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ABoVE: Landsat-derived Annual Dominant Land Cover Across ABoVE Core Domain, 1984-2014

Get Data

Documentation Revision Date: 2020-11-09

Dataset Version: 1

Summary

This dataset provides two 30-m resolution time series products of annual land cover classifications over the Arctic Boreal Vulnerability Experiment (ABoVE) core domain for each year of the period 1984-2014. The data are the annual dominant plant functional type in a given 30-m pixel derived from Landsat surface reflectance, landcover training data mapped across the ABoVE domain (using Random Forests modeling, with clustering and interpretation of field photography) and very high resolution imagery to assign land cover classifications. One product has a 15-class land cover classification that breaks out forest and shrub types into several additional classes; the other product provides a simplified, 10-class approach. Classification accuracy assessment results are provided per year. Assessments were based on a probability-based random sample of reference data that supported statistically robust estimation of areas and uncertainties in mapped areas.

To facilitate analyses, the Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper data were reprojected into the ABoVE standard Alber's equal area projection (30-m grid) and were gridded into 180 x 180 km ABoVE standard B grid tiles (Loboda et al., 2019). This resulted in a total of 175 B grid tiles over the ABoVE core domain. Land cover classifications (10- and 15-class products) are provided for each year from 1984 to 2014 for each tile.

This dataset provides 350 files with landcover data in GeoTIFF (.tif) format which includes 175 files for the 15-class product and 175 files for the 10-class product. Each file is a 31-band GeoTIFF, with each band providing one year of data for the 1984-2014 period, where band 1 is year 1984, band 2 is 1985, and so on until band 31, which is 2014. The accuracy assessment data are provided in two comma-separated (.csv) data files.



Figure 1. Land cover (10-class product) for the year 1984 in the ABoVE domain for analysis tile BH03V04. The pixel resolution is 30 m and a tile is 180 x 180 km. Refer to Figure 3 for the landcover in the same tile for the year 2014. (from ABoVE LandCover BH03V04.tif)

Citation

Wang, J.A., D. Sulla-Menashe, C.E. Woodcock, O. Sonnentag, R.F. Keeling, and M.A. Friedl. 2019. ABoVE: Landsat-derived Annual Dominant Land Cover Across ABoVE Core Domain, 1984-2014. ORNL DAAC, Oak Ridge, Tennessee, USA.

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1. Dataset Overview

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To facilitate analyses, the Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper data were reprojected into the ABoVE standard Alber's equal area projection (30-m grid) and were gridded into 180 x 180 km ABoVE standard B grid tiles (Loboda et al., 2019). This resulted in a total of 175 B grid tiles over the ABoVE core domain. Land cover classifications (10- and 15-class products) are provided for each year from 1984 to 2014 for each tile.

Project: Arctic-Boreal Vulnerability Experiment

The Arctic-Boreal Vulnerability Experiment (ABoVE) is a NASA Terrestrial Ecology Program field campaign taking 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, resulting in reduced Arctic sea ice, thawing of permafrost soils, decomposition of long-frozen organic matter, widespread changes to lakes, rivers, coastlines, and alterations of ecosystem structure and function. ABoVE seeks a better understanding of the vulnerability and resilience of ecosystems and society to this changing environment.

Related Publication

Wang, J. A., Sulla-Menashe, D., Woodcock, C. E., Sonnentag, O., Keeling, R. F., & Friedl, M. A. 2020. Extensive Land Cover Change Across Arctic-Boreal Northwestern North America from Disturbance and Climate Forcing. Global Change Biology 26, 807–822. https://doi.org/10.1111/gcb.14804

Related Dataset

Loboda, T.V., E.E. Hoy, and M.L. Carroll. 2019. ABoVE: Study Domain and Standard Reference Grids, Version 2. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1527

Acknowledgements

This research was funded by the NASA Terrestrial Ecology- Arctic and Boreal Vulnerability Experiment, grant numbers NNX17AE74G and NNX15AU63A and by the National Science Foundation (NSF) under grant number DGE-1247312..

2. Data Characteristics

Spatial Coverage: Alaska and Canada

ABoVE Reference Locations

Domain: Core ABoVE

The Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper data were reprojected into the ABoVE standard Alber's equal area projection (30-m grid) and were gridded into 180 x 180 km ABoVE standard B grid tiles (Loboda et al., 2019). This resulted in a total of 175 B grid tiles over the ABoVE core domain.

