moisture Properties from AirMOSS P-band SAR in Alaska. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1657

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1. Dataset Overview

This dataset provides estimates of soil geophysical properties derived from Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS) P-band polarimetric synthetic aperture radar (PolSAR) data collected in August and October of 2014, 2015, and 2017 over 12 study sites (with some exceptions) across Northern Alaska. Soil properties reported include the active layer thickness (ALT), dielectric constant, soil moisture profile, surface roughness, and their respective uncertainty estimates at 30-m spatial resolution over the 12 flight transects. Most of the study sites are located within the continuous permafrost zone and where the aboveground vegetation consisting mainly of dwarf shrub and tussock/sedge/moss tundra has a minimal impact on P-band radar backscatter.

The data products were produced using a time-series retrieval algorithm approach applied to the AirMOSS P-band polarimetric synthetic aperture radar (PolSAR) data (Chen et al., 2019). The retrieval process is an inversion of a forward radar backscattering model, where a three-layer dielectric structure is used to model the active layer (surface and subsurface layers) and the underlying permafrost. Multiple retrieval runs were performed for each pixel during the inversion process, from which the mean and standard deviation are reported as the retrieved value and associated uncertainty for the desired geophysical parameters. Soil dielectric constants (representing soil with unfrozen water content), soil layer depths, and surface roughness were retrieved.

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 Project: Airborne Microwave Observatory of Subcanopy and Subsurface (AirMOSS)

Related Publication:

Chen, R. H., A. Tabatabaeenejad, and M. Moghaddam. 2019. Retrieval of Permafrost active layer properties using time-series P-band radar observations. *IEEE Transactions on Geoscience and Remote Sensing.* In press.

Related Dataset:

Moghaddam, M. et al. 2019. L1 S-0 Polarimetric Data from AirMOSS P-band SAR, Alaska, 2014-2015. ORNL DAAC, Oak Ridge, Tennessee, USA.

Acknowledgments

2. Data Characteristics

Spatial Coverage: 12 study sites across Northern Alaska: Ambler, Atqasuk, Barrow, Coldfoot, Council, Deadhorse, Huslia, Ivotuk, Kougarok, Koyuk, Teller, and Toolik.

ABoVE Reference Locations:

Domain: Core ABoVE

State/territory: Alaska

Grid cells:

Ah0v0Bh3Bv2Ch0Cv0, Ah0v0Bh4Bv2Ch0Cv0, Ah0v0Bh5Bv2Ch0Cv0, Ah0v0Bh4Bv1Ch0Cv0, Ah0v0Bh3Bv1Ch0Cv0, Ah0v0Bh4Bv3Ch0Cv0, Ah0v0Bh5Bv3Ch0Cv0, Ah1v0Bh6Bv2Ch0Cv0, Ah1v0Bh7Bv2Ch0Cv0, Ah1v0Bh8Bv2Ch0Cv0, Ah1v0Bh9Bv2Ch0Cv0, Ah1v0Bh7Bv1Ch0Cv0, Ah1v0Bh8Bv1Ch0Cv0, Ah1v0Bh7Bv3Ch0Cv0, Ah1v0Bh8Bv3Ch0Cv0, Ah1v0Bh6Bv4Ch0Cv0, Ah1v0Bh7Bv4Ch0Cv0

Spatial resolution: 30 m

Temporal coverage: 2014-10-09 to 2017-08-17

Study Areas: All latitude and longitude given in decimal degrees.

Site	Westernmost Longitude	Easternmost Longitude	Northernmost Latitude	Southernmost Latitude
Northern Alaska	-167.9442	-150.2485	70.8774	64.7127

Table 1. Study Site Summary. Coordinates represent the approximate boundaries of all flights over the site. See Figure 2 for a map.

Study Site (Region)	Site Abbreviation	Sampled in 2014	Sampled in 2015	Sampled in 2017	North Latitude	South Latitude	East Longitude	West Longitude
Ambler (Brooks Range Foothills, south)	ambler	X	X	X	66.7	66.4	-161	-161.6
Atqasuk (North Slope)	atqasu	X	X	X	70.3	70	-159.8	-160.4
Barrow (North Slope)	barrow	X	X	X	70.9	70.6	-158.2	-158.9
Coldfoot (Brooks Range Foothills, south)	coldfo	-	X	X	66.9	66.7	-152.8	-153.4
Council (Seward Peninsula)	council/seward	X	X	-	65	64.8	-166.2	-166.7
Deadhorse	dhorse	X	X	X	69.8	69.5	-151	-151.6

(North Slope)								
Huslia (Interior Alaska)	huslia	-	X	X	65.6	65.4	-156.7	-157.2
Ivotuk (Brooks Range Foothills, north)	ivotuk	X	X	X	68.5	68.2	-157.9	-158.5
Kougarok (Seward Peninsula)	kougar	X	X	X	65.7	65.4	-163.7	-164.2
Koyuk (Interior Alaska)	koyukk	X	X	X	65.1	64.8	-162.4	-162.9
Teller (Seward Peninsula)	seward	-	-	X	65	64.7	-167.5	-167.9
Toolik (North Slope)	toolik	-	-	X	68.9	68.6	-150.2	-150.9

Data File Information

There are 29 data files with this dataset in NetCDF (.nc4) format; one file per year per site. Note, as indicated in Table 1, not all sites were flown each year.