The two landcover classifications are provided for each tile for a total of 350 data files. The respective B grid tiles are identified in the filenames.

Spatial Resolution: 30 m

Temporal Coverage: 1984-01-01 to 2014-12-31

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

Site (Region)	Westernmost	Easternmost	Northernmost	Southernmost	
	Longitude	Longitude	Latitude	Latitude	
ABoVE domain: Alaska and Canada	-170.0058	-98.97401389	76.225675	50.25900556	

Data File Information

This dataset provides 350 files with landcover data in GeoTIFF (.tif) format which includes 175 files for the 15-class product and 175 files for the 10-class product. Each file is a 31-band GeoTIFF, with each band providing one year of data for the 1984-2014 period, where band 1 is year 1984, band 2 is 1985, and so on until band 31, which is 2014. The data values in each band represent the annual dominant plant functional type class (1-15 or 1-10; definitions in Table 2 & 3 below) in each 30-m pixel. The respective B grid tiles are identified in the filenames.

Land cover class accuracy assessment data are provided in two comma-separated (.csv) data files.

User Note: Using the ABOVE Standard Reference Grid System

As described, the Landsat data were reprojected into the ABoVE standard Alber's equal area projection (30-m grid) and were then gridded into 180 x 180 km ABoVE standard B grid tiles. Each of the resulting data filenames includes the respective B grid tile coordinates (Bh**XXvZZ**).

If a user wants to select landcover data files (B grid tiles) based on a defined bounding box, they can identify the respective ABoVE standard B grid tiles based on location by using the shapefiles provided in the related dataset (Loboda et al., 2019; https://doi.org/10.3334/ORNLDAAC/1527).

Table 1. File names and descriptions

File names	Descriptions					
ABoVE_LandCover_BhXXvZZ.tif	Annual landcover classification of 15 plant functional types. The data provide the dominant plant functional type class for a given 30-m pixel in the identified ABoVE B grid tile (Bh XX v ZZ). Where XX is the horizontal ABoVE tile location and ZZ is the vertical ABoVE tile location for the respective B grid.					
ABoVE_LandCover_Simplified_BhXXvZZ.tif	Annual landcover classification of 10 plant functional types. The data provide the dominant plant functional type class for a given 30-m pixel in the identified ABoVE grid tile (Bh XX v ZZ). Where XX is the horizontal ABoVE tile location and ZZ is the vertical ABoVE tile location for the respective B grid.					
accuracy_assess_1984-2014.csv	Classification accuracy assessment results (for the simplified 10-class version) for each year provided as error matrices. The columns indicate reference data and the rows indicate the classification. Refer to Table 4 for example data.					
accuracy_summary_1984-2014.csv	Provides the producer's accuracy (inverse of error rate of omission), the user's accuracy (inverse of error rate of commission) for each class, as well as the overall accuracy for each year.					

GeoTIFF Data Descriptions

Two different land cover classifications are provided to describe the dominant plant functional type at a given pixel: 1) a classification with 15 different classes that breaks out forest and shrub types into several additional classes, and 2) a simplified approach with 10 different classes where forest and shrub types are aggregated.

File properties:

Bands: 31 No Data Value: 255 EPSG: 102001 Resolution: 30 m Number rows x columns: 6,000 x 6,000

Missing values primarily occur as part of the ocean mask or for screened permanent snow/ice pixels.

Table 2. Land cover classes in the 15-class approach

ID	Label	Description
1	Evergreen Forest	Area dominated by tall woody vegetation (> 3m tall) and over 60% canopy coverage with primarily (>75%) evergreen phenological habit (canopy maintains green foliage year-round).
2	Deciduous Forest	Area dominated by tall woody vegetation (> 3m tall) and over 60% canopy coverage with primarily (>75%) deciduous phenological habit (annual cycle of leaf-on and leaf-off periods).
3	Mixed Forest	Area dominated by tall woody vegetation (> 3m tall) and over 60% canopy coverage with neither forest type (deciduous or evergreen) exceeding over 60% of the area.
4	Woodland	Area dominated by tall woody vegetation (> 3m tall) with between 30-60% canopy coverage. Frequently co- exists with peatlands and typically, but not always, evergreen in phenological habit.
5	Low Shrub	Area dominated by dense hemi-prostrate to low-erect shrubs (5-30cm in height) with >60% area coverage. Analogous to "prostrate dwarf-shrub" and primarily occurring in tundra areas.
6	Tall Shrub	Area dominated by woody vegetation between 50cm and 3m tall and shrub canopy coverage >60% coverage. Typically, but not always, deciduous phenological habit.
7	Open Shrubs	Area with woody vegetation less than 3m tall and between 30-60% canopy coverage. Shrubs typically underlain by herbaceous or barren land cover.
8	Herbaceous	Area dominated by herbaceous land cover greater than 60% land cover and tree/shrub cover less than 10%.
9	Tussock Tundra	Tundra-specific herbaceous land dominated by <i>Eriophorum vaginatum</i> and other tussock-forming herbaceous species, coverage over 60%.
10	Sparsely Vegetated	10-30% canopy coverage, any vegetation but typically herbaceous/bryophyte, with rock underneath
11	Fen	Hydrologically connected, sedge/grass dominated wetland
12	Bog	Ombrotrophic, peat and shrub dominated wetland

13	Shallows/littoral	Lakes <1m deep with some vegetation or shoreline mixed with water/land
14	Barren	<10% vegetation, mostly rock
15	Water	Oceans, lakes, and rivers, either salt-water or freshwater.

Table 3. Land cover classes in the 10-class approach

ID	Label	Combines the following classes from the 15-class approach	Combines the following labels:
1	Evergreen Forest	1,4	Evergreen Forest, Woodland
2	Deciduous Forest	2,3	Deciduous Forest, Mixed Forest
3	Shrubland	5,6,7	Low Shrub, Tall Shrub, Open Shrub
4	Herbaceous	8,9	Herbaceous, Tussock Tundra
5	Sparsely Vegetated	10	Sparsely Vegetated
6	Barren	14	Barren
7	Fen	11	Fen
8	Bog	12	Bog
9	Shallows/Littoral	13	Shallows/Littoral
10	Water	15	Water

Accuracy assessment

File: accuracy_assess_1984-2014.csv

This file provides error matrices for classification accuracy assessment results by year, for the years 1984-2014 for the 10-class products. The results for the year 2014 are provided as an example. Reference data are indicated in columns; mapped classification data are in indicated rows. In the error matrix, correct classifications are shown along the diagonal and erroneous classifications are shown in the other cells. Refer to Table 3 for the landcover definitions.

Fable 4. 10-class classification ac	ccuracy assessment	for the year 2014.
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year	landcover	evergreen_forest	deciduous_forest	shrub	herb	sparse_veg	barren	fen	bog	shallows	water
2014	Everg. F	223	9	19	9	5	9	10	2	7	3
2014	Decid. F	5	119	7	1	0	0	4	0	2	0
2014	Shrub	9	14	161	20	2	2	11	0	0	2
2014	Herb	0	1	11	93	4	1	3	0	1	3
2014	Sparse Veg	2	0	10	16	108	1	2	2	1	0
2014	Barren	0	2	3	6	8	52	2	4	1	4
2014	Fen	4	9	18	6	2	0	61	1	2	1
2014	Bog	5	0	0	0	0	0	2	39	0	0
2014	Shallows	2	0	0	4	3	0	1	0	30	2
2014	Water	1	1	4	1	4	2	0	0	9	69

File: accuracy_summary_1984-2014.csv

This file provides the producer's classification accuracy (inverse of error rate of omission), user's classification accuracy (inverse of error rate of commission), and overall classification accuracy for each class in the 10-class products for each year.

year	accuracy	evergreen_forest	deciduous_forest	shrub	herb	sparse_veg	barren	fen	bog	shallows	water
2014	prodAcc	0.8884	0.7677	0.691	0.5962	0.7941	0.7761	0.6354	0.8125	0.566	0.8214
2014	userAcc	0.7534	0.8623	0.7285	0.7949	0.7606	0.6341	0.5865	0.8478	0.7143	0.7582
2014	overAcc	0.7467	0.7467	0.7467	0.7467	0.7467	0.7467	0.7467	0.7467	0.7467	0.7467
2013	prodAcc	0.8889	0.8125	0.7161	0.6562	0.8519	0.9155	0.6771	0.8776	0.6481	0.9059
2013	userAcc	0.8116	0.8904	0.7445	0.8268	0.7468	0.8125	0.619	0.86	0.7778	0.875
2013	overAcc	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792	0.792

Table 5. Example data for the years 2014 and 2013.