The data files provide estimates of the soil active layer properties including soil dielectric constant and moisture profiles, active layer thickness (ALT), surface roughness, and respective uncertainties.

File Naming Convention:

PolSAR_active_layer_prop_**site_YYMMDD_YYMMDD_VV**.nc4

where:

> **site:** Six letter abbreviation of the 12 sites where data were acquired. See Table 1 above.

> **YYMMDD_YYMMDD:** Date (UTC) at the start of a data take, with YY being the last two digits of the year, MM the month of the year (01-12), and DD the day of the month (01-31). There were two PolSAR data takes over the same site used in each file, thus the two dates, August and October, in each file name.

> **VV:** product version number.

Example file name: PolSAR_active_layer_prop_ambler_140816_141009_01.nc4

Spatial Reference Properties:

Coordinate System: Canada_Albers_Equal_Area_Conic

EPSG: 102001

Data Dictionary

Table 2. Variables in the data files. Fill value is -9999.

Variable	Units	Description
X	m	X coordinate of projection
Y	m	Y coordinate of projection
alt	m	Active layer thickness (ALT)
epsilon1_aug		Surface soil dielectric constant at August snapshot
epsilon1_oct		Surface soil dielectric constant at October snapshot
epsilon2		Subsurface soil dielectric constant
mv1_aug	vol/vol	Surface soil moisture at August snapshot
mv1_oct	vol/vol	Surface soil moisture at October snapshot
mv2	vol/vol	Subsurface soil moisture
z1_aug	m	Surface layer depth at August snapshot
z1_oct	m	Surface layer depth at October snapshot
h	m	Surface roughness
lat	degrees	Latitude-degrees north
lon	degrees	Longitude-degrees east
alt_uncertainty	m	Uncertainty of ALT estimates
epsilon1_aug_uncertainty		Uncertainty of epsilon1_aug estimates
epsilon1_oct_uncertainty		Uncertainty of epsilon1_oct estimates

epsilon2_uncertainty		Uncertainty of epsilon2 estimates
mv1_aug_uncertainty	vol/vol	Uncertainty of mv1_aug estimates
mv1_oct_uncertainty	vol/vol	Uncertainty of mv1_oct estimates
mv2_uncertainty	vol/vol	Uncertainty of mv2 estimates
z1_aug_uncertainty	m	Uncertainty of z1_aug estimates
z1_oct_uncertainty	m	Uncertainty of z1_oct estimates
h_uncertainty	m	Uncertainty of h estimates

3. Application and Derivation

Soil moisture profiles and ALT are key variables in understanding the permafrost active layer dynamics that respond to the summer climate and land surface conditions. The provided active layer product estimates capture the effects of soil, topography, and vegetation heterogeneity within each radar transect at the regional scale.

4. Quality Assessment

Multiple retrieval runs were performed for each pixel during the inversion process, from which the mean and standard deviation are reported as the retrieved value and associated uncertainty for the desired geophysical parameters.

The retrieved ALT was validated against manual probing measurements taken at the Circumpolar Active Layer Monitoring (CALM) sites within the radar swaths. Results from the Chen et al. (2019) study show that the retrieved ALT values are generally underestimated for the sites where the in-situ ALT is larger than the P-band sensing depth, with a retrieval bias ranging from -0.05 m to -0.24 m as validated against the in-situ ALT measurements collected at CALM sites. For the sites where the in-situ ALT is smaller than 0.55 m, the retrieval errors are generally less than 0.1 m (Chen et al., 2019).

5. Data Acquisition, Materials, and Methods

The study areas are focused on the flight lines across Northern Alaska (Fig. 2). Most of the sites are located within the continuous permafrost zone and the aboveground vegetation consisting mainly of dwarf shrub and tussock/sedge/moss tundra has minimal impact on P-band radar backscatter and can be ignored, as indicated by the simulations using the scattering model.

To determine the pixels on which the retrieval algorithm will be performed, the land cover information from the National Land Cover Database (NLCD) for the state of Alaska from the year 2011 is used. The pixels classified as open water or developed areas, or forest pixels were excluded.
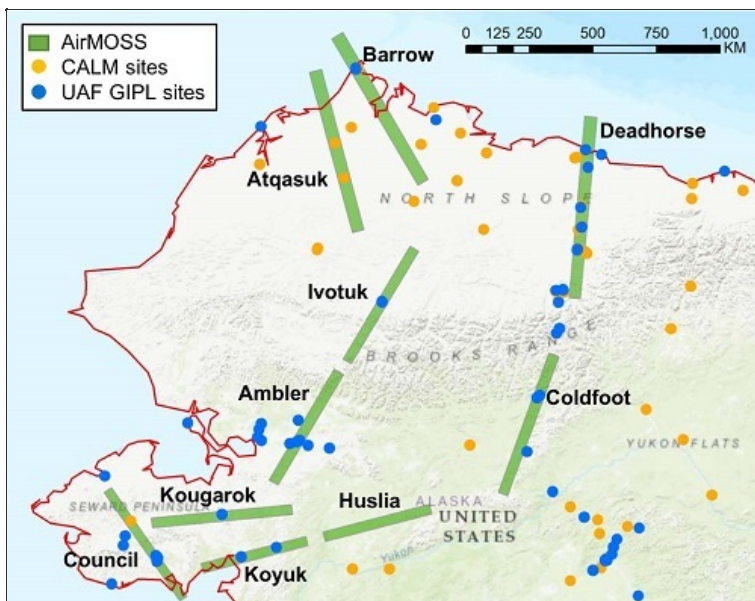