3. Application and Derivation

The data provide information on plant functional types in Arctic and Boreal biomes over a 31-year period which could help to quantify the loss, regrowth, and transitions between evergreen and deciduous tree species in the boreal forest biome at large spatial scales. See Wang et al (2019) for analysis details.

4. Quality Assessment

Two files are included that characterize the year by year accuracy for the simplified land cover classes across all years.

Following established practices for the assessment of remotely sensed land cover maps, the accuracy of the simplified land cover was assessed over each year by drawing a stratified random sample and creating a reference time series of land cover data for each site by visually interpreting very high-resolution imagery, field photography (geolocated photos provided by Kevin Turner (for the Old Crow Flats), Isla Myers-Smith (for Qikiqtaruk-Herschel Island), and Brendan Rogers, and time series of Landsat reflectance data (Olofsson et al., 2014). In reality, these data were stratified across a design intended to assess the accuracy of change detection. These reference data were adapted to year by year analyses and re-estimated year by year variances (Stehman, 2014). Table 6 provides an accuracy summary across all 31 years.

Table 6. Accuracy summary means

Producer's accuracy refers to the inverse of error rate of omission, the user's accuracy refers to the inverse of error rate of commission for each class. The overall accuracy for each year is also provided.

accuracy	evergreen_forest	deciduous_forest	shrub	herb	sparse_veg	barren	fen	bog	shallows	water
Producer's Acc	0.8891	0.7506	0.6949	0.6485	0.8096	0.8558	0.6418	0.8854	0.6567	0.8908
User's Acc	0.8266	0.881	0.6893	0.7882	0.7026	0.7902	0.6128	0.8586	0.7575	0.8883
Overall Acc	0.7735	0.7735	0.7735	0.7735	0.7735	0.7735	0.7735	0.7735	0.7735	0.7735

The land cover data does not correct for short-term changes in climate that may impact the spectral appearance of certain areas. For example, droughts may result in wetlands appearing drier, and subsequently being briefly classified as shrubs. Caution is advised when utilizing the wetland data for this reason (Wang et al., 2019).

5. Data Acquisition, Materials, and Methods

Study area

The study region included the core domain of NASA's ABoVE project which includes the majority of Alaska and northwestern Canada and covers 4.67×10^6 km². To facilitate analyses, the Landsat 5 Thematic Mapper and Landsat 7 Enhanced Thematic Mapper data were reprojected into the ABoVE standard Alber's equal area projection (30-m grid) and were gridded into 180 x 180 km ABoVE standard B grid tiles (Loboda et al., 2019). This resulted in a total of 175 B grid tiles over the ABoVE core domain.

The area mapped was defined by an ocean-land mask that was adopted from the 10-m ocean mask from Natural Earth data repository and manually edited to closely fit the Arctic coastline in our region (Wang et al., 2019).

Data processing

The primary source of data for land cover and disturbance mapping was time series of surface reflectance and brightness temperature from Landsat 5 and Landsat 7 retrieved from the ABoVE Science Cloud, covering the years 1984 to 2014. The *Fmask* algorithm was used to pre-process the Landsat image time series at each site to remove ephemeral contamination from clouds, snow, ice, cloud shadow, and other atmospheric effects that were not screened by the USGS (Zhu and Woodcock, 2012).

Disturbance detection and data modeling using CCDC

The minimum mapping unit and unit of analysis were 30-meter Landsat pixels within the ABoVE tiling system. For each pixel, the Change Detection and Classification (CCDC) algorithm (Zhu and Woodcock, 2014) was used to detect statistical breaks in time series of surface reflectance data. These breaks are hypothesized to represent land cover changes and the time segments intervening the breaks are assumed to be of stable land cover. The CCDC synthetic data was used to calculate a suite of surface reflectance metrics across bands and seasons to characterize the spectral-seasonal behavior of each time segment (e.g. spring versus summer values or annual amplitude for each band). In addition, several spectral indices were calculated as input features and the seasonal metrics were applied to them as well.



Figure 2. Example of time series and disturbance detection for one Landsat band and one pixel using the Continuous Change Detection and Classification (CCDC) algorithm. In this example, surface reflectance for Landsat band 5 (shortwave-infrared) is shown. *Top panel:* points are time series of observations reflectance, grey lines are fitted harmonic models, dashed vertical lines are the approximate timing of breaks in land cover, and colored horizontal lines and arrows indicate between-break time segments of stable land cover. CCDC detects and removes outliers in its model fits. *Bottom panel:* characteristic seasonal cycle of the color-coded time segments indicate the harmonic model fit across those values, averaged across all years within the time segment.

Training and validating the land cover mapping algorithms

Training sites were generated across all ABoVE tiles via stratified random sampling (up to 10 per class in each tile) from existing land cover maps for Alaska and Canada circa 2000 (Jin et al., 2017; Wulder et al., 2008), ensuring coverage across a range of climatic conditions, spectral feature space, and ecosystem types. In total, the training data set included 15,628 sampled from the Canadian and Alaskan land cover datasets, 1,531 sites from the 10-m Scotty Creek land cover map (Chasmer et al., 2014), 970 sites from the Toolik Lake tundra vegetation map (Greaves et al., 2017, unpublished dissertation-data provided by personal communication), and 1,553 sites from field photographs for a total of 19,682 training sites (Wang et al., 2019).



Figure 3. Points represent locations that were included in the clustering algorithm that was used to define the land cover legend and explore the spectral-temporal space within the ABR. Darker blue color indicates the ABoVE Core Study Domain (used for this study), while the lighter blue indicates the ABoVE Extended Study Domain (outside the scope of this study). Red points indicate sites were manually labelled by visual interpretation of very high-resolution imagery or field photographs. Black points were not manually labelled but were included in the clustering and the training data for the Random Forest algorithm (Wang et al., 2019).

Landcover class development

The training site data were clustered using a tree-based clustering method combining the R package *treeClust* (Buttrey and Whittaker, 2015). Each time segment was defined by a specific statistical cluster and mapped across the domain using *Random Forest* (Breiman, 2001). Each time segment was defined by a specific statistical cluster and mapped. The clusters were assigned meaningful land cover labels by visually interpreting a large sample (n = 10,136) of very high-resolution imagery (copyright DigitalGlobe), derived from IKONOS, Geo-Eye, QuickBird, Worldview-2, and Worldview-3, field photographs, and existing higher-resolution land cover maps (Chasmer et al., 2014; Greaves et al., 2017, unpublished dissertation-data provided by personal communication), as well as the Landsat surface reflectance time series. The clusters were cross-walked to land cover based on the interpretation of a set of land cover

characteristics observed in these sources.



Figure 4. Land cover (10-class product) for the year 2014 in the ABoVE domain for analysis tile BH03V04. The pixel resolution is 30 m and a tile is 180 x 180 km. Refer to Figure 1 for the landcover in the same tile for the year 1984. (ABoVE_LandCover_BH03V04.tif)

Several post-processing steps resolved certain artifacts, including the removal of spurious land cover changes and the reduction of certain misclassifications. Once clusters have been reassigned to meaningful land covers, per-pixel series of time segments were analyzed and consecutive time segments with the same land cover label (but possibly differing clusters) were merged into single time segments of the same land cover. Additionally, time segments were extended forward or backward in time to cover time periods that had no CCDC output within a pixel. Therefore, missing data should only exist where *Fmask* identified 100% snow and ice or outside the ocean-land mask. Spurious classifications of water classes in mountainous regions were identified by comparing them with the slope of the pixel, derived from ASTER elevation data, and existing annual Landsat-based maps of global surface water status (Pekel et al., 2016). Those pixels that were mapped as water but had non-zero slope and were not classified as water by Pekel et al. 2016, were set to their second most likely class after water, using the *Random Forest* probabilities (Wang et al., 2019).

6. Data Access

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

ABoVE: Landsat-derived Annual Dominant Land Cover Across ABoVE Core Domain, 1984-2014

Contact for Data Center Access Information:

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

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