Figure 2. AirMOSS radar swaths and permafrost observation sites over Northern Alaska. Note that the 2017 flights over Toolik Lake (North Slope) and Teller (Seward Peninsula) are not displayed. CALM sites: Circumpolar Active Layer Monitoring program site manual probing measurements were used to validate the retrieved ALT data. UAF GIPL sites: Geophysical Institute Permafrost Laboratory (GIPL), University of Alaska Fairbanks (UAF) site in-situ soil moisture and temperature profiles were used to delineate the three-layer dielectric structure model representing the active layer soils and underlying permafrost. From Chen et al. (2019).

Mid-late August and early October flights were selected for the time-series to capture the maximum thaw and partially frozen seasons, when the boundary location between thawed active layer and permafrost is still observable and can be assumed constant over the time window. The dielectric constant of the lower part of the active layer is also assumed to be constant because the unfrozen water content depends only on soil porosity within the saturated zone.

Retrieval of Active Layer Properties

The retrieval of active layer properties was performed using a two-element time-series of measurements, one taken in mid-late August and one taken in early October.

The retrieval process is an inversion of a forward radar backscattering model, where a three-layer dielectric structure was assumed based on the observations made from the in-situ data and is used to model the active layer (surface and subsurface layers) and the underlying permafrost. Soil dielectric constants (representing soil with unfrozen water content), soil layer depths, and surface roughness are retrieved. The values of volumetric soil moisture are translated from the soil dielectric constants using the calibration equation by Engstrom et al. (2005).
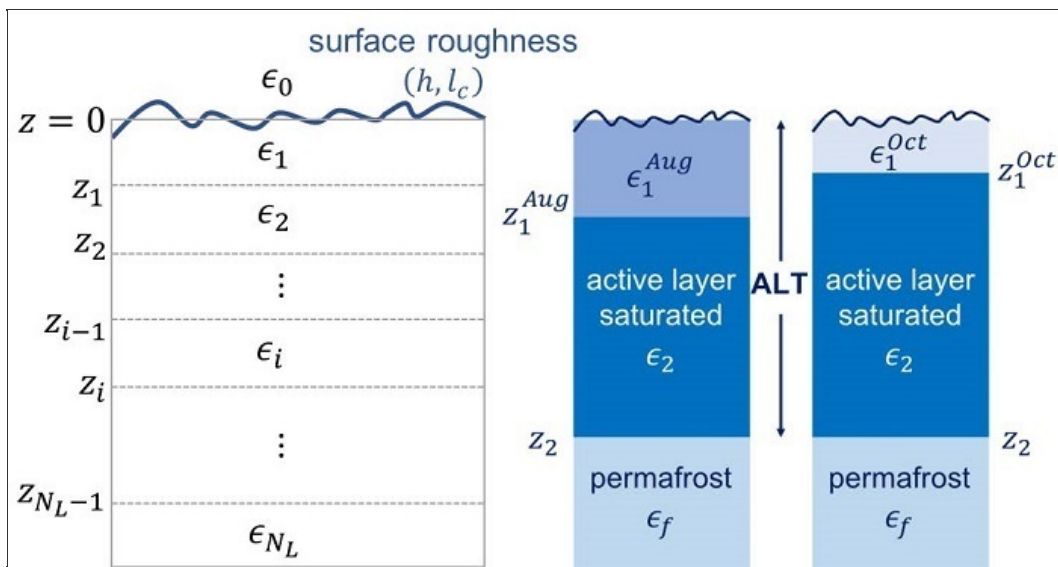
Multiple retrieval runs were performed for each pixel during the inversion process, from which the mean and standard deviation are reported as the retrieved value and associated uncertainty for the desired geophysical parameters.

Figure 3. Diagram of a three-layer dielectric structure used to model the active layer (surface and subsurface layers). Image is from Chen et al. (2019).

For additional details, refer to Chen et al. (2019).

6. Data Access

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

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Contact for Data Center Access Information:

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

7. References

Chen, R.H., A. Tabatabaeenejad, and M. Moghaddam. 2019. Retrieval of permafrost active layer properties using time-series P-band radar observations. IEEE Transactions on Geoscience and Remote Sensing.

Engstrom, R., A. Hope, H. Kwon, D. Stow, and D. Zamolodchikov. 2005. Spatial distribution of near surface soil moisture and its relationship to microtopography in the Alaskan Arctic coastal plain. Hydrology Research, vol. 36, no. 3, pp. 219-234. https://doi.org/10.2166/nh.2005.0016

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